Integration of net zero energy building with smart grid to improve regional electrification ratio towards sustainable development

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Abstract. Indonesia is currently encouraging its physical, social and economy development. Physical development for economic development have to be supported by energy availability. For Indonesia, 90% of electrification ratio is still become an important task that has to be completed by the Government. However, the effort to increase electrification can become an environmental problem if it's done with BAU scenario. The by-product of electric generation is the GHG, which increasing every year since 2006 from various sectors i.e. industry, housing, commercial, transportation, and energy. Net Zero Energy Building (NZEB) is an energy efficient building which can produce energy independently from clean and renewable sources. The energy that is generated by NZEB can be used for the building its elf, and can be exported to the central grid. The integration of NZEB and Smart Grid can solve today's issue on electrification ratio. Literature study will find benchmarks which can be applied in Indonesia along with possible obstacles in applying this technology.

1. Introduction

Indonesia is currently encouraging its physical, social and economy development. Physical development for economic development have to be supported by energy availability. For Indonesia, 90% of electrification ratio is still become an important task that has to be completed by the Government. Hendri Saparini member of the National Committee of Economy and Industry shown that Indonesia is having a deficit on 1,000 MW of power each year [1]. Until today, development is still concentrated on Java Island, thus the electrical power. Most of the electrical power still concentrated on Java Island, leaving electrification ratio outside Java at 82% [2].
Electrification ratio associated with electric consumption is one of indicators of economic activities [3]. The government effort to boost national economic growth by developing outisde Java, including improving national electrification ratio have to based on sustainable development that addressing environmental impact. National development, which require continuous energy supply surely will bring negative effects on the environment. Energy Assessment of Universitas Indonesia found that the

by-product of economic development some of them are rise of the carbon gas emission, which may come from various, sectors e.g. industry, housing, commercial, transportation, and electricity [4].
According to the latest electric power statistics (2016), the number of installed fossil-fuelled power plant capacity 28,122 MW, while the clean power plant e.g. solar powered, wind generator, geothermal, hydropower, only installed at 6.140,27 MW [3].
Energy performance of a building becomes the key element to reduce carbon emission and energy efficiency. Improving energy performance of a building become a solution to minimize the climate change effect, and improving energy availability while developing the economic infrastructure. Energy conservation in building sector have become an intriguing topic since related to environmental preservation.
Net Zero Energy Building (NZEB) is an energy efficient building and can meet its energy needs from cheap, clean, easily available, and renewable sources, e.g. solar power, wind or geothermal. When NZEB having surplus of energy, excess electrical energy can be exported to central power grid with smart grid integration [6]. The distribution of surplus electrical energy will be more optimal by using smart grid. Smart grid is a central power grid system that can detect overload from a sub-system (e.g. building) and redirects it to other sub-systems that are power shortening automatically to prevent blackout and maintain network system stability. This system can meet the increasing demand of consumers without adding infrastructure [7].
Most of the NZEB use photovoltaic panels (PV) on their roofs or façade. Even some NZEB also install wind turbine to harness electricity. Indonesia is a tropical country, which throughout the year exposed to sunlight, so it is potentially for the development of solar-powered NZEB [8].

2. Methodology
This paper written as a set of review conducted from the literature of national, international journals, seminars and scientific meetings, in particular on NZEB and smart grid research, then descriptively described. As a first step in the research activities, the literature study conducted from various scientific publications, focused on the integration aspect between NZEB and smart grid in relation to the sustainability of regional and national electrification of building systems from various case studies in other countries. Then to extract the driving and inhibiting factors its development in Indonesia. The paper will explain several benchmarks on the NZEB and smart Grid integration, and emphasizing on their supporting policy and incentive scheme, thus finding applicable policy and incentive scheme for Indonesia. The benchmarks, which will be explained in this paper, varied from single story residential building to more massive buildings e.g. campus building. All of these buildings are integrated with smart grid system and have renewable energy technology installed within their system.

3. Literature review
3.1. Net Zero Energy Building
Basically the concept of Net Zero Energy Building (NZEB) is a building that can meet its energy needs from cheap, clean, easily available, and renewable sources. A more assertive definition states NZEB produce on-site renewable energy, which is enough to the same even, exceeds its annual energy consumption. NZEB can be define in different ways, usually depends on the purpose of the project. For example, usually building owners more concerned with energy costs that must be spent. There are four different types of definitions commonly used, namely: net zero site energy, net zero source energy, net zero energy cost, and net zero energy emissions. [6]

- Net Zero Site Energy: Net Site ZEB generate at least as much energy required energy needs of the building in a year.
- Net Zero Source Energy: Net Source ZEB generate at least as much energy required energy needs of the building in a year, when it is calculated from the power plant.
- Net Zero Energy Cost: costs paid by the owner of the building for energy at least equal to the money paid providers of energy services to building owners for energy exports to the network.

- Net Zero Emissions: ZEB, which at least barely produce emissions due to use of emission-free power generation technology.

NZEB usually uses a power source from a central grid if the on-site energy generation has not yet fulfilled the energy requirements of the building. When on-site generation is greater than the building requirement, the resulting excess electricity can be exported to the central power grid with a smart grid system. It will be difficult to achieve Zero Energy Without being able to export excess generation to the central grid. NZEB, which are not connected with the smart grid, cannot export their excess energy production, so, in certain seasons (like summer), excess electrical energy cannot be used [4].

3.2. Smart Grid
Smart grid is an electrical grid network that includes a variety of energy performance measuring instruments such as smart meters, and new renewable energy sources. Conditioning and controlling the production and distribution of electricity is an important aspect of the smart grid [10].
Some of the advantages of this smart grid:

- **Sustainability.** Smart grid flexibility makes variety of New Renewable Energy sources that can enter grids such as solar power, or wind power, without the need to install an electric storage battery. The smart grid can optimize the electrical distribution of sources allow anticipate fluctuations of electrical currents that can occur in PV panels, or wind turbines.
- **Reliability.** Smart grid uses technology that can detect grid damage and automatically repair without interfering technicians. This will maintain the stability of the electricity supply and reduce the vulnerability of damage caused by natural factors.
- **Flexibility of network typology.** The smart grid is designed to serve a 2-way electricity distribution, allowing the distribution of current coming from a Roof Building PV panel, which also uses fuel cells, charges power from, or to the battery of an electric car, wind turbine, or PV panel. The conventional electric grid is designed to serve only one-way distribution, so when there is NZEB that generates more electricity than its capability; it may disrupt the stability and safety of the grid [11]. The smart grid is designed to handle the situation [12].
- **Efficiency.** The smart grid efficient on the energy infrastructure especially for demand-side management, such turning off electrical equipment when a momentary raise in electricity prices, or reducing voltage in the distribution line with Voltage/VAR Optimization (VVO). Overall reduces excess load in transmission and distribution lines that can reduce prices (U.S. Department of Energy, 2012).

3.3. NZEB – Smart Grid Integration
Energy consumption in buildings is about 40% of world energy consumption. Therefore, it is expected that in the future buildings in the world can be Zero or Near Zero Energy Building (NZEB). To achieve a zero energy building, smart grid implementation based on technology becomes the main key [9].

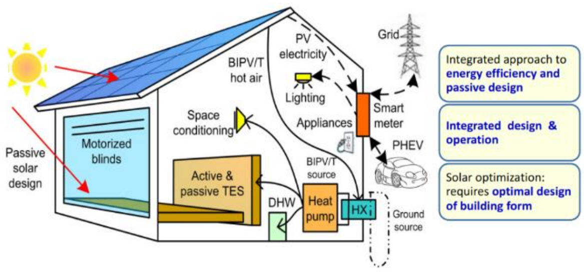

Figure 1. NZEB Integration – Smart Grid [13]

The integration between NZEB and smart grid has been done in some developed countries in the world. One of them is at Leaf House in Italy. This residential building is Nearly Zero Energy Building, which has been integrated with smart grid technology with normal energy consumption of 64kWh/m^2. The operational characteristics of this building include smart monitoring and controls, solar thermal collectors, electrical storage and user-friendly energy management for residents. A more illustrative description can be seen in Figure 1.

Important components in integrating ZEB and NZEB with smart grid is metering device, a smart metering. It is therefore important to measure energy production and consumption and then transmit this information to a database accessible to users and processed by the control system. Regardless of the brand and with different protocols of the system works between one smart grids with another smart grid, it is necessary to test the possibility occurrence of interoperability problems in a simulated building scenario with multiple connected smart meters [9].

This metering system is also important in a commercial point of view when developing a business plan to convert traditional and old buildings into zero-energy buildings, or at near zero, then includes calculations that this new building has renewable energy production to be done precisely by smart meters. The analysis carried out from changing the function of buildings to functional ZEB buildings, in this case for example the function of educational facilities, is now possible to have new values, i.e. commercial and industrial points, by starting from energy consumption and building structures, and then calculating the economic and financially feasibility parameters, then the new paradigm change is made.

Accordingly, ZEB integration with smart grid should be efficient and reliable, satisfying user needs and ensuring comfort. In this view, it demands a focus on services and controls that aim to meet the needs of users in the most economical way.

4. Implementation of NZEB – Smart Grid integration in the world

The following section will show several benchmarks on the NZEB and smart Grid integration, and emphasizing on their supporting policy and incentive scheme. Energy efficient building of NZEB which is used as the desk study object is in dormitory buildings, housing, offices and university buildings. Some examples of successful integration of NZEB and Smart grid cases are described as follows [14]:

4.1. Leaf House

Leaf House is a residential building that has photovoltaic (PV) panels to meet the electrical needs of its inhabitants and the needs of heater and hot water facilities. This Near Zero Energy House (nZEH) was built in Italy in 2007. Total annual electricity consumption of Leaf House annual energy is estimated at 40,000 kWh. The integration of Leaf House with smart grid is supported by smart house system (Smart house) installed in it. With this smart metering meter, the house can record the amount of annual electricity usage and the amount of electricity generated by the PV panel and how much is produced to the central grid network.The view of the Leaf House can be seen in Figure 2.

Regulations on the use of new and renewable energy sources and smart grids in Italy already include financial support in the form of a combination of premium tariffs, feed-in-tariffs, and tender schemes. Smart gird operators are required to give priority access to power plants sourced from new and renewable energy. In addition, Italians apply tax regulations that promote the development of new and renewable energy sources.

Figure 2. *Leaf House,* Angeli in Rosora, Italia [15]

4.2. Leaf Lab Building

As the Leaf House described earlier, adjacent to it there is Leaf Lab Building that are integrated in the area called Leaf Community (as shown in Figure 3). Both Leaf House and Leaf Lab, all integrated with a smart grid system.

The Leaf Lab office building is estimated to consume electricity at 606,000 kWh per year. This office building gets electricity, heater and hot water consumption from PV panels.

As with Leaf House, Leaf Lab in Italy has been supported by various regulations and incentive schemes from the Italian government.

Figure 3. *Leaf Lab,* Angeli in Rosora, Italia [16]

4.3. Technical University of Crete campus building

The NZEB is located at K1 Building of the Environmental Engineering School by having main characteristic of Energy management based on advanced HVAC genetic algorithms optimization with load prediction based on neural network models and fuzzy logic techniques/ IP remote access integrated energy management system. Energy consumption of the building is around 276,000 KWh/year (shown in Figure 4).

Figure 4. *Campus TUC* [17]

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4.4. National University of Singapore

School of Design and Enviroment-3 building at National University of Singapore (as shown in Figure 5) has main characteristic of installation of monitoring systems that utilized as user management with smart metering system renewable energy source, and internal comfort analysed in Smart Gems.

The new building, which will house teaching and research facilities, will serve as a living laboratory to promote research collaboration in sustainable building design. It is conceptualised by the NUS School of Design and Environment, designed to be climate-responsive with net-zero energy consumption consider of six-storey building feature a range of green building designs, such as harnessing solar energy, hybrid cooling approach, natural ventilation and lighting. It is a new addition to the existing three buildings with a gross floor area of 8,514 m^2; it will house a mix of research laboratories, test-bedding facade, design studios, as well as teaching and common learning spaces.

The design concept incorporates a large overhanging roof, which together with the double facades on the East and West of the building, shade it from the sun's heat and provide a cooler interior. Additionally, there is an architectural concept where its shallow plan depth and porous layout allows for cross-breezes, natural lighting and views to the outdoors. Rooms can also be opened to natural breezes, and air conditioning is used only where it is needed, reducing the electricity usage of the building resulting biophillic experience to campus' natural surroundings.

NZEB concept made possible for harvesting solar energy using more than 1,200 solar photovoltaic panels installed on the roof. On days when there is insufficient solar energy, the building will draw energy from the power grid. Consequently, the net amount taken from the grid will be zero.

Typically, air condition accounts for up to 60 per cent of a building's total energy load in a tropical country like Singapore. This resulted in the design of an innovative hybrid cooling system, which ensures that rooms would not be overly cooled. Rooms will be supplied with cool air at higher temperatures and humidity levels than a conventional system augmented with elevated air speeds from ceiling fans to create a highly comfortable environment that is also significantly more energy efficient.

Figure 5. School of Design and Environment-3 building at National University of Singapore [18]

Feed-in Tariffs (FiTs) is a popular form of incentive utilized to promote renewable power installations in Singapore that concern with development of renewable technologies. Consequently, NZEB concept as to perform a building equipped with net-metering well as having introduced the technology for rooftop solar installations.

FiT works by offering eligible energy companies contracts declaring that they will receive a fixed return on the renewable energy they provide proportional to how much it costs to produce, which encourages investment in the industry. In most countries, the introduction of dedicated agencies to coordinate installations and the roll out of FiTs has led to a significant and prompt growth in the corresponding technologies.

Nowadays renewable energy currently accounts for less than 10% of the electricity generated in Singapore. As of 2011, there are 120 commercial solar photovoltaic installations connected to the energy grid in Singapore a total peak capacity of 5.6 MW due its potential location on solar generating power. It identified as a key area of development and its government aims that the industry is able to contribute S$3.4 billion to its GDP in the coming years [19].

5. Discussion

Oversee the progress that is happening in some countries on policies that support the implementation of NZEB, made us also have to observe the pros cons in Indonesia. The latest feed-in-tariffs scheme in Indonesia are regulated in the Ministerial Regulation of Energy and Mineral Resources (ESDM) No.12/2017, previously set in Ministerial Regulation No. 19/2016. However, there is a difference consider the schemes bought by Government (State Own Enterprise considering Electricity-PT PLN) from both regulations. In the previous mentioned that the electricity purchase price is set based on the 5,000 MW quota capacity per area to be offered gradually, and the price of each stage can be different [20]. Meanwhile, according to Minister of Energy and Mineral Resources No.12/2017, the purchase of electric power is carried out by auction system based on quota capacity of PLN's power supply business plan with a minimum of 15 MW as total package and the location of power plant can be spread in several locations [21].

If the cost of electricity local production is above the average Cost of Production National power plant, then the purchase of electricity 85% of the Cost of Production generation in the local electricity system. If the Cost of Local Production is equal to or below the average Cost of Production of a national power plant, then the purchase price of electricity is equal to the Cost of Production Generation in the local electricity system.

Based on existing regulations, it can be seen that purchasing price of renewable energy has decreased. This can be seen from the determination of regional capacity quota, which is regulated in ESDM Regulation no. 19/2016 of 5,000 MW (megawatt), while in the ESDM Regulation no. 12 /2017 is offered a minimum of 15 MW (megawatts).

Some of the factors causing underdevelopment of energy efficient buildings such as NZEB in Indonesia include: (1) high initial cost for the application of NZEB design components, not financially attractive to developers [22], (2) no solar power generators system on smart grid supported policies for incentive, tax and licensing support [23].

6. Conclusion

Poor supporting NZEB Feed-in-tariffs scheme in Indonesia starting from the level of legislation has brought new dilemma to the development of concept whereas the NZEB is unpopular for some reason:

- High initial cost for the application of NZEB design components, not financially attractive to developers,
- No system PLTS on smart grid supported policies for incentive, tax and licensing support. Thence urgently supporting policies that have been implemented in other countries such adopted a number of provisions, which mainly address energy efficiency in buildings.

Apart from that, there have been a number of national programs whose primary aim is to promote energy efficiency through the use of renewable energy sources in public or private buildings. The operator is obliged to connect renewable energy plants to the grid and purchase electricity from renewable sources. Whereby the connection contract, signed between the grid operator, the plant operator and State Own Company dealing with Power, PLN as the owner of the grid, must state that the grid operator is obliged to carry out the necessary grid development works.

Other than that, to comprehend the NZEB as a whole concept to be implemented, and based on the literature review and benchmarks from other countries regarding NZEB implementation, an operating support should be based on a differential compensation price. Whereas tenders become necessary, price shall not be the only criteria, is also expected to be technology specific, by means of pro to the NZEB concept. In addition, plant operators are contractually entitled against the grid operator/ electricity market operator to the payment of electricity exported to the grid.

In addition, the scheme supports electricity generation by renewable energy source e.g. PV installations to a specific amount power generation shall have a guaranteed feed-in tariff. Thus show appreciation, that the national energy supplier measures the electricity exported to the grid and sends electricity bills to the plant operators as its produce power. If the feed-in tariff for the electricity produced exceeds plant operator's electricity charges, the national supplier shall pay the difference. If

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the tariff exceeds the installation operator's electricity bill, he will receive the exceeding amount. The scheme applies to private individuals, small enterprises and public entities.
Feed-in premium exemptions has to be arranged to combined power plants of renewable energy sources and other that connected to the transmission system participate in the electricity market and are awarded a sliding feed-in premium called "Operating support based on a differential compensation price". The exemptions only apply to smaller installations, i.e. small wind energy plants and other small renewable energy installations, which are eligible for a feed-in tariff.
Lastly, introduction of net metering shall include in the regulation, which introduces net metering for all renewable energy sources for autonomous producers, while virtual net metering is applicable to PV and small wind power plants only in certain cases.

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