AUSTRALIAN MEAT PROCESSOR CORPORATION

Efficient lighting options & review of lighting standards for Abattoirs

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1.0 Introduction

Abattoirs across Australia are comprised of buildings and infrastructure which are becoming increasingly costly to operate and maintain, particularly in terms of energy consumption. Energy consumed in lighting office areas and industrial buildings, although not a major energy consuming end use when compared with refrigeration or steam/hot water generation, represents around 1-2% of total energy use at abattoirs [1](including electricity and thermal energy sources).

The lighting industry has made substantial progress in energy efficient lighting equipment and controls, and there is significant potential to apply this new technology to the various working environments at abattoirs.

There has also been a substantive change to the Building Code of Australia (now known as the National Construction Code), mandating minimum lighting control requirements, and energy consumption performance requirements for lighting installations. Also, Australian Standards have evolved to include minimum lighting levels for certain activities within an abattoir, including recommendations on glare in certain locations. These changes to standards may have not been factored into the lighting installation of older abattoirs.

This project involves a review of current lighting and lighting controls technology, aiming to identifying opportunities to improve energy consumption. Other benefits such as reductions to operating costs due to maintenance, and potential increases in productivity due to improved amenity are also investigated.

The outcomes of this project take the form of recommendations on lighting concepts to be implemented in either new or existing abattoirs, their advantages and disadvantages, and the anticipated payback periods based on the inspection undertaken of a local abattoir as an example.

Additional research is recommended to be undertaken to validate the modelled energy and cost savings outlined in this report. It is proposed that this be undertaken through the use of a test abattoir site and the installation of recommended technologies. New lighting installation circuits are then metered over a short period (between 3 and 6 months) and energy consumption is reviewed against historical data.

[1]Energy Consumption Guide for Small to Medium Red Meat Processing Facilities. Australian Meat Industry Council / Energertics Pty Ltd and Minus40 Pty Ltd. June 2014. http://www.amic.org.au/SiteMedia/W3SVC116/Uploads/Documents/Energy%20Consumption%20Guide.pdf

1.1 Milestone

To complete the main milestone of this project, a final report is required to:-

- Document the findings of the previously issued literature review;
- Note the observations taken from the abattoir site inspection;
- Provide a selection of lighting energy efficiency options, and evaluate their effectiveness, using knowledge gained from the site inspection;
- Provide a list of recommended potential upgrades to lighting of various spaces about an abattoir, their expected impact to energy consumption along with their advantages and disadvantages.

1.2 Abstract

To address the rapid change in lighting and lighting control technology along with modifications to Australian Standards and the Building Code of Australia, a review of these technologies and how they can be implemented within existing abattoirs has been undertaken.

This review has included analysis of:-

- State and federal legislation and regulations;
- Australian and International Standards;
- Articles which outline the current tasks and operation of abattoirs;
- Industry case studies outlining recent energy efficiency lighting improvements made within abattoirs, locally and internationally.

From this review a recommended characteristic which energy efficiency improvements can be compared against has been proposed, along with other key criteria that are highlighted in need of consideration.

A site inspection of an abattoir was carried out providing GHD with an example of the key operations and functions undertaken within an abattoir, and how lighting impacts on efficient operation. The site inspection included:-

- Observations of typical lighting types and controls to gain an appreciation of common installation and controls practices; and
- Interviews with maintenance and operations staff to gain an understanding of the importance of lighting and lighting control within the day to day operation of the facility.

The information gained from this site inspection was used to develop two key elements of the next stage of the report:-

1. It provided example dimensions and lighting installations for the various space types within an abattoir; and

2. Gave guidance of the types of environment and occupancy movements which lighting installations contend with within an abattoir. This helped determine proposed efficiency upgrade options to be analysed.

This information was then utilized to critique and determine the impact each option for upgrade using the proposed metric developed as part of the literature review. This, coupled with a review of the advantages and disadvantages of each technology proposed is then refined into a list of recommended initiatives that red meat processing facilities can take to improve lighting energy efficiency.

2.0 Methodology

This project was broken into three elements; a literature review, abattoir site inspection and options analysis.

2.1 Literature Review

To achieve the aim of the literature review, the research team reviewed literature through a hierarchical process, with consideration of importance of articles based on several factors, which were (in order of importance):-

1. Requirements for lighting set out in Australian and State legislation, including the National Construction Code of Australia (NCC), food processing and food health and safety regulations, to determine what statutory minimum requirements lighting within abattoirs need to meet;

2. Relevant current Australian and International standards which outline recommendations for lighting for various tasks within an abattoir, to define what are the important factors for lighting specific areas within a facility;

3. Articles which outline the current mode of operation of abattoirs about Australia, and lesser extent other parts of the world, which assist in understanding the tasks undertaken in various elements of an abattoir, the space which these tasks are completed within, how they are maintained and cleaned;

4. Information from peak bodies and certification organisations that outline requirements for lighting of meat processing facilities;

5. Case studies from Australia on abattoirs which have undertaken lighting upgrades, and what benefits have been measured; and

6. International case studies on abattoirs which have undertaken lighting upgrades, and what benefits have been measured. The latter two to get a better understanding of the important measured outcomes from lighting upgrades and how they were measured.

From this approach, GHD have developed the findings outlined in Section 2.2. These findings aim to:-

- Outline the common operations within an abattoir, and what works are undertaken in them.

- Summarise the relevant legislation, regulation and Australian Standards, and what impact mandatory compliance will potentially have to lighting;

- These first two findings assist in understanding the lighting technical parameters that are mandatory and recommended to be adhered to, what needs to be lit and how it should be lit;

- Determine what impact attempts to improve energy efficiency through lighting upgrades within meat processing facilities has had both locally and internationally, what are the general trends for upgrades and how the impact is measured.

The findings from this review are then used to determine the most appropriate metric for measuring the impact any proposed upgrades to lighting energy efficiency will have within a functional space inside an abattoir.

Other design criteria that are secondary to the metric above are also discussed.

2.2 Site Inspection and Options Analysis

The GHD team visited an abattoir to gain a better understanding of both what the typical lighting and controls installation within an abattoir is, and how this impacts on the day to day operation of such a facility. This inspection included:-

- Noting the type of luminaires, lamps and lighting controls used in the various spaces within the facility;
- Observing the size and height of various spaces;
- Viewing operations and processes in each space and how lighting impacts on these operations;
- Spot measuring lighting levels on surfaces within rooms;
- Typical hours of operation;
- Retrieving annual energy consumption data through review of utility bills;
- Stakeholder discussions to gain an understanding of such issues as:-
  - The impact of fixed lighting on the inspection of meat for food safety requirements;
  - Operational hours of a facility, including discussions on how various spaces within an abattoir are used and when;
  - Current maintenance cycles for lighting;
  - Maintenance issues surrounding lighting; and
  - Lighting levels, the lighting of task areas and its impact on operations.

To begin providing analysis of any proposed lighting energy efficiency improvements, GHD developed a typical energy use per lighting level values, (i.e. kWh/m^2/100 lux) for the room types and lighting installations noted from the site inspection. These are to be considered a baseline to which any energy efficiency improvements are to be measured against. At this point, probable compliance with current Section J6.2 [2] of the National Construction Code (NCC) was also determined both with respect to W/m^2 and lighting control requirements.

To provide a consistent model to which all energy reductions are measured from, a set of standard room parameters (room size, height and reflectivity) for each space have been proposed. These are based around appropriate dimensions of spaces, as noted from the site inspection. Ideally, using the verified actual room sizes from the abattoir visited would be preferred. However due to a lack of building documentation, estimates of 'typical' spaces

[2] National Construction Code 2014, Vol1. Australian Building and Construction Board.

have been used.

From this basis, potential improvements to energy efficiency due to lighting were undertaken. These were done in a step by step process, with kWh/m^2/100lx values compared against the original, 'typical' installation to determine the likely reduction. These steps were (for each space):-

- Replacing lighting controls where appropriate to reduce wasted light due to lack of occupancy within a space;
- Luminaire replacement to higher efficiency luminaires (such as LED) only, keeping controls the same. Firstly as a one for one replacement where luminaires have been chosen that have similar light outputs to what is currently installed. In this analysis an revised average lighting level has also been determined to accommodate for any changes which result from the replacement luminaires light distribution and performance. Secondly it was decided to optimize the installation of recommended replacement luminaires to provide lighting levels equivalent to what is currently experienced on site. It is anticipated in some cases this may result in a reduction of luminaires to be installed within a space;
- A combined luminaire replacement and controls installation strategy. This last option was considered to determine if undertaking both initiatives above within a single room has a significant impact in comparison to undertaking either of the initiatives above in isolation.

Energy savings due to reduction in energy consumption have also been determined. This was completed using tariff information provided by the abattoir operations manager to calculate simple paybacks based on the initial estimated capital cost of replacement.

Potential improvements have been chosen based on the following criteria:-

- The physical conditions of the space (height, access, temperature, cleaning operations etc.);
- Lighting levels to be met. These have been determined based on meeting the current lighting levels as noted on site, or meeting Australian Standard recommendations whichever is higher. Task areas and surfaces have been noted and lighting to these have been prioritized; and
- Occupancy patterns of these spaces observed on site.

Finally advantages and disadvantages for each improvement have also been documented.

The final outcome of this section is a list of recommendations that provide guidance to abattoir owners on improving energy efficiency to lighting within their facilities.

3.0 Findings

3.1 Literature Review

Layout and General Operations

Based on our research, site inspection and discussions with AMPC, a general process model of an abattoir carryout out carcass processing, boning and rendering is shown diagrammatically in Figure 1.

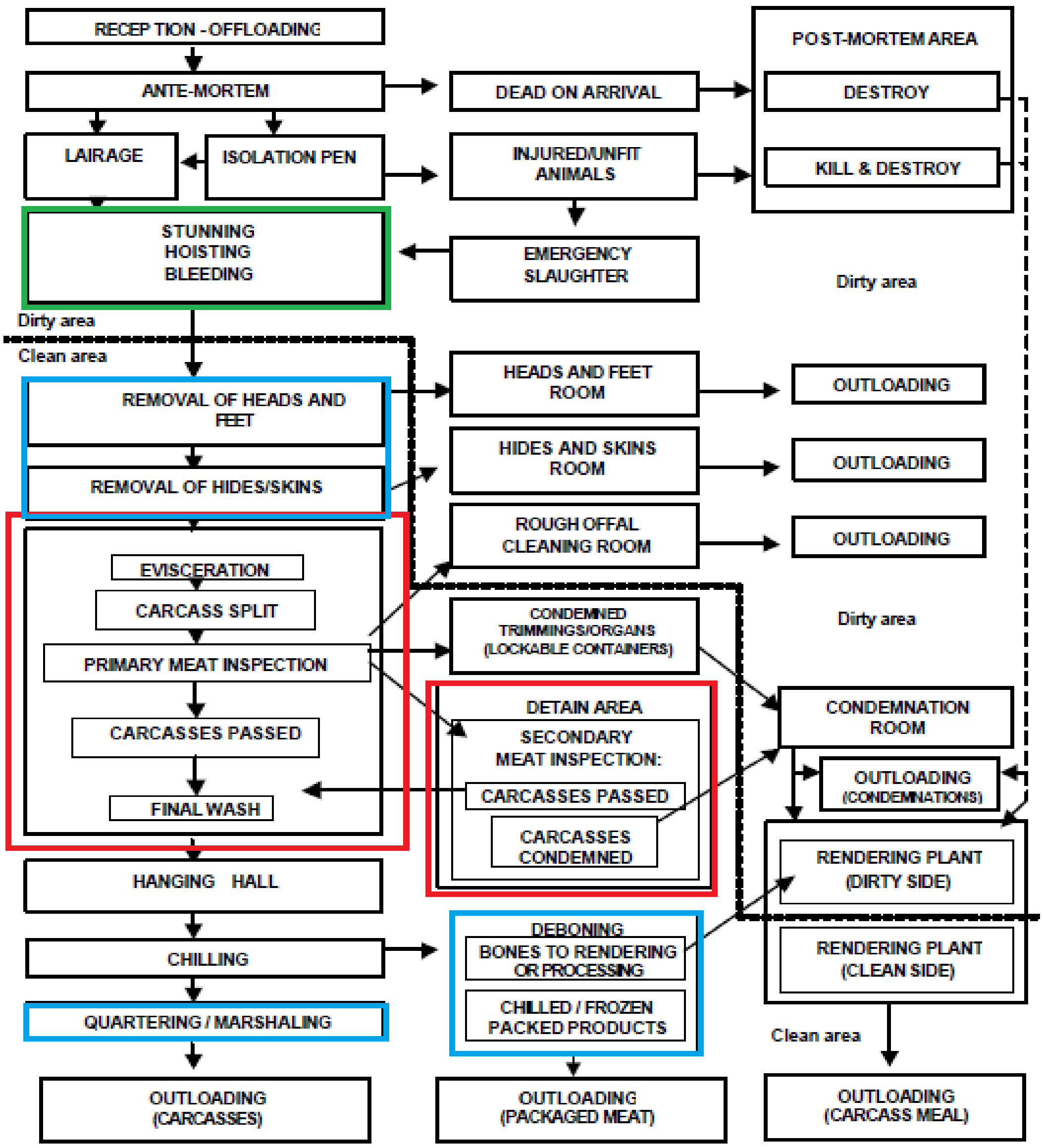

Figure 1 - Abattoir Process Model[3]

- Inspection
- Boning, cleaning, cooking, grinding, canning, packing and cutting
- Slaughtering

[3] (Royal Thai Embassy, Date unknown)

The above figure has been augmented to demonstrate key tasks undertaken in various areas about a facility, to better understand the key types of work undertaken.

Abattoirs are generally separated into “dirty” and “clean” areas, as nominated by the hard black line in the figure above. The way these areas are maintained and hence cleaning requirements differ between these two area types.

Also note, this process model above does not take into consideration other areas essential to the operation of an abattoir, such as:-

- Office areas;
- Amenities blocks, including toilets, showers and change facilities;
- Lunch and training rooms;
- External facilities, such as carparks.

The model outlined above is only an example of what can occur within a given abattoir. The processes performed at a specific abattoir will vary depending on the size and function of the abattoir.

The operating times will also vary with size and function of the abattoir and some abattoirs will run shifts into the night, making security and access lighting an important consideration.

Furthermore the size of each workspace, their orientation and general configuration of an abattoir varies from site to site, likewise the types of finishes of walls and floors also varies.

Regulations - Summary of the National Construction Code (NCC)

The National Construction Code (NCC), also known as the Building Code of Australia is the set of standards and codes which are referenced within state and territory building legislation across Australia. All new building and construction works are legally required to comply with this code.

The NCC outlines ‘classes’ of buildings or building elements, to enable the specific requirements of a building, based on use to be clearly outlined. GHD have reviewed the NCC and outlined the likely classes of building to which elements of a typical abattoir may fall under below. These should be reviewed and confirmed by a building certifier before being utilised by an AMPC stakeholder. The building classes identified include:

- Class 5 – office space;
- Class 7b – warehouse;
- Class 8 – functional area of an abattoir;
- Class 10a – garage or shed.

Each class of building, under the NCC has specific construction and services performance requirements to meet.

The NCC references many Australian Standards to which a building of each respective class is to comply with. In review of the NCC, Class 5, 7b and 8 buildings must comply with Australian Standard AS1680 Part 0 (Interior and workplace lighting – Safe Movement).

This Part of AS 1680 only provides lighting recommendations for safe movement about a space. It does not take into consideration recommended minimum lighting levels to achieve functional tasks, nor does it provide recommended levels of lighting which are suitable to undertake such tasks.

The impact of compliance with this standard is outlined below in Section 2.3.

Following on from this, the NCC requires that building work on classes of building 2 through to 9 inclusive meet minimum energy efficiency requirements under its Section J Energy Efficiency provisions.

For any lighting work to comply with the NCC, the energy efficiency performance of the lighting is assessed against Section J6.2 of the NCC. This section outlines the maximum allowable power per square metre of area (or power density) which lighting can consume for various categorised functional spaces. When determining compliance for a building, the following methodology is outlined within the code:-

- Identify the total area of each type of functional space as categorised in the Table below (Ref Table 1);
- Calculate the total maximum allowable wattage for lighting for each of these spaces;
- Sum these wattages for the whole building to get an 'energy budget' for the building;
- Review the lighting installation wattage across the whole building, and sum together the total expected energy consumption of the building;
- Compare the total expected lighting consumption against the energy budget. If the expected consumption is less than the budget, the installation complies.

Note, there are additional adjustment factors which for room dimensions and efficient controls which can be utilised to improve the energy budget.

These power densities are an important consideration when designing new or upgrading energy efficient lighting systems and will be taken forward to the lighting recommendations.

Table 1: Summary of Table J6.2a (NCC) – Energy Efficiency (excluding emergency lighting).

SPACE	MAX POWER DENSITY (W/m2)
Corridor	8
Kitchen/food preparation area	8
Office (greater than 200 Lux)	9
Office (less than 200 Lux)	7
Toilet	6

Storage with shelving less than 75% of aisle height	8
Storage with shelving greater than 75% of aisle height	10
Whole sale storage and display area	10
160 Lux (slaughtering)	10
400 Lux (boning, cleaning, cooking, grinding, canning, packing and cutting)	13

It is worth noting that these are the minimum requirements, and that any upgrades to lighting that are recommended should exceed these minimum requirements.

Food Safety Standards

Food Standards Australia New Zealand (FSANZ) is an independent statutory agency established under the Food Standards Australia New Zealand Act 1991. The agency has developed a Primary Production and Processing (PPP) Standard for meat as part of a series of national food safety standards. The standards refer to existing State and Territory laws relating to food handling and processing.

The NSW Food Authority regulates businesses within the food industry in NSW including businesses that handle or process meat or poultry. The Authority stipulates that all red meat abattoirs must attain a licence from a national licencing agency, such as HACCP Australia, and must develop and maintain a Food Safety Program (FSP). FSP's are designed to help businesses identify and manage hazards to food safety. These programs are based on Codex Alimentarius Commission's HACCP system and guidelines[4].

In addition to this the Authority must be satisfied that all buildings and equipment connected with the operation meet the requirements of AS4696-2007 (Hygienic production and transportation of meat and meat products for human consumption). The NSW food Authority FSP regulations are typical of other Australian States and Territories including Queensland, Victoria, South Australia and Western Australia. Enforcement of these programs are the responsibility of local governments and councils.

HACCP Australia is a private audit agency within Australia that is responsible for auditing businesses that are required to attain a Food Safety Program license. Within their approvals process, HACCP refer to AS4696:2007((Section 21) – Australian Standard for Hygienic Production and Transport of Meat and Meat Products for Human Consumption – Essential Services)and AS4696-2007 (Hygienic production and transportation of meat and meat products for human consumption)[5]. Compliance with these standards is a requirement to gain a FSP licence. The impact of compliance with these standards is outlined in Section 3.3 below.

Australian Lighting Standards

From our review of the NCC and various state food safety regulations, several key Australian Standards are referenced which are relevant to lighting. These are explained below.

[4] (Codex Alimentarius, 2014)
[5] (HACCP Australia, 2009)

The Interior Lighting Code

Following on from the NCC requirements, the Australian Standards provide recommendations for lighting conditions for the classes of buildings outlined in section 3.2 above. Australian Standard 1680.0 (Interior Lighting – Safe Movement) is referenced by the NCC and thus stands as a legal requirement for lighting within an abattoir. However, AS 1680.0 only requires a low level of lighting within a space to enable safe movement. It does not outline requirements for lighting for a specific task or process.

Another standards, AS1680.1:2006 (Interior and workplace lighting – General principles and recommendations) outlines the general recommendations for interior lighting. The standard recommends sufficient light, from natural or artificial sources, to allow for safe movement of employees around the workplace and allow for the employees to perform their job without having to adopt awkward postures or straining their eyes. The following factors should be taken into account:

- The nature of the work activity;
- The nature of hazards and risks in the workplace;
- The work environment;
- Illumination levels, including both natural and artificial light;
- The transition of natural light over the day;
- Glare;
- Contrast;
- Reflections.

Note, the standards referenced in this section of the review are recommendations only, and are not enshrined in legislation. However, they are widely adopted, including being referenced in Section 2.6 of Safe Work Australia codes of practice. Not meeting these standards may result in Work Health and Safety compliance issues within a facility.

AS1680.1:2006 references a second suite of standards, including AS1680.2.4-1997 (Interior lighting – Industrial tasks and processes) which identifies specific lighting requirements during the completion of certain tasks. This standard highlights recommended lighting levels and luminaire criteria for key operational tasks within an abattoir.

Lighting Recommendations for Activities Undertaken (AS1680.2.4:1997 Table E1)

ACTIVITY	MAINTAINED ILLUMINANCE (LUX)	LAMP COLOUR GROUP	LAMP RENDERING GROUP	MAX GLARE INDEX
Slaughtering	160	1 or 2	2	28*
Boning, cleaning, cooking, grinding, canning, packing and cutting	400	1 or 2	2	22
Inspection	600*	1, 2 or 3	1B or 2	N/A

Lamp Groups (from AS1680.1:2006)

RENDERING GROUP	
GROUP	CRI
1A	Ra>=90
1B	80<=Ra<90
2	60<=Ra<80

APPEARANCE GROUP		
GROUP	APPEARANCE	COLOUR TEMP (K)
1	Warm	<3300
2	Intermediate	3300<=5300
3	Cool	>5300

*Colour temperature is specified from ISO8995/CIES008/E (International standard for workplace lighting).

The standard refers to particular technical criteria:-

- **Illuminance –** the level of light which appears to emit from a surface. This directs how 'bright' a surface may appear, and will affect how occupants perceive object definition. This term is also used in the context of maintained illuminance. It is considered the 'worst case scenario' to which a lighting design should meet, as the maintained illuminance level should be the level which a lighting installation meets when the lamps are close to rated end of life and the luminaire has not been cleaned for some time. Both illuminance and maintained illuminance is measured in lux (or lx). Note that surfaces can be horizontal or vertical.

- **Colour rendering** – this is a rating of how 'true' a colour of an item may look under illumination. The closer the value to 100, the 'truer' the colour is. This plays an important role when inspections of meat are undertaken and the correct definition of colour is an important factor.

- **Appearance** – this is the colour of the light source itself. Lower values provide a 'warmer' looking lamp source; higher values are whiter and appear 'colder'. Choice of colour temperature also affects how the colour of some materials appears. For example if there is a higher content of blue light emitted from a lamp (typically the case in 'colder' or higher colour temperature lamps), the eye perceives reds as brighter, and blue as duller.

To summarise, in the case of lighting an abattoir, the AS 1680.2.4 recommends the following:-

- Lighting levels are dependent upon the level of detail a task requires. The higher the level of detail, the higher recommended lighting levels. Hence why inspection tasks are recommended to be lit to higher level than slaughtering;
- Being able to identify the 'true' colour of the object you are looking at is very important for inspection of carcasses, and less important when processing meat.

AS 1680.2.4 also notes that all lighting measurements when determining performance are taken at the work plane. The work plane can be vertical or horizontal depending on the activity being undertaken. The determination of the work plane is at the discretion of the designer. So, for example the work plane within a cold room inspection may be the skin of the carcass, whereas for dressing and butchering of meat this may be a horizontal table. The key outcome of this is that the lighting for each task area within an abattoir should take into consideration:-

- The surface which 'work' is being undertaken; and
- What kind of work is being undertaken.

On review of these standards, GHD recommend utilizing these standards in two ways within this project:-

- reviewing lighting levels through spot checks within the nominated abattoir to provide an indication on the current condition of the lighting installation, and
- any recommended lighting improvements should be designed to meet the minimum lighting performance criteria set out here.

There are additional qualitative benefits to improving lighting performance in task areas such as:-

- Improvements to worker efficiency and reduce site incidents reducing costs due to staff down time and injury costs.
- Improving the quality of lighting within inspection areas to better portray the true colour of meat has the possibility of improving inspection efficiency and accuracy of meat quality. This in turn could improve the yield of quality products from an abattoir, improving revenue.

Other Standards

In researching food safety, HACCP Australia in their auditing and accreditation process refer to compliance of lighting to AS4696:2007. This standard provides recommendations for the quality of light provided and the hygienic requirements of the lighting fixtures in food preparation areas. HACCP Australia standards also refer to AS4671:2004 (Design, Construction and Fit out of Food Premises). These standards provide the following recommendations for lighting:-

- Lighting does not result in any distortions, including colour. Hence similar to what is outlined in the Australian Standards, lighting which has a good level of colour rendering and a 'neutral' colour temperature is recommended;
- The lighting system is not a source of contamination and light bulbs and fixtures suspended over meat are protected so as to prevent contamination of meat and meat products. This relates to the construction of the luminaires. Lamps should be fully enclosed to ensure that should they shatter, debris does not potentially fall into food;
- Free from any features that would harbour dirt, dust or insects or make the fitting difficult to clean.

To summarize, a table outlining how lighting standards interrelate with relevant codes for abattoirs is shown below.

Code	Relevant AS	Comment
NCC F4.4	AS1680.0	Artificial lighting must be provided in all frequently used spaces.
NCC J6.2b	-	The aggregate design illumination power load must not exceed the sum of the allowances obtained by multiplying the area of each space by the max illumination density from table J6.2a.
NCC 3.8.4.3	AS1680.0	One light fitting per $16m^2$ of floor area or in accordance with AS1680.0 for Class 10a buildings.
NCC Vol 2. 3.12.5.5a(iii)	-	Lamp power density or illumination power density must not exceed $3W/m^2$ for Class 10a buildings.
NCC Vol 2. 3.12.5.5d	-	Halogen lamps must be switched separately from fluorescent lamps for Class 10a buildings.
NCC Vol 2. 3.12.5.5e(i)(ii)	-	Lighting around the perimeter must be controlled by a daylight sensor or have an average light source efficacy of no less than 40 Lumens/W for Class 10a buildings.

HACCP Australia Food Safety Program	AS4696:2007	- The lighting does not result in any distortions, including colour. - The lighting system is not a source of contamination and light bulbs and fixtures suspended over meat are protected so as to prevent contamination of meat and meat products.
HACCP Australia Food Safety Program	AS4671:2004	In areas where open food is handled or stored, light fittings shall be: - Designed and constructed to prevent contamination of food should the globe or tube shatter; - Free from any features that would harbour dirt, dust or insects or make the fitting difficult to clean.
Safe Work Australia Codes of Practice	AS1680.1	Sufficient lighting must be provided, whether it is from a natural or artificial source, to allow safe movement around the workplace and to allow workers to perform their job without having to adopt awkward postures or strain their eyes to see. AS1680.1:2006 Table 3.1 provides recommendations for lighting levels for various activities undertaken.

Common Lamp Technologies

As part of the review, GHD have included a short tabular analysis of the common lamp and controls technologies that are currently used.

To provide some context with respect to the commentary on lamp technologies a guide on what is considered 'good', 'average' and 'poor' standards for each parameter is outlined below, followed by the lamp type analysis. These are arbitrary benchmarks given as a guide only, and are not an exhaustive list of parameters.

Lamp Parameter	Good	Average	Poor
Light Efficacy – This is the 'bang for buck' a lamp will provide; it illustrates the light intensity (measured in lumens /lm) per watt of electrical energy consumed by the lamp.	> 100lm / w	< 100lm/W, >50lm/W	< 50lm/W
Lamp life – The time (in hours) the lamp operate to probability of failure (nominally 50%)	> 20,000 hrs	< 20,000 hrs, >10,000 hrs	< 10,000 hrs.
Re-Strike Time – The time a lamp takes to emit light to full intensity after recently being switched off.	< 2 seconds	> 2 seconds, < 2 minutes	> 2 minutes

Lamp Types

Lamp Type	Description	Typical Performance Characteristics	Pros	Cons
High Pressure Sodium (HPS)	HPS lamps are a type of High Intensity Discharge (HID) lamp that uses high pressure sodium to produce light.	- > 100lm / W Efficacy - 20,000 hr lamp life - Restrike time > 5 minutes.	- Widespread use. - Cheap to maintain.	- Poor colour Rendering. - Produce high temperatures when in operation
Metal Halide (MH)	MH lamps are a type of High Intensity Discharge (HID) lamp that uses metal halides to produce light.	- Between 70 – 80lm/W lamp efficacy - 15,000 – 20,000 hr lamp life - Restrike time approx. 5 minutes	- Good colour rendering. - Widespread use. - Cheap to maintain.	- Produce high temperatures when in operation.
Light Emitting Diode (LED)	LED lamps uses light-emitting diodes as the source of light.	- Depending on LED package between 70 - 120lm /W - > 50,000 hr lamp life - Instantaneous re-strike.	- Long lamp life - Good efficacy. - Fast re-strike time. - Light performance less susceptible to temperature than fluorescent lamps.	- Less widespread use when compared to conventional lamp types. - More expensive than traditional lamp types. - Highly directional. - Highly susceptible to high ambient temperatures and requires large heat sinks to regulate operating temperature.
Fluorescent Lamps	A tubular discharge lamp in which most of the light is emitted by a layer of florescent material	- Approx 100lm/ W Efficacy - Up to 50,000 hr lamp life, depending chosen lamp - Up to 2 seconds re-strike time.	- Most efficient white light source. - Widespread use. - Cheap to maintain. - Used in external and internal applications.	- Fluorescent lamps are susceptible to colder conditions, and will not emit full intensity at colder temperatures.
Induction	(Phosphors) deposited on the wall of the glass tube.	- Between 80 – 100lm /W Efficacy - Between 60,000 to 100,000hr lamp life - Instantaneous Re-strike	- Good efficacy. - Good colour rendering.	- Expensive. - Not widely used - Limited manufacturers who provide this product.

Lighting Controls

Control Type	Description	Pros	Cons
Manual Switching	Manual switching is the most basic of lighting controls and is reliant on the occupant(s) switching lights on and off as required.	- Lights can be turned on and off when desired.	- Can lead to lights operating for 24/7.
Timer Control	Based on automatically turning off lighting after pre-set time periods. Programme schedules will turn off lights at a pre-set time of day. Countdown timers will automatically turn off lighting in a room after a pre-set time.	- Will operate during selected times and will not be left on.	- Less flexibility than manual or sensor control. - Not linked to occupancy of the space, so lighting can be operate when space is not in use.
Microwave Occupancy Sensor	These are reliant on sensing occupancy within a room or space via microwave to control lighting within that area. This form of detection ensures that lighting is only operating when the room or space is occupied and lighting will be automatically turned off when the room is not in use.	- Only operational when an occupant is present in the space. - Not affected by objects within the space (e.g. partitions) - Can have longer ranges in comparison to PIR detection.	- Can operate lighting based on spurious movements; such as water through pipes in walls.
Passive Infra-Red (PIR) Occupancy Sensor	These are reliant on sensing occupancy within a room or space via infra-red to control lighting within that area. This form of detection ensures that lighting is only operating when the room or space is occupied and lighting will be automatically turned off when the room is not in use.	- Only operational when an occupant is present in the space. - Less susceptible to spurious movements	- Affected by objects within a space (e.g. partitions and equipment). - Generally shorter detection ranges in comparison to microwave.

Programmable Lighting Control System	These systems provide additional functionality and flexibility by using input devices (sensors, timers, reed switches etc.), output devices (dimmers and relays) and control software to control the lighting. Examples of this type of system include: • Clipsal C-BUS; • Phillips Dynalite; and • DALI.	- Allows for a higher level of control over conventional sensors and controls. - Higher level of flexibility in control of various spaces, lights and input devices. - Ability to provide overarching control of lighting from a single head end location.	- Higher capital, maintenance and comissioning costs when compared to standard controls.
Photocell	Used to control lighting based on ambient light levels.	- Only uses artificial lighting when natural lighting is insufficient. - Cheap and effective for external applications.	- Inappropriate for internal applications. - Only beneficial where a space is overlit for the requirements of the space.

The information outlined in these tables is to be used in determining the most appropriate recommendations for upgrades to lighting within an abattoir, once the site inspection is complete.

Case Studies

Part of the research conducted by GHD involved a review of Australian and international abattoirs that have undergone lighting upgrades to determine:

- what technology was implemented;
- lessons learnt from the installation; and
- what benefits were considered important to the end user; and
- to what extent these benefits were realized.

The projects which we were able to find information that was considered relevant to this project were as follows:-

True Foods Pty Ltd (Victoria, Australia)

A manufacturer of bread products upgraded their existing lighting in 2013. The lighting upgrade involved the replacement of 400W high bay fittings with 150W LED fitting as well as the replacement of some fluorescent office lighting to appropriate LED lighting. The project has achieved a saving of approximately 450,000kWh/year translating to a saving of approximately $90,000/year in electricity costs[6].

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[6] (AGL, 2013)

The project cost was $140,000, with an overall improvement in lighting levels. In simple terms, this equates to approximately an 18 month return on investment, not taking into account any potential maintenance costs.

Although this facility is not an abattoir, it does demonstrate several key points relevant to meat processing. The key motivation for the upgrades as outlined within the case study was appear to be:

- significant cost reduction due to energy savings, and
- the short payback period as a consequence.

Second, that as part of the agreement with AGL (the company who undertook the upgrade) a 3 year maintenance agreement was included within the project cost – mitigating a key operational expenditure element across the first 3 years of operation. It is therefore difficult to determine if maintenance costs due to poor lamp life or premature lighting failures mitigate any energy savings moving forward. Finally, there was a noted improvement in lighting levels. No actual values of lighting levels before or after installation were mentioned, so it is not clear if this improvement was an actual, or a 'perceived' improvement from stakeholders.

Sterklewies Abattoir (KwaZulu-Natal, South Africa)

Upgrade to existing lighting in 2013. The lighting upgrade included the upgrade of aging fluorescent lighting, replacement HPS floodlighting with LED floodlights and the replacement of MV lighting with compact fluorescent lighting, while needing to maintain compliance with South African building lighting levels of 220 lux in workshops and 540 lux at meat inspection points.

The outcome of this from the case study was a consumption load saving of 18,65kW and an annual energy saving of 118,008,62 kWH[7]. Of note, was that 70% of the construction costs associated with the retrofit were funded through a rebate scheme setup by a local energy provider, Eskon.

This case study although from overseas is of an abattoir and as such holds more relevance to the project at hand than the previous case study. It demonstrates that in other countries, lighting levels for tasks undertaken within an abattoir are mandated by regulation, rather than recommended. It doesn't provide an indication of the size of the facility, the tasks undertaken within the facility, or the operational parameters of the site (e.g., shift work, standard operation hours). It also doesn't refer to any capital costs, improvements in maintenance or other elements of operational costs. Finally, the majority of the capital costs are subsidised, therefore even if the costs were known, the return on investment would be skewed due to the reduced outlay by the abattoir owner. There is also no reference to any additional benefits to the upgrade, apart from energy savings.

Antigonish Abattoir Ltd (Antigonish, Nova Scotia)

Upgrade of existing lighting in 2013. This involved replacement of all of the lighting about their 20,000 sq foot plant, to vapour tight fluorescent fittings, with outdoor LED lighting installed within the carparks. The total cost was noted as around $30,900 AUD, but has

[7] (Eskom, 2013)

resulted in electricity savings of $6,300 CAN and annual maintenance cost savings of $800 CAN. The report also notes that the lighting levels have been noticeably improved, and it has been noted as improving worker safety[8].

Although another international case study, it is provides good information on the return on investment expected on upgrading lighting within an abattoir, and the expected return on investment both due to energy savings but due to maintenance also. The actual numbers however are to be largely ignored, as this is a case study not based in Australia, so energy and maintenance costs will be different to what is experienced within Australia. It does denote that, like the True Foods example, improvements to worker safety and wellbeing from improving lighting are additional benefits to the original energy saving goal.

Nippon Meat Packers Australia (Oakey, QLD)

As part of an integration of new and existing plant within Nippon's facility in Oakey, Queensland it was noted that existing lighting was not being turned off when areas were unoccupied, resulting in cost to the operation. A review of the facility's lighting was undertaken and controls systems were implemented. This included the installation of automated timer and occupancy sensor control. This initiative saved the site approximately $27,000 per year in running costs[9]. Office lighting has also been replaced with LED fixtures. The information for this site was taken from a short youtube video and was light on detail. There is no identification on what areas within the facility that controls were implemented and what type of controls specifically were installed. Likewise, no cost savings associated with luminaire replacement was presented in the video. The primary difference from all of the other case studies however is that the key strategy for improving energy efficiency in this case was through implementing controls rather than bulk luminaire replacement.

From our research, there are key themes which run through the case studies investigated:-

- Cost reduction due to electricity consumption outweighs costs savings due to maintenance. From all three case studies above, the cost savings due to maintenance are either not mentioned (due to being part of a larger installation and maintenance contract), or is a fraction of the running cost savings to the site, when compared to the initial energy savings. This is to be expected, as one would expect new fittings will require less maintenance immediately after installation when compared against the existing installation it replaced. This is obviously based on the assumption that the previous installation was near the end of working life, which is not able to be determined from any of the case studies above. Nevertheless, the initial cost savings are clearly from energy reduction, with maintenance savings being an added bonus.
- Prime motivator for upgrades is energy cost savings. This is an obvious observation, but a key one. The metrics outlined within the case studies are based around money saved due to reduced energy consumption. What isn't quantified in these studies are any improvements in worker efficiency or abattoir output or reduced costs due to fewer or less severe injuries due to improved lighting.

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[8] (Efficiency Nova Scotia Corperation, 2013)

[9] Nippon Meat Packers – Lighting Efficiencies Video (accessed from http://www.amic.org.au/content_common/pg-eeig-webinar-series-case-studies.seo, 4th February 2015)

- Lamp and luminaire replacement the popular choice for energy savings. All but one of the case studies outlined above are based around bulk luminaire or lamp replacements within a facility. Only the Nippon Meat Packers site in Oakey implemented lighting controls as well as some luminaire replacement. As a result other initiatives for energy savings such as:-
    - dimming existing lighting due to increased daylighting into spaces, or
    - using lighting controls to operate lighting only when occupied;
    - may be considered during the analysis stage.

Criteria for Design Recommendations

Key Energy Efficiency Criteria

A key outcome of the literature review is to determine a metric to measure the impact of proposed lighting improvements. This metric will then be used to:-

- benchmark the current energy efficiency of lighting within the site inspected; and
- compare calculated energy initiatives against the benchmark, thus determining the monetary savings and possible payback (if any) a possible initiative may have.

From review of the case studies from across the world, the accepted metric for appraising improvements is to measure the energy savings (in kWh) and in monetary savings due to reduction in energy costs. Maintenance savings due to lighting changes are also taken into consideration. These are typically factored into a simple payback period.

The metrics used in the case studies are valuable, but are site specific and are dependent upon factors such as the site size, maintaining existing lighting levels and local utility rates.

Australian Standards and the Building code typically adopt illumination levels (lux) and energy consumption per sq m are used as metrics. These are widely accepted within the building services industry as worthy metrics for lighting performance.

Ultimately the aim of this project is to provide a set of guidelines that the impact of which can be translated from site to site and based around each type of space under review. Given this, GHD recommends that all proposed energy savings be based around a metric of annual kWh (reduction) /m2/ 100 lux.

The reasoning behind this is metric choice is as follows:-

- Normalising the energy savings to a per m2 basis enables estimated savings to be quickly calculated on a site by site basis;
- Areas which require high lighting levels (such as inspection areas) will as a rule require a higher energy consumption to achieve the recommended levels. By using this metric, recommended lighting levels are not sacrificed to achieve energy savings; and
- Utilising lighting controls to reduce energy consumption can be compared against (or combined with) lamp and luminaire replacement strategies will be accounted for.

Other KPI’s such as comparing it to kg of meat processed, or reduction in injuries have not been considered, for a number of reasons:-

- From the case studies researched, none of them measured improvements in productivity or reductions of accidents due to lighting improvements. This could be for a number of reasons, such as difficulty to measure and model theoretically energy reduction can be simply modelled, and metered after refurbishment.
- Productivity and injury reduction are affected by multiple elements, such as staff training, correct equipment and management for example. All of these elements can be changed independently, and depending on the location may have different effects. Although it is likely better quality lighting will improve these, other improvements over time may mask the exact impact lighting changes make.

Other criteria to consider

GHD recommend the following additional criteria be taken into consideration:-

- If an area under assessment is observed to be under illuminated, any improvements to lighting should bring the lighting within the space up to recommended criteria as per AS 1680 standards outlined above. This may however increase energy consumption;
- Any lighting improvements shall not exceed the maximum illumination power density requirements of the NCC 2014, Section J6.2;
- Maintenance cost savings be included over the estimated useful life of the upgrade;
- Other 'soft' improvements are considered, such as improved lighting levels causing flow on improvements to production efficiency, or reducing workplace injury. Both which have secondary economic benefits. However as noted above, these flow on effects are difficult to measure, and would be qualitative only.

3.2 Site Investigation, Modelling and Options Assessment

Upon determination of a suitable metric for analysis of potential energy savings, a site inspection of a nearby abattoir was undertaken. This was done to gain an appreciation of:-

- How an abattoir operates; what the meat slaughter and preparation process entailed, operating hours and type of work done within each process;
- Typical existing lighting and lighting control installations within each process space;
- Maintenance issues with such types of installations; and
- How lighting impacts on the day to day operation of the facility.
- Condition of existing lighting.

From the information gained from this inspection, recommendations on improvements to lighting energy efficiency have been proposed, providing estimated energy savings, $kWh/m^2/100lx$ reduction estimates, and simple cost paybacks and an outline of the pro's and con's of each option.

General Information

GHD inspected a red meat processing facility in South East NSW.

The site commenced operation several decades ago and has had several ad hoc additions and changes over its life.

The abattoir employs 140 staff, which includes onsite electricians responsible for lighting maintenance. The facility slaughters beef, lambs, mutton, goat and pigs and can operate up to three lines per day. It typically operates from 6 am through to 4 pm, or as required to complete the day's work. At the time of inspection, pigs and lambs were being processed.

The site consists of:-

- Holding pens for cattle, sheep and pigs;
- Beef, pig and sheep slaughter, dressing and processing areas;
- Boning room;
- Sheep skin treatment and storage warehouse;
- Offal processing;
- Rendering Plant;
- Cold Stores, including beef, lamb and pig inspection area rooms;
- Outloading facilities; and
- Offices and support buildings (such as amenities blocks and workshops).

Lighting Observations

While on site, observations of the types of luminaires about the facility were made.

The majority of the site's spaces are typically lit with either High Pressure Sodium high and lowbays, or 36W fluorescent battens of varying combinations and installation types. The maintenance of lighting is good, with most lighting kept clean and well lamped. The exception to this is the stock yard, where lighting is dirty but lamps well maintained.

In areas such as the cold stores, including inspection halls, meat halls and boning rooms where cleaning is undertaken using high pressure water and caustic chemicals, these fittings have been suspended at high level and / or sealed to be water proof.

In plant areas, workshops, the feed lots and the stock handling into the stickpens, these luminaires are typically open fittings, with stick pens lit generally with lowbays and fluorescent battens.

Lighting about offices, amenities blocks and support facilities are generally linear fluorescent surface mounted battens of varying arrangements.

The recently constructed sheep skin shed is illuminated with LED lowbays.

Daylighting of spaces is used selectively about the facility, with daylight ingress through clear sheeting in the kill floor roof and workshop noted. Also, with the feed lots being not fully enclosed, sufficient lighting enters this space to maintain safe movement without needing to operate lighting.

Externally, a mixture of metal halide flood lighting, High Pressure Sodium and LED post tops illuminate the carparks, the weighbridge and the external hard surface areas about the perimeters of the buildings.

Lighting levels were spot measured on site. These measurements indicate the installations within each functional space generally meet or exceed recommended average lighting levels as outlined within Australian Standards, with good lighting to task surfaces noted about the facility.

The exception to the above observation is the rendering plant, where access gantries, and plant spaces are poorly lit in locations. This is due to poor luminaire placement so lighting is blocked by plant, and little supplemental lighting installed to accommodate for this.

Lighting Maintenance

In discussion with the maintenance staff, luminaires are routinely maintained based on regular lamp replacements and on an as need basis, reliant upon staff requests. The areas which these luminaires operate are generally cleaned through the use of high pressure hoses and caustic cleaning agents, but no specific cleaning of luminaires occurs. As such, most of the luminaires within the meat processing section are IP Rated and fully sealed.

Access to luminaires for maintenance varies. In most cold rooms access via a ladder is possible, and locations where lighting is mounted at high level access via catwalk and replacement of lamps from above has been implemented, or access via scissor lift is possible. There are areas where access is limited such as above the beef stickhole, and about the pig stickhole / dressing area. This is due to the height of mounted luminaires, and lack of access due to installed plant.

The maintenance team over time has trialed alternative luminaires, primarily to research lamp options with longer lamp lives, hence reducing lamp replacement costs. Tested luminaires at the time of inspection include:-

- **Induction Lamps** These were trialed in the loadout areas and above the kill floor. These luminaires experienced poor lamp life in comparison to the HPS luminaires which they replaced, with yellowing of lamps noted on site. This is of concern, as induction lamps are typically renowned for longer lamp lives than equivalent HPS lamped fittings. A reason as to why this is occurring is unknown, and could not be determined from observation on site.
- **LED Lowbays** These have been trialed within a cold store, and installed within the new skinning shed. Both installations consist of LED array luminaires with no diffusers of lenses. These have reduced wattages from 150W for to between 75W and 100W, depending on the luminaire chosen. Staff on site is satisfied with the performance of these luminaires, with the exception that the light from the chosen luminaires is too controlled and sharp cutoffs have been noted. Diffusers for these luminaires are being considered and luminaire manufacturers are addressing the issue.

Stakeholder Comments

While on site, GHD met with the inspection team in charge of monitoring diseased meat and the operations manager to investigate any issues or concerns with current lighting conditions about the facility.

Operations Manager

The operations manager noted there are very few complaints about lighting from staff. Generally lamps are replaced due programmed maintenance, and staff note the improvement in lighting levels. Injuries on site were low and no incidents based on his recollection have occurred due to poor lighting conditions.

Inspectors

Meat inspection is done on both carcasses and offal. Carcasses are inspected in cold stores, with inspectors provided task lighting (in the form of a hand torch) as required by their inspection standards. This removes any need for cold store lighting to meet any technical parameters for this task.

Offal inspection is done on the kill floor, utilizing ambient lighting. In discussions with the inspectors, the lighting above within this space is preferred to be as close to daylight in colour as possible (5,000K – 6,000K) to enable inspectors to differentiate colouring and contamination if present.

Meat grading for export was not undertaken at the site. However, on further investigation the inspections undertaken within cold stores are done in a similar manner to disease inspection; not relying upon ambient cold store lighting.

Lighting Controls

Lighting about the facility is typically manually controlled, with the exception of exterior lighting which is controlled by PE cell and timer. This lack of automated lighting control about the facility does not comply with current Section J requirements of the National Construction Code.

From discussions has with the maintenance staff, most of the facility is switched off at the end of shift, with the exception of the cold stores which are left switched on 24/7. The reasoning for lighting within the cold stores being left on permanently is unknown. However, given the type of lighting employed within these rooms and their slow restrike time, and given staff movement through this space is high, it is highly likely leaving the lighting on was seen as the simplest alternative.

Options Assessment

To provide a benchmark of the impact potential modifications to lighting may have on energy consumption. A baseline 'current' installation for each space has been determined; utilising what was noted on site, including luminaire and lamp types, lighting levels, controls and hours of lighting operation, the following kWh/m^2/100lux have been determined.

In the same table, comparison of W/m^2 values against 2014 NCC Section J6.2 maximum values is also made.

Baseline Information – 'current' room information

DESCRIPTION	LENGTH (M)	WIDTH (M)	AREA (M2)	LIGHTING TYPE	ESTIMATED NUMBER OF LIGHTS	NUMBER OF LAMPS PER FITTING	WATTAGE PER LAMP (INC. CONTROL GEAR)	ESTIMATED TOTAL WATTS (W)	MEASURED ILLUMINANCE (LX)	RECOMMENDED ILLUMINANCE LEVEL FROM AS 1680	OPERATIONAL HOURS PER DAY
Meat hall	24	15	360	150W HPS	10	1	180	1,800	80	40	24.0
			360	Emergency 36W Fluroescent	4	1	41	164	-		24.0
Boning room (generally)	20	10	200	150W HPS	6	1	180	1,080	80	40	24.0
Boning benches			200	2x36W Fluroescent	2	2	77	154	400	400	24.0
Blast freezer	15	8	120	150W HPS	4	1	180	720	60	40	24.0
			120	36W Fluroescent backup	4	1	41	164			24.0
Loadout	25	10	250	2x 36W Fluroescent	8	2	77	616	80	40	8.0
Kill floor*	35	20	350	250W HPS	10	1	280	2,800	400	400	8.0
			350	250W MH	10	1	280	2,800	400	400	8.0
Beef storage	15	10	150	150W MH	4	1	180	720	40	40	24.0

			150	36W Fluroescent backup	4	1	41	164			24.0
Lamb inspection	15	10	150	54W T8 Fluros	12	1	59	708	40	40	24.0
Foreman offices/ workshop	5	10	50	2x 36W Fluro	4	2	77	308	290	320	8.0
Laundry/first aid	5	10	50	2x 36W Fluro	6	2	77	462	320	320	8.0
Beef stickhole	3	2	6	150W HPS Low bay	1	1	180	180	80	160	8.0
			6	36W Fluro	1	1	41	41			
Pig stickhole and dressing	20	20	400	250W HPS High bay	12	1	280	3,360	80	40	8.0
Support offices	25	20	500	36W Battens	100	1	162	162	320	40	8.0
Toilets and change rooms	25	10	250	1. 1x36W Battens	6	1	59	708	80	80	8.0

			250	2. 2x36W Battens	6	2	41	308			8.0
Pig cold stores	15	8	120	2x 36W Fluroescent	24	2	41	154	40	40	24.0
Boning and offal removal	10	5	50	2x 36W Fluroescent	8	2	180	180	400	400	8.0
Walkways and corridors	15	3	45	1. 150W HPS	3	1	41	41	100	40	8.0
				2. 2x36 Fluroescent	3	2	280	3,360			8.0
lamb stickhole	5	2	10	36W Fluroescent	4	1	41	4,100	80	160	8.0
maintenance workshop	20	15	300	2x 36W Fluroescent	16	2	41	246	240	160	8.0
Offices / admin	25	20	500	2x 36W Fluro	50	2	77	3,850	320	320	8.0
Plant areas	30	30	900	36W Fluro	50	1	41	2,050	80	80	8.0

*Measurements in table denote horizontal spot measurements taken on site within the kill floor. Additional vertical spot measurements were taken about the task surfaces to determine the levels of illumination on the hanging carcass surfaces. Levels of 100 – 200lx were observed on site.

Baseline Information – 'current' room calculated lighting levels and energy consumption

ROOM	ESTIMATED TOTAL INSTALLED WATTAGE PER AREA (W/M^2)	NCC ALLOWABLE (W/M2)	MEASURED ILLUMINANCE (LX)	ESTIMATEDENERGY USE PER ROOM PER YEAR (KWH)	ESTIMATED ANNUAL KWH/M^2/100LX
Meat hall	5.5	7.5	80	47,136	163.7
Boning room	6.2	13	400	10,810	13.5
Blast freezer	7.4	7.5	60	7,744	107.6
Loadout	2.5	9	80	1,799	9.0
Kill floor	16.0	10	400	16,352	5.8
Beef storage	7.0	7.5	20	9,163	152.7
Lamb Inspection	4.7	7.5	40	6,202	103.4
Foreman offices/ workshop	6.2	11	290	899	6.2
Laundry/first aid	3.1	12	320	450	2.8
Beef stickhole	36.8	10	80	645	134.4
Pig stickhole and dressing	8.4	10	80	9,811	30.7
Support offices	8.2	12	320	11,972	7.5
Toilets and change rooms	2.8	9	80	2,067	10.3
Pig cold stores	15.4	7.5	40	16,188	337.3
Boning and offal removal	12.3	13	400	1,799	9.0
Walkways and corridors	25.2	8	100	6,754	150.1
Lamb stickhole	16.4	12	400	479	12.0
Maintenance workshop	4.1	11	240	3,597	5.0
Offices/admin	7.7	12	400	11,242	7.0
Plant areas	2.3	10	80	5986	8.3

Of note:

- Lamp energy consumption outlined within the table above includes control gear consumption, and
- Many of the areas modelled based on information gained from the site currently comply with the minimum energy standards set out by NCC Section J, without need for any improvement while still achieving lighting levels above Australian Standard recommendations.
- Generally lighting controls do not comply generally with NCC Section J.
- No automated lighting control is implemented on site in any internal areas.

As outlined in the literature review, the NCC does not apply to existing installations. However review of any existing installation against current building codes is valuable in so far as enabling us to review existing installations against current, minimum requirements for buildings.

Using the current room and lighting information, several initiatives for energy reduction are proposed:-

- Automated occupancy based lighting control. Many areas are sporadically occupied during the course of a normal working day, yet the lighting in these spaces are operational the whole day (6am to 4pm), or 24/7. Implementing occupancy based control will assist in the reduction of energy consumption due to wasted light when spaces are not occupied. It will also bring the interior lighting into compliance with current NCC requirements.
- Luminaire replacement. As noted above, the majority of the abattoir is illuminated with linear 36W fluorescent battens and High Pressure Sodium high and low bay luminaires. These two types of lighting solutions pose the following problems:-
    - 36W T8 fluroescent lamps provide less light output for the energy consumed than newer technologies such as T5 fluorescent and LED. T8 lamps do operate better in colder environments than T5 lamps, hence they are still utilized within cold stores and external environments. Current generation LED's in contrast perform well in cold environments, and provide lighting efficacy similar to T5.
    - High pressure sodium lamps require warm up time until they emit light at full brilliance. Also, they require cool down time after operation before re-igniting. Given these issues with HPS lamps, they are not an ideal light source for areas which are sporadically used and rapid switching of lighting is desired. Where HPS lamps have been used in cold stores in similar instances, additional lighting has been installed with quicker re-strike times to enable occupants to safely move about the space while the HPS luminaires re-strike / warm up. Recent advances in LED technology mean that LED luminaires are available that have similar light output to HPS with equivalent or better energy efficiency, and can offer instant full brilliance once turned on.

  Given these problems, replacement of lighting in select areas with LED or high efficiency T5 lamps (where low temperatures are not of a concern) have been investigated.

Further initiatives are investigated below, which are derivatives of these two key options.

Option 1 – Automated Controls

Automated controls are available in a variety of options and levels of complexity as outlined in previous sections of this report.

For this analysis, GHD have chosen the following options outlined below. These have been based around past experience in implementing such systems in other sectors (such as commercial spaces).

Automated lighting control is proposed to be implemented as follows:-

- Installing occupancy based controls within cold storage areas (including the loadout, boning and inspection areas). This could be achieved in two potential ways:-
    1. Installing motion sensors within the cold stores, which are set so that after a predefined time, lighting switches off; or
    2. Installing a momentary reed switch in the top of the sliding cold store door. When the doors are open, the lighting is on. When the door is closed, lights switch off

  There are advantages and disadvantages to each approach. The first approach doesn't rely on the door being opened, potentially causing temperature rises in the store but location of motion sensors would be key, as sensors may not pick up movement in a heavily stocked freezer due to dead zones created by carcasses and hanging rails. Also, motion sensors may be susceptible to moisture and the cold, effecting performance. Reed switches on the other hand are a simpler device, and only require installing within the door. The risk of this alternative solution is accidental door closing while the cold store being occupied potentially leaving staff in absolute darkness.

  In both implementations, we have assumed that:-

    - the total operation of lighting in cold stores would be reduced from 24 hours a day, to 8. This is based on the premise that stores would only be opened for loading and unloading of stock (estimated to be 2-3 hours per load / unload) and incidental inspections or access during a shift (say 1 hr over a shift). These assumptions are likely to be on the conservative side; and
    - that when cold stores are occupied, they are occupied for a lengthy period of time. As the stores are lit with HPS lamps (which are slow to ignite and come to full brilliance in cold conditions) this is important; as regular short occupancies may never allow the sodium lamps to fully warm up, resulting in poor lighting conditions and potential damage to the lamps. As such, replacement of HPS fittings with LED luminaires is a recommended consideration to provide an ideal solution.
- Installing occupancy sensors within toilets, change rooms and support facilities. Given that these rooms are accessed sporadically during the day, the following occupancy pattern has been assumed that over an 8 hour shift:-
    - 1 hr at start and end of shift; and

  - 20 minutes per hour during shift for toilet breaks, change of lines etc.
  - Change rooms, showers and toilets would be accessed.
- Installation of occupancy sensors within offices. Based on staff movements noted on site, occupancy sensors within offices will likely have minimal impact. Therefore 8 hours per workday has been estimated. The only benefit these may have (apart from compliance with current NCC requirements) is that it would reduce inadvertent lighting been left on accidentally after hours.
- Occupancy sensor control of stickholes. It was noted that at any one time, only one stickhole was in operation depending on stock in the yards. Therefore as a broad assumption, on a normal 8 hour day, any one stick hole is in operation for a 1/3 of the total time. Energy savings due to installation of lighting control through motion sensor in these spaces has been based on this assumption.
- Occupancy sensors within corridors. These will be occupied sporadically during the day, depending upon the type of operations being undertaken at the time. This potentially means corridors may be unoccupied but lit. To model potential occupancy, it has been assumed that corridors during shift will be occupied every 30 minutes or so out of every hour of a normal working day, and 15 minutes per hour either side of 'standard' operating hours.
- Timer control with afterhours override for the kill floor and offal removal spaces. Occupancy sensor control for this space could be considered, but there is a risk that given the extent of high mounted railing, racking and gantry equipment within this space that movement about the floor may not be picked up due to sensors becoming obscured, raising a potential safety hazard. Therefore an alternative is proposed, whereby lighting is to operate automatically from 5.30am until 5pm. Should additional lighting be required after 5pm, override switching is allocated adjacent to all entries to turn lighting back on for another 3 hours. As this is based purely upon the demand on the kill floor, which is difficult to model, the team has assumed that normal operational hours are likely for 80% of the year, with an additional 2 hours needed for 10% of the days per year. This methodology would prevent the likelihood of lighting being left on for lengthy periods after hours and over weekends.

Within this option, two different sensors have been proposed:-

- Passive Infra Red (PIR) sensors have been proposed for toilets, offices, corridors, and support facilities. These are due to their lower capital cost to alternative sensors. They are also better suited to spaces that have less physical obstruction.
- Microwave sensors have been recommended for areas where there is a probability of high levels of obstruction within a space due to improved sensitivity. Fully stocked cold store or a kill floor where racking and carcasses may deflect or block PIR sensors.

ROOM	PROPOSED CONTROLS	OPERATIONAL HOURS PRIOR TO CHANGE	OPERATIONAL HOURS POST CHANGE	ESTIMATED KWH/M^2/100LX	ESTIMATED KWH/M^2/100LX REDUCTION	ESTIMATED COST SAVING IN ENERGY / ANNUM	ESTIMATED CAPITAL COSTS	ESTIMATED PAYBACK (YEARS)
Meat hall	Microwave Sensors	24.0	8.0	19.9	143.8	$7,245.20	$2,625.48	0.4
Boning room	Microwave Sensors	24.0	8.0	4.5	9.0	$1,261.15	$2,625.48	2.1
Blast freezer	Microwave Sensors	24.0	8.0	35.9	71.7	$903.45	$1,842.72	2.0
Loadout				9.0	0.0	$-		
Kill floor				5.8	0.0	$-		
Beef storage	Microwave Sensors	24.0	8.0	50.9	101.8	$1,069.01	$1,842.72	1.7
Lamb inspection	Microwave Sensors	24.0	8.0	34.5	68.9	$723.58	$2,625.48	3.6
Foreman offices/ workshop				6.2	0.0	$-		
Laundry/first aid				8.4	0.0	$-		
Beef stickhole	Microwave Sensors	8.0	2.6	43.7	90.7	$76.23	$921.36	12.1
Pig stickhole anddressing	Microwave Sensors	8.0	2.6	10.0	20.7	$1,158.95	$2,764.08	2.4

Support offices				7.5	0.0	$-		
Toilets and change rooms	PIR Sensors	8.0	4.0	5.2	5.2	$180.89	$3,380.16	18.7
Pig cold stores	Microwave Sensors	8.0	4.0	112.4	224.8	$1,888.66	$1,842.72	1.0
Boning and offal removal				9.0	0.0	$-		
Walkways and corridors	PIR Sensors	8.0	4.0	75.0	75.0	$590.97	$2,060.16	3.5
Lamb stickhole	Microwave Sensors	8.0	4.0	3.9	56.0	$391.78	$921.36	2.4
Maintenance workshop				5.0	0.0	$-		
Offices/admin				7.0	0.0	$-		
Plant Areas				8.3	0.0	$-		
Total Energy Saving per Annum						**$15,489.86**		
Total Capital Cost							**$23,451.72**	
Total Est. Payback								**1.5 years**

Areas which have been excluded from potential automated control include:-

- Stockyards. From discussion with staff on site, the stockyard lighting is only rarely used- typically during some days in winter when overcast conditions provide insufficient lighting.
- Exterior Lighting. This is already automatically controlled through the use of a PE cell.

Note that where occupancy control produces no net change in operational times for lighting and hence no net reduction in kWh/m^2/100lx, then no capital cost or payback period for the installation has been noted.

Option 2 – Luminaire Replacement

As outlined above, across the abattoir, each space was reviewed, and possible replacements of luminaires to cheaper, more efficient options are proposed. These initiatives include:-

- 155W LED Lowbay luminaires within cold stores to replace 150W HPS Lowbays.
- 32W LED weatherproof battens to replace 1 x 36W battens within selected cold stores.
- 52W LED weatherproof battens to replace 2 x 36W battens within selected areas
- 190W highbays and 155W LED lowbay luminaires within the kill floor to replace luminaires within the kill floor, stick hole and dressing areas.
- High performance T5 28W battens with varying diffusers and installations about the support areas and amenity blocks.
- T5 28W Troffers within offices areas.

Two sub options were undertaken in this investigation:-

- 1 for 1 luminaire replacement. This was a strict swap of luminaire quantities from what was previously allowed for within the baseline modelling. This is the cheapest of the luminaire replacement options, as existing wiring could be reused. Where
- Optimised installation. As the luminaires chosen to replace existing may provide higher light output, or deliver lighting in a more efficient manner, the resultant calculated lighting levels are anticipated in some cases to exceed the existing levels noted on site. This option proposes a complete redesign of lighting to the nominated space, potentially reducing luminaire numbers further with the aim to maintain existing lighting levels.

LED's have not been recommended to illuminate office areas, as the capital cost for a luminaire which provides similar lighting performance to a T5 fluorescent is significantly more, for no significant improvement in lighting levels or energy consumption.

The estimated kWh/m^2/100lx values for each space are outlined below:-

Option 2a – Lighting Replacement '1 for 1'.

ROOM	REPLACEMENT LUMINAIRE	EXISTING LIGHTING DENSITY	NEW LIGHTING DENSITY	ESTIMATED KWH/M^2/ 100LX	ESTIMATED KWH/M^2/100LX REDUCTION	ESTIMATED COST SAVING IN ENERGY / ANNUM	ESTIMATED CAPITAL COSTS	ESTIMATED PAYBACK (YEARS)
Meat hall	155W LED Lowbay	5.5	4.6	139.2	24.5	$1,234.80	$6,724.50	5.4
Boning room	155W LED Lowbay and 52W LED Batten	6.2	2.0	12.2	1.3	$180.89	$4,579.70	25.3
Blast freezer	155W LED Lowbay	7.4	2.0	81.3	26.3	$331.13	$3,234.80	9.8
Loadout	52W LED Batten	2.5	0.7	6.7	2.3	$81.76	$2,180.00	26.7
Kill floor	250W LED Highbay	16.0	2.7	13.7	0.9	$183.96	$11,550.00	62.8
Beef storage	155W LED Lowbay	7.0	1.6	97.5	55.2	$579.47	$2,689.80	4.6
Lamb inspection	52W LED Batten	4.7	1.7	99.9	3.5	$36.79	$3,270.00	88.9
Foreman offices/ workshop	52W LED Batten	6.2	0.8	2.3	3.9	$99.13	$545.00	5.5
Laundry/first aid	28W T5 Troffer	9.2	0.5	1.2	7.2	$202.36	$545.00	2.7
Beef stickhole	155W LED Lowbay and 52W LED Batten	36.8	13.6	136.3	-1.8	-$1.53	$944.95	-616.4
Pig stickhole anddressing	250W LED Highbay	8.4	2.9	28.7	2.0	$110.38	$6,930.00	62.8

Support offices	28W T5 Troffer	8.2	2.4	6.0	1.5	$408.80	$16,500.00	40.4
Toilets and change rooms	32W and 52W LED Battens	2.8	0.8	8.2	2.1	$73.58	$3,270.00	44.4
Pig cold stores	52W LED Batten	15.4	12.5	249.7	87.6	$735.84	$6,540.00	8.9
Boning and offal removal	52W LED Batten	12.3	1.1	6.7	2.3	$81.76	$2,180.00	26.7
Walkways and corridors	155W LED Low Bays and 52W LED Battens	25.2	16.4	130.8	19.3	$151.77	$8,504.55	56.0
Lamb stickhole	32W LED Batten	16.4	5.4	10.8	49.1	$343.39	$1,090.00	3.2
Maintenance workshop	52W LED Batten	4.1	1.1	3.7	1.3	$163.52	$4,360.00	26.7
Offices/admin	28W T5 Troffer	7.7	2.2	5.6	1.5	$408.80	$8,250.00	20.2
Plant Areas	32W LED Batten	2.3	0.8	7.5	0.8	$102.20	$13,625.00	133.3
Total Energy Saving per annum						**$5,508.80**		
Total Capital Cost							**$107,513.3**	
Total Est. Payback								**19.5 Years**

It is worth noting that the replacement 155W LED lowbays have a higher lamp wattage output than the replacement 150W HPS units in situ. However, when taking into consideration both the lamp and control gear consumption the recommended LED lowbays consume less energy, and are more suitable for the automatic control strategies proposed in option 1.

Option 2b – Optimised Lighting Design

ROOM	ESTIMATED KWH/M^2/100LX	ESTIMATED KWH/M^2/100LX REDUCTION	ESTIMATED COST SAVING IN ENERGY / ANNUM	ESTIMATED CAPITAL COSTS	ESTIMATED PAYBACK (YEARS)
Meat hall	20.3	143.3	$7,224.76	$2,579.80	0.4
Boning room	8.1	5.4	$755.77	$14,040.00	20.0
Blast freezer	20.3	87.2	$1,099.16	$644.95	0.6
Loadout	7.3	1.7	$58.77	$1,934.85	34.3
Kill floor	2.2	12.4	$6,099.30	$9,000.00	1.5
Beef storage	48.8	104.0	$545.75	$644.95	1.2
Lamb inspection	33.3	70.1	$735.84	$1,440.00	2.1
Foreman offices/ workshop	5.7	0.5	$11.75	$1,800.00	164.9
Laundry/first aid	6.6	1.8	$50.59	$1,512.50	35.9
Beef stickhole	34.7	99.8	$83.80	$360.00	4.6
Pig stickhole anddressing	7.2	23.5	$1,315.31	$2,250.00	1.8
Support offices	5.3	2.2	$611.16	$12,100.00	23.8
Toilets and change rooms	5.0	5.3	$187.03	$4,320.00	24.9
Pig cold stores	31.2	306.1	$2,570.84	$1,080.00	0.5
Boning and offal removal	6.7	2.3	$81.76	$2,880.00	37.9
Walkways and corridors	14.8	135.3	$1,065.44	$1,440.00	1.5
Lamb stickhole	20.8	39.1	$54.68	$360.00	7.1
Maintenance workshop	6.9	-1.9	-$244.26	$10,800.00	-47.6
Offices/admin	4.2	2.8	$975.24	$12,100.00	14.9
Plant Areas	8.1	0.2	$28.11	$12,600.00	482.6
Total Energy Saving per Annum			**$23,310.78**		
Total Capital Cost				**$19,018.38**	

Total Est. Payback					**5.4 Years**

Option 3 – Luminaire Replacement and Controls

Finally, a review of full luminaire replacement, and implementation of a controls strategy were considered; combining options 1 and 2. This was undertaken to see if combining the two options provided a combined energy saving which was equal (or greater than) the initiatives undertaken in isolation.

The benefit of this initiative is that with the use of LED and fluorescent luminaires, there is no problem with re-strike times and delays of lighting coming to full brilliance as experienced with HPS lamps. As such, rapid switching of luminaires is possible if required.

An issue with such an installation is the capital cost associated with this option. The existing lighting installation is effectively removed and all new equipment installed.

The estimated kWh/m^2/100lx values for each space are outlined below:-

Option 3– Replacement Lighting and Controls

ROOM	ESTIMATED KWH/M^2/ 100LX	ESTIMATED KWH/M^2/100LX REDUCTION	ESTIMATED COST SAVING IN ENERGY / ANNUM	ESTIMATED CAPITAL COSTS	ESTIMATED PAYBACK (YEARS)
Meat hall	6.8	156.9	$7,907.45	$2,579.80	0.3
Boning room	8.1	5.4	$755.77	$14,040.00	20.0
Blast freezer	6.8	100.8	$1,269.84	$644.95	0.5
Loadout	7.3	1.7	$58.77	$1,934.85	34.3
Kill floor	2.2	12.4	$6,099.30	$9,000.00	1.5
Beef storage	16.3	136.5	$716.42	$644.95	0.9
Lamb inspection	11.1	92.3	$968.86	$1,440.00	1.6
Foreman offices/ workshop	5.7	0.5	$11.75	$1,800.00	164.9
Laundry/first aid	6.6	1.8	$50.59	$1,512.50	35.9
Beef stickhole	11.3	123.2	$103.46	$360.00	3.7
Pig stickhole anddressing	2.3	28.3	$1,586.43	$2,250.00	1.5
Support offices	5.3	2.2	$611.16	$12,100.00	23.8
Toilets and change rooms	5.0	5.3	$187.03	$4,320.00	24.9
Pig cold stores	10.4	326.9	$2,745.60	$1,080.00	0.4
Boning and offal removal	6.7	2.3	$81.76	$2,880.00	37.9
Walkways and corridors	7.4	142.7	$1,123.69	$1,440.00	1.4
Lamb stickhole	6.8	53.1	$74.34	$360.00	5.2
Maintenance workshop	6.9	-1.9	-$244.26	$10,800.00	-47.6
Offices/admin	4.2	2.8	$975.24	$12,100.00	14.9
Plant Areas	8.1	0.2	$28.11	$12,600.00	482.6
Total Energy Saving per Annum			**$20,818.89**		
Total Capital Cost				**$127,046.27**	
Total Est. Payback					**6.1 Years**

3.3 Analysis Results

From the calculations and modelling of the above options, the following has been observed from the results:-

Option 1 – Automated Lighting Controls

- In areas where lighting is generally well controlled with staff training (such as the offices and workshops) there is no reduction in energy consumption, and therefore no actual payback on any initiatives. Therefore in the table above, savings and payback periods due to any changes are omitted deliberately. However, errant lighting consumption after hours accidentally is excluded. So where no data is shown, occupancy control in these spaces would provide additional benefit, as well as compliance with NCC requirements.
- Where areas have been traditionally had lighting left on for lengthy periods of time and yet are not frequently visited (such as the cold stores) automated control demonstrates, good energy savings and short payback times. What this analysis doesn't take into consideration however is the type of lighting which is being controlled. High Pressure Sodium lamps by their nature have slow restart times once they have been switched off, and installing automated controls into spaces which have these luminaires in place may mean staff are walking into dimly lit or un lit spaces initially. This could be resolved with some lighting within the room being un-switched to provide safe lighting to enter the space, while the remaining lighting warms up – this would be a marginal offset to the energy savings.
- Toilets and stick hole payback periods are very long; calculated to be in the order of 19 years. The reasoning for this is suspected to be two fold:-
    - With respect to the toilets and change rooms, the frequency of attendance over such short periods of time during a day means that the lighting within these spaces is on for an estimated 4 hours a day. Given the arrangement of such spaces needing several motion sensors installed so as to ensure lighting doesn't de-activate while occupants there the cost for installation is raised. Both of these drive the payback period out.
    - The stickhole spaces are small, and the lighting installed within them doesn't consume enough electricity over the operation time to make the savings significant enough to pay back the installation cost.

Option 2a -1 for 1 Luminaire Replacement

- Many of the spaces under analysis, the energy savings per annum are low, making the resultant payback periods excessive and not economical. However many of the spaces which have had HPS low / highbays replaced with LED equivalent luminaires of similar light output are now calculated to be lit to far higher levels than originally measured on site. This is explained by the fact that traditional lamp based luminaires (such as HPS and fluorescent) need to accommodate light being emitted from a source in all directions; hence light is lost through reflections out the back and sides of the fitting.

LED's fittings generally however are designed to emit a higher percentage of their light out of the luminaire directly, resulting in a more efficient light output.

- Even with LED luminaires that having similar lamp energy consumption to traditional HPS fittings they replace, the energy reduction due to higher efficiency control gear means that there are still worthwhile energy savings associated with replacement. This is evident with cold stores where simple replacement provides paybacks in the order of 5 years, well within the operational design life of the luminaires.
- As LED and T5 fluorescent lighting is able to be switched or dimmed without any significant delay, these choices of lighting are more suited to the automated controls strategies nominated in Option 1.

Option 2b – Optimized Luminaire Replacement

- As soon as lighting designs are optimized to meet the levels required the resulting energy savings increase significantly in comparison to 1 for 1 replacement. Costs associated with these installations actually decreases marginally and hence payback periods improve.
- Some areas still display low or negative kWh/m^2/100 lux reductions. These areas typically are about the workshops and plant areas. This is likely due to the type of luminaire chosen for this space, and can be optimized further with alternative luminaire choices.
- Due to the higher capital costs however, the payback periods are generally higher per space to installing automated controls alone.

Option 3 – Luminaire Replacement and Automated Lighting Control

- The highest cost savings and reductions in kWh/m^2/100lx occur when combining both optimized lighting replacement with automated controls. This solution however is the most expensive of all options provided.
- Due to this higher cost, the payback periods still do not exceed those generated by simply automating lighting control.

Analysis Summary

When comparing the three options above, the following observations have been made:-

- Installation of automated controls designed about occupancy based control, provides the best payback period. As noted above, some areas have been omitted from this analysis due to existing good occupant control behavior noted on site. However, occupancy based control is likely to provide benefits by reducing accidental energy consumption due to lighting left on after hours. However in locations such as cool rooms where rapid switching of lighting is possible, replacement of luminaires to LED is beneficial as existing lighting technology does not respond well to rapid switching.
- Optimized lighting replacement along with lighting control provides both the highest energy cost savings per annum, but also is the most costly to implement. Simple

replacement of luminaires for new, more efficient luminaires will provide you with energy savings generally. However, some locations due to the arrangement of existing luminaires will result in a solution that provides higher lighting levels than what is witnessed in an optimized design – thus reducing cost savings and increasing payback periods.

4.0 Recommendations and Conclusion

4.1 Recommendations

Based on the information gained from the site inspection and the modelling in the sections above, GHD recommend that should an AMPC stakeholder choose to improve energy consumption due to lighting, the following initiatives be undertaken in the order of effectiveness:-

- **Replace manual controls with automated controls.** Automated controls provide the best return on investment in comparison to other initiatives investigated. Systems can be as simple as timer controls with push button override, localized occupancy sensors through to fully automated, intelligent facility wide systems. If such an initiative is to be installed the abattoir owner should consider:-
    - The conditions which the system is to operate – such as how occupants use the space in question, level of obstructions within the area, temperature and humidity etc. and
    - The type of lighting which is to be controlled - as outlined in this report, some lighting does not respond well to rapid switching and require a delayed ret-strike time. This can be over come within the system design, but does impact on occupant amenity. If regular movements through a space occur and lighting is likely to be switched rapidly, replacement of luminaires as part of the upgrade should be completed.

Such automated occupancy based control within existing abattoirs also ensures that the lighting installation complies with Section J 6.3 of the latest version of the National Construction Code.

- **Replace luminaires with higher efficiency luminaires.** The advent of high efficiency lighting sources such as LED has meant that significant energy savings can be made through luminaire replacement. Such technology compliments automated, occupancy based controls and can tolerate low temperatures. If replacements are to occur, an owner should also consider:-
    - Redesigning the lighting installation to optimize performance. As newer fittings also take full advantage of the light generated, it is recommended that if replacements are to occur, the design of the lighting installation be redone to minimize luminaire costs while maintaining good lighting levels. These levels should meet the minimum standards recommended within the AS 1680 suite of standards.

Other Recommendations

While planning to improve the lighting energy efficiency about an abattoir is recommended that separate metering of lighting, power and mechanical sub-circuits also be considered**.** By separating power, lighting and mechanical supplies at each switchboard onto separate chassis within each switchboard and then metering each chassis there are the following advantages:-

- Energy savings from lighting improvements can be monitored and measured to verify expectations; and
- Separate metering would bring the switchboards up to compliance with Section J 8 of the NCC.

The main disadvantage to these modifications is cost. This work may require a full upgrade of a switchboard to accommodate chassis changes and metering.

4.2 Other Considerations

The key metric under consideration of lighting upgrades within this project has been energy efficiency. There are other side issues that are worth considering when reviewing potential upgrades that are not covered in the analysis of these options.

Impact on Maintenance

What has not been considered within this report is the impact on maintenance costs modifications to lighting systems may have. For example, limiting the daily operation of lamps or luminaires extends the periods between lamp and control gear replacements, hence reducing overall maintenance costs per annum.

Secondly, the example LED battens and High Bays utilized in the analysis have manufacturer nominated lifetimes of 50,000hrs. This is in contrast to HPS lamps which have a nominal life of 10,000 hrs. Likewise T8 fluorescent lamps can be purchased to operate between 13,000 and 50,000hrs.

Hence further maintenance cost savings can be estimated due to a reduction in lamp replacements due to both less light operation per annum, and longer lamp life.

Lighting Quality

This issue is more of a qualitative one but yet is a side effect to the replacement of HPS luminaires with LED equivalents. The light which is omitted from the proposed LED replacement lamps has technical characteristics that will produce a ‘whiter’ light than the currently installed HPS lamps, and show surfaces in a truer colour.

LED replacement will therefore likely result in a space which appears to be better lit, with key elements such as carcass colour seen truer than previously.

Further Works

Leading on from the outcomes of this investigation and to further this work, it is recommended that a test site be found to implement these recommendations within a real world situation. A facility should be chosen where:-

- multiple rooms of similar use, function and conditions are available; and
- separate metering for lighting can be installed.

Variations of the suggested options can be installed and energy consumption monitored over a selected period of time. Feedback from staff and management on the changes can also be noted.

4.3 Conclusion

In conclusion, although energy consumption due to lighting only is only a small fraction of the total energy consumed within an abattoir, this investigation has unearthed opportunities to improve lighting energy efficiency through implementations of newer lighting and controls technologies. The challenge was determining a method of measuring the impact any improvement may have which is relevant to a meat processor, and can be scaled across varying sites.

There is no standard configuration or set of operations for an abattoir. These facilities range in size, operating times, and the range of tasks which they undertake within them. This complicates providing definitive recommendations for meat processors, as how one abattoir operates may impact on expected energy savings if the metric on which the impact of any improvement is measured by isn't flexible enough to accommodate this.

Through investigation, it was noted that the National Construction Code (NCC) provides a minimum standard for energy power density for new installations. The NCC however is the minimum standard to which lighting installations should meet, and any upgrades which are undertaken to improve energy efficiency should aim to exceed these requirements. Likewise, there are recommended performance criteria for lighting of task areas about an abattoir, as well as recommended luminaire construction criteria for luminaires to be used in food preparation areas enshrined within Australian Standards. Note however these are minimum requirements only – any initiatives should strive to meet or exceed these minimum requirements.

Other meat processors in Australia and overseas have made recent attempts at energy efficiency upgrades to lighting. These have typically concentrated on bulk luminaire and lamp replacements, and measured success based upon energy savings over an annual period for a specific site.

Given these observations it was determined that the best criteria for comparing energy efficiency improvements to a specific space within an abattoir would be to calculate the annual kWh reduction/m^2/100 lux, considered in conjunction with the other key criteria above.

Once a suitable metric had been determined, a meat processing site located in South East NSW was visited. This inspection provided a closer insight into:-

- A ‘typical’ lighting installation within an abattoir, including luminaire types and methods of lighting control;
- How various spaces are used, how frequently they are occupied and the key areas to be illuminated;
- Key maintenance and operations issues which are affected by lighting.

This information was then incorporated into an options study that looked at several initiatives for energy reduction due to lighting:-

- Installing automated or occupancy based lighting control within areas which have sporadic occupancy;
- Replacing lighting with higher efficiency lighting sources. This included two separate sub-options:-
    - One for one replacement of quantities outlined in the base case; and
    - Redesign of lighting within the space, based around the new luminaire to meet existing measured lighting levels, effectively providing an ‘optimised’ design.

Analysis of the options study shows that the best payback period for investment on lighting is to convert manual switching to automated, occupancy based controls. Should lighting replacement be considered, upgrading to LED based lighting although costly in comparison to occupancy control will provide good paybacks. However should an new lighting installation be undertaken, the design should be optimized to utilize the performance of the new luminaires, and meet recommended lighting levels set out within AS 1680 for the spaces in question.

Separate metering of lighting circuits, to enable monitoring of the impact of lighting improvements on energy consumption (and to comply with the NCC) is also recommended.

5.0 Glossary

TERM	EXPLANATION
kWh	Killowatt Hours – A measurement of energy consumption, typically electrical energy.
Lx / Lux	Unit measurement of illuminance of a nominated surface
LED	Light Emitting Diode
NCC	National Construction Code (previously known as the Building Code of Australia)
AS	Australian Standard
CRI	Colour Rendering Index – a scale that determines how 'true' the colours illuminated by a lamp source are viewed. The truer the colour the closer the value to 1. Example; incandescent lamps have a CRI of 1, with fluorescent lamps ranging from CRI of 0.7 through to 0.95.
Colour Temperature (K)	The colour of a white lamp is referenced against the temperature in Kelvin (K) at which a tungsten filament is required to reach to obtain that colour. 'Warm' (more yellow) colour temperatures occur about 2700 – 3000K, colder or more blue temperatures occur about 4000 – 6000K.