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Solar Energy Potential in China, South Korea and Japan

Topic and Research Question

Solar energy is an ultimate renewable and zero greenhouse or toxic gasses-emission energy source. The amount of solar energy reaching the earth's surface within an hour is equivalent to the amount of the energy that human beings consume in one year.

Thus, this thesis specifically adds to scientific discourse by investigating the solar energy potential, one of the most important renewable energy sources: facing increasingly adverse effects of climate change, the search for the reduction of greenhouse gas emissions and for sustainable growth strategies raises the advancement of renewable energy-based technologies. In order to contribute to scholarly research as a pathway to sustainable development in East Asia, the paper examines the potential of solar energy in China, South Korea, and Japan, by answering the below research questions.

- How large is the solar energy potential in China, South Korea and Japan?
- What is the theoretical and economic potential of solar energy in East Asia?
- How is the solar energy market situation in East Asia?

State of the Art

The definition of renewable energy potential has been explored by many researchers (Hoogwijk, 2008; Kofoed-Wiuff et al, 2006; Krewitt, 2008; Kreycik, 2010; Resch et al. 2008; Stangeland, 2007; Verbruggen, 2010). Several studies have already analyzed the global level of renewable energy potential (Hoogwijk, 2008; Resch et al. 2008; Krewitt, 2008). In addition, the theoretical potential of solar energy (Tang et al. 2011; Li et al. 2010; Jo, 2006; Kudo, 2010) and the economic potential (Ouyang et al. 2014; Kim and Chang, 2012) have been examined as well. However, scholarly research still lacks a multi-dimensional perspective on the potential of solar energy in East Asia.

Methodology and Approach

As framework of analysis, the structure developed by Kreycik et al. (2010) will be used, focusing on the four dimensions of resource potential, technical potential, economic- and market potential.

More specifically, the resource potential focuses on the solar radiation quantity of specific areas in China, South Korea and Japan.

The technical potential in each country will be assessed with below formula and assumptions. (Please refer to detailed assumption in the paper)

$$E = A \times Gpoa \times \eta \times PR$$

Where, E is the annual electricity production (kWh/yr), A is the usable roof or facade surface (km^2), GPOA the average yearly irradiation in the tilted horizontal or vertical plane of array (POA) per square meter (kWh/m^2/yr), η the average module efficiency (%) and PR is the system performance ratio.

To analyze the economic dimension of solar energy, the value of the levelized cost of electricity (LCOE) will be compared. The LCOE is a widely used measurement tool comparing the life cycle costs of generating electricity. The LCOE includes the overnight construct cost, the annual operation and maintenance costs, the fuel costs, capital recovery factor, the capacity factor, the discount rate and the economic life of the plant.

Finally, the analysis of the market potential includes energy trends, pricing, major market players, and policy regulations. More specifically, the energy trends will cover both conventional and renewable energy prices. Market players cover the product efficiency and financial statement of solar energy related companies in East Asia. The viability of solar energy policy will be examined with 'political viability indicators' by the International Renewable Energy Agency (IRENA) in order to analyze the policy potential in each country.

Main Facts

In China, Tibet, Xinjang, Qinghai, and Inner Mongolia the highest solar radiation was measured recording more than 1,750 kWh/m^2/yr. On the other hand, Chongqing, Sichuan, and Guizhou recorded the lowest radiation with less than 1,050 kWh/m^2/yr. In South Korea, south-eastern cities such as Jinju and Busan recorded 1,408 and 1,361 kWh/m^2/yr while Jeju and Ganneung measured 1,270 and 1,292 kWh/m^2/yr. Osaka recorded 1,427 kWh/m^2/yr whereas Sapporo measured 1,182 kWh/m^2/yr in Japan.

The technical potential in this thesis is given according to rooftop space per province in China, according to building sites in selected cities of South Korea, and according to buildings in dwellings and non-dwellings in Japan. Looking at China, the region of Xinjiang shows the highest technical potential with 115,377 GWh/day. In South Korea, Seoul ranks number one with a technical potential of 86.53 GWh/day due to its large rooftop area of building sites. In Japan, Tokyo was assessed as having the highest technical potential, 187.15 GWh/day in terms of building areas for dwellings in Japan.

Looking at the LCOE of energy sources in three countries, solar PV is yet the most expensive source. The LCOE of solar PV in China is estimated between 186.54 and 272.04 USD/MWh, compared to a relatively low LCOE of other energy sources such as nuclear, coal-fired, and gas-fired electricity (43.72-54.61, 33.26-34.43, and 39.01-39.91 USD/MWh, respectively). In South Korea, the LCOE of nuclear electricity shows 42.09-48.38 USD/MWh, being the least expensive source, while that of solar PV is assessed with as much as 338.62-386.06 USD/MWh. In Japan, the LCOEs of solar is approximately between 76.36-229.09 USD/MWh whereas that of coal, gas, nuclear, and wind are 38-67.88, 42.42-59.39, 53.39-106.06, and 33.94-129.27 USD/MWh, respectively.

In all three countries, conventional energies such as coal, oil, and gas account for more than 80 percent of the energy consumption whereas the renewables remain only few percent. Among the analyzed countries, energy prices are generally the lowest in China, except for coal which is cheapest in Japan. There is not much difference among the efficiencies (between 14.7-16.5 percent) of solar modules based on poly-crystalline silicon among three countries' companies. Looking at the financial statements of these firms in 2013, the researched company's total net revenues are 2.18 (Yingli), 2.73 (OCI), and 12.09 (Kyocera) billion USD though most of them had operating loss. In the policy viability analysis part, the indicators, 'Existence of related policy', 'Longevity of financial political commitments', and 'Existence of incentives for stakeholder' are confirmed in all three nations.

Results

In China, the south-western areas such as Tibet and Qinghai measured the highest solar radiation. On the other hand, the south-eastern part like the Chongqing, Sichuan, and Guizhou, and the north-east areas recorded a low level of radiation. In South Korea, the south-eastern regions show a high resource potential while the north-eastern area and Jeju Island showed relatively low radiation. In Japan, the south-western areas like Osaka receive higher solar radiation than the north-east like Sapporo.

The results of the technical potential show that the Chinese provinces Xinjiang, Tibet, and Inner Mongolia have a large technical potential with respect to the area size. Seoul, Busan, and Daegu were calculated to have the highest technical potential regarding useable building sites among South Korean cities. In Japan, Tokyo, Osaka, and Kagoshima were assessed as having the highest technical potential in terms of building areas for dwellings in Japan.

Looking at the economic potential, solar energy still appears unattractive in terms of LCOE compared to conventional energies and to renewable energy sources, even if climate change cost are included in the calculation. However, costs for the provision of solar energy are likely to decrease, raising the overall competitiveness of this technology.

Lastly, the market analysis shows that solar energy still constitutes for a minority with respect to total energy consumption and renewable electricity generation in all three countries. However, it is revealed that companies are already gaining much volume out of solar energy related products reflecting a growing market. There are also positive signs of fostering solar energy in China, South Korea, and Japan on policy level.

In conclusion, China indeed has great potential of resources and technical capacity, as well as a supportive policy framework. South Korea and Japan are geographically less favored than China, which is why, first, it is suggested to enhance the economic and market potential, and second, to develop a policy framework that is more supportive of high-end solar energy technology.

References

Please refer to the full version of the MA thesis, available at http://othes.univie.ac.at/

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