

1 Article

2 Motion Sensor Application on Building Lighting 3 Installation for Energy Saving and Carbon Reduction 4 Joint Crediting Mechanism

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12

13 **Abstract:** High electricity demand for consumption at current supply level in Indonesia led to the
14 rising cost of electricity bills. This factor is compounded by the fact that many electric generators in
15 Indonesia still use fossil fuels, which contributes to the high basic generation cost. UBL is one of the
16 universities that aim to be a green campus. Our research explores the possibility of installing
17 motion sensor to contribute on the energy efficiency. Although mostly common in developed
18 countries, the use of motion sensor for energy efficiency is still rare, especially in Indonesia. despite
19 rising cost and supply shortages, Indonesian buildings are still of high energy consumption. our
20 experiment shows that simple installation of commercially available motion sensors can contribute
21 to reduce the electricity bill from the increase of energy efficiency. One of the efforts to lower
22 energy demand in consumer side is to use the electricity efficiently, such as turning off lights in a
23 room when it's not in use. This method can be simply done by turning the light switches for office
24 and classrooms, but difficult to do in public spaces such as toilets and corridors. Our experiment
25 shows that simple installation of commercially available motion sensors can contribute to reduce
26 the electricity bill from the increase of energy efficiency. Automatic light switches experimentally
27 installed in sample toilet room prove that electricity consumption from the lamps can contribute to
28 the reduction of total weekly energy that translates into Green House Gas emission reduction.

29 **Keywords:** greenhouse gasses; carbon reduction; energy efficiency; motion sensor; automatic light
30 switch
31

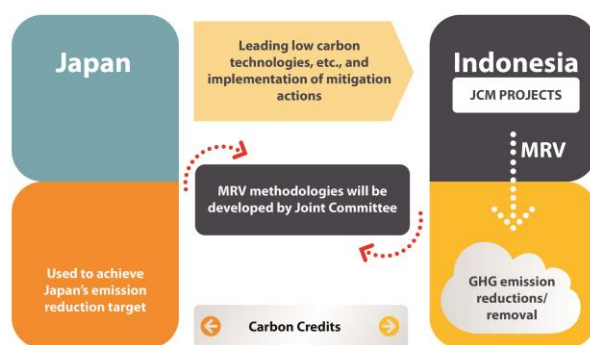
32 1. Introduction

33 The high level of electricity consumption translates into higher cost, moreover, the majority of
34 Indonesian electricity generation power plants are fossil-fueled. A change in oil price affects the fuel
35 price and in turn influences the base electricity fares. One effort to lower the electricity energy
36 consumption cost on the customer side is to increase the efficiency of electricity usage, such as using
37 energy efficient equipment and deactivates electrical equipment when not in use [1].

38 One aspect that can be made more efficient in universities is room lighting. Classrooms
39 electricity consumption in Universitas Budi Luhur is already controlled by a main panel, when no
40 lectures are scheduled in a classroom, that particular classroom can be remotely deactivated. Other
41 aspect of room lighting usage is office room and toilets, which is mostly on from the start of morning
42 workday to the end of night classes. Offices and staff rooms can be manually switched off manually
43 when not occupied, but the use of public facilities such as toilets and enclosed corridors is random,
44 therefore it is impractical to manually switch the lightings. The proposed method in this pilot project

45 is to use an automatic switch which detects the presence of human in a particular room. Aside from
 46 its practical use, no contact with humans needed, it also helps to lower the electricity consumption
 47 and longer lifetime of the lightbulbs, which in turn translates to cost saving. The objective of this
 48 pilot project is to measure the level of reduction in electricity consumption and its correlation to the
 49 reduction of equivalent carbon emission, with the expected benefit is energy efficiency and cost
 50 saving for the campus [2].

51 Joint Crediting Mechanism (JCM) is a bilateral cooperation between Japan and host country in
 52 low carbon development implementation that intended to push Japanese private sector companies
 53 to invest on Low Carbon Development activities in Indonesia, as a host country, by giving financial
 54 and technical incentives. JCM activities covers many sectoral scope, including energy efficiency,
 55 renewable energy, deforestation and forest degradation, waste management, fugitive emission, and
 56 manufacture industry. Indonesia hopes JCM can be an interesting alternative to supported
 57 Greenhouse Gasses (GHG) emissions reduction activities that conducted by both Indonesia private
 58 sectors and public sectors and supporting economic growth without overriding environmental
 59 sustainability. Until mid-2017, 109 feasibility studies have been undertaken under the cooperation
 60 between Japanese Company partnership with Indonesian private companies and central and local
 61 government. From the feasibility studies, both countries implement 28 JCM projects. 15 projects had
 62 been installed and other 13 projects still under construction. Total investment values of the 28
 63 projects are 150 million USD. Figure 1 shows the JCM scheme between Indonesia and Japan where
 64 Indonesian side that able to reduce GHG emission is supported by Japanese side [3].
 65



66 **Figure 1.** Joint Crediting Mechanism Scheme

67 2. Materials and Methods

68 2.1. Motion Detection

69 A motion detection algorithm begins with the segmentation part where foreground or moving
 70 objects are segmented from the background. The simplest way to implement this is to take an image
 71 as background and take the frames obtained at the time t , denoted by $I(t)$ to compare with the
 72 background image denoted by B . Here using simple arithmetic calculations, we can segment out the
 73 objects simply by using image subtraction technique of computer vision meaning for each pixels in
 74 $I(t)$, take the pixel value denoted by $P[I(t)]$ and subtract it with the corresponding pixels at the same
 75 position on the background image denoted as $P[B]$. In mathematical equation it is written as:

$$P[F(t)] = P[I(t)] - P[B] \quad (1)$$

76 where, F refers to the foreground or resulted image after the computation at time t [4].

77 Analysis of human motion is currently one of the most active research topics in computer
 78 vision, in which the moving human body detection is the most important part of the human body
 79 motion analysis, the purpose is to detect the moving human body from the background image, and
 80 for the follow-up treatment such as the target classification, the human body tracking and behavior
 81 understanding, its effective detection plays a very important role. Human motion analysis concerns

82 the detection, tracking and recognition of people behaviors. According to the result of moving
 83 object detection research on video sequences, Rakibe [5] presents a new algorithm for detecting
 84 moving objects from a static background scene to detect moving object based on background
 85 subtraction. Wibowo [6] explored the use of proximity sensor as human presence sensor in a room
 86 with analysis in the performance of the sensor, which works as heat detection. The discussion is
 87 limited to testing the response of the fabricated sensor.

88 2.2. Passive Infrared Sensor

89 IR (Passive Infrared Receiver) is an infrared-based sensor (Figure 2), as the name implies,
 90 "Passive" means the device does not emit any infrared radiation. This differentiates PIR devices
 91 from other IR-based devices such as IR LED and phototransistor [7]. PIR only respond to infrared
 92 radiation emitted by other objects within its detection sphere. The device usually detects human
 93 body temperature and/or movement. PIR sensors detect human presence by sensing the change of
 94 heat radiation caused by body movement, since human body emits thermal radiation when moving
 95 due to energy metabolism to make muscle movement. When PIR detects changes in infrared
 96 radiation and responds by releasing output voltage.
 97



98 **Figure 2.** PIR-based motion sensor switch, the type used in this project [1]

99 2.3. Related Research

100 A simulation for lighting energy savings in office spaces compared with actual consumption.
 101 Aside from installation of control systems, the simulation models the monthly consumption for
 102 several European cities [8], while our experiment deals with actual consumption in equatorial
 103 region with relatively constant pattern. One research investigates the use of smart occupancy sensor
 104 which varies the time delay of the sensor to suit the various activities of the occupants. The
 105 experiment set in a general room with work environment as indicated by the presence of a PC [9].
 106 Our experiment uses toilet room with varying occupancy duration, but of predictable duration for
 107 each occupant. Another research deals with the position of the occupant through the use of Wi-Fi
 108 and smartphone connection calculation, this is useful for workspace energy saving [10]. This project
 109 deals with simpler occupied-or-unoccupied room.

110 2.4. JCM Method

111 The JCM has several methods for GHG emission reduction, one of interest is JCM_ID_AM005,
 112 in which, the method covers about emission reduction in public building through the change of
 113 lighting from fluorescent to LED lights. The method of calculating GHG reduction is derived from
 114 the total power consumption and the CO₂ emission factor [3].

$$RE_p = EC_{PJ,p} \times (\eta_{PJ} \div \eta_{RE}) \times EF_{elec} \quad (2)$$

$$PE_p = EC_{PJ,p} \times EF_{elec} \quad (3)$$

$$ER_p = RE_p - PE_p \quad (4)$$

115 where:

- 116 RE_p Reference emissions during the period p [tCO_2/p]
 117 $EC_{PJ,p}$ Total power consumption of project lighting during the period p [MWh/ p]
 118 η_{PJ} Luminous efficiency of project lighting [lm/W]
 119 η_{RE} Luminous efficiency of reference lighting [lm/W]
 120 EF_{elec} CO₂ emission factor for consumed electricity [tCO_2/MWh] for Java and Bali is 0.84

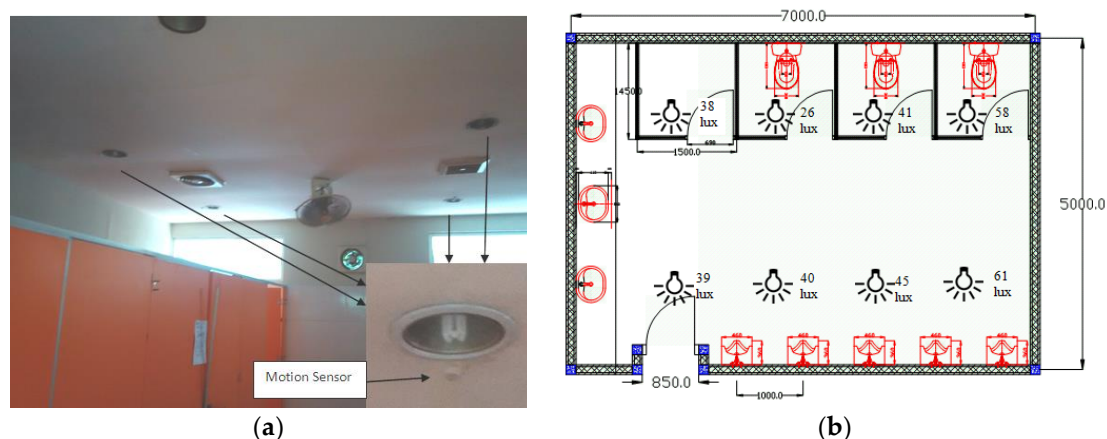
121 Measurement method for the illuminance (lux) of the installed lighting is as follows:

- 122 1. Equipment: Use lux meter which shows the readings of the measurement in illuminance.
 123 Record the model of the lux meter used for the measurement and its most recent record of the
 124 calibration.
 125 2. Measurement points: Illuminance readings are taken under each lights at the height of 1 meter
 126 above the floor.

127 3. Results

128 The electric equipment installed in the experiment room consisted of eight 23W bulbs and six
 129 exhaust fans of 80W each with daily operation of 14 hours from 7:00 to 21:00. Sensors are installed
 130 next to the lamp, as shown in Figure 3(a) Total power consumption is 664 Watt-hour which
 131 translates into 0,664kWh in one hour or 9,3kWh/day or in average 231kWh/month and 2772kWh
 132 annually. Baseline Measurement is taken during semester break, where usage is minimum and
 133 recorded with 7-hour interval up to 84 hours equal to 6-day week of operation. During this period,
 134 total electric power consumption is amounted to 55,576 kWh without the use of motion sensors [1].

135 Measurement for the illuminance (lux) of the installed lighting uses lux meter placed under
 136 each lamp at a height of 1 m above the floor which shows the readings of the measurement in
 137 illuminance as shown in Figure 3(b). Highest illuminance readings recorded is for under the lamps
 near the outside window, with lowest reading is at the cubicle furthest away from both window and
 outside door. The accuracy of lux meter is within $\pm 6\%$. For each measurement, stable numerical
 values are obtained. At the time of measurement, the door of the restroom and room lighting is set to
 be as close as possible to the normal working condition.



138 **Figure 3.** (a) Motion sensor installation next to each lamp; (b) Illumination measurement for points
 139 under each individual lamp, the ones with higher illuminance is near the window, it shows
 140 significant difference, with darkest point is the one furthest away from window and outside door.

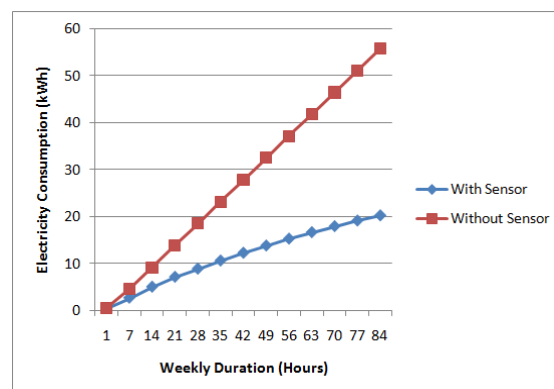
141 During measurement with sensors on Monday, August 1, 2016 at 8:00, with all lamps except
 142 ones near the toilet door are off and only the exhausts operating, the power meter reading shows
 143 304,2W and total consumption is 504,49Wh. This reading is within reduction range after 1 hours of
 144 operation (0,504Wh vs 0,664Wh). Measurement taken on Wednesday August 3, 2016 at 14:30, after
 145 35 hours of operation shows a 10,6kWh of consumption versus 27,9kWh for normal operation. The

146 measurement data is shown in Table 1 and plotted in Figure 4. From Table 1, it can be seen that
 147 reduction to half of the normal consumption is achieved after 28 hours. By the end of the week, the
 148 reduction reached 63.73%.

149 **Table 1.** Power consumption data comparison without sensor installation and after the sensors
 150 installation [1].

Duration (hours)	Electrical Power (kWh)		Energy Reduction (%)
	With Sensor	Without Sensor	
1	0.504	0.664	24.10
7	2.711	4.648	41.67
14	5.058	9.296	45.59
21	7.158	13.944	48.66
28	8.890	18.592	52.18
35	10.622	23.24	54.29
42	12.264	27.888	56.02
49	13.816	32.536	57.54
56	15.278	37.184	58.91
63	16.651	41.832	60.20
70	17.933	46.48	61.42
77	19.126	51.128	62.59
84	20.229	55.776	63.73

151



152

Figure 4. Power measurement comparison graph

153 4. Discussion

154 With the installation of motion sensor for lighting, the expected reduction of monthly electricity
 155 energy consumption is between 30% to 40% lower compared to the one without sensors installation
 156 with 30% reduction is for peak usage in the beginnings of first semester, and 40% for semester
 157 breaks. Base measurement yields power consumption of 55,576 kWh, with base electricity fare of
 158 1.467,28 Rp/kWh this cost Rp 327.356,04 per month or Rp 23.6 Million annually for just six restrooms
 159 only. This figure is constant for each month without modification to the electricity installation. From
 160 Table 1, the expected reduction of 40% is firmly achieved after 14 hours of operation, and after 28
 161 hours, it only consumes half than without sensors for the same duration. First phase of
 162 implementation on restrooms yields a cost saving of Rp 15 Million.

163 For annual CO₂ reduction, ERp must be factored by 60.83, and the resulting annual reduction is
 164 1.812 tCO₂/MWh/year [2] when implemented for all restrooms, projected contribution in reducing
 165 CO₂ emission is calculated at 10.95 tons/year. With carbon credit pricing at US\$ 11.5 per tons of CO₂
 166 equivalent for energy efficiency, this project could potentially save another Rp 1.7 Million.

167 Further phase of implementation would include sensors installation on corridors, replacement
168 of fluorescent lamps with LEDs, and rooftop PV installation on all buildings is expected to reach the
169 target of 150 tons of CO₂ equivalent emission reduction.

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173 performed by Martini and environmental aspect is by Hakim, with method and guidance provided by Dicky
174 Edwin Hindarto

175 **Conflicts of Interest:** The authors declare no conflict of interest.
176

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