RESEARCH ARTICLE

A MODEL OF CARBON EMISSION REDUCTION BASED ON THE EFFICACY OF NATIONAL PUBLIC ROAD LIGHTING IN NORTH SUMATERA PROVINCE

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Manuscript Info	Abstract
………………….. 	……………………………………………………………… Electrical energy is a fundamental requirement necessary for the survival of human activities. Electrical energy is exploited as much as possible in human life due to its availability which is continuously reachable easily and cleanly. In terms of supply, in its operation, the generation of electrical energy with fossil fuels causes environmental pollution whose value can be converted by multiplying by 1.14 KgCO2 / KWh emission factor. From the demand side, street lighting has a light efficacy that can be used for energy conservation. Light lamp efficacy is the ratio of luminal output to electric power consumption expressed by lumen / watt unit. The efficacy of the lamplight affects the light intensity in the candela unit and the intensity of light affects the illumination in lux units. By using Model Type: Utilization of SUTR power through converter to PJU-LED obtained energy conservation of 40.149 GWh and Utilization of SUTR power through converter to PJU-LED and DIM obtained energy conservation of 48,897 GWh of national road along the 2632.22 km in North Sumatera Province, and resulted in a decrease in carbon emissions of 45,769 kTon CO_2 and 55,742 kTon CO_2 respectively, resulting in carbon trading values of US \$83,752.27 and US\$102,013.35.

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Introduction:-
At present, the condition of shortage of electrical energy can occur due to limited supply of electrical energy is smaller than the larger energy needs. The rate of growth of electricity demand will tend to be greater if not addressed will cause the level of availability of electrical energy to be disrupted.

To overcome the limitations of electrical energy, energy conservation efforts are needed[1]. Conservation of electrical energy can be achieved through 2 approaches that are 1.By increasing the efficiency of electrical energy usage and 2. Reducing losses. Conservation efforts can be achieved through two aspects: 1. Aspect of technology and 2. Aspect of human behavior change.

In North Sumatra Province, one method to overcome the limitations of electrical energy is energy conservation based on environment[2]. In the case of electric energy crisis, Bangladesh as one of the developing countries can

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save electricity consumption 3% -20% through changes in human behavior[3]. The management of energy efficiency in the consumer side and service sectors is always based on the application of demand side management[4].

The energy absorbed by the cloud and the earth's surface is reflected back in the form of infrared radiation, but some of the infrared radiation emitted by the earth is held up by clouds and gases of carbon dioxide and other greenhouse gases, to be returned back to the earth's surface. In China, Green House Gases emission can be reduced from N fertilizer[5]. Under normal circumstances, the greenhouse effect is required. With the greenhouse effect the temperature difference between day and night on earth is not too much different.

In the control of regulated air pollution which refers to the maintenance of the environment should be the basis in the development of society[6].

With the electric energy crisis, the development pattern of electric energy generation and the utilization of electrical energy become related to the issue of global warming, so to overcome the thickening of carbon dioxide emission, the utilization of environmentally friendly technology becomes the choice[7].

One of the efforts to obtain potential energy conservation done is on general street lighting due to its use occurs only at night and at the same time the peak load[8]. Particularly for national street lighting a large energy requirement is managed for the convenience of driving at night[9].

To determine the level of carbon emissions caused by the generation and utilization of electrical energy, using data generating electricity in Indonesia, then the CO_2 emission factor is 1.14 Kg / KWh stated by United Nation Development Project (UNDP).

Referring to the results of the National Strategy Study (NSS) indicating that the CDM potential of the energy sector is about 2.1% of Indonesia's total 1200 million tons of CO_2 emissions per year. Thus the CDM potential of the energy sector is 25.2 million tons of CO_2 per year at a price of US \$1.83 per ton.

Theoretical background:
The Power Absorbed By The Lamp And Power Factor Correction:
Electrical power is calculated as follows:

$$P = V.I. \cos \varphi = S. \cos \varphi$$

where: P is electric power
        V is the utility voltage
         I is the electric current
    Cos φ is the power factor.
Energy is the power used in a single unit of time.

$$W = P \times t$$

where:
        W is energy
         t is time
 The energy absorbed by the lamp is

$$W = S \times t$$
$$W = (P / pf) \times t$$
$$W = KWh / pf$$

Power factor correction(Q_c)can be obtained as follows:

$$Q_c = P (\tan \varphi_1 - \tan \varphi_2)$$
$$= V^2 / X_c$$

The value of adding capacitor(C) for power factor increase is

$$C = Q_c / 2\pi f V^2$$

With the increase in power factor improvement which means the increase of Cos φ, will be able to reduce energy generation. This condition can reduce the use of fuel which can ultimately reduce CO_2 emissions generated by the plant.

Energy Conservation:
To get energy conservation, applied Model Type: Utilization of SUTR power through converter to PJU-LED and DIM.

Light Efficacy:
The efficacy of light is the ratio of the lumen output to the power consumption expressed in lumen / watt units.

$K = \emptyset/P$

Where,

K is the light efficacy (Lm / W)

$\emptyset$ is Flux light (Lm)

P is electric power (Watt)

In street lighting, the height of the lamppost affects the spreading of light. The higher the pole is used, the resulting light widened with a smaller level of illumination.

To determine the angle of the line that connects the endpoint of the lamp and the point in the middle of the road with the horizontal line is as follows in Fig.1

$r = \sqrt{h^2 + c^2}$

$\cos\psi = h/r$

Where,

r is the side of beveled line, the distance from the end of the lamp to the point in the middle of the road,

c is the horizontal line, the distance from the projection point of the lamp end to the point in the middle of the road,
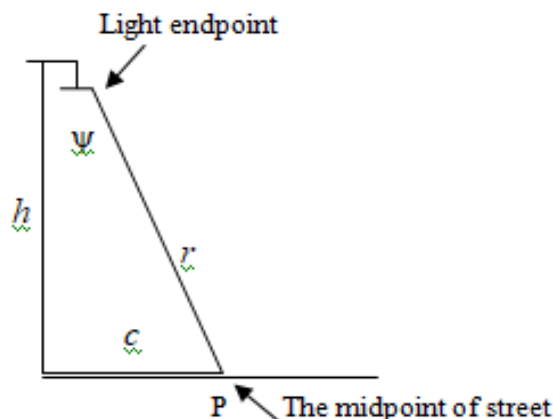
h is the pole height,

ψ is the angle between r and h.

Fig.1:- Effect of lamppost height on illumination.

To calculate the intensity of light (I) in units of candela (cd):

$I = \emptyset/\omega$

$\omega = 4\pi$

$K = \emptyset/P$ or $\emptyset = KxP$

Then, $I = KxP/4\pi$

Illumination E_P in units of Lux at the point P in the middle of the street is

$E_P = I \times \cos \psi/r^2$

Research Method:-
Model type:
Utilization of SUTR power through converter to PJU-LED and DIM:
The $P_{PJUN-SUTR}$ approach model is an approach model with low voltage network (SUTR) as an energy source and High Pressure Mercury Lamp (MBF) is changed to LED Lights as PJU National Public Road Lighting, $PJU_{SUTR-LED}$. Among SUTR and $PJU_{SUTR-LED}$ are used converters that convert alternating current into DC current. Then, used the

$P_{PJUN-DIM}$ approach by dimming the output of lighting at a certain time or shutting down half of the number of lamps that apply.

Energy conservation can be obtained in 2 stages. In stage 1, energy conservation is obtained from 18:00 to 24:00 WIB, as follows:

$P_{PJUN-SUTR}[1] = [P_{SUTR-MBF} - (P_{SUTR-LED} + \Delta P_{Konv})]$

$P_{Konsv-SUTR}[1] = (P_{PJUN-SUTR}[1]) \times n$

$E_{Konsv-SUTR}[1] = P_{Konsv-SUTR}[1] \times Oh$

$J_{Konsv-SUTR}[1] = E_{Konsv-SUTR}[1] \times J_E$

Where :

$J_{Konsv-SUTR}[1]$: Energy conservation is converted to CO_2 emissions (Kg) stage 1
$E_{Konsv-SUTR}[1]$: Annual energy conservation of PJUN-SUTR (KWh / Year)
$P_{Konsv-SUTR}[1]$: Power Conservation PJUN-SUTR (KW)
$P_{PJUN-SUTR}[1]$: Power of PJUN-SUTR lamp.
$P_{SUTR-MBF}[1]$: Power of PJUN-MBF lamp
$P_{SUTR-LED}[1]$: Power of SUTR-LED light
n : Number of lights
Oh : Working hours
J_E : CO_2 Emission Factor (Kg / KWh)

In stage 2, energy conservation is obtained from 24:00 to 06:00 WIB, as follows :

$P_{PJUN-SUTR}[2] = \frac{1}{2}[P_{SUTR-MBF} - (P_{SUTR-LED} + \Delta P_{Konv})]$

$P_{Konsv-SUTR}[2] = (P_{PJUN-SUTR}[2]) \times n$

$E_{Konsv-SUTR}[2] = P_{Konsv-SUTR}[2] \times Oh$

$J_{Konsv-SUTR}[2] = E_{Konsv-SUTR}[2] \times J_E$

Where :

$J_{Konsv-SUTR}[2]$: Energy conservation is converted to CO_2 emissions (Kg) stage 1
$E_{Konsv-SUTR}[2]$: Annual energy conservation of PJUN-SUTR (KWh / Year)
$P_{Konsv-SUTR}[2]$: Power Conservation PJUN-SUTR (KW)
$P_{PJUN-SUTR}[2]$: Power of PJUN-SUTR lamp.
$P_{SUTR-MBF}[2]$: Power of PJUN-MBF lamp
$P_{SUTR-LED}[2]$: Power of SUTR-LED light
Then,
$J_T = J_{Konsv-SUTR}[1] + J_{Konsv-SUTR}[2]$
J_T : Total energy conservation is converted to CO_2 Emissions

Result and Discussion:-
The effect of height variation of light pole on illumination:
As a reference used MBF, 400 watts, 110 Lumen/watt for primary arterial road.

The effect of the height variation of light poles on the illumination produced with certain light efficacy on the primary arterial road at the midpoint of the road is obtained by the following calculation:

1.Lamp type: MBF, 400 Watt, 53 lumens / watt
Road width: 8 m
h = 10 m
c = 2.95 m
$r = \sqrt{10^2 + 2,95^2}$
  = 10.426 m
   $Cos\psi = 10 / 10.426$
        = 0.959
$I = 53 \times 400 / (4 \times 3,14)$
     = 1687.898 cd
Then,

$E_P = 1687.898 \times 0{,}959 / 10.426^2$
     $= 14.891$ Lux

As a reference used MBF, 180 watts, 53 Lumen/watt for primary collector road.

2. Lamp type: MBF, 180 Watt, 53 lumens / watt

Road width: 7 m

h = 7 m

c = 2.6 m

$r = \sqrt{7^2 + 2.6^2}$
  $= 7.467$ m
   $\cos\psi = 7 / 7.467$
        $= 0.937$

$I = 53 \times 180 / (4 \times 3{,}14)$
     $= 759.554$ cd

Then,

$E_P = 759.554 \times 0{,}937 / 7.467^2$
     $= 12.764$ Lux

Using lamp type: LED, 120 watt, 130 lumen / watt For primary arterial road, then

Road width: 8 m

h = 8 m

c = 3.1 m

$r = \sqrt{8^2 + 3.1^2}$
  $= 8.57$ m
   $\cos\psi = 8 / 8.57$
        $= 0.93$

$I = 120 \times 130 / (4 \times 3.14)$
     $= 1242.03$ cd

Then,

$E_P = 1242.03 \times 0{,}93 / 8.57^2$
     $= 15.73$ Lux

For collector road, then

Road width: 7 m

h = 8 m

c = 2.6 m

$r = \sqrt{8^2 + 2.6^2}$
  $= 8.41$ m
   $\cos\psi = 8 / 8.41$
        $= 0.95$

$I = 120 \times 130 / (4 \times 3.14)$
     $= 1242.03$ cd

Then,

$E_P = 1242.03 \times 0{,}95 / 8.41^2$
     $= 16.69$ Lux

Fossil Electrical Energy Requirements for PJU of National Road Segment:

According to criteria of primary artery road with width of road body is 8 m, requirement of lighting quality is 11- 20 Lux, used lamp lamp of MBF, 400 Watt with 11 m pole height with 40 m inter pole distance. For primary collector road with road width is 7 m using MBF lamp, 180 watt with 8 m pole height with 40 m interpole distance.

Therefore, electricity consumption is obtained in 1 year on primary artery road along 1142 Km with operating time 4145 hours in 1 year, as follows:

1. Number of PJU Pillar is (Length of Road/40) + 1
2. PJU electrical power
    $P_{PJU-SUTR} = 400$ Watt x Number of posts
             $= 400$ Watt x 28,551

$$= 11.420 \text{ MW}$$

3. PJU electrical energy requirement in one year is

$W_{PJU-SUTR}$ = 400 Watt x Number of poles x 4145 hours

= 400 Watt x 28.551 pole x   4145 hours

= 47.337 GWh

Electric energy consumption is obtained within 1 year on Collector Primer-1 Road along 1490.22 Km with operating time of 4145 hours in 1 year, as follows:

1. Number of PJU Pillar is (Length of Road / 40)+1
2. PJU electrical power

$P_{PJU-SUTR}$ = 180 Watt x Number of posts

= 180 Watt x 37.256

= 6,706 MW

3. PJU electrical energy requirement in one year is

$W_{PJU-SUTR}$ = 180 Watt x Number of poles x 4145 hours

= 180 Watt x 37.256 pole x 4145 hours

= 27.796 GWh

The need for electrical energy PJU-SUTR National Road along 2632.22 Km in 2019 is equal to 75.133 GWh.

The need for electrical energy on the utilization of SUTR power through converter to PJU-LED:

Electric energy consumption in 1 year on Primary Arterial Road and Primary Collector Road along 2632,22 Km with operation time 4145 hours in 1 year, as follows:

a.The number of PJU pole is (Length of Road/40) +1
b.PJU electrical power

$P_{PJU-LED}$ = 120 Watt x Number of poles

= 120 Watt x 65,807

= 7,896,840 W

$W_{PJU-LED}$ = 7,896,840 x 4145

= 32,732 GWh

Load current,

I = 7,896,840/(220x0,85)

= 42,229.09 A

Losses on SUTR,

ΔW_{SUTR} = 5% x220x42,229.09x4145

= 1.925 GWh

Losses on the converter,

ΔW_{conv} = 1% x 32.732 = 0.327 GWh

So, the energy requirement for the national road is

W_T = 32.732 + 1.925 +0.327

= 34.984 GWh

The need for electrical energy on the utilization of SUTR power through converter to PJU-LED and DIM:

When at 18:00 to 24:00 pm, the lights illuminate all, then the need for electrical energy is

$W_{PJU-LED}$ = 7,896,840 x 2072.5

= 16.366 GWh

ΔW_{SUTR} = 5% x220x42,229.09x2072.5

= 0.962 GWh

ΔW_{conv} = 1% x 16.366 = 0.163 GWh

W[1] = 16.366 GWh + 0.962 GWh + 0.163 GWh

= 17.491 GWh

When half of the LED bulb is turned off at 24.00 - 06.00 WIB, then the need for electrical energy is

W [2] = ½ x 17.491 GWh

= 8.745 GWh

W_T = W [1] + W [2]

= 17.491 GWh + 8.745 GWh

= 26.236 GWh

With model type: SUTR power utilization through converter to PJU-LED and DIM obtained energy conservation as in table 1.

Table 1:- Energy Conservation and obtained the reduction of carbon emissions as in table 2.

	Energy Requirement		Energy Conservation	
En . Ref	With Converter To PJU-LED		With Converter to PJU-LED and DIM	
(GWh)	(GWh)		(GWh)	
75.133	34.984	40.149	26.236	48.897

Table 2:- CO_2 emission reduction.

Emission Factor	Energy Conservation (GWh)		CO_2 Emission reduction ($KgCO_2/kWh$) (kTon CO_2)	
	With Converter To PJU-LED		With Converter to PJU-LED and DIM	
1.14	40.149	45.769	48.897	55.742

According to the energy sector CDM potential by National Strategy Study (NSS) at a price of US $ 1.83 per ton then, in carbon trading is obtained as follows in Table 3

Table 3:- The Value of Carbon Trading.

	Carbon price $/Ton	CO_2 Emission reduction (kTon CO_2)		Carbon Trading Value $	
		With Converter To PJU-LED		With Converter to PJU-LED and DIM	
1.83		45.769	83,752.27	55.742	102,013.35

Conclusion:-

Energy conservation is an energy efficiency use measure by reducing energy consumption or replacing energy sources to get the same benefits. In this paper, energy conservation is obtained by replacing Lighting lamps of the MBF Lights type into LEDs and between Low Voltage Networks as a converted energy source converter. Obtained energy conservation of 45.769 GWh as a stage 1 and by doing Dimmer as stage 2 obtained energy conservation of 55.742 GWh.

By carrying out conservation measures along the 2632.22 km national road in North Sumatera Province using LED-Dimmer Converter, a carbon emission reduction of 55.742 kTon CO2 was obtained with a carbon trading value of US $ 102,013.35. Converter technology makes it possible to conserve energy by using LED lights.

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