

Preliminary study of building a low-carbon emission concept for Bali with nocturnal light analysis

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Abstract. Energy crisis and increase energy consume initiate depletion of natural resources and environmental degradation and that will leads to global warming and climate change. Nowadays, tourism considered being one of the important industries in the world. It also acknowledged as significant largest consumers of energy through many sectors including supporting facilities for tourists that focused on this paper. Bali's most important tourist destination and become proponent of economic has many resorts surrounded by business trade support. Increasing electricity demand becomes present issues. This paper proposes a method to build community-based initiatives for reducing carbon emissions and saving energy. The method consists of procedural to build light threshold regulation. This research uses light-meter survey, a night-time satellite dataset, and other supporting data. The light threshold uses night-time satellite dataset. Classes of light thresholds are defined from histogram analysis. Results show a relationship of lux light-meter survey mean with night-time satellite dataset mean. From results created maps of class regions that show approximate of level energy used.

1. Introduction

Climate change has emerged as one of increasing importance issue to tourism and hospitality industries in terms of both the potential effects of climate change on tourism and the contribution of tourism to climate change [1]. The efficiency of energy on tourism and hospitality sector is not just result of investment in sophisticated technology, but also modified by monitoring and active management of energy consumption [2]. The role of community in reducing carbon emissions and saving energy is essential [3]. Community initiatives can be carrying out by increasing efficiency through use of energy-saving technologies and behaviors in the commercial and residential sectors.

Bali most important tourist destination and represents the world's best tourism laboratory and embraces a complete island together with a language and religion that separates it from other areas. In addition, Bali is an important case study because mainly economic depends on tourism [4]. Bali population has 1.62 percent of total national (about 258.7 million) and tourism growth rate of 23.1 percent (about 11.5 million) [5]. Bali electricity demand is set to grow with customer's rate by 8.5 percent per year. Customers dominated by business followed by household, industrial type only two percent of total customers. The location of customers, mostly concentrated in southern Bali, Denpasar City and Badung Regency [6]. Research and regulations that relate to the role of community or stakeholder in reducing carbon emissions and saving electricity in Indonesia has not regulated well and limited. Rapid development on Bali's tourism industry, Bali needs regulations to maintain the



sustainability of electricity by involving the community or stakeholder in energy-saving behavior roles. It is urgent to carry out fundamental research in order to build low-carbon emission societies generally in Indonesia. Research relates to saving electricity in Bali has been carried out by Swardika and Putri [7], with remote sensing technology equipped with low-light night-time imagery instruments showed large differences in uses of lighting energy (nighttime lighting) on tourism resort centers in municipality of Denpasar and Badung Regency with other regions. Various tourism support businesses in the area use excessive lighting energy overlap and accumulate into a source of light energy pollution that monitored up to remote sensing satellites. However, research that has been carry still limited, more comprehensive and holistic researches needed.

This paper is one part of publication series with theme light threshold for tourism resort in the role of low-carbon emissions community, and energy savings using nighttime satellite data. Especially, this paper aims to build a method of implementation of low carbon emission on tourist resort by analysis of nighttime satellite data that reflect the energy consumption. The method consists of procedural steps for stakeholder to reinforce a regulation. The main concept of the regulation is light threshold limitation for specific designated area. First, this paper provides the procedural flow of method implementation. Brief introduction to nighttime satellite program, step to obtain and processing of nighttime satellite data, procedural of in-situ light meter and environmental indices surveys and then shows results and discuss about all procedural constraints. The next series of paper, continues more in-depth of technical aspect and procedural to obtain supporting dataset i.e. carbon emission and climate change surveys, observations of environmental impact from excessive nocturnal light surveys and implication of light threshold limitation regulation on focus group discussion with stakeholder.

Then, this paper concludes the building of a low carbon emission for specific designated area on tourist resort and the best recommendation for stakeholder in law enforcement of light threshold limitation regulation.

2. Methodology

Figure 1 below shows the procedural on building of a low-carbon emission concept for tourist industry resort. There are two of dataset as input into method, i.e. DPMS-OLS VIIRS radiances and Light meter surveys dataset.

Procedural concept method starts from collecting The Defense Meteorological Satellite Program Operational Linescan System (DMSP OLS) and the Visible Infrared Imaging Radiometer Suite (VIIRS) radiances from world-space agencies i.e. National Oceanic and Atmospheric Administration Comprehensive Large Array-data Stewardship System (NOAA CLASS) and NOAA National Centers for Environmental Information Earth Observation Group (NCEI EOG).

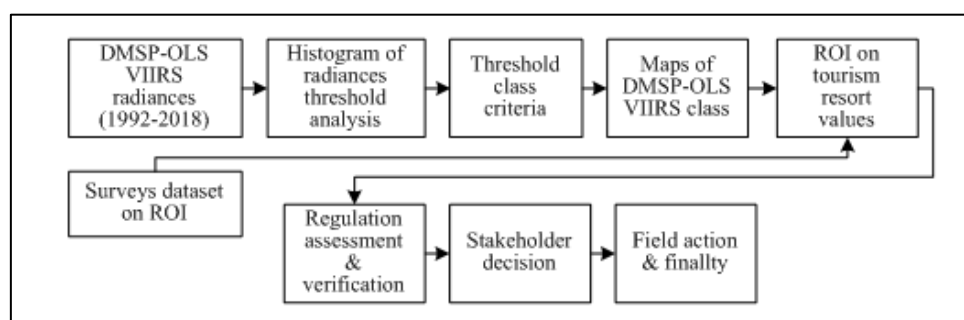


Figure 1. The procedural flow of implementation of low carbon emission on tourist resort.

Dataset is sub-setting into Indonesian region (6°N-11°S, 95°E-141°E), removes other neighborhood country (Singapore, Malaysia), and sub-setting into Bali Island (7.34°S-9.54°S, 113.49°E-116.87°E). The processing step of the satellite data before uses explained on section 3 below. DPMS-OLS VIIRS

radians characteristic obtains from combining long-term years from 1992 until 2018. Histogram analysis uses to determine the radiance threshold criteria, called ambient, moderate and excessive class. Maps of region of interest values confirms with light meter from field surveys. Stakeholder is in charge to assessed and verified results.

3. Dataset

3.1. Nighttime satellite data

Satellite remote sensing data has been widely used on various applications in mapping region that solved problems within wide area coverage even global. Moreover, satellite remote sensing has capability on temporal or re-visiting time, multi-spectral, multi-polarization and carried many types of sensors. In particularly, satellite remote-sensing of low-light nighttime imagery carries a Photo Multiplier Tube (PMT) type sensor in the form of passive panchromatic low-light imaging on the spectral channel 0.47 μm to 0.95 μm . Sensors observe nighttime low light on the surface of the earth that comes from man-made light and natural lighting, such as flames from volcanoes, forest fires and gas combustion in oil fields. Nighttime light can be used as an indicator of human activity that measure from satellites on space and is very suitable in mapping of various settlement problems [8]. Applications of low-light nighttime satellite data open on various applications such as socio-economic problems [9,10]. It uses in modelling of spatial distribution and growth of the human population [11, 12]. Overall energy and energy consumption [13, 14], economic growth rates [15, 16], gas emissions from anthropogenic [17, 18] and various estimation of other indices.

There are only two operational satellites with NASA's low-light nighttime imagery mission, namely the Defense Meteorological Satellite Operational Linescan System (DMSP OLS) Program and the Visible Infrared Imaging Radiometer Suite (VIIRS).

3.1.1. Defense meteorological satellite operational linescan system (DMSP OLS). The Operational Linescan System is a passive panchromatic low-light imaging on the spectral channel at 0.47 μm to 0.95 μm carried by Defense Meteorological Satellite Program. DMSP satellite is a sun-synchronized polar orbit, with local overpass times at descending node and ascending node roughly at 08:30 and 20:30, respectively. OLS sensor is an oscillating scan device with visible and thermal-infrared bands designed to map clouds in both day and night. With a swath wide of 3000 km, it is able to provide daily global coverage. The visible band uses a photo multiplier tube (PMT) to collect radiance ($\text{W}/\text{cm}^2/\mu\text{m}/\text{sr}$). OLS data delivered to end-user of within 6-bit quantization of digital numbers (DN) ranging from 0–63 format (Hsu *et al.*, 2015). Detailed details of the specifications of VIIRS and DMSP / OLS data as described in Li *et al.* [19].

The OLS has no onboard calibrator. Hence, calibration steps to correct nighttime light data of OLS DMSP that tend to be saturated are very important to do, including inconsistent each data sensor in several years of mission. The important step is to reduce the effects of the saturation and subsequent correction of the effects of discontinuity. Elvidge *et al.* and Liu *et al.* the first to introduced the nighttime light inter-calibration method [20, 21]. Wu *et al.* refined the inter-calibration method by introducing the invariant region method to inter- calibrate nighttime light data [22]. The processing of satellite data before use must be carries out with several pre-processing steps, such as an inter-calibration process [23], the process of eliminating saturation effects [24], and the process of applying thresholds [25]. The DPMS OLS starts operational in year 1992 and end in 2013.

3.1.2. Visible infrared imaging radiometer suite (VIIRS). The VIIRS instrument onboard on the National Polar-orbiting Operational Environmental Satellite System (NPOESS) with 827 km altitude polar orbit and nighttime overpass at 01:30 AM. The VIIRS sensors have 3 000 km swath width, 0.742 km spatial resolution. The low-light sensor is panchromatic imaging band-pass 0.5 to 0.9 μm , 14-bit data quantization without saturation. The sensor has detection limit to $2\text{E}^{-11} \text{ W}/\text{cm}^2/\mu\text{m}/\text{sr}$ and uses on-board solar diffuser to calibrate day night band (DNB) data. The VIIRS has mission objectives to

imaging nighttime on visible band of moon light clouds in NOAA Technical Report (2013) [26]. The VIIRS starts operational in year 1992 until present.

3.2. *Light meter surveys*

Measurement of light meter aims to enforce stakeholder decision. Location of sampling point initially obtains from threshold criteria map of DPSM-OLS VIIR data. Surveys carried out with GPS and GIS utilities. Measuring instrument used are a high sensitive radiance lux meter (MS6612 model) and meteorology meter i.e. temperature scanner, anemometer, humidity and GPS. Measurement points determined where the light strongest occurs, in a 1 Km square area that same as spatial resolution of DPSM-OLS VIIR data. A high sensitive lux meter provides 0.01 illuminance resolution (lux). Approximately, 1 lux at 1 meter square divides by their luminous efficacy (lumens per watt) give energy in Watt. Typical luminous efficacy of LED lamp is about 80-100 lm/w. Measurements method used as stated in Dominoni *et al.* [27] and Dharani *et al.* [28].

The purpose of measurements is to obtain the characteristics of existing lighting sources, such as it is important light (essential or decorative), how much energy is used and others (items as in Appendix-A). Light meter surveys data collected and analyzed with description statistics to get their characteristics.

3.3. *Supporting dataset*

The procedural steps on figure 1 shows two major processes i.e. processing of nighttime satellite data, the DPMS-OLS VIIRS dataset and light meter surveys on regions of interest (ROI). As this research aims to raise awareness of society on climate change and carbon emission reduction, holistic study conducts also by surveys, observation and focus group discussion below.

3.3.1. *Carbon emission and climate change surveys.* Climate change has emerged as one of global issue related with energy consumption and related activities on tourism and hospitality industries. Stakeholder had known this issue by close temporarily some tourist destinations to conserves the environment. Bali represents the world's best tourism destination will be potential contribution of tourism to climate change. Fortunately, Bali tourism as managed by local wisdom, namely Tri Hita Karana. This surveys aims to obtain awareness of society on climate change and carbon emission reduction acts (items as in Appendix B). Surveys do in order to know the society perception if they are requested concrete action in reducing carbon emission. Also socio-economic aspects of society related to lighting sources. Survey results analysis by quantitatively of descriptive statistics [29].

3.3.2. *Observations of environmental impact from excessive nocturnal light.* Observation of environmental impact aims to examine animal interactions related to lighting sources (items as in Appendix C). Observations can show animal's behavioral changes, natural bio-cycle disorders and others [30]. Observations do with unconditional ecosystem or natural habitat of animals. A comparative method used to analysis observation results.

3.3.3. *Focus group discussion on light threshold limitation regulation.* Focus group discussion aims to explore processes, challenges and other obstacles, in implementing regulation. For this reason, it is necessary to establish an operating procedure on light threshold limitation. The operating procedure compiled from based maps of nighttime light, land-uses, electrification and supporting dataset (surveys and observation data above). The implementing regulation requires a measurable result. SWOT analysis (strengths, weaknesses, opportunities, threats) in a grand matrix strategy made that shows whether strategies are aggressive, conservative, defensive, or competitive.

4. Results and discussion

4.1. Procedural constraints

Collection and processing of long-term nighttime satellite remote sensing data requires large data storage and reliable of processing computers. One scene global image of DMSP OLS Day Night Band (DNB) uncompressed data approximately becomes three Giga Byte storages. Moreover, its consists of 30 arc-second grids that spanning from -180 to 180 degrees longitude and -65 to 75 degrees latitude. Hence, annual or one scene per year of DPMS OLS data decided to use as collection of dataset. DNB data product of DPMS OLS distributed to end-user not in radiance unit data, but in digital number (DN) non-unit data. Therefore, a routine requires calibration of DMSP OLS DN into radiance unit. Moreover, DMSP OLS known as narrow band of sensitivity and saturated over urban area, the area that focus of this research. DPMS OLS eras end in 1992, VIIRS continues nighttime satellite mission with significant improved until present. As program changes, technical, format and specific data also changes. Light meter surveys of procedures carried out as simple, many factors and methods of measuring light that are complex and require trained personnel is limited.

4.2. General view of Indonesian night-time light

4.2.1. Maps of Indonesian night-time light from DPMS OLS (1992-2013). Figure 2 shows maps of Indonesian nighttime light DMSP-OLS after calibrated using Modified Invariant Region (MIR) method. Coastline overlays in white-color, ocean seems in dark and other in black-color means lowest radiance level. Bright white-color means lit pixels or source of nocturnal light. Insert map is Bali island. On figure (upper) in year 1992 indicated few sources of nocturnal light (lit pixels) emerges over Sumatra, Java island. In 2013 figure (below), within 21 years sources of nocturnal light much escalate mainly over Java Island. Figure 2 shows of evident that Java Island more develops than other region.

Table 1 shows statistical data before and after calibration. The DN original data of DPMS-OLS has range 1-63, (Detects radiance down-to $0.5 \text{ nW/cm}^2/\mu\text{m/sr}$) after calibration become widen (in unit less). The mean values on table 1 in 1992 or 2013, shows Bali more develop than whole of Indonesia region.

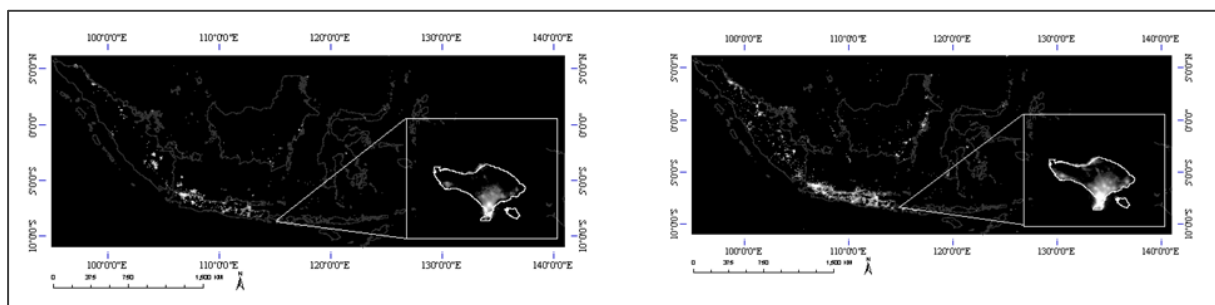


Figure 2. DPMS-OLS Calibrated radiance in (left) 1992 and (right) 2013 Indonesian subset.

Table 1. Statistical data of DMSP-OLS in 1992-2013 before and after calibrations.

	DPMS OLS Original				DPMS OLS Calibrated			
	1992/Ina	1992/Bali	2013/Ina	2013/Bali	1992/Ina	1992/Bali	2013/Ina	2013/Bali
Min	0	0	0	0	0	0	0	0
Max	63	58	63	62	242.65	203.81	203.8	196.95
Mean	0.09	0.59	0.30	1.84	0.12	0.65	0.32	2.62
STD	1.49	3.21	2.63	6.83	3.83	6.96	5.82	16.65

4.2.2. Maps of Indonesian night-time light from VIIRS (2012-2018). Figure 3 shows Indonesian nighttime light from VIIRS in year 2018. Comparison of three figures of nighttime data from year 1992, 2013 and 2018 indicates light source spreading wider to the southern part of Bali Island and lit pixels emerges also at the northern coast of Bali Island.

On the east, Lombok (Mataram city) and the west, East Java (Banyuwangi city) of Bali Island, lit pixels also emerges that shows economic development progress extends on Indonesia country.

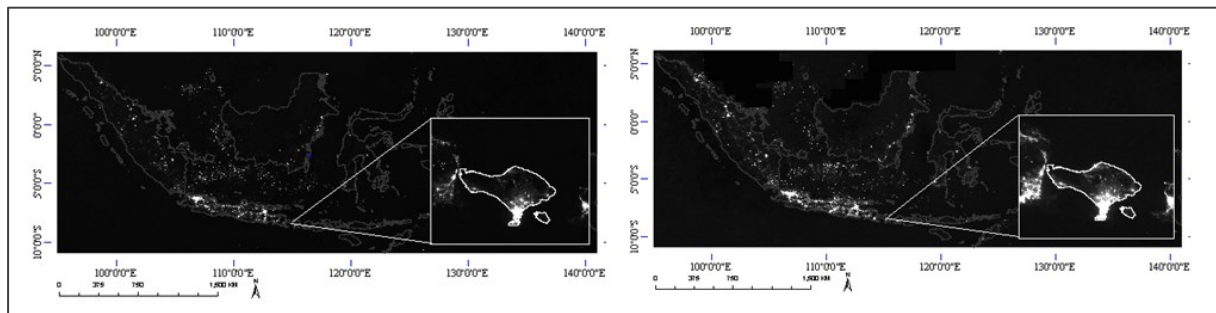


Figure 3. VIIRS nighttime radiance in (left) 2012 and (right) 2018 Indonesian subset.

Table 2 shows progress or statistical data of VIIRS nighttime Indonesia in general and Bali of year 2012 and 2018. The mean radiance value of Bali is higher than Indonesia in general.

Table 2. Statistical data of VIIRS radiance in 2012-2018.

	VIIRS DNB Radiance			
	2012/Ina	2012/Bali	2018/Ina	2018/Bali
Min	0.0	0.0	0.0	0.04
Max	1108.71	62.16	1550.9	86.93
Mean	0.00467	0.35	0.1848	0.69
STD	1.595	1.47	1.091	1.73

The trend of economic grows of Bali, as world first tourism destination can be views from spreading trend of nocturnal light. An assumption uses to state that Indonesia has still undergoing rapid economic development, electric power consumption and urban expansion growth since 1992 even though economic recessions in 1998.

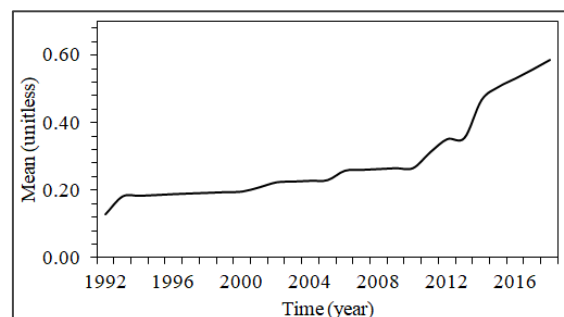


Figure 4. Trend mean of Indonesian DPMS-OLS (1992-2013) and VIIRS (2018).

For this reason, annual mean value of nighttime light in an early year would not be less than mean value in a later year. For that purpose, all of nighttime dataset must be inter-annual calibrated. Figure 4 shows trend of mean of DMSP OLS nighttime radiance after calibration from year 1992 until 2013 and continues with VIIRS nighttime radiance to 2018. Significant increase of trend starts from year 2004.

4.3. Procedural of light meter surveys

The first step on surveys is to determine point of location. Base on maps of annual averaged VIIRS nighttime radiance data in year 2018. Strong and weak radiances mainly around tourism resort i.e. Kuta, Nusa dua, Jimbaran, Ubud and Denpasar city. Total of 64 point marked on the map and get latitude longitude values. Light meter equipment (MS6612 and AS802 model) adjusted to zero with black cloth cover before uses Figure 5 shows field surveys at Kuta Bali, surveyor collects data on safe at roadside.



Figure 5. Lux meter uses MS6612 and AS802 model and action of sampling.

Light measured are in three mode of measurement i.e. hold, max, min mode in lux unit. Measurement did not consider of factors such as light incidence angle, shadows, etc. Measurements made several times and recorded highest results, at point of latitude and longitude of GPS.

Light meter surveys result on March-July 2018 shows on Table 3 below. Numerous of light exist at point of measurement, light source can be from streetlight, advertising, settlement, household, amusement, moon or stray light, etc. Hence, measurement results considered as cumulative of all sources. This is appropriate with dataset of nighttime satellite that used.

Table 3. Statistical data of light meter surveys results.

	Surveys Data (lux)			VIIRS radiance (nW/cm ² /μm/sr)
	Hold	Max	Min	
Min	0.00	0.00	0.00	1.15
Max	97.78	98.19	78.98	57.94
Mean	28.62	28.08	23.65	15.03
STD	23.35	21.41	18.16	12.90

Table 3 also shows mean of VIIRS radiance about 15 nW/cm²/μm/sr. VIIRS has high sensitivity factor. Hence, VIIRS minimum radiance shows none zero value.

4.4. Procedural of environment indices surveys

Before surveys, weather condition must be clear sky. It implies light sources from earth surface and stray light from atmosphere can penetrates into sky and vice versa. Figure 6 surveyor sampling of environment indices i.e. measures of spot temperature of overhead light source.



Figure 6. Surveyor measures of spot temperature of overhead light source.

Field surveys conducted in March-June 2019 on North-West Monsoon. On that time, Indonesia has rainy season until start of dry season. Weather is warm around 25°C and humid about 80%. Wind blows low on speed less than 1 m/s or in Beaufort scale, sometime cloudy and rain. Table 4 below shows environment indices at location of field surveys

Table 4. Environmental indices surveys results.

	Spot. (°C)	Temp.(°C)	Wind (m/s)	Beaufort Scale	Humidity (%)
Min	10.00	25.80	0.00	0.00	51.00
Max	32.00	39.10	3.30	3.00	95.00
Mean	25.20	29.93	0.32	0.24	79.58
STD	5.09	2.10	0.67	0.57	7.12

5. Conclusions

This paper proposes a procedure to encounter an energy crisis that is certain to come about. The method in this paper provides a sustainable solution for Bali's tourism industry to maintain electricity needed and even its can be applied into general electricity crisis issue. Tourism has known as a large amount of energy absorbs and become one of the source causes of environmental change and degradation. Moreover, becomes a threatened industry that has provided many economic benefits to developing countries that depend on tourism industry. The monitoring and active management patterns in regulating use of energy in tourism industry is important and more effective rather than investing of renewable energy. This method provides the most effective in procedural of assessing the excessive uses of electricity by applying the satellite remote sensing technology.

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Appendix A. Additional aspects of light meter surveys

1	Type of Location	[Ambient]/[Excessive]
2	Designation Area	[Settlement]/[Public]/[Business]/[Tourism]
3	Light Condition	[Low-ability]/[Low-visibility]/[Comfortable]
4	Type of Sources	[Uniform]/[Composite]
5	Source of Ownership	[Public]/[Private]
6	Nature of Source	[Essential]/[Decorative]

Appendix B. Carbon emission and climate change surveys

1	General purpose	Survey/questionnaire aims to get an overview/ response from community in order to an active role for supporting low-carbon emission in the context of energy-efficient.
2	Purpose of data collection	Data will be used in research on light thresholds for an area in the context of energy savings.
3	Demography	Age: [20-35] / [36-50] / [50 -] Gender: [Male / Female] Job: [Employee/Entrepreneur]
4	Electrification Power installed	[<2200VA / <5KVA] Percentage of lighting power [%]
5	Types of questions and responses: (1) Dichotomy: [agree /disagree / do not know] (2) Multi-level Scale: [1-5] (3) Options: [A., B., C., D] (4) Ordinal scale: [at least / most] (5) Open: [answer]	I. Knowledge section 1. Do you know about impact of excessive CO2 emissions on global warming and climate change? (4) 2. Do you intend to play a role in reducing excess CO2 emissions? (4) 3. Do you know the way/method/action role in reducing excess CO2 emissions? (1) 4. Do you know the sources of excessive CO2 emissions? (1) 5. Do you know the electricity generated from natural resources of coal which is the main source of excess CO2 emissions? (1) II. Energy section: 6. Do you know the conditions of the world energy crisis and renewable energy? (1) III. Lighting section: 7. Do you know the types of essential and decorative lighting? (1) IV. Regulatory Session 8. Do you willing to restrictions on external lighting? (1)

Appendix C. Observations of environmental impact from excessive nocturnal light surveys

existence of animals: [avian]/[bat]/[bugs]/[inset] [reptile] [specify]	Specific species: [specify]	abundance:[solitary/colony]
sources/ Food chain: [feeds]/[mortal]	Physiological disorders: (There is abnormal body movement)[day and night]	Species abundance/ distribution[solitary/colony]
Natural cycle disorders: (appears at night) [day and night]	Immigration/ Emigration:[day and night]	Note: