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Progress of solar photovoltaic in ASEAN countries: A review

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ABSTRACT

The present global energy scenario, in which fossil fuels play a preponderant role, faces significant energy and environmental challenges. To help address these challenges, countries across the world are increasing the contribution made by renewable energy (RE) resources to their energy supplies. Feed-in Tariff (FiT) is one of the most effective incentive policies used to promote the RE sector especially at the micro-generation level. The key objective of the FiT schemes is to provide financial support to residential, industrial and commercial consumers to encourage them to become RE producers. Solar photovoltaic (PV) is one of the most promising RE technologies. This paper provides an overview of the solar PV developments in the Association of South East Asian Nation (ASEAN) countries. It reflects upon the RE trends in the world as well as providing an introduction to the ASEAN countries. It reviews the progress of solar PV in each of the ASEAN countries especially in terms of RE policies, growth in terms of PV installations and research and development activities. Finally, the paper presents conclusions and a set of recommendations. Out of the 10 ASEAN countries, 5 have implemented FiT as a key policy incentive to stimulate the progress of RE. It is found that the ASEAN countries have great potential for solar PV in term of their annual solar insolation levels, which ranging from 1460 to 1892 kWh/m^2 per year.

Contents

Abbreviations: ACE, ASEAN Center for Energy; MYR, Malaysian Ringgit; ADB, Asian Development Bank; NREP, National Renewable Program; AEDP, Renewable and Alternative Energy Development Plan; NEPC, National Energy Policy Commission; AFTA, ASEAN Free Trade Area; PDP, Power Development Plan; ASEAN, Association of South East Asian Nation; PEP, Philippines Energy Plan; BEEP, Building Energy Efficiency Programme; PS, Pioneer Status; BIPV, Building Integrated Photovoltaic; PV, photovoltaic; BNERI, Brunei National Energy Research Institute; R&D, research and development; CO_2, carbon dioxide; RE, renewable energy; CSPS, Centre for Strategic and Policy Studies; REMP, Rural Electrification Master Plan; DC, direct current; REN21, Renewable Energy Policy Network for the 21st century; DECC, Department of Energy & Climate Change; RES, Rural Electrification Strategy; DOE, Department of Energy; RGC, Royal Government of Cambodia; EDPMO, Energy Department at the Prime Minister's Office; ROI, return on investment; EEDP, Energy Efficiency Development Plan; SCBP, Solar Capability Building Programme; EMA, Energy Market Authority; SEDA, Sustainable Energy Development Authority; ERC, Energy Regulatory Commission; SGD, Singaporean Dollar; FiT, Feed-in Tariff; SHS, solar home systems; GBI, Green Building IndexSREPP; SREPP, Small Renewable Energy Power Programme; GBP, Great British Pound; UK, United Kingdom; GTFS, Green Technology Financing Scheme; UKERC, UK Energy Research Centre; HDB, Housing Development Board; UKM, National University of Malaysia; IDR, Indonesian Rupiah; UM, University of Malaya; ITA, Investment Tax Allowance; UPM, Universiti Putra Malaysia; MBIPV, Malaysia Building Integrated Photovoltaic; USA, United States of America; MEMR, Minister of Energy and Mineral Resources; USM, Universiti Sains Malaysia; MIEEIP, Malaysia Industrial Energy Efficiency Improvement Project; UTM, Universiti Teknologi Malaysia; MoU, Memorandum of understanding; VND, Vietnamese Dong; MTOE, Million Tonnes of Oil Equivalent; WWF, World Wide Fund for Nature

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1. Introduction

Energy is one of the most vital human needs in the 21st century. All modern day activities including household, transportation, industry, agriculture, education and communication crucially depend upon energy. Availability of energy in societies also directly influences their economic wellbeing. Due to the fact that the majority of this energy comes from fossil fuels such as coal, oil and natural gas, this is causing a lot of problems, especially to the environment. Some of the major environmental consequences of using fossil fuels include high carbon dioxide (CO_2) emissions that pollute the atmosphere; depletion of forested areas, which has worsened global warming; and, very importantly, these energy resources are non-renewable and will eventually run out [1]. A recent example to reflect upon the environmental implications of extracting fossil fuels is the explosion of an oil rig in the Gulf of Mexico in April 2010. This led to the loss of 11 human lives and to a massive oil spill that had a devastating impact on the environment. [2]. Another example of the detrimental effects of extracting fossil fuels is the incident reported on February 2014, when hazardous waste from hydraulic fracturing to extract oil was being dumped off the coast of California in the United States of America (USA) for years, creating risks to wildlife and people living near the area [3]. Apart from the associated environmental issues, the use of fossil fuels also has other problems, which include price fluctuations and concerns about security of supply. Another major source of energy, nuclear power, is not without problems either. The incident with the Fukushima nuclear power plant in the aftermath of the tsunami in Japan in November 2011 has prompted many countries to reconsider using nuclear as their primary source of energy [4].

As researchers, scientists and government agencies realise that the world cannot rely on conventional energy resources such as coal, natural gas and petroleum alone, several solutions are being explored. While energy conservation and management through improvements on energy efficiency across all sectors including residential, industrial, commercial and transportation is needed, renewable energy (RE) is regarded as vital for a sustainable energy future. Prominent RE resources include solar power, wind power, hydropower, biomass, geothermal power and wave and tidal power [5]. There are many advantages of using RE sources. These include, not only reducing the dependence on finite energy sources, but also eliminating or minimising the safety issues related to the use of fossil fuels and atomic energy [6]. Furthermore, RE reduces the release of greenhouse gases emissions to the atmosphere, which increases environmental quality and helps to fight climate change. Moreover, RE sources are vast, sustainable and free for the taking, disregarding the process costs and equipment required to collect them.

The global awareness of the need for RE has increased considerably in recent years as more and more countries are shifting their energy generation to RE resources [7]. RE projects are making significant contributions to the national energy supplies of many countries across the world while helping to preserve the environment [8–12]. According to The Energy Report 2011, World Wide Fund for Nature (WWF), the RE supply will be sufficient to fulfil the global energy needs by 2050 and will save almost £4 trillion per year through energy efficiency and reduced fuel costs [13]. RE supplied an estimated 19% of the global final energy consumption by the end of 2012; with approximately 9% coming from traditional biomass[1] and 10% from modern renewables sources[2] (see Fig. 1). RE has grown significantly in the past few years. According to the latest report by the Renewable Energy Policy Network for the 21st century (REN21), the global of RE capacity increased by 8.5% from 2011 to 2012, surpassing 1470 GW in total installed capacity. The report also indicates that the industrial, commercial and residential consumers are increasingly becoming producers of RE [14].

While, as described above, RE offers numerous benefits in general, it has the inherent weakness of intermittency. For optimum results, it is important to identify the right type of renewable technology for a particular country or region. In this respect a number of factors including costs related to the generation of electricity, the efficiency of the chosen system, the land and water requirements and also the social and economic impact related to their implementation have to be taken into account [15].

Solar energy is one of the most promising forms of RE. Solar energy is considered as inexhaustible, sustainable and practically unlimited. The two most popular and well known solar energy technologies are the solar photovoltaic (PV) system and the solar thermal system. In general, solar PV systems harness the sun's energy using PV cells, which is a specialised semiconductor diode that converts solar radiation into direct current (DC) electricity for usage. Solar PV is used in grid-connected systems to power residential appliances, commercial equipment and lighting for most types of buildings. Through stand-alone systems and the use of batteries, it is also well suited for remote regions where there is no other electricity source. PV panels can be ground level mounted or installed on building rooftops. Mostly, PV modules mounted on building roofs can produce as much electricity as the building consumes. Whereas solar thermal refers to harnessing solar energy to generate heats and electricity is generated from it [16,17]. This paper focuses on solar PV.

Solar PV can contribute significantly to address the current energy and environmental challenges because it is considered a carbon-free energy (close to zero) and produces no emissions when in operation. However, the manufacturing of PV panels cells

[1] Traditional biomass here is defined as direct combustion in inefficient ways of woods, charcoals, leaves, agricultural and forest residue and solid waste.

[2] Modern renewables here is defined as modern biomass (more efficient and cleaner ways of using biomass for electricity generation, heat production and production of transportation fuels by adopting advanced and improved technology), solar, wind, geothermal and hydropower energy.