SOLAR ENERGY OPPORTUNITIES FOR INDONESIA AGRICULTURAL SYSTEMS

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Abstract
Indonesia has huge agricultural products, which have to process into other products. Energy efficiency and energy conservation have to ameliorate so that amount of energy demand and cost can be reduced in food processing. Global irradiation data was measured by Eppley Pyranometer with coordinates 100.32^{o} E, 0.20^{o} S at 864.5meters of the sea-level surface while Indonesia agricultural products data were provided by Indonesian ministry of agriculture. The result shows that total mean global irradiation is between 2,111.9 – 2,427.53 W/m^{2}/year while to convert paddy into rice, the energy needed was between 30,054 – 32,586 TWh/year which is about 20 times more than total potential of grid-connected PV in Indonesia. This indicates Indonesia agricultural systems probably have the greatest solar energy potential because it is a tropical country and located in the equator line.

Key words: solar energy, renewable energy, agricultural systems, potential, Indonesia.

INTRODUCTION

Improving energy efficiency and energy conservation in Indonesia agriculture are essential to reduce energy demand and therefore reduce cost. Improving energy efficiency, and thus reducing reliance on fossil fuels, will further reduce greenhouse gas emissions. Application of renewable energy especially solar energy can be used for food production and storage (water pumping for crop production and for cattle, electric livestock fences, aeration pumps for fish and shrimp farms, egg incubators, refrigeration for storage, ice-making for storage), food processing (meat and fish drying, plant/seaweed drying, spice drying, cereal grain processing, coconut fiber processing, grain mills, lighting for processing plants), materials processing (rubber drying, sawmills, silk production, silkworm rearing, textile dyeing) and so forth (ROTA ET AL., 2012).

Indonesia is a tropical country and located in the equator line, the country has abundant potential of solar energy. Indonesia government's targets of electricity production from solar energy are 640 MW in 2020 (PLN, 2015) while the target of the government policy regarding national energy supply is to achieve the optimum energy mix in the year of 2025 (PRESIDENTIAL REGULATION NO 5/2006). The government has also been developing photovoltaic (PV) as shown in Fig. 1 and projected to reduce the PV cell cost from $5/W in 2025 (PLN, 2014). Therefore, this is an opportunity to use in agricultural areas.

Some of related solar technologies already developed in Indonesia such as solar cooker, solar dryer etc. have also been produced locally. But, still abundant of resource of solar energy needs to be utilized using mature and developed technologies. Research in this field is very challenging especially in the small scale electricity generation for rural areas. On the other hand, Solar energy systems have low maintenance costs, and the fuel is free once the higher initial cost of the system is recovered through subsidies and energy savings (from reduced or avoided energy costs). According to the first USDA On-Farm Energy Production Survey, solar panels have been the most prominent way to produce on-farm renewable energy (USDA, 2011). Agriculture hosted some of the first terrestrial photovoltaic (PV) applications of solar energy, as it found uses for solar in remote locations around ranches and farms. Early on, solar electric made economic sense for a number of low power agricultural needs when running utility lines to a specific location was either not possible or too expensive. Therefore, farmers will not lose the chance to get profit for their land. The objective of this study is to show and describe the potential of application solar energy in Indonesia agricultural systems so the new technologies can be developed in future.

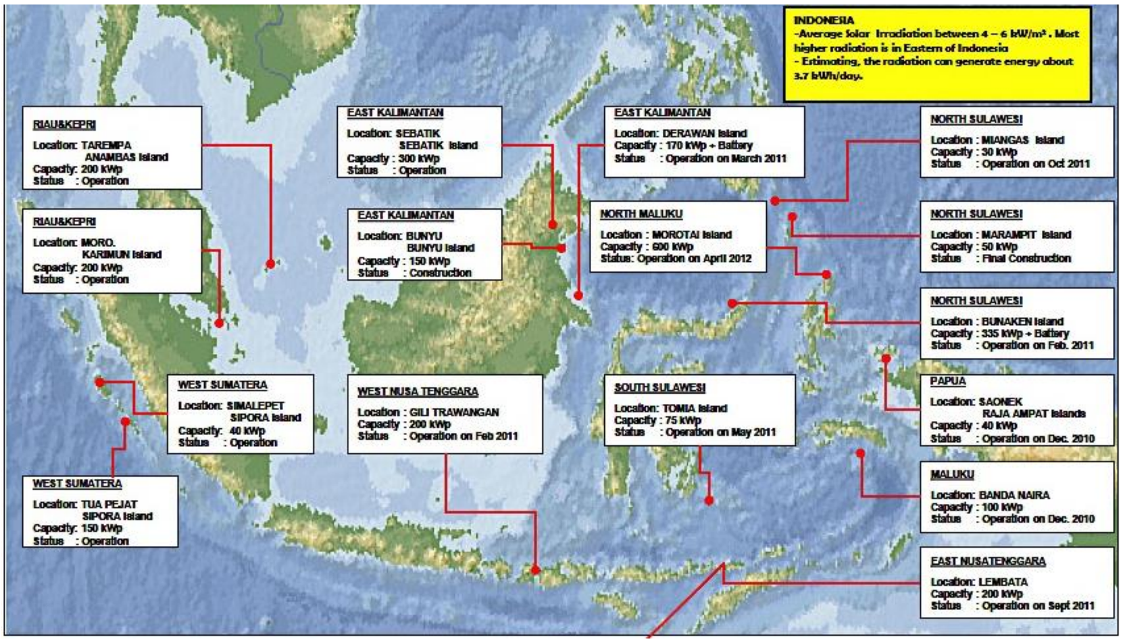

Fig. 1. – Solar PV developed by PLN (2012)

MATERIALS AND METHODS

Global irradiation data was measured by Eppley Pyranometer with coordinates 100.32° E, 0.20° S at 864.5 meters of the sea-level surface while Indonesia agricultural products data was provided by Indonesian ministry of agriculture, which was collected from www.aplikasi.pertanian.go.id. The mean global irradiation was calculated for every month based on daily measurement and the energy demand of agricultural products was calculated based on specific energy consumption.

RESULTS AND DISCUSSION

Based on the daily data collected for 4 years, the monthly mean global irradiation was calculated (Tab. 1), and average global irradiation is displayed (Fig. 2). Tab. 1 shows that the total mean global irradiation is between 2,111.9 – 2,427.53 W/m^2/year. This indicates Indonesia agricultural systems probably have the greatest solar energy potential because it is a tropical country and located in the equator line. Therefore, the country has an abundant potential of solar energy.

According to NASA's data, Indonesia areas get a quite intense of solar irradiation with the average daily irradiation approximately around 5.86 kWh/m^2. The daily average solar irradiation for each month over a period of 22 years between 1983 and 2005 is shown in Fig. 3. Therefore, Indonesia happens to be ideal sites for solar energy production and utilization because of its geographical locations. The solar energy production and utilization in agricultural areas can broadly be categorized into solar photovoltaic (PV) technologies, which convert the sun's energy into electrical energy, and solar thermal technologies. VELDHUIS AND REINDERS (2013) reported that total potential of grid-connected PV in Indonesia was 1100 GWp (Giga Watt Peak) and generating about 1492 TWh, based on current population size and land availability while total potential based on taking restrictions of the present electricity demand during day-time and a minimal base load of conventional power systems was about 27 GWp and generating about 37 TWh/year.

On the other hand, Indonesia agricultural products as shown Tab. 2, which have to be processed, needed huge amount of energy as shown in Tab. 3. The potency solar energy as described above can be applied.

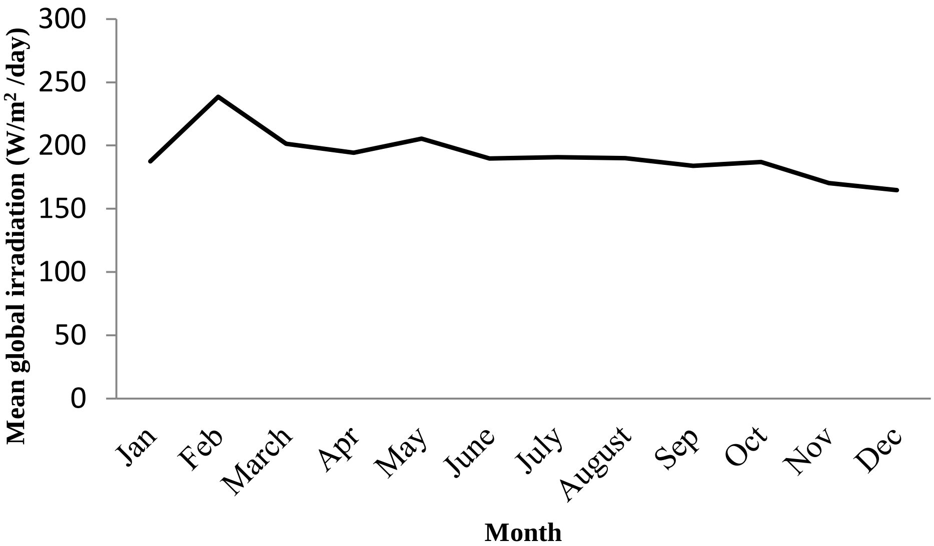

Fig. 2. – Monthly average global irradiation in Indonesia for 4 years

Tab. 1. – Monthly Mean global irradiation in Sumatera island during for 4 years

Month	Mean Global irradiation (W/m^2)			
	2009	2010	2011	2012
Jan	191.22	183.69	178.6	196.62
Feb	195.9	347.58	227.92	182.87
March	219.33	199.43	194.46	192.04
Apr	196.8	192.25	189.46	198.53
May	231.06	192.05	210.85	187.43
June	194.8	190.87	188.46	185.25
July	199.84	173.11	209.99	180.13
August	196.49	200.39	188.7	174.89
Sep	199.62	206.54	173.28	156.83
Oct	197.01	200.51	204.66	146.06
Nov	193.76	158.2	162.28	167.19
Dec	169.47	182.91	162.63	144.06
Sum	2385.3	2427.53	2291.29	2111.9

Tab. 3 shows that the energy needed to convert paddy into rice was between 30,054 – 32,586 TWh/year which is about 20 times more than total potential of grid-connected PV in Indonesia as predicted by VELDHUIS AND REINDERS (2013). According to AHIDUZZAMAN AND ISLAM (2009) the primary energy consumption for mechanical drying was found to be 1,540 MJ/ton of paddy dried to reduce moisture level from 32 % to 14 % under an hot air temperature range of 65 – 130°C. The specific energy consumption was 6.25 MJ/kg of water evaporated from the grain. The electrical energy consumption was found to be 29.26 kWh/ton of paddy processed by a 2 ton per hour capacity modern mill. The milling machinery needs higher electrical load for its several operation viz. pre-cleaning, shelling, separation, grading, polishing, etc. Therefore, it needs mix renewable energy such thermal energy and biomass energy for paddy process because rice is mainly of daily food for Indonesian people.

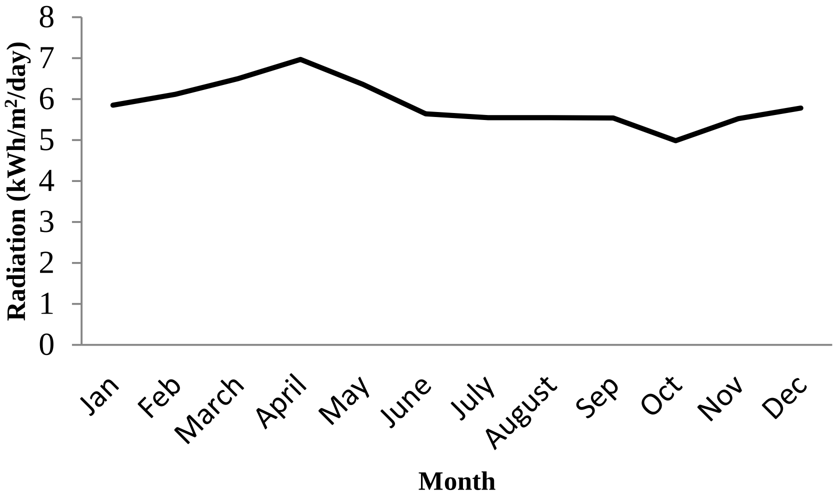

Fig. 3. – Monthly average radiation in Indonesia for 4 years

Energy demand to convert cassava into gari, starch, and flour was between 1.9 – 2.1 TWh. JEKAYINFA AND OLAJIDE (2007); WANG (2009) reported that energy consumption including electrical energy, thermal energy, and labor energy for production of gari, starch, and flour of cassava using efficient and high-capacity processing machines were 0.291, 0.305, and 0.316 MJ/kg, respectively.

Tab. 2. – Indonesian agricultural products at national level

Agricultural products	Production (Ton)			
	2010	2011	2012	2013
Paddy	66 469 394	65 756 904	69 056 126	71 297 709
Corn	18 327 636	17 643 250	19 387 022	18 511 853
Soybean	907 031	851 286	843 153	779 992
Cassava	23 918 118	24 044 025	24 177 372	23 936 921
Palm oil	4 391 624	4 619 308	5 203 104	5 556 401
Coffee	686 921	638 647	691 163	675 915
Tea	156 604	150 776	145 575	145 460
Cacao	837 918	712 231	740 513	720 862

On the other hand, the total energy consumption for drying raw soybean was 1.19 MJ/kg and the electricity generated is used to supply almost all of electricity requirements for palm oil mill, which is estimated to be about 14.36 kWh/ton of FFB (SAMPATTAGUL ET AL., 2011) while to reduce the moisture level from 27 to 13 % in 1 kg corn, an input of 205 kcal fossil energy must be expended (PIMENTEL, 2008). Based on these, energy demand was calculated to produce CPO and to remove moisture level of corn as shown in Tab. 3.

For tea production, A I T (2002) reported that Orthodax tea production, the withering and rolling processes consume more energy (7 kWh/kg) while for cut, tear and curl (CTC) process consume much electrical energy (0.4-0.7 kWh/kg made tea). In this process can use thermal energy for withering and drying process. The ratio consumes both thermal and electrical energy at the ration of 18:15. Drying and freezing processes consume energy 6 MJ to remove 1 kg of water product and 0.3 kWh electricity (1 MJ) to process 1 kg of food products at -20°C, depending on temperature and pressure. In addition, BUNDSCHUH AND CHEN (2014) reported sprinkler irrigation consumed around 10-20 GJ/ha/year of electricity or diesel fuel for pumping water. Pumping water, drying and freezing processes are universal needs for Indonesia agriculture and the use of PV power is a natural choice. Agricultural watering needs are usually the greatest during sunnier dry periods when more water can be pumped with a solar energy system. PV water-pumping systems are simple, reliable, and low maintenance. Larger PV water pumping systems with all balance-of-system components, including the pump, can be installed for under $10 per Watt.

Tab. 3. – Energy demand of Indonesian agriculture to convert products into other products at national level

Agricultural products	Energy Demand (TWh)				Product
	2010	2011	2012	2013	
Paddy	30.379	30.054	31.561	32.586	rice
Corn	4.367	4.204	4.619	4.411	drying
Soybean	3.754	3.523	3.490	3.228	soybean production per ha
	0.300	0.281	0.279	0.258	drying
Cassava	1.933	1.944	1.954	1.935	gari
	2.026	2.037	2.048	2.028	starch
	2.100	2.111	2.122	2.101	flour
Palm oil	0.063	0.066	0.075	0.080	CPO
Coffee	3.244	3.016	3.264	3.192	drying
	0.332	0.308	0.334	0.326	non-roasted
	0.480	0.446	0.483	0.472	roasted
Tea	0.783	0.754	0.728	0.727	CTC
Cacao	1.486	1.263	1.313	1.278	product

CONCLUSIONS

For many agricultural needs, solar energy provides a good alternative for Indonesia agriculture. Indonesia has an abundant potential of solar energy, it indicates from the total mean global irradiation is between 2,111.9 – 2,427.53 W/m^2/year and the average daily irradiation was approximately 5.86 kWh/m^2. Modern, well-designed, simple-to-maintain, and cost-effective solar systems can provide energy that is needed when and where it is needed. Distributed generation, backup in the case of utility grid outage, and net metering present further opportunities for grid-connected solar energy use in agricultural settings in Indonesia.

REFERENCES

1. AHIDUZZAMAN, M. – ISLAM, A. K. M.: Energy utilization and environmental aspects of rice processing industries in Bangladesh. Energies, 2, 2009: 134–149.
2. ASIAN INSTITUTE OF TECHNOLOGY (AIT): Small and medium scale Industries in Asia: energy and environment, tea sector. School of Environment, Resources and Development, Pathumthani, Thailand, 2002.
3. BUNDSCHUN, J. – CHEN, G.: Sustainable energy solutions in agriculture. 8th vol., CRC Press, Taylor & Francis Group, New York, 2014.
4. JEKAYINFA, S.O. AND OLAJIDE, J.O.: Analysis of energy usage in the production of three selected cassava-based foods in Nigeria. Journal of Food Engineering, 82, 2007: 217–226.
5. LYNN, P.A.: Electricity from sunlight. 2nd ed., Collingwood, Australia, Lendlinks 2003.
6. NASA: Atmospheric science data. Available at: https://eosweb.larc.nasa.gov/sse/. Accessed 22 April 2016.
7. PIMENTEL, D., PEMINTEL, M.H.: Food, energy, and society. 3rd ed., CRC Press, Taylor & Francis Group, New York, 2008.
8. PLN: RE Deployment strategies to lower generation cost in isolated grids; renewable energy opportunities from remote Indonesia, 2014.
9. PLN: Power generation and renewable energy, roadmap and opportunities, 2015.
10. ROTA, A., SEHGAL, A., SPERANDINI, S.: Livestock and renewable energy. The International Fund for Agricultural Development (IFAD), Rome, Italy, 2012.
11. SAMPATTAGUL, S., NUTONGKAEW, P., KIATSIRIROAT, T.: Life cycle assessment of palm oil biodiesel production in Thailand. Int. Journal of Renewable Energy, 6, 2011: 1–14.
12. USDA: Solar Energy use in U.S. Agriculture overview and policy issues, 2011. Available at: http://www.usda.gov/oce/reports/energy/Web_SolarEnergy_combined.pdf . Accessed 23 April 2016.
13. VELDHUIS, A.J., REINDERS, A.H.M.E: Reviewing the potential and cost-effectiveness of grid-connected solar PV in Indonesia on a provincial level. Renewable and Sustainable Energy Reviews, 27, 2013: 315–324.
14. WANG, L.: Energy efficiency and management in food processing facilities. CRC Press Taylor & Francis Group, New York, 2009.

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