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A comparative review of China, India and Pakistan renewable energy sectors and sharing opportunities

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ABSTRACT

China, India and Pakistan (CIP) contain almost 40% of the world population and constitute a developing region which is desperately seeking energy resources to fulfill the growing economy requirements. CIP are three main countries of South Eastern Asia with nuclear capability and have greater potential of energy sharing for the regional prosperity and socio economic development. The total energy consumption of China and India is 3682.15 Million tons of Oil Equivalent (MTOE) which is approximately 28% of the world. The energy consumption of Pakistan is far less i.e. 85.75 MTOE however, it can play a pivotal role by providing energy sharing opportunities in the region. This paper presents a comparative and comprehensive review of CIP renewable energy sectors and possible sharing opportunities. Cleaner and abundant Renewable Energy Sources (RES) like hydro, solar, wind, biomass, nuclear and geothermal have been discussed and compared in context of CIP energy requirements. CIP relations and energy sharing opportunities have also been elaborated in context of regional peace and security situation. Exploitation of the CIP energy potential and energy sharing opportunities might contribute to global peace and prosperity.

Contents

1. Introduction

Energy has been a key requirement for mankind since its creation on the planet. Increasing population and modernization race have increased the overall energy requirements and per capita energy consumption, respectively. Modernization and per

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capita energy consumption have stimulated effect on each other i.e. increase in one gives rise to the other. Per capita consumption of some countries is shown in Table 1. According to which China is leading India and Pakistan in per capita consumption [1,2].

Worldwide per capita consumption shows that a significant amount of energy is being used in each and every sector of the society. Per capita energy consumption is directly proportional to the economic growth of a country. The countries like China, France and USA have the highest energy consumption per capita, as a result these countries have rapid economic growth rate [3,4].

To enrich industrial progress, most popular form of energy being used nowadays is electricity. Modern electric power system is an interconnected network comprising of power generation, transmission, distribution and utilization. Power is often generated in remote areas from where transmission network is stretched to transmit the power to load centers. The received power is then distributed to consumers through distribution network. Electrical energy is a key requirement of modern society. Therefore, it is necessary to highlight each possible electricity production resource. By the end of year 2012, global power generation capacity was 22,668 TW h. The largest contributors were fossil fuels (67.9%) and other resources include: nuclear (10.9%), hydro power (16.2%) and other renewables (5%), as depicted in Fig. 1.

The available resources of fossil fuels on the globe are depleting rapidly causing dramatic leaning in their prices which will be economically inappropriate. On the other hand, use of fossil fuels has adverse impact on the environment because of the emissions of the harmful gases like CO_2, SO*x*, and NO*x* usually known as greenhouse gases (GHG) [5,6]. China is the leading country in GHG with 8205.86 Million tons (Mt) and India is at third place with 1954.02 Mt of CO_2 emission [7]. Accumulation of these gases in the atmosphere has triggered some serious environmental issues like increased level of environmental pollution and remarkable change in the climate of the planet. According to the US Environmental Protection Agency (EPA) the net GHG emission has been increased by 42% during 1990–2012 due to human activities [8]. Electricity generation through fossil fuels is the largest contributor in GHG emission [9]. To minimize this adverse effects on the environment, the European commission of climate action set a target of reducing GHG emissions at least 20% below the year 1990 [10]. To address the economic and environmental issues associated with fossil fuels and to achieve the goal of reducing GHG emissions, Renewable Energy Sources (RES) are the best possible solutions to meet the growing energy demand. RES, although produce green energy, are not free of complications. High capital costs, intermittency, difficulties in storage and complications in grid connectivity are the major obstacles in adoption of renewable energy [11]. Some developed countries are including renewable energy in their power systems at a greater pace but many countries are continuously adding significant amount of fossil fuel capacity, resulting in lower growth rate of renewable energy. Therefore owing to barriers in adoption of renewable energy, global power sector still relies on fossil fuels.

Table 1
Comparison of per capita electricity consumption of some countries.

Country	Per capita electricity consumption in kW h
USA	13,361
France	7756
Germany	7217
China	2942
Turkey	2474
India	644
Sri Lanka	636.3
Pakistan	457
Afghanistan	119.8
Bangladesh	278.1
Nepal	454.1

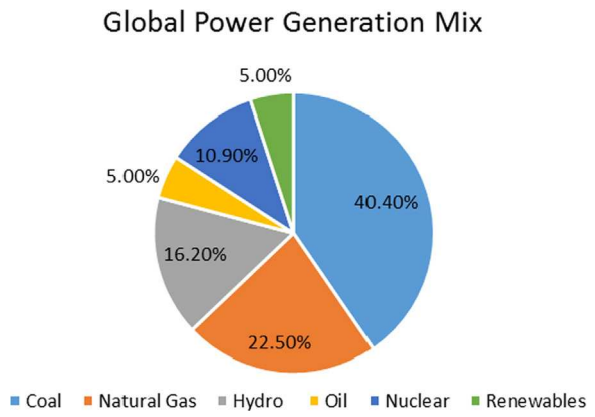


Fig. 1. Share of global energy resources.

China, India and Pakistan (CIP) contain almost 40% of the world population and constitute a developing region which is desperately seeking energy resources to fulfill the growing economy requirements. On the other hand the contribution of CIP in energy consumption is approximately 29% of the entire world [7]. CIP are three main countries of South Eastern Asia with nuclear capability and have greater potential of energy sharing for the regional prosperity and socio economic development.

This paper presents a comparative and comprehensive review of CIP renewable energy sectors and possible energy sharing opportunities. Exploitation of these sharing opportunities is necessary for acceleration of regional economic development. It will also contribute in global peace and prosperity by fulfilling the energy requirements of the world's 40% population. Our approach is to compare the RES in South Eastern Asia and to explore the energy sharing opportunities in context of regional peace and security. The paper also includes future energy demands and renewable energy targets of CIP. Furthermore, the work also presents comparison of CIP renewable energy sectors in light of recent data and analytical graphs. Rest of the paper is arranged as follows. Section 2 presents the brief overview of CIP energy sectors and energy mix. Section 3 describes the detailed discussion of energy resources and various phases of energy projects in CIP. Section 4 elaborates the energy sharing opportunities among CIP. Section 5 concludes the discussion.

2. Overview of CIP energy mix

Pakistan is a developing country having population around 185.1 million people and is facing severe economic and energy crises [12]. Power sector of Pakistan relies on conventional sources of generation. During the year 2007–2008, electricity generated was around 95,860 GW h and stayed at 95.4 GW h for the year 2009. The share of thermal power was 66.5% followed by hydel (29.9%) and nuclear (3.4%). In thermal power, gas had the largest share (34.3%) followed by oil (32.1%) and coal (0.1%). According to Hydrocarbon Development Institute of Pakistan, electricity generated was reduced to 94,653 GW h during 2010–11 [13]. The share of thermal power was 62.5% followed by hydro (33.6%) and nuclear (3.9%). In thermal power, oil had the largest share (27.3%) followed by natural gas (27.3%) and coal (0.1%). Some of the major factors influencing power sector are limited fuel resources, declining economy, lack of capital investment, external and

internal security concerns, aged power system, managerial defects and circular debt [14].

First barrier in implementation of renewable energy technologies is the absence of proper infrastructure. There is insufficient awareness in rural areas regarding RES in Pakistan which is a factor that influence energy problems in the country. In the past few years Pakistan is having serious financial crises due to which many projects and plans for the energy production from renewable and non-REScould not be initiated. Project funding is the major issue in the energy production run [15,16]. Pakistan has very low oil reserves which are shared between many departments. Pakistan spends USD 7 billion which is almost 20% of its foreign exchange on the import of fossil fuels so the electricity generation using oil is not an economical option [17,18].

If we compare the other countries with Pakistan, India is on seventh position by area all over the world, the second-most populous country with more than 1.2 billion population which constitutes 17% of the world population with democratic infrastructure [19,20]. India's annual GDP growth rate was 5.8% within the past two decades, and reached at its peak i.e. 6% during 2011–12 [21]. India is one of the world's fastest-growing economy. India is standing at 140th position worldwide and at 129th position on the basis of GDP per capita at Purchasing Power Parity (PPP). India is the 5th largest power producer of the world where energy demand is increasing day by day, owing to huge increment in population, the modernization of lifestyles, high energy tariff and a rapidly growing economy. The demand of electricity is expected to rise 255,000 MW at 6% GDP growth rate till 2030 and may increase further if the growth rate is higher [21]. Coal is the main contributor in electricity generation, so India is under massive international pressure for the better control of GHG emission. On the other hand approximately 600 million people are living without electricity and 700 million people using biomass as a domestic fuel for cooking. Annual growth in energy demand has reached to 8% recently, double of historical average annual growth rates of the past 30 years. India is set to surpass Japan and Russia to become the world's third largest energy consumer after the U.S. and China [22]. With the growing energy demand and environmental concerns the renewable energy sources are the best alternative for electricity generation. According to Integrated Energy Policy (IEP), Indian government has adopted a five year plan to exploit its large scale hydro potential of 150 GW and increase its nuclear capacity to 63 GW at the end of 2032 [21]. In her neighborhood, India has a big competitor in energy production and consumption i.e. China which is the largest energy producer with the share of 22% of the total world energy [23].

In comparison, China possesses a well-established growing industry. It is a country with population of 1.3 billion which statistically becomes 19.24% of the world's total population, according to these statistics China stands on top of the world population table [24]. China is very consistent in maintaining highly stable economy and rapid GDP growth of 7% or more since preceding years. China is the world second largest oil consumer too with annual consumption of 10.7 million barrels per day [25]. China is a stable country in the energy production run which makes its economy stable. In 2010, China became the world's largest power generator with the production of 4716 TW h bypassing USA which produced 4208 TW h [26]. According to the US Energy Information Administration (EIA) the total energy production of China was approximately 5126 TW h in 2013 [27].

China is a developed country in comparison with Pakistan and India which are in developing phase yet. Exploitation of energy resources is vital for economic growth of a country and development of RES can contribute in GDP growth in context of environmental concerns [28]. Annual GDP growth of CIP is compared in Fig. 2 [29].

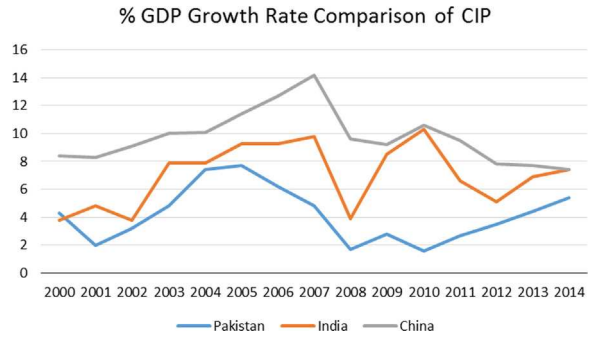


Fig. 2. CIP GDP growth comparison.

Provision of continuous and economical energy supply to sustain socio-economic development and commercial activities is the most important aspect of modern life nowadays. It is essential to make a model to accommodate an economical and environmental friendly fuel mix to maximize the energy production. Despite of economic growth, environment protection is also a massive challenge of the 21st century. China and India are powerful economies with the highest GHG emission rates. China is the leading country while India is on third place in terms of GHG emission. With the growing energy demand, China and India have a massive international pressure to curtail the GHG emission. Both the countries are working on clean energy sources as an alternative choice to meet the energy requirements. Detailed discussion of various RES is presented in the subsequent section.

3. Power generation efficiencies with different resources

Energy generation resources that are mainly used all over the world are fossil fuel i.e. coal, oil and gas while some RES like solar, wind, hydro and geothermal are also used to increase the energy production. According to the worldwide trend, CIP countries are also more dependent on the non-renewable fossil fuels. The total energy produced by China during year 2013 was 5447.231 TW h with the share of coal is 75.46%, hydro 16.89%, nuclear 0.002%, wind 2.5%, solar 0.28% and others 4.15% [27]. Subsequent subsections describe the importance of each renewable energy resource that could overcome the growing energy demands of CIP.

3.1. Solar

Energy production from the sustainable sources is the most challenging task nowadays all over the world. Solar energy is the cleanest and safe energy production source. Hence, practical implementation steps to utilize it are being taken all over the world. To implement a solar power plant, a feasibility study during the planning phase can determine the solar energy potential of the target area. To evaluate the potential of the region, satellites can provide the digital evaluation models, cloud cover map, temperature, surface pressure, surface reluctance, humidity and wind data [30]. Now we will discuss the CIP potential in context of solar energy generation.

Pakistan is giving some serious attention towards solar energy. Pakistan has a very favorable location for solar irradiance due to its geographical location and atmospheric conditions. The sun shine is recorded approximately 7–8 h daily i.e. 2300–2700 h annually [31]. The Balochistan is one of the richest provinces in the world that have 8–8.5 h sun shine a day with the average solar global isolation of 5–7 kW h/m^2, southern Punjab 5–5.5 kW h/m^2 and 4.5–5 kW h/m^2 northern Sindh [32, 33]. The total solar energy potential of Pakistan is approximately 2900 GW h. These statistics

highlight the strong potential for the solar plants' implementation in the province. Investments in this region can facilitate 40,000 villages with electricity [34]. Recently, in Bahawalpur Quaid-e-Azam solar energy park of 1000 MW capacity is under way to suppress the energy shortage in the province of Punjab [35]. On December 15, 2013, an agreement of 300 MW solar plant in Quetta has been signed between Baluchistan government and a South-Korean company [36]. 3000 solar home systems have been installed in 49 villages of Tharkarpar under the rural electrification project (REP), Sindh. Moreover, 51 villages in Sindh and 300 villages in Baluchistan have been approved for solar electrification [37]. This approach will meet the energy demands in the small localities with low transmission cost. Moreover, 1500 units of solar water heaters are being imported and installed in Balochistan, Gilgit-Baltistan, KPK and northern Punjab. Also 22 solar projects with the capacity of 772.99 MW are being installed at different locations which will be commercialized by the end of 2016 [38]. Pakistan has enough solar potential that only 3000 km^2 land would be enough to fulfill the current energy demand.

If we compare this with India, it was expected that nuclear energy will add its contribution in Indian energy production by the end of 2030. However, due to safety reasons as seen in Fukushima power plant in Japan it is hard to rely on nuclear sources. Furthermore, international pressure regarding environmental concerns on the countries has compelled governments to focus on renewable energy resources. Fossil fuels are depleting day by day, so for clean energy production, solar energy is one of the most appropriate options. The total solar energy potential of India is approximately 5000 trillion kW h per year with most of the part receiving average solar irradiance of 4–7 kW h/m^2/day [39,40]. In 2009, India had declared its National Solar Mission (NSM) for installation of 22 GW by end of year 2022. Moreover, 1000 MW in 2013 and 3000 MW by end of 2017 has been planned to be added in the system [41,42]. However, the present Indian Government extensively enhanced the solar energy plans and set a target of installing 100 GW by the end of 2022 [39,43]. In the year 2015–16, 827.22 MW was included in system which increased the total installed capacity up to 4579.24 MW [44]. Building Integrated Photovoltaic (BIPV) is the current developing concept for the integration of solar panels in India. According to this concept, in the new architecture of buildings, roofs are made with double-skin facades and ventilators in which opaque and semitransparent PV elements are used [45].

Now in case of China, it has a lot of potential in solar energy field having 2200 h annual sunshine in its two third parts so it is very economical for the country to use solar energy for electricity production. The daily average irradiance of China is approximately 4 kW h/m^2/day, but it varies with the area. In southern-east part of country, the average irradiance is 2 kW h/m^2/day however, in parts of west the irradiance is 9 kW h/m^2/day [46]. In 2009, first Asian solar project was built by China which was installed in Gansu Dunhuang, Tibet Lhasa desert, the Gobi, waste lands and the other inner lands in Mongolia [47]. There are more than 400 PV companies which produce 18% of the PV products worldwide. PV cells are being installed in the buildings to cover the energy demand. Olympic Village of China is also based on this concept. Many small and large scale solar plants are under installation in China like desert solar PV and rooftop PV plants. According to the National Development and Reform Commission (NDRC), installed capacity of solar energy is being planned to increase up to 1.8 GW by 2020 [48].

According to the national survey report on PV application in China, the total install capacity was 28.05 GW ranked 2nd in the world after Germany [49]. China has adopted a road map to obtain the energy from clean, low carbon emitting, secure and reliable sources by 2050. For this purpose, China is strictly working on RES to curtain the usage oil and coal in energy sector. By 2050, solar

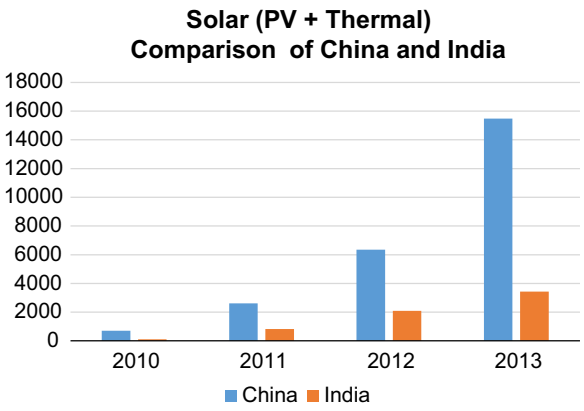


Fig. 3. Solar Energy Comparison China and India.

and wind energy will be the major contributor with the share of 64% of total energy. The average growth rate of PV market will be 35% annually up to 2020 and will be maintained 25–30% during 2020–2030 [50]. The growth of the solar energy will be maintained and total installed capacity will reach to 2.7 billion kW by 2050.

A comparison of electricity generation using solar PV and thermal resources of India and China is shown in Fig. 3. Graph shows rapid development of solar energy in China and India's development is also reasonable. However Pakistan has not generated any electricity at grid level using solar energy during 2010–2013.

3.2. Nuclear energy

Pakistan is a nuclear capable nation, however, the country is still very slow in nuclear energy production due to non-skilled man power and lack of initiative. In 2013 three major power plants Karachi Nuclear Power Plant (KANUPP), Chashma Nuclear Power Plant unit-1 (C-1) and unit-2 (C-2) produced 399 million kW h, 1474 million kW h and 1161 million kW h, respectively [51]. Currently, Chashma Nuclear Power Plant units 3 and 4 are under construction and four plants, each of 1000 MW has been planned in Karachi. Government has a plan of producing 8800 MW from nuclear by 2030. The Indians are somewhat ahead from Pakistan in this respect.

India has limited uranium resource of 141 kton, with some hidden resources too, which are called forecasted and hypothetical resources. Indian total identified assets are 73 kt with confirm presence of uranium 49 kt and 24 kt considered as surplus resources. These resources have capacity to supply about 440 GW annually with the supposition of 17 t uranium required per 1 GW. India also possesses estimated Thorium resources of 225 kt, and using breeder reactors annual production of 155,500 GW could be obtained from it. The issue in using these Thorium resources for nuclear power generation is the requirement of complicated nuclear technologies chain as compared with Uranium.

India has total 19 reactors out of which 17 are Pressurized Heavy Water Reactors (PHWRs) and two are the Boiling Water Reactors (BWRs). The installation of first Asian nuclear plants was performed by two BWRs, commissioned in 1969. The total contribution of the plants was 4.540 GW, 3% of total installed capacity. Since India has limited resources of Uranium therefore the operational capacity of nuclear reactors is just 45–55%. China deals with nuclear energy in a rather different way.

Only 1% electricity has been produced using nuclear resources in China. China's plan is to increase the nuclear contribution in energy production to minimize the coal consumption. Due to 2011

accident in japan, China temporarily suspended nuclear production to revise safety of its nuclear frameworks. By the end of 2011, nuclear contribution was raised to 2%. In 2013, two reactors were added which raised the capacity to 16.7 GW. Currently, 31 reactors are operating with production of 35 GW. In future, the approach of the energy sector is to attain the aim of having 58 GW capacity. For this purpose, plants are being installed and commissioned and will be operational by the end of 2017 [52].

3.3. Hydro electrical

Hydro power is the finest and cheapest energy available. Hydro power plant is usually considered as mega project in the production run. Therefore, feasibility check like precipitation, snow cover, snow temperature, snow melting conditions, water flow, terrain conditions with elevation model and land cover that may alter the river flow are important to notice [30]. This information can be obtained by satellite sensors.

Pakistan is a rich country in hydro power resources. According to the integrated energy plan 2009–22 the total hydro potential of Pakistan is 59 GW whereas the small hydro projects have the capability of producing 2000 MW [53]. In year 2013–14 the total electrical energy production was 97,796 GW h with approximately 31% share of the hydro in total electricity generation [54]. Some of the ongoing mega hydro projects are Neelum–Jhelum, Diamer Basha dam and Dasu dam. Total installed capacity of Neelum–Jhelum is 1000 MW with annual energy generation of 5150 GW h [55]. This project is being constructed on river Jhelum in the vicinity of Muzaffarabad with the help of China and is expected to be completed in 2017. Diamer Basha dam location is on Indus River in Gilgit-Baltistan. The total installed capacity of the dam will be 4500 MW with 16,500 GW h of electricity generation annually and is expected to be completed in 2022 [56]. In developing dams for the hydroelectric power, two major issues are being faced. Firstly, initial investment is very high and second is the resettlement of original inhabitants. Therefore, to address these issues in a developing country like Pakistan micro, pico and mini hydro projects are being installed in hilly terrains [57]. These mini projects cover the energy demands of nearby villages and localities. Target of new government policies is to generate 2700 MW energy in 2015. There is a small level hydro project established in Lahore city on trial basis that uses municipal water wastes to produce energy [58]. It can be an alternative in the country like Pakistan for electricity production.

Pakistan is facing electricity shortfall in thousands of MWs, therefore, serious attention is required to cover this gap. Establishment of small canal plants can help in reducing this gap. Punjab has a strong canal system that is only being used for agricultural purposes. It will be more efficient to use this system for energy production by considering water flow rate and kinetic energy extractor or propeller [59]. With 70% efficiency, these projects can add 13–16 MW each in the system. Comparatively, in hydro energy, India is a titanic.

India's current installed capacity of hydroelectric is approximately 42,472 MW and 15,000 MW power projects are under construction [60]. India's hydro resources stand at seventh position in the world, which is a remarkable figure. According to the Central Electricity Authority (CEA) the total hydro potential of India is about 150 GW, or 84 GW considering the load factor of 60% [61,62]. The hydro potential of India are divided into five regions with Northern part of the country is leading with 55%. The region wise hydro potential are presented in Fig. 4 [63].

Practically India has limited capacity factor of hydropower, keeping in view a national load factor of 43% on average as of 2007. It is due to factors like the design of vintage hydropower plants being used and relying more on monsoon rainfalls. Also 90% (around 98 GW) of the left hydro power is based only on the Himalayan mountain regions. India also has a potential for small hydro plants constituting 15 GW of power distributed among 5400 regions. India has already gained 2.5 GW of this potential by the end of 2009 and the remaining projects contributing about 1.9 GW are in various stages of implementation [64]. Here too, India is far behind her neighbor China.

China has been using its hydro electrical resources with 6% contribution in total electricity mix till 2010. Because of its cost, efficiency and environment friendly features, it looks better to maximize the hydro electrical energy production for any country. Therefore, in 2011, 687 TW h (Terra Watt hour) was generated. In 2012, the total installed capacity reached to 249 GW by the addition of Three Gorges Dam at Yangtze River which is the world largest hydro electrical project having 32 generators of 22.5 GW capacity. By the end of 2014 the total installed capacity of China was 280 GW which produces 1064.34 TW h of electrical energy. In 2015 China has a goal of increasing hydropower capacity to 284 GW and 41 GW of pumping storage capacity [65]. China has set a target of increasing the hydropower capacity up to 510 GW and 150 GW pumped storage by the year 2050 to reduce the share of coal in energy mix.

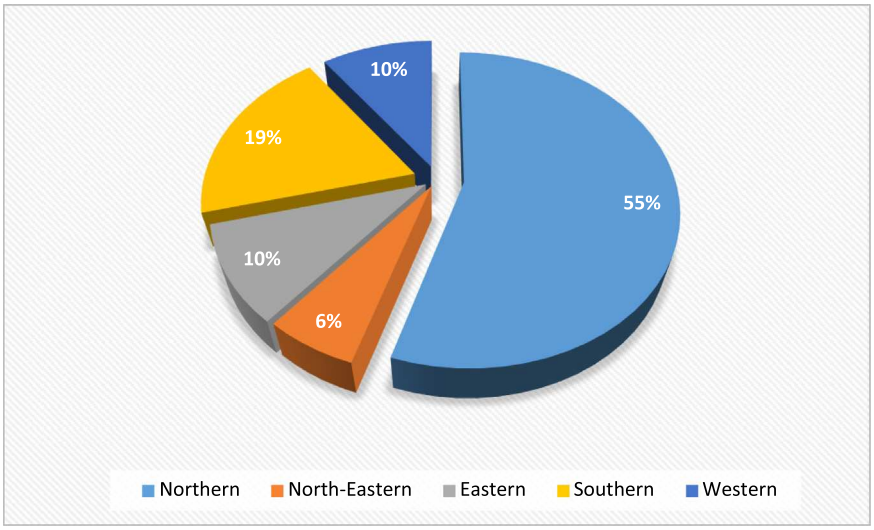


Fig. 4. Percentage of hydro potential of India region-wise.

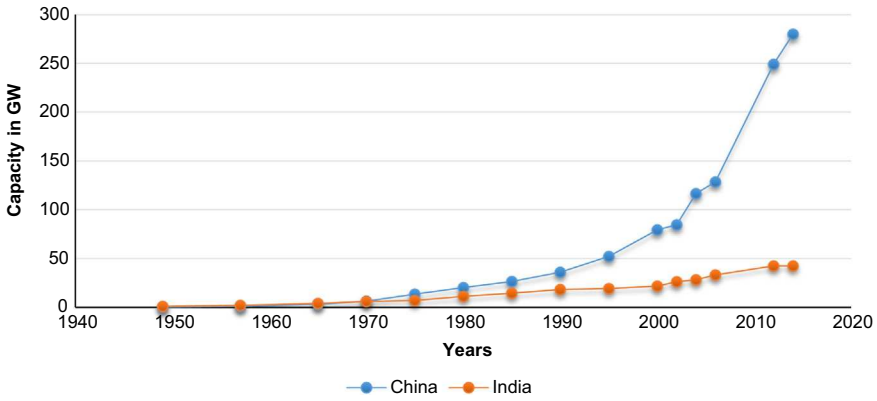


Fig. 5. China and India hydro power growth comparison.

Both China and India has a well-designed frame work in the shape of five year plan to exploit the hydropower energy, while Pakistan has recently published Energy Policy 2015. The comparison of the China and India in hydropower sector is presented in Fig. 5 however, the data for Pakistan is not available for whole of the comparison horizon [63,66].

3.4. Biomass

Biodiesel is another alternative to obtain energy. Different crops are grown to obtain this fuel [67]. To analyses the best production sites, satellites are used that provide the feasibility of the crops like photosynthesis, direct beam solar radiation, diffuse skylight and temperature in specific region, time and sources [30].

Biomass is also a significant source of energy production in Pakistan [68]. There are three types of biogas energy sources: livestock, bagasse and agriculture. Biomass energy is more economical than the coal, oil and other resources. In addition, it has the de-centralized availability all over the country which leads to the production at many sub levels [69]. This sub level production can cope the energy demands in villages and towns having biomass reserves. Biogas has less CO_2 emission but there is a major methane emission to atmosphere which increases the greenhouse effect 23 times as compared to CO_2 which is a major threat. Pakistan has made a policy to add RES for energy production, Alternative Energy Development Board (AEDB) has been established to contribute 5% energy production from renewables. AEDB is now working on energy production project by using huge resource of biogas near Karachi in Landhi cattle colony to produce 30 MW which is being funded by New Zealand. Another letter of intent was issued for 12 MW power plant established for utilization of agricultural wastes in Jhang and 9 MW plant is going to be installed at Pak Ethanol Pvt. Ltd., Sindh. Moreover, 5000 biogas units will be installed all over the country by Pakistan Counsel of Renewable Energy Technologies (PCRET) [70]. Government has invested 356 million to import 1400 biogas plants. Pakistan has a considerable potential of biomass in the form of bagasse which is abundant in sugar mills. In the last 5 years, total bagasse production is 13,569,180 Million tons (Mt) per annum and 5654 Mt per hour. The energy production from this could be 1304 MW/h while the current production is only 478 MW/h [71]. India is ahead here too.

In India, according to current estimates, 20 million hectors consisting of wastelands have the potential that could yield about 5 ton of extra biomass energy per hector per annum if proper use of this land is made possible. Attributing on a lower scale estimation of about 17 MJ/kg, 80–100 MTOE of total energy can be attained from biomass forced plantation. Expecting heap component around 60%, this biomass can maintain 25 GW biomass power as a whole. China heads here as well.

China is an agricultural country so it has penalty of biomass resources like agricultural residue, fuel wood saving and animal manure. China has the most abundant straw resources in the world. Biomass is a major energy source in China in which crops and forest residues of rural areas play main contribution and livestock waste has a minor but considerable contribution. Agricultural residues are the by-products of agricultural crops which increase with the increase in crops production and China has 748.16 Mt potential of this source. Fuel wood is the biomass source obtained by burning the forest woods which is 104,748.6 thousand tons. Animal manure is about 922,286.5 thousand tons in China. It has a potential to cover the 10% energy shortage in the country [72].

3.5. Wind

Wind power can also be the best source for energy production. However, wind power plant installation is a costly and lengthy process. To minimize the cost and length of installation, satellites are used to provide topography, terrain roughness, obstacles, land cover, wind flow and stability. This data is gathered by different instruments installed at the site [30].

Wind is another renewable energy source that can be used to minimize energy crises in Pakistan. Geographically, the sea side of Pakistan possesses enough wind pressure to produce energy. According to metrological department, there is a need of a thorough study to observe the wind potential near higher altitudes. 1000 km coastline in south and some northern hilly areas have a lot of wind potential with monthly average speed of 7–8 m/s [73]. According to the meteorological department of Pakistan the gross wind power production is approximately 43,000 MW in the coastal areas of Sindh [74]. Pakistan has had less progress in wind energy production. There are some plans to produce 700 MW in Gharo near Sindh [57]. There are some long term projects too in which 9.3 GW production is the target till 2030. In December 2010, Fauji Fertilizer Company installed a wind power plant of 50 MW capacity to provide energy to the National Grid (HESCO) and during the same year ZorluEnerji Ltd. installed project of 56.4 MW which was commercialized. Pakistan's coastal region is a very ideal site for wind power production. Some regions of Sindh, Baluchistan and KPK are also very appropriate for the wind power plants and they possess a potential of 50,000 MW. These require some initiatives to be taken for the installation of wind plants. This is possible, if the budget is allocated for these projects by reducing oil or coal share.

India's wind power capacity is around 48–60 GW. The potential is relatively uncertain in comparison with the estimated potential

curve of the total power demand of the country. The larger part of the onshore potential gained from wind is located in Karnataka, Andhra Pradesh and Tamil Nadu which makes up for 54% of the onshore wind potential of the country. India has 7516 km of coastal line and territorial water extended to 12 nautical miles in sea which is an ideal site for wind power plants. India has gained a lot of advantage from these locations and has the third world's largest wind market. Total wind power installation in India by the end of 2011 was 16,084 MW. In 2013, Ministry of New and Renewable Energy (MNRE) has achieved a target of 15,000 MW of new installations and had an aim to achieve 25,000 MW by the end of 2014 [75]. Although India is utilizing its wind resources very efficiently but the production needs to be raised by governmental fund raising if they have to compete with China.

China is one of the countries where coal production is on its peak. In China, coal usage in electricity production has a major contribution towards total generation mix. However, these resources are also being used in other industries. Therefore, China is focusing on the RES like Wind. A policy mechanism Wind Resource Concession (WRC) has been designed to motivate public and private sector to invest on the wind units at appropriate location to obtain an alternative of coal energy production in the form of wind power. Since 2010, China has been increasing its wind energy production by generating 73 TW h. The country possesses such a huge wind potential that its annual capacity has been doubled each year since 2005. Coastal regions and islands have wind density more than 500 W/m^2 and it could contribute 11 GW which is 4% of reserves all over the country [76]. Government has encouraged the National Development and Reform Commission (NDRC) planning to increase the capacity to 100 GW before 2016. Wind plants are being installed and funded by the government to achieve this goal. The yearly comparison of wind electricity generation in CIP is shown in Fig. 6 [77].

3.6. Geothermal

According to research, the heat energy potential in the upper earth surface is about 50,000 times the cumulative oil and gas reserves [78]. Geothermal heat can be used directly for heating or cooling purposes or it can be used for electricity generation. So its utilization can maximize the electricity generation very efficiently. Pakistan has an enormous potential of geothermal which it has not explored till now, but some oil and gas companies are working on it [1].

As far as India is concerned, geothermal power reserves are predominantly situated in the Himalayas, in Jammu and Kashmir and in Himachal Pradesh. In addition, potential destinations of geothermal energy capable regions include: Sonata bowl in Madhya Pradesh and Chhattisgarh, Cambay bowl in Gujarat, Godavari bowl in Andhra Pradesh and Sohana bowl in Rajasthan. The aggregate potential is around 10 GW. India do not possess a single fully functioning geothermal power plant in use as of now but five projects with a combined capacity of total 251 MW are in developing stage.

Now if we analyze China, it also possess good geothermal potential. There are shallow geothermal resources with a potential of 2.78×10^{20} J in some cities of China of which only 2.89 PW h are utilized annually. There also exist many other sources of geothermal energy like sedimentary basins of China and hot dry rocks. China has enough geothermal resources that only 2% enhanced geothermal systems recovery can increase Chinese annual energy production by 5300 times [79].

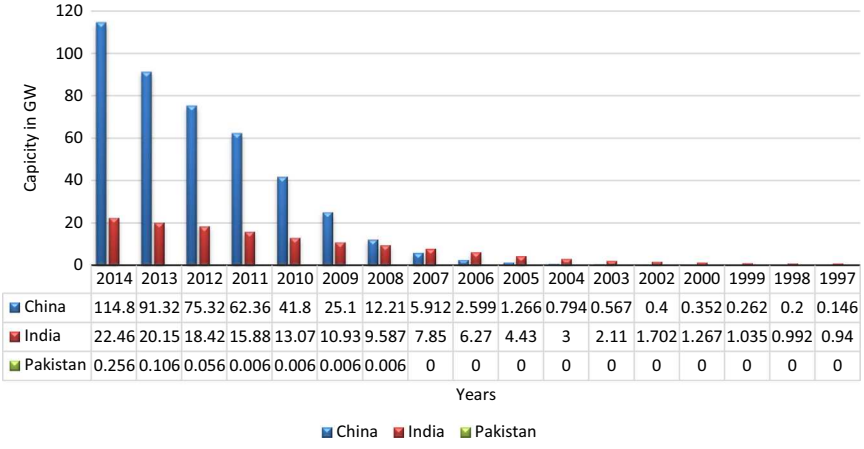
A comparative overview of CIP countries regarding energy resources and related parameters has been shown in Table 2.

4. Energy sharing among CIP countries

This section explores energy sharing opportunities among CIP countries and regional energy security. If we analyses India and Pakistan relations, there has been a lot of ups and downs from the very first day of subcontinent's division. Both the countries have geographical and many other conflicts that are obstacles in trade path and resource sharing between the two countries. Since 2008, both the countries have shown some interest in trade and energy sharing. This step might be a path of peace and economic stability in the region. Recently, India has announced increase in trade with Pakistan from $2.6 billion to $8 billion. In the energy perspective; Turkmenistan, Afghanistan, Pakistan, and India (TAPI) gas pipe line project, Central Asia South-Asia (CASA 1000) and Diamer-Basha dam are positive steps taken by both the countries to share energy resources.

Tajikistan and the Kyrgyz Republic are capable of about 80,000 MW power from water, of which only a very meager percentage i.e. about 10% has been utilized till now. CASA-1000 project is a productive effort to export electricity from Kazakhstan and Tajikistan to Pakistan and Afghanistan. CASA-1000 project will enable the two nations to trade about 1000–1300 MW of usable electricity between them.

To reduce Pakistan's energy shortage, India has offered to export its LNG and electricity. According to the proposed plan, a pipeline would start from Gujrat and will pass through Dahej, Vijaipu, Dadri, Bawana, Nangal and Bhatinda (the Indian Punjab) to Lahore Pakistan. After the Indian government's declaration of an



	2014	2013	2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2000	1999	1998	1997
China	114.8	91.32	75.32	62.36	41.8	25.1	12.21	5.912	2.599	1.266	0.794	0.567	0.4	0.352	0.262	0.2	0.146
India	22.46	20.15	18.42	15.88	13.07	10.93	9.587	7.85	6.27	4.43	3	2.11	1.702	1.267	1.035	0.992	0.94
Pakistan	0.256	0.106	0.056	0.006	0.006	0.006	0.006	0	0	0	0	0	0	0	0	0	0

Fig. 6. CIP yearly wind power generation comparison.

Table 2
Comparison of CIP energy resources and related parameters.

Parameter		Pakistan	India	China
Population in billions (2014)		0.1851	1.2	1.3
GDP (2014)		$246.9 billion	$2.0 trillion	$10.3 trillion
GDP growth rate % (2014)		5.4	7.4	7.4
Inflation % (2014)		7.2	6.4	2.0
Per Capita Electricity Consumption (kW h)		449	680	3298
Electricity	Net generation (billion kW h)	89.60	904.13	3508.39
	Net Consumption (billion kW h)	72.08	660.98	3271.19
	Installed capacity (GW)	22.12	207.72	987.94
Natural gas (BCF)	Production	1382.58	1681.70	3628.65
	Consumption	1382.58	2260.51	4623.51
	Net import/export	0.00	−578.81	−999.86
	Proved reserve (TCF)	26.62	40.75	107.0
Petroleum (thousand barrels)	Production	68.33	995.81	4346.98
	Consumption	418.00	3410.54	9852.08
	Net Import/Export	−349.67	−2414.74	−5505.10
	Proved reserve (billion barrels)	0.28	5.61	20.35
CO_2 emission (Million metric tons)		141.89	1601.24	7997.04
Hydro potential (GW)		59	150	271.5
Wind potential (GW)		50	48–60	100
Solar (GW)		2900 (estimated)	700–2100 (Thar desert estimated)	18.3 (Installed capacity)
Coal (Million tons)	Production	4.044	639.627	3844.942
	Consumption	6.900	721.419	3826.869
	Net import/export	−4.704	−58.995	−139.070
	Reserves (billion tons)	186	267	114.5
Nuclear Installed Capacity (GW) (2014)		0.7	5.78	35

offer in Seoul Nuclear security in 2008, Pakistan also agreed to import 5000 MW electricity from India through Kasur border to recover the short fall in Lahore division and its surrounding areas [80]. Another project to link India and Pakistan has been funded by Asian Development Bank (ADB) is TAPI. This project bears the capacity to bring 33 billion m^3 natural gas in Pakistan and India from Turkmenistan via Afghanistan. For the purpose, ADB has funded $7.6 billion. This pipeline would be completed by the year 2018 and may help reduce 25% shortfall of Pakistan [81]. Now the government of the Punjab, Pakistan has shown willingness to India to import 500 million cubic gas per day and 500 MW electricity to meet the demands of Lahore city. Transmission lines are being installed to give practical shape to the project [82].

Pak–China relations were established in 1956 and a slogan was raised as Pak–chin 'bhai–bhai' (brotherhood). China is the largest arms supplier to Pakistan. From economic and trade point of view, China has shown very positive response towards Pakistan; Gawader port, Karakoram Highway and the construction of airport in Balochistan are practical examples of this approach. China's Great United Petroleum Holdings is going to install an oil refinery of capacity 60,000 barrels of oil per day with an investment of $12.5 billion in Pakistan to meet the growing oil demands [83]. This refinery is the part of the proposed China Pakistan Economic Corridor (CPEC). According to Pak–China Joint Energy Working Group (JEWG), the corridor also includes 19 projects that would be installed within Pakistan to tackle the energy shortfall in the country. These 19 projects include four power generation projects having the total capacity of 2297 MW, a coal plant installation having capacity of 405 MW, a project of mining, power generation from Thar coal and five project of transmission line installation and distribution over the region. These projects have completion period duration of 3–5 years [38]. Furthermore, two power plants would be installed in Thar to produce 18,000 MW using 10 Mt coal annually. Some other projects have been announced later including 660 MW project in Lahore city by the collaboration of Punjab government and Chinese Corporation. Another project of solar plant with capacity of 1000 MW is part of the agreement also. Wind energy generation is also under consideration in these mutually collaborated projects [84]. Moreover, in Karachi, another $130 million of investment is being made by China for the installation of 50 MW project in Gharo, Sindh to meet the increasing energy demands in Pakistan [85].

India and China have independence with difference of two years. There is a natural barrier of Himalayan Mountains between the two countries. To remove this barrier, diplomatic conversations were started in 1950 to encourage the positive relations between the two nations. In 1962, again the wall came in between India and china due to border dispute [86]. In 1976, negotiations were started to regain the old relations, both the countries showed friendly response to make trade and economic development projects. Geographically, the water flows down to India from China, like Brahmputar River that originates from Nepal then passes through Tibet and flows down to India. China gets 110,000 MW from this river and has assured India about water flow level downstream because of Indian dependency on this river in energy production and irrigation context. Arunachal Pradesh is another disputed point between India and China. India gets 30% of its hydro power from the region. Energy sharing can be made possible by resolving the controversial issues between the two countries regarding water and boundary [87]. By bilateral efforts, recently, the Renewable Energy and Energy Efficiency Partnership (REEEP) agreements worth around more than €3.2 million for the development of 35 new projects in the region has been made. In these projects, India and China would be funded for biomass gasifier systems to enhance the use of biomass in energy production [88]. This is the first attempt to maintain a healthy relationship between these two nations for the future development of the region. Furthermore, efforts are being made to explore energy production process between the countries to help increase the energy production of the region.

India has recently objected on Pak–China economic corridor due to her concerns about disputed region of Jammu and Kashmir which could be a serious threat to CIP energy sharing projects. China has been investing in Pakistan to enhance its trade and energy sharing opportunities. In essence, it is needed to explore the energy sharing opportunities among CIP countries in order to ensure the peace and stability of the region.

5. Conclusions

In this paper, we have reviewed the CIP RES and energy sharing opportunities in context of regional development, peace and prosperity. China is leading the heavily populated countries of CIP with respect to the electricity generation of 5447.231 TW h with 19% RES contribution. India is following china with electricity generation of 1193.48 TW h having 17% RES share and Pakistan is lagging far behind with electricity generation of 97.796 TW h and it has 36 % RES contribution. Share of coal resources in electricity generation of China and India is very high which is needed to be gradually replaced by renewables in order to control the carbon emissions. There is a huge potential of RES for the CIP countries which have seen only minor contributions of renewables in their electricity production. Exploration of these potentials can mitigate the shortfall of electricity in the region. If we observe statistically, the countries which have huge populace are led by China as the most appropriate producer and user of energy. India is going fair and has made a rapid development in the sector. Pakistan, being barred by political and economic instability, is lingering behind them with a huge difference.

Energy shortage is a mutual dilemma of CIP countries and there is no better way of overcoming it except mutual understanding, negotiations and enhanced trade and energy sharing relations. All barriers should be removed by mutual consent and the governments of these nations should sort out a way of dealing with various problems that are hindering the consolidation of resources and technology among these nations.

In this work we have also discussed the direction and implementation of five year energy plans in China and India and found that overall situation is encouraging while Pakistan has faced implementation failure in its energy plans because of the economic, political and security problems. However, friendly relationship of China with Pakistan and its heavy investment in Pakistan's energy sector through CPEC is promising. Furthermore, the involvement of India in energy sharing projects among CIP will enhance the pace of regional development.

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