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Reviewing the potential and cost-effectiveness of grid-connected solar PV in Indonesia on a provincial level

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ABSTRACT

Photovoltaic (PV) energy could play a large role in increasing the electrification ratio and decreasing greenhouse gas emissions in Indonesia, especially since Indonesia comprises over 17,000 islands which is a challenge for the distribution of fuels and modern grid connection. The potential of grid-connected PV depends on, a.o. population, electrification ratio, irradiance, electricity demand, electricity generation costs and the urbanization ratio. Large spatial differences exist for these factors in Indonesia, therefore this study aims to assess the energetic potential and cost-effectiveness of grid-connected PV in Indonesia on a provincial level. Taking restrictions of the electricity demand during day-time and a minimal base load of conventional power systems into account, the total potential of grid-connected PV systems is about 27 GWp, generating 37 TWh/year, which is about 26% of the total electricity consumption in Indonesia over 2010. In the eastern provinces of Indonesia the LCOE of PV in grid-connected urban areas is lower than the cost of present electricity generation and could be a viable alternative if excluding high subsidies for electricity production.

Contents

1. Introduction

The Indonesian government is facing enormous challenges to improve the Indonesian electricity system in order to reach their future goals on grid penetration and GHG emission reduction [1,2]. In the period from 1987 to 2009 electricity production boosted by 620% [3] and it is expected that the future electricity demand continues to increase steadily by 9% annually [2]. Although Indonesia has abundant renewable energy resources (Table 1), its electricity production was still highly relying on coal (35%) and oil (26%) in 2010 [4], resulting in a high CO_2 intense electricity generation [5]. At current production rates the national gas and

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oil reserves will be depleted in the coming decades [6,7], therefore the share of coal is expected to increase in the near future due to its relatively low cost, availability and domestic industry.

The electricity price in Indonesia is heavily subsidized, for instance the government allocated an amount of 5.1 billion US dollar for electricity subsidies for the year 2012 [8] leading to a reduction of consumer price of electricity, which is significant lower compared with other Southeast Asian countries [5]. Especially on remote islands outside the main islands Java and Bali expensive diesel is used to generate electricity in a relatively inefficient way [2], which adds to the subsidy burden of the government, taking badly needed resources away from improving infrastructure [9]. For instance at the province East Nusa Tenggara the actual electricity production costs are about 15 $ct/kWh whereas the average price sold is less than 8 $ct/kWh [10]. The amount of subsidies for electricity and the dependency on fossil fuels and its inherent distribution problems will have an adverse effect on the Indonesian economy, therefore the government should take action toward using more renewable energy resources [5,11,12].

According to PLN [4] the total electricity production was 164 TWh in 2010 of which 12% comes from renewables, mainly hydro and geothermal. The share of solar energy is negligible and so far focus was mainly on standalone small scale PV systems like solar home systems and village systems [13], with modest success [14].

Since Indonesia comprises over 17,000 islands the distribution of fuels and energy is a challenge due to this geographically dispersed situation, by differences in developments between the main islands Java/Bali and the others as well as between urbanized and rural regions. This is one of the reasons that the average electrification ratio of households in Indonesia, which was 66% in 2010 [4], is one of the lowest compared with neighboring countries [2,5]. As can be seen in Fig. 1, large differences exist among provinces. For instance, high electrification ratios of more than 90% can be found in the provinces Jakarta and Aceh, while low electrification ratios of 24% can be found in Papua and East Nusa Tenggara. Besides, the inequity between urban (94%) and rural (32%) electrification is the largest in Indonesia compared with other big developing countries [5,16]. This is related to the poverty distribution in Indonesia [17], regions with high poverty ratios are less attractive for investors, because in general the

Table 1
Renewable energy potentials in Indonesia [7,15], ratio of installed capacity vs. resource potential.

Energy source	Resources	Installed capacity (GW)	Ratio (%)
Hydro	75.7 GW	4.2	6
Geothermal	27.0 GW	1.2	4
Mini/micro-hydro	0.5 GW	0.2	46
Biomass	49.8 GW	0.3	1
Solar	4.8 kWh/m^2/day	0.01	–
Wind	9.3 GW	0.0006	0

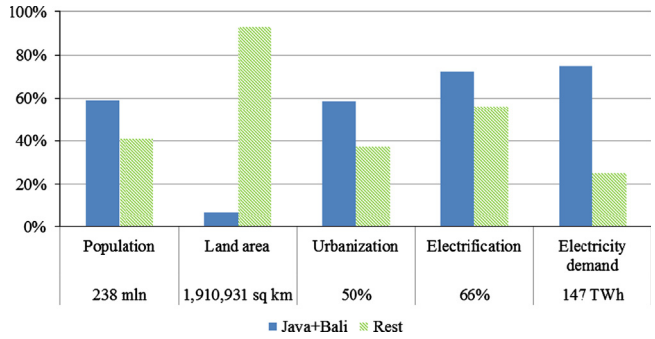

Fig. 2. Comparison of the population, land area, urbanization ratio, electrification ratio and electricity demand for the islands Java–Bali with the rest of Indonesia. Below the bars total figures are shown for each category.

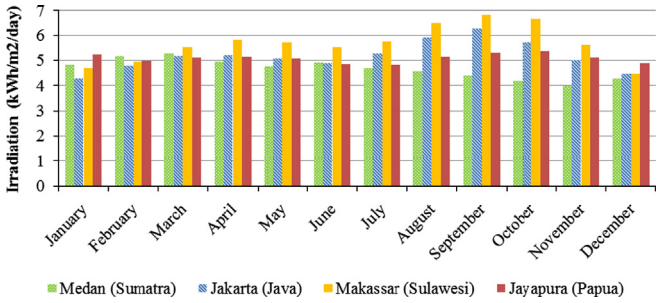

Fig. 3. Daily average solar irradiation (kWh/m^2/day) for four Indonesian cities for each month over a period of 22 years between 1983 and 2005 [22].

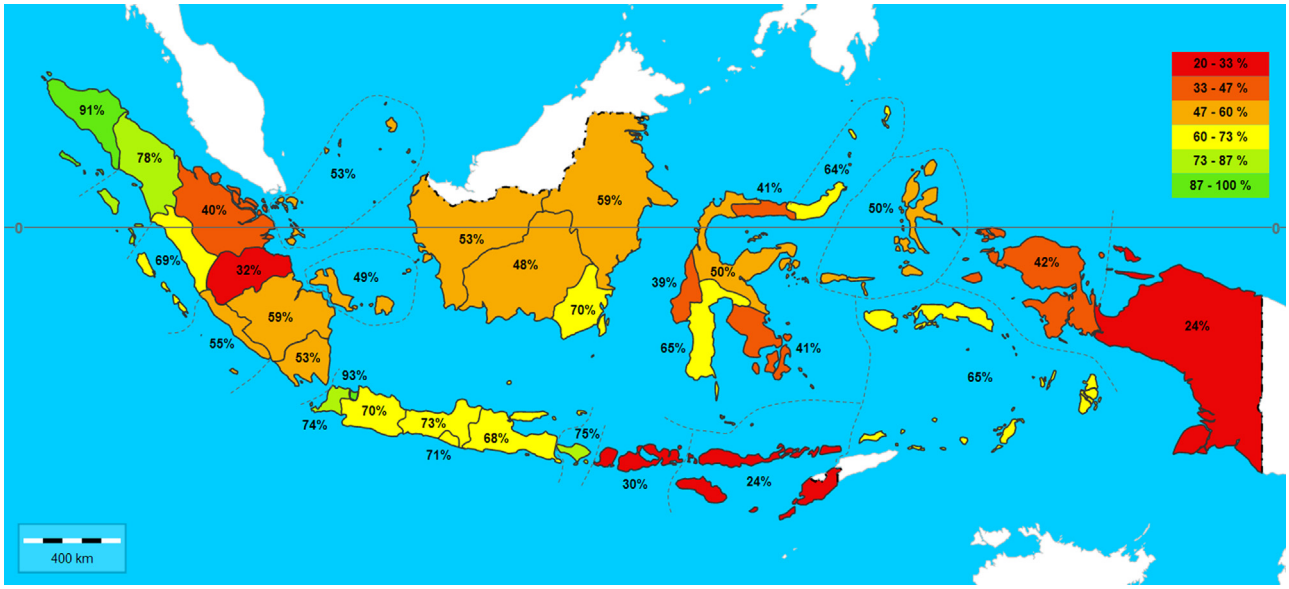

Fig. 1. Electrification ratio of households per province in Indonesia in 2010 [4].