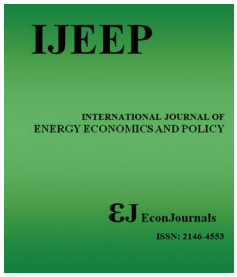

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China in Innovative Development of Alternative Energy Advanced Industrial Technologies

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ABSTRACT

The purpose of this article is to study the specifics of renewable energy development in China, including solar, as well as to identify the main factors limiting the ubiquity of solar energy in the country. Among the main objectives of the article, it makes sense to highlight the following: A study of historical preconditions for the formation of the renewable energy segment in the national energy sectors; an analysis of the main trends in socio-economic and energy development in China; an evaluation of China's activity in the exploitation of renewable energy sources; consideration of the most important prospects and limitations in the use of solar energy.

Keywords: Renewable Energy, Solar Energy, China, Conventional Energy Production, Photovoltaic Cells, Electric Power
JEL Classifications: Q42, Q48, O31

1. INTRODUCTION

At the beginning of the 19th century, a British clergyman Thomas Malthus warned of the dangers of population growth, whose use of natural resources could have a catastrophic impact on the environment.

Closer to our time, the Club of Rome published a report "The Limits to Growth" in 1972, which sparked an ongoing debate about how to manage economic growth within environmental constraints (Chapple, 2008; Krugman and Obstfeld, 2008; Berger and Lester, 2015). Since then, concerns about global warming added. Realizing that the development of new technologies is both a cause and a possible way to solve the problems in the sphere of ecology, there's no denying that technological solutions and science in general have their limits. The effects of climate change are felt over the lifetime of just one generation (Fücks, 2016).

If the solar energy is not considered to be a panacea, it is still one of the surest ways to avoid many of the negative changes in the environment. First of all, that is the solar energy using solar cells. The solar cells reproduce one of the cleverest tricks in nature: Conversion of the solar energy into other forms of energy. Since this process does not require the burning of carbon, the energy is produced without carbon dioxide emissions. In 2010, only 2% of global electricity demand was covered by the solar energy. However, the sector is growing rapidly. According to the estimates of the world energy agency, the share of the solar energy by 2050 could reach 20-25% of global electricity production (Moran and Russell, 2009; World Energy Council, 2013; European Commission, 2013). But in order to become popular in the modern world, the solar energy is to become economically viable.

The levelized cost of electricity indicator is used for comparison of the energy production costs in the world economy. That indicator takes into account the amount of initial capital, discount rate, the costs of the fuel and technology services in continuous operation, as well as eliminating subsidies or any government incentives (Branker et al., 2011; Darling et al., 2011). This type

of analysis helps politicians, researchers and businessmen to make decisions. In most countries, where this parameter is used, the data are unambiguous, because currently, natural gas, geothermal energy and coal are the most cost-effective fuels. Nevertheless, hypothetically in the future, the situation may change if the price of electric power produced from the combustion of hydrocarbons will include a charge for CO_2 emissions (Goldthau and Witte, 2009; Florini and Sovacool, 2009; Farmer and Trancik, 2012). However, the low cost of electric power and the availability of its production from the environment is crucial for the economy. That is why not only the most economically developed countries (primarily the European Union, Japan and the US), but also the countries with transitive economy (the undisputed leader here is China) are interested in the development of the solar energy as the main source of electrical power energy for the economic, social and domestic purposes.

2. METHODOLOGY

This article applies the methods of content analysis, statistical socio-economic analysis, reviews the results of scientific, technical and technological developments in the field of renewable energy and solar energy. The acquired facts are summarized and structured, which allowed the authors to determine not only the prospects of using the solar energy in order to provide the energy needs of the economy and welfare sector of China, but also to clarify the possibility of the use of this country's experience for other countries, whose socio-economic development is characterized by high resource consumption.

3. RESULTS

The 20th century in many studies has been called from an economic point of view as a "century of Asia." The Japanese postwar "economic miracle" fell under this definition, as well as "Korean (South Korean) economic miracle," and the active economic development in Taiwan, Singapore and other ASEAN countries.

At the same time mainly East and South-East Asia were referred to the "economic phenomena," where Japan was a leader before, but now the undisputed Asian leader is China (Kuznetsova, 2013). India has a claim to leadership too, but is perceived as a unique culture of South Asia, and the Muslim countries of Asia (excluding Indonesia, Brunei and Malaysia) are positioned as a unique region of the Near and Middle East (taking into account the development of Iran). Japan continues to lead in technologies, but China for several years has a dominant position in the economic sphere.

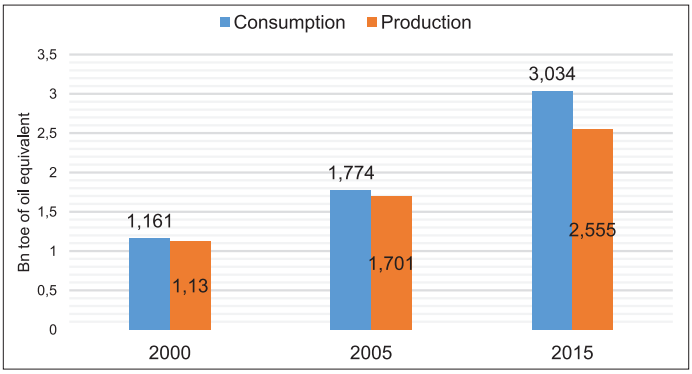
The rapid economic growth in China started from the time of the reforms by Deng Xiaoping in the late 1980s of the last century, when the country began to show growth in the range of 10% per year. Given the scale of China in terms of population and area, there have been not only quantitative but also qualitative changes in the development of the world economy under the influence of the "Chinese economic miracle" (Chai et al., 2015). The global financial and economic crisis in 2008-2010 clearly showed the new leader to the world, which has successfully overcome the problems of economic instability due to accumulated gold and foreign currency reserves (by number of accumulated gold and foreign currency reserves, China until recently was one of the top countries in the world) and a growing economy. But since the last year (crisis 2015), the China's economic growth started to slow down, and within the year more than $500 bn of its gold and foreign currency reserves were spent (Ren et al., 2015).

In addition, China's socio-economic development is very resource-intensive. In 2000, the economy and welfare sector in China consumed about 1.161 billion tons of oil equivalent (billion toe) per year, whereas in 2005 this figure increased to 1.744 billion toe. In 2015, China is the leader in the global energy consumption (about 3.034 billion toe). At the same time, in 2000 and 2005 the volumes of energy consumption almost coincided with the volume of energy resources production, but starting with 2015, the volume of energy consumption is 18-20% higher than the volume of the national energy production (Figure 1).

China is the world's leading exporter of traditional energy resources (oil and gas), the main supplier is Russia (Kuznetsova, 2013). For instance, in 2015 the Chinese company China National United Corporation (a subsidiary of China's state-owned energy company CNPC) exported about 27 million tons of oil from Russia for a total amount of $10.5 billion (Lapshin and Mokrousova, 2016). Moreover, the Chinese company China National United Corporation and the Russian company Rosneft JSC entered into a long term contract to supply China with 365 million tons of oil for 25 years (2013-2038). A construction project of gas transportation system, "Power of Siberia," is also well known, Russia will supply to China more than 1 trillion cubic meters of natural gas for 30 years, and the only supplier is the Russian company Gazprom PJSC (Gazprom Projects: "Power of Siberia," 2015).

The renewable energy in China is less developed than the traditional (hydrocarbon). But here it is worth noting that China is actively increasing the share of the renewable energy for the respective needs of the national economy and the welfare sector. For instance, in 2000-2005, the renewable energy contribution share in ensuring the energy needs of the Chinese economy and welfare sector was about 16.7%, in 2015 the renewable energy

Figure 1: Dynamics of China's energy resources production and consumption (Statistical Yearbook of Global Energy, 2016)



contribution share in ensuring the energy needs of China is about 25.9% (Figure 2).

The renewable energy in China consists mainly of hydropower (provides about 23% of all electrical energy needs). And it is quite natural, given that China's hydrography includes many rivers with a total length of more than 220 thousand kilometers, two of which are recognized as the longest and deepest in Eurasia and Indo-China (the Yangtze and Mekong, respectively).

Despite the favorable geo-climatic conditions, it was not until fairly recently that the solar energy has received its development (from the beginning of the 2000s). Starting in 2011, China adopted the state development program of the main energy industry branches for the period until 2030. In the near period (until 2020), it is scheduled as follows (Choi et al., 2015; Ren et al., 2015):

- Energy intensity reduction of the Chinese economy is not less than 10% (of the level of 2015);
- Installation of power generating stations of 40-50 GW solar energy;
- Installation of power generating stations of wind energy and hydropower of 200 and 380 GW respectively.

Thus, the Chinese government is fully aware of the need for a qualitative development of the national energy sector, but also stimulates the active distribution of the renewable energy, which is reflected in the systematic transition of the welfare sector, as well as public utilities to the use of energy generated from solar radiation energy (solar flux). China is more successful than Japan and the United States in the field of the solar energy operation (from 2005 to 2015, the solar energy contribution share in ensuring the energy needs of the Chinese economy and welfare sector has increased from 0.9% to 3%). Over the past five years, China has gradually increased the volume of electric power production from solar flux (Figure 3).

At the end of 2012-2015, China is steadily ahead of the US on new power stations commissioning for the solar electric power production (China's contribution to the commissioning of the new power stations for solar power production in the world is about 8%), but largely lags behind Germany (its contribution to the solar electric power production is about 32-35%) and Italy (the contribution of this country is about 17-18%). According to experts, the main problem of the solar energy development and commercialization in China centers on the distributed energy industry (Transparent Cost Database, 2016).

4. DISCUSSION

Historically, the major power plants were an integral part of the electrical network. The power stations were specifically located closer to the resources, but at considerable distances from the centers of power consumption. That, in turn, led to the formation of enormous energy distribution networks. Powerful power plants, as a rule, have been designed for specific large industrial facilities and were able to receive significant savings on the basis of "economies of scale."

Figure 2: Renewable energy contribution share in ensuring the energy needs of the Chinese economy and welfare sector (Statistical Yearbook of Global Energy, 2016)

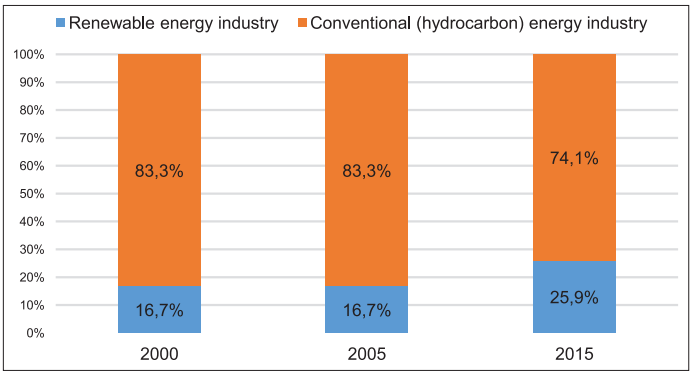
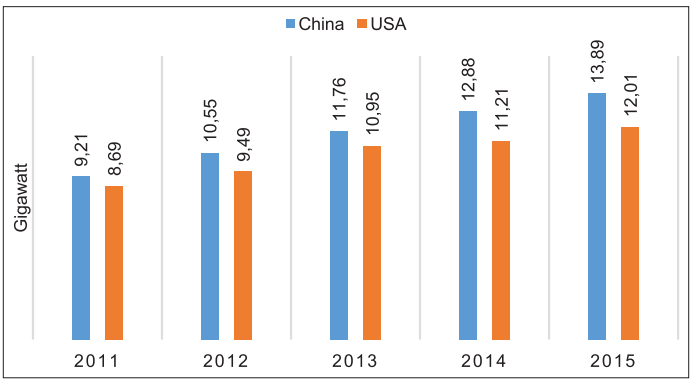


Figure 3: Dynamics of power stations commissioning for solar electric power in the United States and China (Transparent Cost Database, 2016)



In economically developed countries of the OECD, these centralized networks began to fail in the 1960s of the last century. Economy of scale was not enough to cover the electric power transmission costs. This network has become the main driver of the electric power costs for remote customers and the culprit of problems with power supply quality. Moreover, the quality problem has become very acute, since digital equipment requires constant power supply. Increased efficiency depends not so much on the increase in power stations, but on the location closer to the source. For instance, coal-fired power plants are being built away from cities to avoid severe air pollution and harmful effects on human health. In addition, these plants are often built near coal mines to minimize coal transportation costs. The distributed energy industry involves the construction of additional power sources in the vicinity of consumers. The power of these sources is selected on the basis of the consumer's expected demands, taking into account existing limitations (technical, legal, environmental, and so on), and can vary over a wide range (from 2-3 kW to hundreds of kilowatts). In this case, the consumer is not disconnected from the general power supply network.

The solar energy has more advantages in low latitudes, and in the south there is a need for the additional power stations. The higher cost of electric power in the solar energy industry could be compensated by the direct and indirect benefits of the electric power transmission cost reduction for the long-distance

networks. Unfortunately, many of these benefits are not taken into the traditional account of the cash flows. The distributed energy industry reduces the amount of energy lost during the electric power transmission, because the electric power is generated very close to the places of its consumption. Typical distributed energy systems have low operating costs, low environmental pollution and high efficiency. Modern embedded systems may provide the best quality with automated operation and the use of the renewable energy sources, which reduces the size of the profitable power plant.

The solar energy in the solar cells may become a significant, one of the most important elements of the distributed energy industry. The cost evaluation chain is replaced by the cost evaluation network. In fact, it is an industrial social network, communications in which are determined by actual and potential interaction of partners. An important trend is related to the whole renewable energy industry. Previously, the energy, which was produced by windmills, was 2-3 times more expensive than the energy produced by thermal power plants. Now prices are equal, but there is one major problem: If the wind does not blow, the energy is not produced. That is, their operation is unstable. The same problem exists with solar panels. High energy output occurs at midday, the energy is consumed in the residential sector, mainly in the evening. Sun and wind are inexhaustible energy sources. Over the past 2-2.5 years, the Chinese manufacturers have 3-4 times reduced the cost of solar panels, and thus have made them capable to compete with the thermal energy, but the problem of redundancy and energy savings has not been decided (Kalogirou, 2013).

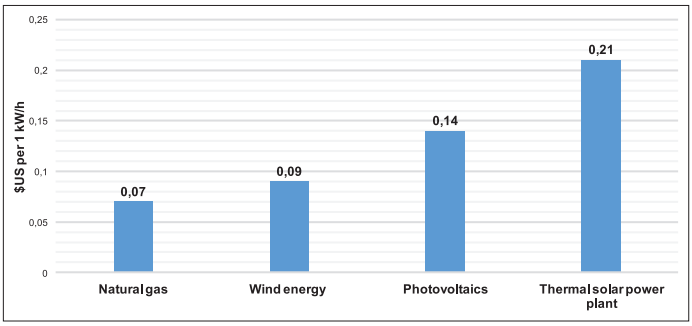
Therefore, at this point it is necessary to create an effective redundancy system of the renewable sources.

The issue of accumulation and redundancy (storage) of the solar electric power can be solved through the establishment of distribution stations using electrochemical storage devices (batteries, hydrogen batteries and redox-cells). The reduction of energy resources unit production cost contributes to active introduction and use of the solar electric power. With the emergence of photovoltaic (PV) cells, the cost of one kilowatt-hour of electric power has decreased by almost 34% (compared to the solar thermal power plants). However, reducing the cost of the solar power production using photovoltaic cells is not a competitive by price compared with other renewable or conventional energy sources (Figure 4).

The cost reduction of the solar power production using the photovoltaic cells was achieved not by increasing the efficiency level (the photoelectric cells efficiency is about 16-25%; for comparison, in the solar collectors of various modifications, the efficiency may range from 10% to 75%), but by the direct one-step transition of the solar energy into electrical energy, which reduces loss and provides a conversion efficiency (Branker et al., 2011; Darling et al., 2011).

Currently, the photoelectric cells of the first and second generations are used, each of which has its advantages. For instance, the first

Figure 4: Average production cost of 1 kilowatt-hour of electric power from different sources (Transparent Cost Database, 2016)



generation photovoltaic cells are based on crystalline wafers produced using silicon (monocrystalline or polycrystalline). Such production is characterized by high capital intensity and toxicity of the materials used, which maximizes their final cost and increases the level of harmful impact on the environment. The second generation photoelectric cells are thin film plates, in which silicon crystals are deposited by vacuum method.

This reduces the level of capital investment in production, however, does not reduce the level of environmental impact. The global and Chinese research centers are developing the third generation photovoltaic cells using less expensive and less toxic materials (for instance, recycled polymers and electrolytes created using nanotechnology). The difference of the third generation is the use of the printing method for the silicon crystals deposit that greatly reduces the cost of production. But the bulk of technological solutions to create the third generation photovoltaic cells is in the research stage and partial testing in the laboratory (International Electrotechnical Commission, 2015).

It should also be borne in mind that the solar collectors and the photovoltaic cells are able to reserve electric power generated from the solar flux for a period of from several hours to several days. This means that both the solar collectors and the photovoltaic cells shall continually receive radiant energy from the Sun in order to generate and replenish the generated electric power. It is obvious that at the moment of the research, the lack of development of accumulation and redundancy technologies of electrical power generated from the solar flux can be considered as the main factor limiting the ubiquity of the solar energy in China (as well as elsewhere in the world).

Here it should be understood that on the one hand, these limitations do not allow us to make the solar energy industry sufficiently mobile. On the other hand, the use of stand-alone solutions (energy supply by converting solar flux of individual buildings, small settlements) solves a serious issue of energy resources supply to the Chinese provinces, which are isolated from centralized energy production networks. In addition, the use of stand-alone solar power solutions allows to gradually reduce the level of harmful carbon dioxide emissions into the atmosphere (China in this indicator can be considered as "anti-leader"), as well as to reduce the level of energy dependence of the economy and welfare sector on external supplies.

5. CONCLUSION

Thus, having all the necessary conditions for the transition to the renewable and primarily to the solar energy, China is faced with the issue that limits the possibility of rapid accumulation and effective long-term redundancy of energy resources derived from the solar flux. Therefore, at this moment, China uses mostly the local autonomous solutions of production and exploitation of electric power generated from the solar radiation energy. Creating the large solar collectors and the photovoltaic cells, which will reserve significant amounts of electric power and release it for a long time as needed (from several days to several weeks or more), is inherent in additional costs (the need to create materials that will be less costly in the solar panels production), as well as in additional environmental impact (the need to dispose the fulfilled solar panels).

Accordingly, to date, the Chinese scientists have faced the objective to find the new technologies that will quickly accumulate and efficiently reserve the electrical power generated from the solar flux. Most likely the solution to this objective will be obtained in the short term due to the use of the nanotechnologies and nanomaterials. This conclusion follows from the fact that the Chinese government has reduced the amount of subsidies to the solar panels production, but is actively investing in the development of distribution systems for the electric power obtained from the solar flux.

At the end of this article, the authors would like to note that despite the difficulties that China faced at the use of the renewable energy sources (especially for the solar energy industry), its experience in the development of alternative energy supply of the economy and welfare sector needs is very instructive. Practice shows that a systematic approach is needed for the development of the renewable energy especially in countries that are characterized by infrastructural and technological backwardness (the BRICS countries and certain countries in South and Latin America). Under this approach, it is necessary not only to develop the segment of power station production, redundancy segment, and the subsequent distribution of the generated electric power. Offer and demand for electric power from renewable energy sources are necessary to be stimulated not only by the financial aspect but also by the social one, by increasing the level of responsibility of the national society for the life quality of current and future generations (Chapple, 2008; Dudin et al., 2013).

In this article, key trends are considered for the use of the solar energy in China; the limitations, which do not allow to use converted solar radiant energy everywhere, are defined. In future articles, the authors plan to consider the economic and social impacts, which have been obtained by China from the use of the renewable energy sources; the following articles will also consider the influence of the renewable energy sources exploitation on the environment.

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