EFFECT OF DAYLIGHT HARVESTING ON BUILDING LIGHTING ENERGY CONSUMPTION

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Abstract

In the beginning, humans used architecture to protect their selves from nature and unsteady environmental conditions. However, with time, modern buildings become more complex, which need to fulfil the different types of functions [1]. So, humans started to concern more about the visual and thermal comfort and energy efficiency of modern buildings.

Daylight is the perfect source of light that human has adapted with respect to evolution. So, daylight harvesting is highly concerned in modern building designs in order to enhance occupants' visual and thermal comfort and reduce artificial lightings costs. Although this should be wisely done since entering direct sunlight to the building envelope could cause visual and thermal discomfort, increasing heat load which causes additional air conditioning costs.

The effect of daylight harvesting depends on many parameters. Building location, building orientation, building geometry, seasonal variation of the sun, window to wall ratio, window glazing parameters, Solar heat gain coefficient, Window height, Building interior parameters, shading devices, and solar control mechanisms are a few major parameters, which affect the outcome of daylight harvesting.

This research discusses the effect of Seasonal variations, building geometry, window to wall ratio and window orientation for a typical office building situated in tropical countries on daylight harvesting.

Acknowledgement

For the successful completion of the special studies report, I would like to especially thank Dr. Asanka Rodrigo who is the supervisor of the research and guided in various stages of the research by using his expert knowledge on the subject. Also, I would like to thank Dr. Inoka Manthilake and Dr. Anusha Wijewardane, the course coordinators of Building Services Engineering Master degree, for their enthusiastic support and motivation extended towards me in completing this report and all the staff members of the Department of Mechanical Engineering, Department of Electrical Engineering, Department of Civil Engineering and Faculty of Architecture for their assistance during the first year of master degree.

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List of Abbreviations

NZEB	Nearly Zero Energy Buildings
BIPV	Building Integrated Photovoltaics
WWR	Window to Wall Ratio
SHGC	Solar Heat Gain Coefficient
HVAC	Heat Ventilation and Air-Conditioning
DNI	Direct Normal Irradiance
USA	United State of America
PV	Photovoltaics
ASF	Adaptive Solar Façade
COP	Coefficient of Performance
LPD	Lighting Power Density

1 INTRODUCTION

Daylight harvesting is one of the major implementations in modern buildings in terms of building energy conservation. Most of the building codes in the world address daylight harvesting in their standards. The amount of daylight is highly variable throughout the day and the year and affect the many design parameters. Also, bad daylight harvesting practices may cause thermal discomfort and elevated air-conditioning costs.

1.1 Background

In the building sector, energy consumption and Greenhouse gas emissions are increased significantly during the past decade. Varies countries have introduced new building regulations and certifications to improve the energy performance of the buildings to overcome this problem [2]. Since energy conservation is one of the major concerns in the twenty-first century, European Union decided to build all of their future building constructions as Nearly Zero Energy Buildings (NZEB) by the top of 2020 [3]. To achieve this goal, it is necessary to implement energy-efficient technologies on air-conditioning and lighting in modern buildings without compromising occupants' visual and thermal comfort [4]. Daylight harvesting is a very common strategy that is used to improve building energy performance, thermal and visual comfort of the occupant.

The effectiveness of daylight harvesting varies with several parameters, such as latitude or location of the building, building architecture, window orientation, window glazing parameters, window to wall ratio, weather and sky condition, nearby vegetation and obstructions, etc. The effect of daylight harvesting is not generating a positive outcome at all times. As an example, the solar heat gain throughout the building envelope could cause thermal discomfort and reduce the effectiveness of air-conditioning.

To enhance building envelope performances, dynamic shading devices are integrated as hi-tech building facades for harvesting daylight, heating, cooling, and ventilation in modern buildings. [5]. Intelligent, adaptive and responsive building envelopes are combined with the latest technology to achieve these requirements. Building envelopes control the heat transfer between the inside and outside. Also control relative humidity heating and cooling demands, daylight level and ventilation. Building façades can generate electricity using building integrated photovoltaics (BIPV) [6]. Intelligent responsive building façades adapt to complex environmental conditions with the measurement and executing numerous data such as indoor and outdoor environmental conditions, occupancy levels, instructions of occupants to adapt to the environmental changes with proper timing and mechanical systems [7]. Specially positioned sensor signals are received by central control systems with intelligent control algorithms are used to control these systems. [8]. Integration of façade systems with special materials and nanotechnology is concerned with modern-day research [9]. Electro-responsive polymorphic materials, which alter their shape with response to an electrical signal such as dielectric electro-active polymers (DEAP), can be used as both sensors and actuators [5]. There are a few non-electric approaches that use passive thermo-hydraulic drive operation in addition to those techniques [7].

However, there are advantages as well as disadvantages of dynamic daylighting systems. Advantages of dynamic shadings systems are enhanced visual and thermal comfort, reduced artificial lighting costs by optimizing daylight harvesting through integrated automatic controlling techniques, reduced air conditioning initial and operation costs by reducing the entering of direct sunlight into the building envelope, reduced building heating cost by increasing solar heat gain in cold climates and increased viewer attraction while disadvantages are an additional cost for materials, controlling mechanisms, and techniques, the complexity of installation, operation and maintenances and viewer disturbance

1.2 Problem formulation

Although daylight is the best source of building lighting, variability of sun's position over the day and throughout the year and effect of building parameters such as building location, building size, building orientation, window to wall ratio, window glazing type, etc makes daylight harvesting a complex and difficult process. A better understanding of the factors which regulates daylight harvesting feasibility is important to improve the efficiency of daylighting and to reduce the negative effects such as visual and thermal discomfort and escalated air-conditioning costs due to solar heat gain.

1.3 Main Objective

Evaluate the effect of Key parameters affecting daylight harvesting on the lighting energy performance of a typical office building in Sri Lanka and identify better daylight harvesting options and prepare recommendations.

1.3.1 Sub-Objectives

1. Evaluate the state of the art of Daylight Harvesting and Shading Systems.
2. Evaluate the daylight availability around the world and key parameters affecting the performance of Daylight Harvesting
3. Identify the daylight harvesting potential in Sri Lanka
4. Analyse the lighting performance with the aid of daylight simulation

1.4 Methodology

Phase I: Literature Review on

- Daylight harvesting fundamentals
- Static and dynamic shading systems
- Solar geometry
- Effect of Solar Heat Gain Coefficient (SHGC)
- Effect of Window to Wall Ratio (WWR)
- Building integrated photovoltaic (BIPV)
- Architectural aspects

Phase II: Simulation, data collection and analysis

- Define the number of cases and design parameters
- Model the typical building using DIALux evo for each case
- Simulate each case with varying parameters
- Record the simulation results
- Analyse the simulation results

Phase III: Evaluation and Conclusion

- Evaluation of simulated results
- Conclusion on the outcome of the simulation results

1.4.1 Workflow chart

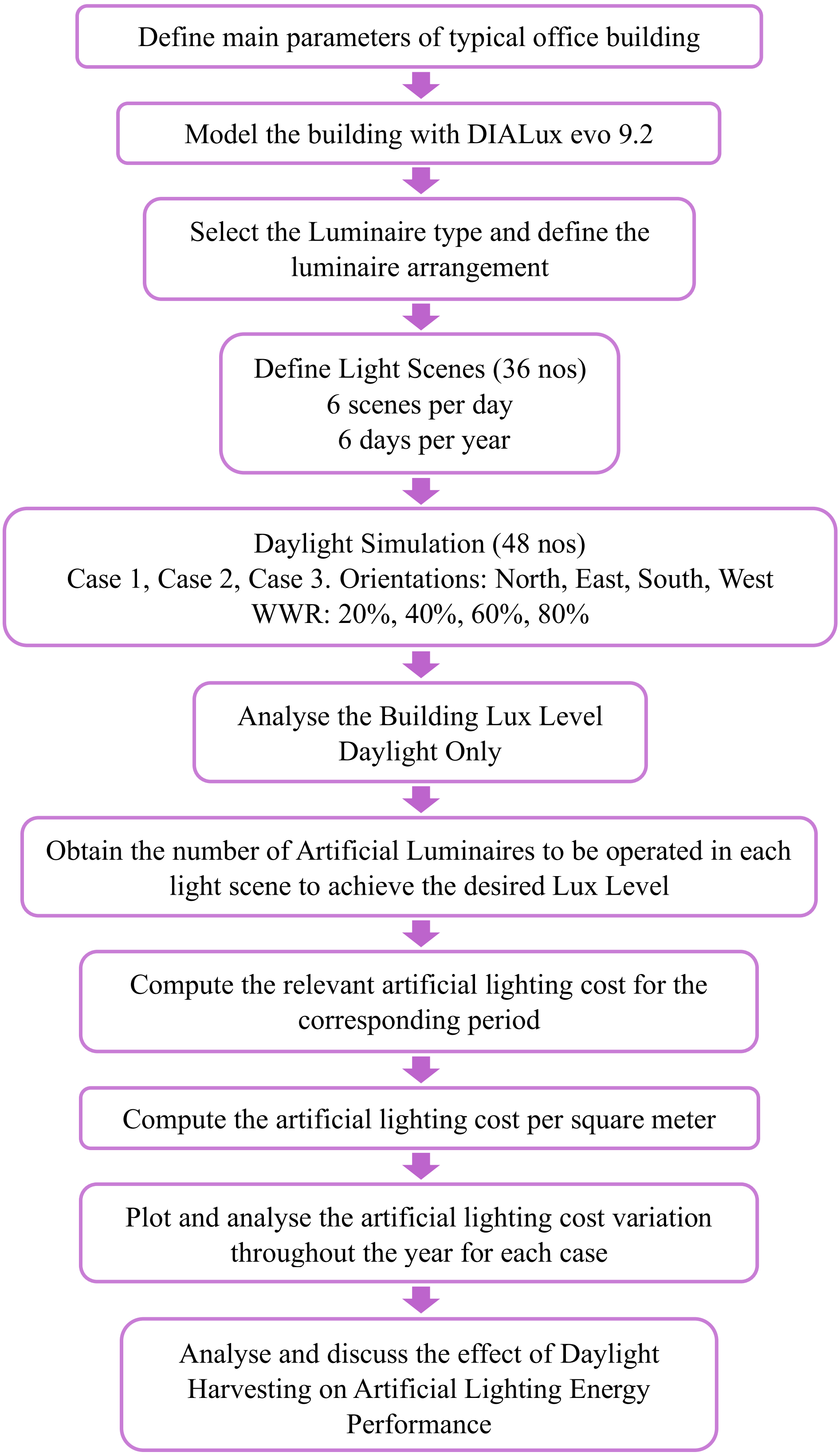


Figure 1: Workflow chart

1.5 Summary

This chapter discusses the importance of daylight harvesting and a basic introduction about the effect of daylight harvesting and the parameters which affects the efficiency of daylighting. Also mentions the daylight harvesting techniques such as static and dynamic shading systems and the control mechanisms. Other topics of this chapter are the aim of the research, objectives, methodology and workflow chart.

The next chapter is a Literature review on daylight harvesting to get a proper understanding of the solar geometry, parameters which affect daylighting and daylight harvesting techniques, etc before the simulation process.

2 LITERATURE REVIEW

2.1 Daylight harvesting

The intention of a Daylight Harvesting system is to reduce the amount of artificial lighting needed, to minimise building energy costs. This is done by a lighting control system integrated with dimmable lighting fixtures by adjusting the artificial light level according to the daylight intensity. Present, daylight harvesting has become one of the major standards in lighting design, sustainable architecture and active daylighting industries [10].

2.1.1 Daylight harvesting system design elements

A daylighting system consists of several major elements. It is mandatory to concern those elements in system designs to get the maximum benefit from an automated dynamic shading system. They can be identified as follows.

2.1.1.a Desired light level

Maintaining the minimum desired Lux level is a major element in daylight harvesting system design. In Offices, the commonly recommended lux level is 500Lux on the desktop. The amount of desired lux level varies with the purpose, occupancy level, location and other design considerations [11].

2.1.1.b Photo-sensors

A daylight harvesting system with an automated dimming control consists of light level sensors (Photo-sensors) to measure the Lux level of the surrounding, in a closed-loop or open-loop system. It gives the signal to the controller to adjust the artificial light level according to ambient light level [12] [13]. An open-loop system detects only the available daylight. The sensor can be mounted either outside the building or inside near a fenestration or skylight. But in a closed-loop system, it detects the total lux level of both daylight and artificial light [13] [14]. Since it is impractical to place the sensor on an office desktop, the sensors are normally placed on the ceiling to detect the lux level on the surface. Also, the signal from the sensor should be properly calibrated to get the desired output [15].

2.1.1.c Control units and dimming circuits

The output signal from the photo-sensor is integrated and executed by the control unit. It gives the signal to the lighting fixture to on and off or dimming concerning the available daylight intensity. If the light fixture is on-off only, the lamp remains on until the daylight level reaches the desired level. Multiple lamps which can be on or off independently in a single light fixture are used to achieve better lighting control. If the light is dimmable the amount of artificial lighting is continuously adjusted according to the ambient light condition [16].

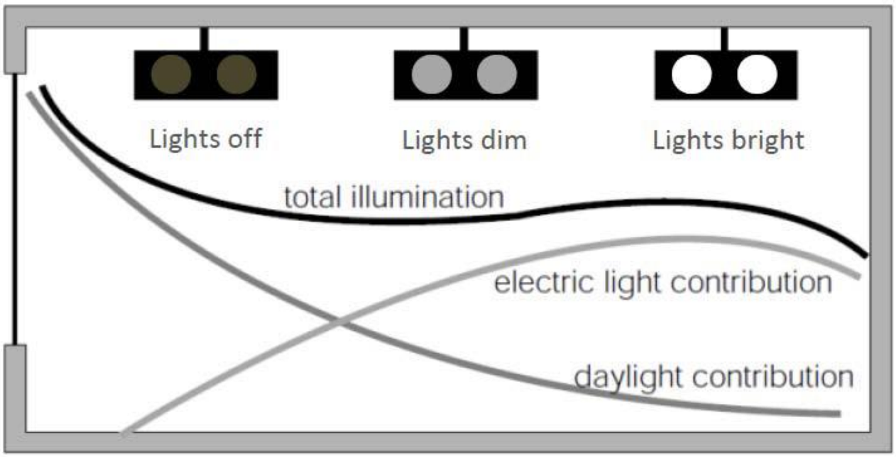


Figure 2:Interaction between natural light and electric light [23]

The cost of the dimming systems is normally higher than on-off systems. However, they can reduce more energy, since they can control its output continuously when daylight meets the space lighting requirement partially. The dimming system also consumes a little amount of energy for its operation [17]. With proper calibration of the dimming system, the occupant may not notice the changes of the lighting level, as on-off or step switching [10].

2.1.1.d Energy saving

The previous studies have shown, with daylight harvesting techniques, energy savings for artificial lighting is about 20-60% [18]. The amount of saving varies with the space condition, and the algorithm used with the control unit. Energy savings can only achieve in areas with considerable daylight or otherwise artificial lighting should be used.

Trying to increase energy savings by increasing window sizes is a very simplistic approach that could cause glare, visual and thermal discomfort for the occupants. This could lead to the use of blinds or shadings and compromise the effectiveness of harvesting daylight. Even with Venetian blinds which are partially deployed, the energy savings could be reduced to half [19].

Remarkable energy savings cannot be achieved in practice because of poor system designs, commissioning faults or calibration errors. Systems that operate by dimming or switching the electric lights in a destructive manner or systems which fails to achieve the sufficient light level can be sabotaged by occupants [20].

The implementation of daylighting systems has been discouraged by the poor performance of the techniques and high initial and operation costs. However, according to studies, the adoption of daylight harvesting can achieve saving of up to 24% per year [21]. The energy savings can be simulated by commercial software such as TRACE 700 and DOE-2, [22].

2.1.1.e Payback and drivers for adaptation

The daylight system has an initial implementation cost and operation and maintenance cost. Dividing the incremental cost by total annual cost saving gives the Simple Payback period for the system, which gives the number of years to recover the investment [23]. The shorter the simple payback period the higher the like hood investment on the system by building owners.

2.1.1.f Sustainability

In the modern world, energy conservation is a major concern in building construction. Energy-efficient architecture design and building practices are encouraged by green and sustainable building movements. There are many green building standards and certifications that exist in the modern world, such as BREEAM, BOMA Best, LEED, Green Star and HK-Beam. All these certification systems offer points for various building design aspect which promotes sustainable building designs. The levels of certification vary according to the number of points gained. One major possibility of gaining points is energy conservation options [24].

In addition to sustainable certifications, energy standards and codes have started addressing daylight harvesting. As an example, primary and secondary daylight zones are intensified by California Energy Code Title 24-2016. In primary zones, a minimum of 50% of the general lighting must be controlled independently from other lighting, and larger zones must be controlled with automatic controllers. By giving power adjustment factor credits which can be applied with the lighting design the code promotes automatic daylight harvesting in secondary zones. The 2015 International Energy Conservation Code (IECC) also identifies daylight control zones and is required to provide separate control in those areas that are independent of the general lighting in the space, which can be stepped or continuous dimming. The 2016 ASHRAE 90.1 energy standard, also addresses daylighting. In ASHRAE 189.1, the first generation of sustainable construction codes define daylight zones and requires daylight harvesting control [25] [10].

2.2 Static shading systems

Static strategies use the environment, such as wind and sunlight, to regulate the light level, temperate of a building and indoor air quality of a building. These strategies help to reduce energy consumption while having very low maintenances. This enables a convenient economical way to achieve an energy-conscious building since they do not need any help of additional mechanical systems [26]. Adjustment of solar radiation enters to a building is a common way of passive cooling to increase the thermal comfort with the harvesting of daylight. The modulation of solar radiation can be obtained by shading systems, orientation and aperture-geometry, surface properties [27].

Shading devices must be selected wisely since they could cause excessive daylight level reduction. With low illuminance levels, occupants may feel uncomfortable to carry their visual tasks, hence they may favour switching the electrical lights on which could cause an increase in electricity demand. Other than that, the absence of proper shading systems may cause glare, thermal and visual discomfort [28].

Figure 3: Static Shading System-Building by Woods Bagot in South Australia [26]

The orientation and size of the window have a close relationship with the visual and thermal comfort of a building. By controlling the orientation and size of the window, shading devices can be used to achieve further improvements. When the orientation and size cannot be changed due to design requirements, shading devices play a major role in controlling solar radiation [27].

The shading devices can be divided into two categories, which are fixed and adjustable shading devices. There are several types of fixed and adjustable shading devices are available. Examples for available external fixed shading systems can be listed as overhangs, vertical fins, vertical and horizontal combinations such as egg-crates, and balconies. Internal fixed devices are light-shelves and light louvres. External adjustable shading devices are blinds, tents, awnings, pergolas. Internal adjustable devices are Venetian blinds rollers and curtains. There are external factors in cases shading to a building such as nearby buildings and vegetation which reduces the effect of solar radiation [27].

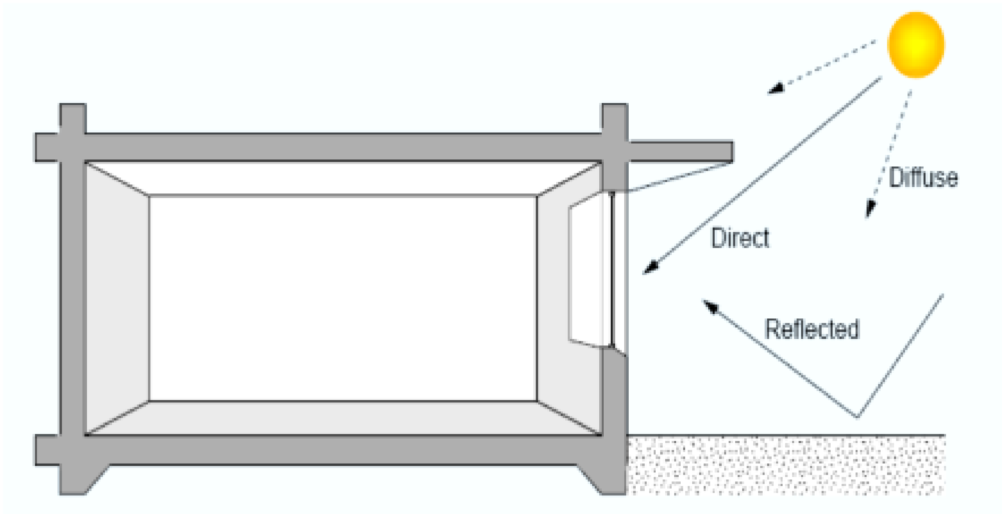


Figure 4: Solar radiation- Direct and indirect [27]

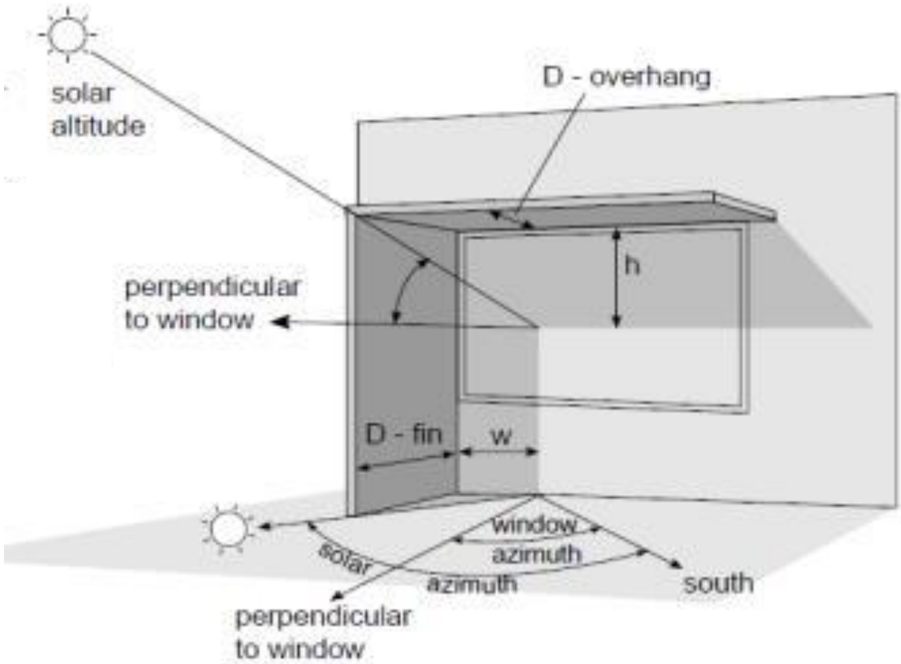
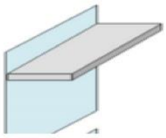
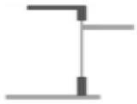
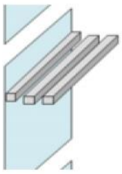
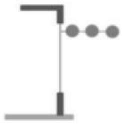
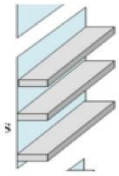
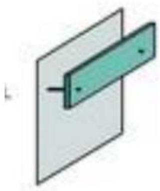
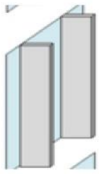
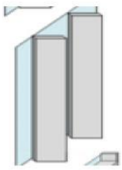
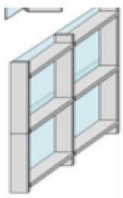


Figure 5: Overhang and side fin Shadow area [27]

Shading devices aim to enhance the effect of indirect illumination, such as sky and ground reflection, by avoiding direct solar radiation. The angle of incidence of sunlight on the window is determined by the sun's position. Direct sunlight can be effectively guided when the incidence angle of the sun equals the angle of the shadow created by the shading system. As a result, the orientation of the sun and the depth of the shading feature become important considerations [27].

Table 1: External shading devices [27]

	3D-View		***Best Orientation***
Overhang			south, west, east
Overhang Horizontal Louver s			south, west, east
Overhang Multiple Blades			south, west, east
Overhang Vertical panel			south, west, east
Vertical Fin			west, east, north
Slanted Vertical Fin			west and east
Eggcrate			west and east

2.3 Dynamic shading systems

Opposite to static strategies, adaptive façades are the ones that incorporate mostly automatized mechanical devices capable of controlling adaptability to perform as climate moderators. With the help of dynamic shading systems, the building can adopt the ability to adapt to its environment. These systems use different types of sensors and complex robotic and mechanical systems, to enable automated climate control [26].

Figure 6:Al Bahar Towers in Abu Dhabi - adaptive shading façades [26].

Although these dynamic shading systems seem to be a more integrated solution, they are highly dependent on automated mechanical devices which need constant maintenance. Most of these innovative solutions are not yet reliable in terms of cost, quality, installation, and operation. [26].

The middle ground of both of these perspectives relies on the user based operating systems to make the dynamic systems less complicated and reliable on the users' experience. Although W. Huesler in 2015 mentioned that regular users and control equipment do not operate regularly as it will be assumed. This constantly leads to the addition of extra mechanical systems to make the building operational [26].

2.3.1 Typical automated shading control system

A typical automated shading control system consists of several major components. Sensors are used to measure outdoor and indoor conditions such as outdoor Lux level, outdoor temperature, indoor Lux level, indoor temperature. Since dynamic shading devices are used to control the amount of daylight there may be sensors to detect the shading device position or orientation.

An intelligent control unit equipped with a smart control algorithm is used to process the input signals and give the desired output accordingly. This controller may have integrated with the lighting control unit, HVAC control system and building's central control system (Building Management System) to improve the energy efficiency, measurements, and data recording and analysing purposes.

Dimmable energy-efficient lights are used to maintain the desired Lux level inside the building. Motorized shading devices are used to regulate the amount of illuminance daylight and heat gain to the building.

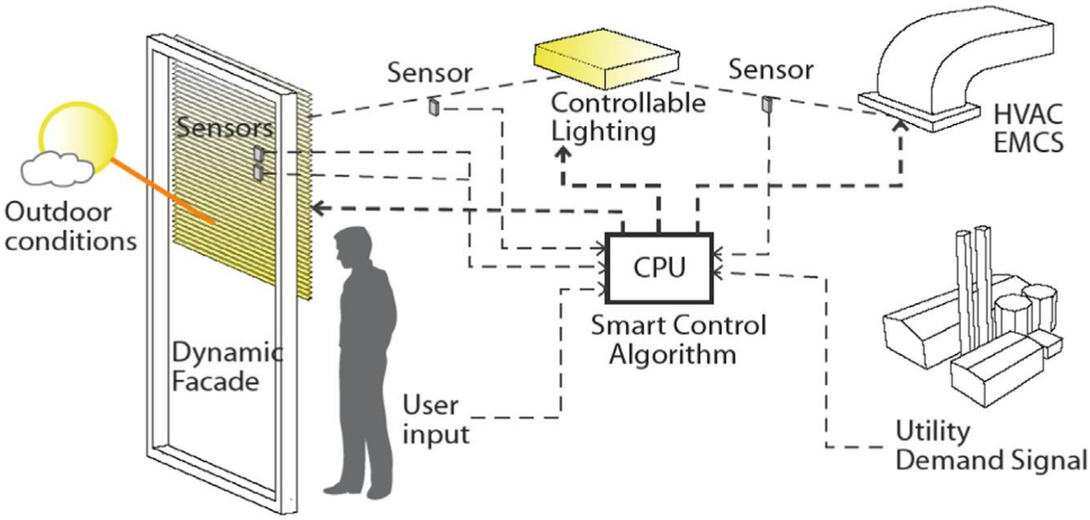


Figure 7. Control system diagram [6].

2.4 Solar geometry

The Earth revolves around its north and south celestial poles perpendicular to the equator. But the axis of rotation is not perpendicular to the ecliptic plane due to the 23½° tilt angle of the axis of rotation with this plane. The plane parallel to the celestial pole of the Earth and through the sun is called the plane of the sun. Every year Earth completes one rotation around the sun passing alternately above and below this plane.

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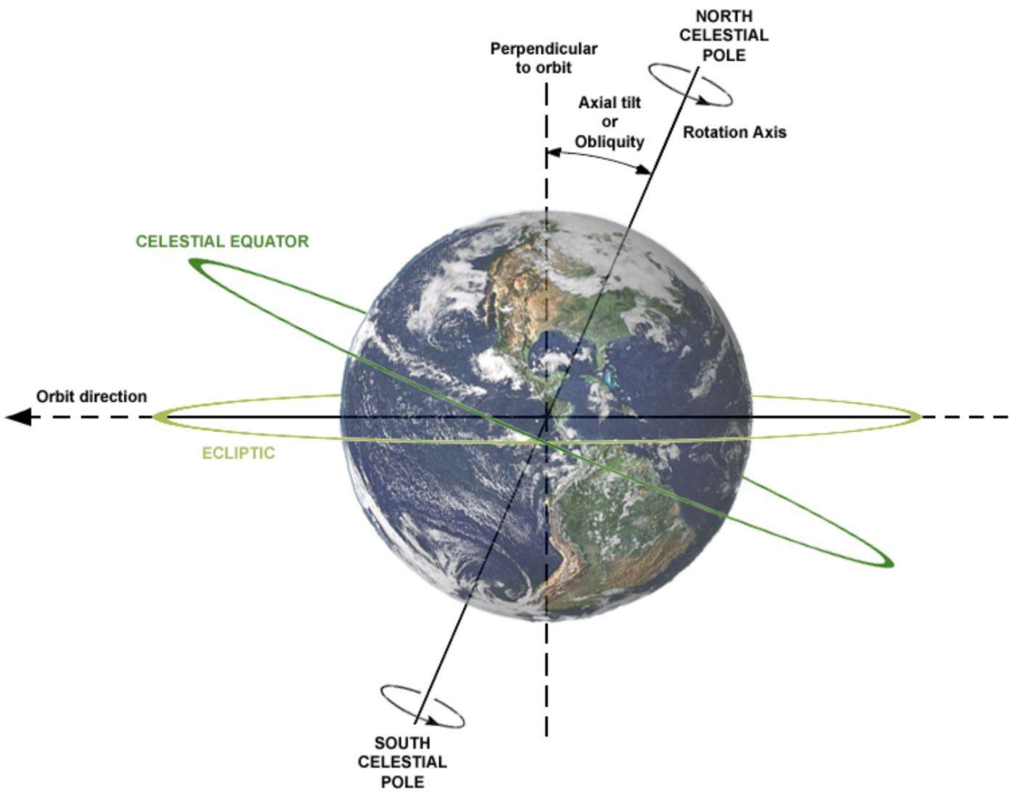


Figure 8: Earth's rotation [51]

2.4.1 Sun angle, solar insolation and duration

To comprehend the Earth-Sun relationship, we must consider how solar radiation intensity varies from place to place throughout the year. Solar insolation is the solar radiation received by Earth. The seasonal variations and temperature differences on earth are primarily due to the fluctuation of solar insolation [29].

The solar insolation is also affected by the Earth's atmosphere. As an example, the heavy cloud can cause the reduction of solar insolation on the earth's surface. But the appearance of clouds is not regular and not predictable. So, with a long period of time, the effect of clouds on solar insolation is negligible. [29].

Solar insolation is affected by two main factors that varies frequently with the Earth's rotation and its journey around the sun, as well as the length of the daytime and the angle of the sun's rays. This influences the amount of solar radiation reaching the surface of the Earth. The duration of solar radiation and the intensity of solar radiation are the major factors of solar insolation at any point on Earth's surface. So, the earth receives more solar insolation of the sun strikes more directly or the sun shines for a longer period or both. [29].

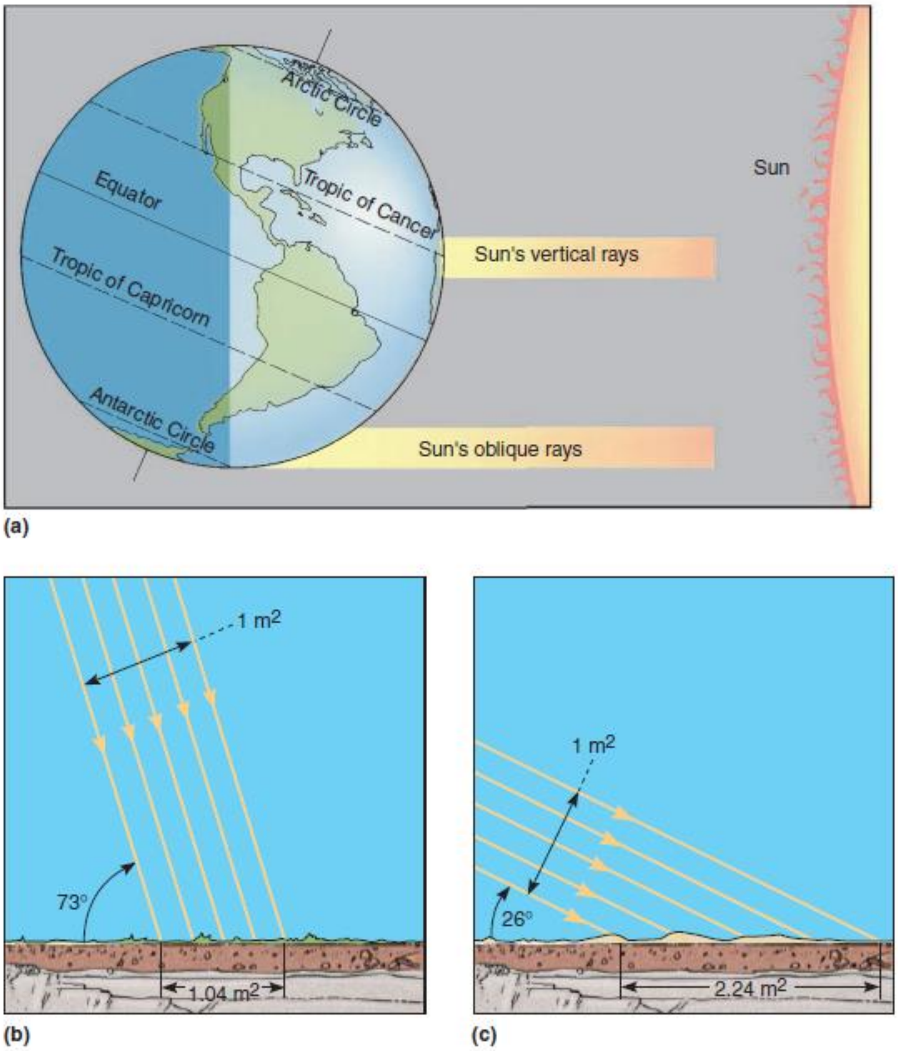


Figure 9: The angle of solar radiation
(a) June condition (b) Summer (c) Winter

The intensity of solar radiation varies from place to place at any given time. This is due to the spherical shape of Earth, only one line of latitude receives solar radiation at a right angle while others receive varying oblique angles as shown in *Figure 9 (a)*. The solar radiation received per unit area on the surface of the Earth depends on the angle of solar rays. The figure shows the June condition on the tropic of Cancer, where sun rays strike the surface perpendicular, creating summer conditions in the Northern Hemisphere. In Sothern Hemisphere, solar radiation strikes the surface more oblique creating winter conditions [29].

Lambert's Law can be used to calculate the amount of solar insolation obtained at any given latitude. This formula is developed by Johann Lambert who is an 18th-century scientist, to calculate the intensity of solar insolation using the Zenith Angle. With this formula, we can identify the amount of solar insolation on Earth’s surface based on latitude. Figure 9 shows the total solar radiation intensity at various latitudes when solar rays directly strike the equator [29].

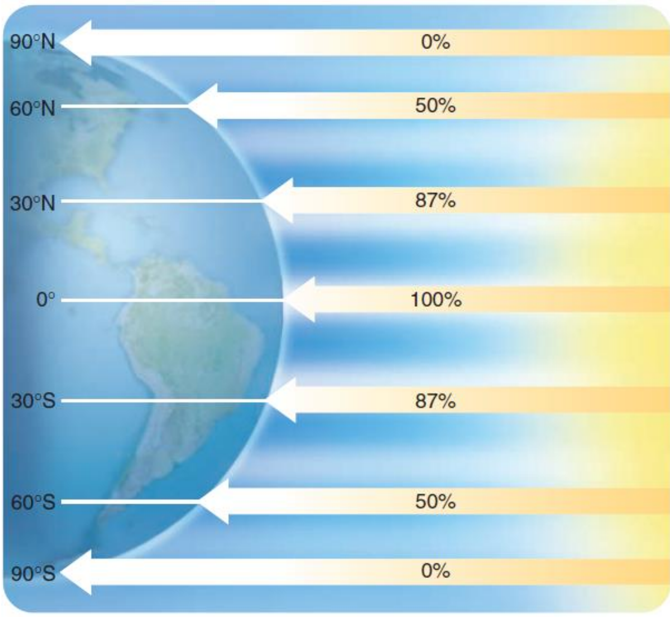


Figure 10: The percentage of incoming solar radiation - Lambert’s Law [29].

In addition to this, the earth’s atmosphere diminishes the solar insolation reaches the Earth’s surface, up to some extent. The oblique rays should travel a greater distance to strike the surface than vertical rays. The greater the distance the greater the amount of isolation lost. The amount of solar radiation dissipated through the atmosphere can be calculated by Beer's law, which is established by a German scientist and mathematician in 1854 [29].

The duration of solar energy depends on the duration of the daytime for any given location on Earth (*Table 2*). It is obvious that with the increase of daytime, a higher amount of solar energy will receive at any given point on Earth [29].

2.4.2 The Seasons

Many people believe the seasonal changes are due to the changes in the distance between the sun and earth through the Earth's journey around the sun. However, the impact of distance is negligible. Northern Hemisphere is closest to the sun in January and farthest away in July (*Figure 11*), which is exactly opposite of the seasonal variation.

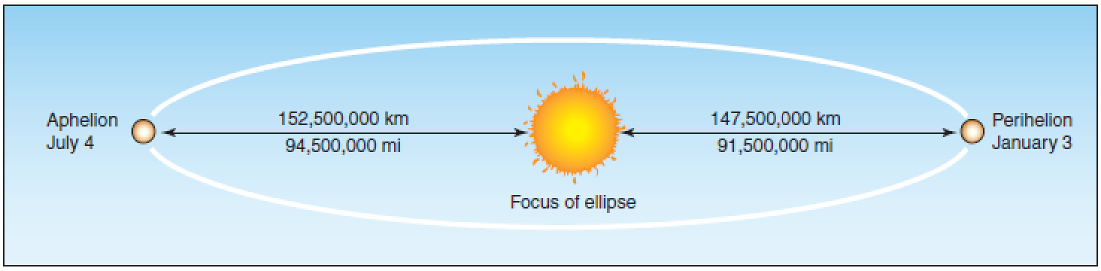


Figure 11: Earth's orbit around the sun [29].

Seasonal changes are due to the 23½° Earth's tilt angle. On June 21^{st} the 23½° N latitude is along the plane of the ecliptic. This day is called as summer solstice of the Northern Hemisphere. This is illustrated in *Figure 12* by position A of the diagram. It clearly indicates that solar radiation is distributed unequally in the Northern and Southern hemispheres. In this condition, The Northern Hemisphere gets more daylight than the Southern part of the Earth. On the other hand, the larger portion of the Sothern Hemisphere stays in darkness than Northern Hemisphere. At the June solstice, a person living above the Arctic Circle has a full 24 hours of daylight. An individual living in New York City has more daylight than a night on the same day. On the other hand, on the same day, a resident of Buenos Aires, Argentina, experiences a long period of the night than day. In the Southern Hemisphere, June 21st is known as the Winter Solstice. This is the longest day of the year in the Northern Hemisphere, with the highest suns angle, and the shortest day of the year in the Southern Hemisphere, with the lowest sun angle [29].

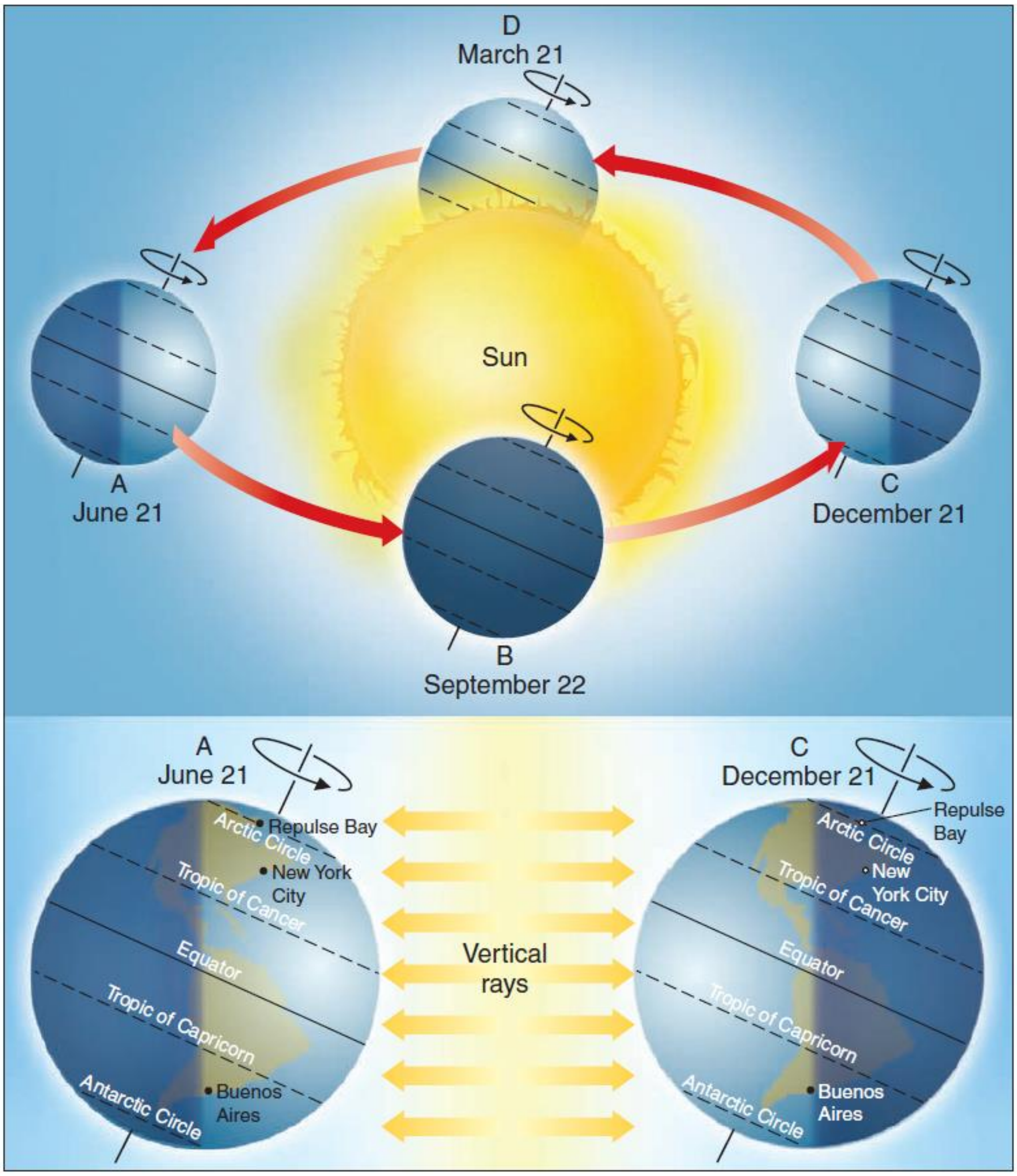


Figure 12: June and December solstices. [29]

When Earth moves from June solstice a quarter of a year in September, the daytime of the above-mentioned cities changes. In July, August and September night-time of Repulse Bay is increased. Sunset arrives in New York earlier. The situation will be reversed in Buenos Aires. In this position of Earth in September, daytime of Southern Hemisphere getting longer while night-time getting shorter [29].

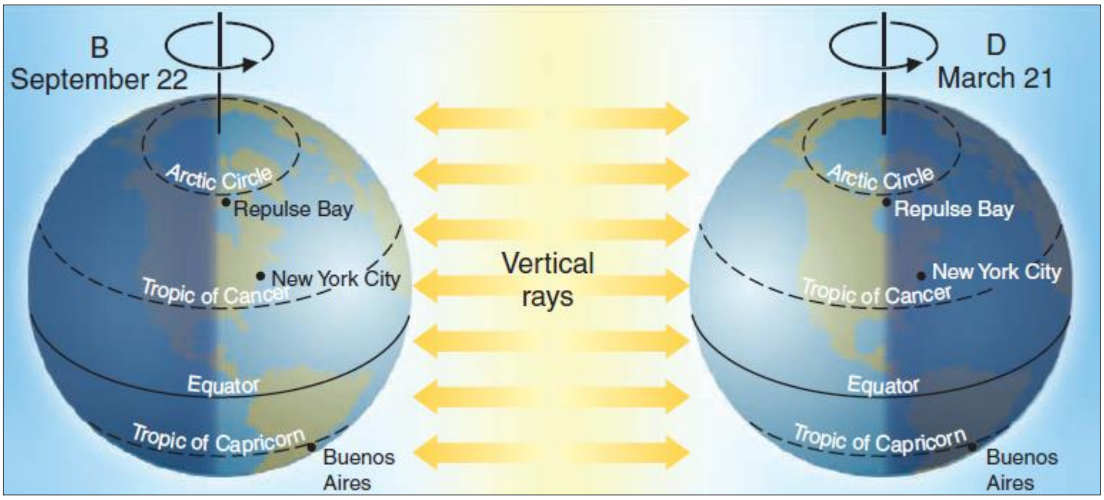


Figure 13: March and September equinoxes [29].

Table 2 clearly shows the variation in the duration of daylight in certain latitudes. The table gives the hours of daytime for June 21st, September 22nd, December 21st and March 21st with the latitude angle varies from 0^0 to 90^0.

Table 2: Duration of daylight for certain latitudes [29]

	Length of Day (Northern Hemisphere) (read down)		
LATITUDE (IN DEGREES)	MAR. 20/SEPT. 22	JUNE 21	DEC. 21
0.0	12 hr	12 hr	12 hr
10.0	12 hr	12 hr 35 min	11 hr 25 min
20.0	12 hr	13 hr 12 min	10 hr 48 min
23.5	12 hr	13 hr 35 min	10 hr 41 min
30.0	12 hr	13 hr 56 min	10 hr 4 min
40.0	12 hr	14 hr 52 min	9 hr 8 min
50.0	12 hr	16 hr 18 min	7 hr 42 min
60.0	12 hr	18 hr 27 min	5 hr 33 min
66.5	12 hr	24 hr	0 hr
70.0	12 hr	24 hr	0 hr
80.0	12 hr	24 hr	0 hr
90.0	12 hr	24 hr	0 hr
LATITUDE	MAR. 20/SEPT. 22	DEC. 21	JUNE 21
	Length of Day (Southern Hemisphere) (read up)		

2.4.3 The Analemma

The analemma is the latitude at which the sun strikes straight above the head at noon. This is also called as sun’s declination angle. When the sun strikes straight above the head at 12°S latitude, the declination angle of the sun is 12°S. *Figure 14* is a modified diagram of Analemma. By refereeing to this diagram, we can say the day which sun strikes overhead at a given Latitude. [29].

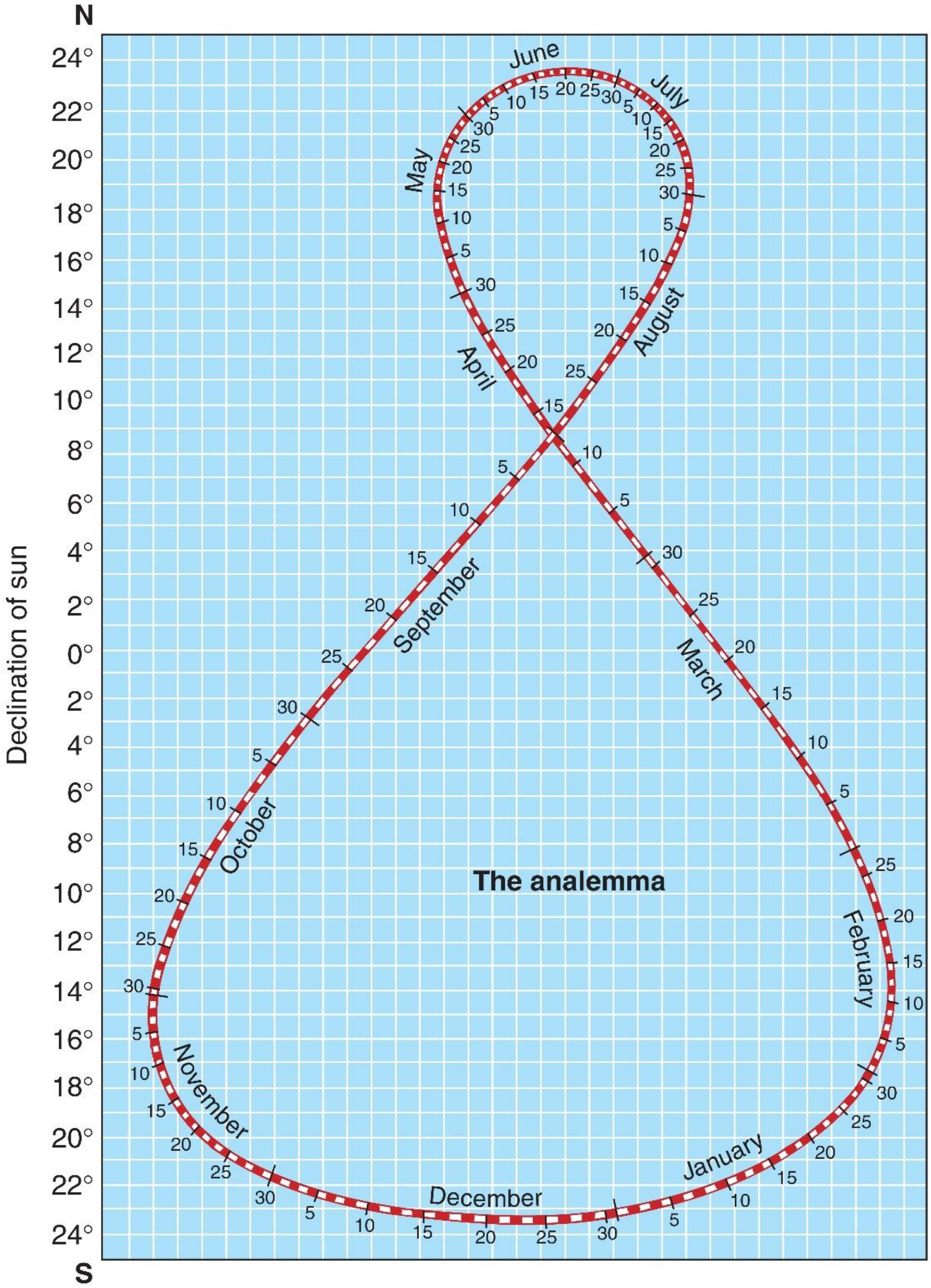


Figure 14: The Analemma [29]

2.5 Window to wall ratio

Window to Wall Ratio (WWR) is the ratio between building window area to its total external envelop area as a percentage. This is a critical parameter that affects a building's energy performance. Window to wall ratio influences heating, cooling, lighting and as well it affects natural environmental conditions such as daylight, ventilation of a building. [30].

When designing building facades, it is possible to go for higher Window to wall ratios than maximum values defined in energy codes, using high-performance window glazing systems with or without integrating with exterior and interior shading systems. The intention of this kind of design is to control the excess amount of solar radiation through large window sizes, at the same time allowing a sufficient amount of day light through the window to minimize the artificial lighting demand [30].

In nearly zero energy buildings (NZEB), the Window-wall ratio (WWR) is considered a major design that enables energy conservation. By analysing the optimum value for the window to wall ratio, achieving nearly zero energy building requirements makes easy. It is important to study the effect of window orientation as well with regards to minimising the energy consumption in Nearly Zero Energy Buildings. [31].

2.5.1 Energy consumption vs WWR

It is important to understand the energy consumption variation with changes in the Window to wall ratio. This section discusses a simulation done by Guohui Feng, Dandan Chi, Xu, Baoyue Dou, Yao, Xiaolong Fu and Yixin Sun to study the effect of WWR on building energy demand.

A Google SketchUp model is created to simulate the effect of WWR in severe cold regions. This is an ordinary Nearly Zero Energy Building, which has a shape-coefficient of 0.54. The building size of length x width x height is 18m x 8.4m x 6.9m respectively, the total area is 302.4m^2 and consists of two floors. The first floor is used as a residential element which has a floor height of 3.3m. The second floor is an office building where a height is 3.6m. The thermal parameters of the building facade are given in *Table 3* [31].

Table 3:Thermal performance of envelope [31]

	External wall	Roof	Ground	External window
K (W/(m²·K))	0.099	0.090	0.113	1.000

EnergyPlus which is a thermal simulation software is used with Thermal Zones. In these Zones, rooms that have the same thermal conditions are considered as a single zone. The room in the Thermal Zone may not be connected. According to *Figure 15,* nine zones are defined in this building model, and they are represented in colours [31].

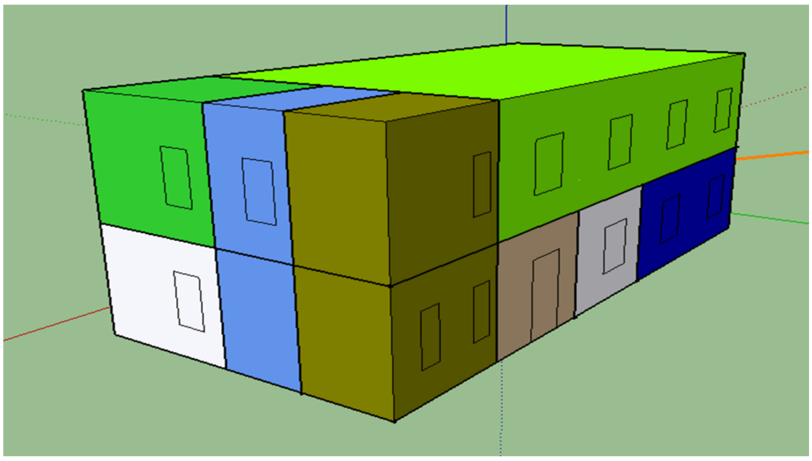


Figure 15: Thermal Zone distribute picture [31]

ASHRAE Shenyang weather parameters area used to conduct this simulation. In Accordance with "Technology Guidelines for Passive Green Ultra Low Energy Building", the value for LPD is 3W/m^2, the heat gain by the internal objects of the building other than lighting should be 2W/m^2, the rate of ventilation should be 0.4 times/h. Venetian blinds are used for all facades except North [31].

By increasing the WWR, the solar radiation heat-gain over the glazing increases. Since in this simulation the heat transfer coefficient of the window is 3.5 times higher than the external wall. Because of this, the heat loss over the fenestration also increases. The "Civil Construction Energy Conservation Design Standards", JGJ26-2010, defines the maximum window to wall ratio values for each window orientation. For domestic buildings in very cold areas, maximum WWR values for east (west), north and south orientations are 30%, 25% and 45% respectively. The window to wall ratio set values are given in *Table 4* [31].

Table 4: WWR Set values [31]

East WWR (%)		South WWR (%)			West WWR (%)		North WWR (%)	
5.0	20.0	5.0	20.0	35.0	5.0	20.0	5.0	20.0
7.5	22.5	7.5	22.5	37.5	7.5	22.5	7.5	22.5
10.0	25.0	10.0	25.0	40.0	10.0	25.0	10.0	25.0
12.5	27.5	12.5	27.5	42.5	12.5	27.5	12.5	
15.0	30.0	15.0	30.0	45.0	15.0	30.0	15.0	
17.5		17.5	32.5		17.5		17.5	

2.5.1.a Simulation results

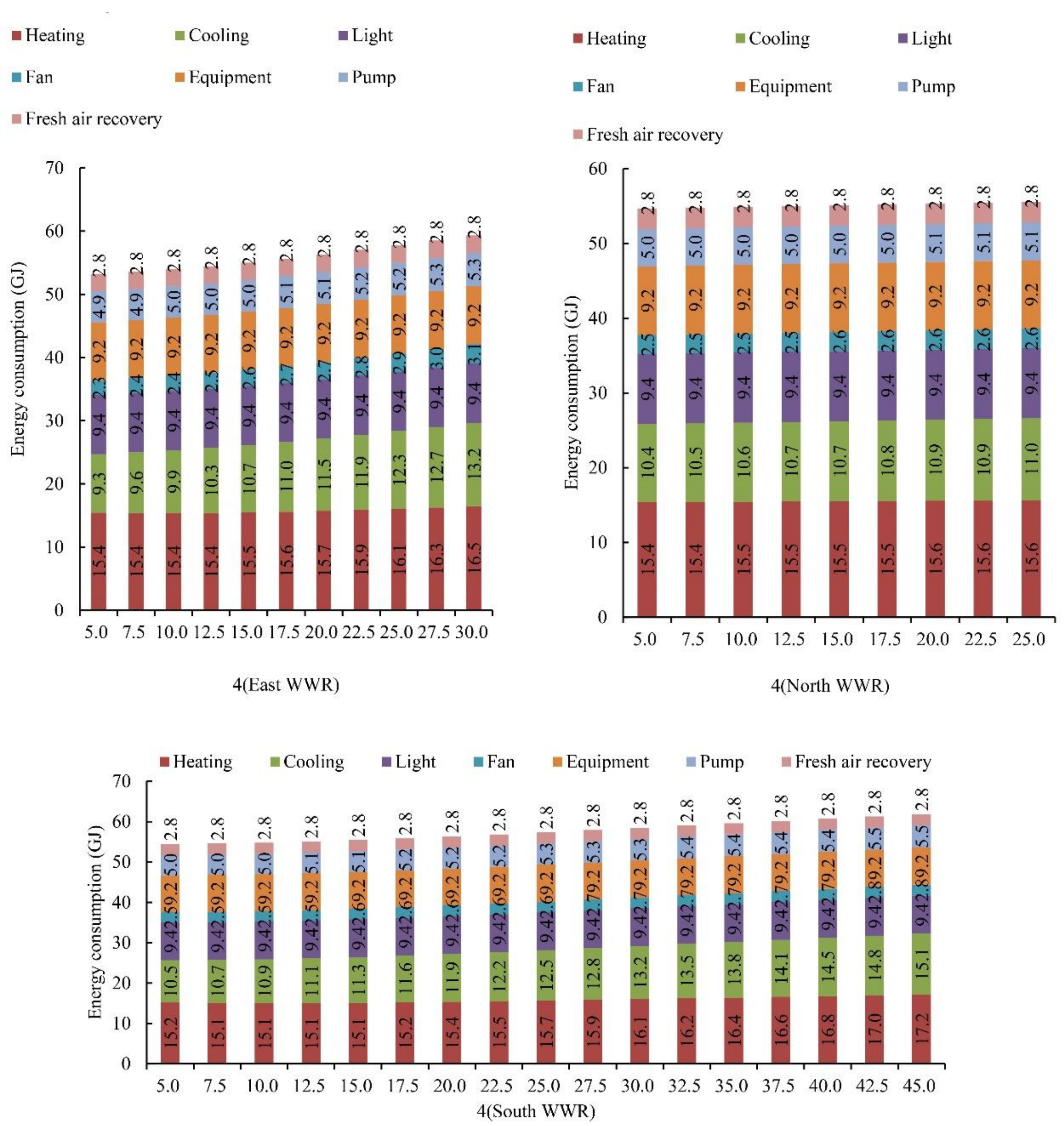


Figure 16: Energy consumption distribute picture [31]

Figure 16 shows the energy consumption for different WWR values with respect to the orientation. *Figure 17* is the summarization of total energy consumption with respect to different orientations. According to the orientation, heat-gain average value and the rate of heat loss is given in *Table 5*. Cooling, heating and the total energy demand variation with window to wall ratio is important to optimize the building performances and shown in *Figure 18, 19 and 20* [31].

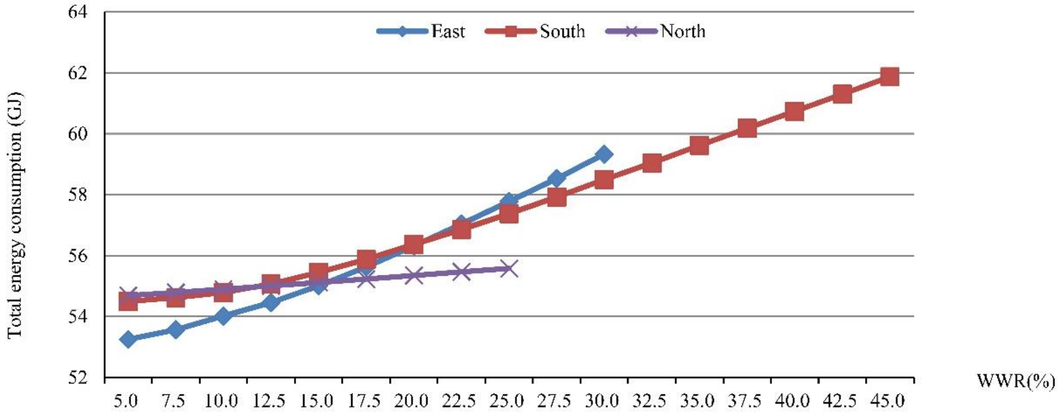


Figure 17: Total Energy consumption of different orientations

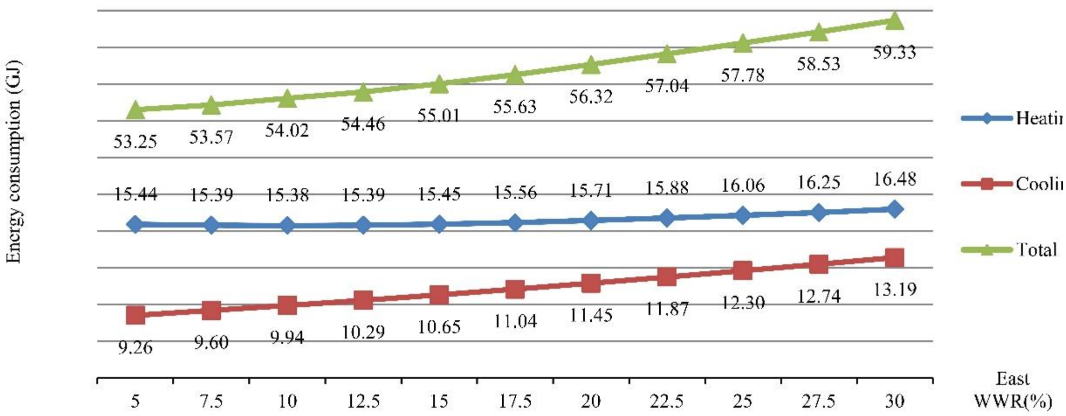


Figure 18:Energy consumption variations over varying East WWR [31]

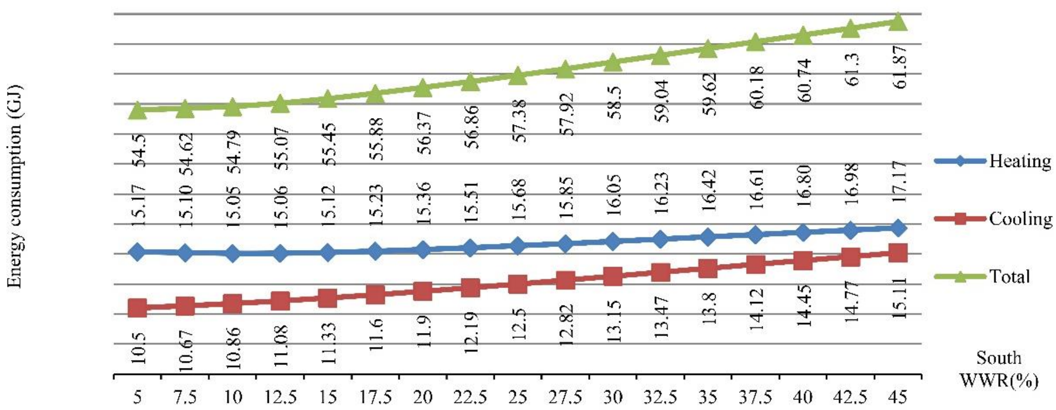


Figure 19:Energy consumption variations over varying South WWR [31]

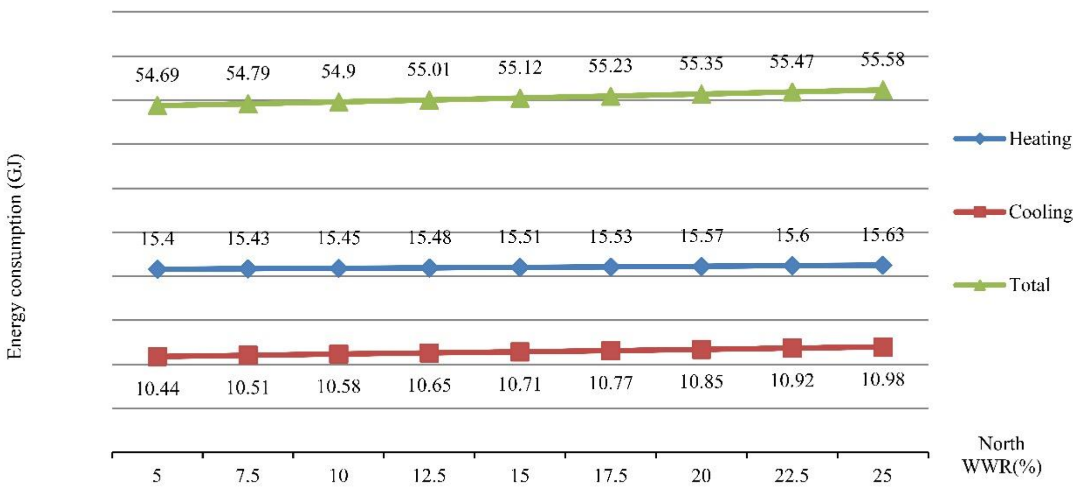


Figure 20: Energy consumption variations over varying North WWR [31]

Table 5: rate of t Heat gain and loss [31]

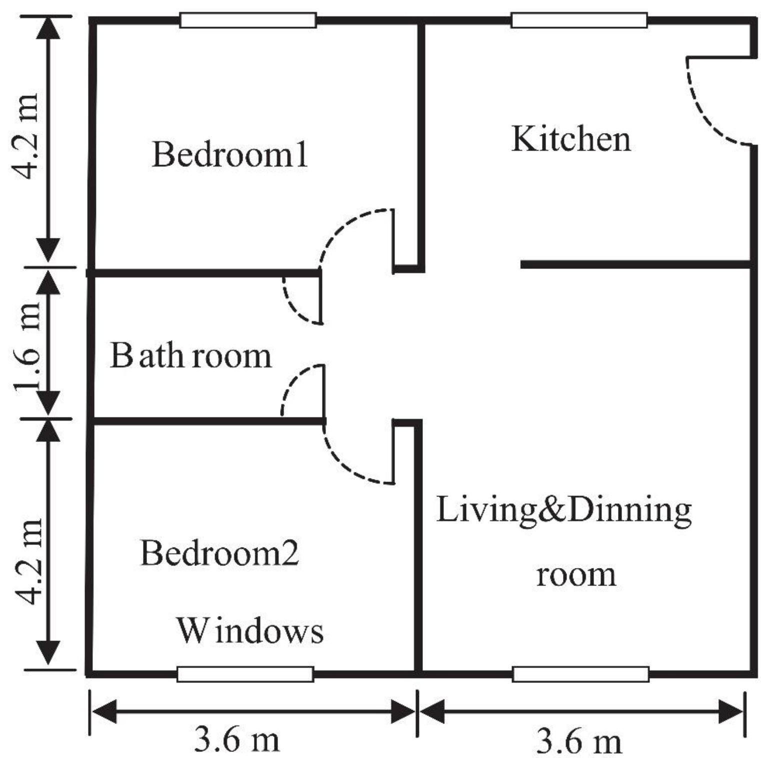
	East WWR		South WWR		North WWR	
	10%	30%	10%	30%	5%	25%
Average heat gain rate (W/h)	408.35	672.94	141.26	213.86	62.36	117.01
Average heat loss rate (W/h)	13	29.21	5.86	8.91	2.79	5.96

According to the *Figure 16* total energy demand is dominated by cooling and heating demand. Although the heating energy consumption is quite large, the variation is not significant. With WWR the total energy demand has increased. According to *Figure 16* the impact of WWR in Net Zero Energy Buildings is highest in east and west facades and lowest in north facades [31].

According to *Table 5*, with the increment of WWR increased from 10% to 30% in the east or west façade, the rate of average heat-gain has been enhanced by 264.59W/h, the increase of the rate of average heat loss is 16.21W/h. The increase of heat gain rate is 16 times the increase of heat loss. So, increasing the east window to wall ratio causes a significant increase in summer cooling demand. With the increase of the south window to wall ratio from 10-30%, an increase of the average heat gain rate is only 72.64W/h, and the heat loss rate by 3.05W/h. In the North window increase of heat-gain rate is 54.74W/h and the increase of heat loss is 3.17W/h. According to the results increase in heat gain rate in the east window is very significant compared to others [31].

2.6 The window performance with Solar Heat Gain Coefficient (SHGC)

Solar Heat Gain Coefficient is an important parameter that affects solar heat gain into a building through a window. This section discusses a simulation done to understand the effect of solar heat gain coefficient for residential building the plan as shown in *Figure 21*. The floor area of the building is 7.2m x 10m and the floor height is 3m. There are two windows at south and north orientations any window at east and west. The height and width of a window are 1.62m and 2m respectively. It has 3mm thick generic double glazing with an air gap. WWR of the building is 0.3. The external wall thickness of the building is 170mm and the heat transfer coefficient is 0.511 W/m^2 K. The set values for cooling and heating temperatures are 26°C and 20°C respectively. Fresh is and infiltration rates are set at 0.4 l/h and 0.15 l/h respectively. The total equipment load of the building is 1280W. The internal occupants' load is 3 [32].



2.6.1 Effect of constant SHGC on building energy performance

The optimum SHGC may get affected by the orientation of the sun and the climate zone. So, 8 cities in USA and 8 cities in China which are located between 20° to 50° latitude angles and which covers 5 climate zones have considered for evaluation. Since solar radiation and building load are affected by a variety of factors, including elevation, latitude, solar irradiation, sunshine period, air temperature, humidity, the annual direct normal irradiance to global horizontal irradiance (DNI/GHI) ratio, solar absorption by water vapour, and scattering by aerosol, etc. The meteorological data of those cities are given in *Tables 6 and 7* [32]

Soar Heat Gain Coefficient is the fraction of external solar radiation transmitted through a window. The value of SHGC varies from 0 to 1. The higher the SHGC the higher the solar radiation transmitted. So SHGC value 0.0 means, a fully opaque window and 1.0 means fully transparent [32].

Thermal load simulation software called TRNSYS is used to analyse the heating and cooling load of the building. Weather data from a typical meteorological year was considered in the calculations. The value of SHGC has changed from 0.0 to 1.0 during the simulation. [32].

Figure 22 shows the annual building load with the variation of SHGC. According to the figure, cities with high latitude angle such as Nashville (36.2°N), Louisville (38.2°N), Columbus (40.0°N), Detroit (42.4°N) and decreases the building load with the increase of the solar heat gain coefficient. On the other hand, cities which are below 30° N latitude angle such as Honolulu (21.3°N), Miami (25.8°N) and New-Orleans (30.0°N) increases their building demand with the increase of the SHGC. According to *Figure 24* which represents the building load in Chinses cities, shows the same pattern. The cities such as Siping (43.2°N) and Qiqihar (47.4°N) decreases the demand with the increase of SHGC but cities such as Haikou (20.0°N) and Guangzhou (23.1°N) increases its demand with solar heat gain coefficient [32].

Figure 24 and 25 shows the annual building load variation for no shading and optimal constant SHGC. Again cities below the 30° N latitude angle shows significant energy saving with optimal constant SHGC and with the increase of the Latitude saving become negligible [32].

Table 6: The meteorological data of 8 cities in the USA [32]

State	Michigan	Ohio	Kentucky	Tennessee	Alabama	Louisiana	Florida	Hawii
City	Detroit	Columbus	Louisville	Nashville	Montgomery	New Orleans	Miami	Honolulu
Climate zone	5A (Cool-humid)	5A (Cool-humid)	4A (Mixed-humid)	4A (Mixed-humid)	3A (Warm-humid)	3A (Warm-humid)	2A (Hot-humid)	1A (Very hot-humid)
Latitude (degrees)	42.4	40.0	38.2	36.2	32.4	30.0	25.8	21.3
Longitude (degrees)	−83.1	−83.0	−85.8	−86.8	−86.3	−90.3	−80.2	−157.8
Elevation (m)	191.0	254.0	149.0	180.0	62.0	3.0	2.0	5.0
Monthly mean max temperature (°C)	37.2	34.4	33.9	38.3	39.4	35.0	33.9	31.7
Monthly mean min temperature (°C)	−20.0	−18.3	−16.1	−19.4	−7.8	−4.4	3.3	13.9
Annual average relative humidity (%)	72.1	67.2	68.5	68.7	70.9	73.9	72.5	67.7

Table 7: The meteorological data of 8 cities in China [32].

Province	Heilongjiang	Liaoning	Beijing	Shanxi	Shanghai	Guangxi	Guangdong	Hainan
City	Qiqihar	Siping	Beijing	Xi'an	Shanghai	Ganzhou	Guangzhou	Haikou
Climate zone	7A (Very cold-humid)	6A (Cool-humid)	4C (Mixed-marine)	4A (Mixed-humid)	3A (Warm-humid)	2A (Hot-humid)	2A (Hot-humid)	1A (Very hot-humid)
Latitude (degrees)	47.4	43.2	39.9	34.3	31.2	25.9	23.1	20.0
Longitude (degrees)	123.9	124.3	116.3	108.9	121.4	115.0	113.3	110.4
Elevation (m)	146.0	165.0	55.0	397.0	7.0	124.0	7.0	14.0
Monthly mean max temperature (°C)	33.7	33.8	37.5	37.3	35.3	38.0	36.3	35.4
Monthly mean min temperature (°C)	−31.0	−25.3	−15.3	−10.7	−6.6	−1.6	2.8	7.6
Annual average relative humidity (%)	66.2	58.8	59.3	62.6	78.2	75.4	75.8	84.7

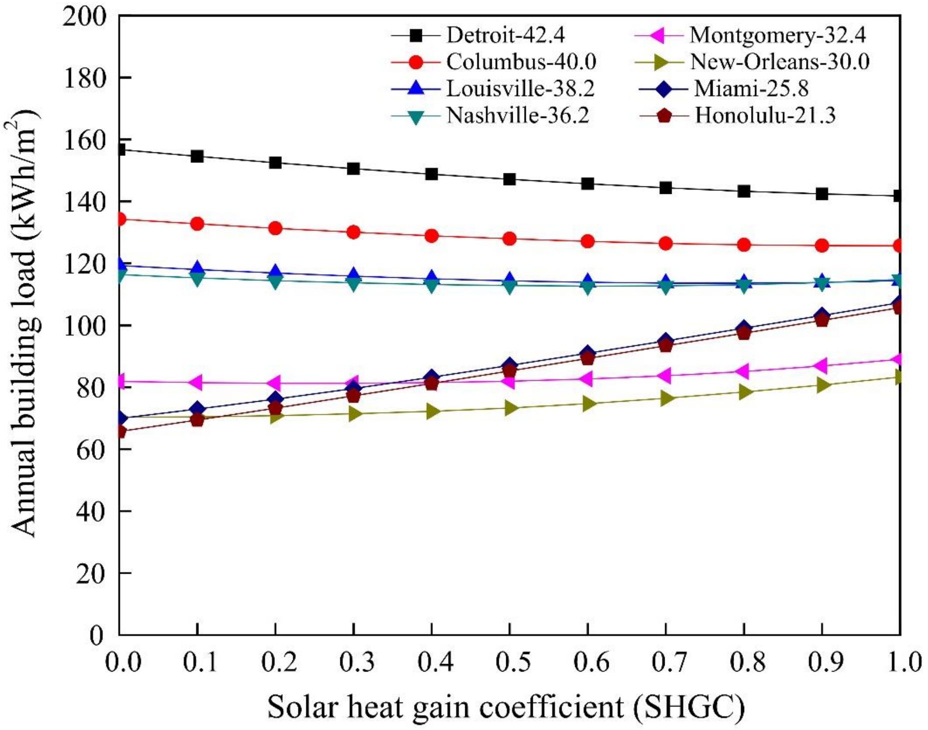


Figure 22: The annual building load over SHGC - USA [32].

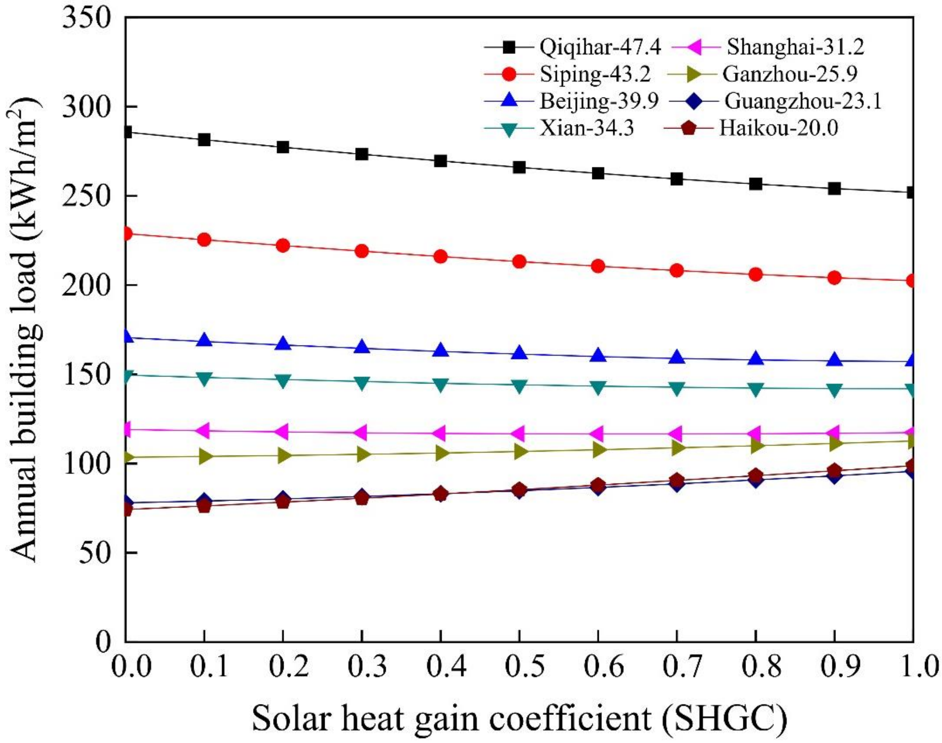


Figure 23: The annual building load over SHGC - China [32]

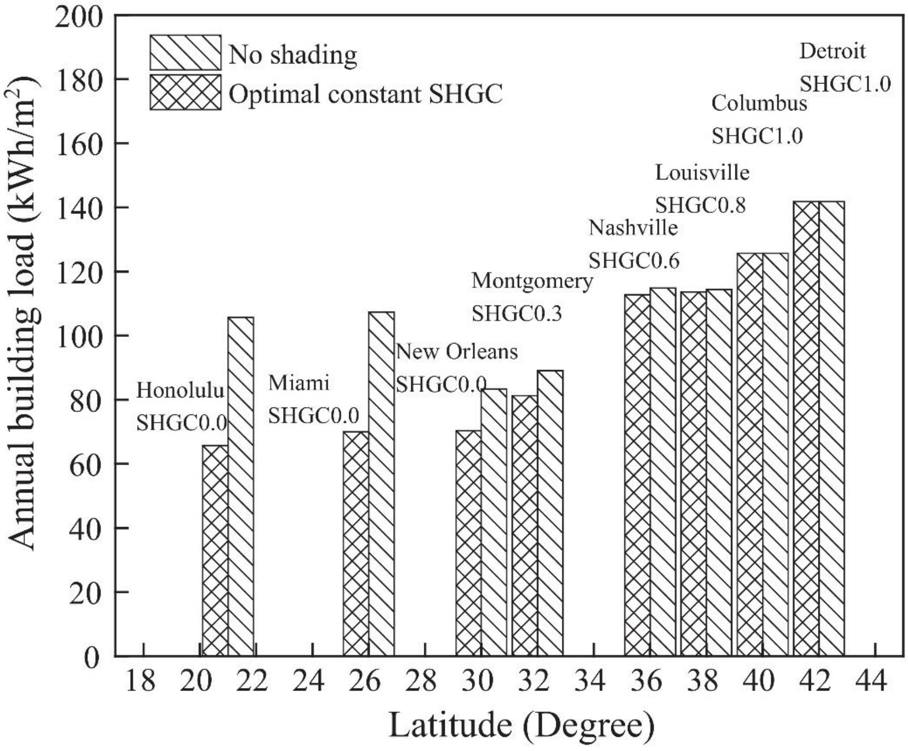


Figure 24: Building load comparison: no shading vs the optimal constant SHGC - USA [32]

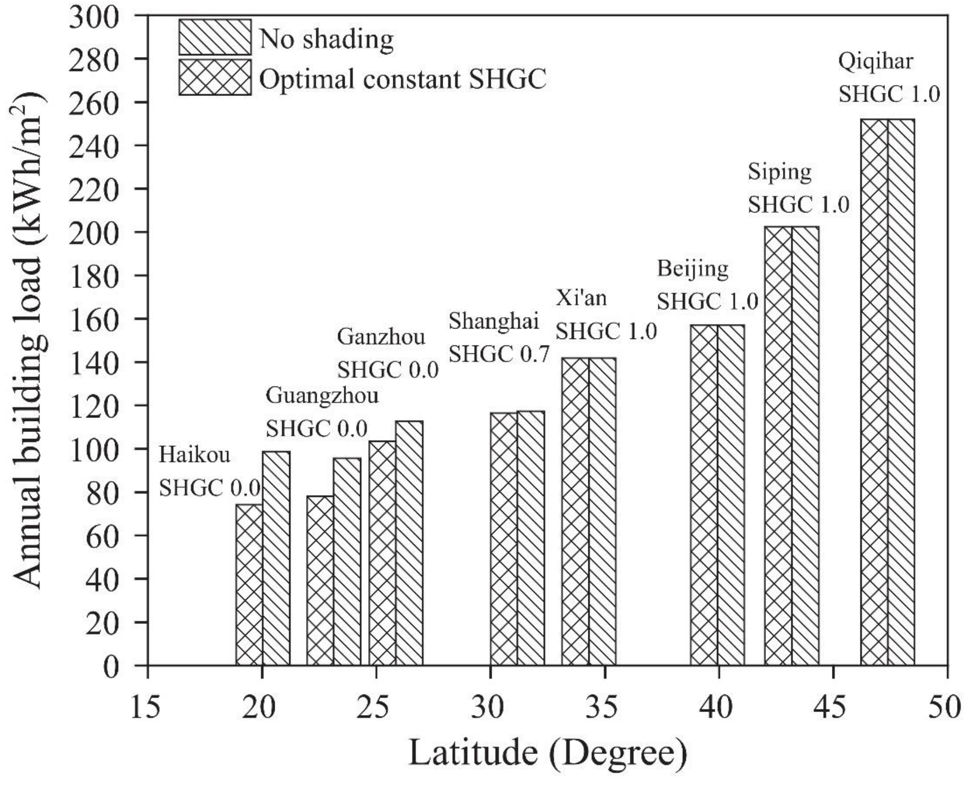


Figure 25: Building load comparison: no shading vs the optimal constant SGHC - China [32]

2.7 Energy demand with shading devices

From the year 1971–2007 world's energy demand has doubled, and 40% of the total energy is for the operation of the building [33]. To overcome this situation developing energy-efficient practices are concerned by the various countries in the world. As a political decision, all countries in the European Union accepted that all new buildings should be Nearly Zero Energy Buildings on top of 2020. [34]. Conservation of energy at all the building functions become an essential requirement [35].

The purpose of constructing buildings is to protect the people from environmental changes and achieve the required level of comfort. The building envelope act as a separator of the environment and the occupant. The selection of optimal façade is important to building comforts levels and energy performance. [36].

Introducing dynamic façades, integrated with the latest technology increase the performance of the building and occupants' visual and thermal comfort. This section discusses a simulation done to understand the improvements of building energy performances with respect to the type of shading devices such as no shading, static shadings and dynamic shadings. The value of providing data that encourages early design decisions with regard to the façade is identified using an integrated simulation [35].

2.7.1 Simulation Process

A simulation tool called iDbuild is used for this process, developed by the Technical University of Denmark which performs the calculation every hour concerning energy requirement for domestic hot water, heating, cooling, ventilation and electrical lighting. The thermal simulation was done using BuildingCalc simulation software and the lighting simulation with the LightCalc software [35].

2.7.1.a Thermal simulation

Every hour, the internal temperature is registered, as well as thermal heat-gain from fenestration and heat exchange between the external and internal environments is evaluated BuildingCalc simulation thermal simulator. According to the internal temperature following elements are controlled in the following sequence to achieve the pre-defined set points.

1. Shading devices
2. Natural ventilation (by the window)
3. Mechanical ventilation
4. Cooling

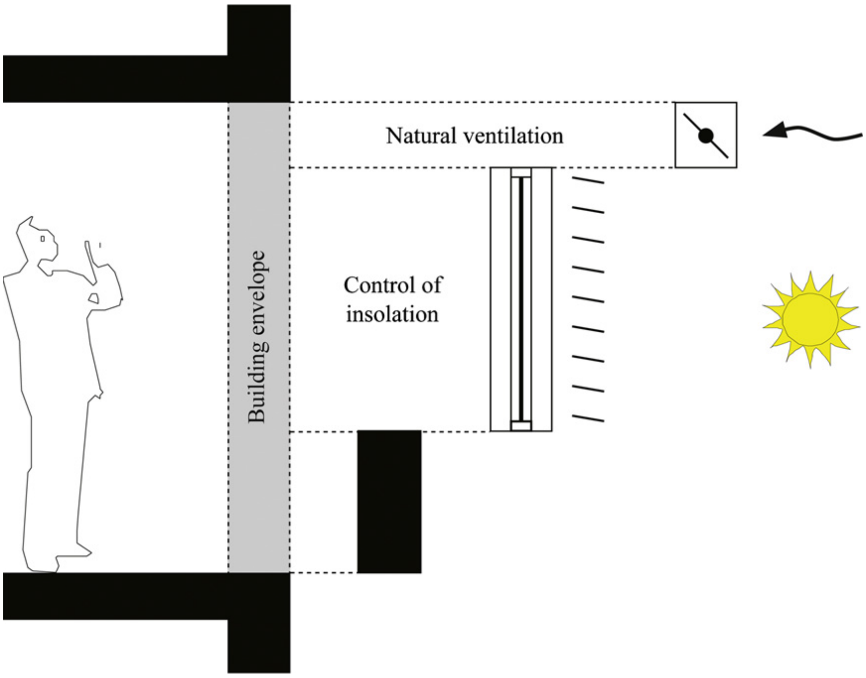


Figure 26: building envelope components [35].

With the activation of the above systems, the indoor thermal condition was simulated again to find the effect on the air temperature of the indoor by this activated system. [35].

The effect of glare or indoor temperature or both factors is considered when controlling the shading system. If any of those parameters, exceeded the desired set points, the shadings were adjusted to block the direct solar radiation accordingly. The daylight glare probability index developed by Christoffersen and Wienold in 2006 was used to estimate the risk of glare. With the activation of the shades, with the use of WinDat, 2006 software light levels at user-defined locations were calculated. The electrical light levels required and the heat gain because of the electrical lighting are considered. Then the natural ventilation is activated and controlled the air flow up to a maximum according to the requirement. If the natural ventilation is not sufficient mechanical ventilation air flow is activated and controlled [35]. When the temperature of the indoors exceeds the set values even after the activation of natural and mechanical ventilation, the mechanical cooling system is activated [35].

2.7.1.b Daylight simulation

The daylight levels are calculated hourly using LightCalc lighting simulation software. In order to calculate the daylight level both direct and diffused components of the daylight is taken into the account. As suggested by Stone and Robinson in 2006, upper and lower sky domes are used to model the diffuse light level scattered from the atmosphere and ground reflection [35].

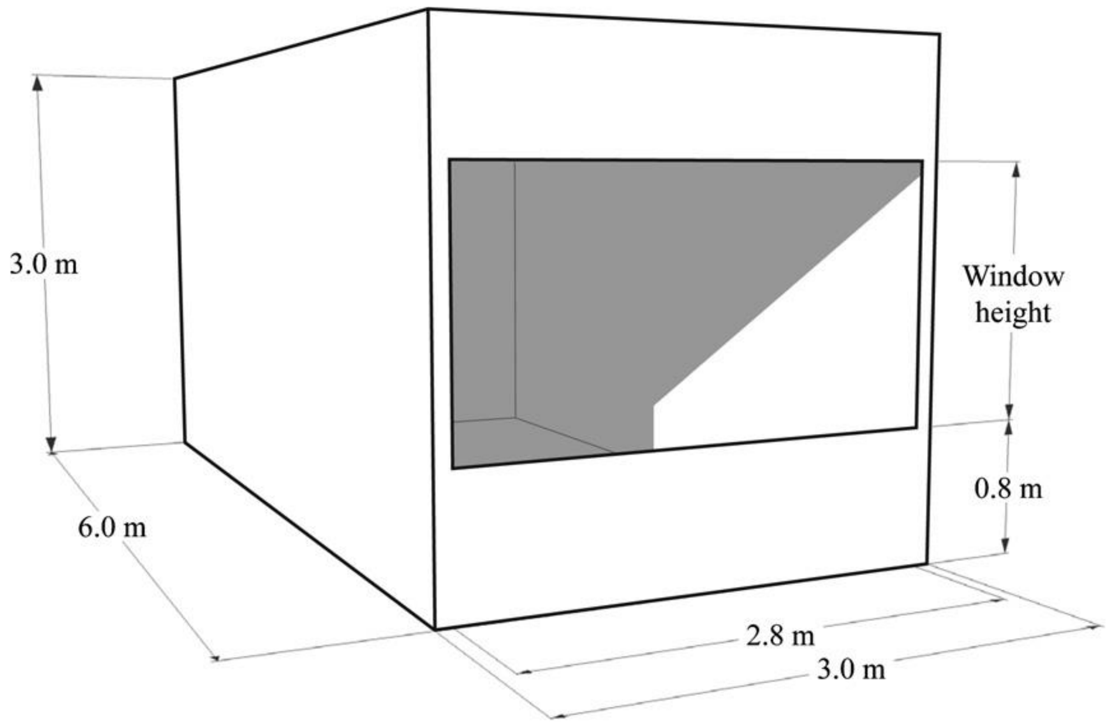


Figure 27: Geometry of the two-person office with the window centred [35]

2.7.2 Parameter variations

In this simulation, it was meant to identify the effect on energy demand and indoor condition with the type of the shading device, variation of several factors was considered. The shading type considered during this process is no shading, static shading and dynamic shading. As shown in *Figure 28* [35].

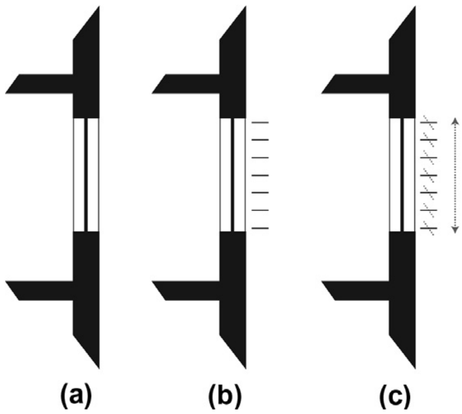


Figure 28: Types of solar shadings
(a)No shading, (b)Fixed shading (c) Dynamic and fully retractable solar shading [35]

The fixed and the dynamic solar shading were modelled as a horizontal, grey Venetian blind with slat thickness, width and distance as 0.22 mm, 50 mm and 42.5 mm respectively and with the reflectance of 0.54. The static shadings were fixed horizontally which are not retractable. The dynamic shadings are fixed as they can change the orientation with respect to the temperature of the indoors while controlling the glare. If the temperature or glare or both exceeded the set values, the shadings are retracted in accordance to block the solar radiation as necessary. This helps maximize the amount of daylight harvested while controlling the glare and overheating of the building. When there is no occupancy, the shades are controlled only considering indoor air temperature [35].

2.7.3 Design variables

These daylighting and thermal simulations were done for no shade, fixed shade and dynamic shade conditions, and performed for two design variables through several parameter variations as seen in *Table 8*.

Table 8: 3-solar shading types, 4-major orientations, 3-different window heights [34]

What	Why	How	Simulated models
Orientation	Influences the incident amount of solar radiation the façade receives	Orientation of window	North, south, east and west
Façade transparency	Defines the amount of heat gain and daylight that enters the room	Window height	1.0 m, 1.5 m and 2.0 m

Table 9:Simulation model input values [34]

Geometry		
Room – width × height × depth		3 × 3 × 6 m
Window width and height		2.8 × 1.5 m
Width of window frame construction		0.1 m
Constructions		
Heat transfer coefficient of opaque façade construction (*U*-value)		0.15 W/m^2 K
Heat transfer coefficient of glazing (*U*-value)		0.7 W/m^2 K
Light transmittance of glazing (LT)		0.53
Total solar energy transmittance of glazing		0.40
Heat transfer coefficient of frame construction (*U*-value)		1.5 W/m^2 K
Linear heat transmittance of window frame (Psi-value)		0.1 W/m K

Systems and internal loads	Occupancy (8 am to 5 pm)	Non-occupancy
Set-point temperatures – heating/cooling		
Summer	20/24 °C	–
Winter	23/26 °C	–
Infiltration	0.1 h^{-1}	0.1 h^{-1}
Mechanical ventilation[a]	1.48 l/sm^2	0.0 l/sm^2
Heat exchanger efficiency of mechanical ventilation[b]	0.8	–
Specific fan power, SFP	1.5 kJ/m^3	–
Venting rate (maximum)[c]	1.8 l/sm^2	0.6 l/sm^2
Mechanical cooling, efficiency (COP)	2.5	–
Internal loads from persons and equipment	10 W/m^2	1 W/m^2
General lighting		
Illuminance set point	200 lux	–
max. power	6 W/m^2	0 W/m^2
min. power (stand-by)	0.5 W/m^2	0 W/m^2
Task lighting		
Illuminance set point	500 lux	–
max. power	1.2 W/m^2	0 W/m^2
min. power	0 W/m^2	0 W/m^2

[a] Equivalent to indoor air quality Class II in the European standard EN 15251:2007 (CEN, 2007).

[b] Bypass of heat exchanger possible.

[c] Defined as ventilation through open windows. Only active outside the heating season and corresponds to maximum values for single-sided natural ventilation in Danish energy calculations (EBST, 2006).

The height of the work plane is 0.8m from the floor and the window height and transparency were defined accordingly. The width of the window is 2.8m which is a constant. So, increasing of glazing height reduces the height of the opaque part of the fenestration and total heat transfer coefficient and thus the solar heat gain is increased accordingly. All the properties of the fenestration, which was used for the simulation are given in *Table 9* [35].

2.7.4 Evaluation criteria

The simulation results were used to test each design variable in terms of energy efficiency and indoor environment. The following criteria were considered during the assessment process.

- Energy demand for artificial lighting
- Energy demand for cooling.
- Energy demand for heating.
- The total energy demand of the model.
- Daylight is represented by the daylight factor and usable area for workstations

To get the total energy demand of the building, the hot water consumption was taken as 100 $l/m^{2,}$ which is the corresponding Danish standard for domestic purposes according to EPBD 2002.

According to the European standard EN 15251:2007 both indoor air quality and thermal conditions are evaluated [37]. The set point values for cooling, heating and mechanical ventilation were according to indoor environment Class II requirements. Since this fulfilled the requirements need for indoor environment quality, the simulation gives a very clear picture of the ability of shading systems of controlling the electrical lighting, cooling and heating to maintain a quality indoor environment [35].

The availability of daylight was assessed using the daylight factor on the working plane and simulated using the CIE standard overcast sky, which provides 10,000 lux on an unobstructed horizontal surface outside. The daylight factor is the ratio of daylight on an internal surface to daylight on an unobstructed external surface. So, this doesn't differ with orientation, day or hour. The threshold is linked to the general lighting level and thus corresponds to the general lighting illuminance set point as described in *Table 9* [35].

2.7.5 Results

Figure 29 shows an energy demand comparison among the corresponding three shading types accordingly [35]. The total annual energy demand per unit area is graphed.

The simulation is run for all scenarios over a year, and the results corresponding to energy usage are graphed per square meter. According to *Figure 28*, all situations annual energy demand lesser than 70kW/m^2. In around 20% of situations, the annual energy consumption is below 50kW/m^2. South façade with dynamic shadings and 1.5m window height, is the best performing façade while fixed shading of window height 1.0m at the north is the worst [35].

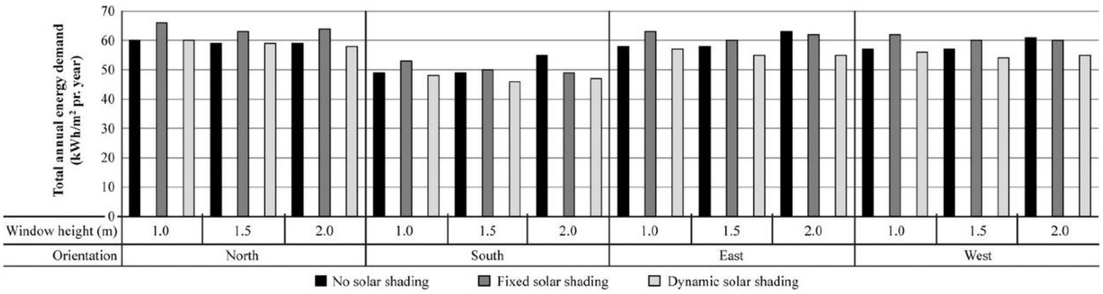


Figure 29:Annual energy demand for simulated models s [35]

According to the figure, dynamic shadings give the best performances. The worst is the fixed shading system. Generally, all three shading types have the same level. This is because energy consumption for hot water and ventilation is constant in all situations [35].

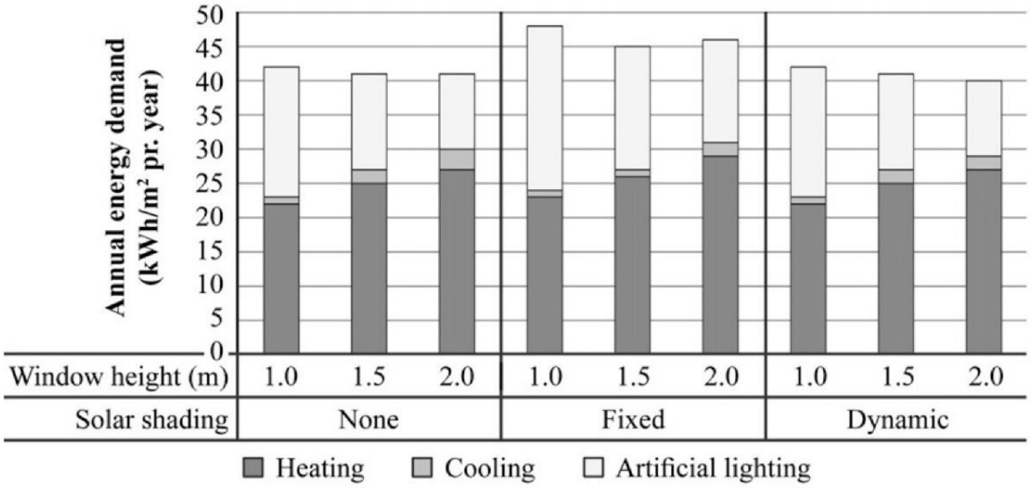


Figure 30: Distribution of annual energy demand : façades facing north [35]

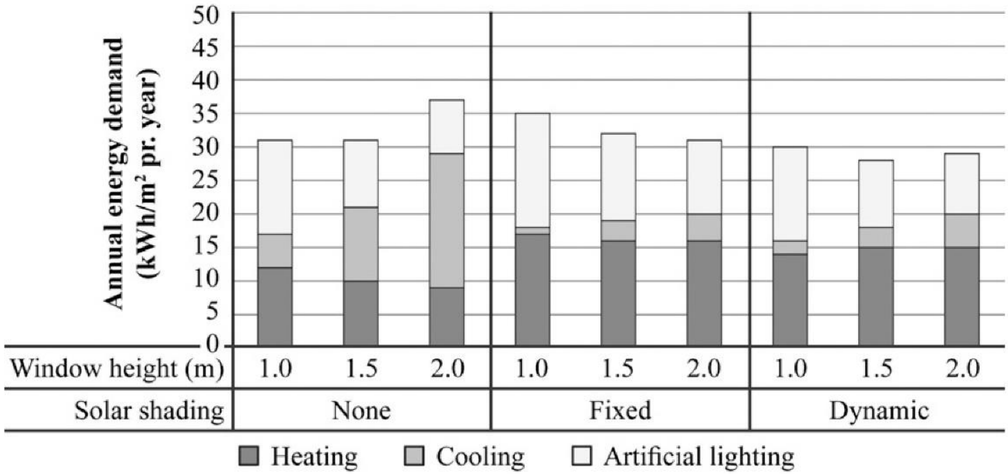


Figure 31: Distribution of annual energy demand :façades facing south [35]

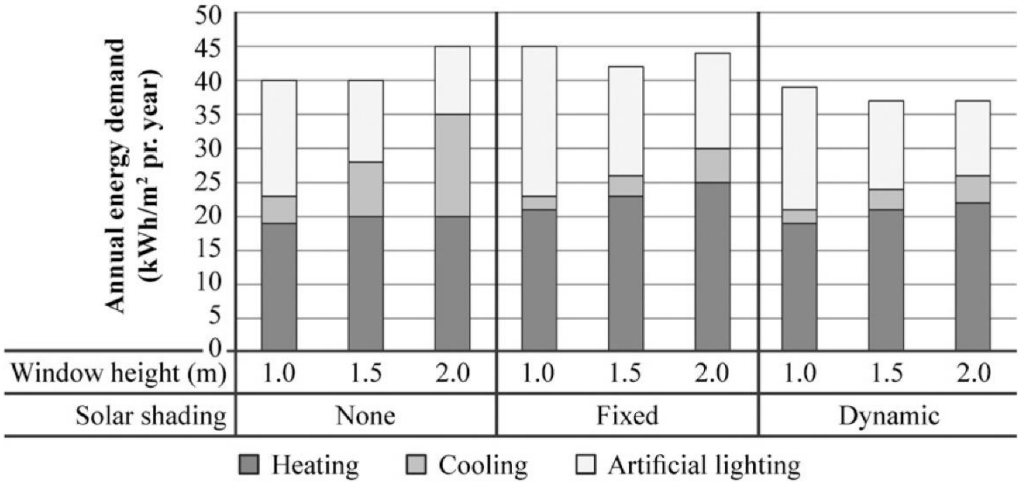


Figure 32: Distribution of annual energy demand : façades facing east [35]

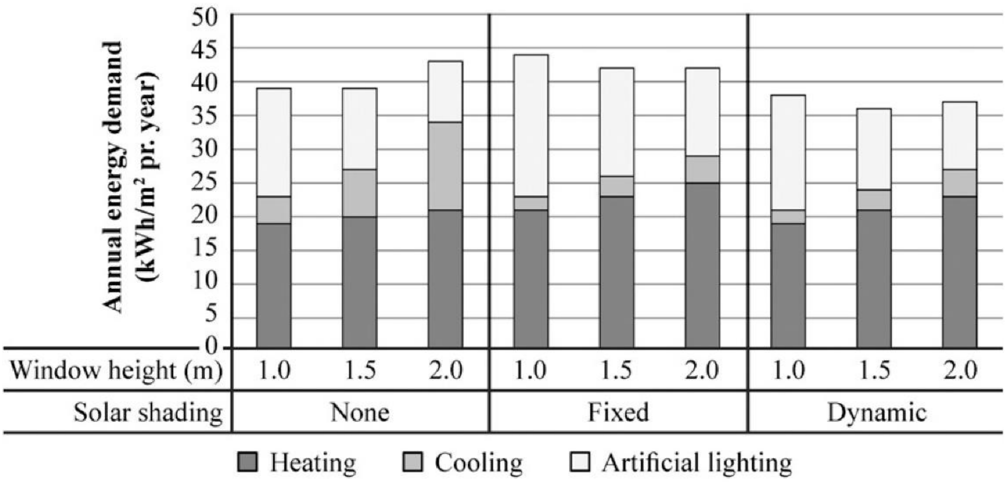


Figure 33: Distribution of annual energy : façades facing west [35]

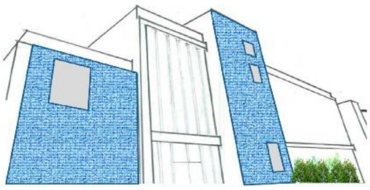
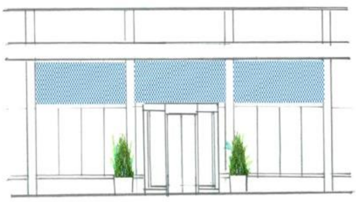
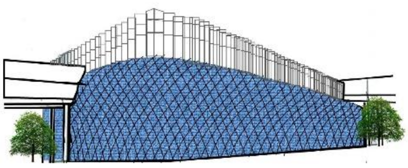
Annual energy consumption per unit area for electrical lighting, cooling and heating are shown in *Figures 30-33*. With the increase of window height, the heating demand of the west, east and north facades have been increased. Annual energy consumption in all models for electrical lighting has decreased with the increase of façade transparency and insolation. The cooling demand normally increases with the window height [35].

2.8 Building integrated photovoltaic (BIPV)

Integrating PV panels with dynamic shading systems can be used to improve the energy performance of the building with control of solar heat gain and daylighting level while generating electricity at the same time. This section discussed the use of Building Integrated Photovoltaics to generate electricity while acting as dynamic shading devices. The amount of electricity generated by PV panels is calculated while taking the partial shading among panels considering. The amount of solar radiation that passes through the fenestration was factored into the space thermal model. In this simulation, the progress was evaluated each hour, to get all possible dynamic configurations. Then the configuration gives the best building performance is selected. The simulation framework is utilized to find out the orientation with the best performances and which generates the highest amount of electricity, without compromising the building's cooling, heating and electrical lighting consumption. In this evaluation, an existing Adaptive Solar Façade (ASF) is considered for the simulation process. According to the study, compared to the equivalent static PV systems, automated systems provide 20% to 80% energy conservation. The percentage depends on the air conditioning and heating system efficiency. There are some cases BIPV systems generate the total energy requirement of the building. Building Integrated Photovoltaics, integrated with solar tracking mechanisms, are becoming an effective solution to control the performance of a building while generating electricity which helps to reduce the net energy demand [38].

The conventional building façades are consisting of walls, glasses, cladding and fenestrations, and other shading elements such as overhangs, balconies, etc. With all these building elements there is a potential of integrating Photovoltaics into the building facades. The main Building Integrated Photovoltaic applications are taken from the literature include shading, glazing and innovative designs. *Table 10* shows commonly used Building-integrated Photovoltaic types, their applications, disadvantages and advantages [39].

Table 10: BIPV façade types, applications, advantages and disadvantages [39]

BIPV Façade Type	Design Impact
1. Curtain Wall/Cladding Systems Solar panels integrated as a conventional cladding system for curtain walls and single layer façades  a.	• Advantages - Intelligent way of balancing daylighting and shading - Iconic importance in the field of architecture - Different colors and visual effects can be included - Regulates the internal temperatures of the building by minimizing solar gain in the summer - Light effects from these panels lead to an ever-changing pattern of shades in the building itself - Impacts on overall architectural image - Maximizes façade wall for energy generation • Disadvantages - Installation costs can be high - Potentially less energy than on roof-top - Requires complex planning and compliance with a great many physical properties - Properly handling needed to prevent view obstruction by electrical cables
2. Solar Glazing and Windows Applied as semi-transparent/translucent parts of the façade based on solar cell transparency. They can be integrated into windows, glazing panels, for view or daylighting  b.	• Advantages - Allowing for filtered view as well as energy generation - Potential application as opaque or semi-transparent/translucent glazing - Special PV elements used thermal insulators in combination with standard double or triple glazing elements - Added functionality as sun shading - The patterns from the shading generate a dynamic experience of spatial variety through the day. • Disadvantages - Potentially lower efficiencies - Increase in cell spacing yields less energy due to fewer cells
3. External Devices/Accessories Sunshades and sunscreens, spandrels, balconies parapets, elements of visual and acoustic shielding  c.	• Advantages - Potential for minimizing both building heat loads and energy consumption - Vertical or horizontal sun shading provided above windows - Use of building shading structure as mounting to prevent additional load on façade - Potential as fixed or adjustable devices - Allows for PV modules of different shapes • Disadvantages - Shadows cast from BIPV panels may need filtering to even out light distribution - Obstruction of view if not transparent or translucent
4. Advanced/Innovative Envelope Systems Such as double skin façades, active skins, rotating or moving façade parts, etc.  d.	• Advantages - Integration with advanced aesthetic polymer technologies - Generation of heat in winter for space heating - Double skin façades assist in cooling of BIPV panels - Possible integration with other building elements for performance and aesthetics • Disadvantages - Potentially more expensive than other types - Energy maybe required for extraction of heat in summer via mechanical means or forced ventilation

2.8.1 Case study

Figure 34 shows an Automated Façade System, built at House of Natural resources, ETH Zurich, which is used as the framework of this case study. 400mm CIGS square solar panels are used in this case with two degrees of freedom and actuated by soft pneumatics. All the panels can rotate independently according to the requirement, continuously within the limited range. But for simplicity, in this case study all the panels are considered as a single unit and actuated in discrete steps of angles. The panel are actuated in 15° steps between 0° fully closed position and 90° fully opened position, on the horizontal axis. The PV panels van rotate around the vertical axis again in 15° steps within +/- 45° range and this arrangement provides the possibility of having 49 different panel configurations [38].

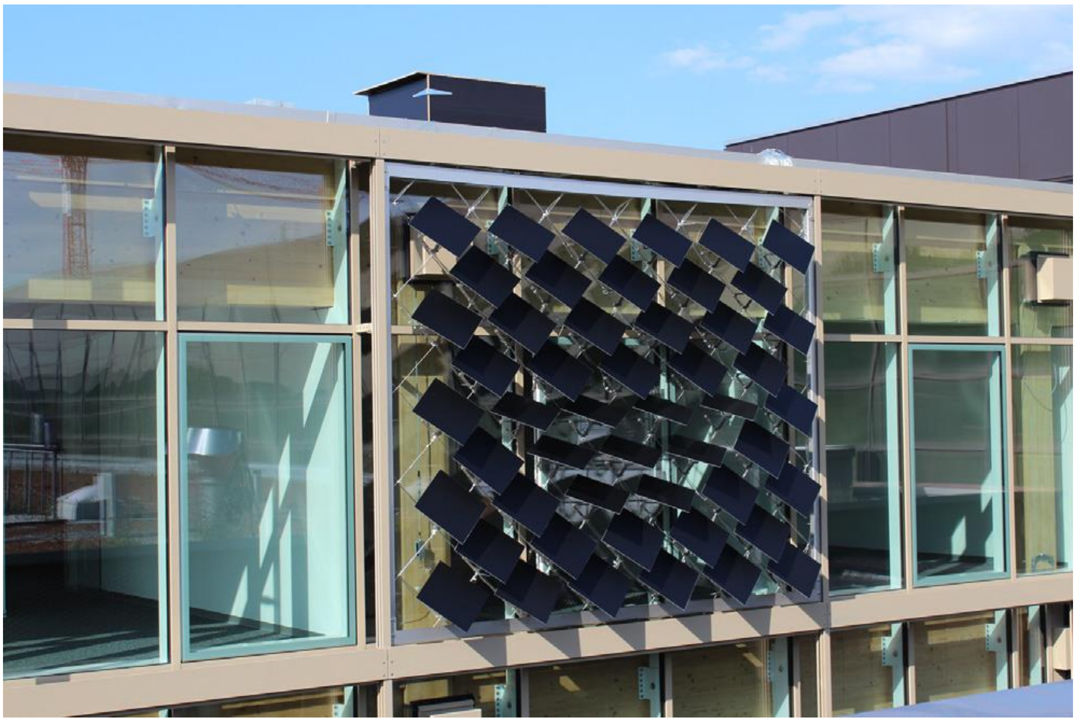


Figure 34: Adaptive Solar Façade [38]

The building used for the study is a two-person office building with height, width and depth of 3.1m, 4.9m and 7m respectively. Energy Plus weather profile of Zurich is used for this simulation. Since the weather data is in hourly time steps, the simulation was also done in hourly time steps. *Table 11* shows all the parameters considered in this simulation process [38].

Table 11: Summary of simulation parameters [38]

Office zone settings	
Office envelope	Internal walls: adiabatic Window: double glazed $U = 1.1$ W/m^2 K External wall: $U = 0.2$ W/m^2 K
Daylighting variables	Glass solar transmittance: 0.68 Maintenance factor: 0.9 Utilisation factor: 0.7
Thermal conductances	$H_{ve} = 39$ W/K $H_w = 14.9$ W/K $H_{em} = 0.34$ W/K $H_{is} = 491$ W/K $H_{ms} = 780$ W/K
Thermal set points	Heating: 22 °C Cooling: 26 °C Set-Back: 4 °C
Building system	Lighting load: 11.8 W/m^2 Lighting control threshold: 300 lx COP heating: 3 COP cooling: 3
Occupancy	Office schedule Ventilation: 1.5 air changes per hour Infiltration: 0.5 air changes per hour Human heat emission: 120 W per person
Location assumptions	
Weather file	Zurich-Kloten, Switzerland 2013
Window orientation	South

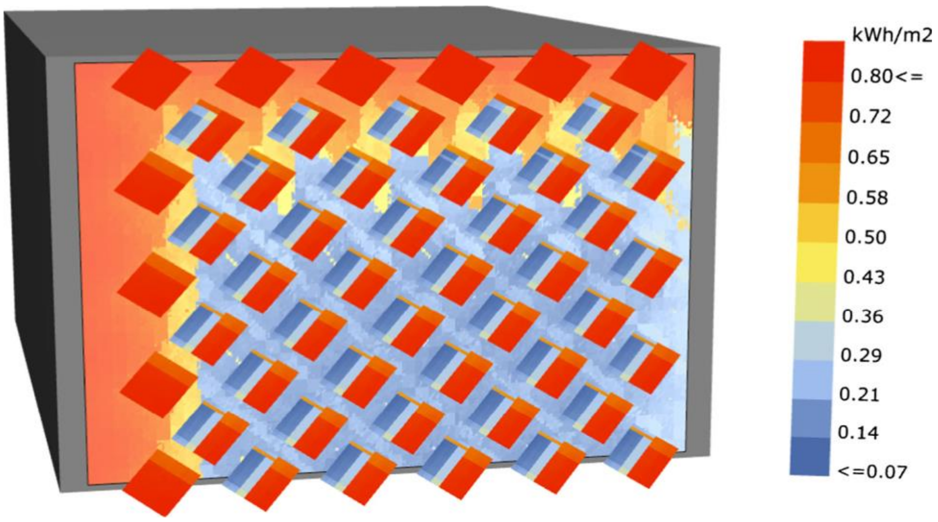
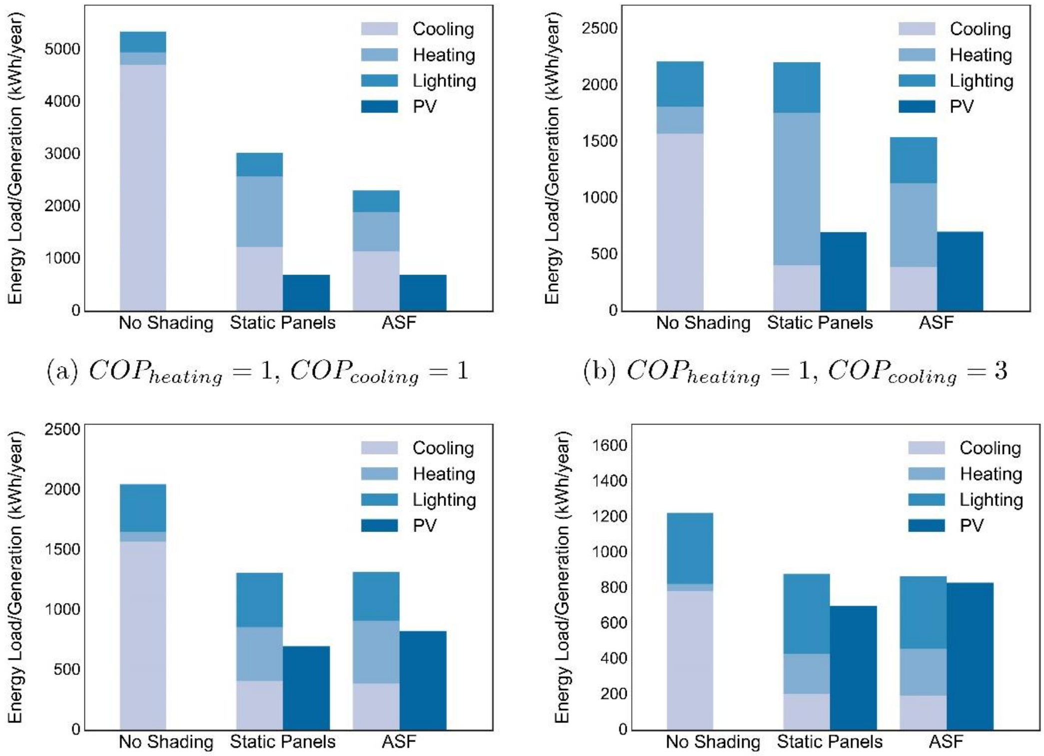


Figure 35: A simulation result showing module and window insolation [38] from 11:00 to 12:00 on the 16 June for a Zurich weather file and a specific module orientation [38]

Figure 36 shows a comparison of the energy demand between three shading types which are no shading, static PV panels and adaptive solar facades. Also, the comparison was done for the different efficiencies of the heating and cooling system. Using the same simulation framework, the optimum static shading device orientation was determined, and a panel inclination of 45° in the altitude direction is close to the energy optimal condition [38].



(a) $COP_{heating} = 1$, $COP_{cooling} = 1$ (b) $COP_{heating} = 1$, $COP_{cooling} = 3$

(c) $COP_{heating} = 3$, $COP_{cooling} = 3$ (d) $COP_{heating} = 6$, $COP_{cooling} = 6$

Figure 36: Breakdown of the operational electricity consumption [38] with no shading, with static panels at 45°, and an ASF for different coefficients of performance of the heating and cooling system. (a) represents an inefficient heating and cooling system, (b) represents a standard cooling system with resistive heating, (c) represents a standard heat pump system for heating and cooling, and (d) represents a high efficiency heating and cooling system

Figure 36(a) is an example of inefficient heating and cooling system. With static PV panels, the cooling demand has decreased significantly as heating demand increased. Adaptable facades have the same amount of cooling demand reduction while having a reduction in heating demand increase. *Figure 36(b)* is an example of a system with a standard cooling system and an inefficient heating system. The difference between no shading and static PV is negligible since while cooling demand decreases, heating demand has increased significantly. The adaptive facade was capable of controlling heating demand and has 44% net saving compared to the static system. According to *Figure 36(c)*, which represents a standard heating and cooling system, the ASF has a 19% increase in electricity generation but no significant variation of total demand compared to a static system. This is due to the angles which generate maximum electricity being capable of controlling solar heat gain significantly, which helps to reduce the net energy demand. A similar result can be observed in *Figure 36(d)*, which has high-efficient heating and cooling system. According to the figure, almost total energy demand can be compromised with the amount of energy generated with the Adaptable Solar façade system [38].

Table 12: Net electricity savings of ASF in kW h/year [38]

$COP_{heating}$	$COP_{cooling}$	ASF vs no shading (kW h/year)	ASF vs static (kW h/year)
1	1	3750 (70%)	724 (31%)
1	3	1370 (62%)	670 (44%)
3	3	1560 (76%)	120 (20%)
6	6	1190 (97%)	145 (80%)

This research gives a clear model to identify the performance of Adaptive Solar facades or Building Integrated Photovoltaics. This is accomplished by using Radiance for radiation simulations, an electrical circuit simulation for PV output that accounts for self-shading effects, and a resistor-capacitor model for building simulations. So, this simulation identifies the best possible orientations for adaptive solar facades, to minimize the building's lighting, cooling and heating demand, while generating the maximum amount of electricity with solar photovoltaic panels. This model can be applied with different geometrical systems, buildings and climate conditions [38].

Ultimately this simulation shows the potential of Adaptable Solar facades on energy conservation over no shading and static photovoltaic shading systems. It is important to orient the panel correctly for Balancing electrical generation and heating, cooling and lighting energy consumption. The orientation gives optimum results concerning electrical generation and cooling, 15° and 45° from the vertical plane. The orientation which gives the optimum solution for lighting and heating is 90° from the vertical plane. With considering all objectives required to optimize net energy demand, the solar façades tend to adjust their orientation to get the maximum electricity generation, other than the winter evenings which favour the allowing of solar radiation into the building [38].

According to the result, an automated solar façade can save 20-80% of energy over a static photovoltaic system and depends on the heating and cooling system's efficiency. On a summer sunny day, the electricity production of ASF is 270% of the total energy demand and on winter sunny day electricity production is 62% of the total demand. All over the year total, electricity generation can fulfil 61% of total energy demand.

On a typical sunny winter day, the ASF's PV generation will cover 62% of the energy demand, while this increases to 270% on a sunny summer day. The PV supply covers 61% of the annual energy demand over the year, including cloudy days. Even up to 95% of the demand can be compensated with efficient cooling and heating systems of COP value 6 [38] [40].

2.9 Architectural aspects

Shading devices of daylight harvesting systems can be used as an architectural element that enhances the aesthetics of a building. When creating architectural aesthetics, designers must concern about connecting space consistency and internal lighting conditions. Shading devices can play a huge role concerning the above requirement. Although implementing shading devices required a high initial investment, up to 80% lighting demand reduction can be achieved with the correct techniques.

2.9.1 Architectural space dynamics

The shape of space is revealed by daylight, which also gives the space its dynamic characteristics. Furthermore, daylight variations and their varied visual aspects produce a variety of illuminance atmospheres in architectural spaces, and dynamic daylight prevents architectural spaces from being bland and still and gives them a unique character. Light effects or reflected daylight seen by the eye (luminance) should be used to design the illuminated appearance of architectural space, not illuminance, which is not seen by the eye [40].

Revising daylight quality literature and according to the purposes of this study, the architectural space dynamics is defined as “The active motive effects due to variations of architectural space shape including dimensions, colours, and appearance, which is caused by continuous differences of visual daylight aspects during daytime or from day to day through months and seasons over the year” [40].

visual aspects of architectural space dynamic can be discussed as,

- The influence of dimensions of architectural spaces depends on the nature of the internal architectural surfaces. The spaciousness and the depth of architectural space can be enhanced by the dynamic lighting and shading patterns, the brightness level of the space. The difference in the lux level of the rear and front of any architectural space could improve the sense of the depth of the occupants [40].

- The variations of the daylight condition due to changes in the orientation of the sun and shadings in the building could also create colour variations, rhythmic shadow patterns and attractive dynamic reflections [40].
- Rhythmic dynamic shadow patterns can refresh the architectural aspect inside a building with continuous changes of daylight and also helps to define surfaces, shapes of architectural spaces, depth and space perspectives [40].

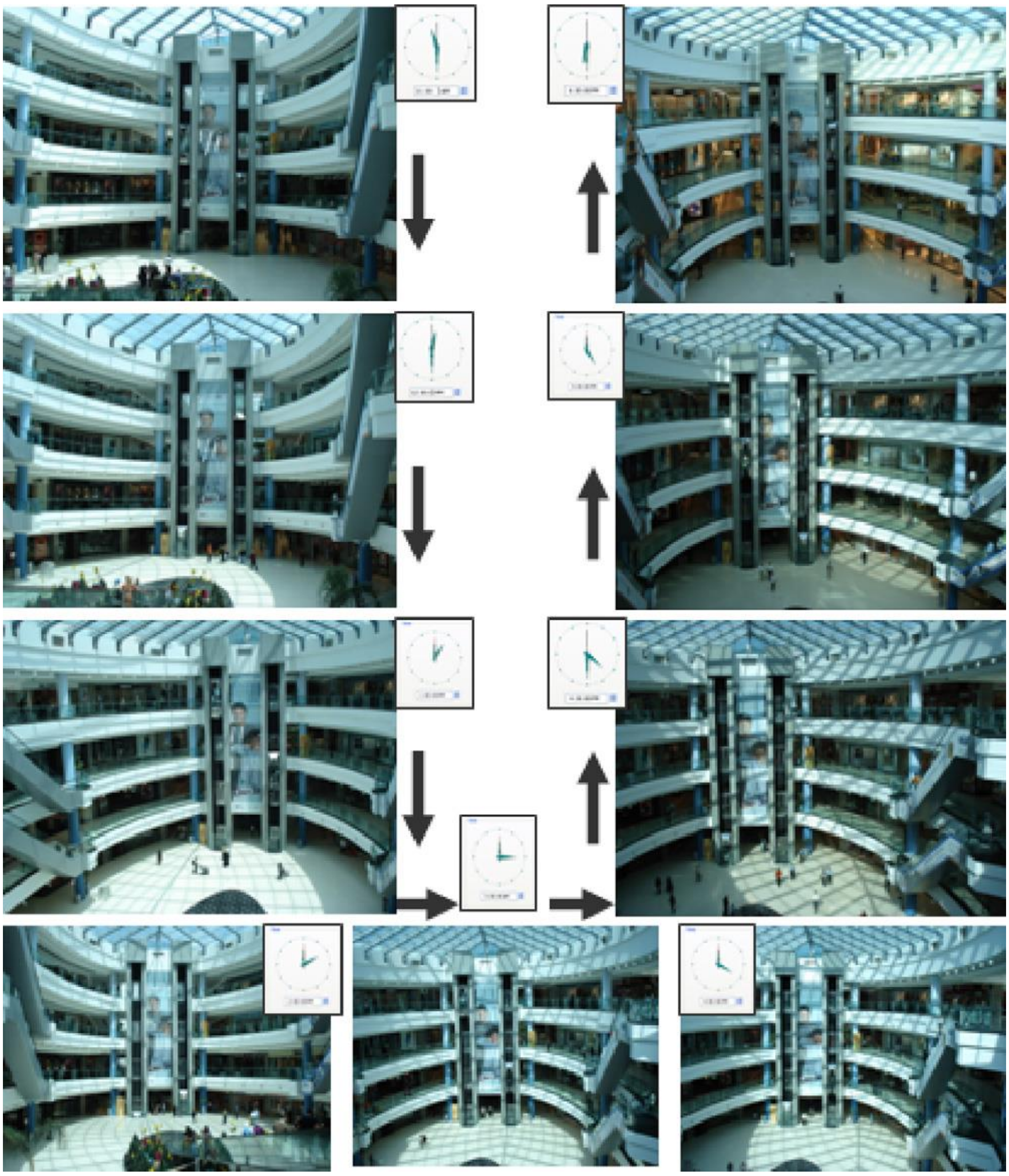


Figure 37: Dynamic shadows rhythm during daytime in the main atrium of City Mall

2.9.1.a Questionnaire

A set of questions based on photos based on architectural aspects were presented to fourth-year architecture students at Jordan University, who have already followed the concepts of architecture and design practices. The intention of the questionnaire was to find out the impact of the quality of daylight on its occupants. Three questions were presented to the students in this case study. They are,

1. Rating daylight as an effective architectural design element
2. Impact of daylight quality on increasing aesthetic aspects of architectural space
3. Impact of daylight quality on increasing psychological aspect of architectural spaces.

Figure 37 shows the results of the questionnaire [40].

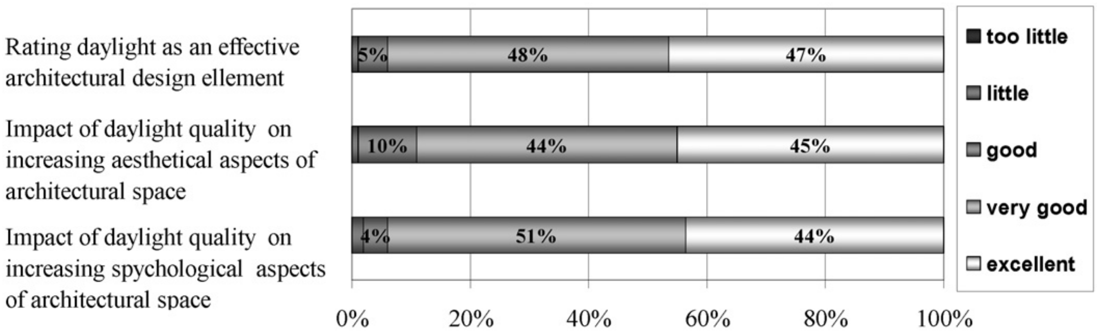


Figure 38: Rating daylight as a design element for the architectural space.

According to the result of the questionnaire more the 95% of the students have given positive answers for all the questions, confirming the potential of increasing the aesthetics of architectural space with dynamic daylighting.

2.9.2 Kinetic architecture

Kinetic architecture design technique provides the ability to rotate or move balding elements without compromising the integrity of the building structure. The intentions of constructing a building that has the ability to move are, enhancement of the aesthetics of the building, adapting to the external conditions such as solar radiation, and performing special building functions as required. The potential of implementing kinetic architecture in practice was encouraged in the late twentieth century with the enchantment of advanced engineering techniques such as mechanical, electrical, mechatronics and robotics [41].

Figure 39-43 show examples of famous kinetic buildings in the world.

Figure 39: One Ocean Thematic Pavilion EXPO 2012, designed by soma [47]

Figure 40: Kiefer Technic Showroom [49]

Figure 41: Shutters on the Kolding Campus (image courtesy of Jens Lindhe) [42]

Figure 42: The Mashrabiya of the Abu Dhabi's Al Bahar Towers [48]

Figure 43: Shanghai Kinetic Building [50]

3 SIMULATION, DATA COLLECTION AND ANALYSIS

Daylighting is a highly variable source of light that depends on various parameters. It varies with the solar geometry and many building parameters. To understand the potential of daylight harvesting in terms of reducing electrical lighting costs, it is essential to study the effect of these parameters. This study discusses the variation of artificial lighting costs concerning a few critical parameters.

3.1 Assumptions and limitations

Since a vast number of parameters are associated with the process of daylight harvesting, only major parameters which affect artificial lighting cost were considered during the study. So, some assumptions and limitations must be made to continue the research process.

1. Each simulation date and time gives the average condition of the corresponding period
2. Thermal discomfort or effect on air-conditioning systems due to solar radiation was not considered
3. Visual discomfort due to glare was ignored
4. No building element was used to control the incoming light other than the window
5. Obstructions due to vegetation, buildings were not considered
6. The effect of internal building elements and objects were not considered

3.2 Parameter variations

The effect of variation of several parameters was considered to study the variation of artificial lighting requirements.

3.2.1 Variation of the sun

To understand the effect of the variation of the zenith angle throughout the day the working hours 08:00 AM to 05:00 PM period was divided into six segments and the period of the year was divided into six segments for variation of the altitude angle of the sun. Relevant simulation time and dates according to the period are shown in *Table 13*.

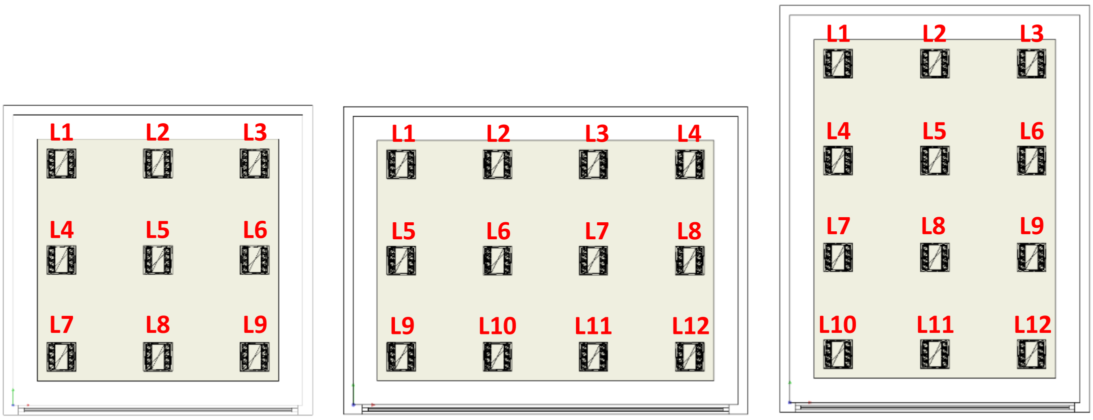
Table 13: Simulation time and date

Period of the Day	Simulation Time	Period of the Year	Simulation Date
08:00AM - 09:30AM	08:45AM	January - February	1st of February
09:30AM - 11:00AM	10:15AM	March - April	1st of April
11:00AM - 12:30PM	11:45AM	May - June	1st of June
12:30PM - 02:00PM	01:15PM	July - August	1st Of August
02:00PM - 03:30PM	02:45PM	September - October	1st of October
03:30PM - 05:00PM	04:15PM	November - December	1st of December

3.2.2 Variation of building parameters

Variation of three major building parameters was considered in this research, which is building size, building orientation and window to wall ratio (WWR).

1. Three building sizes are simulated with varying width and depth as shown in *Figure 44* and *Table 14*
2. Building orientations: North, East, South, West
3. Window to Wall Ratios: 20%, 40%, 60%, 80%



(a) Case 1 (b) Case 2 (c) Case 3

Figure 44: Building layout. (a) Case 1, (b) Case 2, (c) Case 3

Table 14: Building layout parameters

	Width	Depth	Height	No of Luminaires
Case 1	6m	6m	3m	9
Case 2	9m	6m	3m	12
Case 3	6m	9m	3m	12

3.3 Building parameters

It is necessary to define the relevant building parameters we are going to consider for the study. Since the availability of daylight is highly variable and there was no daylight control method was used to manage incoming light, it was quite difficult to maintain the average lux level inside the building in a certain range. Also, most of the time the area adjacent to the window was over illuminated. This over-illumination critically affects the uniformity level inside the building.

Due to the above concerns, instead of maintaining an average lux level on the working plane, a minimum lux level was considered. To minimize the effect of over-illumination at the window area, a 0.5m wall zone was defined for the working plane. It is considered to maintain a minimum lux level of 500lx at the working plane in most cases. But if the under illuminated area was very small compared to the total building area, the lux level at those areas are kept above 400lx. The minimum uniformity value was kept at 0.40, but even 0.39 was accepted where the average lux level was very high.

3.4 Daylight simulation

Nowadays, most of the complicated calculations and data gathering through physical modelling are replaced by computer simulation software. As far as we know, daylight calculations are very complex and time-consuming, since the final output affects many variable factors. In this research, one of the world's most famous free computer software was used for the daylight simulation process, which is DIALux evo 9.2 [43]. EN12464-1:2011 lighting standard is used in DIALux evo for indoor workplaces.

First, typical buildings of all three cases were modelled using DIALux evo 9.2 software [43]. Building parameters of the three cases were defined as per the *Table 15*.

Luminaire arrangements were generated with the software as shown in the *Figure 44*. The luminaire type used was Philips RC360B SRD W60L60 1 x LED34S/940, which is a LED louvre type model. The data sheet of the luminaire is displayed in *Appendix A*. Lighting Power Density (LPD) of all cases were kept at a constant value.

All together 48 daylighting simulations were considered for three building cases, four Window to wall ratios and four orientations. For each simulation, 36 light scenes were created to represent six-time segments of the day and six-time periods of the year. The total number of light scenes is 1728. During the simulation reference, sky type was considered as Average sky and ignored the Direct Sun Light.

First, the values at the working plane, Minimum lux level (E_m), Average lux level (E_{avg}) and Uniformity (U_1) were recorded for each light scene considering only daylight.

$$U_1 = E_m / E_{avg}$$

Then, artificial lights were turned ON manually in each light scene to get the desired light level inside the building and data recorded.

Table 15: Simulation parameters

Location	Colombo, Sri Lanka (79.9^{0}N, 6.9^{0}E)
Building type	General office
Lux level	500lx
Uniformity	> 0.4
Working plane height	0.8m
Wall zone	0.5m
Wall reflectance	60%
Ceiling reflectance	70%
Floor reflectance	20%
Working hours	08:00AM - 05:00PM
Window glazing type	Double solar control glass II
Glazing reflectance	15.4%
Glazing transmission	51.7%
Reference sky type	Average
Direct sun light	No

3.5 Sample simulation

Case 1, North orientation, 60% window to wall ratio option is considered for this sample simulation. Each luminaire was concerned as an individual light group to enable more flexibility on artificial lighting requirements. The simulation was carried out and results were recorded for all 36 light scenes for daylighting only and with artificial lighting scenarios.

3.5.1 Lighting layout and building parameters

Table 16: Sample simulation parameters

Case	Case 1
Window to wall ratio	60%
Window orientation	North
Building area	$36m^2$
Light scenes per day	6
No. of days per year	6
Total no. of light scenes	36
No. of light luminaires	9
No. of light groups	9

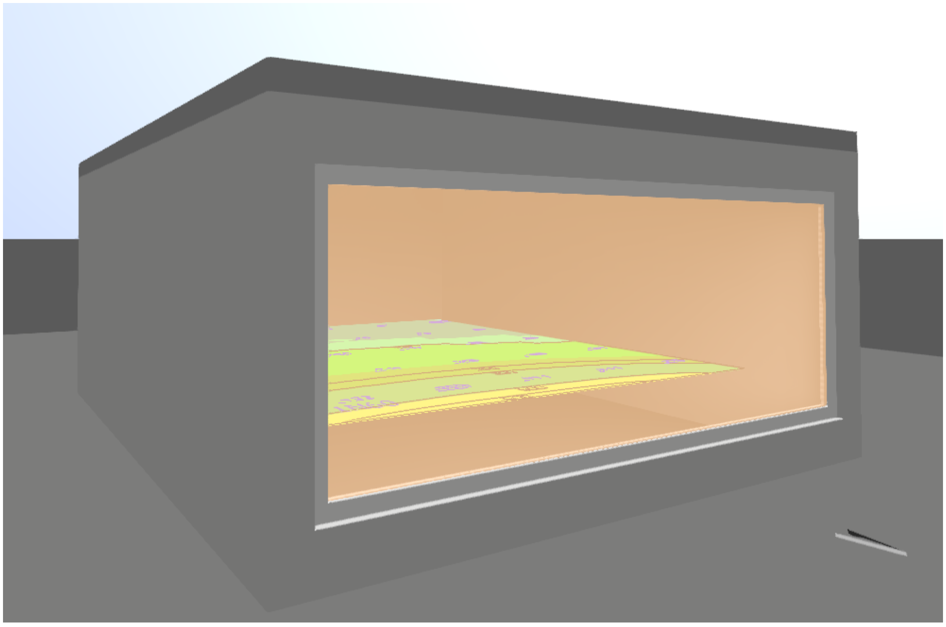


Figure 45: Building external view Case 1, 60% WWR, North orientation

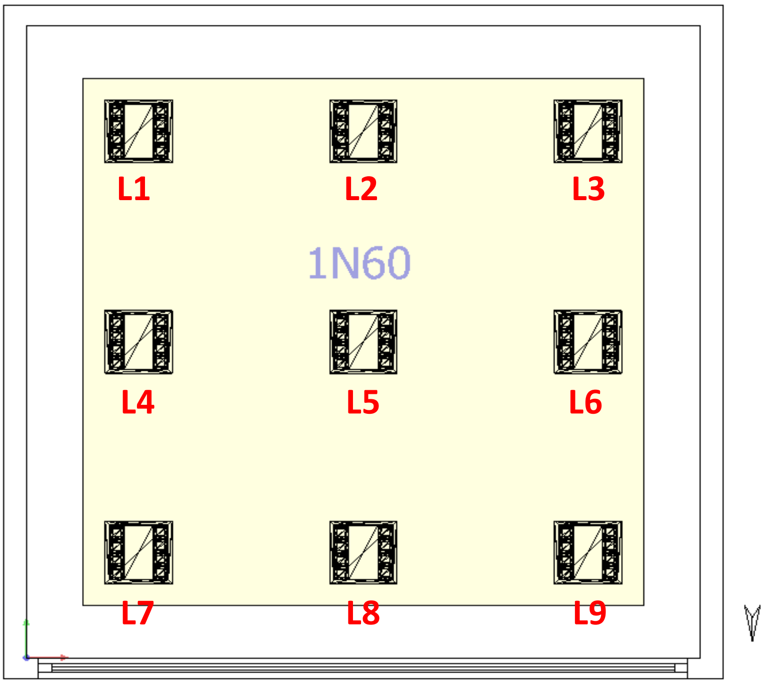
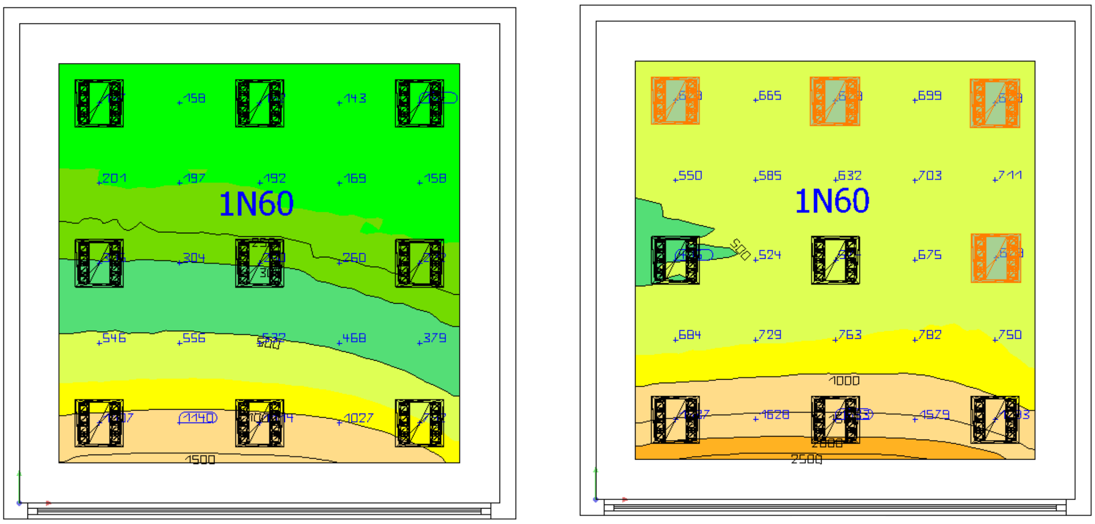


Figure 46: Building lighting layout, Case 1

3.5.2 Daylighting and artificial lighting

After running the simulation, lighting levels only with daylighting is observed and relevant data were recorded. Then the required amount of artificial lights were turned ON manually to get the desired light level and data recorded.



(a) (b)

Figure 47: Simulation results of the light scene 1st of April, 01:15PM. (a) Daylighting only, (b) With the aid of artificial lighting

Figure 47 shows the simulation results of the light scene on 1st of April, 01:15 PM, lux levels only with daylighting and after corrected with artificial lighting. In this scene, four artificial light groups L1, L2, L3 and L6 are manually turned ON to get the desired light level. *Table 17* shows lighting data only with daylighting and after correcting with artificial lighting.

Table 17: Lighting simulation data. 1st of April, 01:15 PM

	Daylighting only	With artificial lighting
No. of active luminaires	0	4
Minimum lux level (E_m)	151	460
Maximum lux level	2530	2564
Average lux level (E_{avg})	580	854
Uniformity (U_1)	0.26	0.54

3.5.3 Artificial lighting cost calculation

This process was repeated for all 36 light scenes and relevant data were recorded. All gathered data are shown in *Table 18*. All the simulation data tables are displayed in *Appendix B*. After collecting the relevant data, the average number of luminaries active on the corresponding dates were calculated. With the use of gathered data, artificial lighting cost per square meter was calculated.

$$Cost_{square\ meter} = \frac{L_{avg} \times D \times h \times P_{Luminaire} \times E_{unit}}{1000 \times A}$$

Where,

$Cost_{square\ meter}$	Artificial lighting cost per square meter
L_{avg}	Average numbers of luminaires active
D	Number of working days in the relevant period
h	Number of working hours per day
$P_{Luminaire}$	Luminaire power
E_{unit}	Electricity unit price
A	Total floor area

Table 18: Simulation data. Case 1, North, 60% WWR

Date	Time	Before			Luminaire Status (ON=1, OFF=0)									Luminaires		After		
		E_m	E_{avg}	U_1	L1	L2	L3	L4	L5	L6	L7	L8	L9	Total	Avg.	E_m	E_{avg}	U_1
01 February 2021	08:45 AM	157	572	0.27	1	1	1	1	0	0	0	0	0	4	4.50	504	845	0.60
	10:15 AM	148	529	0.28	1	1	1	1	0	0	0	0	0	4		456	802	0.57
	11:45 AM	111	386	0.29	1	1	1	1	0	1	0	0	0	5		525	737	0.70
	01:15 PM	137	493	0.28	1	1	1	1	0	1	0	0	0	5		556	843	0.66
	02:45 PM	162	600	0.27	1	1	1	0	0	1	0	0	0	4		512	873	0.59
	04:15 PM	89.8	310	0.29	1	1	1	1	0	1	0	0	0	5		491	661	0.74
01 April 2021	08:45 AM	237	863	0.27	1	1	1	0	0	0	0	0	0	3	4.00	499	1060	0.47
	10:15 AM	153	572	0.27	1	1	1	1	0	0	0	0	0	4		463	845	0.55
	11:45 AM	171	602	0.28	1	1	1	1	0	1	0	0	0	5		589	952	0.62
	01:15 PM	151	580	0.26	1	1	1	0	0	1	0	0	0	4		460	854	0.54
	02:45 PM	229	867	0.26	1	1	1	0	0	0	0	0	0	3		504	1063	0.47
	04:15 PM	122	437	0.28	1	1	1	1	0	1	0	0	0	5		541	788	0.69
01 June 2021	08:45 AM	311	1164	0.27	1	0	1	0	0	0	0	0	0	2	3.00	527	1283	0.41
	10:15 AM	237	916	0.26	1	1	1	0	0	0	0	0	0	3		524	1113	0.47
	11:45 AM	181	662	0.27	1	1	1	0	0	1	0	0	0	4		447	935	0.48
	01:15 PM	256	987	0.26	1	1	1	0	0	0	0	0	0	3		555	1184	0.47
	02:45 PM	304	1140	0.27	1	0	1	0	0	0	0	0	0	2		540	1259	0.43
	04:15 PM	144	511	0.28	1	1	1	0	0	1	0	0	0	4		470	784	0.60
01 August 2021	08:45 AM	293	1084	0.27	1	0	1	0	0	0	0	0	0	2	3.17	525	1203	0.44
	10:15 AM	225	843	0.27	1	1	1	0	0	0	0	0	0	3		501	1040	0.48
	11:45 AM	149	542	0.27	1	1	1	1	0	1	0	0	0	5		570	893	0.64
	01:15 PM	225	828	0.27	1	1	1	0	0	0	0	0	0	3		481	1025	0.47
	02:45 PM	294	1099	0.27	1	0	1	0	0	0	0	0	0	2		527	1208	0.43
	04:15 PM	154	558	0.28	1	1	1	0	0	1	0	0	0	4		508	832	0.61
01 October 2021	08:45 AM	209	761	0.27	1	1	1	0	0	0	0	0	0	3	4.17	457	958	0.48
	10:15 AM	127	465	0.27	1	1	1	1	0	1	0	0	0	5		552	816	0.68
	11:45 AM	89.3	314	0.28	1	1	1	1	0	1	0	0	0	5		457	664	0.69
	01:15 PM	162	594	0.27	1	1	1	0	0	1	0	0	0	4		478	867	0.55
	02:45 PM	204	745	0.27	1	1	1	0	0	0	0	0	0	3		545	941	0.48
	04:15 PM	83.9	293	0.29	1	1	1	1	0	1	0	0	0	5		471	644	0.73
01 December 2021	08:45 AM	147	555	0.26	1	1	1	1	0	1	0	0	0	5	5.00	571	906	0.63
	10:15 AM	134	484	0.28	1	1	1	1	0	1	0	0	0	5		556	835	0.67
	11:45 AM	121	418	0.29	1	1	1	1	0	1	0	0	0	5		540	768	0.70
	01:15 PM	146	532	0.27	1	1	1	0	0	1	0	0	0	4		464	806	0.58
	02:45 PM	137	509	0.27	1	1	1	0	0	1	0	0	0	4		465	783	0.59
	04:15 PM	50	173	0.29	1	1	1	1	1	1	0	0	1	7		491	682	0.72

Table 19: Calculation parameters

Luminaire Power ($P_{Luminaire}$)	27 W
Total number of luminaries	9
Electricity unit price (E_{unit})	$ 0.15
Total floor area (A)	36 m^2
No. of working hours per day (h)	9 h

Calculated artificial lighting costs are shown in *Table 20*. All the calculated artificial lighting cost tables are displayed in *Appendix C*.

Table 20: Artificial lighting cost calculations. Case 1, North, 60% WWR

Period	No. of Working Days	Artificial Lighting			
		Average No. of Luminaires	Energy Consumption (kWh)	Electricity Cost	Cost per Square Meter
January - February	39	4.50	42.65	$ 6.40	$ 0.18
March - April	40	4.00	38.88	$ 5.83	$ 0.16
May - June	39	3.00	28.43	$ 4.26	$ 0.12
July - August	42	3.17	32.32	$ 4.85	$ 0.13
September - October	40	4.17	40.50	$ 6.08	$ 0.17
November - December	43	5.00	52.25	$ 7.84	$ 0.22
Annual	243		235.02	$ 35.25	$ 0.98

3.5.4 Artificial lighting cost analysis

Calculates artificial lighting costs are plotted and analysed.

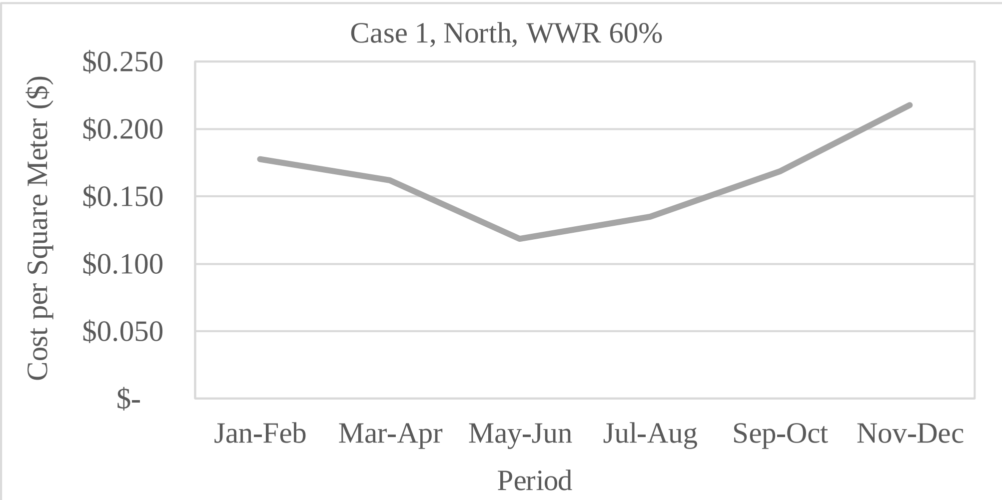


Figure 48: Artificial lighting cost variation over the year

3.6 Artificial lighting cost variations

3.6.1 Cost variation over the year

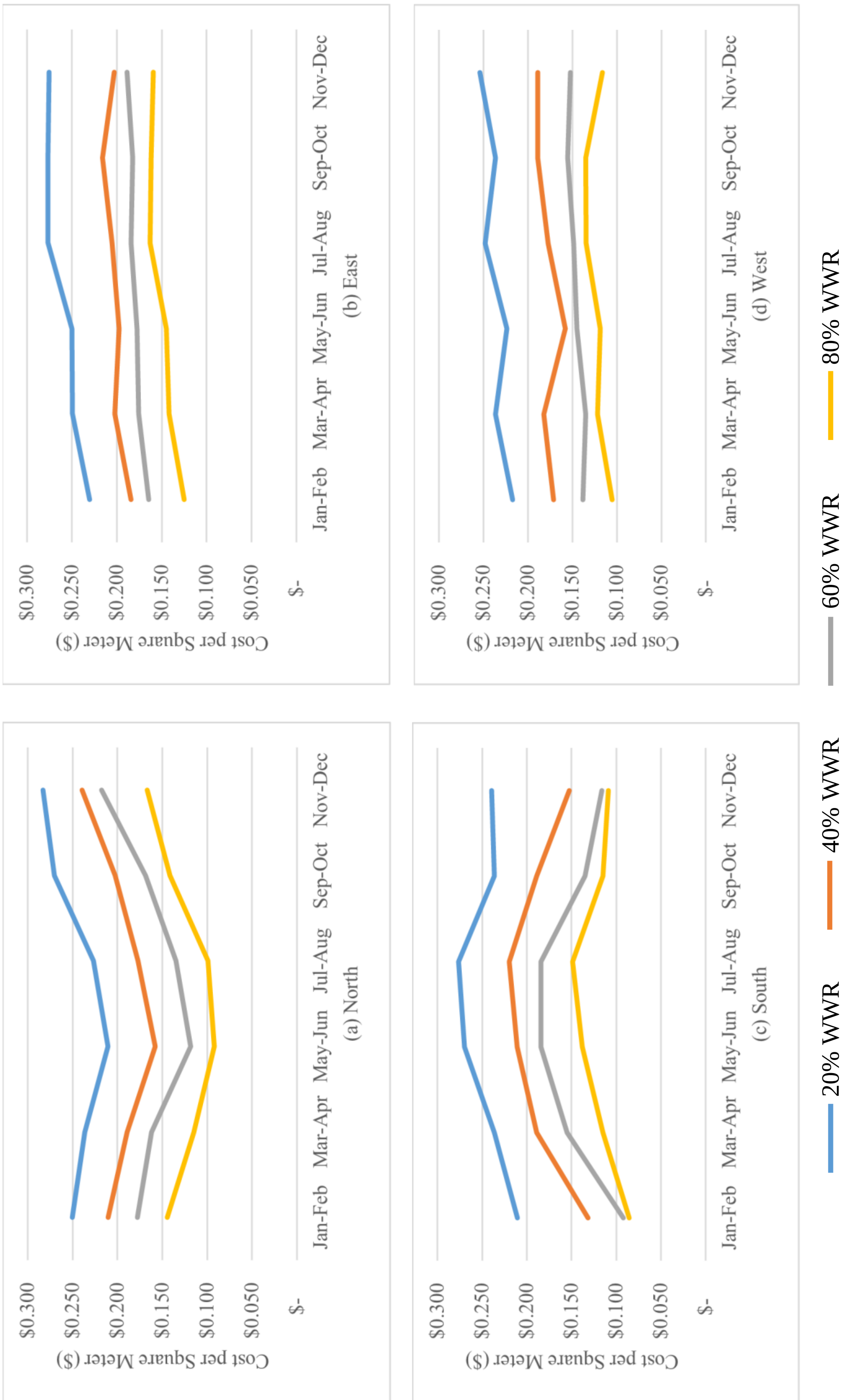


Figure 49: Artificial lighting cost variation, Case 1. (a) North, (b) East, (c) South, (d) West

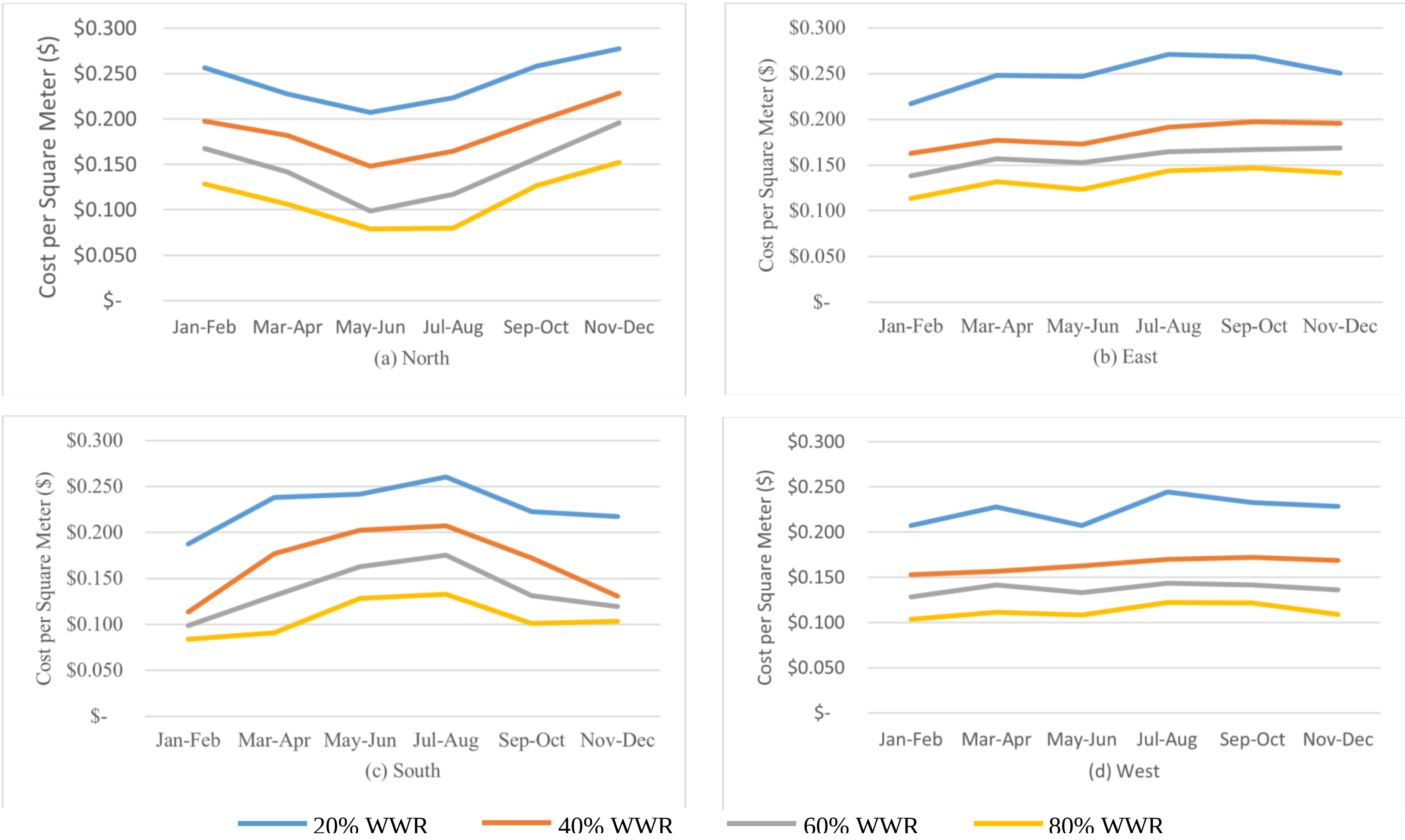


Figure 50: Artificial lighting cost variation, Case 2. (a) North, (b) East, (c) South, (d) West

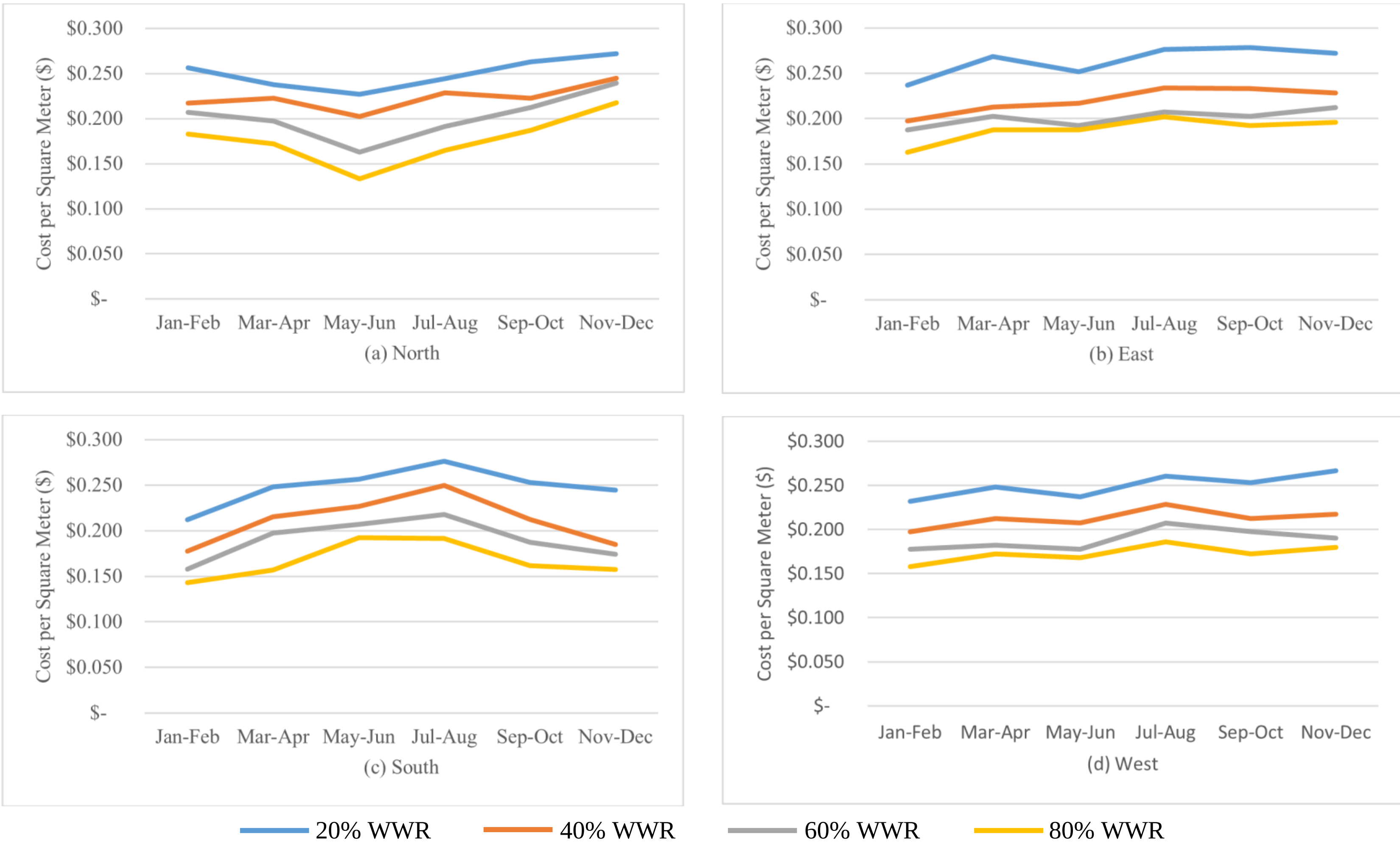


Figure 51:Artificial lighting cost variation, Case 3. (a) North, (b) East, (c) South, (d) West

3.6.2 Annual electricity cost

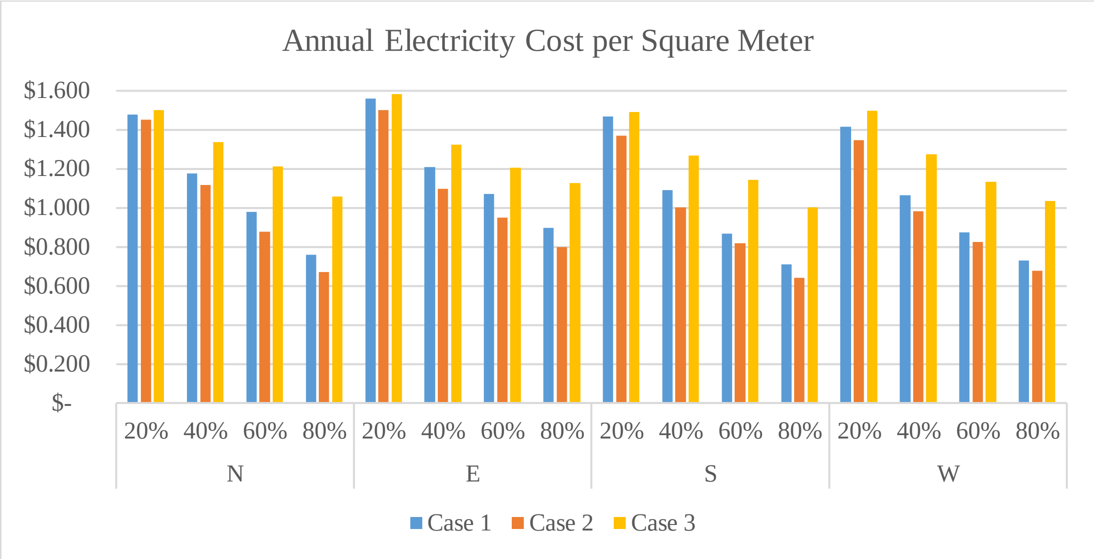


Figure 52: Annual electricity cost per square meter

Figure 52 shows the annual electricity cost per square meter for all 48 simulations.

3.6.3 Annual electricity cost percentage variation

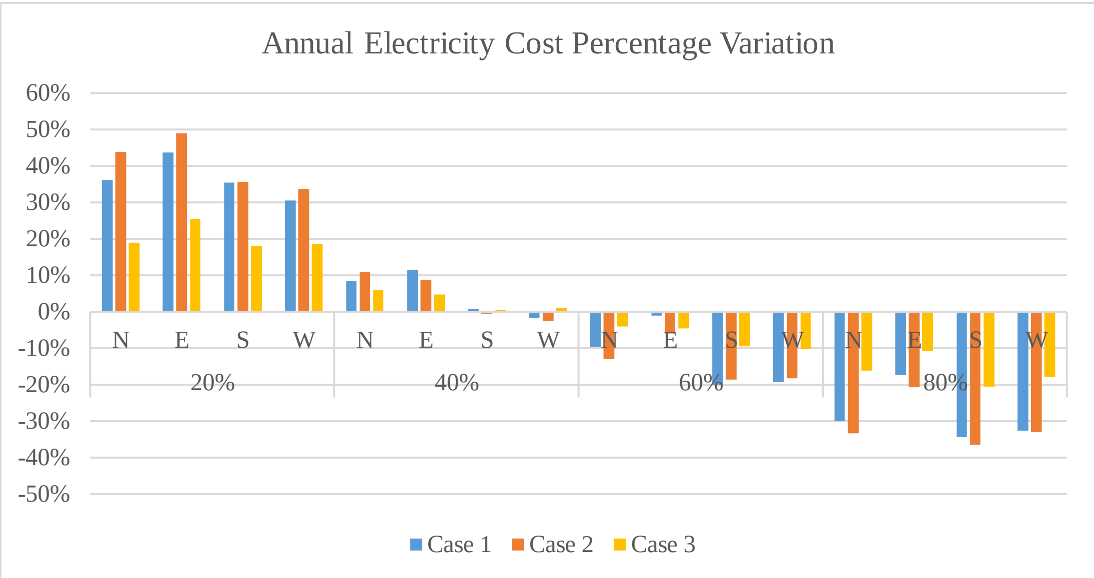


Figure 53: Annual electricity cost percentage variation

The mean annual electricity cost per square meter for Case 1, Case 2 and Case 3 are $1.085, $ 1.008 and $ 1.262 respectively. *Figure 53* shows the cost variation percentage over its corresponding mean value.

3.7 Case study – office building in Colombo, Sri Lanka

After conducting the daylighting simulation for 3 typical cases, an actual building located in Colombo, Sri Lanka was considered to do a case study on daylight harvesting cost-saving, to get a better understanding of daylight harvesting potential in Sri Lanka. In this study, heat-load increase due to daylight harvesting is also considered to get the air-conditioning cost increase of the building.

The building parameters which are not available were assumed.

3.7.1 Daylight simulation

Daylight simulation was carried out the same as the previous cases, considering six simulation times per day and six simulation days per year. In this situation, four lighting fixtures were considered as a single lighting group since there is a total of 48 luminaires. Due to this reason, the flexibility of controlling artificial lighting was quite lower compared to previous cases. So, instead of minimum 500Lux level, 300Lux level was considered.

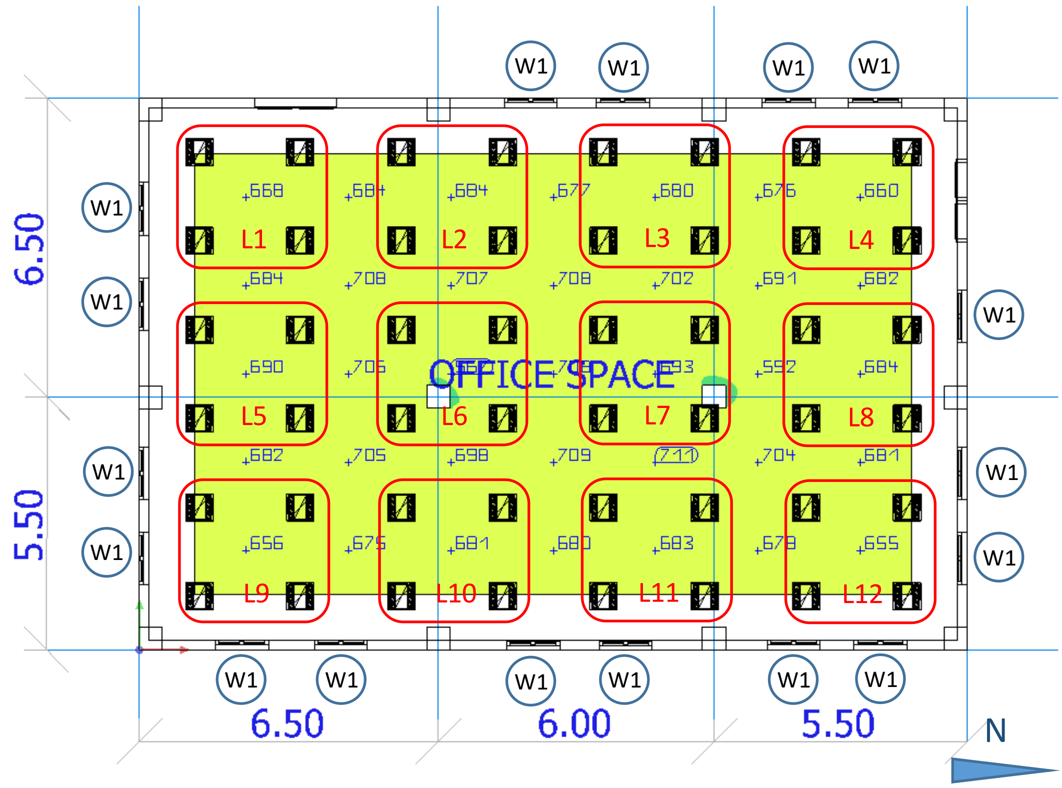


Figure 54: Building and lighting layout

Table 21: Building Parameters

Location	Colombo, Sri Lanka (79.9^{0}N, 6.9^{0}E)
Building type	General office
Building Size	12m x 18m (216m^2)
Lux level	300lx
Uniformity	> 0.4
Working plane height	0.8m
Wall zone	1m
Wall reflectance	50%
Ceiling reflectance	70%
Floor reflectance	20%
Working hours	08:00AM - 05:00PM
Window glazing type	Transparent glass
Glazing transmission	90%
Reference sky type	Average
Direct sunlight	No

6mm clear glass was used for the windows which have 90% transmissivity. Due to high transmittivity, the areas adjacent to the windows were over illuminated. This cases higher lux levels inside the working plane and disturbs the uniformity values inside the building. To overcome this issue, a 1m wall zone was defined.

No shading mechanism was concerned during the simulation process.

Table 22: Simulation data. Case study - office building in Colombo, Sri Lanka

Date	Time			Lighting Group Status (ON=1, OFF=0)												Luminaires			
		E_{avg}	U_1	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	Total	Avg.	E_{avg}	U_1
01 February 2021	08:45 AM	461	0.32	0	1	0	0	0	1	1	0	0	0	0	0	12		670	0.41
	10:15 AM	432	0.33	0	1	0	0	0	1	1	0	0	0	0	0	12		641	0.41
	11:45 AM	298	0.36	0	1	0	0	0	1	1	1	0	0	0	0	16	17.33	567	0.40
	01:15 PM	360	0.36	0	1	0	0	0	1	1	0	0	1	0	0	16		627	0.37
	02:45 PM	413	0.33	0	1	0	0	0	1	1	0	0	1	0	0	16		680	0.38
	04:15 PM	191	0.31	1	1	0	0	1	1	1	1	0	1	1	0	32		681	0.39
01 April 2021	08:45 AM	509	0.31	0	1	0	0	0	1	1	0	0	0	0	0	12		718	0.42
	10:15 AM	294	0.35	0	1	1	0	1	1	1	1	0	0	0	0	24		681	0.35
	11:45 AM	249	0.41	1	1	0	0	1	1	1	1	0	1	0	0	28	21.33	681	0.40
	01:15 PM	262	0.34	0	1	0	0	1	1	1	1	0	1	0	0	24		693	0.28
	02:45 PM	420	0.29	1	0	0	0	0	1	1	0	0	0	0	0	12		615	0.38
	04:15 PM	212	0.28	1	0	0	0	1	1	1	1	0	1	1	0	28		643	0.28
01 June 2021	08:45 AM	494	0.29	0	1	0	0	0	1	1	0	0	0	0	0	12		703	0.41
	10:15 AM	319	0.31	0	1	1	0	1	1	1	0	0	0	0	0	20		647	0.33
	11:45 AM	194	0.31	1	1	1	0	1	1	1	1	0	1	1	0	36	21.33	742	0.35
	01:15 PM	314	0.29	1	0	0	0	0	1	1	0	0	1	0	0	16		544	0.39
	02:45 PM	412	0.26	1	0	0	0	0	1	1	0	0	0	0	0	12		608	0.40
	04:15 PM	199	0.27	1	1	0	0	0	1	1	1	1	1	1	0	32		674	0.38
01 August 2021	08:45 AM	499	0.31	1	0	0	0	0	1	1	0	0	0	0	0	12		695	0.36
	10:15 AM	322	0.32	1	0	1	0	0	1	1	0	0	0	0	0	16		576	0.37
	11:45 AM	168	0.33	1	1	0	1	0	1	1	1	1	1	1	0	36	21.33	687	0.35
	01:15 PM	278	0.30	1	0	0	0	1	1	1	0	0	1	0	0	20		591	0.36
	02:45 PM	417	0.27	1	0	0	0	0	1	1	0	0	1	0	0	16		671	0.36
	04:15 PM	227	0.27	1	0	0	0	1	1	1	1	0	1	1	0	28		659	0.29
01 October 2021	08:45 AM	503	0.32	0	1	0	0	0	1	1	0	0	0	0	0	12		712	0.42
	10:15 AM	277	0.35	1	1	1	0	0	1	1	1	0	0	0	0	24		649	0.35
	11:45 AM	164	0.39	1	1	0	1	0	1	1	1	1	1	1	0	36	23.33	684	0.40
	01:15 PM	319	0.33	1	0	0	0	0	1	1	0	0	1	1	0	20		631	0.34
	02:45 PM	408	0.29	1	0	0	0	0	1	1	0	0	0	0	0	12		603	0.38
	04:15 PM	152	0.29	1	1	0	1	1	1	1	1	0	1	1	0	36		687	0.45
01 December 2021	08:45 AM	478	0.31	0	1	0	0	0	1	1	0	0	0	0	0	12		687	0.42
	10:15 AM	419	0.34	0	1	0	0	0	1	1	0	0	0	0	0	12		628	0.39
	11:45 AM	346	0.35	0	1	0	0	0	1	1	1	0	0	0	0	16	17.33	614	0.42
	01:15 PM	412	0.34	0	1	0	0	0	1	1	0	0	0	0	0	12		621	0.39
	02:45 PM	361	0.35	0	1	0	0	0	1	1	0	0	1	0	0	16		628	0.36
	04:15 PM	106	0.34	1	1	1	0	1	1	1	1	0	1	1	0	36		655	0.38

Table 23: Calculation parameters

Luminaire Power ($P_{Luminaire}$)	27 W
Total number of luminaries	48
Electricity unit price (E_{unit})	22 LKR
No. of working hours per day (h)	9 h

With the use of simulation data and calculation parameters, artificial lighting electricity cost saving was calculated.

Table 24: Artificial lighting cost calculations.

Period	No. of Working Days	Artificial Lighting					
		Average No. of Luminaires	Energy Consumption (kWh)	Electricity Cost (LKR)		Cost Saving (LKR)	
January - February	39	17.33	164.27	Rs.	3,614	Rs.	6,394
March - April	40	21.33	207.36	Rs.	4,562	Rs.	5,702
May - June	39	21.33	202.18	Rs.	4,448	Rs.	5,560
July - August	42	21.33	217.73	Rs.	4,790	Rs.	5,988
September - October	40	23.33	226.80	Rs.	4,990	Rs.	5,275
November - December	43	17.33	181.12	Rs.	3,985	Rs.	7,050
Annual	243		1199.45	Rs.	26,388	Rs.	35,968

3.7.2 Heat load simulation

Daylight harvesting increases the solar heat gain into the building. Increased heat load will cause increased air conditioning costs. So, it is important to understand the air conditioning costs increase to calculate total energy saving with daylight harvesting.

To determine the heat-load increase of the building, Carrier's Hourly Analysis Program (HAP) Version 4.9 [44] was used. Hourly Analysis Program is a powerful tool used for Air-conditioning designing purposes. The speciality of this program is, it can analyse the hourly maximum heat load values of a month.

Energy standard ASHRAE 90.1-2010 and ventilation standard ASHRAE 62.1-2010 Was selected for the heat load simulation.

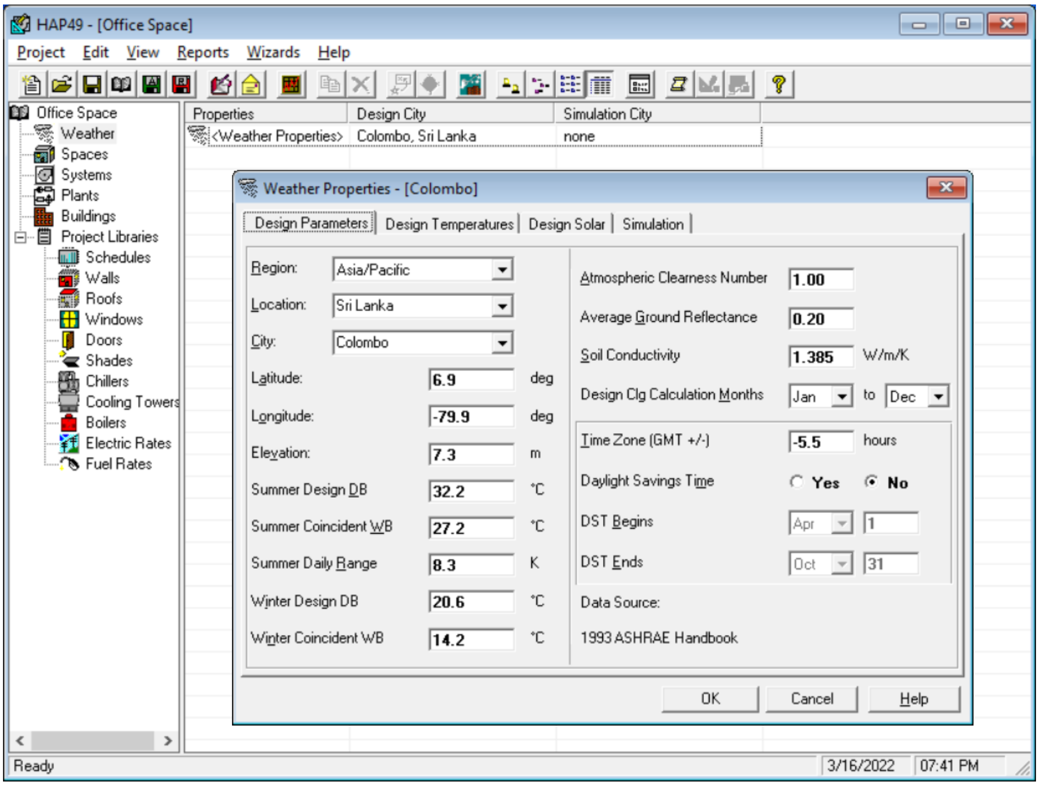


Figure 55: Carrier's Hourly Analysis Program (HAP) [44]

In this simulation, solar heat-gain through external building walls and windows and artificial lighting heat-loads varies while daylight harvesting was considered. It is assumed that all other heat loads were not varied with daylight harvesting. Any other parameter which is not available was assumed.

Table 25: Heat load simulation parameters

Wall Parameters	
Wall type	Face Brick + 100mm Brick
Outside surface colour	Medium
Total floor area (A)	206 m^2
Overall U-Value	2.36 $W/m^{2o}C$
Window Parameters	
Window type	6mm clear glass with Aluminium frame
Window Size	1.15m x 1.5m
U-Value	5.8 $W/m^{2o}C$
SHGC	0.81

Using the HAP software, hourly maximum heat load values were obtained for each month. Then the average of the maximum heat load values was calculated.

First, heat load simulation was conducted without considering daylight. No windows were considered, and all 48 artificial lights were turned ON.

Table 26: Hourly heat load values - Without Daylight Harvesting

Time	Heat Load (W)												Average
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
8:00	-564	41	959	1428	1839	2446	2689	2643	2052	1557	571	-223	1287
9:00	-144	452	1351	1839	2262	2857	3086	3035	2456	2015	1043	225	1706
10:00	446	1021	1870	2334	2770	3373	3603	3535	2947	2546	1611	818	2240
11:00	1046	1596	2382	2803	3257	3880	4117	4022	3416	3041	2152	1406	2760
12:00	1574	2096	2820	3193	3673	4324	4568	4439	3810	3450	2607	1916	3206
13:00	2009	2497	3174	3521	4034	4709	4953	4789	4151	3812	3009	2352	3584
14:00	2426	2878	3526	3867	4413	5103	5339	5149	4519	4211	3436	2790	3971
15:00	2890	3315	3940	4280	4849	5545	5775	5569	4945	4664	3910	3271	4413
16:00	3365	3774	4379	4719	5298	5999	6227	6012	5380	5113	4376	3749	4866
Average	1450	1963	2711	3109	3599	4249	4484	4355	3742	3379	2524	1812	**3115**

Next, heat load simulation was conducted considering daylight. Windows were added to the simulation data. The average number of luminaires turned ON was 20.33.

Table 27: Hourly heat load values - With Daylight Harvesting

Time	Heat Load (W)												Average
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
8:00	1472	1972	2800	3316	3836	4494	4702	4599	4019	3714	2801	1904	3302
9:00	2271	2730	3471	3952	4491	5171	5382	5251	4648	4394	3543	2691	4000
10:00	2984	3398	4032	4456	5024	5746	5968	5791	5138	4917	4145	3375	4581
11:00	3517	3869	4403	4793	5418	6186	6408	6170	5474	5299	4609	3903	5004
12:00	4059	4328	4815	5227	5912	6694	6893	6617	5955	5867	5229	4513	5509
13:00	4790	5005	5453	5853	6568	7358	7546	7252	6615	6576	5982	5280	6190
14:00	5535	5713	6119	6502	7240	8040	8225	7910	7272	7262	6709	6034	6880
15:00	6186	6345	6718	7086	7834	8644	8833	8499	7838	7830	7303	6670	7482
16:00	6610	6784	7137	7483	8221	9044	9248	8896	8174	8113	7587	7029	7860
Average	4158	4460	4994	5407	6061	6820	7023	6776	6126	5997	5323	4600	**5645**

Average heat-load values without daylight harvesting = 3.115kW

Average heat-load values with daylight harvesting = 5.645kW

Heat load increase after daylight harvesting (HL) = 2.53kW

Table 28: Calculation Parameters

Electricity consumption per 1kW heat load	0.3kW ; *Appendix A*
No. of working hours per day (N_{hours})	9 h
Number of working days per annum (N_{annum})	243
Electricity unit price (E_{unit})	22 LKR

Air-conditioning cost increase per annum = $HL \times 0.3 \times N_{hours} \times N_{annum} \times E_{unit}$

Air-conditioning cost increase per annum = 2.53 x 0.3 x 9 x 243 x 22

= LKR 36,518

Annual Artificial lighting cost-saving = LKR 35,968

Annual total cost increase with daylight harvesting = LKR 550

3.8 Summery

The daylighting simulation was done using DIALux evo 9.2 software [43]. The simulation intends to study the variation of daylight harvesting potential over various factors which are seasonal variation through the year, the effect of building width and depth, Orientation of the building and the window to wall ratio. A total of 48 simulations were carried out with 36 light scenes each.

Next, a case study was conducted for an office building in Colombo, Sri Lanka. Both daylighting simulation and heat-load simulation were conducted for this case.

The effect of the above factors on daylight harvesting is discussed in the next chapter. Specially focused on the percentage variation of artificial lighting cost over variation of building size, Orientation and window to wall ratio.

4 RESULTS AND DISCUSSION

After conducting the daylighting simulation with DIALux evo [43] software, all the data were recorded and analysed. Variation of the artificial lighting cost was analysed with the variation of the considered factors accordingly. Percentage variations of the artificial lighting costs over building size, orientation and WWR were graphed and discussed the result in this chapter.

4.1 Lighting cost variation over building size

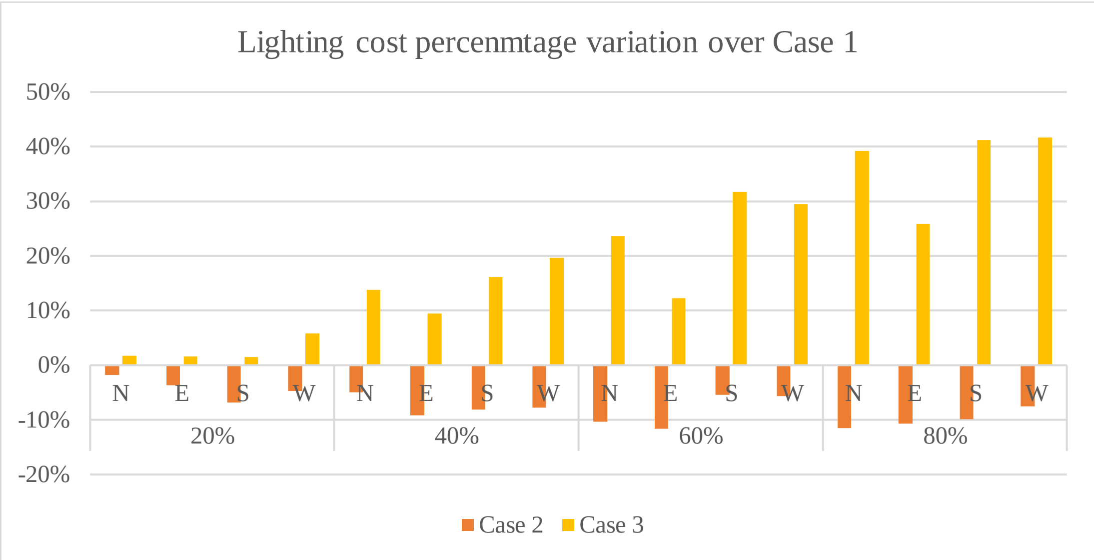


Figure 56: Lighting coat percentage variation over Case 1

Figure 56 shows the artificial lighting cost percentage variation over Case 1. Here, the corresponding Case 1 values were taken as the reference and the percentage variation of Case 2 and Case 3 was graphed accordingly.

All the values of the Case 2 are lower than the Case 1 values. So, increasing the width of a building reduces the lighting cost for the same orientation and WWR. But the maximum difference obtained by the simulation is 12%. According to the data, there is no significant change in artificial lighting cost, when changing the width of the building while keeping the depth unchanged.

According to Case 3, when increasing the depth of the building, artificial lighting cost increases. Although there is no significant increase for 20% WWR, the cost increases with the WWR significantly. The highest difference is 42% in 80% WWR and west orientation. The cost increase for east orientation is quite lower compared to others.

4.2 Lighting cost variation over orientation

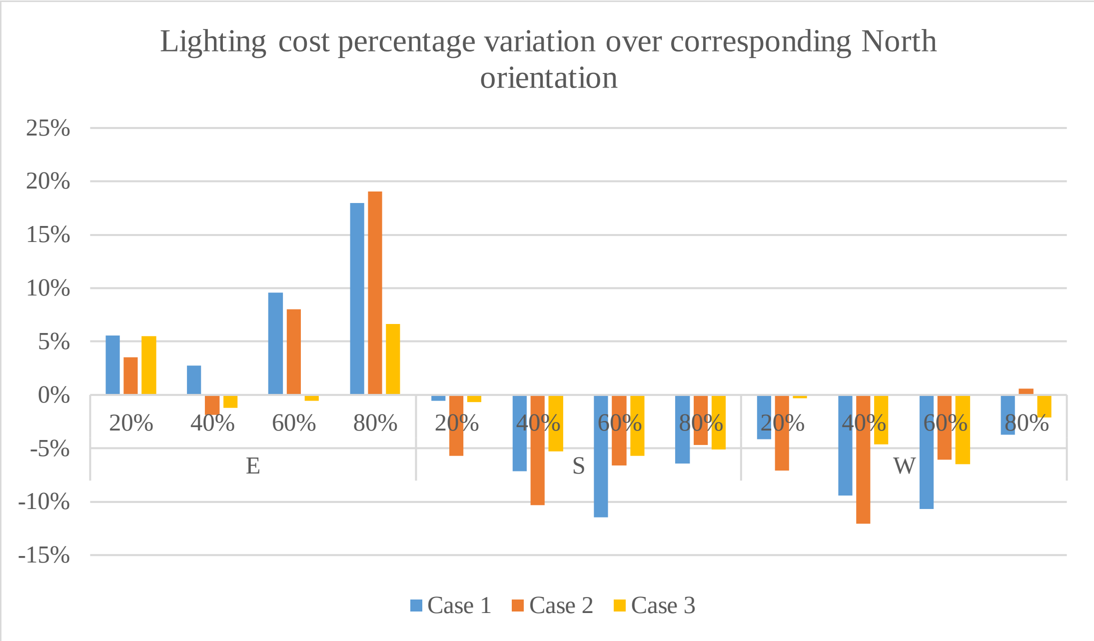


Figure 57: Lighting cost percentage variation over North orientation

Figure 57 shows the artificial lighting cost percentage variation over North window orientation. The percentage difference is plotted with reference to the corresponding North orientation values.

East orientation lighting costs are normally higher compared to north orientation, while South and west values are lower.

East orientation, 80% WWR situation Case 1 and Case 2 values are higher than the reference orientation by 18% and 19% respectively. Other than that, all the values show a maximum 12% difference. So, there is no significant change in artificial lighting cost with the window orientation.

4.3 Lighting cost variation over WWR

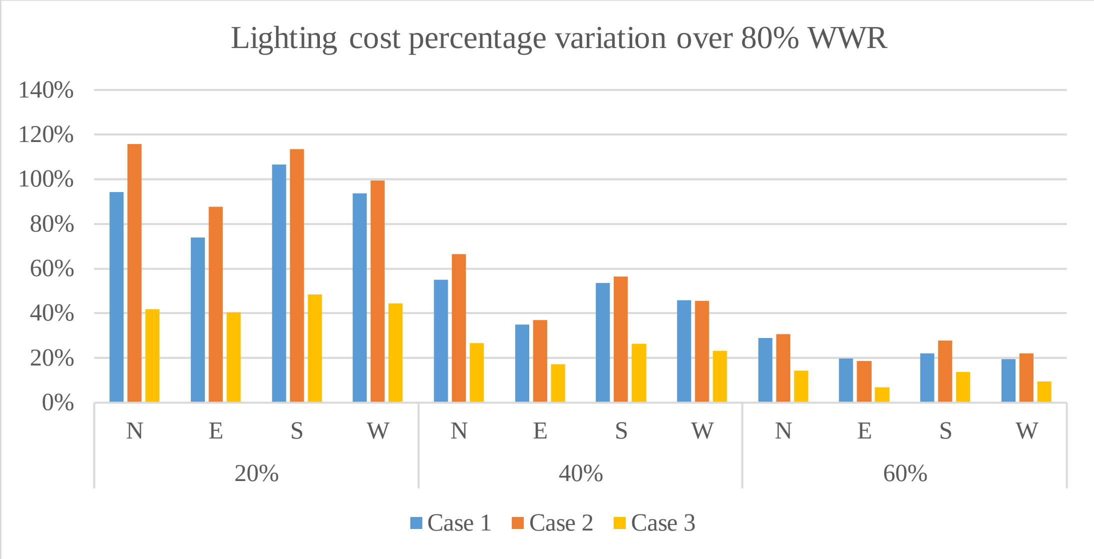


Figure 58: Lighting cost percentage variation over 80% WWR

Figure 58 shows the artificial lighting percentage cost difference over the corresponding 80% Window to wall ratio.

For Case 1 and Case 2, lighting cost significantly increases with decreasing window to wall ratio. The highest difference is 107% and 116% for Case 1 and Case 2 respectively in 20% WWR situation. The increase in east window orientation is quite lower compared to other orientations.

The increase of lighting cost with decreasing window to wall ratio, in Case 3 is lower compared to Case 1 and Case 2. The maximum artificial lighting cost increase for Case 3 is 49% in 20% WWR and south orientation.

4.4 Effect of seasonal variation

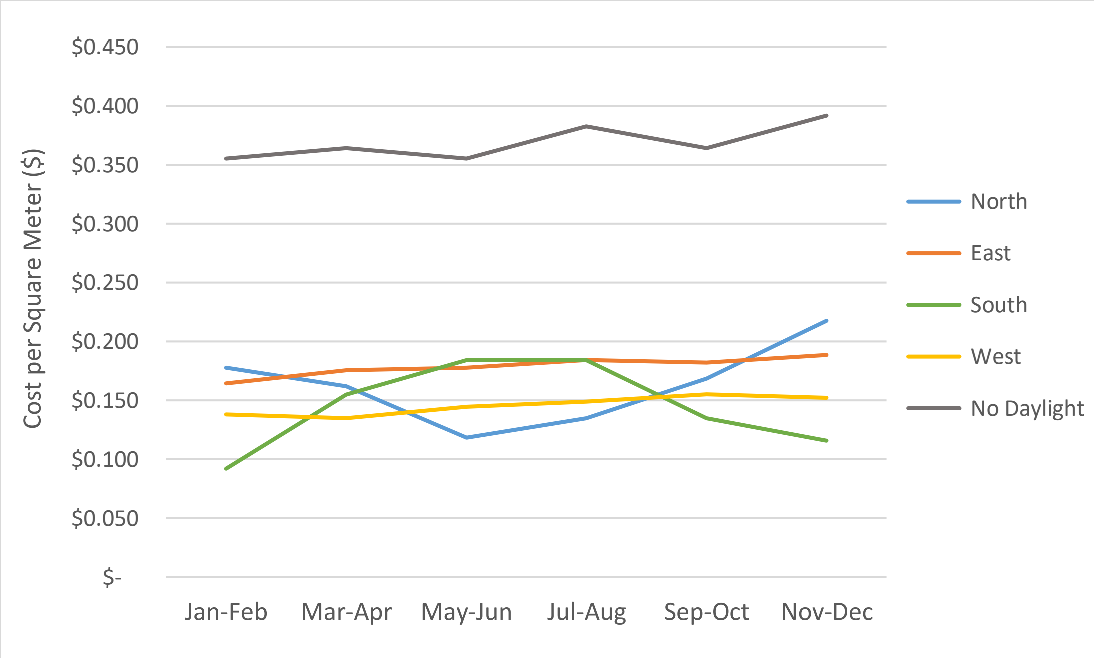


Figure 59: Artificial lighting cost variation – Case 1, WWR 60%

Figure 59 shows the artificial lighting cost variation in Case 1, 60% window to wall ratio.

The lowest lighting cost in North orientation is in May – June period while the highest lighting cost is in November – December period. In the south orientation, the lowest lighting cost can be seen in January – February period and the highest cost in July – August.

Although there is no significant lighting cost variation in East and West orientations, the lighting cost is higher in West orientation than the east orientation.

4.5 Effect of heat load

According to the actual case study results for an office building in Colombo Sri Lanka, artificial lighting electricity cost savings obtained was LKR 35,968. But due to heat gain increase with daylight harvesting, Air-conditioning cost increased by LKR 36,518. So, the overall cost increase is LKR 550 with daylight harvesting. Since there were not any shading devices were used daylight harvesting can increase the overall building energy cost. In this case study, energy-efficient LED lights fixtures were used for the daylight simulation. When lower efficient fixtures are used in a building, it will give a significant total energy cost saving even with increased air-conditioning costs. The intention of daylight harvesting is not only to increase building energy performance but also to enhance the visual comfort of the occupants.

4.6 Summery

This chapter discusses the result of this research and the percentage cost variation with the building size, window orientation and window to wall ratio. Although there is no significant effect with the window orientation and width of the building, a significant cost variation can be observed with the building depth and WWR.

When there are no shading devices are used, the overall cost will be increased with daylight harvesting due to the increase of the air-conditioning cost.

The next chapter discusses the conclusion of the study, key findings, recommendations and future work.

5 CONCLUSION AND FUTURE WORK

With the implementation of building standards and certification schemes to promote sustainable architecture, daylight harvesting became a major strategy of energy conservation. A better understanding of factors that affects daylight harvesting potential is essential to develop better and more efficient systems. This research intends to identify the degree of influence by those factors on typical office buildings which are located within the tropics such as Sri Lanka.

Also, a case study on an office building located in Colombo, Sri Lanka was conducted to understand the effect of heat load while harvesting daylight.

5.1 Conclusion

Although there are a lot of factors that affect daylighting, the variable parameters considered for this research are seasonal variation throughout the year, building width and depth, window orientation and window to wall ratio. The daylighting simulation was done with one of the world's most popular simulation software DIALux evo 9.2 [43]. The analyses and results of this research solely depend on the accuracy of the software. Total 48 simulations were done with varying parameters and each simulation consists of 36 light scenes.

For the typical 3 cases where no air-conditioning cost was considered, minimum lighting cost saving obtained was \$0.63/m^2/Annum in Case 3, East window orientation and 20% window to wall ratio. Maximum lighting cost saving obtained was \$1.573/ m^2 /Annum for Case 2, South window orientation and 80% window to wall ratio. So, the lighting cost-saving potential with daylight harvesting is 28.5% to 71%.

But in the actual case study, the overall cost was increased by LKR 550 per annum due to increased air-conditioning costs.

5.1.1 Key findings

The key finding of the study can be expressed as follows,

1. Effect of seasonal variation - In north orientation, the lowest lighting cost is in May–June period while the highest is in November–December period. In south

orientation highest is in July-August and the lowest is in January-February. Although there is no significant high or low periods that can be observed in the east and west orientations, lighting cost is higher in East orientation compared to West. The lighting cost distribution is quite moderate throughout the year.

2. Effect of building width and depth - Although increasing the width of the building, reduces the artificial lighting cost, there is no significant saving that can be observed. By increasing the width from 6m to 8m, a maximum of 12% saving is obtained. On other hand increasing the depth of the building significantly affect the lighting cost, especially for higher window to wall ratios. By increasing the depth by 33%, the maximum artificial lighting cost increase is 42% in 80% WWR.
3. Effect of building orientation - Other than the East orientation, the cost difference is below 12% in all other cases, compared to the north orientation. East orientation has higher costs while South and West have lower.
4. Effect of the window to wall ratio – Window to wall ratio is the major factor that critically affects the artificial lighting cost. Concerning 80% WWR, in 20% WWR situation shows the maximum increase in lighting cost which is 116%. With the increase of the building depth, the effect of WWR reduces, where the highest increase is 49% for 8m depth and 20% WWR.
5. Effect of heat load - When daylight harvesting without the aid of proper shading mechanisms, overall building electricity cost can be increased due to air-conditioning cost increase. But a considerable total building energy cost saving can be obtained with daylight harvesting where lower efficient luminaries such as fluorescent tube bulbs are used.

5.1.2 Recommendations

1. East orientation has higher artificial lighting costs while South and West have a lower costs. Recommended using South and west oriented windows to achieve higher artificial lighting cost savings.
2. Especially in East orientation, over illuminated areas adjacent to the windows can be seen due to direct solar radiation into the building. This disturbs the

average lux level and uniformity of the space. It is recommended to use a higher degree of solar control at east orientation.

3. On and Off states were used with luminaries in this simulation. When the daylight level is superimposed with the artificial light level it may create over illuminated areas and spots, which affects the uniformity of the working plane. By using dimmable lights with controllers, a better average lux level and uniformity will be obtained.
4. When there are no shading mechanisms used while daylight harvesting, overall building electricity cost can be increased with the increased air-conditioning cost due to solar heat gain. So, daylight harvesting must be done very wisely, and it is highly recommended to use dynamic shading mechanisms while daylight harvesting through building façade.

5.2 Limitation of the study

1. When simulating with DIALux evo [43], artificial lights should be turned on manually to get the desired light level in every light scene, which could lead to human errors.
2. Visual and thermal discomfort was not considered in this research.
3. Effect of heat gain, which can cause escalated air-conditioning cost was not considered for typical office building cases.
4. No solar controlling mechanisms were used other than window glazing.

5.3 Future work

Future studies are important to improve daylight harvesting efficiency. The following areas can be highlighted as major areas for further studies.

1. Study the effect of static and dynamic shading systems to improve the daylight harvesting efficiency
2. Study the effect of daylighting in terms of visual and thermal comfort
3. Study the effect on air-conditioning cost and obtain the optimum operation point to get the maximum cost-benefit from both daylighting and air-conditioning
4. Development of advanced daylight control mechanisms and algorithms

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DIALux

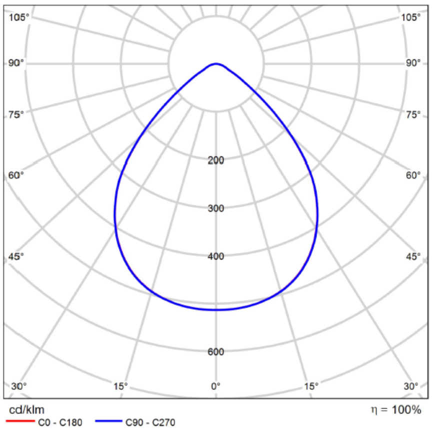
Product data sheet

PHILIPS RC360B SRD W60L60 1 xLED34S/940

PHILIPS

P	27.0 W
Φ_{Lamp}	3400 lm
$\Phi_{Luminaire}$	3400 lm
η	100.00 %
Luminous efficacy	125.9 lm/W
CCT	3000 K
CRI	100

PowerBalance gen2 – sustainable performance When it comes to lighting an office space with LED luminaires, people are usually willing to invest in sustainability provided the investment pays back. At the same time, the system should comply with office lighting norms to ensure a comfortable working environment. PowerBalance gen2 is Philips' most energy-efficient office-norm-compliant LED luminaire. It more than halves energy costs compared to a T5 solution, and the light source has a longer lifetime. This results in significantly lower operational costs, ensuring a payback that meets the needs of the specification market.The gen2 architecture enables a range of highly versatile modular and semi-modular luminaires. These luminaires can be easily mounted in ceilings with exposed T-bar and concealed T-bar, as well as plaster ceilings and bandraster-type ceilings. PowerBalance is also available in a surface-mounted version.



Polar LDC

Glare evaluation according to UGR

ρ Ceiling		70	70	50	50	30	70	70	50	50	30
ρ Walls		50	30	50	30	30	50	30	50	30	30
ρ Floor		20	20	20	20	20	20	20	20	20	20
Room size X	Y	Viewing direction at right angles to lamp axis					Viewing direction parallel to lamp axis				
2H	2H	17.9	19.1	18.2	19.3	19.5	18.0	19.1	18.2	19.3	19.5
	3H	18.0	19.0	18.3	19.2	19.5	18.0	19.0	18.3	19.2	19.5
	4H	18.0	18.9	18.3	19.2	19.5	18.0	19.0	18.4	19.2	19.5
	6H	18.0	18.9	18.4	19.2	19.5	18.0	18.9	18.4	19.2	19.5
	8H	18.0	18.8	18.4	19.1	19.5	18.0	18.9	18.4	19.2	19.5
	12H	18.0	18.8	18.4	19.1	19.4	18.0	18.8	18.4	19.1	19.5
4H	2H	18.0	19.0	18.4	19.2	19.5	18.1	19.0	18.4	19.3	19.5
	3H	18.2	18.9	18.5	19.3	19.6	18.2	19.0	18.5	19.3	19.6
	4H	18.2	18.9	18.6	19.3	19.6	18.2	18.9	18.6	19.3	19.6
	6H	18.3	18.9	18.7	19.3	19.7	18.3	18.9	18.7	19.3	19.7
	8H	18.3	18.9	18.7	19.3	19.7	18.3	18.9	18.8	19.3	19.7
	12H	18.3	18.8	18.7	19.2	19.7	18.3	18.8	18.8	19.3	19.7
8H	4H	18.2	18.8	18.6	19.1	19.6	18.2	18.8	18.6	19.2	19.6
	6H	18.3	18.8	18.8	19.2	19.6	18.3	18.8	18.8	19.2	19.7
	8H	18.3	18.8	18.8	19.2	19.7	18.4	18.8	18.8	19.2	19.7
	12H	18.4	18.7	18.9	19.2	19.7	18.4	18.8	18.9	19.2	19.7
12H	4H	18.2	18.7	18.6	19.1	19.5	18.2	18.7	18.6	19.1	19.5
	6H	18.3	18.7	18.8	19.1	19.6	18.3	18.7	18.8	19.2	19.6
	8H	18.3	18.7	18.8	19.2	19.7	18.4	18.7	18.9	19.2	19.7
Variation of the observer position for the luminaire distances S											
S = 1.0H		+1.1 / -1.8					+1.1 / -1.8				
S = 1.5H		+2.0 / -3.9					+2.0 / -3.8				
S = 2.0H		+3.3 / -4.9					+3.3 / -4.9				
Standard table		BK01					BK01				
Correction summand		0.3					0.4				
Corrected glare indices referring to 3400lm Total luminous flux											

UGR diagram (SHR: 0.25)

AIR-COOLED SPECIFICATION TABLE (380V)

Item	Unit	RPS-NP52AE	RAC-NP52AE	RPS-NP82AE	RAC-NP82AE	RPS-NP102AE	RAC-NP102AE	RP-NP152AE	RCR-NP152AE	RP-NP152AEL	RCR-NP152AE	RP-NP222AE	RCR-NP222AE	RP-NP302AE	RCR-NP162AEx2
※Cooling Capacity	kW	16.0		25.0		32.0		48.9		48.9		72.0		98.0	
Power Source	–	AC 3Φ 380V 60Hz													
Dimensions – Width	mm	950	1060	1250	1240	1400	1240	1400	1850	1400	1850	1700	1980	2000	1850
Dimensions – Depth	mm	500	345	500	500	500	500	750	940	750	940	750	1000	900+65	940
Dimensions – Height	mm	1950	1325	1950	1425	1950	1625	2150	1138	1880	1138	1880	1128	2000+30	1138
Dimensions – Separable Height	mm	1730+250	–	1730+250	–	1730+250	–	1880+300	–	–	–	–	–	1365+665	–
※※Electrical Characteristics – Power Consumption	kW	4.74		7.32		9.7		15.3		15.6		22.86		32.67	
※※Electrical Characteristics – Operation Current	A	8.3		12.5		16.9		26.5		27.9		40		57.7	
※※Electrical Characteristics – Starting Current	A	62		88		62		88		88		88		194	
Energy Efficiency Ratio (EER)	W/W	3.38		3.42		3.30		3.20		3.15		3.15		3.00	
Cooling Device – Compressor – Model	–	High Efficiency Fully Enclosed Scroll Compressor													
Cooling Device – Compressor – Power (Pole)	kW	–	3.75(2)	–	6.4(2)	–	3.75(2)	6.4(2)+4.9(2)	–	6.4(2)+4.9(2)	–	6.4(2)+3.75(2)	–	11.2(2)	–
Cooling Device – Compressor – Quantity	–	–	1	–	1	–	2	2	–	2	–	2+1	–	2	–
Cooling Device – Condenser	–	Multi-path Vortex Fin Tubing													
Cooling Device – Evaporator	–	Multi-path Vortex Fin Tubing													
Coolant Control Device	–	Multi-path Capillary Tubing													
Fan Device – Model	–	Multi-blade Fanx1	Propeller Fanx2	Multi-blade Fanx2	Propeller Fanx1	Multi-blade Fanx2	Propeller Fanx1	Multi-blade Fanx1	Propeller Fanx2	Multi-blade Fanx1	Propeller Fanx2	Multi-blade Fanx2	Propeller Fanx2	Multi-blade Fanx2	Propeller Fanx2
Fan Device – Motor Power (Pole)	kW	0.25(6)	0.125(6)x2	0.37(4)	0.49(8)	0.75(4)	0.45(8)	2.2(4)	0.49(8)x2	2.2(4)	0.49(8)x2	3.7(4)	0.4(6)x2	5.5(4)	0.3(8)x2
Fan Device – Motor Power Source	–	AC 1Φ 220V 60Hz		AC 3Φ 380V 60Hz											
Fan Device – Air Volume (High/Low)	m^3/min	44/38	50x2	66	160	88	160	130	420	130	420	180	410	260	420
Fan Device – External Static Pressure	pa (mmAg)	0	–	0	–	0	–	0	–	50(5)	–	50(5)	–	80(8)	–
Fan Device – Automatic Direction of Rotation – Direction of Rotation	–	Left-Right Wind Direction Automatic Scan		–											
Fan Device – Automatic Direction of Rotation – Motor Power	W	3	–												
Protective Devices	–	Current Overload Relay (Fan, except for RPS-NP52AE), hidden temperature switch (Fan, except for RPS-NP52AE), Pressure Switch, Anti-freeze switch, outlet temperature switch (compressor), Current Overload Relay (Compressor)													
Dimensions of Tubings – Refrigerant – Gas Line	mm	Welding for Indoor Unit/Flare Nut for Outdoor Unit Φ19.05		Welding for Indoor Unit/Flare Nut for Outdoor Unit Φ22.2		Welding for Indoor Unit/Flare Nut for Outdoor Unit Φ19.05 +Φ19.05		Welding for Indoor Unit/Flare Nut for Outdoor Unit Φ15.88 +Φ15.88				Welding for Indoor Unit/Flare Nut for Outdoor Unit Φ15.88 +Φ12.7 +Φ15.88		Welding for Indoor Unit/Flare Nut for Outdoor Unit Φ19.05 +Φ19.05	
Dimensions of Tubings – Refrigerant – Liquid Line	mm	Welding for Indoor Unit/Flare Nut for Outdoor Unit Φ9.53		Welding for Indoor Unit/Flare Nut for Outdoor Unit Φ12.7		Welding for Indoor Unit/Flare Nut for Outdoor Unit Φ9.53 +Φ9.53		Welding for Indoor Unit/Flare Nut for Outdoor Unit Φ12.7 +Φ12.7				Welding for Indoor Unit/Flare Nut for Outdoor Unit Φ12.7 +Φ9.53 +Φ12.7		Welding for Indoor Unit/ Outdoor Unit Φ15.88 +Φ15.88	
Dimensions of Tubings – Condensed Liquid Drain	–	FPT1													
Dimensions of Tubings – Emergency Drain	–	FPT1/2													
Wiring – Power Source Connection	–	Outdoor unit						Indoor unit							
Wiring – Indoor and Outdoor Power Source Line	mm^2	2 Cores (1.25)		3 Cores (1.25)				6 Cores (1.25)						3 Coresx2 (1.25)	
Wiring – Indoor and Outdoor Control Line	mm^2	8 Cores (0.75)		6 Cores (0.75)		10 Cores (0.75)		–							
Product Weight	kg	115	130	155	175	155	195	420	190	390	190	530	270	665	185

Note:
1. The nominal cooling capacity is based on the standard of CNS. Evaporate Air Inlet Temperature is 27℃ DB and 19℃ WB. Condenser Air Inlet is 35℃ DB. One-way coolant tubing between indoor and outdoor units is 7.5m).
2. Electrical Characteristics are values obtained by testing at CNS conditions (specified above). For actual electrical properties, please apply a 1.2 multiplier.
3. Changes made to specification in the table may be made without prior notice.
4. Operation Range:Evaporator Intake Air Temperature (standard air volume):
   Maximum: 32℃ DB/23℃ WB
   Minimum: 21℃ DB/15℃ WB
   Condenser Intake Air Temperature: Maximum 43℃ DB/Minimum 21℃ DB

APPENDIX B: SIMULATION DATA

Table 29: Simulation data. Case 1, North, 20% WWR

Date	Time	Before			Luminaire Status (ON=1, OFF=0)									Luminaires		After		
		E_m	E_{avg}	U_1	L1	L2	L3	L4	L5	L6	L7	L8	L9	Total	Avg.	E_m	E_{avg}	U_1
01 February 2021	08:45 AM	55.9	233	0.24	1	1	1	1	1	1	0	0	0	6	6.33	443	689	0.64
	10:15 AM	50.9	212	0.24	1	1	1	1	1	1	0	0	0	6		433	668	0.65
	11:45 AM	39.2	151	0.26	1	1	1	1	0	1	0	1	0	6		443	621	0.71
	01:15 PM	49.1	196	0.25	1	1	1	1	1	1	0	0	0	6		426	652	0.65
	02:45 PM	58.7	244	0.24	1	1	1	1	1	1	0	0	0	6		455	700	0.65
	04:15 PM	30.9	127	0.24	1	1	1	1	1	1	1	0	1	8		482	700	0.69
01 April 2021	08:45 AM	80.4	350	0.23	1	1	1	1	0	1	0	0	0	5	5.83	482	704	0.68
	10:15 AM	52.9	223	0.24	1	1	1	1	1	1	0	0	0	6		433	679	0.64
	11:45 AM	60.2	213	0.28	1	1	1	1	1	1	0	0	0	6		436	669	0.65
	01:15 PM	54.7	227	0.24	1	1	1	1	1	1	0	0	0	6		437	683	0.64
	02:45 PM	78.5	352	0.22	1	1	1	1	0	1	0	0	0	5		485	705	0.69
	04:15 PM	42.3	180	0.24	1	1	1	1	1	1	0	0	1	7		488	695	0.70
01 June 2021	08:45 AM	104	473	0.22	1	1	1	1	0	1	0	0	0	5	5.33	529	826	0.64
	10:15 AM	81.7	358	0.23	1	1	1	1	0	1	0	0	0	5		477	712	0.67
	11:45 AM	63.1	249	0.25	1	1	1	1	1	1	0	0	0	6		481	705	0.68
	01:15 PM	91.9	388	0.24	1	1	1	1	0	1	0	0	0	5		498	742	0.67
	02:45 PM	107	464	0.23	1	1	1	1	0	1	0	0	0	5		524	818	0.64
	04:15 PM	49.4	211	0.23	1	1	1	1	1	1	0	0	0	6		417	667	0.63
01 August 2021	08:45 AM	100	441	0.23	1	1	1	1	0	1	0	0	0	5	5.33	522	795	0.66
	10:15 AM	77.9	330	0.24	1	1	1	1	0	1	0	0	0	5		463	684	0.68
	11:45 AM	51.3	200	0.26	1	1	1	1	1	1	0	0	0	6		434	657	0.66
	01:15 PM	74.8	324	0.23	1	1	1	1	0	1	0	0	0	5		460	677	0.68
	02:45 PM	102	446	0.23	1	1	1	1	0	1	0	0	0	5		519	799	0.65
	04:15 PM	54.9	231	0.24	1	1	1	1	1	1	0	0	0	6		434	687	0.63
01 October 2021	08:45 AM	72.6	308	0.24	1	1	1	1	0	1	0	0	0	5	6.67	460	662	0.69
	10:15 AM	44.6	181	0.25	1	1	1	1	1	1	1	0	0	7		469	696	0.67
	11:45 AM	31.8	117	0.27	1	1	1	1	1	1	1	0	1	8		484	689	0.70
	01:15 PM	57.1	235	0.24	1	1	1	1	1	1	0	0	0	6		450	695	0.65
	02:45 PM	71.3	303	0.24	1	1	1	1	1	0	1	0	0	6		545	657	0.69
	04:15 PM	30.1	121	0.25	1	1	1	1	1	1	1	0	1	8		481	693	0.69
01 December 2021	08:45 AM	54.6	226	0.24	1	1	1	1	1	1	0	0	0	6	6.50	440	682	0.65
	10:15 AM	46.9	193	0.24	1	1	1	1	1	1	0	0	0	6		426	649	0.66
	11:45 AM	43.5	165	0.26	1	1	1	1	0	1	1	0	1	7		455	635	0.72
	01:15 PM	51.6	214	0.24	1	1	1	1	1	1	0	0	0	6		438	670	0.65
	02:45 PM	49	208	0.24	1	1	1	1	1	1	0	0	0	6		421	664	0.63
	04:15 PM	17.3	71.1	0.24	1	1	1	1	1	1	1	0	1	8		468	644	0.73

Table 30: Simulation data. Case 1, North, 40% WWR

Date	Time	Before			Luminaire Status (ON=1, OFF=0)									Luminaires		After		
		E_m	E_{avg}	U_1	L1	L2	L3	L4	L5	L6	L7	L8	L9	Total	Avg.	E_m	E_{avg}	U_1
01 February 2021	08:45 AM	111	434	0.26	1	1	1	1	0	1	0	0	0	5	5.33	533	786	0.68
	10:15 AM	98.9	397	0.25	1	1	1	1	0	1	0	0	0	5		521	749	0.70
	11:45 AM	79.2	286	0.28	1	1	1	1	1	1	0	0	0	6		518	741	0.70
	01:15 PM	94.9	369	0.26	1	1	1	1	0	1	0	0	0	5		504	721	0.70
	02:45 PM	113	454	0.25	1	1	1	1	0	1	0	0	0	5		530	806	0.66
	04:15 PM	60	236	0.25	1	1	1	1	1	1	0	0	0	6		449	690	0.65
01 April 2021	08:45 AM	153	652	0.23	1	1	1	1	0	0	0	0	0	4	4.67	512	926	0.55
	10:15 AM	105	422	0.25	1	1	1	1	0	1	0	0	0	5		528	774	0.68
	11:45 AM	116	422	0.27	1	1	1	1	0	1	0	0	0	5		504	774	0.65
	01:15 PM	104	429	0.24	1	1	1	1	0	1	0	0	0	5		521	781	0.67
	02:45 PM	163	655	0.25	1	1	1	0	0	1	0	0	0	4		506	929	0.54
	04:15 PM	86.7	334	0.26	1	1	1	1	0	1	0	0	0	5		496	686	0.72
01 June 2021	08:45 AM	209	879	0.24	1	1	1	0	0	0	0	0	0	3	4.00	467	1076	0.43
	10:15 AM	160	676	0.24	1	1	1	1	0	0	0	0	0	4		474	950	0.50
	11:45 AM	121	478	0.25	1	1	1	1	0	1	0	0	0	5		539	830	0.65
	01:15 PM	178	730	0.24	1	1	1	0	0	1	0	0	0	4		509	1004	0.51
	02:45 PM	212	861	0.25	1	1	1	0	0	0	0	0	0	3		472	1058	0.45
	04:15 PM	99.4	390	0.25	1	1	1	1	0	1	0	0	0	5		515	742	0.69
01 August 2021	08:45 AM	198	820	0.24	1	1	1	0	0	0	0	0	0	3	4.17	441	1017	0.43
	10:15 AM	143	623	0.23	1	1	1	1	0	0	0	0	0	4		458	897	0.51
	11:45 AM	101	388	0.26	1	1	1	1	0	1	0	0	0	5		492	740	0.66
	01:15 PM	150	610	0.25	1	1	1	1	0	1	0	0	0	5		570	963	0.59
	02:45 PM	204	828	0.25	1	1	1	0	0	0	0	0	0	3		459	1025	0.45
	04:15 PM	107	427	0.25	1	1	1	1	0	1	0	0	0	5		520	779	0.67
01 October 2021	08:45 AM	140	574	0.24	1	1	1	1	0	0	0	0	0	4	5.00	469	849	0.55
	10:15 AM	87.2	343	0.25	1	1	1	1	0	1	0	0	0	5		483	695	0.69
	11:45 AM	63.9	226	0.28	1	1	1	1	1	1	0	0	0	6		460	681	0.68
	01:15 PM	106	442	0.24	1	1	1	1	0	1	0	0	0	5		525	794	0.66
	02:45 PM	139	564	0.25	1	1	1	0	0	1	0	0	0	4		459	838	0.55
	04:15 PM	56.8	224	0.25	1	1	1	1	1	1	0	0	0	6		434	678	0.64
01 December 2021	08:45 AM	105	420	0.25	1	1	1	1	0	1	0	0	0	5	5.50	528	772	0.68
	10:15 AM	95.2	362	0.26	1	1	1	1	0	1	0	0	0	5		500	714	0.70
	11:45 AM	87.2	311	0.28	1	1	1	1	0	1	0	0	0	5		462	663	0.70
	01:15 PM	104	400	0.26	1	1	1	1	0	1	0	0	0	5		521	752	0.69
	02:45 PM	96.1	386	0.25	1	1	1	1	0	1	0	0	0	5		515	738	0.70
	04:15 PM	33.3	132	0.25	1	1	1	1	1	1	1	0	1	8		482	699	0.69

Table 31: Simulation data. Case 1, North, 60% WWR

Date	Time	Before			Luminaire Status (ON=1, OFF=0)									Luminaires		After		
		E_m	E_{avg}	U_1	L1	L2	L3	L4	L5	L6	L7	L8	L9	Total	Avg.	E_m	E_{avg}	U_1
01 February 2021	08:45 AM	157	572	0.27	1	1	1	1	0	0	0	0	0	4	4.50	504	845	0.60
	10:15 AM	148	529	0.28	1	1	1	1	0	0	0	0	0	4		456	802	0.57
	11:45 AM	111	386	0.29	1	1	1	1	0	1	0	0	0	5		525	737	0.70
	01:15 PM	137	493	0.28	1	1	1	1	0	1	0	0	0	5		556	843	0.66
	02:45 PM	162	600	0.27	1	1	1	0	0	1	0	0	0	4		512	873	0.59
	04:15 PM	89.8	310	0.29	1	1	1	1	0	1	0	0	0	5		491	661	0.74
01 April 2021	08:45 AM	237	863	0.27	1	1	1	0	0	0	0	0	0	3	4.00	499	1060	0.47
	10:15 AM	153	572	0.27	1	1	1	1	0	0	0	0	0	4		463	845	0.55
	11:45 AM	171	602	0.28	1	1	1	1	0	1	0	0	0	5		589	952	0.62
	01:15 PM	151	580	0.26	1	1	1	0	0	1	0	0	0	4		460	854	0.54
	02:45 PM	229	867	0.26	1	1	1	0	0	0	0	0	0	3		504	1063	0.47
	04:15 PM	122	437	0.28	1	1	1	1	0	1	0	0	0	5		541	788	0.69
01 June 2021	08:45 AM	311	1164	0.27	1	0	1	0	0	0	0	0	0	2	3.00	527	1283	0.41
	10:15 AM	237	916	0.26	1	1	1	0	0	0	0	0	0	3		524	1113	0.47
	11:45 AM	181	662	0.27	1	1	1	0	0	1	0	0	0	4		447	935	0.48
	01:15 PM	256	987	0.26	1	1	1	0	0	0	0	0	0	3		555	1184	0.47
	02:45 PM	304	1140	0.27	1	0	1	0	0	0	0	0	0	2		540	1259	0.43
	04:15 PM	144	511	0.28	1	1	1	0	0	1	0	0	0	4		470	784	0.60
01 August 2021	08:45 AM	293	1084	0.27	1	0	1	0	0	0	0	0	0	2	3.17	525	1203	0.44
	10:15 AM	225	843	0.27	1	1	1	0	0	0	0	0	0	3		501	1040	0.48
	11:45 AM	149	542	0.27	1	1	1	1	0	1	0	0	0	5		570	893	0.64
	01:15 PM	225	828	0.27	1	1	1	0	0	0	0	0	0	3		481	1025	0.47
	02:45 PM	294	1099	0.27	1	0	1	0	0	0	0	0	0	2		527	1208	0.43
	04:15 PM	154	558	0.28	1	1	1	0	0	1	0	0	0	4		508	832	0.61
01 October 2021	08:45 AM	209	761	0.27	1	1	1	0	0	0	0	0	0	3	4.17	457	958	0.48
	10:15 AM	127	465	0.27	1	1	1	1	0	1	0	0	0	5		552	816	0.68
	11:45 AM	89.3	314	0.28	1	1	1	1	0	1	0	0	0	5		457	664	0.69
	01:15 PM	162	594	0.27	1	1	1	0	0	1	0	0	0	4		478	867	0.55
	02:45 PM	204	745	0.27	1	1	1	0	0	0	0	0	0	3		545	941	0.48
	04:15 PM	83.9	293	0.29	1	1	1	1	0	1	0	0	0	5		471	644	0.73
01 December 2021	08:45 AM	147	555	0.26	1	1	1	1	0	1	0	0	0	5	5.00	571	906	0.63
	10:15 AM	134	484	0.28	1	1	1	1	0	1	0	0	0	5		556	835	0.67
	11:45 AM	121	418	0.29	1	1	1	1	0	1	0	0	0	5		540	768	0.70
	01:15 PM	146	532	0.27	1	1	1	0	0	1	0	0	0	4		464	806	0.58
	02:45 PM	137	509	0.27	1	1	1	0	0	1	0	0	0	4		465	783	0.59
	04:15 PM	50	173	0.29	1	1	1	1	1	1	0	0	1	7		491	682	0.72

Table 32: Simulation data. Case 1, North, 80% WWR

Date	Time	Before			Luminaire Status (ON=1, OFF=0)									Luminaires		After		
		E_m	E_{avg}	U_1	L1	L2	L3	L4	L5	L6	L7	L8	L9	Total	Avg.	E_m	E_{avg}	U_1
01 February 2021	08:45 AM	213	713	0.30	1	1	1	0	0	0	0	0	0	3	3.67	472	909	0.52
	10:15 AM	197	666	0.30	1	1	1	0	0	0	0	0	0	3		457	862	0.53
	11:45 AM	153	490	0.31	1	1	1	1	0	1	0	0	0	5		584	840	0.70
	01:15 PM	185	621	0.30	1	1	1	0	0	0	0	0	0	3		446	817	0.55
	02:45 PM	234	750	0.31	1	1	1	0	0	0	0	0	0	3		493	946	0.52
	04:15 PM	121	386	0.31	1	1	1	1	0	1	0	0	0	5		536	735	0.73
01 April 2021	08:45 AM	322	1079	0.30	1	0	1	0	0	0	0	0	0	2	2.83	549	1198	0.46
	10:15 AM	206	729	0.28	1	1	1	0	0	0	0	0	0	3		464	924	0.50
	11:45 AM	221	797	0.28	1	1	1	0	0	0	0	0	0	3		482	993	0.49
	01:15 PM	210	741	0.28	1	1	1	0	0	0	0	0	0	3		475	936	0.51
	02:45 PM	319	1086	0.29	1	0	1	0	0	0	0	0	0	2		551	1204	0.46
	04:15 PM	173	542	0.32	1	1	1	0	0	1	0	0	0	4		517	815	0.63
01 June 2021	08:45 AM	417	1457	0.29	1	0	1	0	0	0	0	0	0	2	2.33	684	1576	0.43
	10:15 AM	323	1169	0.29	1	0	1	0	0	0	0	0	0	2		547	1287	0.43
	11:45 AM	242	858	0.28	1	1	1	0	0	0	0	0	0	3		541	1054	0.51
	01:15 PM	349	1255	0.28	1	0	1	0	0	0	0	0	0	2		574	1373	0.42
	02:45 PM	421	1425	0.30	1	0	1	0	0	0	0	0	0	2		665	1544	0.43
	04:15 PM	201	631	0.32	1	1	1	0	0	0	0	0	0	3		435	827	0.53
01 August 2021	08:45 AM	397	1357	0.29	1	0	1	0	0	0	0	0	0	2	2.33	647	1475	0.44
	10:15 AM	295	1074	0.27	1	0	1	0	0	0	0	0	0	2		514	1193	0.43
	11:45 AM	200	708	0.28	1	1	1	0	0	0	0	0	0	3		455	903	0.50
	01:15 PM	295	1056	0.28	1	0	1	0	0	0	0	0	0	2		518	1174	0.44
	02:45 PM	407	1374	0.30	1	0	1	0	0	0	0	0	0	2		647	1492	0.43
	04:15 PM	215	692	0.31	1	1	1	0	0	0	0	0	0	3		464	887	0.52
01 October 2021	08:45 AM	283	954	0.30	1	0	1	0	0	0	0	0	0	2	3.50	505	1072	0.47
	10:15 AM	172	593	0.29	1	1	1	1	0	0	0	0	0	4		489	866	0.56
	11:45 AM	119	407	0.29	1	1	1	1	0	1	0	0	0	5		532	756	0.70
	01:15 PM	219	751	0.29	1	1	1	0	0	0	0	0	0	3		487	947	0.51
	02:45 PM	275	929	0.30	1	0	1	0	0	0	0	0	0	2		495	1047	0.47
	04:15 PM	114	364	0.31	1	1	1	1	0	1	0	0	0	5		531	713	0.74
01 December 2021	08:45 AM	209	694	0.30	1	1	1	0	0	0	0	0	0	3	3.83	479	890	0.54
	10:15 AM	186	608	0.31	1	1	1	0	0	0	0	0	0	3		445	804	0.55
	11:45 AM	170	527	0.32	1	1	1	1	0	1	0	0	0	5		592	877	0.68
	01:15 PM	203	668	0.30	1	1	1	0	0	0	0	0	0	3		462	863	0.54
	02:45 PM	193	634	0.30	1	1	1	0	0	0	0	0	0	3		445	830	0.54
	04:15 PM	66	215	0.31	1	1	1	1	0	1	0	0	1	6		471	620	0.76

Table 33: Simulation data. Case 1, East, 20% WWR

Date	Time	Before			Luminaire Status (ON=1, OFF=0)									Luminaires		After		
		E_m	E_{avg}	U_1	L1	L2	L3	L4	L5	L6	L7	L8	L9	Total	Avg.	E_m	E_{avg}	U_1
01 February 2021	08:45 AM	141	612	0.23	1	1	1	1	0	0	0	0	0	4	5.83	443	888	0.50
	10:15 AM	117	515	0.23	1	1	1	1	0	1	0	0	0	5		540	869	0.62
	11:45 AM	62.9	362	0.24	1	1	1	1	1	1	0	0	0	6		467	719	0.65
	01:15 PM	50.8	212	0.24	1	1	1	1	1	1	0	0	0	6		434	669	0.65
	02:45 PM	45.2	189	0.24	1	1	1	1	1	1	0	0	0	6		420	645	0.65
	04:15 PM	21	88.1	0.24	1	1	1	1	1	1	1	0	1	8		476	661	0.72
01 April 2021	08:45 AM	178	725	0.25	1	1	1	1	0	0	0	0	0	4	6.17	447	1001	0.45
	10:15 AM	93.2	379	0.25	1	1	1	1	0	1	0	0	0	5		494	773	0.67
	11:45 AM	64.6	227	0.28	1	1	1	1	1	1	0	0	0	6		437	683	0.64
	01:15 PM	37.2	146	0.25	1	1	1	1	1	1	1	0	1	8		490	719	0.68
	02:45 PM	44.8	177	0.25	1	1	1	1	1	1	0	0	0	6		440	634	0.69
	04:15 PM	24	91.9	0.26	1	1	1	1	1	1	1	0	1	8		476	664	0.72
01 June 2021	08:45 AM	158	680	0.23	1	1	1	0	0	1	0	0	0	4	6.33	446	956	0.47
	10:15 AM	92.3	388	0.24	1	1	1	1	0	1	0	0	0	5		498	742	0.67
	11:45 AM	42.5	169	0.25	1	1	1	1	1	1	0	0	1	7		440	683	0.64
	01:15 PM	44.8	179	0.25	1	1	1	1	1	1	0	0	1	7		468	694	0.67
	02:45 PM	47.1	185	0.25	1	1	1	1	1	1	0	0	1	7		480	699	0.69
	04:15 PM	22.6	91.9	0.25	1	1	1	1	1	1	1	0	1	8		475	665	0.71
01 August 2021	08:45 AM	166	698	0.24	1	1	1	0	0	1	0	0	0	4	6.50	452	973	0.46
	10:15 AM	96	407	0.24	1	1	1	1	0	1	0	0	0	5		507	760	0.67
	11:45 AM	39.6	153	0.26	1	1	1	1	1	1	1	0	1	8		491	726	0.68
	01:15 PM	40.8	162	0.25	1	1	1	1	1	1	0	0	1	7		436	676	0.64
	02:45 PM	48.8	185	0.26	1	1	1	1	1	1	0	0	1	7		477	700	0.68
	04:15 PM	26.5	102	0.26	1	1	1	1	1	1	1	0	1	8		477	674	0.71
01 October 2021	08:45 AM	161	708	0.23	1	1	1	1	0	0	0	0	0	4	6.83	454	984	0.46
	10:15 AM	80.3	337	0.24	1	1	1	1	0	1	0	0	0	5		466	691	0.67
	11:45 AM	36.2	136	0.27	1	1	1	1	1	1	1	0	1	8		489	708	0.69
	01:15 PM	42.7	168	0.25	1	1	1	1	1	1	1	0	1	8		498	740	0.67
	02:45 PM	43.9	170	0.26	1	1	1	1	1	1	1	0	1	8		502	743	0.68
	04:15 PM	17.6	68.7	0.26	1	1	1	1	1	1	1	0	1	8		470	641	0.64
01 December 2021	08:45 AM	143	610	0.23	1	1	1	1	0	1	0	0	0	5	6.33	562	963	0.58
	10:15 AM	107	455	0.24	1	1	1	1	0	1	0	0	0	5		529	809	0.65
	11:45 AM	65.9	269	0.24	1	1	1	1	1	1	0	0	0	6		475	725	0.66
	01:15 PM	53.8	226	0.24	1	1	1	1	1	1	0	0	0	6		445	682	0.65
	02:45 PM	40	166	0.24	1	1	1	1	1	1	1	0	1	8		499	738	0.68
	04:15 PM	12.5	52.7	0.24	1	1	1	1	1	1	1	0	1	8		467	625	0.75

Table 34: Simulation data. Case 1, East, 40% WWR

Date	Time	Before			Luminaire Status (ON=1, OFF=0)									Luminaires		After		
		E_m	E_{avg}	U_1	L1	L2	L3	L4	L5	L6	L7	L8	L9	Total	Avg.	E_m	E_{avg}	U_1
01 February 2021	08:45 AM	272	1129	0.24	1	0	1	0	0	0	0	0	0	2	4.67	495	1248	0.40
	10:15 AM	230	962	0.24	1	1	1	0	0	0	0	0	0	3		495	1160	0.43
	11:45 AM	125	496	0.25	1	1	1	1	0	1	0	0	0	5		549	848	0.65
	01:15 PM	99.1	399	0.25	1	1	1	1	0	1	0	0	0	5		521	751	0.69
	02:45 PM	87.8	351	0.25	1	1	1	1	0	1	0	0	0	5		496	703	0.70
	04:15 PM	43.2	164	0.26	1	1	1	1	1	1	1	0	1	8		496	732	0.68
01 April 2021	08:45 AM	345	1337	0.26	1	1	1	0	0	0	0	0	0	3	5.00	687	1534	0.45
	10:15 AM	185	718	0.26	1	1	1	1	0	0	0	0	0	4		449	992	0.45
	11:45 AM	123	450	0.27	1	1	1	1	0	1	0	0	0	5		518	802	0.65
	01:15 PM	76.5	277	0.28	1	1	1	1	1	1	0	0	0	6		513	732	0.70
	02:45 PM	89.7	331	0.27	1	1	1	1	0	1	0	0	0	5		483	683	0.71
	04:15 PM	46.2	171	0.27	1	1	1	1	1	1	0	0	1	7		444	682	0.65
01 June 2021	08:45 AM	303	1255	0.24	1	1	1	0	0	0	0	0	0	3	5.00	623	1452	0.43
	10:15 AM	172	731	0.24	1	1	1	0	0	1	0	0	0	4		483	1006	0.48
	11:45 AM	83.4	323	0.26	1	1	1	1	1	1	0	0	0	6		519	777	0.67
	01:15 PM	90.4	338	0.27	1	1	1	1	0	1	0	0	0	5		478	690	0.69
	02:45 PM	90.2	345	0.26	1	1	1	1	0	1	0	0	0	5		491	697	0.70
	04:15 PM	44.1	171	0.26	1	1	1	1	1	1	0	0	1	7		464	682	0.68
01 August 2021	08:45 AM	325	1288	0.25	1	1	1	0	0	0	0	0	0	3	4.83	640	1485	0.43
	10:15 AM	194	767	0.25	1	1	1	0	0	0	0	0	0	3		444	964	0.46
	11:45 AM	74.7	296	0.25	1	1	1	1	1	1	0	0	0	6		504	750	0.67
	01:15 PM	81.6	306	0.27	1	1	1	1	0	1	0	0	0	5		459	658	0.70
	02:45 PM	88.7	346	0.26	1	1	1	1	0	1	0	0	0	5		495	698	0.71
	04:15 PM	49.3	189	0.26	1	1	1	1	1	1	0	0	1	7		485	700	0.69
01 October 2021	08:45 AM	323	1309	0.25	1	1	1	0	0	0	0	0	0	3	5.33	657	1506	0.44
	10:15 AM	160	640	0.25	1	1	1	1	0	1	0	0	0	5		585	992	0.59
	11:45 AM	68.4	262	0.26	1	1	1	1	1	1	0	0	0	6		481	717	0.67
	01:15 PM	82.7	315	0.26	1	1	1	1	0	1	0	0	0	5		469	667	0.70
	02:45 PM	86.9	318	0.27	1	1	1	1	0	1	0	0	0	5		476	670	0.71
	04:15 PM	33.9	128	0.26	1	1	1	1	1	1	1	0	1	8		485	695	0.70
01 December 2021	08:45 AM	274	1125	0.24	1	0	1	0	0	0	0	0	0	2	4.67	496	1244	0.40
	10:15 AM	200	851	0.24	1	1	1	0	0	0	0	0	0	3		466	1048	0.44
	11:45 AM	120	506	0.24	1	1	1	1	0	1	0	0	0	5		548	858	0.64
	01:15 PM	107	422	0.25	1	1	1	1	0	1	0	0	0	5		530	774	0.68
	02:45 PM	76.7	308	0.25	1	1	1	1	0	1	0	0	0	5		470	660	0.71
	04:15 PM	24.4	98.1	0.25	1	1	1	1	1	1	1	0	1	8		477	666	0.72

Table 35: Simulation data. Case1, East, 60% WWR

Date	Time	Before			Luminaire Status (ON=1, OFF=0)									Luminaires		After		
		E_m	E_{avg}	U_1	L1	L2	L3	L4	L5	L6	L7	L8	L9	Total	Avg.	E_m	E_{avg}	U_1
01 February 2021	08:45 AM	409	1478	0.28	1	0	1	0	0	0	0	0	0	2	4.17	666	1597	0.42
	10:15 AM	352	1289	0.27	1	1	1	0	0	0	0	0	0	3		651	1486	0.44
	11:45 AM	177	670	0.26	1	1	1	1	0	0	0	0	0	4		509	944	0.54
	01:15 PM	147	533	0.28	1	1	1	1	0	1	0	0	0	5		569	883	0.64
	02:45 PM	133	466	0.29	1	1	1	1	0	1	0	0	0	5		554	816	0.68
	04:15 PM	63.4	216	0.29	1	1	1	1	1	1	0	0	0	6		466	669	0.70
01 April 2021	08:45 AM	515	1768	0.29	1	0	1	0	0	0	0	0	0	2	4.33	728	1887	0.39
	10:15 AM	265	980	0.27	1	1	1	0	0	0	0	0	0	3		559	1177	0.47
	11:45 AM	181	643	0.28	1	1	1	1	0	1	0	0	0	5		599	993	0.60
	01:15 PM	112	375	0.30	1	1	1	1	0	1	0	0	0	5		516	726	0.71
	02:45 PM	132	440	0.30	1	1	1	1	0	1	0	0	0	5		552	790	0.70
	04:15 PM	67.3	226	0.30	1	1	1	1	1	1	0	0	0	6		502	679	0.74
01 June 2021	08:45 AM	466	1660	0.28	1	1	1	0	0	0	0	0	0	3	4.50	814	1856	0.44
	10:15 AM	248	994	0.25	1	1	1	0	0	0	0	0	0	3		557	1190	0.47
	11:45 AM	119	444	0.27	1	1	1	1	0	1	0	0	0	5		537	795	0.68
	01:15 PM	132	454	0.29	1	1	1	1	0	1	0	0	0	5		550	805	0.68
	02:45 PM	133	457	0.29	1	1	1	1	0	1	0	0	0	5		552	808	0.68
	04:15 PM	64.5	226	0.29	1	1	1	1	1	1	0	0	0	6		477	678	0.70
01 August 2021	08:45 AM	482	1701	0.28	1	0	1	0	0	0	0	0	0	2	4.33	701	1820	0.39
	10:15 AM	270	1042	0.26	1	1	1	0	0	0	0	0	0	3		578	1239	0.47
	11:45 AM	114	412	0.28	1	1	1	1	0	1	0	0	0	5		520	762	0.68
	01:15 PM	119	413	0.29	1	1	1	1	0	1	0	0	0	5		535	763	0.70
	02:45 PM	138	459	0.30	1	1	1	1	0	1	0	0	0	5		556	810	0.69
	04:15 PM	69.9	249	0.28	1	1	1	1	1	1	0	0	0	6		504	702	0.72
01 October 2021	08:45 AM	486	1733	0.28	1	0	1	0	0	0	0	0	0	2	4.50	719	1852	0.39
	10:15 AM	225	875	0.26	1	1	1	0	0	0	0	0	0	3		512	1071	0.48
	11:45 AM	96	364	0.26	1	1	1	1	0	1	0	0	0	5		492	715	0.69
	01:15 PM	121	423	0.29	1	1	1	1	0	1	0	0	0	5		544	774	0.70
	02:45 PM	124	421	0.29	1	1	1	1	0	1	0	0	0	5		545	771	0.71
	04:15 PM	50.5	169	0.30	1	1	1	1	1	1	1	0	0	7		447	677	0.66
01 December 2021	08:45 AM	401	1479	0.27	1	0	1	0	0	0	0	0	0	2	4.33	650	1598	0.41
	10:15 AM	298	1140	0.26	1	1	1	0	0	0	0	0	0	3		603	1336	0.45
	11:45 AM	181	679	0.27	1	1	1	1	0	0	0	0	0	4		528	952	0.55
	01:15 PM	151	561	0.27	1	1	1	1	0	0	0	0	0	4		477	834	0.57
	02:45 PM	116	407	0.29	1	1	1	1	0	1	0	0	0	5		538	758	0.71
	04:15 PM	36.8	129	0.29	1	1	1	1	1	1	1	0	1	8		488	693	0.70

Table 36: Simulation data. Case1, East, 80% WWR

Date	Time	Before			Luminaire Status (ON=1, OFF=0)									Luminaires		After		
		E_m	E_{avg}	U_1	L1	L2	L3	L4	L5	L6	L7	L8	L9	Total	Avg.	E_m	E_{avg}	U_1
01 February 2021	08:45 AM	570	1837	0.31	1	0	1	0	0	0	0	0	0	2	3.17	840	1955	0.43
	10:15 AM	467	1628	0.29	1	0	1	0	0	0	0	0	0	2		710	1746	0.41
	11:45 AM	239	853	0.28	1	1	1	0	0	0	0	0	0	3		518	1049	0.49
	01:15 PM	203	672	0.30	1	1	1	0	0	0	0	0	0	3		457	868	0.53
	02:45 PM	180	582	0.31	1	1	1	1	0	0	0	0	0	4		515	855	0.60
	04:15 PM	82.1	270	0.30	1	1	1	1	0	1	0	0	0	5		473	620	0.76
01 April 2021	08:45 AM	707	2209	0.32	1	0	1	0	0	0	0	0	0	2	3.50	943	2328	0.41
	10:15 AM	358	1257	0.28	1	0	1	0	0	0	0	0	0	2		564	1376	0.41
	11:45 AM	233	852	0.27	1	1	1	0	0	0	0	0	0	3		498	1048	0.48
	01:15 PM	150	477	0.31	1	1	1	1	0	1	0	0	0	5		572	826	0.69
	02:45 PM	181	551	0.33	1	1	1	0	1	0	0	0	0	4		490	849	0.58
	04:15 PM	93.7	282	0.33	1	1	1	1	0	1	0	0	0	5		485	632	0.77
01 June 2021	08:45 AM	621	2077	0.30	1	1	1	0	0	0	0	0	0	3	3.67	982	2273	0.43
	10:15 AM	356	1266	0.28	1	0	1	0	0	0	0	0	0	2		575	1385	0.42
	11:45 AM	164	572	0.29	1	1	1	0	0	1	0	0	0	4		455	844	0.54
	01:15 PM	172	574	0.30	1	1	1	0	0	1	0	0	0	4		486	846	0.57
	02:45 PM	180	572	0.31	1	1	1	0	0	1	0	0	0	4		496	844	0.59
	04:15 PM	91.9	282	0.33	1	1	1	1	0	1	0	0	0	5		483	632	0.76
01 August 2021	08:45 AM	567	2123	0.31	1	0	1	0	0	0	0	0	0	2	3.83	921	2241	0.41
	10:15 AM	376	1331	0.28	1	0	1	0	0	0	0	0	0	2		592	1450	0.41
	11:45 AM	149	535	0.28	1	1	1	1	0	1	0	0	0	5		565	884	0.64
	01:15 PM	161	524	0.31	1	1	1	1	0	1	0	0	0	5		584	873	0.67
	02:45 PM	182	574	0.32	1	1	1	0	0	1	0	0	0	4		492	846	0.58
	04:15 PM	98.3	311	0.32	1	1	1	1	0	1	0	0	0	5		509	661	0.77
01 October 2021	08:45 AM	657	2171	0.30	1	0	1	0	0	0	0	0	0	2	4.00	915	2289	0.40
	10:15 AM	309	1125	0.27	1	0	1	0	0	0	0	0	0	2		525	1243	0.42
	11:45 AM	134	474	0.28	1	1	1	1	0	1	0	0	0	5		564	823	0.69
	01:15 PM	169	536	0.32	1	1	1	1	0	1	0	0	0	5		590	885	0.67
	02:45 PM	170	527	0.32	1	1	1	0	0	1	0	0	0	4		461	800	0.58
	04:15 PM	69	211	0.33	1	1	1	1	1	1	0	0	0	6		480	662	0.73
01 December 2021	08:45 AM	558	1843	0.30	1	0	1	0	0	0	0	0	0	2	3.67	815	1961	0.42
	10:15 AM	408	1438	0.28	1	0	1	0	0	0	0	0	0	2		651	1556	0.42
	11:45 AM	244	858	0.28	1	1	1	0	0	0	0	0	0	3		528	1054	0.50
	01:15 PM	211	704	0.30	1	1	1	0	0	0	0	0	0	3		477	900	0.53
	02:45 PM	156	509	0.31	1	1	1	1	0	0	0	0	0	4		482	781	0.62
	04:15 PM	50.8	162	0.31	1	1	1	1	1	1	1	0	1	8		501	723	0.69

Table 37: Simulation data. Case1, South, 20% WWR

Date	Time	Before			Luminaire Status (ON=1, OFF=0)									Luminaires		After		
		E_m	E_{avg}	U_1	L1	L2	L3	L4	L5	L6	L7	L8	L9	Total	Avg.	E_m	E_{avg}	U_1
01 February 2021	08:45 AM	104	454	0.23	1	1	1	1	0	1	0	0	0	5	5.33	518	807	0.64
	10:15 AM	119	517	0.23	1	1	1	1	0	1	0	0	0	5		536	870	0.62
	11:45 AM	98.9	419	0.24	1	1	1	1	0	1	0	0	0	5		509	773	0.66
	01:15 PM	111	494	0.22	1	1	1	1	0	1	0	0	0	5		536	847	0.63
	02:45 PM	112	492	0.23	1	1	1	1	0	1	0	0	0	5		534	846	0.63
	04:15 PM	47.9	201	0.24	1	1	1	1	1	1	1	0	0	7		498	715	0.70
01 April 2021	08:45 AM	84	360	0.23	1	1	1	1	0	1	0	0	0	5	5.83	490	713	0.69
	10:15 AM	57.6	245	0.24	1	1	1	1	1	1	0	0	0	6		449	701	0.64
	11:45 AM	69.5	245	0.28	1	1	1	1	1	1	0	0	0	6		464	701	0.66
	01:15 PM	59.4	248	0.24	1	1	1	1	1	1	0	0	0	6		459	704	0.65
	02:45 PM	83.3	357	0.23	1	1	1	1	0	1	0	0	0	5		491	711	0.69
	04:15 PM	41.3	172	0.24	1	1	1	1	1	1	1	0	0	7		490	687	0.71
01 June 2021	08:45 AM	64.4	268	0.24	1	1	1	1	1	1	0	0	0	6	6.83	475	725	0.66
	10:15 AM	46.6	187	0.25	1	1	1	1	1	1	0	0	1	7		475	701	0.68
	11:45 AM	33.3	123	0.27	1	1	1	1	1	1	1	0	1	8		485	696	0.70
	01:15 PM	49.5	204	0.24	1	1	1	1	1	1	0	0	0	6		423	660	0.64
	02:45 PM	60.2	264	0.23	1	1	1	1	1	1	0	0	0	6		472	721	0.65
	04:15 PM	32	134	0.24	1	1	1	1	1	1	1	0	1	8		488	706	0.69
01 August 2021	08:45 AM	65.4	285	0.23	1	1	1	1	1	1	0	0	0	6	6.50	482	741	0.65
	10:15 AM	49.2	201	0.24	1	1	1	1	1	1	0	0	0	6		419	657	0.64
	11:45 AM	31.2	116	0.27	1	1	1	1	1	1	1	0	1	8		484	688	0.70
	01:15 PM	48.9	195	0.25	1	1	1	1	1	1	0	0	0	6		412	652	0.63
	02:45 PM	62.9	284	0.22	1	1	1	1	1	1	0	0	0	6		483	740	0.65
	04:15 PM	36.6	157	0.23	1	1	1	1	1	1	1	0	0	7		472	672	0.70
01 October 2021	08:45 AM	93.3	411	0.23	1	1	1	1	0	1	0	0	0	5	5.83	511	765	0.67
	10:15 AM	65.1	275	0.24	1	1	1	1	1	1	0	0	0	6		483	732	0.66
	11:45 AM	49.2	190	0.26	1	1	1	1	1	1	1	0	0	7		434	704	0.62
	01:15 PM	75.9	341	0.22	1	1	1	1	0	1	0	0	0	5		472	695	0.68
	02:45 PM	87.6	382	0.23	1	1	1	1	0	1	0	0	0	5		510	736	0.69
	04:15 PM	32.5	134	0.24	1	1	1	1	1	1	1	0	0	7		437	649	0.67
01 December 2021	08:45 AM	116	524	0.22	1	1	1	1	0	1	0	0	0	5	5.50	531	878	0.60
	10:15 AM	122	559	0.22	1	1	1	1	0	1	0	0	0	5		539	912	0.59
	11:45 AM	122	514	0.24	1	1	1	1	0	1	0	0	0	5		544	868	0.63
	01:15 PM	130	575	0.23	1	1	1	1	0	1	0	0	0	5		551	929	0.59
	02:45 PM	98.8	435	0.23	1	1	1	1	0	1	0	0	0	5		518	789	0.66
	04:15 PM	27.2	113	0.24	1	1	1	1	1	1	1	0	1	8		479	686	0.70

Table 38: Simulation data. Case1, South, 40% WWR

Date	Time	Before			Luminaire Status (ON=1, OFF=0)									Luminaires		After		
		E_m	E_{avg}	U_1	L1	L2	L3	L4	L5	L6	L7	L8	L9	Total	Avg.	E_m	E_{avg}	U_1
01 February 2021	08:45 AM	205	841	0.24	1	1	1	0	0	0	0	0	0	3	3.33	448	1038	0.43
	10:15 AM	228	966	0.24	1	1	1	0	0	0	0	0	0	3		506	1163	0.44
	11:45 AM	200	793	0.25	1	1	1	0	0	0	0	0	0	3		470	990	0.47
	01:15 PM	217	926	0.23	1	1	1	0	0	0	0	0	0	3		476	1123	0.42
	02:45 PM	220	912	0.24	1	1	1	0	0	0	0	0	0	3		467	1109	0.42
	04:15 PM	96	372	0.26	1	1	1	1	0	1	0	0	0	5		515	724	0.71
01 April 2021	08:45 AM	159	669	0.24	1	1	1	0	0	1	0	0	0	4	4.67	513	944	0.54
	10:15 AM	116	464	0.25	1	1	1	1	0	1	0	0	0	5		534	816	0.65
	11:45 AM	132	485	0.27	1	1	1	1	0	1	0	0	0	5		540	837	0.65
	01:15 PM	118	469	0.25	1	1	1	1	0	1	0	0	0	5		340	821	0.66
	02:45 PM	156	664	0.23	1	1	1	1	0	0	0	0	0	4		518	939	0.55
	04:15 PM	78.5	319	0.25	1	1	1	1	0	1	0	0	0	5		483	671	0.72
01 June 2021	08:45 AM	124	501	0.25	1	1	1	1	0	1	0	0	0	5	5.33	541	853	0.63
	10:15 AM	89.7	353	0.25	1	1	1	1	0	1	0	0	0	5		489	705	0.69
	11:45 AM	66	236	0.28	1	1	1	1	1	1	0	0	0	6		482	690	0.70
	01:15 PM	93.5	384	0.24	1	1	1	1	0	1	0	0	0	5		509	736	0.69
	02:45 PM	121	492	0.25	1	1	1	1	0	1	0	0	0	5		547	844	0.65
	04:15 PM	62.9	248	0.25	1	1	1	1	1	1	0	0	0	6		463	702	0.66
01 August 2021	08:45 AM	126	530	0.24	1	1	1	1	0	1	0	0	0	5	5.17	546	882	0.62
	10:15 AM	95.7	379	0.25	1	1	1	1	0	1	0	0	0	5		503	731	0.69
	11:45 AM	61.5	223	0.28	1	1	1	1	1	1	0	0	0	6		460	677	0.68
	01:15 PM	91.9	369	0.25	1	1	1	1	0	1	0	0	0	5		496	721	0.69
	02:45 PM	130	529	0.25	1	1	1	1	0	1	0	0	0	5		553	881	0.63
	04:15 PM	75.2	293	0.26	1	1	1	1	0	1	0	0	0	5		463	645	0.72
01 October 2021	08:45 AM	187	765	0.24	1	1	1	0	0	0	0	0	0	3	4.67	433	962	0.45
	10:15 AM	128	522	0.25	1	1	1	1	0	1	0	0	0	5		547	874	0.63
	11:45 AM	93.3	368	0.25	1	1	1	1	0	1	0	0	0	5		480	720	0.67
	01:15 PM	149	640	0.23	1	1	1	1	0	1	0	0	0	5		479	915	0.52
	02:45 PM	172	710	0.24	1	1	1	1	0	0	0	0	0	4		549	984	0.56
	04:15 PM	62.2	249	0.25	1	1	1	1	1	1	0	0	0	6		463	703	0.66
01 December 2021	08:45 AM	232	970	0.24	1	1	1	0	0	0	0	0	0	3	3.50	503	1167	0.43
	10:15 AM	256	1044	0.25	1	1	1	0	0	0	0	0	0	3		533	1241	0.43
	11:45 AM	239	965	0.25	1	1	1	0	0	0	0	0	0	3		526	1162	0.45
	01:15 PM	250	1072	0.23	1	1	1	0	0	0	0	0	0	3		535	1269	0.42
	02:45 PM	189	804	0.24	1	1	1	0	0	0	0	0	0	3		441	1001	0.44
	04:15 PM	53.4	209	0.26	1	1	1	1	1	1	0	0	0	6		421	664	0.63

Table 39: Simulation data. Case1, South, 60% WWR

Date	Time	Before			Luminaire Status (ON=1, OFF=0)									Luminaires		After		
		E_m	E_{avg}	U_1	L1	L2	L3	L4	L5	L6	L7	L8	L9	Total	Avg.	E_m	E_{avg}	U_1
01 February 2021	08:45	292	1106	0.26	1	0	1	0	0	0	0	0	0	2	2.33	523	1225	0.43
	10:15	327	1294	0.25	1	0	1	0	0	0	0	0	0	2		559	1413	0.40
	11:45	288	1078	0.27	1	0	1	0	0	0	0	0	0	2		487	1197	0.41
	01:15	330	1246	0.26	1	0	1	0	0	0	0	0	0	2		554	1365	0.41
	02:45	319	1204	0.26	1	0	1	0	0	0	0	0	0	2		550	1323	0.42
	04:15	143	485	0.29	1	1	1	1	0	0	0	0	0	4		466	758	0.61
01 April 2021	08:45	231	887	0.26	1	1	1	0	0	0	0	0	0	3	3.83	508	1083	0.47
	10:15	168	629	0.27	1	1	1	0	0	1	0	0	0	4		475	903	0.53
	11:45	196	696	0.28	1	1	1	0	1	0	0	0	0	4		462	994	0.46
	01:15	173	635	0.27	1	1	1	1	0	0	0	0	0	4		502	909	0.55
	02:45	240	878	0.27	1	1	1	0	0	0	0	0	0	3		495	1075	0.46
	04:15	118	418	0.28	1	1	1	1	0	1	0	0	0	5		541	769	0.70
01 June 2021	08:45	187	663	0.28	1	1	1	0	0	1	0	0	0	4	4.67	553	937	0.59
	10:15	138	475	0.29	1	1	1	1	0	1	0	0	0	5		554	825	0.67
	11:45	91.9	322	0.29	1	1	1	1	0	1	0	0	0	5		471	673	0.70
	01:15	143	516	0.28	1	1	1	1	0	1	0	0	0	5		566	866	0.65
	02:45	183	650	0.28	1	1	1	1	0	0	0	0	0	4		551	923	0.60
	04:15	94.8	325	0.29	1	1	1	1	0	1	0	0	0	5		505	676	0.75
01 August 2021	08:45	195	702	0.28	1	1	1	0	0	0	0	0	0	3	4.33	439	898	0.49
	10:15	138	511	0.27	1	1	1	1	0	1	0	0	0	5		557	861	0.65
	11:45	85.6	308	0.28	1	1	1	1	0	1	0	0	0	5		460	659	0.70
	01:15	137	497	0.28	1	1	1	1	0	1	0	0	0	5		558	848	0.66
	02:45	189	699	0.27	1	1	1	0	0	0	0	0	0	3		432	896	0.48
	04:15	107	384	0.28	1	1	1	1	0	1	0	0	0	5		529	735	0.72
01 October 2021	08:45	266	1017	0.26	1	0	1	0	0	0	0	0	0	2	3.33	487	1136	0.43
	10:15	185	711	0.26	1	1	1	0	0	0	0	0	0	3		435	907	0.48
	11:45	138	515	0.27	1	1	1	1	0	1	0	0	0	5		559	865	0.65
	01:15	229	862	0.27	1	1	1	0	0	0	0	0	0	3		502	1058	0.47
	02:45	258	936	0.28	1	0	1	0	0	0	0	0	0	2		478	1054	0.45
	04:15	92.6	325	0.28	1	1	1	1	0	1	0	0	0	5		508	676	0.75
01 December 2021	08:45	346	1279	0.27	1	0	1	0	0	0	0	0	0	2	2.67	576	1398	0.41
	10:15	372	1399	0.27	1	0	1	0	0	0	0	0	0	2		593	1517	0.39
	11:45	354	1306	0.27	1	1	1	0	0	0	0	0	0	3		549	1424	0.39
	01:15	358	1427	0.25	1	0	1	0	0	0	0	0	0	2		611	1546	0.40
	02:45	296	1055	0.28	1	0	1	0	0	0	0	0	0	2		514	1174	0.44
	04:15	81.9	273	0.30	1	1	1	1	0	1	0	0	0	5		460	623	0.74

Table 40: Simulation data. Case1, South, 80% WWR

Date	Time	Before			Luminaire Status (ON=1, OFF=0)									Luminaires		After		
		E_m	E_{avg}	U_1	L1	L2	L3	L4	L5	L6	L7	L8	L9	Total	Avg.	E_m	E_{avg}	U_1
01 February 2021	08:45 AM	404	1378	0.29	1	0	1	0	0	0	0	0	0	2	2.17	659	1496	0.44
	10:15 AM	472	1632	0.29	1	0	1	0	0	0	0	0	0	2		702	1751	0.40
	11:45 AM	407	1380	0.29	1	0	1	0	0	0	0	0	0	2		604	1498	0.40
	01:15 PM	448	1578	0.28	1	0	1	0	0	0	0	0	0	2		686	1696	0.40
	02:45 PM	438	1503	0.29	1	0	1	0	0	0	0	0	0	2		1621	696	0.43
	04:15 PM	184	601	0.31	1	1	1	0	0	0	0	0	0	3		424	796	0.53
01 April 2021	08:45 AM	324	1109	0.29	1	0	1	0	0	0	0	0	0	2	2.83	562	1228	0.46
	10:15 AM	227	803	0.28	1	1	1	0	0	0	0	0	0	3		494	999	0.49
	11:45 AM	250	922	0.27	1	1	1	0	0	0	0	0	0	3		525	1118	0.47
	01:15 PM	222	809	0.27	1	1	1	0	0	0	0	0	0	3		498	1005	0.50
	02:45 PM	330	1100	0.30	1	0	1	0	0	0	0	0	0	2		561	1218	0.46
	04:15 PM	161	519	0.31	1	1	1	1	0	0	0	0	0	4		507	792	0.64
01 June 2021	08:45 AM	250	830	0.30	1	0	1	0	0	0	0	0	0	2	3.50	460	949	0.48
	10:15 AM	182	603	0.30	1	1	1	0	0	1	0	0	0	4		494	875	0.56
	11:45 AM	126	415	0.30	1	1	1	1	0	1	0	0	0	5		551	764	0.72
	01:15 PM	192	653	0.29	1	1	1	0	0	0	0	0	0	3		439	848	0.52
	02:45 PM	242	813	0.30	1	0	1	0	0	0	0	0	0	2		453	931	0.49
	04:15 PM	126	405	0.31	1	1	1	1	0	1	0	0	0	5		548	754	0.73
01 August 2021	08:45 AM	254	878	0.29	1	0	1	0	0	0	0	0	0	2	3.50	483	997	0.48
	10:15 AM	187	648	0.29	1	1	1	0	0	0	0	0	0	3		434	884	0.51
	11:45 AM	119	399	0.30	1	1	1	1	0	1	0	0	0	5		528	749	0.70
	01:15 PM	186	631	0.29	1	1	1	0	1	0	0	0	0	4		468	929	0.50
	02:45 PM	257	875	0.29	1	0	1	0	0	0	0	0	0	2		482	993	0.49
	04:15 PM	145	477	0.30	1	1	1	1	0	1	0	0	0	5		567	826	0.69
01 October 2021	08:45 AM	369	1272	0.29	1	0	1	0	0	0	0	0	0	2	2.83	611	1391	0.44
	10:15 AM	249	911	0.27	1	0	1	0	0	0	0	0	0	2		454	1029	0.44
	11:45 AM	186	673	0.28	1	1	1	1	0	0	0	0	0	4		466	945	0.49
	01:15 PM	297	1094	0.27	1	0	1	0	0	0	0	0	0	2		526	1213	0.43
	02:45 PM	352	1168	0.30	1	0	1	0	0	0	0	0	0	2		590	1286	0.46
	04:15 PM	129	403	0.32	1	1	1	1	0	1	0	0	0	5		555	753	0.74
01 December 2021	08:45 AM	477	1597	0.30	1	0	1	0	0	0	0	0	0	2	2.50	734	1715	0.43
	10:15 AM	513	1767	0.29	1	0	1	0	0	0	0	0	0	2		755	1885	0.40
	11:45 AM	492	1660	0.30	1	0	1	0	0	0	0	0	0	2		704	1779	0.40
	01:15 PM	516	1795	0.29	1	0	1	0	0	0	0	0	0	2		777	1914	0.41
	02:45 PM	397	1310	0.30	1	0	1	0	0	0	0	0	0	2		646	1429	0.45
	04:15 PM	107	338	0.32	1	1	1	1	0	1	0	0	0	5		517	687	0.75

Table 41: Simulation data. Case1, West, 20% WWR

Date	Time	Before			Luminaire Status (ON=1, OFF=0)									Luminaires		After		
		E_m	E_{avg}	U_1	L1	L2	L3	L4	L5	L6	L7	L8	L9	Total	Avg.	E_m	E_{avg}	U_1
01 February 2021	08:45 AM	43.5	175	0.25	1	1	1	1	1	1	0	0	1	7	5.50	472	689	0.69
	10:15 AM	50.7	213	0.24	1	1	1	1	1	1	0	0	0	6		437	669	0.65
	11:45 AM	56.9	240	0.24	1	1	1	1	1	1	0	0	0	6		447	696	0.64
	01:15 PM	104	454	0.23	1	1	1	1	0	1	0	0	0	5		521	808	0.64
	02:45 PM	146	644	0.23	1	1	1	0	1	0	0	0	0	4		417	945	0.44
	04:15 PM	75.9	291	0.26	1	1	1	1	0	1	0	0	0	5		470	644	0.73
01 April 2021	08:45 AM	47.5	178	0.27	1	1	1	1	1	1	0	0	0	6	5.83	437	634	0.69
	10:15 AM	39.6	146	0.27	1	1	1	1	1	1	1	0	1	8		491	718	0.68
	11:45 AM	64.9	229	0.28	1	1	1	1	1	1	0	0	0	6		444	686	0.65
	01:15 PM	92.4	386	0.24	1	1	1	1	0	1	0	0	0	5		494	740	0.67
	02:45 PM	180	725	0.25	1	1	1	0	1	0	0	0	0	4		476	1025	0.46
	04:15 PM	91.7	340	0.27	1	1	1	1	1	1	0	0	0	6		506	694	0.73
01 June 2021	08:45 AM	47.5	190	0.25	1	1	1	1	1	1	0	0	0	6	5.67	428	646	0.66
	10:15 AM	41.8	173	0.24	1	1	1	1	1	1	1	0	0	7		459	687	0.67
	11:45 AM	44.8	181	0.25	1	1	1	1	1	1	1	0	0	7		457	696	0.66
	01:15 PM	101	444	0.23	1	1	1	1	0	1	0	0	0	5		523	797	0.66
	02:45 PM	153	677	0.23	1	1	1	1	0	0	0	0	0	4		466	952	0.49
	04:15 PM	77.5	307	25.00	1	1	1	1	0	1	0	0	0	5		479	660	0.73
01 August 2021	08:45 AM	42.9	184	0.23	1	1	1	1	1	1	0	0	0	6	5.83	427	640	0.67
	10:15 AM	41.8	164	0.25	1	1	1	1	1	1	1	0	0	7		437	678	0.64
	11:45 AM	38.7	150	0.26	1	1	1	1	1	1	1	0	1	8		494	723	0.68
	01:15 PM	91.3	392	0.23	1	1	1	1	0	1	0	0	0	5		497	745	0.67
	02:45 PM	152	697	0.22	1	1	1	1	0	0	0	0	0	4		462	973	0.47
	04:15 PM	92.1	360	0.26	1	1	1	1	0	1	0	0	0	5		515	713	0.72
01 October 2021	08:45 AM	47.2	183	0.26	1	1	1	1	1	1	0	0	0	6	5.83	434	640	0.68
	10:15 AM	38.8	148	0.26	1	1	1	1	1	1	0	1	0	7		456	738	0.62
	11:45 AM	42.3	163	0.26	1	1	1	1	1	1	0	1	0	7		421	695	0.61
	01:15 PM	112	481	0.23	1	1	1	1	0	1	0	0	0	5		531	835	0.64
	02:45 PM	164	695	0.24	1	1	1	0	1	0	0	0	0	4		450	995	0.45
	04:15 PM	67.2	236	0.28	1	1	1	1	1	1	0	0	0	6		499	692	0.72
01 December 2021	08:45 AM	47.4	195	0.24	1	1	1	1	1	1	0	0	0	6	5.83	422	652	0.65
	10:15 AM	58.1	236	0.25	1	1	1	1	1	1	0	0	0	6		452	692	0.65
	11:45 AM	71.1	313	0.23	1	1	1	1	0	1	0	0	0	5		456	666	0.68
	01:15 PM	123	544	0.23	1	1	1	1	0	1	0	0	0	5		553	897	0.62
	02:45 PM	125	552	0.23	1	1	1	1	0	1	0	0	0	5		542	905	0.60
	04:15 PM	38.6	151	0.26	1	1	1	1	1	1	1	0	1	8		486	724	0.67

Table 42: Simulation data. Case1, West, 40% WWR

Date	Time	Before			Luminaire Status									Luminaires		After		
		E_m	E_{avg}	U_1	L1	L2	L3	L4	L5	L6	L7	L8	L9	Total	Avg.	E_m	E_{avg}	U_1
01 February 2021	08:45 AM	87	325	0.27	1	1	1	1	0	1	0	0	0	5	4.33	478	677	0.71
	10:15 AM	102	398	0.26	1	1	1	1	0	1	0	0	0	5		519	750	0.69
	11:45 AM	114	454	0.25	1	1	1	1	0	1	0	0	0	5		533	806	0.66
	01:15 PM	211	851	0.25	1	1	1	0	0	0	0	0	0	3		471	1048	0.45
	02:45 PM	300	1188	0.25	1	1	1	0	0	0	0	0	0	3		591	1385	0.43
	04:15 PM	144	535	0.27	1	1	1	1	0	1	0	0	0	5		557	887	0.63
01 April 2021	08:45 AM	90.5	332	0.27	1	1	1	1	0	1	0	0	0	5	4.50	483	684	0.71
	10:15 AM	76	275	0.28	1	1	1	1	1	1	0	0	0	6		511	730	0.70
	11:45 AM	125	454	0.28	1	1	1	1	0	1	0	0	0	5		520	806	0.65
	01:15 PM	182	731	0.25	1	1	1	0	1	0	0	0	0	4		491	1031	0.48
	02:45 PM	345	1337	0.26	1	1	1	0	0	0	0	0	0	3		697	1534	0.45
	04:15 PM	183	625	0.29	1	1	1	0	1	0	0	0	0	4		467	926	0.50
01 June 2021	08:45 AM	90.7	355	0.26	1	1	1	1	0	1	0	0	0	5	4.00	497	707	0.70
	10:15 AM	85.5	326	0.26	1	1	1	1	0	1	0	0	0	5		474	678	0.70
	11:45 AM	87.4	347	0.25	1	1	1	1	0	1	0	0	0	5		478	699	0.68
	01:15 PM	197	833	0.24	1	1	1	0	0	0	0	0	0	3		457	1030	0.44
	02:45 PM	313	1247	0.25	1	0	1	0	0	0	0	0	0	2		529	1367	0.39
	04:15 PM	152	565	0.27	1	1	1	1	0	0	0	0	0	4		455	839	0.54
01 August 2021	08:45 AM	92.3	343	0.27	1	1	1	1	0	1	0	0	0	5	4.17	486	695	0.70
	10:15 AM	81.1	309	0.26	1	1	1	1	0	1	0	0	0	5		461	661	0.70
	11:45 AM	74.5	291	0.26	1	1	1	1	1	1	0	0	0	6		502	745	0.67
	01:15 PM	179	740	0.24	1	1	1	0	0	0	0	0	0	3		430	937	0.46
	02:45 PM	316	1287	0.25	1	1	1	0	0	0	0	0	0	3		631	1484	0.43
	04:15 PM	178	662	0.27	1	1	1	0	0	0	0	0	0	3		424	859	0.49
01 October 2021	08:45 AM	91.6	342	0.27	1	1	1	1	0	1	0	0	0	5	4.67	487	694	0.70
	10:15 AM	73.4	282	0.26	1	1	1	1	1	1	0	0	0	6		508	736	0.69
	11:45 AM	80.8	316	0.26	1	1	1	1	1	1	0	0	0	6		516	770	0.67
	01:15 PM	223	906	0.25	1	1	1	0	0	0	0	0	0	3		509	1103	0.46
	02:45 PM	335	1281	0.26	1	1	1	0	0	0	0	0	0	3		662	1478	0.45
	04:15 PM	128	434	0.29	1	1	1	1	0	1	0	0	0	5		543	786	0.69
01 December 2021	08:45 AM	94.2	364	0.26	1	1	1	1	0	1	0	0	0	5	4.33	505	716	0.71
	10:15 AM	113	442	0.26	1	1	1	1	0	1	0	0	0	5		530	794	0.67
	11:45 AM	144	587	0.25	1	1	1	1	0	1	0	0	0	5		563	939	0.60
	01:15 PM	247	1014	0.24	1	1	1	0	0	0	0	0	0	3		519	1211	0.43
	02:45 PM	250	1014	0.25	1	1	1	0	0	0	0	0	0	3		530	1211	0.44
	04:15 PM	76.9	280	0.27	1	1	1	1	0	1	0	0	0	5		461	632	0.73

Table 43: Simulation data. Case1, West, 60% WWR

Date	Time	Before			Luminaire Status									Luminaires		After		
		E_m	E_{avg}	U_1	L1	L2	L3	L4	L5	L6	L7	L8	L9	Total	Avg.	E_m	E_{avg}	U_1
01 February 2021	08:45 AM	124	431	0.29	1	1	1	1	0	1	0	0	0	5	3.50	540	781	0.69
	10:15 AM	152	531	0.29	1	1	1	1	0	1	0	0	0	5		569	882	0.65
	11:45 AM	165	613	0.27	1	1	1	0	0	1	0	0	0	4		481	886	0.54
	01:15 PM	295	1146	0.26	1	0	1	0	0	0	0	0	0	2		511	1265	0.40
	02:45 PM	424	1566	0.27	1	0	1	0	0	0	0	0	0	2		664	1685	0.39
	04:15 PM	220	695	0.32	1	1	1	0	0	0	0	0	0	3		483	891	0.54
01 April 2021	08:45 AM	137	442	0.31	1	1	1	1	0	1	0	0	0	5	3.33	555	792	0.70
	10:15 AM	110	372	0.30	1	1	1	1	0	1	0	0	0	5		513	722	0.71
	11:45 AM	181	650	0.28	1	1	1	0	0	1	0	0	0	4		452	948	0.48
	01:15 PM	273	1000	0.27	1	0	1	0	0	0	0	0	0	2		464	1119	0.41
	02:45 PM	514	1764	0.29	1	0	1	0	0	0	0	0	0	2		726	1883	0.39
	04:15 PM	261	812	0.32	1	0	1	0	0	0	0	0	0	2		465	931	0.50
01 June 2021	08:45 AM	137	470	0.29	1	1	1	1	0	1	0	0	0	5	3.67	559	821	0.68
	10:15 AM	129	440	0.29	1	1	1	1	0	1	0	0	0	5		551	790	0.70
	11:45 AM	124	478	0.26	1	1	1	1	0	1	0	0	0	5		546	828	0.66
	01:15 PM	300	1127	0.27	1	0	1	0	0	0	0	0	0	2		498	1246	0.40
	02:45 PM	443	1641	0.27	1	0	1	0	0	0	0	0	0	2		706	1760	0.40
	04:15 PM	230	732	0.31	1	1	1	0	0	0	0	0	0	3		490	928	0.53
01 August 2021	08:45 AM	123	454	0.27	1	1	1	1	0	1	0	0	0	5	3.50	552	805	0.69
	10:15 AM	120	416	0.29	1	1	1	1	0	1	0	0	0	5		542	767	0.71
	11:45 AM	108	404	0.27	1	1	1	1	0	1	0	0	0	5		518	754	0.69
	01:15 PM	260	1007	0.26	1	0	1	0	0	0	0	0	0	2		474	1126	0.42
	02:45 PM	471	1701	0.28	1	0	1	0	0	0	0	0	0	2		0.39	1820	0.39
	04:15 PM	277	859	0.32	1	0	1	0	0	0	0	0	0	2		477	978	0.49
01 October 2021	08:45 AM	134	454	0.30	1	1	1	1	0	1	0	0	0	5	3.83	551	805	0.68
	10:15 AM	106	381	0.28	1	1	1	1	0	1	0	0	0	5		520	732	0.71
	11:45 AM	120	441	0.27	1	1	1	1	0	1	0	0	0	5		536	791	0.68
	01:15 PM	318	1225	0.26	1	0	1	0	0	0	0	0	0	2		521	1343	0.39
	02:45 PM	492	1681	0.29	1	0	1	0	0	0	0	0	0	2		727	1800	0.40
	04:15 PM	187	562	0.33	1	1	1	0	1	0	0	0	0	4		484	860	0.56
01 December 2021	08:45 AM	139	482	0.29	1	1	1	1	0	1	0	0	0	5	3.50	556	832	0.67
	10:15 AM	165	590	0.28	1	1	1	0	0	1	0	0	0	4		490	863	0.57
	11:45 AM	209	790	0.26	1	1	1	0	0	0	0	0	0	3		463	986	0.47
	01:15 PM	355	1350	0.26	1	0	1	0	0	0	0	0	0	2		593	1469	0.40
	02:45 PM	370	1325	0.28	1	0	1	0	0	0	0	0	0	2		612	1444	0.42
	04:15 PM	113	362	0.31	1	1	1	1	0	1	0	0	0	5		526	712	0.74

Table 44: Simulation data. Case1, West, 80% WWR

Date	Time	Before			Luminaire Status (ON=1, OFF=0)									Luminaires		After		
		E_m	E_{avg}	U_1	L1	L2	L3	L4	L5	L6	L7	L8	L9	Total	Avg.	E_m	E_{avg}	U_1
01 February 2021	08:45 AM	170	537	0.32	1	1	1	0	1	0	0	0	0	4	2.67	451	835	0.54
	10:15 AM	201	669	0.30	1	1	1	0	0	0	0	0	0	3		461	864	0.53
	11:45 AM	218	779	0.28	1	1	1	0	0	0	0	0	0	3		493	974	0.51
	01:15 PM	405	1450	0.28	1	0	1	0	0	0	0	0	0	2		649	1569	0.41
	02:45 PM	585	1952	0.30	1	0	1	0	0	0	0	0	0	2		874	2070	0.42
	04:15 PM	296	856	0.35	1	0	1	0	0	0	0	0	0	2		515	975	0.53
01 April 2021	08:45 AM	183	553	0.33	1	1	1	0	1	0	0	0	0	4	3.00	491	851	0.58
	10:15 AM	148	473	0.31	1	1	1	1	0	1	0	0	0	5		573	823	0.70
	11:45 AM	244	863	0.28	1	1	1	0	0	0	0	0	0	3		507	1059	0.48
	01:15 PM	378	1280	0.30	1	0	1	0	0	0	0	0	0	2		564	1399	0.40
	02:45 PM	723	2210	0.33	1	0	1	0	0	0	0	0	0	2		995	2328	0.41
	04:15 PM	367	1001	0.37	1	0	1	0	0	0	0	0	0	2		581	1119	0.52
01 June 2021	08:45 AM	177	590	0.30	1	1	1	1	0	0	0	0	0	4	3.00	514	862	0.60
	10:15 AM	168	556	0.30	1	1	1	1	0	0	0	0	0	4		473	829	0.57
	11:45 AM	174	615	0.28	1	1	1	1	0	0	0	0	0	4		483	888	0.54
	01:15 PM	399	1436	0.28	1	0	1	0	0	0	0	0	0	2		629	1555	0.40
	02:45 PM	623	2050	0.30	1	0	1	0	0	0	0	0	0	2		903	2168	0.42
	04:15 PM	313	903	0.35	1	0	1	0	0	0	0	0	0	2		533	1021	0.52
01 August 2021	08:45 AM	182	569	0.32	1	1	1	1	0	0	0	0	0	4	3.17	497	841	0.59
	10:15 AM	162	528	0.31	1	1	1	1	0	0	0	0	0	4		454	801	0.57
	11:45 AM	150	524	0.29	1	1	1	1	0	1	0	0	0	5		574	873	0.66
	01:15 PM	353	1288	0.27	1	0	1	0	0	0	0	0	0	2		577	1406	0.41
	02:45 PM	647	2127	0.30	1	0	1	0	0	0	0	0	0	2		905	2245	0.40
	04:15 PM	361	1059	0.34	1	0	1	0	0	0	0	0	0	2		600	1177	0.51
01 October 2021	08:45 AM	183	570	0.32	1	1	1	0	0	1	0	0	0	4	3.33	483	843	0.57
	10:15 AM	148	486	0.30	1	1	1	1	0	1	0	0	0	5		567	835	0.68
	11:45 AM	156	574	0.27	1	1	1	1	0	1	0	0	0	5		584	923	0.63
	01:15 PM	443	1559	0.28	1	0	1	0	0	0	0	0	0	2		670	1677	0.40
	02:45 PM	683	2095	0.33	1	0	1	0	0	0	0	0	0	2		931	2214	0.42
	04:15 PM	262	692	0.38	1	0	1	0	0	0	0	0	0	2		455	811	0.56
01 December 2021	08:45 AM	188	602	0.31	1	1	1	0	0	0	0	0	0	3	2.67	440	798	0.55
	10:15 AM	219	743	0.29	1	1	1	0	0	0	0	0	0	3		488	938	0.52
	11:45 AM	286	1000	0.29	1	0	1	0	0	0	0	0	0	2		501	1118	0.45
	01:15 PM	472	1698	0.28	1	0	1	0	0	0	0	0	0	2		746	1817	0.41
	02:45 PM	515	1645	0.31	1	0	1	0	0	0	0	0	0	2		783	1764	0.44
	04:15 PM	152	446	0.34	1	1	1	0	0	1	0	0	0	4		444	718	0.62

Table 45: Simulation data. Case2, North, 20% WWR

Date	Time	Before			Luminaire Status												Luminaires		After		
		E_m	E_{avg}	U_1	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	Total	Avg.	E_m	E_{avg}	U_1
01 February 2021	08:45 AM	56.6	243	0.23	1	1	1	1	1	1	1	1	0	0	0	0	8	8.67	439	710	0.62
	10:15 AM	54.6	221	0.25	1	1	1	1	1	1	1	1	0	0	0	0	8		429	688	0.62
	11:45 AM	44.2	158	0.28	1	1	1	1	1	1	1	1	1	0	0	1	10		499	710	0.70
	01:15 PM	52.9	204	0.26	1	1	1	1	1	1	1	1	0	0	0	0	8		416	671	0.62
	02:45 PM	61.1	254	0.24	1	1	1	1	1	1	1	1	0	0	0	0	8		450	721	0.62
	04:15 PM	31.8	133	0.24	1	1	1	1	1	1	1	1	1	0	0	1	10		485	684	0.71
01 April 2021	08:45 AM	82	364	0.23	1	1	1	1	1	0	0	1	0	0	0	0	6	7.50	488	748	0.65
	10:15 AM	57.7	232	0.25	1	1	1	1	1	1	1	1	0	0	0	0	8		430	699	0.62
	11:45 AM	65.6	221	0.30	1	1	1	1	1	1	1	1	0	0	0	0	8		429	688	0.62
	01:15 PM	55.8	235	0.24	1	1	1	1	1	1	1	1	0	0	0	0	8		434	702	0.62
	02:45 PM	86	366	0.23	1	1	1	1	1	0	0	1	0	0	0	0	6		519	758	0.68
	04:15 PM	45.6	188	0.24	1	1	1	1	1	1	1	1	0	0	0	1	9		494	697	0.71
01 June 2021	08:45 AM	108	491	0.22	1	1	1	1	1	0	0	1	0	0	0	0	6	7.00	473	807	0.59
	10:15 AM	87.6	371	0.24	1	1	1	1	1	1	0	1	0	0	0	0	7		506	762	0.66
	11:45 AM	67	258	0.26	1	1	1	1	1	1	1	1	0	0	0	0	8		477	725	0.66
	01:15 PM	93.9	402	0.23	1	1	1	1	1	1	0	1	0	0	0	0	7		513	793	0.65
	02:45 PM	109	482	0.23	1	1	1	1	1	0	0	1	0	0	0	0	6		465	798	0.58
	04:15 PM	51.4	220	0.23	1	1	1	1	1	1	1	1	0	0	0	0	8		407	687	0.59
01 August 2021	08:45 AM	101	459	0.22	1	1	1	1	1	0	0	1	0	0	0	0	6	7.00	456	775	0.59
	10:15 AM	78.7	342	0.23	1	1	1	1	1	0	1	1	0	0	0	0	7		474	733	0.65
	11:45 AM	57.2	208	0.28	1	1	1	1	1	1	1	1	0	0	0	0	8		427	675	0.63
	01:15 PM	81.1	335	0.24	1	1	1	1	1	1	0	1	0	0	0	0	7		470	726	0.65
	02:45 PM	105	463	0.23	1	1	1	1	1	0	0	1	0	0	0	0	6		462	779	0.59
	04:15 PM	57.3	240	0.24	1	1	1	1	1	1	1	1	0	0	0	0	8		426	707	0.60
01 October 2021	08:45 AM	72.9	321	..23	1	1	1	1	1	1	0	1	0	0	0	0	7	8.50	488	712	0.69
	10:15 AM	45.6	188	0.24	1	1	1	1	1	1	1	1	1	0	0	0	9		461	698	0.66
	11:45 AM	34.6	122	0.28	1	1	1	1	1	1	1	1	1	0	0	1	10		486	673	0.72
	01:15 PM	59	244	0.24	1	1	1	1	1	1	1	1	0	0	0	0	8		442	711	0.62
	02:45 PM	73.7	316	0.23	1	1	1	1	1	1	0	1	0	0	0	0	7		454	707	0.64
	04:15 PM	30.9	126	0.25	1	1	1	1	1	1	1	1	1	0	0	1	10		485	677	0.72
01 December 2021	08:45 AM	56.2	235	0.24	1	1	1	1	1	1	1	1	0	0	0	0	8	8.50	435	702	0.62
	10:15 AM	53	202	0.26	1	1	1	1	1	1	1	1	0	0	0	0	8		421	668	0.63
	11:45 AM	48.7	172	0.28	1	1	1	1	1	1	1	1	0	0	0	0	8		408	639	0.64
	01:15 PM	56.2	223	0.25	1	1	1	1	1	1	1	1	0	0	0	0	8		432	690	0.63
	02:45 PM	50.6	216	0.23	1	1	1	1	1	1	1	1	0	0	0	0	8		416	683	0.61
	04:15 PM	18.2	74	0.25	1	1	1	1	1	1	1	1	1	1	0	1	11		476	682	0.70

Table 46: Simulation data. Case2, North, 40% WWR

Date	Time	Before			Luminaire Status												Luminaires		After		
		E_m	E_{avg}	U_1	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	Total	Avg.	E_m	E_{avg}	U_1
01 February 2021	08:45 AM	112	452	0.25	1	1	1	1	1	0	0	1	0	0	0	0	6	6.67	470	767	0.61
	10:15 AM	109	414	0.26	1	1	1	1	1	0	0	1	0	0	0	0	6		436	728	0.60
	11:45 AM	85.6	299	0.29	1	1	1	1	1	0	1	1	0	0	0	0	7		460	688	0.67
	01:15 PM	102	384	0.27	1	1	1	1	1	1	0	1	0	0	0	0	7		514	773	0.66
	02:45 PM	115	474	0.24	1	1	1	1	1	0	0	1	0	0	0	0	6		478	788	0.61
	04:15 PM	60.9	247	0.25	1	1	1	1	1	1	1	1	0	0	0	0	8		441	712	0.62
01 April 2021	08:45 AM	167	680	0.25	1	1	1	1	1	0	0	0	0	0	0	0	5	6.00	527	938	0.56
	10:15 AM	106	439	0.24	1	1	1	1	1	0	0	1	0	0	0	0	6		442	753	0.59
	11:45 AM	128	436	0.29	1	1	1	1	1	1	0	1	0	0	0	0	7		526	826	0.64
	01:15 PM	109	446	0.24	1	1	1	1	1	0	0	1	0	0	0	0	6		445	760	0.59
	02:45 PM	165	683	0.24	1	1	1	1	0	0	0	1	0	0	0	0	5		529	941	0.56
	04:15 PM	91.6	349	0.26	1	1	1	1	1	1	0	1	0	0	0	0	7		493	738	0.67
01 June 2021	08:45 AM	207	915	0.23	1	1	1	1	0	0	0	0	0	0	0	0	4	5.00	468	1116	0.42
	10:15 AM	177	700	0.25	1	1	1	1	1	0	0	0	0	0	0	0	5		490	958	0.51
	11:45 AM	135	494	0.27	1	1	1	1	1	0	0	1	0	0	0	0	6		462	808	0.57
	01:15 PM	186	755	0.25	1	1	1	1	0	0	0	1	0	0	0	0	5		518	1013	0.51
	02:45 PM	218	897	0.24	1	1	1	1	0	0	0	0	0	0	0	0	4		461	1099	0.42
	04:15 PM	98.8	407	0.24	1	1	1	1	1	0	0	1	0	0	0	0	6		443	721	0.61
01 August 2021	08:45 AM	201	854	0.24	1	1	1	1	0	0	0	0	0	0	0	0	4	5.17	452	1056	0.43
	10:15 AM	161	646	0.25	1	1	1	1	1	0	0	0	0	0	0	0	5		466	904	0.52
	11:45 AM	108	401	0.27	1	1	1	1	1	1	0	1	0	0	0	0	7		511	790	0.65
	01:15 PM	151	633	0.24	1	1	1	1	0	0	0	1	0	0	0	0	5		457	890	0.51
	02:45 PM	210	862	0.24	1	1	1	1	0	0	0	0	0	0	0	0	4		453	1064	0.43
	04:15 PM	110	445	0.25	1	1	1	1	1	0	0	1	0	0	0	0	6		469	759	0.62
01 October 2021	08:45 AM	150	599	0.25	1	1	1	1	1	0	0	0	0	0	0	0	5	6.50	492	857	0.57
	10:15 AM	92.2	357	0.26	1	1	1	1	1	1	0	1	0	0	0	0	7		506	746	0.68
	11:45 AM	69.7	235	0.30	1	1	1	1	1	1	1	1	0	0	0	0	8		460	700	0.66
	01:15 PM	120	460	0.26	1	1	1	1	1	0	0	1	0	0	0	0	6		459	774	0.59
	02:45 PM	141	588	0.24	1	1	1	1	0	0	0	1	0	0	0	0	5		489	846	0.58
	04:15 PM	58.4	234	0.25	1	1	1	1	1	1	1	1	0	0	0	0	8		426	698	0.61
01 December 2021	08:45 AM	110	439	0.25	1	1	1	1	1	0	0	1	0	0	0	0	6	7.00	460	753	0.61
	10:15 AM	97.6	378	0.26	1	1	1	1	1	1	0	1	0	0	0	0	7		525	767	0.68
	11:45 AM	93.6	325	0.29	1	1	1	1	1	1	0	1	0	0	0	0	7		480	714	0.67
	01:15 PM	106	417	0.25	1	1	1	1	1	0	0	1	0	0	0	0	6		440	731	0.60
	02:45 PM	99.4	403	0.25	1	1	1	1	1	0	0	1	0	0	0	0	6		437	717	0.61
	04:15 PM	35.3	138	0.26	1	1	1	1	1	1	1	1	1	0	0	1	10		487	685	0.71

Table 47: Simulation data. Case2, North, 60% WWR

Date	Time	Before			Luminaire Status (ON=1, OFF=0)												Luminaires		After		
		E_m	E_{avg}	U_1	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	Total	Avg.	E_m	E_{avg}	U_1
01 February 2021	08:45 AM	173	603	0.29	1	1	1	1	1	0	0	0	0	0	0	0	5	5.67	526	860	0.61
	10:15 AM	153	557	0.27	1	1	1	1	1	0	0	0	0	0	0	0	5		467	814	0.57
	11:45 AM	128	406	0.32	1	1	1	1	1	0	0	1	0	0	0	0	6		442	719	0.61
	01:15 PM	145	518	0.28	1	1	1	1	1	0	0	1	0	0	0	0	6		523	831	0.63
	02:45 PM	174	632	0.28	1	1	1	1	0	0	0	1	0	0	0	0	5		539	889	0.61
	04:15 PM	93.2	327	0.29	1	1	1	1	1	1	0	1	0	0	0	0	7		486	715	0.68
01 April 2021	08:45 AM	247	909	0.27	1	1	0	1	0	0	0	0	0	0	0	0	3	4.67	500	1052	0.48
	10:15 AM	161	600	0.27	1	1	1	1	1	0	0	0	0	0	0	0	5		476	857	0.65
	11:45 AM	186	626	0.30	1	1	1	1	1	0	0	1	0	0	0	0	6		525	939	0.56
	01:15 PM	163	609	0.27	1	1	1	1	0	0	0	1	0	0	0	0	5		473	866	0.55
	02:45 PM	232	913	0.25	1	0	1	1	0	0	0	0	0	0	0	0	3		500	1057	0.47
	04:15 PM	131	461	0.28	1	1	1	1	1	0	0	1	0	0	0	0	6		507	774	0.66
01 June 2021	08:45 AM	324	1221	0.27	1	0	1	0	0	0	0	0	0	0	0	0	2	3.33	513	1322	0.39
	10:15 AM	246	956	0.26	1	1	0	1	0	0	0	0	0	0	0	0	3		507	1100	0.46
	11:45 AM	200	688	0.29	1	1	1	1	0	0	0	0	0	0	0	0	4		439	889	0.49
	01:15 PM	269	1030	0.26	1	1	0	1	0	0	0	0	0	0	0	0	3		524	1174	0.45
	02:45 PM	315	1198	0.26	1	0	1	1	0	0	0	0	0	0	0	0	3		595	1342	0.44
	04:15 PM	151	537	0.28	1	1	1	1	0	0	0	1	0	0	0	0	5		484	794	0.61
01 August 2021	08:45 AM	297	1140	0.26	1	1	0	1	0	0	0	0	0	0	0	0	3	3.67	577	1284	0.45
	10:15 AM	230	881	0.26	1	1	0	1	0	0	0	0	0	0	0	0	3		469	1025	0.46
	11:45 AM	148	563	0.26	1	1	1	1	1	0	0	1	0	0	0	0	6		511	876	0.58
	01:15 PM	236	865	0.27	1	0	1	1	0	0	0	0	0	0	0	0	3		463	1009	0.46
	02:45 PM	309	1154	0.27	0	1	0	1	0	0	0	0	0	0	0	0	2		487	1254	0.39
	04:15 PM	168	589	0.29	1	1	1	1	0	0	0	1	0	0	0	0	5		522	845	0.62
01 October 2021	08:45 AM	218	802	0.27	1	1	0	1	0	0	0	0	0	0	0	0	3	5.17	464	946	0.49
	10:15 AM	133	487	0.27	1	1	1	1	1	0	0	1	0	0	0	0	6		491	800	0.61
	11:45 AM	98	327	0.30	1	1	1	1	1	1	0	1	0	0	0	0	7		469	715	0.66
	01:15 PM	171	624	0.27	1	1	1	1	0	0	0	1	0	0	0	0	5		502	881	0.57
	02:45 PM	213	784	0.27	1	0	1	1	0	0	0	0	0	0	0	0	3		454	928	0.49
	04:15 PM	90.2	309	0.29	1	1	1	1	1	0	1	1	0	0	0	0	7		496	697	0.71
01 December 2021	08:45 AM	162	586	0.28	1	1	1	1	1	0	0	0	0	0	0	0	5	6.00	516	843	0.61
	10:15 AM	149	508	0.29	1	1	1	1	1	0	0	1	0	0	0	0	6		515	821	0.63
	11:45 AM	140	439	0.32	1	1	1	1	1	0	0	1	0	0	0	0	6		468	752	0.62
	01:15 PM	153	560	0.27	1	1	1	1	0	0	0	1	0	0	0	0	5		477	817	0.58
	02:45 PM	154	537	0.29	1	1	1	1	0	0	0	1	0	0	0	0	5		483	794	0.68
	04:15 PM	51	182	0.28	1	1	1	1	1	1	1	1	0	0	0	1	9		488	686	0.71

Table 48: Simulation data. Case2, North, 80% WWR

Date	Time	Before			Luminaire Status (ON=1, OFF=0)												Luminaires		After		
		E_m	E_{avg}	U_1	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	Total	Avg.	E_m	E_{avg}	U_1
01 February 2021	08:45 AM	228	751	0.30	1	1	0	1	0	0	0	0	0	0	0	0	3	4.33	474	894	0.53
	10:15 AM	216	700	0.31	1	1	1	1	0	0	0	0	0	0	0	0	4		461	900	0.51
	11:45 AM	171	513	0.33	1	1	1	1	1	0	0	1	0	0	0	0	6		539	825	0.65
	01:15 PM	201	652	0.31	1	1	1	1	0	0	0	0	0	0	0	0	4		453	852	0.53
	02:45 PM	238	789	0.30	1	0	1	1	0	0	0	0	0	0	0	0	3		488	932	0.52
	04:15 PM	121	406	0.30	1	1	1	1	1	0	0	1	0	0	0	0	6		492	717	0.69
01 April 2021	08:45 AM	329	1134	0.29	1	0	1	0	0	0	0	0	0	0	0	0	2	3.50	531	1234	0.43
	10:15 AM	211	761	0.28	1	1	1	1	0	0	0	0	0	0	0	0	4		470	961	0.49
	11:45 AM	240	826	0.29	1	1	1	1	0	0	0	0	0	0	0	0	4		496	1026	0.48
	01:15 PM	230	774	0.30	1	1	1	1	0	0	0	0	0	0	0	0	4		476	974	0.49
	02:45 PM	332	1139	0.29	0	1	0	1	0	0	0	0	0	0	0	0	2		524	1239	0.42
	04:15 PM	177	571	0.31	1	1	1	1	0	0	0	1	0	0	0	0	5		549	827	0.66
01 June 2021	08:45 AM	446	1527	0.29	1	0	0	0	0	0	0	0	0	0	0	0	1	2.67	605	1570	0.39
	10:15 AM	347	1216	0.29	1	0	1	1	0	0	0	0	0	0	0	0	3		579	1359	0.43
	11:45 AM	260	889	0.29	1	1	0	1	0	0	0	0	0	0	0	0	3		465	1032	0.45
	01:15 PM	365	1307	0.28	1	0	1	1	0	0	0	0	0	0	0	0	3		645	1450	0.44
	02:45 PM	422	1494	0.28	0	1	0	1	0	0	0	0	0	0	0	0	2		663	1594	0.42
	04:15 PM	197	664	0.30	1	1	1	1	0	0	0	0	0	0	0	0	4		434	864	0.50
01 August 2021	08:45 AM	405	1424	0.28	1	0	0	0	0	0	0	0	0	0	0	0	1	2.50	567	1467	0.39
	10:15 AM	317	1121	0.28	1	1	0	1	0	0	0	0	0	0	0	0	3		579	1264	0.46
	11:45 AM	212	733	0.29	1	1	1	1	0	0	0	0	0	0	0	0	4		461	933	0.49
	01:15 PM	300	1100	0.27	1	0	1	1	0	0	0	0	0	0	0	0	3		569	1243	0.46
	02:45 PM	417	1442	0.29	0	0	0	1	0	0	0	0	0	0	0	0	1		575	1485	0.39
	04:15 PM	226	728	0.31	1	0	1	1	0	0	0	0	0	0	0	0	3		467	871	0.54
01 October 2021	08:45 AM	293	1002	0.29	1	1	0	1	0	0	0	0	0	0	0	0	3	4.17	565	1146	0.49
	10:15 AM	180	621	0.29	1	1	1	1	1	0	0	0	0	0	0	0	5		511	877	0.58
	11:45 AM	133	424	0.31	1	1	1	1	1	0	0	1	0	0	0	0	6		446	735	0.61
	01:15 PM	230	787	0.29	1	0	1	1	0	0	0	0	0	0	0	0	3		461	930	0.50
	02:45 PM	278	976	0.28	0	1	0	1	0	0	0	0	0	0	0	0	2		446	1077	0.41
	04:15 PM	122	383	0.32	1	1	1	1	1	0	0	1	0	0	0	0	6		475	694	0.68
01 December 2021	08:45 AM	226	730	0.31	1	1	1	1	0	0	0	0	0	0	0	0	4	4.67	478	930	0.51
	10:15 AM	200	639	0.31	1	1	1	1	0	0	0	0	0	0	0	0	4		442	840	0.53
	11:45 AM	189	554	0.34	1	1	1	1	0	0	0	0	0	0	0	0	4		427	754	0.57
	01:15 PM	219	703	0.31	1	1	1	1	0	0	0	0	0	0	0	0	4		473	903	0.52
	02:45 PM	200	668	0.30	1	1	1	1	0	0	0	0	0	0	0	0	4		442	868	0.51
	04:15 PM	71.9	227	0.32	1	1	1	1	1	1	1	1	0	0	0	0	8		422	688	0.61

Table 49: Simulation data. Case2, East, 20% WWR

Date	Time	Before			Luminaire Status (ON=1, OFF=0)												Luminaires		After		
		E_m	E_{avg}	U_1	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	Total	Avg.	E_m	E_{avg}	U_1
01 February 2021	08:45 AM	150	633	0.24	1	1	1	1	1	0	0	0	0	0	0	0	5	7.33	449	892	0.50
	10:15 AM	122	532	0.23	1	1	1	1	1	0	0	1	0	0	0	0	6		487	848	0.57
	11:45 AM	64.2	272	0.24	1	1	1	1	1	1	0	1	0	0	0	0	7		445	664	0.67
	01:15 PM	55	221	0.25	1	1	1	1	1	1	1	1	0	0	0	0	8		428	688	0.62
	02:45 PM	49.4	197	0.24	1	1	1	1	1	1	1	1	0	0	0	0	8		416	664	0.63
	04:15 PM	22.8	91.9	0.25	1	1	1	1	1	1	1	1	1	0	0	1	10		460	644	0.71
01 April 2021	08:45 AM	188	784	0.25	1	1	1	1	1	0	0	0	0	0	0	0	5	8.17	455	1006	0.45
	10:15 AM	99.9	391	0.26	1	1	1	1	1	1	0	1	0	0	0	0	7		505	782	0.65
	11:45 AM	68.1	236	0.29	1	1	1	1	1	1	1	1	0	0	0	0	8		440	702	0.63
	01:15 PM	41.6	153	0.27	1	1	1	1	1	1	1	1	1	0	0	1	10		497	704	0.71
	02:45 PM	52	185	0.28	1	1	1	1	1	1	1	1	1	0	0	0	9		442	695	0.64
	04:15 PM	26.5	96	0.28	1	1	1	1	1	1	1	1	1	0	0	1	10		468	648	0.72
01 June 2021	08:45 AM	167	701	0.24	1	1	1	1	1	0	0	1	0	0	0	0	6	8.33	575	1017	0.57
	10:15 AM	95.8	401	0.24	1	1	1	1	1	1	0	1	0	0	0	0	7		509	792	0.64
	11:45 AM	45.3	175	0.26	1	1	1	1	1	1	1	1	0	0	0	1	9		432	684	0.63
	01:15 PM	49.9	187	0.27	1	1	1	1	1	1	1	1	0	0	0	1	9		461	696	0.66
	02:45 PM	49.5	193	0.26	1	1	1	1	1	1	1	1	0	0	0	1	9		476	702	0.68
	04:15 PM	24.7	96	0.26	1	1	1	1	1	1	1	1	1	0	0	1	10		468	648	0.72
01 August 2021	08:45 AM	173	719	0.24	1	1	1	1	0	0	0	1	1	0	0	0	6	8.50	456	978	0.47
	10:15 AM	105	420	0.25	1	1	1	1	1	0	0	1	0	0	0	0	6		417	736	0.57
	11:45 AM	40.9	159	0.26	1	1	1	1	1	1	1	1	1	0	0	1	10		496	711	0.70
	01:15 PM	44.6	169	0.26	1	1	1	1	1	1	1	1	1	0	0	1	10		499	720	0.69
	02:45 PM	52	193	0.27	1	1	1	1	1	1	1	1	0	0	0	1	9		469	702	0.67
	04:15 PM	26.6	106	0.25	1	1	1	1	1	1	1	1	1	0	0	1	10		482	658	0.73
01 October 2021	08:45 AM	165	728	0.23	1	1	1	1	1	0	0	0	0	0	0	0	5	8.83	459	988	0.46
	10:15 AM	87.6	349	0.25	1	1	1	1	1	0	1	1	0	0	0	0	7		479	740	0.65
	11:45 AM	38.8	141	0.28	1	1	1	1	1	1	1	1	1	0	0	1	10		492	693	0.71
	01:15 PM	47.3	175	0.27	1	1	1	1	1	1	1	1	1	0	0	1	10		503	726	0.69
	02:45 PM	48.2	178	0.27	1	1	1	1	1	1	1	1	1	0	0	1	10		504	730	0.69
	04:15 PM	18.6	71.7	0.26	1	1	1	1	1	1	1	1	1	1	0	1	11		479	679	0.71
01 December 2021	08:45 AM	143	630	0.23	1	1	1	1	1	0	0	0	0	0	0	0	5	7.67	463	889	0.52
	10:15 AM	108	471	0.23	1	1	1	1	1	0	0	1	0	0	0	0	6		459	787	0.58
	11:45 AM	64.8	279	0.23	1	1	1	1	1	1	0	1	0	0	0	0	7		452	671	0.67
	01:15 PM	57.5	235	0.24	1	1	1	1	1	1	1	1	0	0	0	0	8		440	702	0.63
	02:45 PM	43.9	173	0.25	1	1	1	1	1	1	1	1	1	0	0	0	9		459	682	0.67
	04:15 PM	13.6	55	0.25	1	1	1	1	1	1	1	1	1	1	0	1	11		475	663	0.72

Table 50: Simulation data. Case2, East, 40% WWR

Date	Time	Before			Luminaire Status (ON=1, OFF=0)												Luminaires		After		
		E_m	E_{avg}	U_1	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	Total	Avg.	E_m	E_{avg}	U_1
01 February 2021	08:45 AM	281	1166	0.24	1	1	0	1	0	0	0	0	0	0	0	0	3	5.50	550	1310	0.42
	10:15 AM	241	997	0.24	1	1	0	1	0	0	0	0	0	0	0	0	3		484	1141	0.42
	11:45 AM	127	515	0.25	1	1	1	1	1	0	0	1	0	0	0	0	6		490	829	0.59
	01:15 PM	109	416	0.26	1	1	1	1	1	0	0	1	0	0	0	0	6		437	730	0.60
	02:45 PM	94.4	368	0.26	1	1	1	1	1	1	0	1	0	0	0	0	7		527	757	0.70
	04:15 PM	47.4	171	0.28	1	1	1	1	1	1	1	1	0	0	0	0	8		400	636	0.63
01 April 2021	08:45 AM	362	1379	0.26	1	1	0	1	0	0	0	0	0	0	0	0	3	5.83	594	1524	0.39
	10:15 AM	193	741	0.26	1	1	1	1	0	0	0	0	0	0	0	0	4		449	943	0.48
	11:45 AM	134	466	0.29	1	1	1	1	1	0	0	1	0	0	0	0	6		436	780	0.56
	01:15 PM	85.8	289	0.30	1	1	1	1	1	1	0	1	0	0	0	0	7		453	678	0.67
	02:45 PM	101	346	0.29	1	1	1	1	1	1	0	1	0	0	0	0	7		502	736	0.68
	04:15 PM	51.1	179	0.29	1	1	1	1	1	1	1	1	0	0	0	0	8		430	643	0.67
01 June 2021	08:45 AM	319	1296	0.25	1	1	1	1	0	0	0	0	0	0	0	0	4	5.83	643	1497	0.43
	10:15 AM	190	756	0.25	1	1	1	1	0	0	0	0	0	0	0	0	4		437	958	0.46
	11:45 AM	87.2	335	0.26	1	1	1	1	1	0	1	1	0	0	0	0	7		481	724	0.66
	01:15 PM	94.8	352	0.27	1	1	1	1	0	0	1	0	0	0	0	0	5		456	721	0.63
	02:45 PM	96.4	360	0.27	1	1	1	1	1	1	0	1	0	0	0	0	7		517	750	0.69
	04:15 PM	50.5	179	0.28	1	1	1	1	1	1	1	1	0	0	0	0	8		407	644	0.63
01 August 2021	08:45 AM	339	1329	0.26	1	0	1	1	0	0	0	0	0	0	0	0	3	6.00	595	1474	0.40
	10:15 AM	207	792	0.26	1	1	1	1	0	0	0	0	0	0	0	0	4		456	994	0.46
	11:45 AM	82.1	307	0.27	1	1	1	1	1	0	1	1	0	0	0	0	7		454	696	0.65
	01:15 PM	87.9	319	0.28	1	1	1	1	1	0	1	1	0	0	0	0	7		478	708	0.68
	02:45 PM	96.9	361	0.27	1	1	1	1	1	0	1	1	0	0	0	0	7		515	751	0.69
	04:15 PM	56	197	0.28	1	1	1	1	1	1	1	1	0	0	0	0	8		438	662	0.66
01 October 2021	08:45 AM	347	1347	0.26	1	1	0	1	0	0	0	0	0	0	0	0	3	6.50	592	1491	0.40
	10:15 AM	163	660	0.25	1	1	1	1	1	0	0	0	0	0	0	0	5		434	918	0.47
	11:45 AM	72.8	272	0.27	1	1	1	1	1	1	0	1	0	0	0	0	7		432	662	0.65
	01:15 PM	88	329	0.27	1	1	1	1	1	1	0	1	0	0	0	0	7		485	718	0.68
	02:45 PM	92.9	332	0.28	1	1	1	1	1	1	0	1	0	0	0	0	7		495	722	0.69
	04:15 PM	38.2	134	0.29	1	1	1	1	1	1	1	1	1	0	0	1	10		491	681	0.72
01 December 2021	08:45 AM	281	1163	0.24	1	1	0	1	0	0	0	0	0	0	0	0	3	6.00	541	1307	0.41
	10:15 AM	211	882	0.24	1	1	1	1	0	0	0	0	0	0	0	0	4		465	1083	0.43
	11:45 AM	131	526	0.25	1	1	1	1	1	0	0	1	0	0	0	0	6		500	840	0.60
	01:15 PM	116	441	0.26	1	1	1	1	1	0	0	1	0	0	0	0	6		457	755	0.61
	02:45 PM	82.5	323	0.26	1	1	1	1	1	1	0	1	0	0	0	0	7		498	712	0.70
	04:15 PM	26.3	102	0.26	1	1	1	1	1	1	1	1	1	0	0	1	10		473	650	0.73

Table 51: Simulation data. Case2, East, 60% WWR

Date	Time	Before			Luminaire Status (ON=1, OFF=0)												Luminaires		After		
		E_m	E_{avg}	U_1	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	Total	Avg.	E_m	E_{avg}	U_1
01 February 2021	08:45 AM	423	1542	0.27	1	1	0	1	0	0	0	0	0	0	0	0	3	4.67	729	1685	0.43
	10:15 AM	362	1347	0.27	1	1	0	1	0	0	0	0	0	0	0	0	3		625	1490	0.42
	11:45 AM	180	700	0.26	1	1	1	1	0	0	0	0	0	0	0	0	4		425	901	0.47
	01:15 PM	157	561	0.28	1	1	1	1	1	0	0	0	0	0	0	0	5		467	818	0.57
	02:45 PM	141	491	0.29	1	1	1	1	1	0	0	1	0	0	0	0	6		516	804	0.64
	04:15 PM	68.1	228	0.30	1	1	1	1	1	1	0	1	0	0	0	0	7		435	616	0.71
01 April 2021	08:45 AM	556	1836	0.30	1	1	0	1	0	0	0	0	0	0	0	0	3	5.17	794	1980	0.40
	10:15 AM	280	1019	0.27	1	1	0	1	0	0	0	0	0	0	0	0	3		506	1163	0.44
	11:45 AM	194	669	0.29	1	1	1	1	1	0	0	1	0	0	0	0	6		547	982	0.56
	01:15 PM	120	393	0.31	1	1	1	1	1	0	0	1	0	0	0	0	6		431	706	0.61
	02:45 PM	147	465	0.32	1	1	1	1	1	0	0	1	0	0	0	0	6		495	777	0.64
	04:15 PM	77	239	0.32	1	1	1	1	1	1	0	1	0	0	0	0	7		438	626	0.70
01 June 2021	08:45 AM	486	1729	0.28	1	1	0	1	0	0	0	0	0	0	0	0	3	5.17	751	1873	0.40
	10:15 AM	276	1036	0.27	1	1	0	1	0	0	0	0	0	0	0	0	3		485	1180	0.41
	11:45 AM	128	463	0.28	1	1	1	1	1	0	0	1	0	0	0	0	6		469	776	0.60
	01:15 PM	144	477	0.30	1	1	1	1	1	0	0	1	0	0	0	0	6		496	790	0.63
	02:45 PM	148	482	0.31	1	1	1	1	1	0	0	1	0	0	0	0	6		511	794	0.64
	04:15 PM	72.4	239	0.30	1	1	1	1	1	0	1	1	0	0	0	0	7		440	626	0.70
01 August 2021	08:45 AM	503	1768	0.28	1	1	0	1	0	0	0	0	0	0	0	0	3	5.17	758	1911	0.40
	10:15 AM	302	1086	0.28	1	1	0	1	0	0	0	0	0	0	0	0	3		523	1229	0.43
	11:45 AM	118	430	0.27	1	1	1	1	1	0	0	1	0	0	0	0	6		435	743	0.59
	01:15 PM	126	433	0.29	1	1	1	1	1	0	0	1	0	0	0	0	6		463	746	0.62
	02:45 PM	149	484	0.31	1	1	1	1	1	0	0	1	0	0	0	0	6		508	796	0.64
	04:15 PM	79.7	264	0.30	1	1	1	1	1	0	1	1	0	0	0	0	7		463	651	0.71
01 October 2021	08:45 AM	1802	516	0.29	1	1	0	1	0	0	0	0	0	0	0	0	3	5.50	800	1946	0.41
	10:15 AM	249	910	0.27	1	1	0	1	0	0	0	0	0	0	0	0	3		472	1054	0.45
	11:45 AM	110	381	0.29	1	1	1	1	1	1	0	1	0	0	0	0	7		514	769	0.67
	01:15 PM	131	445	0.29	1	1	1	1	1	0	0	1	0	0	0	0	6		475	758	0.63
	02:45 PM	138	444	0.31	1	1	1	1	1	0	0	1	0	0	0	0	6		484	757	0.64
	04:15 PM	57.3	179	0.32	1	1	1	1	1	1	1	1	0	0	0	0	8		423	641	0.66
01 December 2021	08:45 AM	437	1545	0.28	1	1	0	1	0	0	0	0	0	0	0	0	3	5.17	734	1688	0.43
	10:15 AM	314	1192	0.26	1	1	0	1	0	0	0	0	0	0	0	0	3		573	1336	0.43
	11:45 AM	188	712	0.26	1	1	1	1	0	0	0	0	0	0	0	0	4		423	913	0.46
	01:15 PM	164	591	0.28	1	1	1	1	1	0	0	0	0	0	0	0	5		497	848	0.59
	02:45 PM	122	430	0.28	1	1	1	1	1	0	0	1	0	0	0	0	6		479	743	0.64
	04:15 PM	39.8	137	0.29	1	1	1	1	1	1	1	1	1	0	0	1	10		490	681	0.72

Table 52: Simulation data. Case2, East, 80% WWR

Date	Time	Before			Luminaire Status (ON=1, OFF=0)												Luminaires		After		
		E_m	E_{avg}	U_1	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	Total	Avg.	E_m	E_{avg}	U_1
01 February 2021	08:45 AM	595	1912	0.31	1	0	0	1	0	0	0	0	0	0	0	0	2	3.83	813	1998	0.41
	10:15 AM	483	1697	0.28	1	1	0	1	0	0	0	0	0	0	0	0	3		814	1840	0.44
	11:45 AM	259	890	0.29	1	1	0	1	0	0	0	0	0	0	0	0	3		504	1033	0.49
	01:15 PM	214	706	0.30	1	1	1	1	0	0	0	0	0	0	0	0	4		461	906	0.51
	02:45 PM	194	613	0.32	1	1	1	1	0	0	0	0	0	0	0	0	4		438	813	0.54
	04:15 PM	91.6	284	0.32	1	1	1	1	1	1	0	1	0	0	0	0	7		498	671	0.74
01 April 2021	08:45 AM	756	2290	0.33	1	0	0	1	0	0	0	0	0	0	0	0	2	4.33	942	2376	0.40
	10:15 AM	393	1303	0.30	1	1	0	1	0	0	0	0	0	0	0	0	3		621	1446	0.43
	11:45 AM	259	884	0.29	1	1	1	1	0	0	0	0	0	0	0	0	4		522	1084	0.48
	01:15 PM	167	499	0.33	1	1	1	1	1	0	0	1	0	0	0	0	6		527	810	0.65
	02:45 PM	201	580	0.35	1	1	1	1	0	0	0	0	0	0	0	0	4		460	780	0.59
	04:15 PM	105	297	0.35	1	1	1	1	1	1	0	1	0	0	0	0	7		504	683	0.74
01 June 2021	08:45 AM	643	2158	0.30	1	0	0	1	0	0	0	0	0	0	0	0	2	4.17	876	2244	0.39
	10:15 AM	373	1316	0.28	1	1	0	1	0	0	0	0	0	0	0	0	3		618	1460	0.42
	11:45 AM	176	596	0.30	1	1	1	1	0	0	0	1	0	0	0	0	5		471	851	0.55
	01:15 PM	189	602	0.31	1	1	1	1	0	0	0	0	0	0	0	0	4		427	802	0.53
	02:45 PM	192	602	0.32	1	1	1	1	0	0	0	0	0	0	0	0	4		444	802	0.55
	04:15 PM	95.2	297	0.32	1	1	1	1	1	0	1	1	0	0	0	0	7		508	683	0.74
01 August 2021	08:45 AM	707	2205	0.32	1	0	0	1	0	0	0	0	0	0	0	0	2	4.50	903	2291	0.39
	10:15 AM	406	1383	0.29	1	1	0	1	0	0	0	0	0	0	0	0	3		634	1526	0.42
	11:45 AM	166	556	0.30	1	1	1	1	1	0	0	1	0	0	0	0	6		525	867	0.61
	01:15 PM	176	549	0.32	1	1	1	1	0	0	0	1	0	0	0	0	5		456	805	0.57
	02:45 PM	201	605	0.33	1	1	1	1	0	0	0	0	0	0	0	0	4		454	805	0.56
	04:15 PM	114	328	0.35	1	1	1	1	1	1	0	1	0	0	0	0	7		524	715	0.73
01 October 2021	08:45 AM	714	2251	0.32	1	1	0	1	0	0	0	0	0	0	0	0	3	4.83	1000	2394	0.42
	10:15 AM	333	1166	0.29	1	1	0	1	0	0	0	0	0	0	0	0	3		575	1309	0.44
	11:45 AM	146	493	0.30	1	1	1	1	1	0	0	1	0	0	0	0	6		491	805	0.61
	01:15 PM	183	562	0.33	1	1	1	1	1	0	0	0	0	0	0	0	5		463	818	0.57
	02:45 PM	190	555	0.34	1	1	1	1	0	0	0	0	0	0	0	0	4		477	810	0.59
	04:15 PM	75	223	0.34	1	1	1	1	1	1	1	1	0	0	0	0	8		481	684	0.70
01 December 2021	08:45 AM	574	1922	0.30	1	0	1	0	0	0	0	0	0	0	0	0	2	4.33	806	2022	0.40
	10:15 AM	427	1502	0.28	1	1	0	1	0	0	0	0	0	0	0	0	3		739	1645	0.45
	11:45 AM	261	899	0.29	1	0	1	1	0	0	0	0	0	0	0	0	3		481	1042	0.46
	01:15 PM	224	740	0.30	1	1	1	1	0	0	0	0	0	0	0	0	4		481	940	0.51
	02:45 PM	170	536	0.32	1	1	1	1	1	0	0	1	0	0	0	0	6		501	792	0.63
	04:15 PM	54.5	170	0.32	1	1	1	1	1	1	1	1	0	0	0	0	8		446	671	0.66

Table 53: Simulation data. Case2, South, 20% WWR

Date	Time	Before			Luminaire Status (ON=1, OFF=0)												Luminaires		After		
		E_m	E_{avg}	U_1	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	Total	Avg.	E_m	E_{avg}	U_1
01 February 2021	08:45 AM	108	471	0.23	1	1	1	1	1	0	0	1	0	0	0	0	6	6.33	462	787	0.59
	10:15 AM	122	534	0.23	1	1	1	1	1	0	0	1	0	0	0	0	6		481	849	0.57
	11:45 AM	108	433	0.25	1	1	1	1	1	0	0	1	0	0	0	0	6		425	748	0.57
	01:15 PM	117	510	0.23	1	1	1	1	1	0	0	1	0	0	0	0	6		470	826	0.57
	02:45 PM	115	511	0.23	1	1	1	1	1	0	0	1	0	0	0	0	6		482	827	0.58
	04:15 PM	49	209	0.23	1	1	1	1	1	1	1	1	0	0	0	0	8		402	676	0.59
01 April 2021	08:45 AM	82.1	374	0.22	1	1	1	1	1	0	1	1	0	0	0	0	7	7.83	518	765	0.68
	10:15 AM	62.3	254	0.25	1	1	1	1	1	1	1	1	0	0	0	0	8		449	721	0.62
	11:45 AM	74.3	254	0.29	1	1	1	1	1	1	1	1	0	0	0	0	8		461	721	0.64
	01:15 PM	60.6	257	0.24	1	1	1	1	1	1	1	1	0	0	0	0	8		451	724	0.62
	02:45 PM	81.9	372	0.22	1	1	1	1	1	1	0	1	0	0	0	0	7		520	763	0.68
	04:15 PM	42.9	179	0.24	1	1	1	1	1	1	1	1	1	0	0	0	9		492	689	0.71
01 June 2021	08:45 AM	67	280	0.24	1	1	1	1	1	0	1	1	0	0	0	0	7	8.17	461	671	0.69
	10:15 AM	50.1	194	0.26	1	1	1	1	1	1	1	1	0	0	0	0	8		404	661	0.61
	11:45 AM	36.2	128	0.28	1	1	1	1	1	1	1	1	1	0	0	1	10		489	680	0.72
	01:15 PM	51.6	212	0.24	1	1	1	1	1	1	1	1	0	0	0	0	8		419	679	0.62
	02:45 PM	64.3	276	0.23	1	1	1	1	1	1	0	1	0	0	0	0	7		456	667	0.68
	04:15 PM	33.9	139	0.24	1	1	1	1	1	1	1	1	1	0	0	0	9		427	648	0.66
01 August 2021	08:45 AM	72.5	297	0.24	1	1	1	1	1	0	1	1	0	0	0	0	7	8.17	473	688	0.69
	10:15 AM	51.9	209	0.25	1	1	1	1	1	1	1	1	0	0	0	0	8		411	676	0.61
	11:45 AM	34.7	120	0.29	1	1	1	1	1	1	1	1	1	0	0	1	10		487	672	0.72
	01:15 PM	49.8	203	0.25	1	1	1	1	1	1	1	1	0	0	0	0	8		408	670	0.61
	02:45 PM	67.8	295	0.23	1	1	1	1	1	1	0	1	0	0	0	0	7		474	687	0.69
	04:15 PM	40.2	164	0.25	1	1	1	1	1	1	1	1	1	0	0	0	9		465	674	0.69
01 October 2021	08:45 AM	95.8	427	0.22	1	1	1	1	1	0	0	1	0	0	0	0	6	7.33	440	743	0.59
	10:15 AM	67.8	285	0.24	1	1	1	1	1	0	1	1	0	0	0	0	7		447	676	0.66
	11:45 AM	52.1	196	0.27	1	1	1	1	1	1	1	1	0	0	0	0	8		412	663	0.62
	01:15 PM	82.3	353	0.23	1	1	1	1	1	1	0	1	0	0	0	0	7		498	744	0.67
	02:45 PM	88	398	0.22	1	1	1	1	1	1	0	1	0	0	0	0	7		526	789	0.67
	04:15 PM	33.6	140	0.24	1	1	1	1	1	1	1	1	1	0	0	0	9		432	649	0.67
01 December 2021	08:45 AM	123	543	0.23	1	1	1	1	1	0	0	1	0	0	0	0	6	6.67	500	859	0.58
	10:15 AM	135	576	0.23	1	1	1	1	1	0	0	1	0	0	0	0	6		501	892	0.56
	11:45 AM	132	531	0.25	1	1	1	1	1	0	0	1	0	0	0	0	6		479	846	0.57
	01:15 PM	138	595	0.23	1	1	1	1	1	0	0	1	0	0	0	0	6		517	911	0.57
	02:45 PM	98.6	452	0.22	1	1	1	1	1	0	0	1	0	0	0	0	6		459	768	0.60
	04:15 PM	28.8	118	0.24	1	1	1	1	1	1	1	1	1	0	0	1	10		479	669	0.72

Table 54: Simulation data. Case2, South, 40% WWR

Date	Time	Before			Luminaire Status (ON=1, OFF=0)												Luminaires		After		
		E_m	E_{avg}	U_1	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	Total	Avg.	E_m	E_{avg}	U_1
01 February 2021	08:45 AM	211	874	0.24	1	1	1	1	0	0	0	0	0	0	0	0	4	3.83	444	1076	0.41
	10:15 AM	243	998	0.24	1	1	0	1	0	0	0	0	0	0	0	0	3		484	1143	0.42
	11:45 AM	214	818	0.26	1	1	1	1	0	0	0	0	0	0	0	0	4		472	1020	0.46
	01:15 PM	238	958	0.25	1	1	0	1	0	0	0	0	0	0	0	0	3		463	1102	0.42
	02:45 PM	226	950	0.24	1	1	0	1	0	0	0	0	0	0	0	0	3		480	1094	0.44
	04:15 PM	96.2	387	0.25	1	1	1	1	1	0	0	1	0	0	0	0	6		429	701	0.61
01 April 2021	08:45 AM	168	697	0.24	1	1	1	1	0	0	0	1	0	0	0	0	5	5.83	538	955	0.56
	10:15 AM	119	481	0.25	1	1	1	1	1	0	0	1	0	0	0	0	6		473	795	0.59
	11:45 AM	141	502	0.28	1	1	1	1	1	0	0	1	0	0	0	0	6		454	817	0.56
	01:15 PM	119	486	0.24	1	1	1	1	1	0	0	1	0	0	0	0	6		472	800	0.59
	02:45 PM	165	693	0.24	1	1	1	1	1	0	0	0	0	0	0	0	5		540	951	0.57
	04:15 PM	85.3	333	0.26	1	1	1	1	1	1	0	1	0	0	0	0	7		512	723	0.71
01 June 2021	08:45 AM	129	523	0.25	1	1	1	1	1	0	0	1	0	0	0	0	6	6.83	506	837	0.60
	10:15 AM	94.7	367	0.26	1	1	1	1	1	0	1	1	0	0	0	0	7		518	757	0.68
	11:45 AM	70.2	245	0.29	1	1	1	1	1	1	1	1	0	0	0	0	8		478	710	0.67
	01:15 PM	100	400	0.25	1	1	1	1	1	1	0	1	0	0	0	0	7		536	790	0.68
	02:45 PM	131	514	0.25	1	1	1	1	1	0	0	1	0	0	0	0	6		506	828	0.61
	04:15 PM	67	259	0.26	1	1	1	1	1	1	0	1	0	0	0	0	7		450	648	0.69
01 August 2021	08:45 AM	134	553	0.24	1	1	1	1	0	0	0	1	0	0	0	0	5	6.50	460	811	0.57
	10:15 AM	103	394	0.26	1	1	1	1	1	0	1	1	0	0	0	0	7		536	783	0.68
	11:45 AM	67.7	232	0.29	1	1	1	1	1	1	1	1	0	0	0	0	8		466	696	0.67
	01:15 PM	100	384	0.26	1	1	1	1	1	1	0	1	0	0	0	0	7		530	773	0.69
	02:45 PM	131	552	0.24	1	1	1	1	1	0	0	0	0	0	0	0	5		459	810	0.57
	04:15 PM	76.4	305	0.25	1	1	1	1	1	1	0	1	0	0	0	0	7		484	695	0.70
01 October 2021	08:45 AM	192	796	0.24	1	1	1	1	0	0	0	0	0	0	0	0	4	5.67	424	998	0.42
	10:15 AM	134	540	0.25	1	1	1	1	1	0	0	1	0	0	0	0	6		497	854	0.58
	11:45 AM	104	380	0.27	1	1	1	1	1	1	0	1	0	0	0	0	7		505	769	0.66
	01:15 PM	161	665	0.24	1	1	1	1	1	0	0	0	0	0	0	0	5		488	923	0.53
	02:45 PM	170	740	0.23	1	1	1	1	1	0	0	0	0	0	0	0	5		568	998	0.57
	04:15 PM	65.4	260	0.25	1	1	1	1	1	1	0	1	0	0	0	0	7		448	649	0.69
01 December 2021	08:45 AM	246	1007	0.24	1	0	1	1	0	0	0	0	0	0	0	0	3	4.00	506	1152	0.44
	10:15 AM	263	1078	0.24	1	0	1	1	0	0	0	0	0	0	0	0	3		505	1222	0.41
	11:45 AM	252	995	0.25	1	0	1	1	0	0	0	0	0	0	0	0	3		467	1139	0.41
	01:15 PM	265	1108	0.24	1	0	1	1	0	0	0	0	0	0	0	0	3		493	1253	0.39
	02:45 PM	200	837	0.24	1	1	1	1	0	0	0	0	0	0	0	0	4		436	1039	0.42
	04:15 PM	58.2	218	0.27	1	1	1	1	1	1	1	1	0	0	0	0	8		415	683	0.61

Table 55: Simulation data. Case2, South, 60% WWR

Date	Time	Before			Luminaire Status (ON=1, OFF=0)												Luminaires		After		
		E_m	E_{avg}	U_1	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	Total	Avg.	E_m	E_{avg}	U_1
01 February 2021	08:45 AM	296	1162	0.25	1	0	1	1	0	0	0	0	0	0	0	0	3	3.33	587	1306	0.45
	10:15 AM	357	1351	0.26	1	0	1	1	0	0	0	0	0	0	0	0	3		634	1494	0.42
	11:45 AM	321	1120	0.29	1	0	1	1	0	0	0	0	0	0	0	0	3		526	1263	0.42
	01:15 PM	345	1299	0.27	1	1	0	1	0	0	0	0	0	0	0	0	3		612	1442	0.42
	02:45 PM	325	1265	0.26	1	1	0	1	0	0	0	0	0	0	0	0	3		632	1408	0.45
	04:15 PM	143	510	0.28	1	1	1	1	1	0	0	0	0	0	0	0	5		484	767	0.63
01 April 2021	08:45 AM	246	933	0.26	1	0	1	1	0	0	0	0	0	0	0	0	3	4.33	503	1077	0.47
	10:15 AM	181	658	0.28	1	1	1	1	0	0	0	1	0	0	0	0	5		493	915	0.54
	11:45 AM	211	724	0.29	1	1	1	1	0	0	0	1	0	0	0	0	5		449	980	0.46
	01:15 PM	174	665	0.26	1	1	1	1	0	0	0	0	0	0	0	0	4		511	922	0.55
	02:45 PM	245	926	0.26	1	1	0	1	0	0	0	0	0	0	0	0	3		500	1069	0.47
	04:15 PM	126	441	0.29	1	1	1	1	1	0	0	1	0	0	0	0	6		496	754	0.66
01 June 2021	08:45 AM	191	699	0.27	1	1	1	1	0	0	0	0	0	0	0	0	4	5.50	432	900	0.48
	10:15 AM	145	499	0.29	1	1	1	1	1	0	0	1	0	0	0	0	6		504	811	0.62
	11:45 AM	101	338	0.30	1	1	1	1	1	1	0	1	0	0	0	0	7		493	726	0.68
	01:15 PM	151	541	0.28	1	1	1	1	1	0	0	0	0	0	0	0	5		457	798	0.57
	02:45 PM	197	686	0.29	1	1	1	1	0	0	0	0	0	0	0	0	4		416	887	0.47
	04:15 PM	93.5	343	0.27	1	1	1	1	1	1	0	1	0	0	0	0	7		525	731	0.72
01 August 2021	08:45 AM	203	740	0.27	1	1	1	1	0	0	0	0	0	0	0	0	4	5.50	439	941	0.47
	10:15 AM	146	536	0.27	1	1	1	1	1	0	0	1	0	0	0	0	6		529	849	0.62
	11:45 AM	99.4	323	0.31	1	1	1	1	1	0	1	1	0	0	0	0	7		472	711	0.66
	01:15 PM	150	522	0.29	1	1	1	1	1	0	0	1	0	0	0	0	6		516	835	0.62
	02:45 PM	201	737	0.27	1	1	1	1	0	0	0	0	0	0	0	0	4		443	938	0.47
	04:15 PM	114	405	0.28	1	1	1	1	1	0	0	1	0	0	0	0	6		464	717	0.65
01 October 2021	08:45 AM	288	1067	0.27	1	0	1	1	0	0	0	0	0	0	0	0	3	4.33	544	1211	0.45
	10:15 AM	201	743	0.27	1	1	1	1	0	0	0	0	0	0	0	0	4		442	944	0.47
	11:45 AM	151	535	0.28	1	1	1	1	1	0	0	1	0	0	0	0	6		494	848	0.58
	01:15 PM	235	903	0.26	1	1	0	1	0	0	0	0	0	0	0	0	3		481	1046	0.46
	02:45 PM	267	986	0.27	1	1	0	1	0	0	0	0	0	0	0	0	3		530	1130	0.47
	04:15 PM	96.8	343	0.28	1	1	1	1	1	1	0	1	0	0	0	0	7		521	731	0.71
01 December 2021	08:45 AM	250	1341	0.26	1	0	1	1	0	0	0	0	0	0	0	0	3	3.67	651	1484	0.44
	10:15 AM	387	1457	0.27	1	0	1	1	0	0	0	0	0	0	0	0	3		661	1601	0.41
	11:45 AM	373	1357	0.27	1	0	1	1	0	0	0	0	0	0	0	0	3		602	1501	0.40
	01:15 PM	384	1490	0.26	1	1	0	1	0	0	0	0	0	0	0	0	3		696	1634	0.43
	02:45 PM	289	1109	0.26	1	1	0	1	0	0	0	0	0	0	0	0	3		567	1253	0.45
	04:15 PM	84.4	287	0.29	1	1	1	1	1	1	0	1	0	0	0	0	7		474	675	0.70

Table 56: Simulation data. Case2, South, 80% WWR

Date	Time	Before			Luminaire Status (ON=1, OFF=0)												Luminaires		After		
		E_m	E_{avg}	U_1	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	Total	Avg.	E_m	E_{avg}	U_1
	08:45 AM	411	1444	0.28	0	0	1	1	0	0	0	0	0	0	0	0	2		612	1544	0.40
	10:15 AM	496	1701	0.29	1	0	1	1	0	0	0	0	0	0	0	0	3		800	1844	0.43
01 February 2021	11:45 AM	441	1429	0.31	1	0	1	1	0	0	0	0	0	0	0	0	3	2.83	670	1572	0.43
	01:15 PM	473	1641	0.29	1	1	0	1	0	0	0	0	0	0	0	0	3		776	1784	0.43
	02:45 PM	448	1575	0.28	1	0	0	1	0	0	0	0	0	0	0	0	2		652	1661	0.39
	04:15 PM	192	631	0.30	1	1	1	1	0	0	0	0	0	0	0	0	4		424	831	0.51
	08:45 AM	345	1167	0.30	0	1	0	1	0	0	0	0	0	0	0	0	2		520	1267	0.41
	10:15 AM	236	838	0.28	1	0	1	1	0	0	0	0	0	0	0	0	3		478	981	0.49
01 April 2021	11:45 AM	281	958	0.29	1	0	1	1	0	0	0	0	0	0	0	0	3	3.00	476	1101	0.43
	01:15 PM	242	845	0.29	1	0	1	1	0	0	0	0	0	0	0	0	3		454	988	0.46
	02:45 PM	327	1154	0.28	1	0	1	0	0	0	0	0	0	0	0	0	2		539	1254	0.43
	04:15 PM	167	546	0.31	1	1	1	1	1	0	0	0	0	0	0	0	5		538	802	0.67
	08:45 AM	252	872	0.29	1	0	1	1	0	0	0	0	0	0	0	0	3		526	1015	0.52
	10:15 AM	194	631	0.31	1	1	1	1	0	0	0	0	0	0	0	0	4		429	831	0.52
01 June 2021	11:45 AM	140	433	0.32	1	1	1	1	1	0	0	1	0	0	0	0	6	4.33	468	744	0.63
	01:15 PM	207	684	0.30	1	1	1	1	0	0	0	0	0	0	0	0	4		449	884	0.51
	02:45 PM	254	856	0.30	1	1	0	1	0	0	0	0	0	0	0	0	3		510	999	0.51
	04:15 PM	133	426	0.31	1	1	1	1	1	0	0	1	0	0	0	0	6		506	737	0.69
	08:45 AM	275	923	0.30	1	0	1	1	0	0	0	0	0	0	0	0	3		536	1066	0.50
	10:15 AM	207	679	0.30	1	1	1	1	0	0	0	0	0	0	0	0	4		439	879	0.50
01 August 2021	11:45 AM	131	416	0.31	1	1	1	1	1	0	0	1	0	0	0	0	6	4.17	442	728	0.25
	01:15 PM	197	661	0.30	1	1	1	1	0	0	0	0	0	0	0	0	4		441	861	0.51
	02:45 PM	274	920	0.30	1	1	0	1	0	0	0	0	0	0	0	0	3		537	1064	0.50
	04:15 PM	155	502	0.31	1	1	1	1	1	0	0	0	0	0	0	0	5		507	758	0.67
	08:45 AM	381	1335	0.29	0	1	0	1	0	0	0	0	0	0	0	0	2		600	1435	0.42
	10:15 AM	268	948	0.28	1	0	1	1	0	0	0	0	0	0	0	0	3		510	1091	0.47
01 October 2021	11:45 AM	201	697	0.29	1	1	1	1	0	0	0	0	0	0	0	0	4	3.33	450	897	0.50
	01:15 PM	316	1143	0.28	1	1	0	1	0	0	0	0	0	0	0	0	3		603	1286	0.47
	02:45 PM	359	1228	0.29	1	1	0	0	0	0	0	0	0	0	0	0	2		526	1328	0.40
	04:15 PM	131	424	0.31	1	1	1	1	1	0	0	1	0	0	0	0	6		511	735	0.70
	08:45 AM	490	1671	0.29	0	1	0	1	0	0	0	0	0	0	0	0	2		715	1771	0.40
	10:15 AM	513	1837	0.28	1	0	1	1	0	0	0	0	0	0	0	0	3		852	1980	0.43
01 December 2021	11:45 AM	517	1721	0.30	1	0	1	1	0	0	0	0	0	0	0	0	3	3.17	761	1864	0.41
	01:15 PM	530	1869	0.28	1	1	0	1	0	0	0	0	0	0	0	0	3		870	2012	0.43
	02:45 PM	417	1376	0.30	1	0	0	1	0	0	0	0	0	0	0	0	2		588	1462	0.40
	04:15 PM	113	355	0.32	1	1	1	1	1	0	0	1	0	0	0	0	6		454	666	0.68

Table 57: Simulation data. Case2, West, 20% WWR

Date	Time	Before			Luminaire Status (ON=1, OFF=0)												Luminaires		After		
		E_m	E_{avg}	U_1	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	Total	Avg.	E_m	E_{avg}	U_1
01 February 2021	08:45 AM	46.5	182	0.26	1	1	1	1	1	1	1	1	0	0	0	0	8	7.00	402	649	0.62
	10:15 AM	56.6	221	0.26	1	1	1	1	1	1	1	1	0	0	0	0	8		429	688	0.62
	11:45 AM	57.9	249	0.23	1	1	1	1	1	1	1	1	0	0	0	0	8		442	716	0.62
	01:15 PM	109	470	0.23	1	1	1	1	1	0	0	1	0	0	0	0	6		452	786	0.58
	02:45 PM	153	666	0.23	1	1	1	1	0	0	0	1	0	0	0	0	5		458	925	0.50
	04:15 PM	77	300	0.26	1	1	1	1	1	0	1	1	0	0	0	0	7		490	692	0.71
01 April 2021	08:45 AM	52.7	186	0.28	1	1	1	1	1	1	1	1	0	0	0	0	8	7.50	437	653	0.67
	10:15 AM	43.2	151	0.29	1	1	1	1	1	1	1	1	1	0	0	1	10		496	703	0.71
	11:45 AM	71.8	238	0.30	1	1	1	1	1	1	1	1	1	0	0	0	9		442	705	0.63
	01:15 PM	99.8	399	0.25	1	1	1	1	1	0	1	1	0	0	0	0	7		513	790	0.65
	02:45 PM	193	747	0.26	1	1	1	1	0	0	0	0	0	0	0	0	4		438	949	0.46
	04:15 PM	96.3	351	0.27	1	1	1	1	1	0	1	1	0	0	0	0	7		518	743	0.70
01 June 2021	08:45 AM	49.1	198	0.25	1	1	1	1	1	1	1	1	0	0	0	0	8	7.00	422	665	0.63
	10:15 AM	44.7	180	0.25	1	1	1	1	1	1	1	1	0	0	0	0	8		397	647	0.61
	11:45 AM	49	188	0.26	1	1	1	1	1	1	1	1	0	0	0	0	8		389	655	0.59
	01:15 PM	106	458	0.23	1	1	1	1	1	0	0	1	0	0	0	0	6		440	774	0.57
	02:45 PM	165	698	0.24	1	1	1	1	1	0	0	0	0	0	0	0	5		472	957	0.49
	04:15 PM	83.3	317	0.26	1	1	1	1	1	1	0	1	0	0	0	0	7		500	708	0.71
01 August 2021	08:45 AM	50.1	192	0.26	1	1	1	1	1	1	1	1	0	0	0	0	8	7.67	424	659	0.64
	10:15 AM	44.9	170	0.26	1	1	1	1	1	1	1	1	1	0	0	0	9		435	680	0.64
	11:45 AM	41.8	156	0.27	1	1	1	1	1	1	1	1	1	0	0	1	10		493	708	0.70
	01:15 PM	94.6	405	0.23	1	1	1	1	1	1	0	1	0	0	0	0	7		522	796	0.66
	02:45 PM	173	719	0.24	1	1	1	1	1	0	0	0	0	0	0	0	5		462	978	0.47
	04:15 PM	93.9	371	0.25	1	1	1	1	1	1	0	1	0	0	0	0	7		535	763	0.70
01 October 2021	08:45 AM	52.6	191	0.28	1	1	1	1	1	1	1	1	0	0	0	0	8	7.67	431	658	0.66
	10:15 AM	42.1	155	0.27	1	1	1	1	1	1	1	1	1	0	0	1	10		498	706	0.71
	11:45 AM	44.9	169	0.27	1	1	1	1	1	1	1	1	0	0	0	1	9		412	678	0.61
	01:15 PM	119	497	0.24	1	1	1	1	1	1	1	1	0	0	0	0	8		464	813	0.57
	02:45 PM	170	717	0.24	1	1	1	1	0	0	0	0	0	0	0	0	4		429	920	0.47
	04:15 PM	70.6	243	0.29	1	1	1	1	1	1	0	1	0	0	0	0	7		440	635	0.69
01 December 2021	08:45 AM	51	204	0.25	1	1	1	1	1	1	1	1	0	0	0	0	8	7.00	419	671	0.62
	10:15 AM	59.2	246	0.24	1	1	1	1	1	0	1	1	0	0	0	0	7		429	637	0.67
	11:45 AM	73.7	324	0.23	1	1	1	1	1	0	1	1	0	0	0	0	7		484	716	0.68
	01:15 PM	126	562	0.22	1	1	1	1	1	0	0	1	0	0	0	0	6		505	878	0.58
	02:45 PM	133	569	0.23	1	1	1	1	1	0	0	1	0	0	0	0	6		524	885	0.59
	04:15 PM	42	157	0.27	1	1	1	1	1	1	1	0	0	0	0	1	8		430	666	0.65

Table 58: Simulation data. Case2, West, 40% WWR

Date	Time	Before			Luminaire Status (ON=1, OFF=0)												Luminaires		After		
		E_m	E_{avg}	U_1	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	Total	Avg.	E_m	E_{avg}	U_1
01 February 2021	08:45 AM	92.1	340	0.27	1	1	1	1	1	0	1	1	0	0	0	0	7	5.17	507	730	0.69
	10:15 AM	107	415	0.26	1	1	1	1	1	0	0	1	0	0	0	0	6		437	729	0.60
	11:45 AM	119	471	0.25	1	1	1	1	1	0	0	1	0	0	0	0	6		462	786	0.59
	01:15 PM	223	882	0.25	1	1	1	1	0	0	0	0	0	0	0	0	4		465	1084	0.43
	02:45 PM	305	1229	0.25	1	0	1	1	0	0	0	0	0	0	0	0	3		561	1374	0.41
	04:15 PM	149	554	0.27	1	1	1	1	0	0	0	1	0	0	0	0	5		445	812	0.55
01 April 2021	08:45 AM	102	347	0.29	1	1	1	1	1	1	0	1	0	0	0	0	7	5.17	502	737	0.68
	10:15 AM	82.4	287	0.29	1	1	1	1	1	1	0	1	0	0	0	0	7		449	676	0.66
	11:45 AM	136	471	0.29	1	1	1	1	1	0	0	1	0	0	0	0	6		436	785	0.56
	01:15 PM	192	755	0.25	1	1	1	1	0	0	0	0	0	0	0	0	4		449	957	0.47
	02:45 PM	367	1378	0.27	1	0	1	1	0	0	0	0	0	0	0	0	3		598	1523	0.39
	04:15 PM	194	647	0.30	1	1	1	1	0	0	0	0	0	0	0	0	4		450	849	0.53
01 June 2021	08:45 AM	101	371	0.27	1	1	1	1	1	1	0	1	0	0	0	0	7	5.50	524	760	0.69
	10:15 AM	89.9	340	0.26	1	1	1	1	1	1	0	1	0	0	0	0	7		499	729	0.68
	11:45 AM	94.7	360	0.26	1	1	1	1	1	1	0	1	0	0	0	0	7		498	749	0.66
	01:15 PM	207	863	0.24	1	1	1	1	0	0	0	0	0	0	0	0	4		464	1064	0.44
	02:45 PM	320	1287	0.25	1	1	0	1	0	0	0	0	0	0	0	0	3		581	1432	0.41
	04:15 PM	154	584	0.26	1	1	1	1	1	0	0	0	0	0	0	0	5		450	842	0.53
01 August 2021	08:45 AM	99.2	358	0.28	1	1	1	1	1	1	0	1	0	0	0	0	7	5.33	519	748	0.69
	10:15 AM	87.4	322	0.27	1	1	1	1	1	1	0	1	0	0	0	0	7		483	712	0.68
	11:45 AM	81.9	301	0.27	1	1	1	1	1	0	1	1	0	0	0	0	7		443	691	0.64
	01:15 PM	193	765	0.25	1	1	1	1	0	0	0	0	0	0	0	0	4		443	967	0.46
	02:45 PM	331	1328	0.25	1	1	0	1	0	0	0	0	0	0	0	0	3		588	1473	0.40
	04:15 PM	186	684	0.27	1	1	1	1	0	0	0	0	0	0	0	0	4		429	886	0.48
01 October 2021	08:45 AM	102	358	0.28	1	1	1	1	1	1	0	1	0	0	0	0	7	5.67	507	747	0.68
	10:15 AM	82.4	293	0.28	1	1	1	1	1	0	1	1	0	0	0	0	7		457	683	0.67
	11:45 AM	86.7	327	0.27	1	1	1	1	1	0	1	1	0	0	0	0	7		471	716	0.66
	01:15 PM	238	934	0.25	1	1	1	1	0	0	0	0	0	0	0	0	4		520	1136	0.46
	02:45 PM	344	1320	0.26	1	0	1	1	0	0	0	0	0	0	0	0	3		591	1464	0.40
	04:15 PM	137	449	0.31	1	1	1	1	1	0	0	1	0	0	0	0	6		487	763	0.64
01 December 2021	08:45 AM	97.5	380	0.26	1	1	1	1	1	1	0	1	0	0	0	0	7	5.17	516	770	0.67
	10:15 AM	113	461	0.25	1	1	1	1	1	0	0	1	0	0	0	0	6		470	775	0.61
	11:45 AM	146	610	0.24	1	1	1	1	0	0	0	1	0	0	0	0	5		467	868	0.54
	01:15 PM	247	1048	0.24	1	0	1	1	0	0	0	0	0	0	0	0	3		495	1192	0.42
	02:45 PM	264	1049	0.25	1	0	1	1	0	0	0	0	0	0	0	0	3		516	1193	0.43
	04:15 PM	79.6	290	0.27	1	1	1	1	1	0	1	1	0	0	0	0	7		485	679	0.71

Table 59: Simulation data. Case2, West, 60% WWR

Date	Time	Before			Luminaire Status (ON=1, OFF=0)												Luminaires		After		
		E_m	E_{avg}	U_1	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	Total	Avg.	E_m	E_{avg}	U_1
01 February 2021	08:45 AM	133	454	0.29	1	1	1	1	1	0	0	1	0	0	0	0	6	4.33	495	767	0.65
	10:15 AM	161	559	0.29	1	1	1	1	0	0	0	1	0	0	0	0	5		469	816	0.57
	11:45 AM	177	642	0.28	1	1	1	1	0	0	0	1	0	0	0	0	5		494	899	0.55
	01:15 PM	327	1197	0.27	1	0	1	1	0	0	0	0	0	0	0	0	3		577	1341	0.43
	02:45 PM	451	1633	0.28	1	0	1	1	0	0	0	0	0	0	0	0	3		720	1776	0.41
	04:15 PM	235	726	0.32	1	1	1	1	0	0	0	0	0	0	0	0	4		488	927	0.53
01 April 2021	08:45 AM	147	466	0.32	1	1	1	1	1	0	0	1	0	0	0	0	6	4.67	501	778	0.64
	10:15 AM	121	391	0.31	1	1	1	1	1	1	0	1	0	0	0	0	7		539	779	0.69
	11:45 AM	194	676	0.29	1	1	1	1	1	0	0	1	0	0	0	0	6		550	989	0.56
	01:15 PM	295	1038	0.28	1	0	1	1	0	0	0	0	0	0	0	0	3		510	1182	0.43
	02:45 PM	537	1836	0.29	1	0	1	1	0	0	0	0	0	0	0	0	3		799	1980	0.40
	04:15 PM	283	846	0.33	1	1	0	1	0	0	0	0	0	0	0	0	3		513	989	0.52
01 June 2021	08:45 AM	146	496	0.29	1	1	1	1	1	0	0	1	0	0	0	0	6	4.50	518	809	0.64
	10:15 AM	139	461	0.30	1	1	1	1	1	0	0	1	0	0	0	0	6		484	774	0.63
	11:45 AM	141	499	0.29	1	1	1	1	1	0	0	1	0	0	0	0	6		486	811	0.60
	01:15 PM	311	1176	0.26	1	1	0	1	0	0	0	0	0	0	0	0	3		575	1320	0.44
	02:45 PM	480	1711	0.28	1	0	1	1	0	0	0	0	0	0	0	0	3		747	1854	0.40
	04:15 PM	237	765	0.31	1	1	0	1	0	0	0	0	0	0	0	0	3		486	909	0.53
01 August 2021	08:45 AM	146	479	0.30	1	1	1	1	1	0	0	1	0	0	0	0	6	4.50	508	792	0.64
	10:15 AM	130	437	0.30	1	1	1	1	1	0	0	1	0	0	0	0	6		462	750	0.62
	11:45 AM	116	421	0.28	1	1	1	1	1	1	0	1	0	0	0	0	7		547	809	0.68
	01:15 PM	281	1049	0.27	1	1	0	1	0	0	0	0	0	0	0	0	3		517	1192	0.43
	02:45 PM	505	1770	0.29	1	1	0	1	0	0	0	0	0	0	0	0	3		812	1914	0.42
	04:15 PM	286	897	0.32	1	1	0	0	0	0	0	0	0	0	0	0	2		542	1040	0.52
01 October 2021	08:45 AM	147	479	0.31	1	1	1	1	1	0	0	1	0	0	0	0	6	4.67	506	792	0.64
	10:15 AM	119	401	0.30	1	1	1	1	1	0	0	1	0	0	0	0	6		437	713	0.61
	11:45 AM	129	459	0.28	1	1	1	1	1	0	0	1	0	0	0	0	6		453	772	0.59
	01:15 PM	360	1272	0.28	1	0	1	1	0	0	0	0	0	0	0	0	3		589	1416	0.42
	02:45 PM	494	1747	0.28	1	0	1	1	0	0	0	0	0	0	0	0	3		788	1891	0.42
	04:15 PM	200	586	0.34	1	1	1	1	0	0	0	0	0	0	0	0	4		450	787	0.57
01 December 2021	08:45 AM	154	508	0.30	1	1	1	1	0	0	0	1	0	0	0	0	5	4.17	448	765	0.59
	10:15 AM	171	620	0.28	1	1	1	1	0	0	0	1	0	0	0	0	5		499	877	0.57
	11:45 AM	221	828	0.27	1	0	1	1	0	0	0	0	0	0	0	0	3		468	971	0.48
	01:15 PM	368	1412	0.26	1	0	1	1	0	0	0	0	0	0	0	0	3		670	1555	0.43
	02:45 PM	389	1386	0.28	1	0	1	1	0	0	0	0	0	0	0	0	3		561	1472	0.38
	04:15 PM	123	378	0.33	1	1	1	1	1	0	0	1	0	0	0	0	6		466	691	0.67

Table 60: Simulation data. Case2, West, 80% WWR

Date	Time	Before			Luminaire Status (ON=1, OFF=0)												Luminaires		After		
		E_m	E_{avg}	U_1	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	Total	Avg.	E_m	E_{avg}	U_1
01 February 2021	08:45 AM	185	566	0.33	1	1	1	1	0	0	0	1	0	0	0	0	5	3.50	506	822	0.62
	10:15 AM	215	702	0.31	1	1	1	1	0	0	0	0	0	0	0	0	4		468	902	0.52
	11:45 AM	237	814	0.29	1	0	1	1	0	0	0	0	0	0	0	0	3		478	958	0.50
	01:15 PM	428	1511	0.28	1	1	0	1	0	0	0	0	0	0	0	0	3		692	1654	0.42
	02:45 PM	617	2030	0.30	1	0	1	1	0	0	0	0	0	0	0	0	3		969	2173	0.45
	04:15 PM	309	891	0.35	1	0	1	1	0	0	0	0	0	0	0	0	3		570	1035	0.55
01 April 2021	08:45 AM	203	582	0.35	1	1	1	1	0	0	0	0	0	0	0	0	4	3.67	468	783	0.60
	10:15 AM	162	496	0.33	1	1	1	1	1	0	0	1	0	0	0	0	6		524	807	0.65
	11:45 AM	259	894	0.29	1	1	1	1	0	0	0	0	0	0	0	0	4		517	1095	0.47
	01:15 PM	393	1327	0.30	1	0	1	1	0	0	0	0	0	0	0	0	3		628	1470	0.43
	02:45 PM	757	2290	0.33	1	1	0	1	0	0	0	0	0	0	0	0	3		1051	2433	0.43
	04:15 PM	397	1040	0.38	1	0	0	1	0	0	0	0	0	0	0	0	2		510	1126	0.45
01 June 2021	08:45 AM	198	621	0.32	1	1	1	1	0	0	0	0	0	0	0	0	4	3.67	451	821	0.55
	10:15 AM	184	583	0.32	1	1	1	1	1	0	0	0	0	0	0	0	5		485	839	0.58
	11:45 AM	188	641	0.29	1	1	1	1	1	0	0	0	0	0	0	0	5		497	897	0.55
	01:15 PM	413	1492	0.28	1	1	0	1	0	0	0	0	0	0	0	0	3		699	1635	0.43
	02:45 PM	653	2129	0.31	1	1	0	1	0	0	0	0	0	0	0	0	3		1012	2272	0.45
	04:15 PM	317	940	0.34	1	0	0	1	0	0	0	0	0	0	0	0	2		473	1026	0.46
01 August 2021	08:45 AM	202	598	0.34	1	1	1	1	0	0	0	0	0	0	0	0	4	3.83	453	799	0.57
	10:15 AM	173	553	0.31	1	1	1	1	1	0	0	0	0	0	0	0	5		461	809	0.57
	11:45 AM	154	545	0.28	1	1	1	1	1	0	0	1	0	0	0	0	6		521	857	0.61
	01:15 PM	376	1336	0.28	1	1	0	1	0	0	0	0	0	0	0	0	3		636	1479	0.43
	02:45 PM	686	2207	0.31	1	1	0	1	0	0	0	0	0	0	0	0	3		1027	2350	0.44
	04:15 PM	382	1102	0.35	1	0	0	1	0	0	0	0	0	0	0	0	2		537	1188	0.45
01 October 2021	08:45 AM	206	600	0.34	1	1	1	1	0	0	0	0	0	0	0	0	4	4.00	458	800	0.57
	10:15 AM	165	508	0.32	1	1	1	1	1	0	0	1	0	0	0	0	6		529	820	0.65
	11:45 AM	171	596	0.29	1	1	1	1	0	0	0	1	0	0	0	0	5		445	851	0.52
	01:15 PM	482	1616	0.30	1	0	1	1	0	0	0	0	0	0	0	0	3		744	1759	0.42
	02:45 PM	724	2173	0.33	1	0	1	1	0	0	0	0	0	0	0	0	3		1048	2316	0.45
	04:15 PM	264	720	0.37	1	0	1	1	0	0	0	0	0	0	0	0	3		496	863	0.57
01 December 2021	08:45 AM	200	634	0.32	1	1	1	1	0	0	0	0	0	0	0	0	4	3.33	448	835	0.54
	10:15 AM	233	779	0.30	1	0	1	1	0	0	0	0	0	0	0	0	3		473	922	0.51
	11:45 AM	294	1047	0.28	1	0	1	1	0	0	0	0	0	0	0	0	3		573	1190	0.48
	01:15 PM	519	1772	0.29	1	0	1	1	0	0	0	0	0	0	0	0	3		854	1915	0.45
	02:45 PM	534	1716	0.31	1	0	0	1	0	0	0	0	0	0	0	0	2		750	1802	0.42
	04:15 PM	165	465	0.35	1	1	1	1	0	0	0	1	0	0	0	0	5		452	721	0.63

Table 61: Simulation data. Case3, North, 20% WWR

Date	Time	Before			Luminaire Status (ON=1, OFF=0)												Luminaires		After		
		E_m	E_{avg}	U_1	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	Total	Avg.	E_m	E_{avg}	U_1
01 February 2021	08:45 AM	30.6	171	0.18	1	1	1	1	0	1	1	1	1	0	0	0	8	8.67	433	623	0.70
	10:15 AM	29	156	0.19	1	1	1	1	0	1	1	1	1	0	0	0	8		425	607	0.70
	11:45 AM	21.8	111	0.20	1	1	1	1	1	1	1	1	1	0	1	0	10		434	686	0.63
	01:15 PM	27.2	144	0.19	1	1	1	1	0	1	1	1	1	0	0	0	8		415	595	0.70
	02:45 PM	34	179	0.19	1	1	1	1	0	1	1	1	1	0	0	0	8		447	631	0.71
	04:15 PM	17.8	93.9	0.19	1	1	1	1	0	1	1	1	1	1	0	1	10		465	630	0.74
01 April 2021	08:45 AM	45.4	257	0.18	1	1	1	1	0	1	1	1	1	0	0	0	8	7.83	485	709	0.68
	10:15 AM	30	164	0.18	1	1	1	1	0	1	1	1	1	0	0	0	8		422	615	0.69
	11:45 AM	34.4	157	0.22	1	1	1	1	0	1	1	1	1	0	0	0	8		423	608	0.70
	01:15 PM	31	167	0.19	1	1	1	1	0	1	1	1	1	0	0	0	8		423	618	0.68
	02:45 PM	46.1	259	0.18	1	1	1	1	0	1	1	0	1	0	0	0	7		431	689	0.63
	04:15 PM	25.3	133	0.19	1	1	1	1	0	1	1	1	1	0	0	0	8		378	584	0.65
01 June 2021	08:45 AM	61.7	348	0.18	1	1	1	1	0	1	1	0	1	0	0	0	7	7.67	449	723	0.62
	10:15 AM	48	263	0.18	1	1	1	1	0	1	1	1	1	0	0	0	8		488	715	0.68
	11:45 AM	36	183	0.20	1	1	1	1	0	1	1	1	1	0	0	0	8		471	635	0.74
	01:15 PM	52.5	285	0.18	1	1	1	1	0	1	1	1	1	0	0	0	8		493	737	0.67
	02:45 PM	62.5	341	0.18	1	1	1	1	0	1	1	0	1	0	0	0	7		448	717	0.62
	04:15 PM	28.2	156	0.18	1	1	1	1	0	1	1	1	1	0	0	0	8		411	607	0.68
01 August 2021	08:45 AM	59.3	325	0.18	1	1	1	1	0	1	1	0	1	0	0	0	7	7.67	453	743	0.61
	10:15 AM	44.4	243	0.18	1	1	1	1	0	1	1	1	1	0	0	0	8		484	694	0.70
	11:45 AM	29.2	148	0.18	1	1	1	1	0	1	1	1	1	0	0	0	8		431	641	0.67
	01:15 PM	42.4	238	0.18	1	1	1	1	0	1	1	1	1	0	0	0	8		482	689	0.70
	02:45 PM	60	327	0.18	1	1	1	1	0	1	1	0	1	0	0	0	7		441	703	0.63
	04:15 PM	31.5	170	0.19	1	1	1	1	0	1	1	1	1	0	0	0	8		427	621	0.69
01 October 2021	08:45 AM	41.9	227	0.18	1	1	1	1	0	1	1	1	1	0	0	0	8	8.67	481	678	0.71
	10:15 AM	25.9	133	0.19	1	1	1	1	0	1	1	1	1	0	0	0	8		432	639	0.68
	11:45 AM	18	86.2	0.21	1	1	1	1	0	1	1	1	1	1	0	1	10		465	622	0.75
	01:15 PM	31.5	173	0.18	1	1	1	1	0	1	1	1	1	0	0	0	8		438	624	0.70
	02:45 PM	40.7	223	0.18	1	1	1	1	0	1	1	1	1	0	0	0	8		480	675	0.71
	04:15 PM	16.7	88.9	0.19	1	1	1	1	0	1	1	1	1	1	0	1	10		464	625	0.74
01 December 2021	08:45 AM	31.6	166	0.19	1	1	1	1	0	1	1	1	1	0	0	0	8	8.33	429	617	0.70
	10:15 AM	26.9	142	0.19	1	1	1	1	0	1	1	1	1	0	0	0	8		425	636	0.67
	11:45 AM	24.3	122	0.20	1	1	1	1	0	1	1	1	1	0	0	0	8		406	573	0.71
	01:15 PM	29.6	157	0.19	1	1	1	1	0	1	1	1	1	0	0	0	8		428	609	0.70
	02:45 PM	28.5	153	0.19	1	1	1	1	0	1	1	1	1	0	0	0	8		414	604	0.69
	04:15 PM	10.2	52.3	0.20	1	1	1	1	0	1	1	1	1	1	0	1	10		458	588	0.78

Table 62: Simulation data. Case3, North, 40% WWR

Date	Time	Before			Luminaire Status (ON=1, OFF=0)												Luminaires		After		
		E_m	E_{avg}	U_1	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	Total	Avg.	E_m	E_{avg}	U_1
01 February 2021	08:45 AM	62	322	0.19	1	1	1	1	0	1	1	0	1	0	0	0	7	7.33	450	696	0.65
	10:15 AM	57.5	294	0.20	1	1	1	1	0	1	1	0	1	0	0	0	7		427	669	0.64
	11:45 AM	42.8	212	0.20	1	1	1	1	0	1	1	1	1	0	0	0	8		485	662	0.73
	01:15 PM	55.2	273	0.20	1	1	1	1	0	1	1	0	1	0	0	0	7		421	647	0.65
	02:45 PM	64	336	0.19	1	1	1	1	0	1	1	0	1	0	0	0	7		452	711	0.64
	04:15 PM	34.8	175	0.20	1	1	1	1	0	1	1	1	1	0	0	0	8		478	66	0.72
01 April 2021	08:45 AM	94.5	484	0.20	1	1	1	1	0	1	1	1	1	0	0	0	8	7.33	508	858	0.59
	10:15 AM	60.5	313	0.19	1	1	1	1	0	1	0	1	0	0	0	0	6		435	687	0.63
	11:45 AM	65.1	312	0.21	1	1	1	1	0	1	1	1	1	0	0	0	8		507	762	0.67
	01:15 PM	58.6	318	0.18	1	1	1	1	0	1	1	0	1	0	0	0	7		435	692	0.63
	02:45 PM	95.6	485	0.20	1	1	1	1	0	1	0	1	1	0	0	0	7		453	862	0.53
	04:15 PM	49.2	248	0.20	1	1	1	1	0	1	1	1	1	0	0	0	8		489	698	0.70
01 June 2021	08:45 AM	123	652	0.19	1	1	1	1	0	1	1	0	0	0	0	0	6	6.83	515	969	0.53
	10:15 AM	95.8	500	0.19	1	1	1	1	0	1	1	0	1	0	0	0	7		508	874	0.58
	11:45 AM	69.5	353	0.20	1	1	1	1	0	1	1	0	1	0	0	0	7		447	728	0.61
	01:15 PM	102	540	0.19	1	1	1	1	0	1	1	0	1	0	0	0	7		518	914	0.57
	02:45 PM	122	638	0.19	1	1	1	1	0	1	0	0	1	0	0	0	6		510	955	0.53
	04:15 PM	57.8	290	0.20	1	1	1	1	0	1	1	1	1	0	0	0	8		435	664	0.66
01 August 2021	08:45 AM	114	607	0.19	1	1	1	1	0	1	1	0	0	0	0	0	6	7.17	496	924	0.54
	10:15 AM	83.7	461	0.18	1	1	1	1	0	1	1	0	1	0	0	0	7		488	835	0.58
	11:45 AM	55.8	287	0.19	1	1	1	1	0	1	1	1	1	0	0	0	8		498	737	0.68
	01:15 PM	84.7	452	0.19	1	1	1	1	0	1	1	1	1	0	0	0	8		488	826	0.59
	02:45 PM	114	613	0.19	1	1	1	1	0	1	0	0	1	0	0	0	6		499	930	0.54
	04:15 PM	63.1	317	0.20	1	1	1	1	0	1	1	1	1	0	0	0	8		446	691	0.65
01 October 2021	08:45 AM	80.5	426	0.19	1	1	1	1	0	1	1	0	1	0	0	0	7	7.33	489	801	0.61
	10:15 AM	51.9	255	0.20	1	1	1	1	0	1	1	0	1	0	0	0	7		408	629	0.65
	11:45 AM	34.8	168	0.21	1	1	1	1	0	1	1	1	1	0	0	0	8		478	671	0.71
	01:15 PM	64	327	0.20	1	1	1	1	0	1	1	0	1	0	0	0	7		455	743	0.61
	02:45 PM	81	418	0.19	1	1	1	1	0	1	1	0	1	0	0	0	7		487	793	0.61
	04:15 PM	32.6	166	0.20	1	1	1	1	0	1	1	1	1	0	0	0	8		425	616	0.69
01 December 2021	08:45 AM	60.1	312	0.19	1	1	1	1	0	1	1	0	0	0	0	0	6	7.50	500	762	0.66
	10:15 AM	53.2	268	0.20	1	1	1	1	0	1	1	0	1	0	0	0	7		419	643	0.65
	11:45 AM	46.5	231	0.20	1	1	1	1	0	1	1	1	1	0	0	0	8		487	681	0.72
	01:15 PM	60.5	297	0.20	1	1	1	1	0	1	1	0	1	0	0	0	7		432	671	0.64
	02:45 PM	55.7	286	0.19	1	1	1	1	0	1	1	0	1	0	0	0	7		446	714	0.62
	04:15 PM	19.4	98	0.20	1	1	1	1	0	1	1	1	1	1	0	1	10		466	630	0.74

Table 63: Simulation data. Case3, North, 60% WWR

ate	Time	Before			Luminaire Status (ON=1, OFF=0)												Luminaires		After		
		E_m	E_{avg}	U_1	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	Total	Avg.	E_m	E_{avg}	U_1
01 February 2021	08:45 AM	93.8	426	0.22	1	1	1	1	0	1	1	0	1	0	0	0	7	7.00	506	799	0.63
	10:15 AM	85.3	393	0.22	1	1	1	1	0	1	1	0	1	0	0	0	7		497	807	0.62
	11:45 AM	64.9	287	0.23	1	1	1	1	0	1	1	0	1	0	0	0	7		436	660	0.66
	01:15 PM	81.8	366	0.22	1	1	1	1	0	1	1	0	1	0	0	0	7		472	739	0.64
	02:45 PM	96.3	447	0.22	1	1	1	1	0	1	1	0	1	0	0	0	7		511	820	0.62
	04:15 PM	51.6	231	0.22	1	1	1	1	0	1	1	0	1	0	0	0	7		417	605	0.69
01 April 2021	08:45 AM	137	642	137.00	1	1	1	1	0	1	0	0	0	0	0	0	5	6.50	460	901	0.51
	10:15 AM	88.6	425	0.21	1	1	1	1	0	1	1	0	1	0	0	0	7		495	798	0.62
	11:45 AM	99.5	445	0.22	1	1	1	1	0	1	1	0	1	0	0	0	7		488	819	0.60
	01:15 PM	92.7	431	0.22	1	1	1	1	0	1	1	0	1	0	0	0	7		496	805	0.62
	02:45 PM	142	645	0.22	1	1	1	1	0	1	0	0	0	0	0	0	5		458	904	0.51
	04:15 PM	71.8	326	0.22	1	1	1	1	0	1	1	1	1	0	0	0	8		464	699	0.66
01 June 2021	08:45 AM	184	867	0.21	1	1	1	1	0	0	0	0	0	0	0	0	4	5.50	447	1068	0.42
	10:15 AM	142	680	0.21	1	1	1	1	0	1	0	0	0	0	0	0	5		477	939	0.51
	11:45 AM	105	490	0.21	1	1	1	1	0	1	1	0	1	0	0	0	7		435	824	0.53
	01:15 PM	155	733	0.21	1	1	1	1	0	1	0	0	0	0	0	0	5		508	992	0.51
	02:45 PM	183	848	0.22	1	1	1	1	0	1	0	0	0	0	0	0	5		558	1107	0.50
	04:15 PM	87.1	381	0.23	1	1	1	1	0	1	1	0	1	0	0	0	7		481	754	0.64
01 August 2021	08:45 AM	169	807	0.21	1	1	1	1	0	1	0	0	0	0	0	0	5	6.00	541	1066	0.51
	10:15 AM	129	626	0.21	1	1	1	1	0	1	1	0	0	0	0	0	6		516	942	0.55
	11:45 AM	85.5	402	0.21	1	1	1	1	0	1	1	0	1	0	0	0	7		476	775	0.61
	01:15 PM	130	614	0.21	1	1	1	1	0	1	0	0	1	0	0	0	6		511	931	0.55
	02:45 PM	173	817	0.21	1	1	1	1	0	1	0	0	0	0	0	0	5		556	1076	0.52
	04:15 PM	95.3	416	0.23	1	1	1	1	0	1	1	0	1	0	0	0	7		503	790	0.64
01 October 2021	08:45 AM	121	566	0.21	1	1	1	1	0	1	1	0	0	0	0	0	6	7.00	507	883	0.57
	10:15 AM	76.6	345	0.22	1	1	1	1	0	1	1	0	1	0	0	0	7		458	719	0.64
	11:45 AM	52.3	232	0.23	1	1	1	1	0	1	1	1	1	0	0	0	8		491	681	0.72
	01:15 PM	92.2	441	0.21	1	1	1	1	0	1	1	0	1	0	0	0	7		504	814	0.62
	02:45 PM	120	554	0.22	1	1	1	1	0	1	0	0	1	0	0	0	6		503	870	0.58
	04:15 PM	49.6	219	0.23	1	1	1	1	0	1	1	1	1	0	0	0	8		489	667	0.73
01 December 2021	08:45 AM	92.7	413	0.22	1	1	1	1	0	1	1	0	1	0	0	0	7	7.33	495	787	0.63
	10:15 AM	80.4	360	0.22	1	1	1	1	0	1	1	0	1	0	0	0	7		471	733	0.64
	11:45 AM	67.7	310	0.22	1	1	1	1	0	1	1	0	1	0	0	0	7		444	684	0.65
	01:15 PM	87.9	396	0.22	1	1	1	1	0	1	1	0	1	0	0	0	7		488	769	0.63
	02:45 PM	81	379	0.21	1	1	1	1	0	1	1	0	1	0	0	0	7		484	753	0.64
	04:15 PM	29.2	129	0.23	1	1	1	1	0	1	1	1	1	0	0	1	9		471	618	0.76

Table 64: Simulation data. Case3, North, 80% WWR

Date	Time	Before			Luminaire Status (ON=1, OFF=0)												Luminaires		After		
		E_m	E_{avg}	U_1	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	Total	Avg.	E_m	E_{avg}	U_1
01 February 2021	08:45 AM	127	535	0.24	1	1	1	1	0	1	0	1	0	0	0	0	6	6.17	484	868	0.56
	10:15 AM	116	498	0.23	1	1	1	1	0	1	1	0	0	0	0	0	6		490	814	0.60
	11:45 AM	88.8	367	0.24	1	1	1	1	0	1	1	0	1	0	0	0	7		481	739	0.65
	01:15 PM	107	465	0.23	1	1	1	1	0	1	0	0	1	0	0	0	6		468	780	0.60
	02:45 PM	134	561	0.24	1	1	1	1	0	1	0	0	0	0	0	0	5		467	820	0.57
	04:15 PM	69.5	289	0.24	1	1	1	1	0	1	1	0	1	0	0	0	7		459	662	0.69
01 April 2021	08:45 AM	186	808	0.23	1	1	1	1	0	0	0	0	0	0	0	0	4	5.67	470	1009	0.47
	10:15 AM	119	544	0.22	1	1	1	1	0	1	1	0	0	0	0	0	6		505	859	0.59
	11:45 AM	128	593	0.22	1	1	1	1	0	1	1	1	1	0	0	0	8		546	965	0.57
	01:15 PM	123	553	0.22	1	1	1	1	0	1	0	0	1	0	0	0	6		504	868	0.58
	02:45 PM	177	813	0.22	1	1	1	0	0	1	0	0	0	0	0	0	4		456	1013	0.45
	04:15 PM	100	408	0.25	1	1	1	1	0	1	0	0	1	0	0	0	6		462	723	0.64
01 June 2021	08:45 AM	249	1091	0.23	1	1	1	1	0	0	0	0	0	0	0	0	4	4.50	581	1332	0.44
	10:15 AM	185	871	0.21	1	1	1	1	0	0	0	0	0	0	0	0	4		442	1072	0.41
	11:45 AM	136	638	0.21	1	1	1	1	0	1	0	0	0	0	0	0	5		474	897	0.53
	01:15 PM	206	937	0.22	1	1	1	0	0	1	0	0	0	0	0	0	4		463	1138	0.41
	02:45 PM	242	1068	0.23	1	1	1	0	0	1	0	0	0	0	0	0	4		559	1269	0.44
	04:15 PM	119	474	0.25	1	1	1	1	0	1	0	0	1	0	0	0	6		497	790	0.63
01 August 2021	08:45 AM	233	1016	0.23	1	1	1	1	0	0	0	0	0	0	0	0	4	5.17	554	1257	0.44
	10:15 AM	173	802	0.22	1	1	1	1	0	1	0	0	0	0	0	0	5		553	1060	0.52
	11:45 AM	115	526	0.22	1	1	1	1	0	1	1	0	1	0	0	0	7		528	899	0.59
	01:15 PM	172	788	0.22	1	1	1	1	0	1	0	0	0	0	0	0	5		561	1046	0.54
	02:45 PM	239	1030	0.23	1	1	1	0	0	1	0	0	0	0	0	0	4		540	1231	0.44
	04:15 PM	123	519	0.24	1	1	1	1	0	1	0	0	1	0	0	0	6		521	835	0.62
01 October 2021	08:45 AM	163	714	0.23	1	1	1	1	0	1	0	0	0	0	0	0	5	6.17	527	972	0.54
	10:15 AM	99.6	443	0.22	1	1	1	1	0	1	1	0	1	0	0	0	7		513	816	0.63
	11:45 AM	68.5	303	0.23	1	1	1	1	0	1	1	0	1	0	0	0	7		440	676	0.65
	01:15 PM	126	562	0.22	1	1	1	1	0	1	0	0	1	0	0	0	6		518	877	0.59
	02:45 PM	167	696	0.24	1	1	1	1	0	1	0	0	0	0	0	0	5		525	955	0.55
	04:15 PM	67.4	273	0.25	1	1	1	1	0	1	1	0	1	0	0	0	7		454	646	0.70
01 December 2021	08:45 AM	124	520	0.24	1	1	1	1	0	1	1	0	0	0	0	0	6	6.67	515	836	0.62
	10:15 AM	107	455	0.24	1	1	1	1	0	1	1	0	1	0	0	0	7		525	828	0.63
	11:45 AM	95.1	394	0.24	1	1	1	1	0	1	1	0	1	0	0	0	7		500	767	0.65
	01:15 PM	118	500	0.24	1	1	1	1	0	1	0	0	1	0	0	0	6		490	815	0.60
	02:45 PM	112	475	0.24	1	1	1	1	0	1	0	0	1	0	0	0	6		487	791	0.62
	04:15 PM	39.9	162	0.25	1	1	1	1	0	1	1	1	1	0	0	0	8		419	609	0.69

Table 65: Simulation data. Case3, East, 20% WWR

Date	Time	Before			Luminaire Status (ON=1, OFF=0)												Luminaires		After		
		E_m	E_{avg}	U_1	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	Total	Avg.	E_m	E_{avg}	U_1
01 February 2021	08:45 AM	82	452	0.18	1	1	1	1	0	1	1	0	1	0	0	0	7	8.00	494	829	0.60
	10:15 AM	67	379	0.18	1	1	1	1	0	1	1	0	1	0	0	0	7		455	754	0.60
	11:45 AM	36.3	193	0.19	1	1	1	1	0	1	1	1	1	0	0	0	8		454	644	0.70
	01:15 PM	29	156	0.19	1	1	1	1	0	1	1	1	1	0	0	0	8		425	607	0.70
	02:45 PM	25.9	139	0.19	1	1	1	1	0	1	1	1	1	0	0	0	8		412	590	0.70
	04:15 PM	12.4	64.8	0.19	1	1	1	1	0	1	1	1	1	1	0	1	10		459	601	0.76
01 April 2021	08:45 AM	94.7	533	0.18	1	1	1	1	0	1	1	0	1	0	0	0	7	8.83	514	909	0.57
	10:15 AM	49.7	279	0.18	1	1	1	1	0	1	1	0	1	0	0	0	7		416	654	0.64
	11:45 AM	36.2	168	0.22	1	1	1	1	0	1	1	1	1	0	0	0	8		429	619	0.69
	01:15 PM	22	108	0.20	1	1	1	1	1	1	1	0	1	1	0	1	10		445	644	0.69
	02:45 PM	25.8	130	0.20	1	1	1	1	1	1	1	0	1	1	0	1	10		469	666	0.70
	04:15 PM	12.8	67.5	0.19	1	1	1	1	1	1	1	0	1	1	1	1	11		475	658	0.72
01 June 2021	08:45 AM	89	500	0.18	1	1	1	1	0	1	1	0	1	0	0	0	7	8.50	501	875	0.57
	10:15 AM	51.9	286	0.18	1	1	1	1	1	1	1	0	1	0	0	0	8		502	737	0.68
	11:45 AM	24.3	124	0.20	1	1	1	1	1	1	1	0	1	1	0	1	10		456	660	0.69
	01:15 PM	25.8	132	0.20	1	1	1	1	1	0	1	1	1	0	0	0	8		400	583	0.69
	02:45 PM	36.3	136	0.19	1	1	1	1	1	0	1	1	1	0	0	0	8		415	587	0.71
	04:15 PM	12.6	67.6	0.19	1	1	1	1	0	1	1	1	1	1	0	1	10		460	604	0.76
01 August 2021	08:45 AM	93.2	513	0.18	1	1	1	1	0	1	1	0	1	0	0	0	7	8.67	513	931	0.55
	10:15 AM	54.5	299	0.18	1	1	1	1	0	1	1	0	1	0	0	0	7		426	675	0.63
	11:45 AM	22.4	113	0.20	1	1	1	1	0	1	1	0	1	1	0	1	9		445	649	0.69
	01:15 PM	23.6	119	0.20	1	1	1	1	0	1	1	1	1	1	0	1	10		472	655	0.72
	02:45 PM	26.1	136	0.19	1	1	1	1	0	1	1	1	1	0	1	0	9		459	642	0.71
	04:15 PM	13.9	74.7	0.19	1	1	1	1	0	1	1	1	1	1	0	1	10		462	611	0.76
01 October 2021	08:45 AM	89	520	0.17	1	1	1	1	0	1	1	0	1	0	0	0	7	9.17	509	896	0.57
	10:15 AM	46.1	248	0.19	1	1	1	1	0	1	1	1	1	0	0	0	8		483	700	0.69
	11:45 AM	20	100	0.20	1	1	1	1	0	1	1	1	1	1	0	1	10		465	636	0.73
	01:15 PM	24.2	123	0.20	1	1	1	1	0	1	1	1	1	1	0	1	10		471	659	0.71
	02:45 PM	23.9	125	0.19	1	1	1	1	0	1	1	1	1	1	0	1	10		471	661	0.71
	04:15 PM	9.84	50.3	0.20	1	1	1	1	0	1	1	1	1	1	0	1	10		456	586	0.78
01 December 2021	08:45 AM	77.1	449	0.17	1	1	1	1	0	1	1	0	1	0	0	0	7	8.33	482	824	0.58
	10:15 AM	58.7	334	0.18	1	1	1	1	0	1	1	0	1	0	0	0	7		445	710	0.63
	11:45 AM	36.9	198	0.19	1	1	1	1	0	1	1	1	1	0	0	0	8		463	649	0.71
	01:15 PM	30.2	166	0.18	1	1	1	1	0	1	1	1	1	0	0	0	8		437	617	0.71
	02:45 PM	222	122	0.18	1	1	1	1	0	1	1	1	1	0	1	0	9		427	628	0.68
	04:15 PM	7.18	38.7	0.19	1	1	1	1	1	1	1	0	1	1	1	1	11		469	629	0.75

Table 66: Simulation data. Case3, East, 40% WWR

Date	Time	Before			Luminaire Status (ON=1, OFF=0)												Luminaires		After		
		E_m	E_{avg}	U_1	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	Total	Avg.	E_m	E_{avg}	U_1
01 February 2021	08:45 AM	161	836	0.19	1	1	1	1	0	1	0	0	0	0	0	0	5	6.67	531	1096	0.48
	10:15 AM	134	713	0.19	1	1	1	1	0	1	0	0	0	0	0	0	5		464	973	0.48
	11:45 AM	69.7	367	0.19	1	1	1	1	0	1	1	0	1	0	0	0	7		458	742	0.62
	01:15 PM	58.7	296	0.20	1	1	1	1	0	1	1	0	1	0	0	0	7		430	670	0.64
	02:45 PM	49.8	261	0.19	1	1	1	1	0	1	1	0	1	0	0	0	7		417	635	0.66
	04:15 PM	24.7	122	0.20	1	1	1	1	1	1	1	0	1	0	1	0	9		408	625	0.65
01 April 2021	08:45 AM	195	990	0.20	1	1	1	1	0	1	0	0	0	0	0	0	5	7.00	582	1250	0.47
	10:15 AM	102	531	0.19	1	1	1	1	0	1	0	1	0	0	0	0	6		446	886	0.52
	11:45 AM	68.7	334	0.21	1	1	1	1	0	1	1	0	1	0	0	0	7		439	708	0.62
	01:15 PM	42.5	206	0.21	1	1	1	1	0	1	1	1	1	0	0	0	8		481	656	0.73
	02:45 PM	49.7	246	0.20	1	1	1	1	0	1	1	1	1	0	0	0	8		489	696	0.70
	04:15 PM	24.6	127	0.19	1	1	1	1	0	1	1	1	1	0	0	0	8		422	577	0.73
01 June 2021	08:45 AM	175	930	0.19	1	1	1	1	0	1	0	0	0	0	0	0	5	7.33	569	1190	0.48
	10:15 AM	101	541	0.19	1	1	1	1	0	1	1	0	1	0	0	0	7		518	914	0.57
	11:45 AM	47.3	239	0.20	1	1	1	1	0	1	1	1	1	0	0	0	8		488	689	0.71
	01:15 PM	50	251	0.20	1	1	1	1	0	1	1	1	1	0	0	0	8		493	701	0.70
	02:45 PM	51.8	256	0.20	1	1	1	1	0	1	1	1	1	0	0	0	8		494	706	0.70
	04:15 PM	25.3	127	0.20	1	1	1	1	0	1	1	1	1	0	0	0	8		401	577	0.69
01 August 2021	08:45 AM	184	954	0.19	1	1	1	1	0	1	0	0	0	0	0	0	5	7.33	580	1214	0.48
	10:15 AM	108	568	0.19	1	1	1	1	0	1	1	0	1	0	0	0	7		530	942	0.56
	11:45 AM	44.8	220	0.20	1	1	1	1	0	1	1	1	1	0	0	0	8		486	670	0.73
	01:15 PM	45.3	227	0.20	1	1	1	1	0	1	1	1	1	0	0	0	8		487	677	0.72
	02:45 PM	51.6	257	0.20	1	1	1	1	0	1	1	1	1	0	0	0	8		492	706	0.70
	04:15 PM	27.2	140	0.19	1	1	1	1	0	1	1	1	1	0	0	0	8		426	590	0.72
01 October 2021	08:45 AM	183	968	0.19	1	1	1	1	0	1	0	0	0	0	0	0	5	7.67	575	1227	0.47
	10:15 AM	89	474	0.19	1	1	1	1	0	1	1	0	1	0	0	0	7		496	849	0.58
	11:45 AM	38.7	195	0.20	1	1	1	1	0	1	1	1	1	0	0	0	8		469	645	0.73
	01:15 PM	45.7	234	0.20	1	1	1	1	0	1	1	1	1	0	0	0	8		487	684	0.71
	02:45 PM	48.1	236	0.20	1	1	1	1	0	1	1	1	1	0	0	0	8		488	686	0.71
	04:15 PM	19.1	94.8	0.20	1	1	1	1	1	1	1	0	1	1	0	1	10		435	627	0.69
01 December 2021	08:45 AM	164	834	0.20	1	1	1	1	0	1	0	0	0	0	0	0	5	7.00	517	1093	0.47
	10:15 AM	116	630	0.18	1	1	1	1	0	1	1	0	0	0	0	0	6		499	947	0.53
	11:45 AM	70	375	0.19	1	1	1	1	0	1	1	0	1	0	0	0	7		460	749	0.61
	01:15 PM	60.7	313	0.19	1	1	1	1	0	1	1	0	1	0	0	0	7		444	688	0.65
	02:45 PM	45.1	229	0.20	1	1	1	1	0	1	1	0	1	0	0	0	7		404	603	0.67
	04:15 PM	14.6	72.8	0.20	1	1	1	1	1	1	1	0	1	1	0	1	10		411	605	0.68

Table 67: Simulation data. Case3, East, 60% WWR

Date	Time	Before			Luminaire Status (ON=1, OFF=0)												Luminaires		After		
		E_m	E_{avg}	U_1	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	Total	Avg.	E_m	E_{avg}	U_1
01 February 2021	08:45 AM	247	1101	0.22	1	1	1	1	0	0	0	0	0	0	0	0	4	6.33	529	1302	0.41
	10:15 AM	195	958	0.20	1	1	1	1	0	1	0	0	0	0	0	0	5		600	1217	0.49
	11:45 AM	105	498	0.21	1	1	1	1	0	1	1	0	0	0	0	0	6		462	814	0.57
	01:15 PM	87	396	0.22	1	1	1	1	0	1	1	0	1	0	0	0	7		486	770	0.63
	02:45 PM	78.6	347	0.23	1	1	1	1	0	1	1	0	1	0	0	0	7		470	721	0.65
	04:15 PM	35.3	161	0.22	1	1	1	1	1	1	1	0	1	0	1	0	9		470	663	0.71
01 April 2021	08:45 AM	292	1315	0.22	1	1	1	1	0	1	0	0	0	0	0	0	5	6.67	710	1574	0.45
	10:15 AM	151	728	0.21	1	1	1	1	0	1	0	0	0	0	0	0	5		498	987	0.50
	11:45 AM	104	477	0.22	1	1	1	1	0	1	1	0	1	0	0	0	7		496	850	0.58
	01:15 PM	64	279	0.23	1	1	1	1	0	1	1	0	1	0	0	0	7		430	652	0.66
	02:45 PM	76.4	327	0.23	1	1	1	1	0	1	1	1	1	0	0	0	8		460	701	0.66
	04:15 PM	38.4	168	0.23	1	1	1	1	0	1	1	1	1	0	0	0	8		478	616	0.77
01 June 2021	08:45 AM	267	1236	0.22	1	1	1	1	0	1	0	0	0	0	0	0	5	6.50	687	1495	0.46
	10:15 AM	154	739	0.21	1	1	1	1	0	1	0	0	0	0	0	0	5		514	997	0.52
	11:45 AM	72.3	330	0.22	1	1	1	1	0	1	1	0	1	0	0	0	7		447	703	0.64
	01:15 PM	75.4	338	0.22	1	1	1	1	0	1	1	0	1	0	0	0	7		462	711	0.65
	02:45 PM	78.7	340	0.23	1	1	1	1	0	1	1	0	1	0	0	0	7		465	713	0.65
	04:15 PM	38.2	168	0.23	1	1	1	1	0	1	1	1	1	0	0	0	8		464	617	0.75
01 August 2021	08:45 AM	278	1268	0.22	1	1	1	1	0	1	0	0	0	0	0	0	5	6.50	696	1524	0.46
	10:15 AM	161	774	0.21	1	1	1	1	0	1	0	0	0	0	0	0	5		526	1033	0.51
	11:45 AM	66	305	0.22	1	1	1	1	0	1	1	0	1	0	0	0	7		436	679	0.64
	01:15 PM	69	307	0.22	1	1	1	1	0	1	1	0	1	0	0	0	7		444	680	0.65
	02:45 PM	77.9	341	0.23	1	1	1	1	0	1	1	0	1	0	0	0	7		467	715	0.65
	04:15 PM	41.3	186	0.22	1	1	1	1	0	1	1	1	1	0	0	0	8		480	634	0.76
01 October 2021	08:45 AM	279	1289	0.22	1	1	1	1	0	1	0	0	0	0	0	0	5	6.67	700	1548	0.45
	10:15 AM	139	649	0.21	1	1	1	1	0	1	0	0	0	0	0	0	5		472	908	0.52
	11:45 AM	56.8	271	0.21	1	1	1	1	0	1	1	1	1	0	0	0	8		495	719	0.69
	01:15 PM	70.6	315	0.22	1	1	1	1	0	1	1	0	1	0	0	0	7		447	689	0.65
	02:45 PM	72.1	313	0.23	1	1	1	1	0	1	1	0	1	0	0	0	7		453	687	0.66
	04:15 PM	28.8	126	0.23	1	1	1	1	0	1	1	1	1	0	0	0	8		418	574	0.73
01 December 2021	08:45 AM	237	1102	0.22	1	1	1	1	0	0	0	0	0	0	0	0	4	6.50	525	1303	0.40
	10:15 AM	180	847	0.21	1	1	1	1	0	1	0	0	0	0	0	0	5		558	1106	0.50
	11:45 AM	104	505	0.21	1	1	1	1	0	1	1	0	0	0	0	0	6		473	821	0.58
	01:15 PM	89.2	417	0.21	1	1	1	1	0	1	1	0	1	0	0	0	7		497	791	0.63
	02:45 PM	68	303	0.22	1	1	1	1	0	1	1	0	1	0	0	0	7		451	677	0.67
	04:15 PM	21.7	96.3	0.23	1	1	1	1	0	1	1	1	1	1	0	1	10		466	626	0.74

Table 68: Simulation data. Case3, East, 80% WWR

Date	Time	Before			Luminaire Status (ON=1, OFF=0)												Luminaires		After		
		E_m	E_{avg}	U_1	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	Total	Avg.	E_m	E_{avg}	U_1
01 February 2021	08:45 AM	323	1378	0.23	1	1	1	0	1	0	0	0	0	0	0	0	4	5.50	619	1596	0.39
	10:15 AM	264	1216	0.22	1	1	1	1	0	1	0	0	0	0	0	0	5		701	1475	0.48
	11:45 AM	139	637	0.22	1	1	1	1	0	1	0	0	0	0	0	0	5		483	895	0.54
	01:15 PM	118	503	0.23	1	1	1	1	0	1	1	0	0	0	0	0	6		488	818	0.60
	02:45 PM	103	436	0.24	1	1	1	1	0	1	1	0	0	0	0	0	6		466	751	0.62
	04:15 PM	47.4	202	0.23	1	1	1	1	0	1	1	0	1	0	0	0	7		409	575	0.71
01 April 2021	08:45 AM	396	1654	0.24	1	1	1	1	0	1	0	0	0	0	0	0	5	6.17	842	1912	0.44
	10:15 AM	197	938	0.21	1	1	1	1	0	1	0	0	0	0	0	0	5		603	1196	0.50
	11:45 AM	137	634	0.22	1	1	1	1	0	1	0	1	0	0	0	0	6		502	967	0.52
	01:15 PM	85.2	356	0.24	1	1	1	1	0	1	1	0	1	0	0	0	7		474	728	0.65
	02:45 PM	101	413	0.24	1	1	1	1	0	1	1	0	1	0	0	0	7		511	785	0.65
	04:15 PM	52.4	211	0.25	1	1	1	1	0	1	1	0	1	0	0	0	7		428	636	0.67
01 June 2021	08:45 AM	355	1554	0.23	1	1	1	0	0	1	0	0	0	0	0	0	4	6.33	702	1755	0.40
	10:15 AM	202	945	0.21	1	1	1	1	0	1	0	0	0	0	0	0	5		623	1024	0.52
	11:45 AM	93.4	426	0.22	1	1	1	1	0	1	1	0	1	0	0	0	7		497	798	0.62
	01:15 PM	101	429	0.24	1	1	1	1	0	1	1	0	1	0	0	0	7		507	802	0.63
	02:45 PM	104	428	0.24	1	1	1	1	0	1	1	0	1	0	0	0	7		519	801	0.65
	04:15 PM	50.9	211	0.24	1	1	1	1	0	1	1	1	1	0	0	0	8		491	459	0.75
01 August 2021	08:45 AM	372	1589	0.23	1	1	1	0	0	1	0	0	0	0	0	0	4	6.33	702	1789	0.39
	10:15 AM	218	993	0.22	1	1	1	1	0	1	0	0	0	0	0	0	5		632	1251	0.51
	11:45 AM	88.2	398	0.22	1	1	1	1	0	1	1	0	1	0	0	0	7		481	771	0.62
	01:15 PM	92.7	391	0.24	1	1	1	1	0	1	1	0	1	0	0	0	7		496	764	0.65
	02:45 PM	105	430	0.24	1	1	1	1	0	1	1	0	1	0	0	0	7		526	855	0.62
	04:15 PM	55.8	233	0.24	1	1	1	1	0	1	1	1	1	0	0	0	8		494	681	0.73
01 October 2021	08:45 AM	379	1623	0.23	1	1	1	1	0	0	0	0	0	0	0	0	4	6.33	704	1824	0.39
	10:15 AM	180	838	0.21	1	1	1	1	0	1	0	0	0	0	0	0	5		570	1097	0.52
	11:45 AM	76.2	353	0.22	1	1	1	1	0	1	1	0	1	0	0	0	7		461	725	0.64
	01:15 PM	90.9	400	0.23	1	1	1	1	0	1	1	0	1	0	0	0	7		502	773	0.65
	02:45 PM	96	394	0.24	1	1	1	1	0	1	1	0	1	0	0	0	7		504	767	0.66
	04:15 PM	38.8	158	0.25	1	1	1	1	0	1	1	1	1	0	0	0	8		472	606	0.78
01 December 2021	08:45 AM	324	1381	0.23	1	1	1	1	0	0	0	0	0	0	0	0	4	6.00	682	1581	0.43
	10:15 AM	229	1076	0.21	1	1	1	1	0	0	0	0	0	0	0	0	4		538	1276	0.42
	11:45 AM	142	641	0.22	1	1	1	1	0	1	0	0	0	0	0	0	5		482	900	0.54
	01:15 PM	126	527	0.24	1	1	1	1	1	1	0	0	0	0	0	0	6		461	861	0.54
	02:45 PM	89.9	381	0.24	1	1	1	1	0	1	1	0	1	0	0	0	7		500	754	0.66
	04:15 PM	28.7	121	0.24	1	1	1	1	0	1	1	1	1	1	0	1	10		473	649	0.73

Table 69: Simulation data. Case3, South, 20% WWR

ate	Time	Before			Luminaire Status (ON=1, OFF=0)												Luminaires		After		
		E_m	E_{avg}	U_1	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	Total	Avg.	E_m	E_{avg}	U_1
01 February 2021	08:45 AM	61.6	334	0.18	1	1	1	1	0	1	1	0	1	0	0	0	7	7.17	446	710	0.63
	10:15 AM	67.3	379	0.18	1	1	1	1	0	1	1	0	1	0	0	0	7		457	0.755	0.61
	11:45 AM	56.6	308	0.18	1	1	1	1	0	1	1	0	1	0	0	0	7		440	726	0.61
	01:15 PM	63.7	363	0.18	1	1	1	1	0	1	1	0	1	0	0	0	7		453	738	0.61
	02:45 PM	62	362	0.17	1	1	1	1	0	1	1	0	1	0	0	0	7		456	738	0.62
	04:15 PM	27.7	148	0.19	1	1	1	1	0	1	1	1	1	0	0	0	8		401	599	0.67
01 April 2021	08:45 AM	48.2	265	0.18	1	1	1	1	0	1	1	1	1	0	0	0	8	8.17	489	716	0.68
	10:15 AM	33.6	180	0.19	1	1	1	1	0	1	1	1	1	0	0	0	8		439	632	0.69
	11:45 AM	38.8	180	0.22	1	1	1	1	0	1	1	1	1	0	0	0	8		451	632	0.71
	01:15 PM	33	182	0.18	1	1	1	1	0	1	1	1	1	0	0	0	8		446	633	0.70
	02:45 PM	46.7	263	0.18	1	1	1	1	0	1	1	1	1	0	0	0	8		486	714	0.68
	04:15 PM	24.9	127	0.20	1	1	1	1	0	1	1	1	1	1	0	0	9		468	620	0.75
01 June 2021	08:45 AM	36.9	198	0.19	1	1	1	1	0	1	1	1	1	0	0	0	8	8.67	464	649	0.71
	10:15 AM	25.9	137	0.19	1	1	1	1	0	1	1	1	1	0	0	0	8		400	589	0.68
	11:45 AM	18.1	90.5	2.00	1	1	1	1	0	1	1	1	1	1	0	1	10		465	625	0.74
	01:15 PM	28.5	150	0.19	1	1	1	1	0	1	1	1	1	0	0	0	8		413	601	0.69
	02:45 PM	35.1	194	0.18	1	1	1	1	0	1	1	1	1	0	0	0	8		458	646	0.71
	04:15 PM	18.6	98.3	0.19	1	1	1	1	0	1	1	1	1	1	0	1	10		465	634	0.73
01 August 2021	08:45 AM	38.5	209	0.18	1	1	1	1	0	1	1	1	1	0	0	0	8	8.67	472	661	0.71
	10:15 AM	28.4	148	0.19	1	1	1	1	0	1	1	1	1	0	0	0	8		409	599	0.68
	11:45 AM	17.4	85.1	0.20	1	1	1	1	0	1	1	1	1	1	0	1	10		465	621	0.75
	01:15 PM	26.3	144	0.18	1	1	1	1	0	1	1	1	1	0	0	0	8		405	595	0.68
	02:45 PM	38.9	209	0.19	1	1	1	1	0	1	1	1	1	0	0	0	8		473	660	0.72
	04:15 PM	21.9	116	0.19	1	1	1	1	0	1	1	1	1	1	0	1	10		468	652	0.72
01 October 2021	08:45 AM	53	302	0.18	1	1	1	1	0	1	1	0	1	0	0	0	7	8.33	431	678	0.64
	10:15 AM	37.7	202	0.19	1	1	1	1	0	1	1	1	1	0	0	0	8		471	654	0.72
	11:45 AM	28	140	0.20	1	1	1	1	0	1	1	1	1	1	0	1	10		473	676	0.70
	01:15 PM	45.7	250	0.18	1	1	1	1	0	1	1	0	1	0	0	0	7		407	625	0.65
	02:45 PM	52.2	281	0.19	1	1	1	1	0	1	1	1	1	0	0	0	8		492	732	0.67
	04:15 PM	19.1	98.9	0.19	1	1	1	1	0	1	1	1	1	1	0	1	10		466	635	0.73
01 December 2021	08:45 AM	68	386	0.18	1	1	1	1	0	1	1	0	1	0	0	0	7	7.50	463	761	0.61
	10:15 AM	73.8	411	0.18	1	1	1	1	0	1	1	0	1	0	0	0	7		481	841	0.57
	11:45 AM	67.1	378	0.18	1	1	1	1	0	1	1	0	1	0	0	0	7		458	754	0.61
	01:15 PM	72.1	423	0.17	1	1	1	1	0	1	1	0	1	0	0	0	7		474	799	0.59
	02:45 PM	57.4	320	0.18	1	1	1	1	0	1	1	0	1	0	0	0	7		442	696	0.64
	04:15 PM	16.2	83.4	0.19	1	1	1	1	0	1	1	1	1	1	0	1	10		459	619	0.74

Table 70: Simulation data. Case3, South, 40% WWR

Date	Time	Before			Luminaire Status (ON=1, OFF=0)												Luminaires		After		
		E_m	E_{avg}	U_1	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	Total	Avg.	E_m	E_{avg}	U_1
01 February 2021	08:45 AM	116	623	0.19	1	1	1	1	0	1	0	0	1	0	0	0	6	6.00	507	940	0.54
	10:15 AM	134	715	0.19	1	1	1	1	0	1	0	0	0	0	0	0	5		473	974	0.49
	11:45 AM	112	587	0.19	1	1	1	1	1	1	0	0	0	0	0	0	6		460	922	0.50
	01:15 PM	126	686	0.18	1	1	1	1	0	1	1	0	0	0	0	0	6		516	1002	0.51
	02:45 PM	127	676	0.19	1	1	1	1	0	1	1	0	0	0	0	0	6		523	993	0.53
	04:15 PM	54.8	276	0.20	1	1	1	1	0	1	1	0	1	0	0	0	7		443	692	0.64
01 April 2021	08:45 AM	94.4496	496	0.19	1	1	1	1	0	1	1	0	1	0	0	0	7	7.10	508	871	0.58
	10:15 AM	66.6	343	0.19	1	1	1	1	0	1	1	0	1	0	0	0	7		445	718	0.62
	11:45 AM	75.5	360	0.21	1	1	1	1	0	1	1	0	1	0	0	0	7		451	734	0.61
	01:15 PM	67.8	347	0.20	1	1	1	1	0	1	1	0	1	0	0	0	6.62		449	722	0.62
	02:45 PM	93.9	493	0.19	1	1	1	1	0	1	1	0	1	0	0	0	7		510	867	0.59
	04:15 PM	47.5	237	0.20	1	1	1	1	0	1	1	1	1	0	0	0	8		487	687	0.71
01 June 2021	08:45 AM	74	371	0.20	1	1	1	1	0	1	1	0	1	0	0	0	7	7.67	467	746	0.63
	10:15 AM	50.7	261	0.19	1	1	1	1	0	1	1	1	1	0	0	0	8		493	711	0.69
	11:45 AM	36	175	0.21	1	1	1	1	0	1	1	1	1	0	0	0	8		473	624	0.76
	01:15 PM	54	285	0.19	1	1	1	1	0	1	1	1	1	0	0	0	8		495	735	0.67
	02:45 PM	68.6	365	0.19	1	1	1	1	0	1	1	0	1	0	0	0	7		463	739	0.63
	04:15 PM	36.6	184	0.20	1	1	1	1	0	1	1	1	1	0	0	0	8		449	634	0.71
01 August 2021	08:45 AM	79.8	393	0.20	1	1	1	1	0	1	1	0	1	0	0	0	7	7.83	471	768	0.61
	10:15 AM	54.4	281	0.19	1	1	1	1	0	1	1	0	1	0	0	0	7		423	655	0.65
	11:45 AM	34.9	165	0.21	1	1	1	1	0	1	1	1	1	1	0	1	10		481	698	0.69
	01:15 PM	53.4	273	0.20	1	1	1	1	0	1	1	1	1	0	0	0	8		494	723	0.68
	02:45 PM	76	392	0.19	1	1	1	1	0	1	1	0	1	0	0	0	7		473	767	0.62
	04:15 PM	43.3	217	0.20	1	1	1	1	0	1	1	1	1	0	0	0	8		484	667	0.73
01 October 2021	08:45 AM	108	567	0.19	1	1	1	1	0	1	0	0	1	0	0	0	6	7.00	490	937	0.52
	10:15 AM	74.2	386	0.19	1	1	1	1	0	1	1	0	1	0	0	0	7		464	761	0.61
	11:45 AM	53.9	272	0.20	1	1	1	1	0	1	1	1	1	0	0	0	8		493	722	0.68
	01:15 PM	91.5	474	0.19	1	1	1	1	0	1	1	0	1	0	0	0	7		497	848	0.59
	02:45 PM	101	526	0.19	1	1	1	1	0	1	1	0	0	0	0	0	6		468	843	0.56
	04:15 PM	38	185	0.21	1	1	1	1	0	1	1	1	1	0	0	0	8		449	635	0.71
01 December 2021	08:45 AM	137	718	0.19	1	1	1	1	0	1	0	0	0	0	0	0	5	5.67	473	978	0.48
	10:15 AM	142	772	0.18	1	1	1	1	0	1	0	0	0	0	0	0	5		501	1031	0.49
	11:45 AM	133	715	0.19	1	1	1	1	0	1	0	0	0	0	0	0	5		477	975	0.49
	01:15 PM	146	793	0.18	1	1	1	1	0	1	0	0	0	0	0	0	5		501	1052	0.48
	02:45 PM	119	597	0.20	1	1	1	1	0	1	1	0	0	0	0	0	6		495	914	0.54
	04:15 PM	31.8	156	0.20	1	1	1	1	0	1	1	1	1	0	0	0	8		411	605	0.68

Table 71: Simulation data. Case3, South, 60% WWR

Date	Time	Before			Luminaire Status (ON=1, OFF=0)												Luminaires		After		
		E_m	E_{avg}	U_1	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	Total	Avg.	E_m	E_{avg}	U_1
01 February 2021	08:45 AM	181	824	0.22	1	1	1	1	0	1	0	0	0	0	0	0	5	5.33	555	1083	0.51
	10:15 AM	197	960	0.21	1	1	1	1	0	1	0	0	0	0	0	0	5		602	1219	0.49
	11:45 AM	169	800	0.21	1	1	1	1	0	1	0	0	0	0	0	0	5		538	1059	0.51
	01:15 PM	187	924	0.20	1	1	1	1	0	1	0	0	0	0	0	0	5		593	1188	0.50
	02:45 PM	187	896	0.21	1	1	1	1	0	1	0	0	0	0	0	0	5		581	1155	0.50
	04:15 PM	82.6	362	0.23	1	1	1	1	0	1	1	0	1	0	0	0	7		483	735	0.66
01 April 2021	08:45 AM	139	660	0.21	1	1	1	1	0	1	0	0	0	0	0	0	5	6.50	461	919	0.50
	10:15 AM	98.8	468	0.21	1	1	1	1	0	1	1	0	1	0	0	0	7		506	841	0.60
	11:45 AM	111	515	0.22	1	1	1	1	0	1	1	0	1	0	0	0	7		506	888	0.57
	01:15 PM	100	472	0.21	1	1	1	1	0	1	1	0	1	0	0	0	7		507	845	0.60
	02:45 PM	140	654	0.21	1	1	1	1	0	1	1	0	0	0	0	0	6		548	970	0.56
	04:15 PM	71	312	0.23	1	1	1	1	0	1	1	0	1	0	0	0	7		458	685	0.67
01 June 2021	08:45 AM	108	494	0.22	1	1	1	1	0	1	0	0	1	0	0	0	6	7.00	472	810	0.58
	10:15 AM	80	353	0.23	1	1	1	1	0	1	1	0	1	0	0	0	7		463	727	0.64
	11:45 AM	53.7	239	0.22	1	1	1	1	0	1	1	1	1	0	0	0	8		492	688	0.72
	01:15 PM	84.9	383	0.22	1	1	1	1	0	1	1	0	1	0	0	0	7		480	757	0.63
	02:45 PM	110	484	0.23	1	1	1	1	0	1	1	0	0	0	0	0	6		472	800	0.59
	04:15 PM	53.4	243	0.22	1	1	1	1	0	1	1	1	1	0	0	0	8		492	691	0.71
01 August 2021	08:45 AM	116	522	0.22	1	1	1	1	0	1	0	0	1	0	0	0	6	6.83	486	838	0.58
	10:15 AM	81.3	379	0.21	1	1	1	1	0	1	1	0	1	0	0	0	7		472	752	0.63
	11:45 AM	50.7	229	0.22	1	1	1	1	0	1	1	1	1	0	0	0	8		490	677	0.72
	01:15 PM	79.8	369	0.22	1	1	1	1	0	1	1	0	1	0	0	0	7		471	743	0.63
	02:45 PM	113	521	0.22	1	1	1	1	0	1	1	0	0	0	0	0	6		485	837	0.58
	04:15 PM	61.6	286	0.22	1	1	1	1	0	1	1	0	1	0	0	0	7		442	659	0.67
01 October 2021	08:45 AM	155	756	0.21	1	1	1	1	0	1	0	0	0	0	0	0	5	6.17	513	1015	0.51
	10:15 AM	113	527	0.21	1	1	1	1	0	1	0	0	1	0	0	0	6		464	843	0.55
	11:45 AM	79.8	381	0.21	1	1	1	1	0	1	1	0	1	0	0	0	7		468	754	0.62
	01:15 PM	133	641	0.21	1	1	1	1	0	1	1	0	0	0	0	0	6		461	899	0.51
	02:45 PM	142	696	0.20	1	1	1	1	0	1	0	0	0	0	0	0	5		487	955	0.51
	04:15 PM	56.4	243	0.23	1	1	1	1	0	1	1	1	1	0	0	0	8		496	691	0.72
01 December 2021	08:45 AM	203	952	0.21	1	1	1	1	0	1	0	0	0	0	0	0	5	5.33	610	1210	0.50
	10:15 AM	217	1039	0.21	1	1	1	1	0	1	0	0	0	0	0	0	5		627	1298	0.48
	11:45 AM	202	968	0.21	1	1	1	1	0	1	0	0	0	0	0	0	5		600	1227	0.49
	01:15 PM	214	1058	0.20	1	1	1	1	0	0	0	0	0	0	0	0	4		494	1259	0.39
	02:45 PM	168	787	0.21	1	1	1	1	0	1	0	0	0	0	0	0	5		541	1045	0.52
	04:15 PM	47.8	204	0.23	1	1	1	1	0	1	1	1	1	0	0	0	8		476	652	0.46

Table 72: Simulation data. Case3, South, 80% WWR

Date	Time	Before			Luminaire Status (ON=1, OFF=0)												Luminaires		After		
		E_m	E_{avg}	U_1	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	Total	Avg.	E_m	E_{avg}	U_1
01 February 2021	08:45 AM	233	1032	0.23	1	1	1	0	0	1	0	0	0	0	0	0	4	4.83	1233	554	0.45
	10:15 AM	270	1221	0.22	1	1	1	0	0	1	0	0	0	0	0	0	4		569	1421	0.40
	11:45 AM	220	1028	0.21	1	1	1	1	0	1	0	0	0	0	0	0	5		644	1286	0.50
	01:15 PM	257	1177	0.22	1	1	1	1	0	1	0	0	0	0	0	0	5		686	1435	0.48
	02:45 PM	255	1126	0.23	1	1	1	1	0	1	0	0	0	0	0	0	5		684	1385	0.49
	04:15 PM	109	451	0.24	1	1	1	1	0	1	1	0	0	0	0	0	6		481	766	0.63
01 April 2021	08:45 AM	195	830	0.23	1	1	1	0	0	1	0	0	0	0	0	0	4	5.17	469	1031	0.45
	10:15 AM	133	599	0.22	1	1	1	1	0	1	0	0	1	0	0	0	6		527	915	0.58
	11:45 AM	144	684	0.21	1	1	1	1	0	1	0	0	0	0	0	0	5		466	943	0.49
	01:15 PM	131	604	0.22	1	1	1	1	0	1	0	0	0	0	0	0	5		454	862	0.53
	02:45 PM	193	823	0.23	1	1	1	1	0	0	0	0	0	0	0	0	4		475	1024	0.46
	04:15 PM	94.9	390	0.24	1	1	1	1	0	1	1	0	1	0	0	0	7		513	762	0.67
01 June 2021	08:45 AM	146	622	0.23	1	1	1	1	0	1	0	0	1	0	0	0	6	6.50	559	937	0.60
	10:15 AM	103	450	0.23	1	1	1	1	0	1	1	0	1	0	0	0	7		517	823	0.63
	11:45 AM	72.6	309	0.23	1	1	1	1	0	1	1	0	1	0	0	0	7		448	682	0.66
	01:15 PM	115	488	0.24	1	1	1	1	0	1	1	0	1	0	0	0	7		536	860	0.62
	02:45 PM	142	609	0.23	1	1	1	1	0	1	0	0	0	0	0	0	5		478	867	0.55
	04:15 PM	75.4	304	0.25	1	1	1	1	0	1	1	0	1	0	0	0	7		467	676	0.69
01 August 2021	08:45 AM	151	657	0.23	1	1	1	1	0	1	0	0	0	0	0	0	5	6.00	504	916	0.55
	10:15 AM	112	485	0.23	1	1	1	1	0	1	0	0	1	0	0	0	6		474	800	0.59
	11:45 AM	66.7	298	0.22	1	1	1	1	0	1	1	0	1	0	0	0	7		439	670	0.66
	01:15 PM	104	472	0.22	1	1	1	1	0	1	1	0	0	0	0	0	6		466	787	0.59
	02:45 PM	152	655	0.23	1	1	1	1	0	1	0	0	0	0	0	0	5		502	914	0.55
	04:15 PM	85.6	358	0.24	1	1	1	1	0	1	1	0	1	0	0	0	7		497	731	0.68
01 October 2021	08:45 AM	217	953	0.23	1	1	1	0	0	1	0	0	0	0	0	0	4	5.33	506	1154	0.46
	10:15 AM	145	679	0.21	1	1	1	1	0	1	0	0	0	0	0	0	5		499	937	0.53
	11:45 AM	105	500	0.21	1	1	1	1	0	1	1	0	1	0	0	0	7		519	873	0.59
	01:15 PM	175	817	0.21	1	1	1	1	0	1	0	0	0	0	0	0	5		570	1075	0.53
	02:45 PM	204	875	0.23	1	1	1	1	0	0	0	0	0	0	0	0	4		496	1076	0.46
	04:15 PM	73.2	303	0.24	1	1	1	1	0	1	1	0	1	0	0	0	7		470	676	0.70
01 December 2021	08:45 AM	261	1196	0.22	1	1	1	0	0	1	0	0	0	0	0	0	4	4.83	1397	601	0.43
	10:15 AM	289	1320	0.22	1	1	1	0	0	1	0	0	0	0	0	0	4		593	1521	0.39
	11:45 AM	277	1238	0.22	1	1	1	1	0	1	0	0	0	0	0	0	5		701	1496	0.47
	01:15 PM	291	1341	0.22	1	1	1	1	0	1	0	0	0	0	0	0	5		720	1600	0.45
	02:45 PM	231	983	0.23	1	1	1	1	0	0	0	0	0	0	0	0	4		544	1184	0.46
	04:15 PM	63.4	254	0.25	1	1	1	1	0	1	1	0	1	0	0	0	7		444	626	0.71

Table 73: Simulation data. Case3, West, 20% WWR

Date	Time	Before			Luminaire Status (ON=1, OFF=0)												Luminaires		After		
		E_m	E_{avg}	U_1	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	Total	Avg.	E_m	E_{avg}	U_1
01 February 2021	08:45 AM	24.7	128	0.19	1	1	1	1	0	1	1	1	1	0	0	1	9	7.83	461	622	0.74
	10:15 AM	29.1	156	0.19	1	1	1	1	0	1	1	1	1	0	0	0	8		426	608	0.70
	11:45 AM	33.3	176	0.19	1	1	1	1	0	1	1	1	1	0	0	0	8		438	628	0.70
	01:15 PM	60.3	334	0.18	1	1	1	1	0	1	1	0	1	0	0	0	7		438	709	0.62
	02:45 PM	85.4	474	0.18	1	1	1	1	0	1	1	0	1	0	0	0	7		493	850	0.58
	04:15 PM	42.9	215	0.20	1	1	1	1	0	1	1	1	1	0	0	0	8		482	666	0.72
01 April 2021	08:45 AM	24.6	131	0.19	1	1	1	1	0	1	1	1	1	0	0	0	8	8.17	428	582	0.74
	10:15 AM	21.3	107	0.20	1	1	1	1	0	1	1	1	1	1	0	1	10		468	643	0.73
	11:45 AM	36.9	169	0.22	1	1	1	1	0	1	1	1	1	0	0	0	8		430	620	0.69
	01:15 PM	50.9	284	0.18	1	1	1	1	0	1	1	1	1	0	0	0	8		487	735	0.66
	02:45 PM	97.2	534	0.18	1	1	1	1	0	1	1	0	1	0	0	0	7		515	909	0.57
	04:15 PM	52.3	252	0.21	1	1	1	1	0	1	1	1	1	0	0	0	8		488	703	0.69
01 June 2021	08:45 AM	27.1	140	0.19	1	1	1	1	0	1	1	1	1	0	0	0	8	8.00	417	591	0.71
	10:15 AM	24.2	127	0.19	1	1	1	1	0	1	1	1	1	1	0	0	9		447	621	0.72
	11:45 AM	26.2	133	0.20	1	1	1	1	0	1	1	1	1	1	0	0	9		446	627	0.71
	01:15 PM	59	326	0.18	1	1	1	1	0	1	1	0	1	0	0	0	7		435	702	0.62
	02:45 PM	87.6	498	0.18	1	1	1	1	0	1	1	0	1	0	0	0	7		502	873	0.58
	04:15 PM	44.1	226	0.20	1	1	1	1	0	1	1	1	1	0	0	0	8		479	678	0.71
01 August 2021	08:45 AM	26.2	135	0.19	1	1	1	1	0	1	1	1	1	0	0	0	8	8.17	417	586	0.71
	10:15 AM	23.4	120	0.20	1	1	1	1	0	1	1	1	1	1	0	0	9		430	614	0.70
	11:45 AM	22.4	111	0.20	1	1	1	1	0	1	1	1	1	1	0	1	10		467	647	0.72
	01:15 PM	51.5	288	0.18	1	1	1	1	0	1	1	1	1	0	0	0	8		489	740	0.66
	02:45 PM	92.1	513	0.18	1	1	1	1	0	1	1	0	1	0	0	0	7		507	889	0.57
	04:15 PM	52	266	0.20	1	1	1	1	0	1	1	0	1	0	0	0	7		425	642	0.66
01 October 2021	08:45 AM	26.2	135	0.19	1	1	1	1	0	1	1	1	1	0	0	0	8	8.33	423	586	0.72
	10:15 AM	21	109	0.19	1	1	1	1	0	1	1	1	1	1	0	1	10		469	654	0.73
	11:45 AM	24	120	0.20	1	1	1	1	0	1	1	1	1	1	0	1	10		407	614	0.66
	01:15 PM	65.5	354	0.19	1	1	1	1	0	1	1	0	1	0	0	0	7		446	730	0.61
	02:45 PM	97.3	512	0.19	1	1	1	1	0	1	1	0	1	0	0	0	7		510	888	0.57
	04:15 PM	36.5	174	0.21	1	1	1	1	0	1	1	1	1	0	0	0	8		475	625	0.76
01 December 2021	08:45 AM	26.9	144	0.19	1	1	1	1	0	1	1	1	1	0	0	1	9	8.17	471	637	0.74
	10:15 AM	32.2	173	0.19	1	1	1	1	0	1	1	1	1	0	0	0	8		441	625	0.71
	11:45 AM	42.2	230	0.18	1	1	1	1	0	1	1	1	1	0	0	0	8		484	681	0.71
	01:15 PM	73	400	0.18	1	1	1	1	0	1	1	0	1	0	0	0	7		467	775	0.60
	02:45 PM	73.5	406	0.18	1	1	1	1	0	1	1	0	1	0	0	0	7		473	782	0.60
	04:15 PM	23.1	112	0.21	1	1	1	1	0	1	1	1	1	1	0	1	10		470	648	0.73

Table 74: Simulation data. Case3, West, 40% WWR

Date	Time	Before			Luminaire Status (ON=1, OFF=0)												Luminaires		After		
		E_m	E_{avg}	U_1	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	Total	Avg.	E_m	E_{avg}	U_1
01 February 2021	08:45 AM	48.2	241	0.20	1	1	1	1	0	1	1	1	1	0	0	0	8	6.67	489	691	0.71
	10:15 AM	57.5	295	0.19	1	1	1	1	0	1	1	0	1	0	0	0	7		428	669	0.64
	11:45 AM	63	336	0.19	1	1	1	1	0	1	1	0	1	0	0	0	7		445	710	0.63
	01:15 PM	120	629	0.19	1	1	1	1	0	1	0	0	1	0	0	0	6		497	946	0.53
	02:45 PM	170	882	0.19	1	1	1	1	0	1	0	0	0	0	0	0	5		557	1141	0.49
	04:15 PM	85.4	398	0.21	1	1	1	1	0	1	1	0	1	0	0	0	7		491	772	0.64
01 April 2021	08:45 AM	51.4	246	0.21	1	1	1	1	0	1	1	1	1	0	0	0	8	7.00	492	696	0.71
	10:15 AM	43	204	0.21	1	1	1	1	0	1	1	1	1	0	0	0	8		484	654	0.74
	11:45 AM	69.2	336	0.21	1	1	1	1	0	1	1	0	1	0	0	0	7		442	711	0.62
	01:15 PM	104	541	0.19	1	1	1	1	0	1	1	0	1	0	0	0	7		519	915	0.57
	02:45 PM	185	990	0.19	1	1	1	1	0	1	0	0	0	0	0	0	5		589	1249	0.47
	04:15 PM	104	466	0.22	1	1	1	1	0	1	1	0	1	0	0	0	7		520	841	0.62
01 June 2021	08:45 AM	51.2	263	0.19	1	1	1	1	0	1	1	1	1	0	0	0	8	7.00	491	713	0.69
	10:15 AM	48.8	242	0.20	1	1	1	1	0	1	1	1	1	0	0	0	8		489	691	0.71
	11:45 AM	48.9	257	0.19	1	1	1	1	0	1	1	1	1	0	0	0	8		492	706	0.20
	01:15 PM	111	617	0.18	1	1	1	1	0	1	1	0	0	0	0	0	6		486	934	0.52
	02:45 PM	178	924	0.19	1	1	1	1	0	1	0	0	0	0	0	0	5		568	1183	0.48
	04:15 PM	88.1	420	0.21	1	1	1	1	0	1	1	0	1	0	0	0	7		498	794	0.63
01 August 2021	08:45 AM	51.4	254	0.20	1	1	1	1	0	1	1	1	1	0	0	0	8	7.17	491	704	0.70
	10:15 AM	46.3	229	0.20	1	1	1	1	0	1	1	1	1	0	0	0	8		486	679	0.72
	11:45 AM	42	215	0.20	1	1	1	1	0	1	1	1	1	0	0	0	8		483	665	0.73
	01:15 PM	105	547	0.19	1	1	1	1	0	1	1	0	1	0	0	0	7		517	921	0.56
	02:45 PM	175	954	0.18	1	1	1	1	0	1	0	0	0	0	0	0	5		583	1213	0.48
	04:15 PM	100	492	0.20	1	1	1	1	0	1	1	0	1	0	0	0	7		526	867	0.61
01 October 2021	08:45 AM	51.1	253	0.20	1	1	1	1	0	1	1	1	1	0	0	0	8	7.00	493	703	0.70
	10:15 AM	41.8	209	0.20	1	1	1	1	0	1	1	1	1	0	0	0	8		482	658	0.73
	11:45 AM	45.7	234	0.20	1	1	1	1	0	1	1	1	1	0	0	0	8		488	684	0.71
	01:15 PM	129	670	0.19	1	1	1	1	0	1	0	0	1	0	0	0	6		507	987	0.51
	02:45 PM	190	948	0.20	1	1	1	1	0	1	0	0	0	0	0	0	5		582	1208	0.48
	04:15 PM	72.8	323	0.23	1	1	1	1	0	1	1	0	1	0	0	0	7		462	698	0.66
01 December 2021	08:45 AM	54.8	270	0.20	1	1	1	1	0	1	1	1	1	0	0	0	8	6.67	496	720	0.69
	10:15 AM	65.9	327	0.20	1	1	1	1	0	1	1	0	1	0	0	0	7		442	702	0.63
	11:45 AM	82.3	435	0.19	1	1	1	1	0	1	1	0	1	0	0	0	7		486	809	0.60
	01:15 PM	141	750	0.19	1	1	1	1	0	1	0	0	0	0	0	0	5		482	1010	0.48
	02:45 PM	144	752	0.19	1	1	1	1	0	1	0	0	0	0	0	0	5		503	1011	0.50
	04:15 PM	43.7	208	0.21	1	1	1	1	0	1	1	1	1	0	0	0	8		482	658	0.73

Table 75: Simulation data. Case3, West, 60% WWR

Date	Time	Before			Luminaire Status (ON=1, OFF=0)												Luminaires		After		
		E_m	E_{avg}	U_1	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	Total	Avg.	E_m	E_{avg}	U_1
01 February 2021	08:45 AM	71.2	320	0.22	1	1	1	1	0	1	1	0	1	0	0	0	7	6.00	455	694	0.66
	10:15 AM	85	395	0.22	1	1	1	1	0	1	1	0	1	0	0	0	7		481	768	0.63
	11:45 AM	96.7	455	0.21	1	1	1	1	0	1	1	0	1	0	0	0	7		506	828	0.61
	01:15 PM	174	851	0.20	1	1	1	1	0	1	0	0	0	0	0	0	5		557	1109	0.50
	02:45 PM	255	1165	0.22	1	1	1	0	0	1	0	0	0	0	0	0	4		533	1367	0.39
	04:15 PM	125	519	0.24	1	1	1	1	0	1	0	0	1	0	0	0	6		503	835	0.60
01 April 2021	08:45 AM	72.8	328	0.22	1	1	1	1	0	1	1	0	1	0	0	0	7	6.00	462	702	0.66
	10:15 AM	62.9	276	0.23	1	1	1	1	0	1	1	0	1	0	0	0	7		503	725	0.69
	11:45 AM	105	481	0.22	1	1	1	1	0	1	1	0	1	0	0	0	7		497	854	0.58
	01:15 PM	157	741	0.21	1	1	1	1	0	1	0	0	0	0	0	0	5		507	1000	0.51
	02:45 PM	294	1312	0.22	1	1	1	1	0	1	0	0	0	0	0	0	5		716	1571	0.46
	04:15 PM	151	608	0.25	1	1	1	1	0	1	0	0	0	0	0	0	5		509	867	0.20
01 June 2021	08:45 AM	77.1	350	0.22	1	1	1	1	0	1	1	0	1	0	0	0	7	6.00	470	724	0.65
	10:15 AM	67.2	326	0.21	1	1	1	1	0	1	1	0	1	0	0	0	7		451	700	0.64
	11:45 AM	73.6	354	0.21	1	1	1	1	0	1	1	0	1	0	0	0	7		455	727	0.63
	01:15 PM	176	838	0.21	1	1	1	1	0	1	0	0	0	0	0	0	5		551	1097	0.50
	02:45 PM	260	1221	0.21	1	1	1	1	0	1	0	0	0	0	0	0	5		679	1480	0.46
	04:15 PM	136	547	0.25	1	1	1	1	0	1	0	0	0	0	0	0	5		454	806	0.56
01 August 2021	08:45 AM	75.3	338	0.22	1	1	1	1	0	1	1	0	1	0	0	0	7	6.50	465	711	0.65
	10:15 AM	65.9	309	0.21	1	1	1	1	0	1	1	0	1	0	0	0	7		445	683	0.65
	11:45 AM	64.9	299	0.22	1	1	1	1	0	1	1	1	1	0	0	0	8		502	748	0.67
	01:15 PM	153	474	0.20	1	1	1	1	0	1	1	0	1	0	0	0	7		588	1173	0.50
	02:45 PM	269	1264	0.21	1	1	1	1	0	1	0	0	0	0	0	0	5		686	1523	0.45
	04:15 PM	156	643	0.24	1	1	1	1	0	1	0	0	0	0	0	0	5		523	901	0.58
01 October 2021	08:45 AM	77.2	338	0.23	1	1	1	1	0	1	1	0	1	0	0	0	7	6.50	462	711	0.65
	10:15 AM	62.9	283	0.22	1	1	1	1	0	1	1	1	1	0	0	0	8		502	732	0.69
	11:45 AM	67.8	326	0.21	1	1	1	1	0	1	1	0	1	0	0	0	7		439	699	0.63
	01:15 PM	190	909	0.21	1	1	1	1	0	1	0	0	0	0	0	0	5		574	1168	0.49
	02:45 PM	291	1253	0.23	1	1	1	1	0	1	0	0	0	0	0	0	5		711	1511	0.47
	04:15 PM	111	421	0.26	1	1	1	1	0	1	1	0	1	0	0	0	7		520	794	0.65
01 December 2021	08:45 AM	79.4	358	0.22	1	1	1	1	0	1	1	0	1	0	0	0	7	5.83	476	732	0.65
	10:15 AM	96	438	0.22	1	1	1	1	0	1	1	0	1	0	0	0	7		500	812	0.62
	11:45 AM	125	587	0.21	1	1	1	1	0	1	0	0	1	0	0	0	6		502	903	0.56
	01:15 PM	205	1003	0.20	1	1	1	0	0	1	0	0	0	0	0	0	4		482	1205	0.40
	02:45 PM	218	988	0.22	1	1	1	0	0	1	0	0	0	0	0	0	4		487	1189	0.41
	04:15 PM	65.3	271	0.24	1	1	1	1	0	1	1	0	1	0	0	0	7		444	644	0.69

Table 76: Simulation data. Case3, West, 80% WWR

Date	Time	Before			Luminaire Status (ON=1, OFF=0)												Luminaires		After		
		E_m	E_{avg}	U_1	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	Total	Avg.	E_m	E_{avg}	U_1
01 February 2021	08:45 AM	96.1	403	0.24	1	1	1	1	0	1	1	0	1	0	0	0	7	5.33	510	775	0.66
	10:15 AM	117	500	0.23	1	1	1	1	0	1	0	0	1	0	0	0	6		487	815	0.60
	11:45 AM	127	581	0.22	1	1	1	1	0	1	0	0	1	0	0	0	6		524	897	0.58
	01:15 PM	228	1082	0.21	1	1	1	0	0	1	0	0	0	0	0	0	4		518	1283	0.40
	02:45 PM	338	1461	0.23	1	1	1	0	0	1	0	0	0	0	0	0	4		677	1662	0.41
	04:15 PM	172	645	0.27	1	1	1	1	0	1	0	0	0	0	0	0	5		551	903	0.61
01 April 2021	08:45 AM	104	414	0.25	1	1	1	1	0	1	1	0	1	0	0	0	7	5.67	512	787	0.65
	10:15 AM	85.3	353	0.24	1	1	1	1	0	1	1	0	1	0	0	0	7		475	726	0.65
	11:45 AM	140	641	0.22	1	1	1	1	0	1	0	1	0	0	0	0	6		505	974	0.52
	01:15 PM	208	954	0.22	1	1	1	1	0	1	0	0	0	0	0	0	5		615	1212	0.51
	02:45 PM	399	1654	0.24	1	1	1	1	0	1	0	0	0	0	0	0	5		820	1912	0.43
	04:15 PM	211	754	0.28	1	1	1	0	0	1	0	0	0	0	0	0	4		622	1013	0.61
01 June 2021	08:45 AM	108	442	0.24	1	1	1	1	0	1	1	0	1	0	0	0	7	5.67	527	814	0.65
	10:15 AM	94	416	0.23	1	1	1	1	0	1	1	0	1	0	0	0	7		504	788	0.64
	11:45 AM	99.8	458	0.22	1	1	1	1	0	1	1	0	1	0	0	0	7		512	831	0.62
	01:15 PM	235	1072	0.22	1	1	1	1	0	0	0	0	0	0	0	0	4		503	1273	0.40
	02:45 PM	357	1536	0.23	1	1	1	1	0	0	0	0	0	0	0	0	4		721	1737	0.42
	04:15 PM	182	680	0.27	1	1	1	1	0	1	0	0	0	0	0	0	5		564	938	0.60
01 August 2021	08:45 AM	103	426	0.24	1	1	1	1	0	1	1	0	1	0	0	0	7	5.83	518	799	0.65
	10:15 AM	90.7	395	0.23	1	1	1	1	0	1	1	0	1	0	0	0	7		495	767	0.65
	11:45 AM	85.6	390	0.22	1	1	1	1	0	1	1	0	1	0	0	0	7		479	763	0.63
	01:15 PM	197	959	0.21	1	1	1	1	0	1	0	0	0	0	0	0	5		618	1217	0.51
	02:45 PM	380	1592	0.24	1	1	1	1	0	1	0	0	0	0	0	0	5		727	1793	0.41
	04:15 PM	207	798	0.26	1	1	1	1	0	0	0	0	0	0	0	0	4		472	999	0.47
01 October 2021	08:45 AM	105	427	0.25	1	1	1	1	0	1	1	0	1	0	0	0	7	5.67	515	799	0.64
	10:15 AM	85.8	363	0.24	1	1	1	1	0	1	1	0	1	0	0	0	7		477	736	0.65
	11:45 AM	92.8	427	0.22	1	1	1	1	0	1	1	0	1	0	0	0	7		493	800	0.62
	01:15 PM	255	1161	0.22	1	1	1	0	0	1	0	0	0	0	0	0	4		525	1362	0.39
	02:45 PM	388	1570	0.25	1	1	1	0	0	1	0	0	0	0	0	0	4		713	1771	0.40
	04:15 PM	147	522	0.28	1	1	1	1	0	1	0	0	0	0	0	0	5		501	781	0.64
01 December 2021	08:45 AM	110	451	0.24	1	1	1	1	0	1	1	0	1	0	0	0	7	5.50	529	824	0.64
	10:15 AM	126	555	0.23	1	1	1	1	0	1	0	0	1	0	0	0	6		516	871	0.59
	11:45 AM	169	747	0.23	1	1	1	1	0	1	0	0	0	0	0	0	5		542	1006	0.54
	01:15 PM	277	1270	0.22	1	1	1	0	0	1	0	0	0	0	0	0	4		606	1471	0.41
	02:45 PM	294	1234	0.24	1	1	1	0	0	1	0	0	0	0	0	0	4		620	1435	0.43
	04:15 PM	91.5	336	0.27	1	1	1	1	0	1	1	0	1	0	0	0	7		493	709	0.70

APPENDIX C: ARTIFICIAL LIGHTING COST

Table 77: Artificial lighting cost per square meter. Case 1, North

Period	Case 1, North, WWR 20%	Case 1, North, WWR 40%	Case 1, North, WWR 60%	Case 1, North, WWR 80%
January - February	$ 0.250	$ 0.211	$ 0.178	$ 0.145
March - April	$ 0.236	$ 0.189	$ 0.162	$ 0.115
May - June	$ 0.211	$ 0.158	$ 0.118	$ 0.092
July - August	$ 0.227	$ 0.177	$ 0.135	$ 0.099
September - October	$ 0.270	$ 0.203	$ 0.169	$ 0.142
November - December	$ 0.283	$ 0.239	$ 0.218	$ 0.167
Annual	$ 1.477	$ 1.177	$ 0.979	$ 0.760

Table 78: Artificial lighting cost per square meter. Case 1, East

Period	Case 1, East, WWR 20%	Case 1, East, WWR 40%	Case 1, East, WWR 60%	Case 1, East, WWR 80%
January - February	$ 0.230	$ 0.184	$ 0.165	$ 0.125
March - April	$ 0.250	$ 0.203	$ 0.176	$ 0.142
May - June	$ 0.250	$ 0.197	$ 0.178	$ 0.145
July - August	$ 0.276	$ 0.206	$ 0.184	$ 0.163
September - October	$ 0.277	$ 0.216	$ 0.182	$ 0.162
November - December	$ 0.276	$ 0.203	$ 0.189	$ 0.160
Annual	$ 1.559	$ 1.209	$ 1.073	$ 0.896

Table 79: Artificial lighting cost per square meter. Case 1, South

Period	Case 1, South, WWR 20%	Case 1, South, WWR 40%	Case 1, South, WWR 60%	Case 1, South, WWR 80%
January - February	$ 0.211	$ 0.132	$ 0.092	$ 0.086
March - April	$ 0.236	$ 0.189	$ 0.155	$ 0.115
May - June	$ 0.270	$ 0.211	$ 0.184	$ 0.138
July - August	$ 0.276	$ 0.220	$ 0.184	$ 0.149
September - October	$ 0.236	$ 0.189	$ 0.135	$ 0.115
November - December	$ 0.239	$ 0.152	$ 0.116	$ 0.109
Annual	$ 1.469	$ 1.092	$ 0.867	$ 0.711

Table 80: Artificial lighting cost per square meter. Case 1, West

Period	Case 1, West, WWR 20%	Case 1, West, WWR 40%	Case 1, West, WWR 60%	Case 1, West, WWR 80%
January - February	$ 0.217	$ 0.171	$ 0.138	$ 0.105
March - April	$ 0.236	$ 0.182	$ 0.135	$ 0.122
May - June	$ 0.224	$ 0.158	$ 0.145	$ 0.118
July - August	$ 0.248	$ 0.177	$ 0.149	$ 0.135
September - October	$ 0.236	$ 0.189	$ 0.155	$ 0.135
November - December	$ 0.254	$ 0.189	$ 0.152	$ 0.116
Annual	$ 1.415	$ 1.066	$ 0.874	$ 0.731

Table 81: Artificial lighting cost per square meter. Case 2, North

Period	Case 2, North, WWR 20%	Case 2, North, WWR 40%	Case 2, North, WWR 60%	Case 2, North, WWR 80%
January - February	$ 0.257	$ 0.197	$ 0.168	$ 0.128
March - April	$ 0.228	$ 0.182	$ 0.142	$ 0.106
May - June	$ 0.207	$ 0.148	$ 0.099	$ 0.079
July - August	$ 0.223	$ 0.165	$ 0.117	$ 0.080
September - October	$ 0.258	$ 0.197	$ 0.157	$ 0.127
November - December	$ 0.278	$ 0.229	$ 0.196	$ 0.152
Annual	$ 1.451	$ 1.119	$ 0.878	$ 0.672

Table 82: Artificial lighting cost per square meter. Case 2, East

Period	Case 2, East, WWR 20%	Case 2, East, WWR 40%	Case 2, East, WWR 60%	Case 2, East, WWR 80%
January - February	$ 0.217	$ 0.163	$ 0.138	$ 0.114
March - April	$ 0.248	$ 0.177	$ 0.157	$ 0.132
May - June	$ 0.247	$ 0.173	$ 0.153	$ 0.123
July - August	$ 0.271	$ 0.191	$ 0.165	$ 0.144
September - October	$ 0.268	$ 0.197	$ 0.167	$ 0.147
November - December	$ 0.250	$ 0.196	$ 0.169	$ 0.141
Annual	$ 1.502	$ 1.098	$ 0.949	$ 0.800

Table 83: Artificial lighting cost per square meter. Case 2, South

Period	Case 2, South, WWR 20%	Case 2, South, WWR 40%	Case 2, South, WWR 60%	Case 2, South, WWR 80%
January - February	$ 0.188	$ 0.114	$ 0.099	$ 0.084
March - April	$ 0.238	$ 0.177	$ 0.132	$ 0.091
May - June	$ 0.242	$ 0.202	$ 0.163	$ 0.128
July - August	$ 0.260	$ 0.207	$ 0.175	$ 0.133
September - October	$ 0.223	$ 0.172	$ 0.132	$ 0.101
November - December	$ 0.218	$ 0.131	$ 0.120	$ 0.103
Annual	$ 1.368	$ 1.003	$ 0.820	$ 0.641

Table 84: Artificial lighting cost per square meter. Case 2, West

Period	Case 2, West, WWR 20%	Case 2, West, WWR 40%	Case 2, West, WWR 60%	Case 2, West, WWR 80%
January - February	$ 0.207	$ 0.153	$ 0.128	$ 0.104
March - April	$ 0.228	$ 0.157	$ 0.142	$ 0.111
May - June	$ 0.207	$ 0.163	$ 0.133	$ 0.109
July - August	$ 0.245	$ 0.170	$ 0.144	$ 0.122
September - October	$ 0.233	$ 0.172	$ 0.142	$ 0.122
November - December	$ 0.229	$ 0.169	$ 0.136	$ 0.109
Annual	$ 1.348	$ 0.984	$ 0.825	$ 0.676

Table 85: Artificial lighting cost per square meter. Case 3, North

Period	Case 3, North, WWR 20%	Case 3, North, WWR 40%	Case 3, North, WWR 60%	Case 3, North, WWR 80%
January - February	$ 0.257	$ 0.217	$ 0.207	$ 0.183
March - April	$ 0.238	$ 0.223	$ 0.197	$ 0.172
May - June	$ 0.227	$ 0.202	$ 0.163	$ 0.133
July - August	$ 0.245	$ 0.229	$ 0.191	$ 0.165
September - October	$ 0.263	$ 0.223	$ 0.213	$ 0.187
November - December	$ 0.272	$ 0.245	$ 0.239	$ 0.218
Annual	$1.502	$ 1.339	$ 1.211	$ 1.058

Table 86: Artificial lighting cost per square meter. Case 3, East

Period	Case 3, East, WWR 20%	Case 3, East, WWR 40%	Case 3, East, WWR 60%	Case 3, East, WWR 80%
January - February	$ 0.237	$ 0.197	$ 0.188	$ 0.163
March - April	$ 0.268	$ 0.213	$ 0.203	$ 0.187
May - June	$ 0.252	$ 0.217	$ 0.193	$ 0.188
July - August	$ 0.276	$ 0.234	$ 0.207	$ 0.202
September - October	$ 0.278	$ 0.233	$ 0.203	$ 0.192
November - December	$ 0.272	$ 0.229	$ 0.212	$ 0.196
Annual	$ 1.584	$ 1.323	$ 1.205	$ 1.128

Table 87: Artificial lighting cost per square meter. Case 3, South

Period	Case S, South, WWR 20%	Case 3, South, WWR 40%	Case 3, South, WWR 60%	Case 3, South, WWR 80%
January - February	$ 0.212	$ 0.178	$ 0.158	$ 0.143
March - April	$ 0.248	$ 0.216	$ 0.197	$ 0.157
May - June	$ 0.257	$ 0.227	$ 0.207	$ 0.193
July - August	$ 0.276	$ 0.250	$ 0.218	$ 0.191
September - October	$ 0.253	$ 0.213	$ 0.187	$ 0.162
November - December	$ 0.245	$ 0.185	$ 0.174	$ 0.158
Annual	$ 1.491	$ 1.268	$ 1.142	$ 1.004

Table 88: Artificial lighting cost per square meter. Case 3, West

Period	Case 3, West, WWR 20%	Case 3, West, WWR 40%	Case 3, West, WWR 60%	Case 3, West, WWR 80%
January - February	$ 0.232	$ 0.197	$ 0.178	$ 0.158
March - April	$ 0.248	$ 0.213	$ 0.182	$ 0.172
May - June	$ 0.237	$ 0.207	$ 0.178	$ 0.168
July - August	$ 0.260	$ 0.229	$ 0.207	$ 0.186
September - October	$ 0.253	$ 0.213	$ 0.197	$ 0.172
November - December	$ 0.267	$ 0.218	$ 0.190	$ 0.180
Annual	$ 1.497	$ 1.276	$ 1.133	$ 1.036