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Comparative Assessment and Obstacles in the Advancement of Renewable Energy in India and China

Ocena porównawcza rozwoju energii odnawialnej w Indiach i Chinach

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Abstract

This paper presents a comparative in-depth investigation of the energy standings, opportunities and the barriers that occur in the expansion of renewable energy in the Asia's two fastest growing economies, i.e. India and China. These two countries contain almost 36% of the world's population and constitute the fastest emerging hub for trade and industries in the energy sector in which different types of energy resources are sought to meet the energy demands. Non-conventional sources of energy are the inevitable alternative for the achievement of economic improvement, ecological balance, nature friendly environment and sustainable development. It is recommended to eliminate the obstacles to achieving the estimated energy targets of the 13th financial year plan (FYP) of both nations and stimulate the enhancement of the rate of green energy resources exploitation.

Key words: biomass energy, hydro power, ocean energy, solar energy, wind energy

Streszczenie

Niniejszy artykuł przedstawia porównawcze dogłębne badanie możliwości i barier, które występują w ekspansji energii odnawialnej w dwóch najszybciej rozwijających się gospodarkach Azji, tj. w Indiach i Chinach. Te dwa kraje to prawie 36% ludności świata, stanowią one najszybciej rozwijające się centrum handlu i przemysłu w sektorze energetycznym, w którym różne rodzaje zasobów energetycznych są brane pod uwagę w kontekście zaspokojenia zapotrzebowania na energię. Niekonwencjonalne źródła energii są nieuniknioną alternatywą dla osiągnięcia postępu ekonomicznego, równowagi ekologicznej, środowiska przyjaznego naturze i zrównoważonego rozwoju. Zaleca się wyeliminowanie przeszkód w osiąganiu celów energetycznych w ramach trzynastego planu roku budżetowego (FYP) obu narodów i stymulowanie wzrostu wykorzystania zielonych zasobów energii.

Słowa kluczowe: energia biomasy, energia wodna, energia oceanów, energia słoneczna, energia wiatru

1. Introduction

Renewable energy is the energy produced from the sources that can be naturally replenished, such as solar, wind, rivers, biogas, ocean (Sharma et al., 2017). Sustainable energy system serves the energy demand of the contemporary without compromising the capability of future power generation to meet their energy requirements. The principle of sustainable development includes three correlated aspects of development, i.e. environment, economy and society (Joshi et al., 2010). Non-conventional energy is very essential for strengthening the security of the future energy supply. Taking the environmental aspect into consideration, conversion of one form of energy into another form for electricity generation utilizing fossil fuels, directly relates pollution in terms of greenhouse gas emission. Major ingredients of it also cause global warming to the environment. Subsequently, it leads to the melting of polar ice caps with the overall rise in global temperature. Therefore, renewable energy is the novel alternative for the pro-

duction of energy in an eco-friendly manner. The transition from fossil fuel to green energy sources will add a needful kick to the economy of a nation by creating new jobs and providing energy to the consumers at lower prices than traditional energy. The promotion of small scale distributed renewable energy based generation units will act as a catalyst in reducing the economic burden of the government's budget for electrification of the areas, where transmission of electricity is highly uneconomical. Moreover, advanced renewable energy technologies (RETs) offer an uplift to the present education system by electrifying primary and secondary schools, having no electricity with off-grid power generation systems (Sovacool et al., 2014). In remote areas, electrification through green energy resources acts as a revolutionary step towards the access of modern media like television, cell phones, internet etc. It will help to increase the standard of living of people as well as the human development index. In this way, deployment of renewable energy sources (RES) can result in the overall increase of sustainability indices to a remarkable level (Power to the People, 2017). Hence, RES are the key booster for the sustainable development.

According to the renewable energy policy network for the 21st century 2018 report, 26.5% of total electricity generation of the world at the end of year of the 2017 is from RES. The total global electricity generated from RES is further distributed into 16.4% from hydro power, 5.6% from wind power, 2.2% from bio-power, 1.9% from solar PV and 0.4% from other resources (REN21, 2018).

In the past years, accidents like the Chernobyl disaster and the Fukushima Daiichi disaster have been major alarming situations for the climate change because of the combustion of coal, fossil fuels etc. in countries like India, China and USA. Still, more than 70% of the world's total electricity production is fulfilled with crude oil, fossil fuels and nuclear power (REN21, 2018).

In Asia, India and China strong renewable energy paths are being built to meet their climate targets. As India, China and US release over 50% of the total CO_2 produced by the world, China is planning to increase their renewable energy capacity up to 38% of in 2020, compared to the 2015 level. This is equal to 680 GW of installed capacities and $361 billion investment. India is also taking vital steps to dramatically raise its renewable energy capacity. In December 2018, the India's total renewable power installed capacity including large hydro was 113.41 GW. For 2022, India renewable energy targets is 175 GW in which 60 GW corresponds to wind, 100 GW – solar, 10 GW – biomass and 5 GW – small hydro power (JNNSM, 2017).

This paper is organized as two main sections in which the first section deals with the comparative assessments of energy targets and opportunities of two countries with their plans. The second section deals with the obstacles in the path to achieve the renewable energy targets of two nations.

2. Current Status and Comparative Advancement Approach of RETs of India and China

In the last decade, a remarkable rise in RETs investment has been noticed in India and China. The scope of renewable energy industry is increasing with continuous technology advancements (Assmann et al., 2006, Chu et al., 2016). Therefore, both countries have planned green energy targets to boost their financial decisions in RETs (Liu et al., 2017).

2.1. Renewable Energy Technologies

Classification of solar PV technologies is twofold, into standalone and utility interactive systems. The standalone systems are not connected to the grid, while the utility interactive system utilizes a grid through the inverter units and energy storage technologies in order to maintain the uninterrupted power during the absence of solar irradiation (Manju et al., 2017). Moreover, another classification includes active and passive technologies. The active solar technologies take the solar energy directly from the sun and change it to another form or store it for future use (Chakraborty et al., 2016). In turn, the passive solar technology directly gathers the energy from sun without transforming it to another form. (Wolff et al., 2008).

The wind turbine technology divides it into vertical and horizontal axis turbines. Small capacity wind turbines are very common in practice and used for DC batteries on bus stands and also to provide auxiliary power for small ships. For domestic and large farm operations, medium and large wind turbines are used from 300kW to 8 MW (Vestas V164).

The hydro power plant has two types of turbines which are classified as an impulse turbine and a reaction turbine. In the impulse turbine, the hydraulic energy is converted into kinetic energy and drives the wheel, while in the case of reaction turbine, pressure and velocity of the water rotate the turbine when water goes out from the turbine nozzle.

The technologies associated with biomass include combustion, gasification, fast pyrolysis, carbonization & torrefaction and anaerobic digestion. Bio-organic materials (biomass) are utilized for the production of energy (Christiane Brauner, 2011). Therefore, it comprises animal dung, waste products and vegetable matierals (Pingali, 2012). There are three stages of biogas production: hydrolysis, acidification and methane formation. The composition of the biogas includes methane (50-80%) as main constituents, as well as contains carbon dioxide (20-50%) and trace elements like nitrogen and hydrogen sulphide. The potential of biogas of India is assessed as 17,000MW (Biogas Technology in India: More than Gandhi's Dream?, 2017).

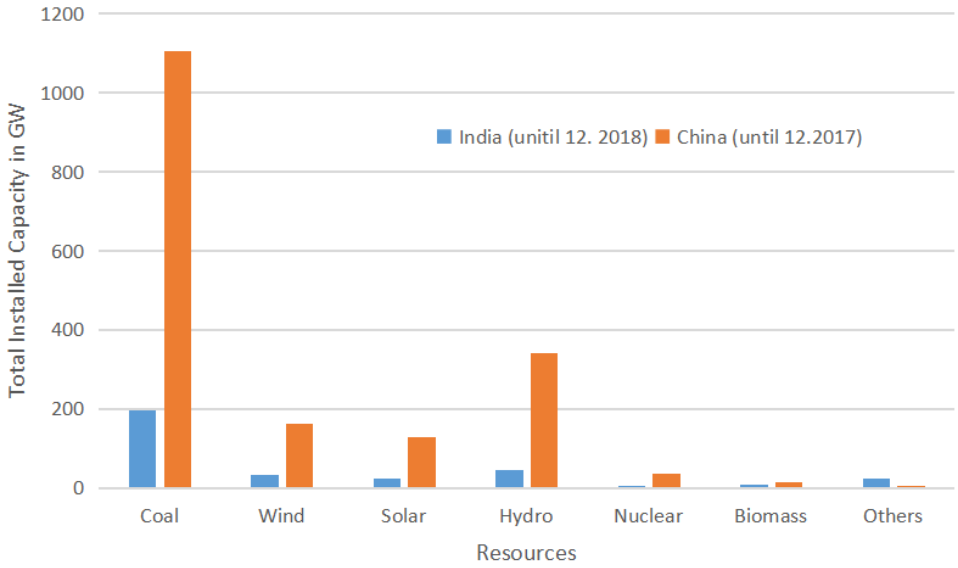

Figure 1. Installed power generation capacity of India and China (CEA, 2017, NBSC, 2017)

Table 1. Renewable energy targets of India and China (NITI, 2015)

	India's target by 2022 (in GW)	China's target by 2020 (in GW)
Hydro power	5	350
Biomass power	10	30
Solar power	100	100
Wind power	60	200
Total	175	655

Ocean energy technologies include thermal, wave, tidal and ocean current as power driver resources (Andres et al., 2017). Ocean thermal energy is based on Rankine cycle, which utilizes the temperature difference between surface water and deep level cold water. In turn, the wave energy technologies are based on wave interactions, i.e. terminator, attenuator and point observer. The power generation from tidal current utilizes large bays and estuaries along the coastline (Esteban et al., 2016).

2.2. Comparative Analysis of Energy Status and Strategies of India and China

World's two rising economies, i.e. India and China are the leading users of coal. China holds the top place while India is the second position. As per the statistical report of Fig. 1, energy mix of China (1797.97 GW) is five times greater as compared to India (343.21 GW). The current installed capacity of India amounts to 24.02 GW of solar energy and 34.61 GW of wind energy. Moreover, China leads with 130.25 GW of solar power installation and 163.67 GW of wind power generation. In India, the current clean energy generation contributes about 20% to the total power generation, excluding the large-scale hydro projects. (Whose power plans are greener: China or India?, 2017).

In order to enhance the rate of growth of renewable energy sector, both countries have proposed five years plan (FYP) as shown in Table 1. India's 13th FYP runs from 2017-2022, while China's FYP runs 2016-2020. The estimated plan presumes to boost the renewable energy sector of India with an annual increment of 60% in solar power as shown in Fig. 2(a). Moreover, it will double the wind capacity at the end of 13th FYP as represented in Fig. 2(b) (Highlights of proposals for China's 13th Five-Year Plan, 2017, NDRC, 2017, CEA, 2017).

India is not only executing its policies to strengthen RETs targets, but also intending to reduce the fossil fuel consumption. After completion of the 50 GW coal-based project, India will need no more exploitation of coal for power generation till 2027. In this regard, China's limitation is 1,100 GW. Despite the huge opportunities in China, the India's plan of power generation is greener than China, as shown in Fig. 3. The rate of expansion of RETs in China is slow as per the requirement (CEA, 2017). It reveals that India will claim 56.7% of total installed capacity through renewable energy by 2027 (NITI, 2015, NDRC, 2017). In order to promote solar rooftop and ground mounted solar projects, India has launched Jawaharlal Nehru National Solar Mission in 2011 (JNNSM, 2017).

China is the top global leader of the largest dam manufactured for hydro power project. Table 2 depicts the comparative aspects of maximum installed capacities of solar, wind and hydro power plants in two countries. Although ocean energy is under-utilized

Table 2. Maximum installed capacity for solar, wind and hydro power project in India and China

	India	China
Photo voltaic Power Stations	Ananthapuramu Ultra Mega Solar Park of 1,500 MW	Tengger Desert Solar Park of 1,500 MW
Wind Power Stations	Muppandal wind farm of 1,500 MW	Gansu Wind Farm of 6,800 MW
Hydro Power Stations	Tehri Dam 2,400 MW	Three Gorges Dam of 22,500 MW

due to many obstacles, but India is stepping up its endeavor to exploit all possible ocean energy technologies. Power projects in the Gulf of Kutch, Gulf of Chambay, Kalpasar etc. are the indication of ocean energy contribution towards robust sustained development of India (MNRE, 2017). India has tested a floating ocean thermal energy conversion plant of capacity 1 MW at Tamilnadu. On the other hand, to achieve an accelerated growth index in the ocean energy sector China it intended greater supports on the R and D platform and international collaborations for advancement of the ocean energy technologies (Tidal Energy Today, 2017).

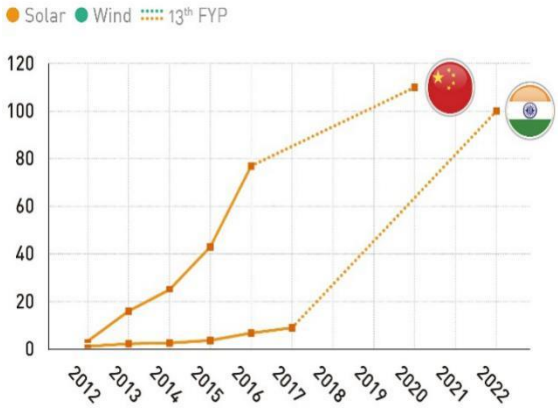

Figure 2(a). Target of solar energy capacity in 13th FYP of India and China (CEA, 2017, NDRC, 2017).

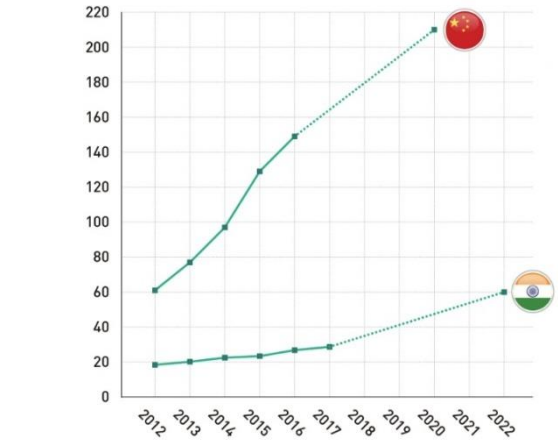

Figure 2(b). Target of wind energy capacity in 13th FYP of India and China (CEA, 2017, NDRC, 2017).

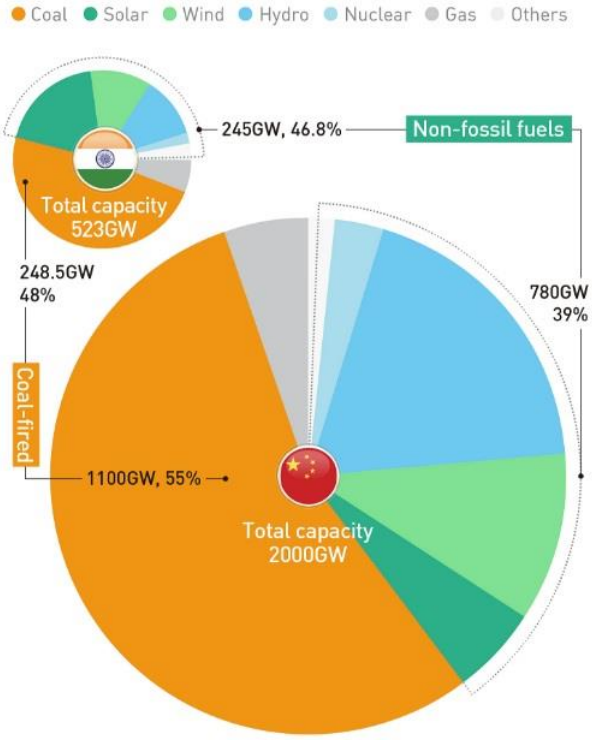

Figure 3. India and China: estimated power generation capacity at the end of 13th FYP (CEA, 2017, NDRC, 2017).

3. Obstacles in the Advancement of Renewable Energy in India and China

The transition of the current non-renewable energy needs of the Indian and Chinese societies to renewable energy depends on diverse components like economic, technical, institutional, environmental and societal factors (Manju et al., 2017, Sen et al., 2017). In this regard, India and China need long-term potential actions to achieve the solutions of the following common barriers.

3.1. Economic Obstacles

Following economic problems are involved with the development of RETs in two countries:

Solar:

i. Lack of appropriate financing system decelerates the process of enlargement and completion of solar energy projects in India and China.

ii. Lack of security in the incentives for the development of solar photovoltaic technology.
iii. Relevant stakeholders and investors lose their trust due to sudden reversal of the government policies related to the PV technologies.
iv. PV modules are not cost effective due to high initial investment. However, it also requires high capital investment during installation and maintenance.
v. Low rate of return and poor incentives leads to longer payback periods of the solar energy projects.

Wind:

i. Like other renewable energy resources, wind energy is also faced with the lack of proper financing sources.
ii. Generation of electricity from wind energy normally depends on wind speed, site, season and air temperature. Therefore, the numerous monitoring systems involved for monitoring these factors increase the cost of power generation.
iii. A large part of the hardware cost is usually spent on the design of the tower (for turbine support).
iv. In the case of onshore and offshore wind farms, transmission of the generated power to the load center exhibits severe line loss. Additional devices like synchronous condenser, capacitor banks, etc. are used to compensate the them, which adds to the incurred costs.

Hydro Power:

i. In some locations of the hydro projects, landslides, hill ramp destruction and the huge flood cause the blockage of road in rainy seasons which delays the project completion time. If the cost of road connectivity is incorporated into the project infrastructure, then it results in a rise of overall initial investment of the project.
ii. In some places in India (for example Arunachal Pradesh) and China, land documents are missing with land and revenue departments, which compels the project investors to bear the dual economic load by settling the compensation to the local public as well as the State Forest Department.
iii. The participation of public sector undertaking organizations or state government funded companies in hydro power projects, grant smooth access to the capital debt required for the investment because the organizations have state assurance. However, involvement of private developers, produces a risk in the project completion, because huge liability is not a full-recourse investment in this case (Tan-mullins et al., 2017).
iv. Many hydro power sites are located in the places touched with revolt and military operated regions. For security reasons, government laws and orders delay in the implementation of the venture which becomes a key factor for the cost overrun.

Biomass Energy:

i. Cost of production and transportation of biomass is very high.
ii. Biomass boiler has a very high initial cost compared to the regular gas or oil boiler.
iii. There is a risk involving a hike in the global food price, when energy crops are preferred to traditional crops for biomass energy production. It is the significant root cause of poverty, hunger and malnutrition in poor and developing countries.

Ocean Energy:

i. High initial investment is required for the construction of the ocean energy plant.
ii. Limited lifetime of equipment raises the maintenance cost of the wave and tidal energy plants.
iii. Ocean thermal energy conversion plant involve expensive unit, in which costly and large cross-sectional area intake pipes are immersed in the depth of more than a kilometer (KM) in ocean to bring low temperature water to the surface.

3.2. Technical Obstacles

India and China have not been competent to achieve their non-conventional energy targets compared to other developed countries due to many technical challenges. Some technical barriers in this regard have been identified as follows:

Solar Energy:

i. The competitiveness of the solar energy technologies is reduced due to low capacity factor of solar panels (below 0.25) compared to the coal based power stations (0.70 - 0.80).
ii. Intermittent occurrence of solar irradiation also makes it very difficult to provide uninterrupted power supply to the consumer.
iii. Research and development organizations realize the problem of constraint over the access of advanced technologies.
iv. The low penetration level of solar irradiation on solar panels reduces its efficiency. It occurs due to natural degradation, visual discoloration, hot spot formation, compo-

v. nent failure and dust layer formation on the panels.

Wind Energy:

i. Inconsistency in the reliability of wind energy plants occurs due to the fluctuating wind patterns.
ii. Due to low energy density of wind turbines, wind energy plant demands large quantities of wind turbines in operation for production of 1 MW of energy.
iii. The performance of many signal receivers decreases at the receiving end due to the interference of television, radio and other signals with wind turbine movement.

Hydro Power:

i. Hydro power projects are explicitly limited to the site of installation.
ii. Rate of progress work of the project decelerates due to unavailability of grid power at the constructional period of the project.
iii. For the safety requirements, standard and high quality materials are needed for the construction of a reservoir or dam for hydro power project to avoid any undesired breakage. For example, Banqiao Dam in China took the lives of 171,000 people and millions became homeless due to the dam failure.
iv. The hydro power plants situated in the Himalayan zone in India, encounter the problem of silt at the time of the high inflow season due to natural weak geology, rock immaturity and deforestation. It ceases to erode of turbine and negatively impacts the power generation and cooling water system.
v. Creation of void and bubbles causes formation of cavities in the turbines of the hydro power plant. At the portion of the cavity, the pressure of the water changes frequently by decreasing the efficiency as well as the life of the turbine.
vi. Load fluctuations in hydro turbines cause fatigue on the turbine due to varying cyclic stress. It weakens the turbine's material and further leads to the failure of the turbine.
vii. The lack of development-aligned skilled contractors, skilled workers and technically sound technicians appear as a hurdle for the rapid advancement of the hydro projects.

Biomass Energy:

i. The efficiency of the biomass energy is very low compared to the traditional energy produced from fossil fuels because it takes huge amount of energy from the feedstock to convert it into a biofuel.
ii. Long distance transmission of bio-gas through a pipe is very complex.
iii. Slow advancement of biomass energy technologies is an impediment to the investors.

Ocean Energy:

i. Reliability of the ocean wave energy is highly depends on wavelength and water density. Hence, unpredictable parameter behavior is a major drawback for the advancement of ocean wave energy technology.
ii. Lesser number of tidal barrage locations in India and China restrict expansion in the power generation potential from tidal energy.
iii. Due to the heterogeneous wave parameters, the output of the wave energy converters (WEC) is affected. When the WEC operates below the designed standards, output reduces and when it works under overloaded conditions, it may become damaged.
iv. Long distance transmission of the electricity from the generation site to the load center is also a big problem.

3.3. Institutional Obstacles

India and China need a more unified approach towards policy making and research for the achievement of the proposed renewable energy targets (Verzijlbergh et al., 2017). However, following challenges need to be overcome for the structural shift of energy system, which is primarily based on non-conventional energy (Suzuki, 2014):

i. Unfruitful marketing and educational campaign reduce the market size.
ii. Lack of policy backing creates a hurdle in the development of the basic infrastructure for the PV technology.
iii. Absence of constructive research and development culture is a major barrier for lacking interest of the researchers in the organizational level.
iv. Inadequacy of participation of stakeholders in the execution of decision results in misplaced priorities.
v. Conflict of interest leads potent lobbies against RETs.
vi. Long preparation procedure of detailed project report (DPR) of hydro power projects becomes a cause of slow development of such projects.
vii. Many mandatory clearances like land procurement, environment, wildlife, and forest, etc. take an unpredictable amount of time to complete the process of settlement. It occurs due to the dynamic nature of the required criteria for clearances and erroneous way of circulation to the public and entrepreneurs.

viii. Weak coordination of biofuel policies at an international level leads to the failure of global agriculture policies.

3.4. Environmental Obstacles

The development of RETs also contributes to the environment which can be assessed in two scales, i.e. the national scale and local scale. The national scale includes global challenges like ozone layer depletion. In turn, the local scale issues include the barriers like a shadow flickering of wind turbines, sound pollution due to turbine movement, etc. (Papay et al., 2010). Following are some dominant obstructions in this regard:

i. In the process of manufacturing of solar cell, greenhouse gas nitrogen trifluoride (NF_3) is obtained as the byproduct which is 17,000 times more dominant than carbon dioxide (CO_2).
ii. Silicosis caused by silicon (Si) dust badly affects the human respiratory system. About 25 people died due to silicosis at Khambhat, India.
iii. Hazardous chemicals like hydrochloric acid (HCl), sulfuric acid (H_2SO_4), nitric acid (HNO_3), hydrogen fluoride (HF), 1,1,1 - trichloroethane ($C_2H_3Cl_3$) and acetone (C_3H_6O) are used to clean and purify the semiconductor surface during the process of photovoltaic cell manufacturing.
iv. Aerodynamic and mechanical noise along with shadow flickering is the vital public health and a communal matter linked to the operation of the wind turbine.
v. Landscape perception and visual impact are also some crucial environmental challenges for the development of wind farms.
vi. Hydro power plants are indirectly becoming a cause of the greenhouse gas emission. It occurs due to the accumulation of vast water bodies in local areas as a result of the diversion of the natural way of the river at the time of construction of the dam.
vii. Production of methane gas takes place when animal and human wastes are utilized for power engines in biomass firms. It also leads to the depletion of the earth ozone layer of causing many serious problems to a human beings like skin cancer, eye damage, damage of immune system, ageing of skin, etc.
viii. Incomplete combustion of biomass fuel, for example, ethanol produces black carbon, which is a basic source of global warming.
ix. A number of large machines are submersed in the sea or kept near the water to gather energy from propagating waves. These machines adversely affect the marine ecosystem by creating noise and disturbances. It also causes water pollution by discharging toxic chemicals in water.

3.5. Social Obstacles

For developing countries like India and China, social challenges towards renewable energy advancements are often under-appreciated and under-examined. The government programs and business attention, assign insufficient weight to the recognition and remediation of following challenges which occur in our society:

i. Lack of consumer and social acceptance of unfamiliar RETs devices lead to a decrease in the market size.
ii. Growth or establishment of new RETs projects requires relocation of people which turns into a huge public protest and riots.
iii. The location issue is a prime concern over the implementation of hydro power projects. Due to lack of communication and basic infrastructure, remote area projects face the huge problems of transportation of machines, equipments etc. to the project site.
iv. According to the Indian and Chinese constitution, no objection certificate (NOC) is needed from every downstream state for the implementation of any hydro power projects. NOC approval is delayed or rejected due to the conflict between the states. It leads to the postponement or cancellation of the hydro projects. Moreover, some projects are also rejected due to inter-country disputes.
v. Lack of perennial river is also a prime concern towards the expansion of the hydro power projects.
vi. Extinction of fish or other aquatic animals are observed due to installation of dams and reservoirs at the breeding areas of these species. Additionally, some aquatic species find the path to the pen-stock and turbine, which causes the disruption of the aquatic ecosystem.
vii. Relocation and proper compensation of the vast population near the projected dam area is a colossal challenge to the establishment of hydro power projects. For example, a hydro power project at the Sardar Sarovar Dam in Gujrat, India, went through a huge protest.
viii. Chance of deforestation is a serious issue to the use of biomass energy. It causes extinction of many animals, birds, etc. and exerts adverse effects on the balanced ecosystem.
ix. Operation of biomass plant needs a great deal of water. Sometimes, it badly decreases the groundwater level as well as also adversely affects the irrigation system

of farmers to fulfil the required amount of water for the plants.

x. The biomass boiler system needs a separate storage area for fuel. Therefore, the area required is larger than that of a traditional gas or oil boiler.

xi. In some places, consumption of the biogas generated from sewage wastes is avoided for cooking purposes and other household uses.

xii. A great area of land is needed for the production of biomass crops. After the production, a large area is also required for storage before converting it into energy.

xiii. If seasonal crops and food grains like wheat, corn, etc. are used for the biomass energy production, then the possibility of scarcity of food (Palanisamy et al., 2016) can arise as a major problem for the highly populated countries like India and China.

xiv. Ocean energy is also location specific. India and China have a huge potential for ocean energy, but landlocked nations like Afghanistan, Mongolia, etc., need to depend on other alternatives of renewable energy resources.

xv. The pleasant coastal look can be spoiled by the installation of large machines in the center of the ocean.

xvi. The habitat of the fishes and other wildlife near the barrages becomes affected due to movement of the spinning turbines.

xvii. Physical existence of devices in the ocean energy farms and offshore wind energy farms, reduce the size of the shipping route and fishing area in the sea.

In the recent global energy development index of the year 2017, China is the leader while India became the second best nation in renewable energy attractiveness index (REAI). Though India has made large scale strides in energy efficiency in the past few years, the gap between the energy level of India and China is still significant. In addition,, the promotion of mega size projects and cost-effective foreign funding in India pulled down the solar tariff to 0.0378 $/kWh, which is a record low till May 2017 (Ahuja et al., 2017).

In a recent episode of the Paris climate accord, based on the concerns of global warming, one of the largest US stakeholders pulled out the deal by claiming that the accord favored India and China (World News, 2017). It will inimically impact the target of achieving of the reduced global temperature to 2° C above the pre-industrial levels.

India has proposed a refined institutional approach which is relevant to its market economy and constitutional system. It relies on the privatization of energy production, ensuring competition in the availability of resources through IRDEA and state law's guidelines. On the other hand, China focuses on economical supports for developing clean energy corridor and technology. In the field of biomass, China has focused on the development of highly efficient micro turbines in the biomass sector (Hart et al., 2009, Rethinking Energy, 2017).

Foreign direct investment (FDI) is one of the pragmatic approaches for the development of the green energy sector because it offer to the transfer of advanced technology, skill and capital from one nation to another. India has allowed FDI up to 100% in RETs subject to the constraint of the Electricity Act 2003. In the past 10 years, the highest beneficiary of RETs projects in Asia is India (USD 24688 million till 2016), while China (USD 13555 million till 2016) is the second largest recipient (Economic Outlook for Southeast Asia, China and India, 2017, Make in India, 2017).

4. Conclusions

The above-mentioned assessment is based on the premises of the present energy status and future plan for green energy of both the countries. It shows not only technical challenges to attain the goal, but also the associated huge commercial, political and social hurdles. It is noteworthy to mention that the presented analysis based on the structure of renewable energy between India and China, will be valuable to boost the exchange of technologies and collaboration between the two countries.

Although India and China have planned equal capacity of 100 GW towards the expansion of solar energy in their 13th FYP, India lags far behind from China in terms of hydro energy (345 GW), wind energy (140 GW) and biomass energy (20 GW). However, at the end of the proposed FYP of both nations, the India's RETs plan is much greener than that of China because, India will exploit 46.8% of total energy consumption by RES, whereas China's exploitation only amounts to 39%.

The potential of renewable energy in India and China shows enormous opportunities to accomplish the exponential rise in the demand for electricity. In this regard, various challenges like financing issues, high capital cost, difficult or no access to technologies, poor research and development culture etc. are need to be abated for the deployment of renewable energy resources. Long time taking for the completion of large projects for hydro power, biomass energy etc. causes a cost overrun. As India is second after China in terms of human population, it is highly important to put emphasis on the balance between energy crops and food crops in order to overcome the food security problem towards the growth of biomass sector. Moreover, there are strong indications for India to take immediate steps for the expansion of the hydro power project like in China. The ocean energy sector is even highly underutilized in both countries and it is at the early stage of development. In this way, the

advancement of each sector of renewable energy will also put a revolutionary growth in infrastructure development and creation of new jobs in two countries.

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