Organic Response
Case Study
134 William St Tenancy

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CONTENTS

1 SUMMARY

Organic Response (OR) have developed a new and innovative lighting control system. The system does away with the need to physically connect luminaires to a control system, and captures energy savings in transient occupancy situations in buildings.

A case study was undertaken to report on the performance of the Organic Response lighting control system, in the context of a lighting system retrofit at a 189 m2 office tenancy at 134 William Street with access to daylight during the day. The original lighting system comprised 2 x 36 Watt T8 fluorescent fittings in with parabolic reflectors that was manually switched at the door. These were retrofitted with 32 Watt LED flush fitting "Organic Response enabled" luminaires. The results indicate that:

- for this tenancy, the retrofitted lighting system shows an energy consumption saving of around 92% on a typical working day; and about a third of these savings are directly attributable to the Organic Response lighting control system
- findings from the study would suggest that in most retrofit situations the energy savings on a typical working day, could be in the order of 60 – 80%, as older technologies would be swapped out for more efficient lamps and luminaires, and the ease of commissioning would allow facility managers, or lighting contractors, to readily install and commission the new systems to a recommended light level and an appropriate control "personality"
- a cost comparison exercise indicated that even in the small tenancy site at 134 William St, the Organic Response lighting control system is cost competitive against C-BUS and DALI (Dynalite) systems. This is valid even when the control configurations for the DALI and CBUS systems are designed to have a coarser control functionality (4 luminaires controlled by one sensor), and therefore potentially lower energy savings
- there is potential for project management and project administration cost savings during installation for the Organic Response enabled lighting system which were not captured in the cost comparison
- the Organic Response lighting control system also offers the potential to rapidly adapt lighting control operation, at negligible cost, to changes in office layout and operation, and continue to provide energy savings that might be lost if competing control systems were deployed

2 INTRODUCTION

Organic Response (OR) have developed a new and innovative lighting control system. The system does away with requirement to physically connect luminaires to a control system, and captures energy savings in transient occupancy situations in buildings.

A large percentage of the annual energy consumption of a non-residential building, particularly that of office buildings is that of the energy used for lighting. In Australian buildings, energy consumption by lighting is separated into tenancy lighting (traditionally paid for by the tenant) and base building lighting (generally paid for by the building owner). The OR lighting control system is designed to be applied to all situations, in the first instance in non-residential buildings.

This report is a documentation of early results of a detailed case study being carried out in a commercial office tenancy. Results will vary for other locations based on daylight availability, occupancy patterns and weather conditions.

3 SYSTEM DESCRIPTION

The Organic Response (OR) lighting control system has two major components:

- a small sensor "node" incorporating multiple sensors, distributed intelligence are integrated on each lighting luminaire, and
- short range infrared communication between luminaires fitted with these sensor nodes

Each Organic Response sensor node incorporates a motion sensor, infrared transmitter, infrared receiver and an ambient light sensor, as shown in the figures below. The sensor nodes are integrated into the luminaires during manufacture/assembly before delivery to a building site for ease of installation (there is no requirement for a tradesman to adjust anything on the luminaire at site).

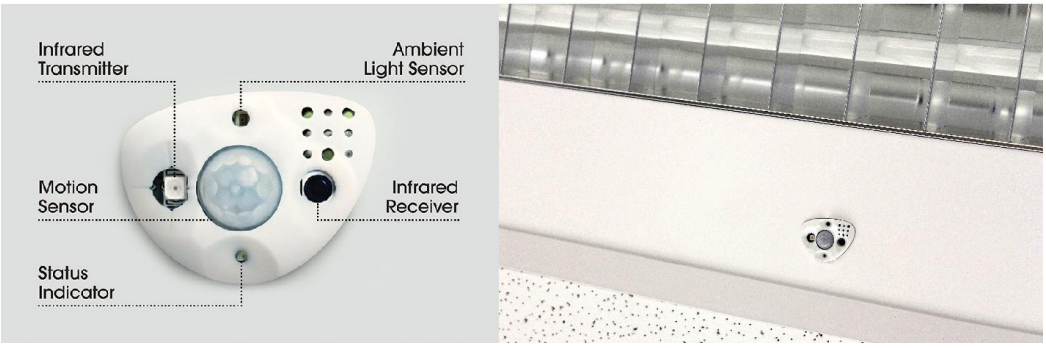

Figure 1 (a): Organic Response sensor node, and (b) integrated into a luminaire

When a Sensor Node senses motion, it switches on its light to a predetermined (commissioned) level (L1) and simultaneously sends its neighbours a proximity limited wireless infrared signal, informing them it can sense an occupant. On receipt of this signal, each neighbouring Sensor Node switches its light on to a specified level (L2) and simultaneously relays a signal to its own neighbours, telling them that the light next to it can see someone. This proximity limited wireless infrared signal propagates rapidly throughout the floor, (upto L32!) the lights turning on as signals are received. Each level (L1, L2, etc) can have a separate specified light level, (which can adjust for ambient light if daylight dimming is activated). The process is illustrated below.

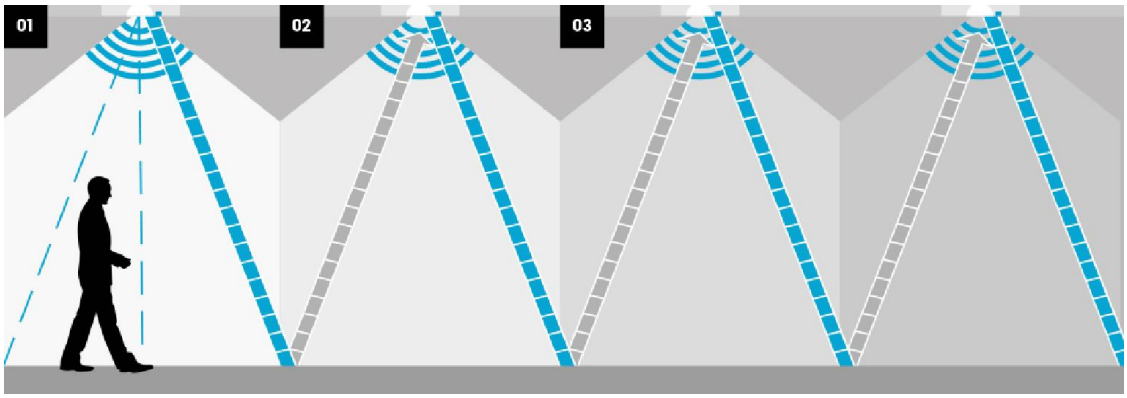

Figure 2: Propagation of proximity limited wireless infrared signal in an open plan office tenancy

The OR control system incorporates modern “Plug and Play” technology to make digital control available to a facility manager, lighting contractor or other interested party. The OR system starts to function as soon as mains power is connected to the Organic Response “enabled” luminaire. An infra-red “dongle” and an app have been developed for the iPhone, and a short tutorial was found to provide sufficient familiarity with the control system for carrying out commissioning and optimisation tasks.

4 CASE STUDY

4.1 SITE DESCRIPTION

A carefully constructed case study for a before and after installation has been carried out at L5, 134 William St, Woolloomooloo, a city suburb of Sydney, Australia. The tenancy floor plate used for the case study has an area of 189 m2 and is an occupied office space.

The building has large south facing windows on the long side and windows on the western end as well. The western windows are partially shaded by the adjacent building, and there is a need to draw blinds to exclude the western sun in the late afternoon.

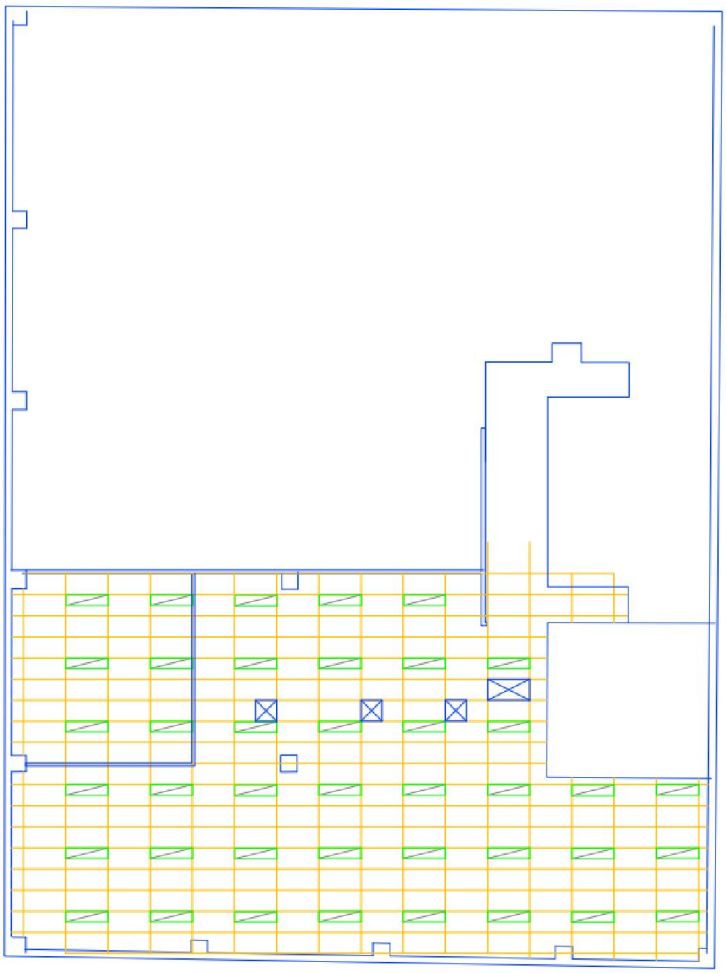

Figure-3: Reflected ceiling plan for the case study tenancy at L5, 134 William St, Woolloomooloo. (North is top of the page)

4.2 METHOD

Two measurement grids were selected in the tenancy space, one with 12 measuring points (A1 – D4 in Figure-4) that includes an internal wall edge, and another with 20 measuring points (A10 – E14 in Figure-4) that includes an external wall edge.

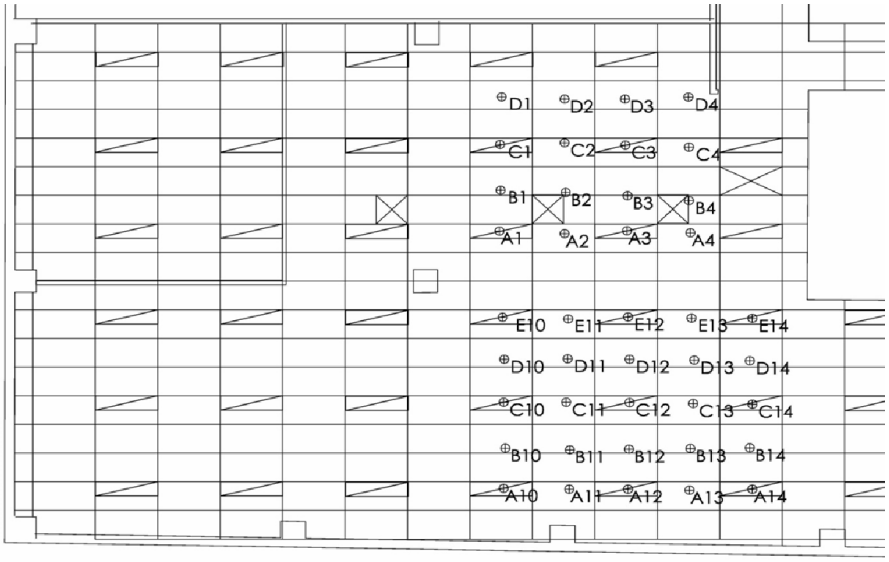

Figure-4: Selected grids for light level measurements

Calibrated digital metering was installed to record energy consumption data from the three electrical circuits that energised the tenancy lighting. The energy consumption of the lighting system was recorded in five minute increments throughout the entire analysis period. This data was downloaded to excel spreadsheets for further analysis. The daily power consumption was integrated for each day and then averaged over the period of each of the sections of the analysis.

The energy consumption for each day was divided into peak, shoulder and off-peak times based on Energy Australia's time-of-use tariff and this was used to calculate the average cost of the energy usage.

A number of weekends and some public holidays were part of the monitored time periods during the course of the case study. However, the recorded data for these days was discarded, and all the average energy consumptions were computed from data recorded and integrated for working days only.

ORIGINAL FLUORESCENT LIGHTING SYSTEM (T8 NO CONTROL)

The original lighting system comprised 2 x 36 Watt T8 fluorescent fittings in with parabolic reflectors, and was manually switched at the door. Light levels were measured after dark to discount any daylight component, and an average illuminance level of 610 lux was recorded for this original lighting system. It should be noted that the lamps were not new, but as they were good quality tri-phosphor lamps the lumen maintenance of the lamps would still be around 95%.

This original installation was measured for four days before the lighting retrofit was carried out. During this period the lights were manually switched by staff. An average consumption of 47.3 kWh/day was recorded for these four working days.

RETROFIT LED LIGHTING SYSTEM (LED NO CONTROL)

A lighting retrofit was then carried out, with the original luminaires being replaced with 32 Watt LED flush fitting "Organic Response enabled" luminaires. Each luminaire was factory fitted with the "sensor node" incorporating the Organic Response control system. Initially, the new LED lighting system was left at full output for about a week, without activating the Organic Response control system (lights were switched manually at this stage of the retrofit).

Light level measurements (at night) were made using the same grid points as before and showed an average light level of 591 lux for the new LED lighting system at default maximum output. This was a difference of only 3% from the 610 lux recorded for the original lighting system, and was considered an adequate baseline for comparison between the original (fluorescent T8) and retrofit (LED) lighting systems for this study. Recorded data was collected for three working days during this period, and an average consumption of 16.3 kWh/day was computed.

TRIMMING LED LIGHTING SYSTEM OUTPUT (LED TRIMMED)

Next, the light levels were trimmed using the Organic Response control system to get as close to the 320 lux prescribed for office workspaces. This was carried out by selecting an arbitrary luminaire in the space, and using the i-Phone app to lower the light output of that luminaire close to this value, and then broadcasting this new "maximum" light level to all the luminaires in the tenancy. Light levels were measured on the same grid points as before and the average was computed. It took two adjustments to get the measured average light level down to an average of 326 lux. This trimming process was completed within a 30 minute period. Data was recorded for a 24 hour period that included the working day and energy consumption was computed to be 10.6 kWh/day. Lights were still switched manually at this stage of the case study.

ACTIVATING ORGANIC RESPONSE – STAGE 1 (LED Trim + Occ)

The final steps in this case study was to activate a "personality" for the Organic Response lighting control system. For the case study, the "Open Floor" personality was activated across the retrofitted LED lighting system in the tenancy. This was initiated in two stages, first in response to occupancy, and then in response to both occupancy and daylight availability.

The occupancy sensing control in the Organic Response system works by detecting motion below the luminaire. The lamps in the luminaire are then powered up to the maximum pre-set level of 320 lux, and communicates via proximity limited wireless infrared signal with the adjacent luminaires. These in turn communicate with the luminaires adjacent to them. The adjacent luminaires are dimmed progressively as they move further from the initial luminaires.

The Organic Response lighting control system allows different "personalities" to be selected that change the relative dimming levels relative to the maximum level set at 320 lux. The "Open Floor" personality selected at this stage adjusts the levels in the primary luminaire and the adjacent

luminaires to 100%, the next circle of luminaires to 70%, the next circle of luminaires to 40% and the remainder of the luminaires to 10%.

Since the Organic Response system now controls the lighting system based on motion sensing, office staff were instructed to leave all light switches alone, and the lighting switch was taped to the "on" position to discourage unwanted tenant control!

Data was recorded for approximately one month between 18DEC2013 to 20JAN2014, and energy consumption was computed to be an average of 7.0 kWh/day for a typical working day.

ACTIVATING ORGANIC RESPONSE – STAGE 2 (LED Trim + Occ + Daylight)

The daylight integration function of the Organic Response system was switched on to monitor the luminance of the surfaces below the sensor node and adjusts the light output of the LED luminaire to maintain the pre-set lighting level of approximately 320 lux.

At this stage the Organic Response system controlled all functionality of the lighting system. It switches on lighting when office staff arrive in the morning based on occupant sensing using the "Open Floor" personality described previously. Lighting power levels are adjusted appropriately in the presence of daylight. Light levels are controlled to maximum pre-set level in the absence of daylight. No switching control is necessary.

Data was recorded for approximately one month between 30JAN2014 to 01MAR2014, and energy consumption was computed to be an average of 3.97 kWh/day for a typical working day. It is noted that the daylight contribution of the energy savings will vary based on access to ambient lighting. The case study tenancy at William St., has good access to daylight from it's two external façade walls. It is also noted that the monitoring has been carried out in summer, when the days are long. Daylight savings recorded would be near maximums for this tenancy. The daylight contribution in winter would be lower due to shorter daytimes.

5 RESULTS

The figure below presents recorded data for selected days, and illustrates the reduction in energy consumption for each stage of the retrofit process described in the previous section (and keyed to the Cases in Table-1 below).

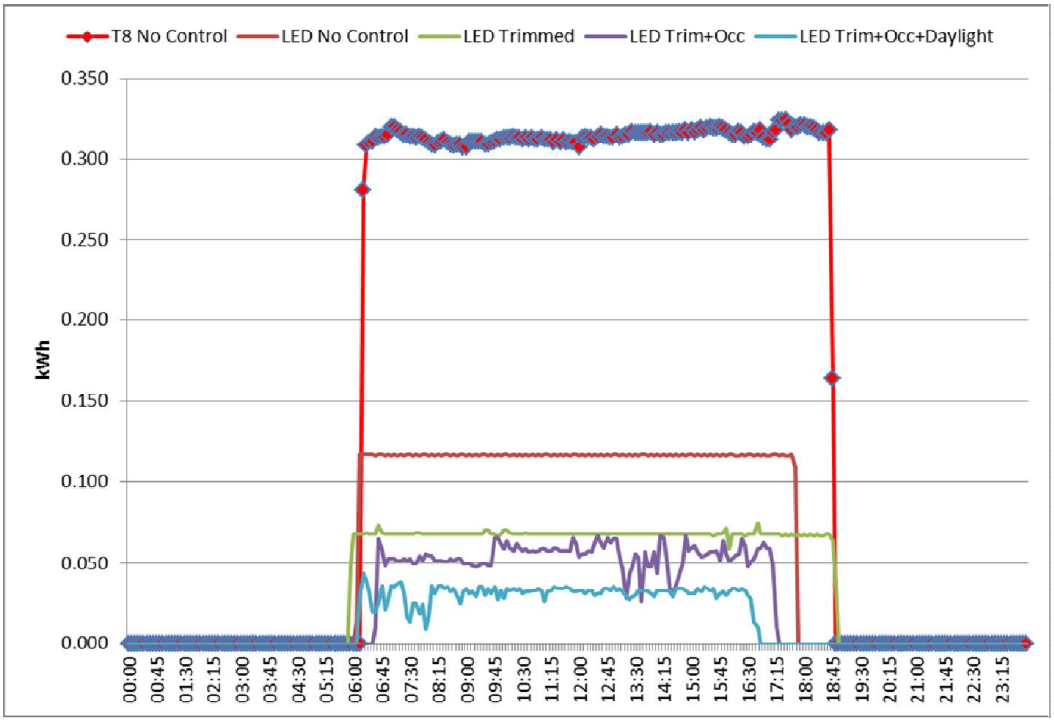

Figure 3: Recorded data from calibrated digital metering for the three lighting circuits supplying the tenancy

Table 1: Summary of energy savings results from the lighting retro-fit

Col 1	*Col 2*	*Col 3*	*Col 4*	*Col 5*	*Col 6*	*Col 7*	*Col 8*	*Col 9*
case	*system description*	*kWh/day*	*kWh/day/m2 (area = 189m2)*	*max Lux*	*energy saving for a typical working day relative to* ***T8 No Control*** *system*	*energy saving for a typical working day relative to* ***LED No Control*** *system*	*energy saving for a typical working day relative to* ***LED Trimmed*** *system*	*Comments*
case 1	T8 No Control	47.293	0.250	610				existing T8 2X36W fluorescent fittings
case 2	LED No Control	16.324	0.086	591	*65%*			retro-fitted with Organic Response enabled LED based Eagle Aurora fittings, full output, no control
case 3	**LED Trimmed**	**10.568**	**0.056**	**326**	*78%*	*35%*		(commissioned) to approximately 320 lux fixed output using Organic Response dongle and i-phone app
case 4	LED Trim+Occ	7.005	0.037	326	*85%*	*57%*	***34%***	Organic Response system enabled on trimmed LED system to sense occupancy only
case 5	LED Trim+Occ+Daylight	3.967	0.021	326	*92%*	*76%*	***62%***	Organic Response system enabled on trimmed LED system to sense occupancy and ambient daylight

The following observations can be made from the results listed in Table-1 (referenced by *Case* or *Col* number):

- For this particular tenancy, which has access to reasonably good daylight availability, the retrofit of the original T8 lighting system (*T8 No Control, Col 6*), which provided almost double the recommended lighting levels, with more efficient luminaires fitted with the Organic Response lighting control system, commissioned to illuminate to 320 lux, is predicted to provide energy consumption saving of around 92% on a typical working day. This is an astonishing result; and 27% of this 92% savings are attributable to the Organic Response lighting system

- The original T8 lighting system (*T8 No Control, Col 6*) was illuminating the office floors to almost twice the required lighting level. The retrofit system, fitted with Organic Response enabled luminaires and LED lamps, provided a similar amount of excess illumination when first installed (*LED No Control, Case 2*). The energy savings for a typical working day between the two systems was 65% and this is simply due to the improvement in lamp technologies (between T8s and LEDs).
  When the retrofit LED lighting system is commissioned to provide the correct lighting level of 320 lux (*LED Trimmed, Case 3*), using the Organic Response i-phone dongle and app, these energy savings increase to 78% on a typical working day. *This additional 13% energy saving is easily accessible to the Organic Response enabled lighting system because of the ease of commissioning possible with the system*.
  Turning on the Organic Response "Open Floor" personality control function with occupancy sensing and ambient daylight dimming (*LED Trimmed+Occ+Daylight, Case 5*), increased this energy savings on a typical working day to 92%.

- A more representative energy savings figure, attributable exclusively to the operation of the Organic Response lighting control system, is the savings relative to the new LED lighting system *when correctly commissioned (LED Trimmed, Case 3) to provide the*

recommended lighting levels in the tenancy. In this case the energy saving on a typical working day would lie somewhere between 34% (based on occupancy tracking only) and 62% (based on occupancy and ambient daylighting dimming) for this case study tenancy. This conservative energy saving prediction is still a very significant energy saving

- The above results and discussion would suggest that in most retrofit situations the energy savings on a typical working day, could be in the order of 60 – 80%, as older technologies would be swapped out for more efficient lamps and luminaires, and the ease of commissioning would allow facility managers, or lighting contractors, to readily install and commission the new systems to a recommended light level and an appropriate control "personality"

6 COST COMPARISONS

A costing comparison exercise was carried out between the Organic Response (OR), DALI and C-BUS systems, and is discussed in this section.

6.1 BASE LUMINAIRE COSTS

A total number of 41 luminaires were retro-fitted at the tenancy at 134 William St. Each fitting was costed at $498, for a total fitting cost of $20,418. This cost is for luminaires fitted with lamps and dimmable ballasts only, excluding any costs for control systems, eg., sensors, notes, detectors, controllers, display panels, control cables etc.. The luminaire cost component is common for all the cases discussed below.

Table-2: Base luminaire cost

Number of Luminaires	41
Cost per Luminaire	$ 498
Total cost of luminaires	**$ 20,418**
Area, m2	189
luminaire cost per m2	**$ 108.03**

6.2 CONTROL SYSTEM OPTIONS

Five control system options are compared:

1. Organic Response: each luminaire is factory fitted with an integrated sensor node
2. DALI (4 fittings): a group of four luminaires controlled by a single DALI detector. Such a system does not provide the fine grain lighting control as the OR system, however, it would be the configuration against which the OR system is compared for retrofit projects, like the William St tenancy for this case study
3. CBUS (4 fittings): a group of four luminaires controlled by a single detector. Such a system does not provide the fine grain lighting control as the OR system, however, it would be the configuration against which the OR system is compared for retrofit projects, like the William St tenancy for this case study
4. DALI (individual control): each luminaire controlled by a DALI detector. This configuration could provide a similar level of control as the OR system with the requisite programming input. However, reprogramming this DALI system to a different scheme would require significantly more time and effort compared to changing the “personality” of the OR system
5. CBUS (individual control): each luminaire controlled by a detector. This configuration could provide a similar level of control as the OR system with the requisite programming input. However, reprogramming this CBUS system to a different scheme would require significantly more time and effort compared to changing the “personality” of the OR system

6.3 DALI AND C-BUS CONTROL SYSTEMS

There are three methods of dimming LEDs and fluorescent lamps:

- 0-10 Volt control signal
- DSI (Digital Serial Interface) is a protocol that is proprietary to Tridonic Atco
- DALI (Digital Addressable Lighting Interface) is a European standard protocol.

The 0-10V and DSI both require a separate dimming channel for each luminaire requiring separate control. With these systems a separate control cable is required for each lamp that is to be controlled separately from the others.

A universal DALI controller can individually control up to 64 individual lamps. These 64 lamps can all be controlled by a single two core cable that can be daisy chained between the luminaires.

In contrast, there is no need to install a control system for the Organic Response (OR) system, as there is a factory fitted sensor in each luminaire. The only information transfer required is between the luminaires, and this is done via the native proximity limited IR communication, the distributed intelligence inherent to Organic Response.

Alternative control systems were configured with the DALI (Dynalite) and CBUS systems to achieve similar (but not identical) control and energy efficiency performance to the Organic Response system. These alternative control configurations are based on having one sensor for every four luminaires and the sensor controls for this group of luminaires. This reduced level of control will still achieve most of the overall lighting control functionality, but without the control sophistication of the Organic Response system.

To achieve the level of lighting control achieved by Organic Response it would be necessary to have individual luminaire control which enables separate dimming for each luminaire, along with a significant programming effort. Control systems with the capability of control to provide an identical level of the OR control systems were also designed and costed for DALI and CBUS systems with individual detectors and control for each luminaire. The cost comparisons (included in the next sections) indicate that the cost of the control portion of these systems is significantly higher compared to that of the OR configuration.

6.4 ORGANIC RESPONSE

The programming cost for the Organic Response system depends on who programs it and how the cost is allocated. If it is programmed by a specialist programmer then we should allow approximately 2 hours and $120 per hour. However, our experience with the system indicates that the programming can be easily carried out by the electrical contractor, and 2 hours at $95 have been included for this exercise.

Alternatively, if the system is programmed by the owner or a staff member of the owner, then there will be a learning time so the amount of time should probably be at least doubled. However, it can be argued that as the person doing the programming is a salaried employee, the programming cost is zero.

The total OR lighting control system cost is estimated at $5,520 or $29.21/m2 for the William St tenancy.

Table-3: Organic Response lighting system

DETECTOR		
number of sensor nodes	41	
cost of sensor	$ 130	
		$ 5,330
hours to install detectors	0	
hourly rate	$ 95	
		$ -
Supply and install detectors		**$ 5,330**

CONTROL GEAR		
number of controllers	0	
cost of controllers	$ -	
		$ -
number of controllers	0	
hours to install controllers	0	
hourly rate	$ 95	
		$ -
number of detectors	41	
supp cntrl cable detectors	$ -	
		$ -
number of luminaires	41	
supp contrl cable luminaires	$ -	
		$ -
Supply and install control gear		**$ -**

Programming Hourly Rate	$ 95	
Programming time	2	
Programming cost		**$ 190**

Supply and install detectors	$ 5,330
Supply and install control gear	$ -
Programming cost	$ 190
Total Control Cost	**$ 5,520**
Control Cost/m2	**$ 29.21**

6.5 DALI (4 LUMINAIRES)

The following cost tables are for a DALI control system designed to control four luminaires with a single detector, ie., 10 detectors are used. Cost components are broken down as before. Additional components required by the DALI system are costed. Six hours are estimated for programming the system to have the control capability that is similar to, but without the sophistication of the OR system. The hourly programming cost is estimated as per market rates at $120 per hour.

The total DALI lighting control system cost in the four luminaire per detector configuration is estimated at $7,090 or $37.51/m2 for the William St tenancy.

Table-4: DALI lighting control system (4 luminaires)

DETECTOR		
no detectors	10	
cost of detectors	$ 180	
		$ 1,800
hours install detectors	16	
hourly rate	$ 95	
		$ 1,520
number of detectors	10	
supp cntrl cable detectors	$ 20	
		$ 200
Supply and install detectors		**$ 3,520**
CONTROL GEAR		
no controllers	1	
cost of controllers	$ 600	
		$ 600
number of controllers	1	
hours to install controllers	6	
hourly rate	$ 95	
		$ 570
number of luminaires	41	
supp contrl cable luminaires	$ 20	
		$ 820
Dinrail mounting		$ 300
PC interface		$ 360
Real time clock		$ 200
Supply and install control gear		**$ 2,850**
Programming Hourly Rate	$ 120	
Programming time	6	
Programming cost		**$ 720**
Supply and install detectors	$ 3,520	
Supply and install control gear	$ 2,850	
Programming cost	$ 720	
Total Control Cost	**$ 7,090**	
Control Cost/m2	**$ 37.51**	

6.6 CBUS (4 LUMINAIRES)

The following cost tables are for a CBUS control system designed to control four luminaires with a single detector, ie., 10 detectors are used. Cost components are broken down as before. Additional components required by the CBUS system are costed. Seven hours are estimated for programming the system to have the control capability that is similar to, but without the sophistication of the OR system. The hourly programming cost is estimated as per market rates at $120 per hour.

The total CBUS lighting control system cost in the four luminaire per detector configuration is estimated at $8,508 or $45.02/m2 for the William St tenancy.

Table-5: CBUS lighting control (4 luminaires)

DETECTOR		
no detectors	10	
cost of detectors	$ 219	
		$ 2,190
hours install detectors	8	
hourly rate	$ 95	
		$ 760
number of detectors	10	
supp cntrl cable detectors	$ 20	
		$ 200
Supply and install detectors		**$ 3,150**
CONTROL GEAR		
no controllers	1	
cost of Dali controllers	$ 446	
		$ 446
number of controllers	1	
hours to install controllers	12	
hourly rate	$ 95	
		$ 1,140
number of luminaires	41	
supp contrl cable luminaires	$ 20	
		$ 820
C-BUS power supply		$ 462
C-BUS Touch Screen		$ 1,250
Dali Power Supply		$ 100
Dinrail mounting for controller		$ 300
Supply and install control gear		**$ 4,518**
Programming Hourly Rate	$ 120	
Programming time	7	
Programming cost		**$ 840**
Supply and install detectors	$ 3,150	
Supply and install control gear	$ 4,518	
Programming cost	$ 840	
Total Control Cost	**$ 8,508**	
Control Cost/m2	**$ 45.02**	

6.7 DALI (INDIVIDUAL CONTROL)

The following cost tables are for a DALI control system designed to be able to provide an identical level of control as the OR system, ie., each luminaire is controlled with a single detector. Cost components are broken down as before. Additional components required by the DALI system are costed. 10 hours are estimated for programming the system to control all 41 detectors. The hourly programming cost is estimated as per market rates at $120 per hour.

The total DALI lighting control system cost in the four luminaire per detector configuration is estimated at $17,880 or $94.60/m2 for the William St tenancy.

Table-6: DALI lighting control system (individual control)

DETECTOR		
number of detectors	41	
cost of detectors	$ 180	
		$ 7,380
labor hours to install detectors	24	
hourly rate	$ 95	
		$ 2,280
number of detectors	41	
supp cntrl cable detectors	$ 20	
		$ 820
Supply and install detectors		**$ 10,480**
CONTROL GEAR		
number of controllers	5	
cost of controllers	$ 600	
		$ 3,000
number of controllers	5	
hours to install controllers	16	
hourly rate	$ 95	
		$ 1,520
number of luminaires	41	
supp contrl cable luminaires	$ 20	
		$ 820
Dinrail mounting		$ 300
PC interface		$ 360
Real time clock		$ 200
Supply and install control gear		**$ 6,200**
Programming Hourly Rate	$ 120	
Programming time	10	
Programming cost		**$ 1,200**
Supply and install detectors	$ 10,480	
Supply and install control gear	$ 6,200	
Programming cost	$ 1,200	
Total Control Cost	**$ 17,880**	
Control Cost/m2	**$ 94.60**	

6.8 CBUS (INDIVIDUAL CONTROL)

The following cost tables are for a CBUS control system designed to be able to provide an identical level of control as the OR system, ie., each luminaire is controlled with a single detector. Cost components are broken down as before. Additional components required by the CBUS system are costed. 12 hours are estimated for programming the system to control all 41 detectors. The hourly programming cost is estimated as per market rates at $120 per hour.

The total CBUS lighting control system cost in the four luminaire per detector configuration is estimated at $17,277 or $91.41/m2 for the William St tenancy.

Table-7: CBUS lighting control (individual control)

DETECTOR		
no detectors	41	
cost of detectors	$ 219	
		$ 8,979
hours install detectors	16	
hourly rate	$ 95	
		$ 1,520
number of detectors	41	
supp cntrl cable detectors	$ 20	
		$ 820
Supply and install detectors		**$ 11,319**
CONTROL GEAR		
no controllers	1	
cost of Dali controllers	$ 446	
		$ 446
number of controllers	1	
hours to install controllers	12	
hourly rate	$ 95	
		$ 1,140
number of luminaires	41	
supp contrl cable luminaires	$ 20	
		$ 820
C-BUS power supply		$ 462
C-BUS Touch Screen		$ 1,250
Dali Power Supply		$ 100
Dinrail mounting for controller		$ 300
Supply and install control gear		**$ 4,518**
Programming Hourly Rate	$ 120	
Programming time	12	
Programming cost		**$ 1,440**
Supply and install detectors	$ 11,319	
Supply and install control gear	$ 4,518	
Programming cost	$ 1,440	
Total Control Cost	**$ 17,277**	
Control Cost/m2	**$ 91.41**	

6.9 FIRST COSTS

Table-8: Cost summary

ITEM	ORGANIC RESPONSE	DALI (4 luminaires)	CBUS (4 luminaires)	DALI (single luminaire)	CBUS (single luminaire)
Total Luminaire Cost	$ 20,418	$ 20,418	$ 20,418	$ 20,418	$ 20,418
Total Control Cost	$ 5,520	$ 7,090	$ 8,508	$ 17,880	$ 17,277
Total Lighting System Cost	$ 25,938	$ 27,508	$ 28,926	$ 38,298	$ 37,695
Luminaire Cost/m2	$ 108.03	$ 108.03	$ 108.03	$ 108.03	$ 108.03
Control Cost/m2	$ 29.21	$ 37.51	$ 45.02	$ 94.60	$ 91.41
Lighting System Cost/m2	$ 137.24	$ 145.54	$ 153.05	$ 202.63	$ 199.44
Control Cost differential	0.0%	28.4%	54.1%	223.9%	213.0%
Lighting System Cost differential	0.0%	6.1%	11.5%	47.7%	45.3%

Table-8 lists the cost summary of the lighting system options configured in the previous sections. For the tenancy at William St., the Organic Response lighting control system is already cost competitive against the DALI and C-BUS systems, even when compared against system configurations that control groups of four luminaires, rather than each luminaire.

As the cost of luminaires is the same for each lighting system, comparing the cost of the lighting control systems indicate that the DALI (4 luminaires) is about 28%, and the CBUS (4 luminaires) is 54% higher in cost compared to the OR control system with individual luminaire control.

The DALI (Dynalite) and C-Bus systems have to have additional data cabling and control equipment that has to be mounted in the distribution board cupboard, another cupboard or in the ceiling space. The cost of this will vary from installation to installation depending on the accessibility of the ceiling and the distance to the suitable location for the equipment.

The Organic Response system comes with its own firmware that has the relationships between the sensors and the dimming level built in. With the DALI and CBUS systems, this firmware is not a standard offering and would have to be programmed for the individual project. For the 4 luminaire control system options for DALI and CBUS, it is assumed that each group of four fittings and sensor would operate autonomously. Such a configuration does not have the level of interaction or sophistication as the Organic Response system. To try and achieve this with the alternate systems would be a major programming task and would not be viable for a simple project such as this. As demonstrated by the numbers in the last two columns in Table-8, the increased control system cost to achieve individual luminaire control would see the cost of the total lighting system increase by 48% for the DALI system, and 43% for the CBUS system. Reviewing the increase in cost of just the control system components indicate significant increases in costs, 224% for the DALI system and 213% for the CBUS system if an equivalent level of control were to be sought. The larger the project, the more complex this programming task becomes.

The retrofit area at 134 William St was possibly a bit too small to demonstrate the full ability of the Organic Response system. The OR system has the ability to control six different groups of lights circumferentially from the activated fitting. In the small office area of test site it was only possible to achieve three groups. The room also had significant daylight contribution for the majority of the space which overrode much of the occupancy sensor operation. In addition, with the alternate systems, once the installation exceeds 64 luminaries there is additional control equipment needed

to interconnect the DALI universes. These physical limitations mean that the current case study may not demonstrate the full energy saving potential of the Organic Response lighting control system.

6.10 OTHER COST SAVINGS

There could also be other hidden savings associated with the Organic Response system in a retrofit situation. Lighting luminaires in a typical office building are plugged into sockets in the ceiling. If there is no need to change the circuit wiring, an electrician may not be required to change the luminaires. This work could be done by general maintenance staff. Such a situation would not only become a potential cost saving but also a significant project management saving. Luminaires could be progressively replaced and not in any specific area or order. The installed luminaires can be sequentially programmed immediately after installation using the i-phone app and dongle. Such savings would be site and project specific and there is no way of generalising them.

With the alternative DALI and CBUS systems, in addition to installing the luminaires, there is the need to install control cabling and control gear. This work will require an electrician and the installation may not be operable until the system is complete. This also involves some level of project management and greater disruption to occupants. The level of disruption and the amount of project management required would increase with the size of the lighting installation.

The Organic Response system is relatively simple to program using the i-phone app and dongle. Initial programming can be carried out by the lighting contractor/electrician and future adjustments can be carried out by an on-site facility manager, or indeed by building occupants. This ease of re-programming means potential energy savings can be captured every time there is a significant change in the layout of the tenancy or it's operation. In contrast, programming a DALI or CBUS systems can only be carried out by a specialist programmer. Modifications to the lighting control due to changes in tenancy layout or operation can only be made by the specialist programmer.

7 CONCLUSION

The analysis developed for this case study indicate that the Organic Response lighting control system can provide substantial levels of energy savings to an office tenancy lighting retrofit. However, it is noted that the actual energy and cost savings will depend significantly on the particular space configuration, and the occupancy pattern of the tenants. For the William St tenancy site, installation of the Organic Response lighting control resulted in energy savings of between 62 and 76% depending on the point of reference.

The highest energy savings would be realised if the space has access to daylight (without glare) and when occupancy is quite transient in nature. The least energy savings will be realised when the space has no access to daylight, and almost all of the tenants are regularly present during pre-determined office hours during the working week.

A cost comparison exercise indicated that even in the small tenancy site at 134 William St, the Organic Response lighting control system is cost competitive against C-BUS and DALI (Dynalite) systems. This is even when the control configurations for the DALI and CBUS systems are designed to have a coarser control functionality (the 4 luminaire options), and therefore potentially lower energy savings.

The Organic Response control system also offers the potential to rapidly adapt lighting control operation to changes in office layout and operation, and continue to provide energy savings that can be lost if competing control systems were deployed.