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Potency of Solar Energy Applications in Indonesia

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ABSTRACT: Currently, 80% of conventional energy is used to fulfill general public's needs and industries. The depletion of oil and gas reserves and rapid growth in conventional energy consumption have continuously forced us to discover renewable energy sources, like solar, wind, biomass, and hydropower, to support economic development in the future. Solar energy travels at a speed of 186,000 miles per second. Only a small part of the radiant energy that the sun emits into space ever reaches the Earth, but that is more than enough to supply all our energy demand. Indonesia is a tropical country and located in the equator line, so it has an abundant potential of solar energy. Most of Indonesian area get enough intensity of solar radiation with the average daily radiation around 4 kWh/m^2. Basically, the solar systems use solar collectors and concentrators for collecting, storing, and using solar radiation to be applied for the benefit of domestics, commercials, and industrials. Common applications for solar thermal energy used in industry are the SWHs, solar dryers, space heating, cooling systems and water desalination.

Keywords: fossil fuel, Indonesia, solar energy

1. Introduction

Last decades, energy becomes an important concern in all countries. Human lifestyle in the modern days have a very close relationship with energy's quantity and quality. Currently, 80% of conventional energy is used to meet general public's needs and industries **[1]**. The global energy consumption will increase 1,5% per year until 2030 **[1,2]**. The depletion of oil and gas reserves and rapid growth in conventional energy consumption have continuously forced us to discover renewable energy sources, like solar, wind, biomass, and hydropower, to support economic development in the future **[2,3]**.

2. Country Background

Indonesia is an archipelago country consisting 17.000 islands covered area about 9.822.570 km^2 stretching along the equator and 3.000.000 km^2 of sea area **[1,4,5,6]**. Indonesia has a tropical climate and commonly, the dry season occurs from june to September, while the rainy season occurs from December to March. The map of Indonesia is presented in Fig.1.

Fig. 1 The map of Indonesia

After 1998, when economic recession happened, Indonesia energy consumption increased with annual growth rate 7% and not balanced with adequate fossil fuel reserves **[1]**. While the fossil fuel reserves are limited, the dependency is still high. The transportation and industrial fields is the highest energy consumers in Indonesia **[7]**. Figure 2 shows final energy consumptin by sector in Indonesia.

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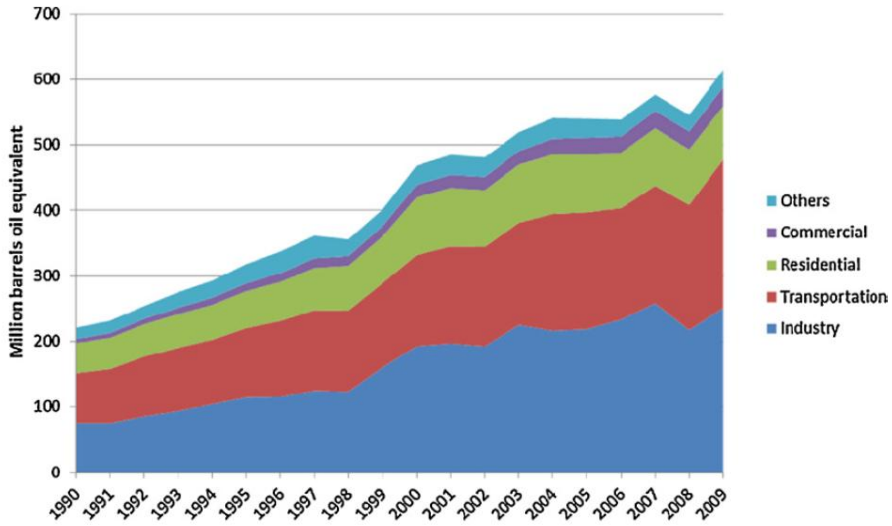

Fig. 2 Final energy consumption in Indonesia **[1]**

3. Solar Energy Potential in Indonesia

Presidential Decree No. 5 mandates an increase in renewable energy production from 7 percent to 15 percent of generating capacity by 2025 **[6]**. In order to accomplish that goal, 6.7 GW of new renewable energy capacity must be installed in the next 15 years based on current growth projections (see Fig. 3) **[6]**. The Directorate General of Electricity and Energy Utilization, has also promoted green energy which is the union of renewable energy, including solar energy, energy efficiency and clean energy to create sustainable development, in July 2012 **[5]**.

Indonesia is a tropical country and located in the equator line, so it has abundant potential of solar energy. Most of Indonesian area get enough intensity of solar radiation with the average daily radiation about around 4 kWh/m^2 **[1,5,8,9]**.

The solar radiation distribution can divided into Western and Eastern area **[5]**. This classification based on solar radiation data collected from 18 location in Indonesia. Distribution of solar radiation is estimated around 4.5 kWh/m^2/day with a monthly variation of about 10% for the West Region and 5.1 kWh/m^2/day with a variation of about 9% for the Eastern Region **[1,5,10]**.

Indonesia has so many small and isolated islands which desperately need of electricity. In addition, the distribution of electricity to the area require adequate transportation and high cost. Photovoltaic solar energy is one of solutions to meet the electricity needs including lighting for the units of public services and the means of worship **[1,2]**.

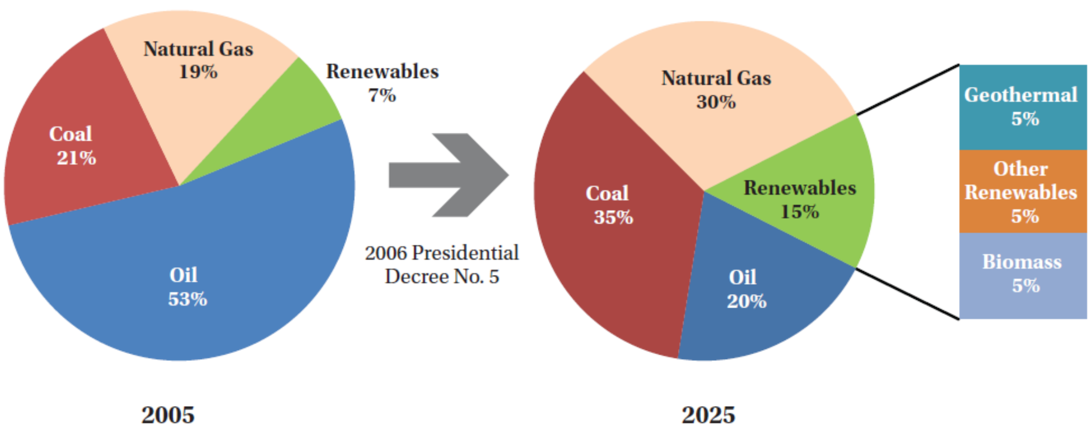

Fig. 3 Current Energy Mix versus Future Energy Goals **[6]**

4. Solar Energy

The sun's energy just over eight minutes to travel the 93 million miles to Earth. Solar energy travels at a speed of 186,000 miles per second **[10]**. Only a small part of the radiant energy that the sun emits into space ever reaches the Earth, but that is more than enough to supply all our energy needs. Every day enough solar energy reaches the Earth to supply our nation's energy needs for a year.

Solar is one of the most promising sources of renewable energy and it has the greatest potential in comparison with other energy sources to solve the world's energy problems **[1,2]**. Nowadays, solar energy has become more popular as an energy supply in the world and is considered as the most economical alternative **[1-10]**. Solar energy is designed to convert all or any portion of available light into electrical energy **[5]**. This conversion process does not use a chemical reaction **[2,5,11]**.

5. State of The Art

In 1839, the development of the solar cell derived from the work of the French physicist Antoine-César Becquerel. In 1927, another metal semiconductor-junction solar cell which was made of copper and the semiconductor copper oxide, had been demonstrated. By the 1930s both the selenium cell and the copper oxide cell were being used in light-sensitive devices, such as photometers, for use in photography. Early in its development, the efficiency of solar energy only achieved less than 1% **[5]**. In 1989 a concentrator solar cell, a type of device in which sunlight is concentrated onto the cell surface by means of lenses, achieved an efficiency of 37 percent due to the increased intensity of the collected energy. In general, solar cells of widely varying efficiencies and cost are now available **[8]**. Table 2 shows the solar energy research in recent years.

6. Principal of Solar Energy

Basically, the solar systems use solar collectors and concentrators for collecting, storing, and using solar radiation to be applied for the benefit of domestics, commercials, and industrials **[2]**. Figure 4 shows a block diagram of a typical industrial energy system and Figure 5 presents a schematic diagram of solar irradiation conversion to mechanical energy **[2, 12, 13]**.

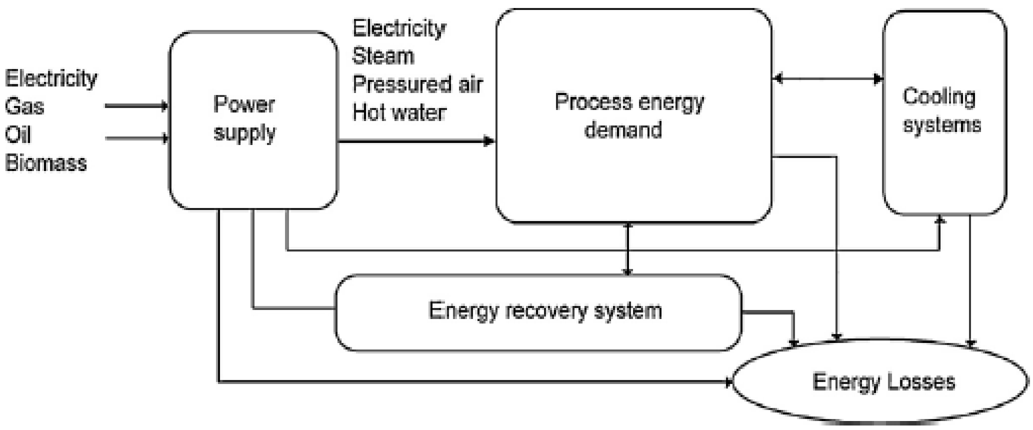

Fig. 4 Block diagram of a typical industrial energy system **[12]**

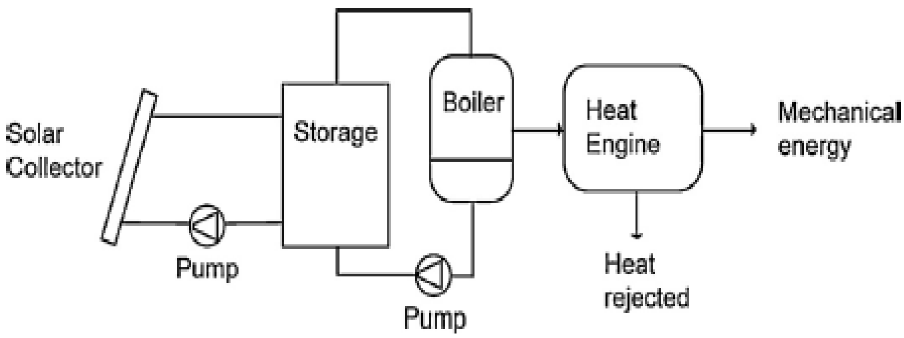

Fig. 5 Schematic of a solar-thermal conversion system **[13]**

The location, types of collector, and working fluida are important factors to determine required storage volume. The information of storage volume and the size of system are needed to determine the heat exchanger size. However, the load is the main factor that need to be considered for determine the type of applications **[14]**. Types of solar collectors is showed in Tabel 1.

However, it has to be noted for some applications that solar energy is not available continuously for 24 h. In such cases, addition supplementary measures should be provided to accumulate solar irradiation during sunny days, store it in an embedded phase transition and release it in a controlled manner in severe conditions.

In fact, there is a crucial factor to be noted that solar is not continuosly available in 24 hours. In some applications, it is advisable to use additional equipment to accumulate the solar irradiation during the day, then store in a transitional phase and releasing it in a controlled manner under certain conditions **[2]**. Table 1 illustrates the three main categories and types of solar collectors currently used. A concentration ration, defined as the aperture area divided by the receiver/absorber area of the collector of each type is presented as well.

Each collector is dedicated for a specific application. From Tabel 1, we can see that flat-plate collectors (FPC) are properly designed to be used in low temperature applications, the concentrating and sun-tracking parabolic trough collectors (PTC) are suitable for high temperature applications in which the system can obtain temperature higher than 250 °C with high efficiency, two axes tracking collectors are applied in power generation, stationary (non-tracking) and one axis PTCs are mainly used in industrial heat processes **[2]**. Among the collectors, movable collectors require higher maintenance cost compared to other collectors. Initial investment and the type of solar collector which is used will specify the cost of solar energy production ranges from 0.015 to 0.028 C£/kWh **[14]**. Generally, large-scale solar systems are more economical than the small-scale systems, because it requires less of initial investment.

Tabel 1
Types of solar energy collector **[14]**

Motion	Collector Type	Absorber Type	Concentration Ratio	Indicative Temperature Range (°C)
Stationary	Flat plate collector (FPC)	Flat	1	30 – 80
	Evacuated tube collector (ETC)	Flat	1	50 – 200
	Compound parabolic collector (CPC)	Tubular	1 – 5	60 – 240
Single-axis tracking			5 – 15	60 – 300
	Fresnel lens collector (FLC)	Tubular	10 – 40	60 – 250
	Parabolic trough collector (PTC)	Tubular	15 – 45	60 – 300
	Cylindrical trough collector (CTC)	Tubular	10 – 50	60 – 300
Two-axix tracking	Parablic dish reflector (PDR)	Point	100 – 1000	100 – 500
	Heliostat field collector (HFC)	Point	100 – 1500	150 – 2000

Tabel 2
Research development on solar energy

Year	Reserach Topics	Refference
2012	described application of SSTES to individual residential homes. Specifically, TRNSYS is used to simulate, evaluate, and optimize storage of the sun's thermal energy during the warm season so it can be harvested later during the cold season.	**[15]**
2011	Investigated solar tracking to maximize the capture of both direct beam and diffuse solar radiation, i.e., on both sunny and cloudy days	**[16]**
2010	Focused on the BIPV/T system and the integrated energy concept of the house.	**[17]**
2008	Models for the solar energy capture(SEC) and the oil – pebble bed TES are developed using energy balance equations	**[18]**
2007	Tested the physical properties and thermal behavior of solar filters based on iron oxides. These filters consisted of a thin film of FeO and Fe_2O_3	**[19]**
2006	Investigated he performance degradation of GaAs/Ge space solar cells is. The low-energy protons with a fluence of 1.2 $x10^{13}$ cm^{-2} were used with energies ranging from 0.1 to 3.0 MeV. Performed the current–voltage (I–V) characteristic measurements about the effect of low-energy proton irradiation on GaAs/Ge solar cells with coverglass and with no. Evaluated and analyzed the effects of lowenergy proton irradiation and the coverglass protection.	**[20]**
2005	Presented some results of theoretical analysis on the selection of optimum band gap semiconductor absorbers for application in either single or multijunction (up to five junctions) solar cells.	**[21]**
2004	This paper presented the results of a net energy analysis of solar hot water systems, comparing them with conventional hot water systems in Melbourne, Australia.	**[22]**

7. Application of Solar Energy

Most common applications for solar thermal energy used in industry are the SWHs, solar dryers, space heating, cooling systems and water desalination. Tabel 3 shows solar energy apllications, and technologies. Solar system is widely used for heat engines in many industrial applications. Using solar energy to generate thermal energy for industrial processes not only reduces dependency on fossil fuel resources but also minimizes greenhouse emissions such as CO_2, SO_2, NO_x **[2]**.

Tabel 3
Solar energy application **[13]**

Solar energy aplication	Solar system technologi	Type of system
SWH	Integrated collector storage	Passive
	Air systems	Active
Space heating	Water systems	Active
and cooling	Heat pump systems	Active
Solar	Adsorption units	Active
refrigeration	Absorption units	Active
Industrial heat	Industrial air & water system	Active
demand process	Steam generation systems	Active
Solar	Vapor compression (VC)	Active
desalination	Multistage flash (MSF)	Active
Solar thermal	Solar furnace	Active
prower system	Parabolic tower systems	Active

7.1 Solar water heating (SWH)

SWHs usually consists of solar collectors and storage space. It works on the basis of inequality density of hot and cold water or thermo siphon. Due to the simple and compact structure, integrated collector / storage SWHs more common in cold countries **[2]**. Batch solar collectors are more suitable for use in the afternoon and evening.

SWH technologies are mostly used in cleaning process in the food industry. Water that has been used is not allowed to circulate longer in the system because because of the possibility of contamination. Figure 4 is the block diagram of SWH systems which is commonly used in industrial applications.

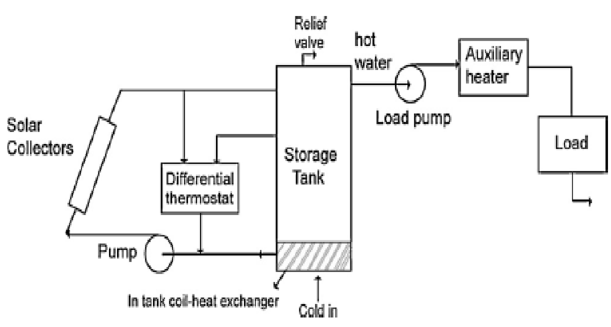

Fig. 6 Block diagram of SWH system **[23]**

Fig. 7 SWH system installed on a rooftop [26]

7.2 Solar drying and dehydration systems

Currently, electricity is always used to heat the air and as an additional energy source. Conventional drying systems using fossil fuels as a source of combustion, while solar dryer use solar irradiation for drying in industries, such as brick, crops, fruits, coffee, wood, textiles, leather, green malt and sewage sludge **[24]**.

There are two main groups of dryer, high and low temperature dryers. Almost all high-temperature dryers using fossil fuels or electricity for the heating process. While the low-temperature dryers can use fossil fuels or solar energy. Low temperatures generated by solar energy is ideal for use in the preheating process **[25]**.

Based on the difference methods of air flow, solar dryer is divided into two main groups, the natural circulation (passive) and the convection flow (active) dryers [2]. Generally, passive solar dryer using solar energy is abundantly available in the environment, while active solar drying system using solar energy in combination with electricity or fossil fuel to generate electricity to provide air circulation.

7.3 Solar thermal in food industry

The food industry has beneficial conditions for the use of solar heat from the treatment and storage of food products are very durable. Food preservation industries also use solar heat in scalding, sterilization (vegetables, meat and fish), cleaning, pre-cooking, can sealing, cooling and refrigeration **[2]**. Dairy industries can also fully use solar energy for their various process operations. They usually operate for the whole week with no day off. Thus solar systems can be considered very cost effective in this type of industry. Dairy industries mainly use thermal energy for pasteurization (60–85°C), sterilization (130–150°C) processes and even for drying milk to produce powder **[2]**.

8. Future Challenge

Indonesia's goverment have target of electricity production from solar energy are 120, 180 and 400 MW in year 2016, 2021, and 202 respectively. The government also projected to reduce the PV cell cost from $5/W in 2025. Some of related solar technologies already developed in Indonesia such as solar cooker, solar dryer, and etc have also been produced locally. But, still abundant of Resource of solar energy need to be utiliza using mature and developed technologies. Research in this field is very challenging specially in the small scale electricity generation for rural areas.

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