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A WAY TO A SUSTAINABLE FUTURE: THE SOLAR INDUSTRY IN JAPAN

ABSTRACT. Solar energy is considered one of the most promising and rapidly growing sectors of the world economy. In line with the international trend of switching to renewable energy sources, particularly solar, and because of the tragic events at the Fukushima nuclear power station, Japan is experiencing a real "solar boom." However, despite all obvious advantages of using solar power (ensuring national energy security, overcoming concerns about environmental consequences of using fossil energy sources, etc.), Japan is facing several problems in its development. The most important one is the fact that technological and social progresses in Japan do not match each other as a result of a unique history of the nation. In order to promote renewable technology, the emphasis should be made on the role of the governmental policy and the effects of built-in tariffs for renewable energy sources. Considering dynamics and character of solar energy development in Japan, new energy strategy, and megasolar plants construction, the conclusion might be drawn that in the nearest future Japan will keep its place among the leaders in this field.

KEY WORDS: solar energy; photovoltaics in Japan; "solar boom" in Japan; solar panels; new energy strategy; megasolar power plants.

INTRODUCTION

The Sun is a powerful inexhaustible (and free!) source of renewable clean energy. If the total energy flux from the Sun during a year is to be converted into conventional fuel for oil, then this figure will be about 100 trillion tons that is ten thousand times more than the total current energy consumption of the Earth.

Not surprisingly, the solar energy industry is developing rapidly and steadily. At the end of 2010, there were 27.2 GW of solar photovoltaic power (PV) installed in the world and the growth rate in their capacity in just one year totaled 118 %. At the end of 2011, the installed capacity of photovoltaics in the world reached 69 GW and in 2012 – 103 GW, i.e. during 2010–2012, it increased by 3.8 times [Masson et al, 2013]. No other industry in the world, including telecommunications and computers, had such impressive growth. This is the most promising renewable energy industry; its growth rate is more than twice higher than that of its main competitor – the wind.

At present, solar energy is used in more than 60 countries, and in some countries is able to cause the most serious competition for conventional energy, especially in achieving grid parity (when the price of 1 kW•h produced using renewable energy sources is equal to or less than the cost of 1 kWh produced by conventional sources of energy).

The great potential of the solar industry development is the reason that many countries aim to ensure national energy security and are concerned about ecological consequences of fossil energy sources use and the volatility of their prices.

Among the factors that increase the attractiveness of solar energy is constant price reduction of electricity generated by solar power systems as a result of innovation and technological advancement. If 20 years ago 1 kWh cost 1 euro, now it costs 10 cents and sometimes even less [Masson et al, 2013]. Solar power systems are modular and allow creating power-generating stations of any capacity. They can work either connected to the public main electric networks (on-grid, or grid-connected), or standalone (off-grid).

At the same time, the solar industry development faces such problems as dependence on weather and time of a day, difficulties of energy accumulation, high cost of facilities, and the need for cleaning dust from reflecting surfaces, although all of them are gradually becoming technically solvable. For example, photovoltaic systems can operate using both direct and scattered solar radiation. And energy specific storage technologies are applied to ensure operation of the solar power around the clock, usually molten salt, or battery, or diesel generator adding to photovoltaic systems.

The vast majority of works dedicated to the solar industry have mainly economic or technical context and cannot be applied to geographical matters, which makes this study unique. This paper is based on the official statistical data and annual reports from international organizations involved in the solar energy field such as the International Energy Agency, the European Photovoltaic Industrial Association (EPIA), etc. The methods used are statistical and comparative analysis allowing studying the problem from different angles.

SOLAR ENERGY IN JAPAN

Japan is among the five leading countries developing solar energy (accounting for about 11 % of the world capacity (Fig. 1.)), which is partly due to a very high level of insolation in the country – 4.3–4.8 kW*h/m^2 per day.

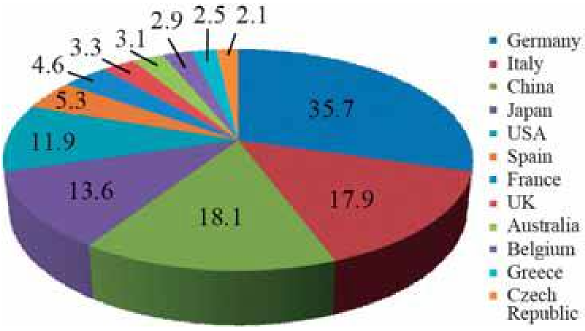

Fig. 1. Total photovoltaic capacity in 2013 (by leading countries).

At the beginning stage of the industry development, an important role in enhancing competitiveness and investment attractiveness is played by the state policy and governmental support measures including soft loans, grants, loans, and tax incentives. Japan was the first country to begin the development of solar energy at the legislative level. In 1994, the Ministry of Economy, Trade and Industry (METI) has adopted a program to subsidize individual solar installations and originally they covered 50 % of the photovoltaic systems cost. Precisely since then the solar industry has begun to develop rapidly. After the introduction of the renewable energy portfolio standards in 2003, the renewables share in the electricity production in Japan doubled and solar power gained a new impetus towards increasing capacity; though it is still extremely low and accounts for 2.4 % [International energy…, 2014]).

In 2004, Japan became the first country in the world to overcome the mark of 1 GW of solar power (Fig. 2), but remained the most powerful solar power generator (38 % of the world's installed photovoltaic capacity) only until 2005 [Japan lags behind…, 2007], when Germany has outstripped and is still leading in the photovoltaics field.

Japan's early leadership was achieved due to the above-mentioned measures of stimulating the solar industry. However, in the mid-2000s, its development has slowed down somewhat, for some time, partly because of the adoption of a new energy program in

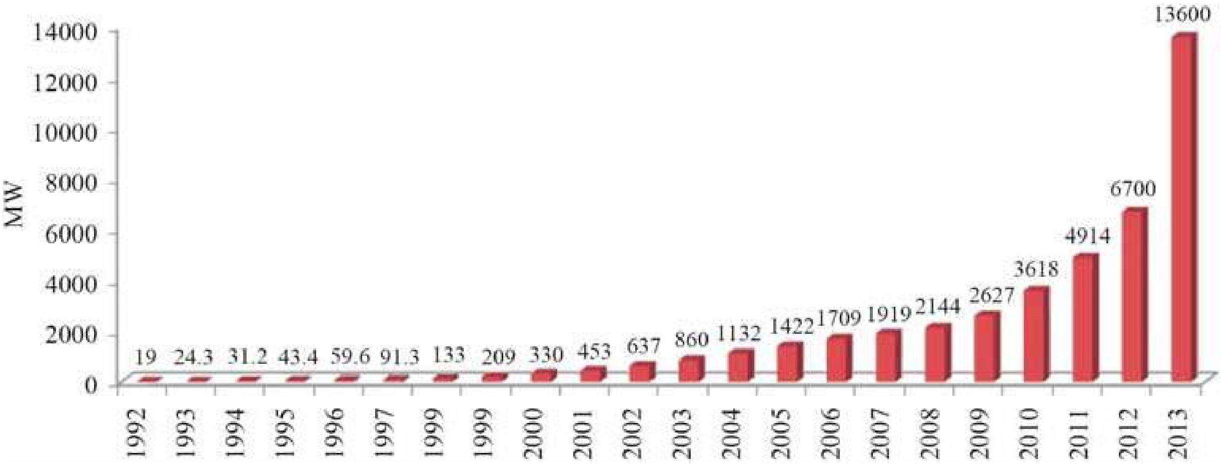

Fig. 2. Dynamics of photovoltaics' development in Japan, 1992-2013.

2002 aimed at further expansion of nuclear power to a capacity equivalent to 17.5 GW.

In accordance with METI Plan of innovative energy technologies "Cool Earth 50" adopted in 2008, by 2100, the share of nuclear energy in the primary energy mix was to be increased from 10 % to 60 % and the share of renewable resources from 5 % to 10 % (while the share of fossil fuel reduced from 85 % to 30 %). This scenario was developed by Nuclear Regulation Authority for the purpose of reducing carbon emissions by 2100 by 90 %, with half of this to be achieved by increasing the contribution of nuclear energy [Cool Earth…, 2008]. In June 2010, in order to ensure energy security and reduce carbon emissions, METI decided to increase self-sufficiency in terms of energy sources up to 70 % by 2030, mainly due to nuclear energy [Nuclear Power in Japan…, 2011].

However, the Great East Japan Earthquake in March 2011 has led to the revision of the national energy strategy, not least under public pressure, from increasing nuclear capacity to its abandonment and significant increase of the share of renewables in the energy mix.

In 2012, the Japanese government imposed an unprecedentedly high tariff on electricity generated by solar power systems: 42 yen per kWh (at that time an equivalent of about $0.53). In April 2013, it was decreased to 37.8 yen, or about $0.38 per kWh due to falling prices of solar cells. In accordance with this policy, the price of solar electricity is fixed for 20 years ahead. As a result, in just one year, the country of the rising sun joined the world "solar club," the group of the countries that have a total capacity of solar energy over 10 GW.

Immediately after the approval of the new tariff, in July 2012, Japanese homeowners installed capacity of 300 MW (i.e., about 10 MW per day), and in February 2013 – 837 MW, or 30 MW per day; industrial power stations commissioned 53 MW and 420 MW, accordingly [Masson et al, 2013]. A boom like that has not been seen anywhere else in the world. Thus, a doubling of this energy sector happened again in just one year. Its share in all of the country's generating capacity also doubled – up to 5 %.

As for solar cells and solar panels, in 2012 its total production in Japan was 2286 MW – slightly less than in 2011 (2497 MW). However, imports of solar cells actually tripled up to 776 MW (in 2011 – 263 MW) [Yamada, Ikki, 2013].

The distinctive feature about solar energy in Japan is the absolute predominance of individual photovoltaic installations (70 % of solar power in 2012 [Burger, 2012]), which differs Japan from Europe and America. They cover 900 thousand houses (overall there are 27 million houses in Japan). In the period ahead, through the use of battery chargers and "smart" meters, photovoltaic systems in Japan are expected to turn into a regular "household appliance." Such orientation is quite natural as the country lacks large vacant spaces required for the power stations of industrial scale operation. Land-based power plants and other local sources not included in the overall grid accounted for only 20 % in 2011, although next year their share already rose to 30 % [Feed-in Tariff Scheme in Japan…, 2012], in line with the global trend towards solar megaprojects.

There are 40 solar parks in Japan. Basically, they were built due to existing subsidies for the purpose of experimental research, and now are going through the transition stage to commercialization. Their cost is still high, 400–500 thousand yen per kWh (while in other countries, there are cases when it is less than 300 thousand yen). With the release of China's solar panels to market, their value decreased; so in terms of international competitiveness, the cost of installing holders and auxiliary equipment comes to the forefront, as well as power drives.

One of the proposed megaprojects in Japan, the solar power station Kagoshima Nanatsujima (70 MW), in Prefecture Kagoshima, was launched in November 2013 by Kyocera. It is the largest sea-based solar power plant in Japan. Clean energy generated by this power station is fed into the national grid through a local utility company [Kyocera starts…, 2013]. The site is located close to the shore without disturbing the existing sea and land routes. In Tahara, on the peninsula Atsumi, a large solar power plant with capacity of 77 MW was expected to be built in 2014 [One of Japan's largest…, 2013].

Therefore, we can conclude that the factors of solar energy development in Japan are, on the one hand, the lack of free space, which prevents wide industrial implementation of it, and, on the other hand, the existence of the consumers who are aware of the profitability of individual photovoltaic installation from economic as well as from environmental perspective.

Corporate structure of the solar industry.

An early emergence of the photovoltaic market in Japan has had an evident influence on the development of high-tech industries and the production of solar cells and solar panels. Companies that gained from the state preferences at the first stage and are now leading the photovoltaics development in the country are Sharp, Sanyo, and Kyocera. Specifically these Japanese companies helped keeping development and production of solar panels worldwide afloat when, in 1990, the U.S. government decided to cancel funding of this industry.

The Sharp Company accounts for 3 % of the world solar panels market. Its products are used in various projects in the field of alternative energy: from electrifying satellites and lighthouses to powering industrial and residential facilities. Sharp's first research in the field of solar panels dates back as early as to 1959 and only in four years the company achieved mass production. In 1966, solar panels made by Sharp Solar Co. were installed on the largest lighthouse at that time. Ten years later, their products were installed on the Japanese satellite as well.

Since 1994, photovoltaic systems of this company have been used by homeowners. In 2005, Sharp Solar increased its annual production capacity to 400 MW and started mass production of thin film solar cells that can be used as a replacement to windows and building materials. In 2008, Sharp Solar was the first to hit the mark of 2 GW of power-generating capacity. Two years later, the company began mass production of solar photovoltaic systems with an efficiency of over 32.5 %, and its annual production capacity grew to 2.8 GW, which allowed it to become the number one producer of photovoltaic cells, in terms of revenues [Sincerity and creativity…, 2012].

Sharp Solar has three facilities in Japan: a production factory of photovoltaic cells and solar panels in Katsuragi, and plants in Tochigi and Yao (Osaka), that produce end solar products. Apart from Japan, this company has facilities in the USA and in Europe: production of photovoltaic modules in the state of Memphis and in Wrexham, United Kingdom, that began in 2003.

In 2012, twelve Japanese companies were engaged in the production of solar panels: Sharp, Kyocera, Sanyo Electric Co., Ltd., Mitsubishi Electric (MELCO), Kaneka, Fuji Electric, Honda Soltec (a member of the Honda Motor Group), Solar Frontier (a part of Showa Shell Sekiyu Group), Clean Venture 21, PVG Solutions, Hi-nergy, and Choshu Industry Co. Most companies produce the first generation silicon solar cells, principally from the single-crystal silicon.

Obstacles and opportunities for solar energy development

Although Japan remains a tough market for "non-Japanese" companies, as Japanese consumers prefer to buy solar panels, like everything else, produced at home and not abroad, the country is really interested in attracting foreign companies to its market to accelerate the supply of photovoltaic components and, therefore, power stations construction.

It is even harder for foreign companies to get through to the customer on the Japanese market of inverters (power converters) because of the strict rules of certification, which are also constantly being tightened. It is not rare when a product needs to be upgraded before it can pay off. Therefore, today the market of inverters is the "bottleneck" that hinders the industry development in whole.

There is also an additional problem in Japan preventing the full implementation of solar installations into the existing grid that has roots in its history. Since the Meiji era, the electrical grid of Japan has a unique "Euro-American" structure: in the northeast, the current frequency is 50 Hz (as in Europe), and in the south-west – 60 Hz (as in the U.S.). This happened because in 1885, Tokyo Electric Light Co bought electrical equipment in Germany for the installation in the eastern part of Japan, where it had solid position and strong connections; Osaka Electric Lamp, in turn, purchased equipment from General Electrics to be used in the western part of the country. At the moment, there is only one frequency converter with a total capacity of 1 GW between these two power systems, which is far less than the existing electricity demand in Japan [Gordenker, 2011].

In order to be able to shift electricity to another part of the country, it is necessary to separate the electricity transportation capacity from its generation and sales. Thereby it will put an end to a more than a century of the fragmentation of the electricity grid.

In October 2013, Abe Government revised the law aimed at the liberalization of the energy market in 2015–2020 to create the monitoring service of electricity demand and supply in different regions of the country. This service will have the authority to order utility companies to supply more energy in case of deficit and, if necessary, even at the expense of increasing power generation. It will also be responsible for planning the highly variable production of renewable energy in order to distribute it more widely and effectively [Monitor power…, 2013].

However, creation of such an organization and considering the interests of all stakeholders, needs time, especially in Japan, where achieving a consensus after many discussions and consultations is a lengthy process. In this regard, energy companies may face certain problems. During the day, many consumers will be using the energy generated by their own solar panels, and selling expensive grid generated energy (due to the growing share of solar energy its price will inevitably raise) to them seems unreal. As a result, there will be underutilization of photovoltaic capacities.

And if the share of solar energy in the electricity generation in the country reaches

20 %, it will be impossible to sell the major part of this energy to consumers, as no one will be storing it for the night use.

Despite the current rapid development of solar energy in Japan, the existing subsidizing policy raises concern among members of the Japanese business groups. As experts rightly believe that supporting alternative energy may result in rising utility bills and slowdown in the domestic economy recovery, in connection with which, the new energy program of Japan once again appeals to the nuclear energy return as a temporary forced measure.

At the end of 2013, Keidanren announced that stopping nuclear power generation in Japan costs 3.6 trillion yen annually [A proposal for future…, 2013] that leave the country, as domestic investments are becoming extremely unprofitable. In addition, economic growth, of course, requires affordable energy that is also a powerful argument for keeping nuclear energy.

At the end of October 2014, only two reactors operated in Japan. Ccommissioning of the other 48 is only possible after they fully comply with the new requirements. The requirements include providing special countermeasures in case of critical emergency situations, such as the meltdown of the reactor core occurred in the 2011. For example, according to the Nuclear Regulation Authority, in September 2014, two reactors at the plant «Sendai» in Kagoshima Prefecture received a permit for commissioning, but only if the population of that area agrees.

Under the influence and pressure of all these circumstances, Japan, which has the complete nuclear fuel cycle (it includes enrichment and reprocessing of spent nuclear fuel for recycling), is turning back to the past. Contrary to the public expectations of a total abandonment of nuclear power plants, the new basic plan, released by the government in May 2014, not only turned back to nuclear power, but, in spite of the Kyoto Protocol, to the use of coal.

Despite certain difficulties named above (the lack of solar cells, the crisis of overproduction in other industrial segments of solar power system, the fragmentation of the country's electricity network), it can be assumed that Japan will continue to increase photovoltaic and solar thermal capacity, as incentives for the solar energy development have not disappeared, and a certain reserve, which was established in 2012, is the guarantee of the competitiveness of this sector. In support of this idea there are examples of large, sometimes seemingly incredible, solar projects.

"Luna Ring." Japanese construction company Shimizu, which has longer than 200-year history, has developed an original concept of "Luna Ring." Its goal is to generate solar energy on the Moon and transmit it to the Earth with the help of advanced space technologies [The energy paradigm shifts…, 2009]. Implementation of this project (the company hopes to accomplish it by 2035) would allow the clean energy production without interruption, regardless of weather conditions, and its use anywhere in the world.

In accordance with this plan, a ring of solar panels, producing a steady stream of energy, will be installed along the entire length of the equator of the Moon (11 thousand km). This stream of energy will go to the transmitting stations located on the front side of the Moon. Those will convert it into microwave energy and the laser light beams, and by using antenna 20 km in diameter, will pass it in the direction of the Earth.

The conversion of received energy into electrical one will be performed on the Earth and then supplied to the electricity grid or used for obtaining hydrogen (for storage or use as fuel).

"Space solar power." Japan Aerospace Exploration Agency (JAXA) has proposed an idea of building the space station to collect solar energy.

The basic concept of orbital solar park, which can meet the energy needs of humanity, involves the creation of a giant photovoltaic platform in the Earth orbit. This platform will be used to collect solar energy with its subsequent direction in the form of microwaves to receiving stations located on our planet. Thereafter, the received energy will be converted into electricity.

For the realization of this project, the Japanese Aerospace Exploration Agency has developed a complicated scheme. Road map, compiled by Japanese experts, describes the creation of a commercial system consisting of a series of ground-based and orbiting stations with a total capacity of 1 GW by 2030. This is comparable with a standard nuclear power plant.

The project, presented in the journal IEEE Spectrum, involves the construction of an artificial island of 3 kilometers in length, where a huge network of 5 billion tiny antennas will be rolled out to convert the microwave frequency radio waves into electricity [Sasaki, 2014]. A substation on the island will be used for the transmission of electricity via underwater cable to Tokyo to support the industrial zones and urban neighborhoods. Collection of solar energy will be carried out at an altitude of 36 thousand kilometers above the Earth's surface.

Experts emphasize that it will be difficult and expensive, but the result is worth it, not only from the economic point of view. Throughout human history the appearance of each new energy source, starting with wood, continuing with coal, oil, gas, and ending with nuclear energy, was associated with the revolution. If the humanity masters collecting solar energy in space, satellites in the orbit could provide its almost infinite energy, putting an end to conflicts occurring as a result of the struggle for energy resources of the Earth. Placing an increasing number of equipment in space will give rise to the development of a prosperous and peaceful civilization beyond the Earth.

"Village of the Future." In the coastal town of Minamisoma, Fukushima Prefecture, contaminated in 2011 as a result of the accident at the nuclear power plant, a real, on the contrary, down-to-Earth project is being developed, that is a model of the village of the future. This project is being performed in the area, two-thirds of agricultural land of which is in the evacuation zone due to nuclear contamination. There are already 120 photovoltaic panels that produce 30 kilowatts of power in the proposed village.

The centerpiece of the project is what the Japanese call "solar sharing" (i.e., joint use of solar energy), which allows growing crops under elevated solar panels. The project is supported by generous tariffs set by the government. Income from yields and energy will be reinvested in the project.

Its proponents hope that this model will be used by farmers, whose livelihood had been undermined because of nuclear contamination that occurred in the 2011 after the Fukushima accident. The model of the village of renewable energy offers a way out of a difficult situation. It could help save the Earth and the settlements, and by generating revenue from two sources at the same time could even lead to higher returns than in the past.

CONCLUSION

Due to the revision of the subsidy program for solar energy and the introduction of the feed-in tariff in 2012, four times the world average, there is a rapid progress in the solar industry development in Japan. As a result, it overtook Germany to become the world leader in photovoltaics in terms of value.

Obviously, the real breakthrough in solar energy in Japan has already occurred, although a complete substitution of fossil fuels is possible only with the exponential technological, social, and political development. However, given its high dependence on energy recourses import and the problems caused by the disaster in 2011, Japan will definitely be among the leaders hereafter as well. Possible return to nuclear energy and coal in accordance with the new energy strategy can be regarded as an emergency temporary measure to support the national economy. In terms of this transition, a cut in government subsidies for solar energy will result in nothing else but the decrease in price of solar electricity, which, in turn, will help solar energy to achieve grid parity. As a result, in years to come, the industry will become self-sufficient, and the prospects of its development will be even more favorable. ■

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