Harnessing the hybrid power supply systems of utility grid and photovoltaic panels at retrofit residential single family building in Medan

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Abstract. The paper describes improvisation mode of energy supply source by collaboration between national utility grid as represented by fossil fuels and PV as independent renewable power resource in order to aim the energy consumptions efficiently in retrofit single family house. In this case, one existing single family house model in Medan, Indonesia was observed for the possibility of future refurbishment. The eco-design version of the house model and prediction analyses regarding nearby potential renewable energy resource (solar system) had been made using Autodesk Revit MEP 2015, Climate Consultant 6.0 and Green Building Studio Analysis. Economical evaluation of using hybrid power supply is discussed as well.

1. Introduction

The escalation of energy demands in digital age are significantly increased due to the using of automation devices that need electric power source perpetually in order to make the integrated automation systems working properly. To fulfil the power demand from time to time, the energy supply no longer can hang on to the fossil fuel source but should migrate into conservation of the renewable resources such as solar, geothermal, wind, etc.

Contribution of renewable energy resources as energy supplies have gradually increased shifting the role of fossil fuels technology around the world and it depends on the type of potential renewable energy that could be found surround the power demand area. Positive impacts to the level of environment quality, i.e. reducing carbon dioxide emissions and economical values for the long term, i.e. lifecycle cost for 50 years are expected to be realized.

Residential buildings have 3rd largest portion in term of consume energy and produce waste energy in all over the world [1, 6]. The solution to reduce this trend is applying the concept of Near Zero Energy Building (NZEB). Recently, the automation building systems are the latest issue that could be brought to make residential buildings become more efficient in term of managing the energy circulation for itself. Moreover, old / existing residential buildings have big possibility to refurbish and become the eco-friendly building.

Medan is located in tropical area and has characteristic hot and humid, by using software Climate Consultant 6.0 analyzed based on the most frequency distribution relative humidity is between 80%-

90% (30% of the year). The annual average temperature is 28 - 29 °C and relatively constant. The hottest month is in March with the average daily max/min temperature is 33 °C/ 23°C and the coldest month is December with average daily max/min temperature is 31 °C/ 22°C.

Sophisticated solar collector technologies are very potential to be installed in the area since the solar resources available throughout the year based on geographical climate analysis. In other hand, the cooling load for indoor air quality will take big part in power demand for reaching thermal comfort of the occupants [6]. However, there is limited research on the quality level of occupants' satisfaction in residential buildings since too many variation of variables must be taken so that the comfort satisfaction standard could be formulized.

2. Methodology

The study established an observation of one existing conventional single family house built on 1983 without any of central electrical/mechanical cooling system, electrical security system, domestic hot water installation, nor renewable energy conversion equipment. The spacious area is 1570 m^2 contains house building with size 300 m^2, an ex-office building 140 m^2 (20m x 7m), one 24m^2 bedroom (6m x 4m) and a warehouse / garage building with size 84 m^2(12m x 7m). The building shape is not exactly rectangle, for the rest of the area is garden and paving block. Front side of the house and the office building in the area is heading South, meanwhile for the warehouse entrance door is heading West.

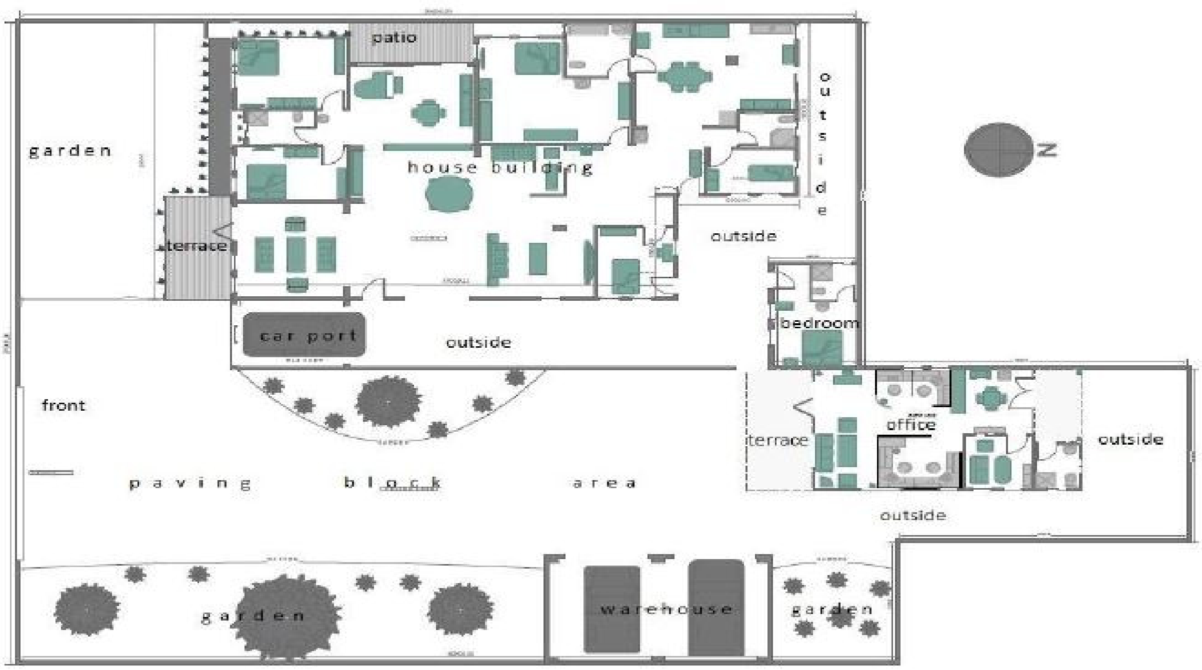

Fig. 1. Spacious Area

The house contains 5 bedrooms, 3 bathrooms, kitchen, living room, terrace, carport and patio. The power load only estimate for the house building and surrounding area, meanwhile the ex-office building and warehouse will not be discussed in this paper.

2.1. Net Zero Energy Building

According to National Renewable Energy Laboratory US Government, a net zero building is the building that receive energy supply from at least 50 % renewable resources per annum and reproduce at same quantity. The intent is to achieve aggressive level of energy efficiency (5 kWh/m^2/year) for cooling / heating purpose [3]. Residential Energy Services Network issues index for rating the residential energy system as displayed below:

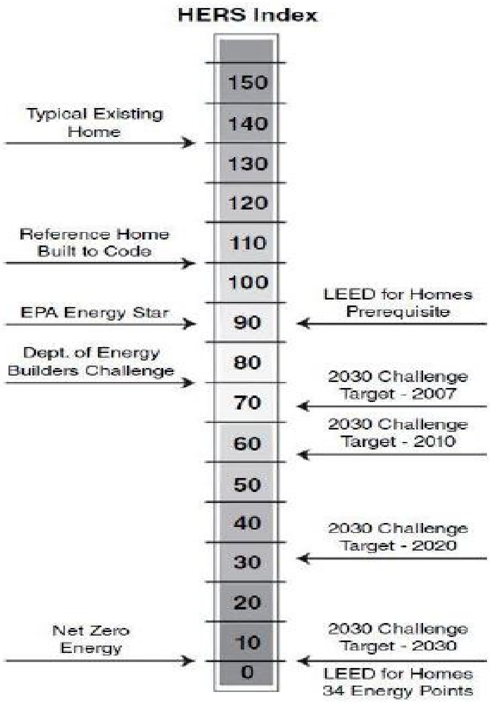

Fig. 2. Home Energy Rating System Index (kWh/m^2per year) [2]

2.2. *Electricity Load*

As modern house, many electronic devices will be installed and used inside the building. Hence, the power consumption considered higher than conventional single family house. The electricity load maybe varies, but approximately load could be determined as shown in Table 1.

Table 1 Electrical Load per Area

Area	Lighting Load(W)	Other Loads (W)
Hall	350	1506
Bathroom 1	35	66
Bathroom 2	35	51
Bathroom 3	35	84
Bedroom 1	75	200
Bedroom 2	75	400
Bedroom 3	75	153
Bedroom 4	75	500
Bedroom 5	75	100
Living Room	135	50
Kitchen	75	340
Patio	30	N/A

Based on the electrical load data, energy simulation analysis had been done using Green Building Studio, the electric demand each month in a year found the highest peak in the middle of March and mid of June around 7.1 kW as shown in the figure 3.

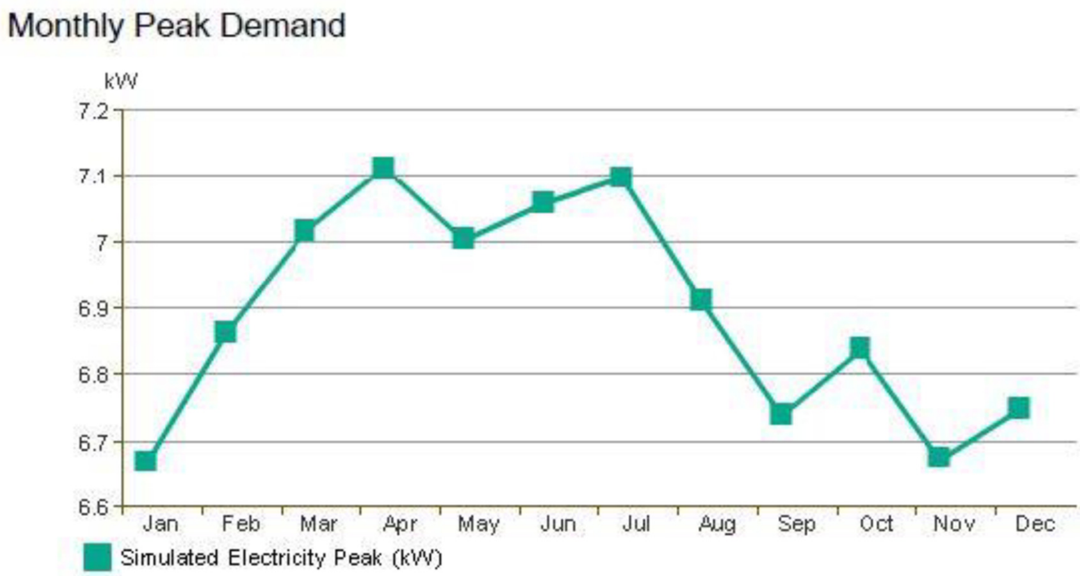

Fig. 3. Simulation Electricity Monthly Peak Demand

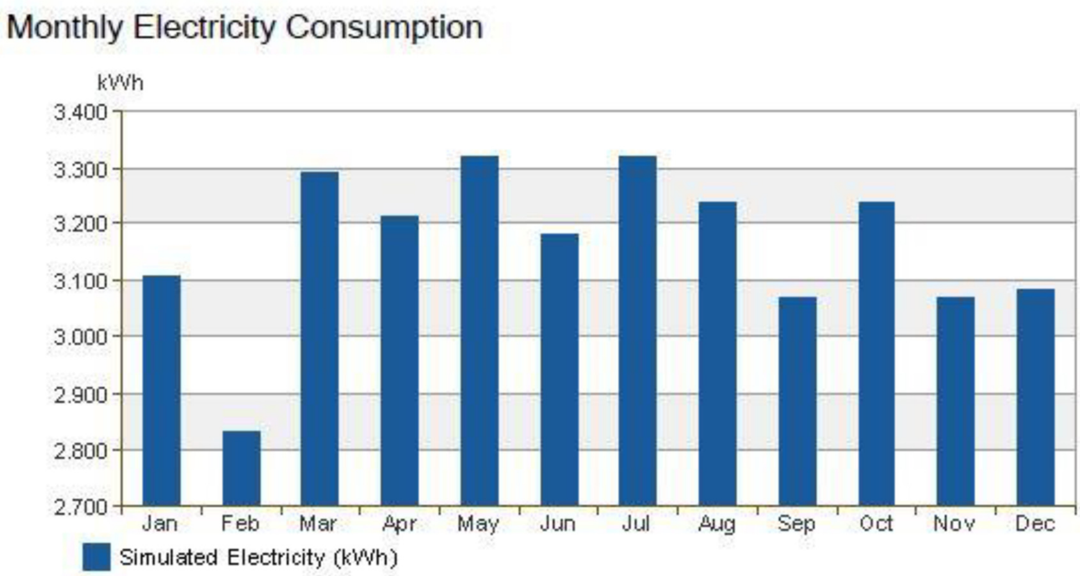

Fig .4. Simulation Electricity Monthly Consumption, 2015

The data shows that the highest consumption is in May and July around 3300 kWh, meanwhile the lowest is in February. This data related to the weather condition in Indonesia in 2015, which May and July are the highest average temperature during the year. Hence, the active cooling is needed longer and more than the other months.

IOP Conf. Series: Journal of Physics: Conf. Series **801** (2017) 012086 doi:10.1088/1742-6596/801/1/012086

2.3. Electric Utility Service and PV Panel Hybrid System

Recently, there is no policy issued by Indonesian national electric company to the clients who using PV panel regarding intensive cost or reduction price of the electric tariff. There is no standardisation for PV arrays installation had been officially published by the government. Generally, for the residential buildings, the PV panel attached on the roof. The hybrid scheme and PV arrays placement on the roof of the refurbishment house shown in Figure 3 & 4 respectively;

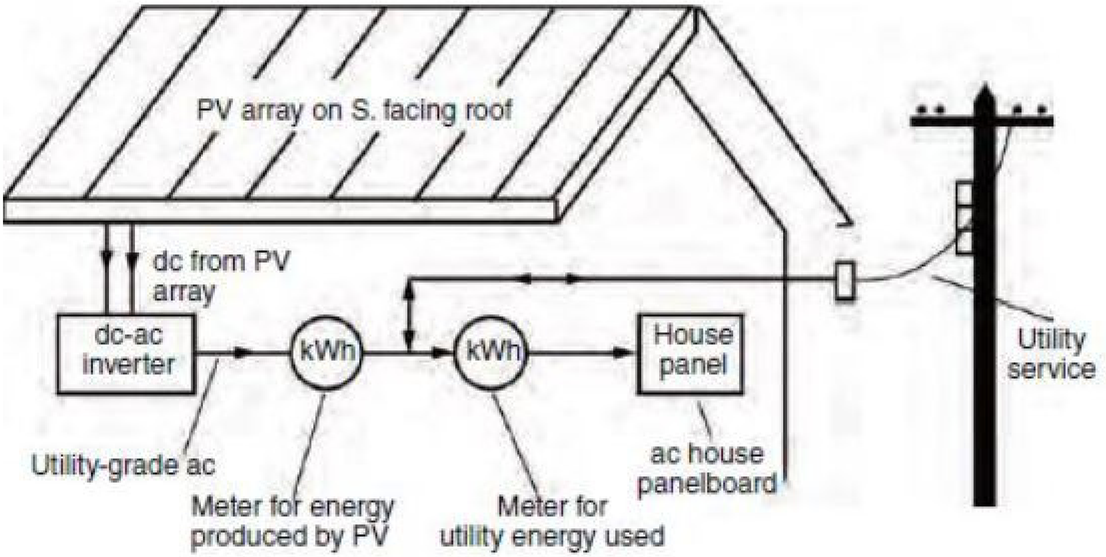

Fig. 5. PV panels and utility service connection scheme [1]

The electrical panel connected to power meter from utility grid and DC to AC inverter as PV panel source, since the loads in the system are all AC. Battery 12 V 100 AH is used with backup capability.

Fig. 6. Mount Roof PV Panel design using Revit MEP 2015

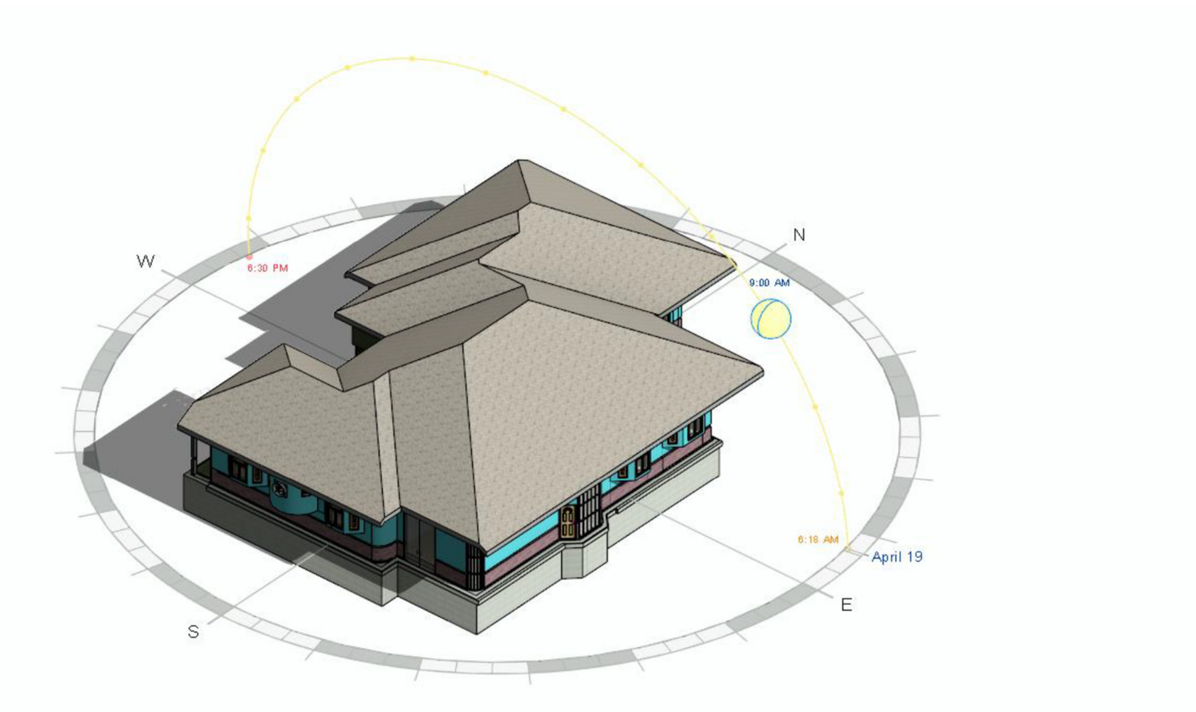

Fig. 8. Sun Position at 9 am, GMT+7

The PV array installed heading east and west using grid connected technique, since the sun exposure mostly bright from 9am-3pm during the year in Indonesia.

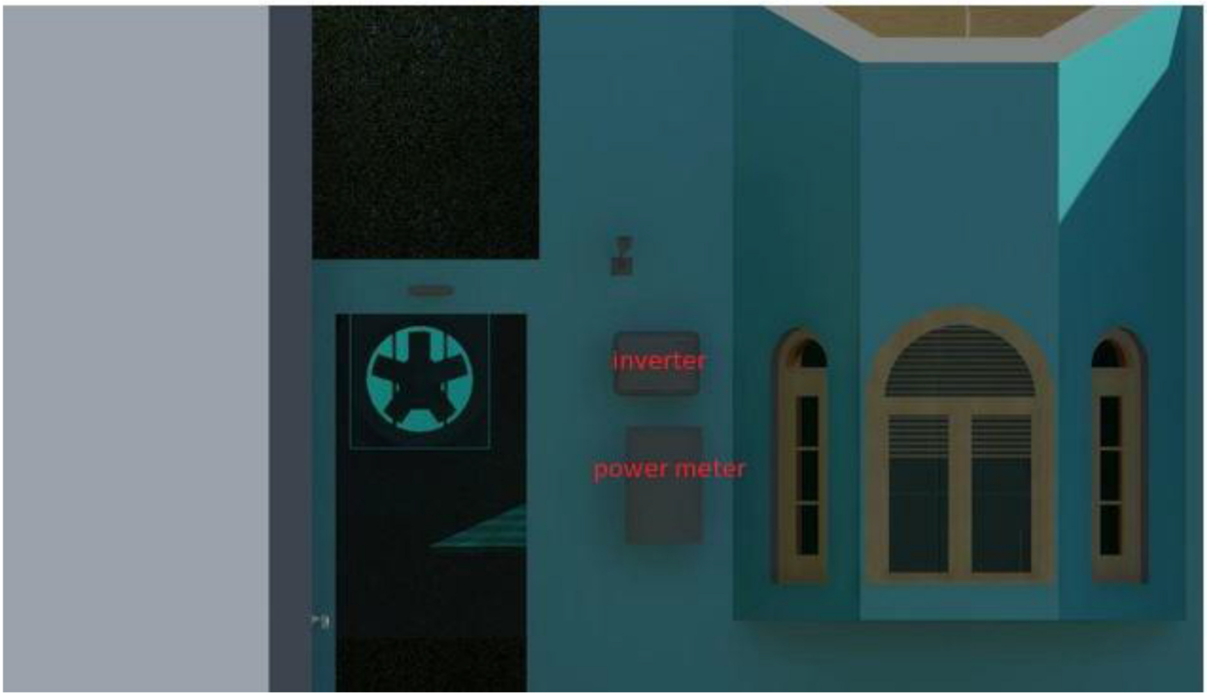

Fig. 7. Power meter and DC to AC inverter at retrofit house eco-design using Revit MEP 2015

2.4. *Solar Potential Energy in the Area*

Indonesia has 4.8 kWh $/m^2$ per day solar energy, equals to 112000 GW [4]. The specification of PV panel used in this plan is Single Crystalline with efficiency 13.8% (102745.6 kWh /year) [5]. By analyse the estimation of PV system energy using software Green Building Studio, can be shown;

Table 2. PV System Energy Estimation per Annum

Renewable Energy Potential

Roof Mounted PV System (Low efficiency):	37,227 kWh / yr
Roof Mounted PV System (Medium efficiency):	74,453 kWh / yr
Roof Mounted PV System (High efficiency):	111,680 kWh / yr
Single 15' Wind Turbine Potential:	147 kWh / yr

*PV efficiencies are assumed to be 5%, 10% and 15% for low, medium and high efficiency systems

The energy efficiency of PV system is calculated based on equation:

$$\eta = \frac{P_m}{E.A_c} \qquad (1)$$

Where:
P_m is performance of a PV panel [W]
E is total intensity of solar radiation [W/m^2]
A_c is surface area of PV cell [W m^2]

2.5. *Economic Evaluation*

Based on electric tariff adjustment categories issued by PLN (Perusahaan Listrik Negara), the Indonesian national electric company per June 2015, this house belongs to R-3/TR (residential category, more than 6600 W), that is 1524 IDR/kWh (€0.09/kWh). The prices still subsidize by the Indonesian government.

Table 2. Electric Tariff in Indonesian Rupiah before Adjustment, June 2015

Golongan Tarif Tariff Class	Tegangan Voltage	TTL Tariff	BPP Basic Cost of Electricity Production	Subsidi Subsidy
P.1 s/d 2.200 s/d 5.500 VA	TR	1.018,1	1.473,0	454,9
P.1/> 6.600 s/d 200 kVA	TR	1.337,4	1.473,0	135,6
P.2/> 200 kVA	TM	966,5	1.273,5	307,0
P.3	TR	926,6	1.473,0	546,4
T/> 200 kVA	TM	737,5	1.273,5	536,0
C/> 200 kVA	TM	1.169,7	1.273,5	604,8
L	TM	1.169,7	1.273,5	103,8

The subsidies are calculated from negative difference between the selling prices of electricity on average (IDR/kWh) of each tariff group minus the basic cost of electricity production (IDR/kWh) on the voltage at each tariff group multiplied by sales volume (kWh) for each tariff group. Common residential house in Indonesia using utility grid with 220 V single phase 2 wire. For power supply source, which provide from national electrical grid may be vary based on the price per kWh between 1300VA, 2200VA, 3500VA -5500VA, and more than 6600VA. In this model, the house use 6600VA from utility grid and 1100VA from the photovoltaic panel, hence the total available power is 7700W (35A).

Simple PV payback period of the investment is given by the equation:

$$T_s = \frac{IN}{CF} \qquad (2)$$

Where:
IN is the capital expenditure of the project
CF is the annual benefits of the project

Table 3. PV Payback Period

Panel Type	Installed Panel Cost	Applied Electric Cost	Max Payback Period
Single Crystalline – 13.8%	€5/watt	€0.09/kWh	20 years/ surface

*1€= 15000 IDR

Photovoltaic panel economic calculations start with the initial cost of the PV panel for 1100 W is €5 x 1100 = €5500 with annual return is €275. The payback period is within 20 years; hence the installation of PV panels is still not profitable in this project in the current years. The other consideration is low tariff of utility grid because the subsidy from national government.

3. Conclusion

In the future, the PV price in the world market will decrease in conjunction with government's policy to withdraw the subsidy gradually. Overall result of the paper should can be applied and contributed in Indonesia near future for new residential building as one of the reference or as the second opinion towards the national government's program about saving energy in building and harnessing the Indonesian renewable energy potential.

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