Current Energy Situation And Comparative Solar Power Possibility Analysis For Obtaining Sustainable Energy Security In South Asia

Anmona Shabnam Pranti, M. Shahed Iqubal, A. Z. A. Saifullah, Md Kayesar Ahmmed

Abstract: Now a day energy crisis is the burning question. Electrification rate increment is necessary to obtain sustainable energy security for South Asian region. This paper deals with current social and energy situation of different South Asian countries, comparative study of solar energy intensities and cost of electricity production, necessity and feasibility of solar power in South Asia with developed countries. In South Asia electricity demand is increasing because of high population growth rate compared with very limited source of primary energy as well as policy and technology which is used for producing electricity. All the data have been collected from different authentic websites and books. The primary source of energy for producing electricity is very limited in South Asia which leads to think about the renewable energy. Since solar energy is available in all most all the regions in South Asia, it could be the main source of producing electrical energy in future to accomplish energy security.

Index Term: South Asia, population growth, electricity demand, energy security, renewable energy, solar energy, sustainable economy.

1 INTRODUCTION

Energy plays an important role in our daily life as well as in the national security of a country. It runs the wheel of economy of the country. The recent increase in energy prices, population and industrialization in developing countries are the most significant threats to energy security. The South Asian region is poorly endowed with energy resources. It has vast population with limited land. The per capita commercial energy consumption is very low. A significant portion of South Asian society is still unable to access electricity. The energy demand is increasing day by day with population growth indicating poor security of energy. The regular shortages of energy and electricity infrastructure are the major factors to keep this region at a low growth economic condition and the lowest per capita electricity consumption. But South Asian region is blessed by plenty of renewable energy possibilities which can be used to eliminate energy scarcity problem and to get a sustainable economic growth.

2 REGION OF SOUTH ASIA

Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, and Sri Lanka are in the South Asian region. More than one-fifth of the world's people live in these countries having lowest per capita income in the world. With the population of 1.55 billion [16], South Asia has become important world's energy market. Because of over population, this region is facing rapidly growing energy demand.

- *Anmona Shabnam Pranti, M.Sc student, Dhaka University of Engineering and Technology, Gazipur, Bangladesh. Email: a_s_pranti@yahoo.com*
- *A. M. Shahed Iqubal, Faculty, Department of ME, IUBAT— International University of Business Agriculture and Technology, Dhaka, Bangladesh. E mail: iqubal.shahed@iubat.edu*
- *A. Z. A. Saifullah, Professor & Chair, Department of ME, IUBAT— International University of Business Agriculture and Technology, Dhaka, Bangladesh. E mail: d.saifullah@gmail.com*
- *Md Kayesar Ahmmed, Assistant Manager, EEE Department, Green Land Builders Limited, Dhaka, Bangladesh. Email: maks_eee_cuet@yahoo.com*

Fig. 1. Region of South Asia

Figure 1 shows the region of South Asia. Because of over population, this region is facing rapidly growing energy demand.

TABLE 1
POPULATION, POPULATION GROWTH RATE AND GDP/CAPITA BY COUNTRIES

Country	Bangladesh	Bhutan	India	Maldives	Pakistan	Nepal	Sri Lanka	Total
Population (million)	156	0.69	1,166	0. 396	176	29	21	1549.08
GDP/cap[14]	1300	4100	2500	4,400	2400	1000	3900	2359.84
Population growth rate[16]	1.29	1.27	1.55	-0.17	1.95	1.28	0.9	1.15

Table 1 shows population, population growth rate and GDP/capita by countries.

3 SOUTH ASIAN ENERGY SITUATIONS

The developing South Asian countries have high population growth as well as economic advancement. So in recent years, energy consumption has increased rapidly. In 1980 total primary energy consumption in South Asia was 1.7% of the total world energy consumption which grew 2.36% in 2006 [13]. Though the energy consumption increases

drastically, this region still remains in the lowest per capita energy consumption region of the world [3]. Most of the rural people of this region use non-conventional form of energy. Moreover, a significant number of them depend on biomass. In 2008, biomass was used for meeting 80% residential energy needs and it is also expected to remain 70% in 2020 [3].

3.1 Commercial energy

Fig. 2 shows commercial energy mix in South Asia.

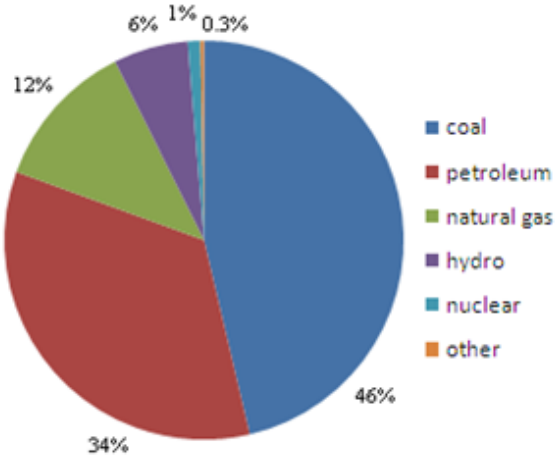

Fig. 2. Commercial energy mix in South Asia

South Asia's commercial energy mix may vary from country to country. But they are all most similar. Coal is the dominating fuel along with petroleum and others, mostly non-renewable form of energy. The contribution of renewable energy is very negligible in the mix. In recent years, South Asia is facing a rising energy demand because of both insufficient energy sources and uprising population. The energy crisis affects the electricity generation. A large number of people remains without electricity and economic growth are going downward.

3.2 Oil

South Asia has a proven oil reserve of only 5.7 billion barrels which is 0.5% of world's reserve [3]. In 2002, this region consumed around 0.00272 bbl/d of oil and produced 0.0007bbl/d [3]. In2009, the region consumed around 2970750 bbl/d of oil and produced 909566 bbl/d [20]. From the figure, it is clear that, the production of oil is very little in comparison with consumption. So, South Asia has to import huge amount of oil per year to meet its demand. Thus, South Asia is a net oil importer region. Figure 3 shows oil production and consumption in 2002 and 2009 respectively.

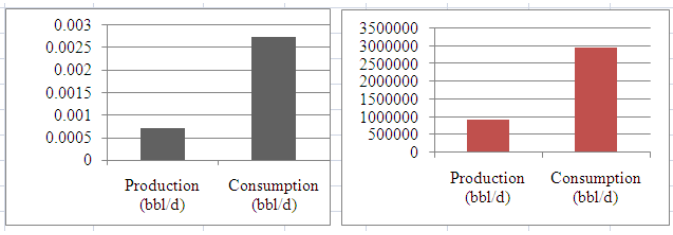

Fig. 3. Oil Production and consumption in 2002 and 2009 respectively [4], [24]

3.3 Natural gas

South Asia's proven natural gas reserve is estimated as 1.96×1012 cubic meter [21], which is approximately 1% of the world's total gas reserve. Among seven South Asian countries, only India, Pakistan and Bangladesh have natural gas reserve. Moreover, almost all natural gas produced is consumed domestically [3]. Though there is no net import of natural gas, there is no net export also which can help to raise the economy.

3.4 Coal

South Asia has proven coal reserve of 95.5 billion short tons or approximately 9% of the world's total reserve. Coal accounts for 46% of South Asia's total energy consumption. In 2008, coal production and consumption were 572.219 million short tons and 651.063 million short tons respectively [5],[6],[7],[8], [9],[10],[11]. Figure 4 shows production and consumption of coal in 2008.

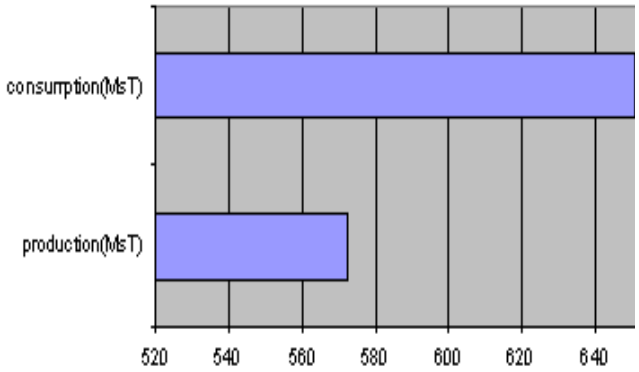

Fig. 4. Production and consumption of coal in 2008

From the above figure, it is evident that South Asia is a net coal importer region. Most of this imported coal is used in power generation. Coal consumption and the consequent carbon dioxide emission are expected to increase in the coming decades.

3.5 Electricity

In recent year, South Asia generates 798.6 billion kWh of electricity [12]. Of which, 81% comes from thermal power plant and only 1% comes from renewable energy sources (except hydro electricity) [3]. In the coming decades coal fired electric power generation is expected to increase in South Asia. Hydro electricity will be the dominating in Bhutan and Nepal who have mostly this kind of energy source. Other renewable like solar and wind will have small contribution [3]. South Asian electricity infrastructure is very poor. Due to this infrastructure, 221.115 billion kWh of electricity was lost in 2007 [3].

4 ELECTRICITY SITUATION BASIS COUNTRY ANALYSES

Electricity demand in South Asia rises day by day with the increasing population. A little percentage of this huge population can access electricity. Those who can access electricity are suffering from chronic shortage of electricity or massive load shading. The main reasons for this situation are primary energy shortage, poor generating technology, low load factor and losses of power due to

transmission [3]. An analysis of different energy according to the countries is given below:

4.1 India

34% of global energy consumption has made India the world's 6th largest energy consumer [22]. Indian power generation install capacity is considered as 149391.91 MW [22]. Fig. 5 shows source wise electricity production in India.

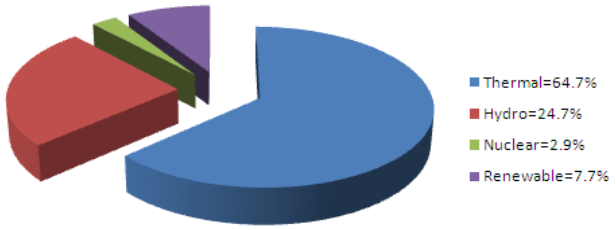

Fig.5. Source wise electricity production in India

From the figure it is clear that thermal power is dominating means of power production in India and the install capacity is 93398.64 MW [22]. However, renewable energy install capacity is only 13242.41 MW [22], which is much lower compared with thermal power generation. Among thermal power coal base power generation is significant, around 77458.88 MW [22]. Oil and gas base power plant produce 1199.75 MW and 14734.01 MW power respectively [22]. Transmission loss is 30-45% in India [22]. Due to high transmission losses huge amount of power is wasted. Indian demand for electricity grows 3.6% per year [22]. Though 80% population can access electricity but they always face power shortage and black out. However 80% villages have electricity line but 56% rural household cannot access electricity. Current per capita electricity consumption is 487 kWh. The electricity generation is 30% below the demand. Total demand of electricity is expected to grow up to 950000 MW by 2030 [22].

4.2 Pakistan

Pakistan's install capacity of power generation is 19505 MW [23]. Fig. 6 shows source wise electricity production in Pakistan. From the figure it is clear that, in Pakistani power generation mix, thermal power is dominating. On the other hand there is no contribution of renewable source in power production of Pakistan. Thermal power installed capacity is 12580 MW [23].

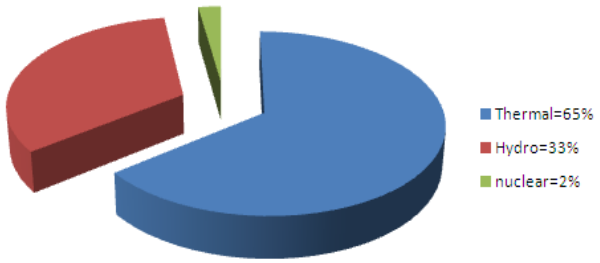

Fig.6. Source wise electricity production in Pakistan

Very few rural populations can access electricity and more than 50% people are not connected to national grid [23]. Moreover, transmission loss is 30% due to poor transmission system [3]. In 2009, power demand of Pakistan was 17868 MW where as generation was 16110 MW. In 2018, the generation is expected to grow 24481 MW but at the same time the demand will grow up to 34918 MW [23]. Pakistan is suffering from a massive electricity shortage. Very few people are connected with national grid and electricity shortage is 15%. So power blackout has become a usual event in Pakistan [23].

4.3 Bangladesh

Bangladesh has a net installed electricity generation capacity of 5719 MW, of which 4162 MW is considered to be available. Power demand is 6,066 MW [24]. Only 40% population of this country can access electricity and per capita electricity consumption is 136 kWh/year [12], which is among the lowest ones in the world. Fig. 7 shows source wise electricity production in Bangladesh.

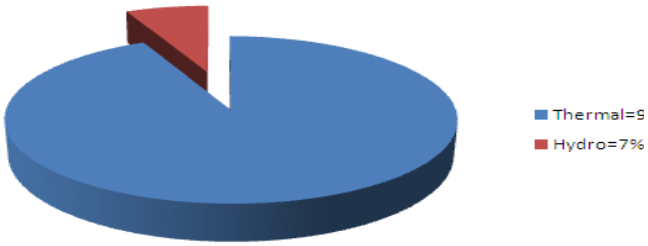

Fig. 7. Source wise electricity production in Bangladesh

Thermal power is the main contributor in power generation which is 5789 MW. Hydro electric power installed is only 230 MW. There are no contributions of other sources or any other renewable power sources in power generation of Bangladesh [24]. Bangladesh has very little energy reserve. Small amount of oil, coal and countable amount of natural gas are reserved here. 93% power producers, thermal power plants, are mostly gas based. But gas is needed for fertilizer and other industries. So, the country has to compromise between power production and industrial growth because it is not economic to use all of this gas reserve in power production. Country's coal reserve is too small to support the increasing demand. If they want to produce power by imported coal, it will be very expensive [1]. Energy situation in Bangladesh is deteriorating day by day. The generation capacity is too low; on the other hand the energy infrastructure is quite poor. Transmission and distribution loss is 13.57% [24]. Huge amount of power is lost on the way to the consumers. Industries loss their productions due to shortage of power supply. All of these have negative effects on GDP growth. Though Bangladesh has a 15MW house hold solar and 1.9 MW wind power probability, peoples are deprived of power [38].

4.4 Sri Lanka

The total power installed capacity of Sri Lanka is 2,684 MW. The total power is contributed almost equally by Hydro power plant and thermal power plant. Thermal power installed capacity is 1290 MW and Hydro electric power installed capacity is 1207 MW [25]. Fig. 8 shows source wise electricity production in Sri Lanka

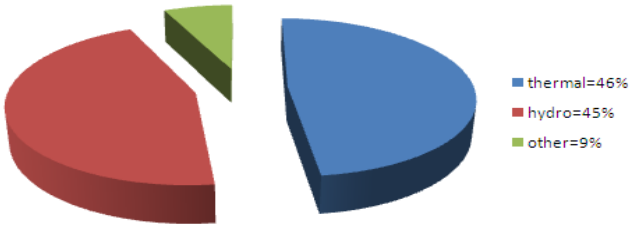

Fig.8. Source wise electricity production in Sri Lanka

From the fig. 8 it is seen that, the contribution of renewable source in power generation is small compared with thermal and hydro. The use of wind energy was seen to be existing in this country even before 500 BC. But there is no suitable use of this. Grid-connected solar power facilities has been introduced recently, with only one project of 0.022 MW approved by the Sri Lanka Sustainable Energy Authority (SLSEA) [25]. Per capita electricity consumption is 400.8 kWh/year[12] and Transmission loss is 2.4%.The electrification rate is 30% [17].

4.5 Nepal

Nepal's power installed capacity is 609 MW, of which 9% is thermal power and 91% is hydro electricity [38]. Fig. 9 shows source wise electricity production in Nepal. Hydro is the main power source of Nepal and it has huge potential of hydroelectric power estimated as 83,000 MW [38]. Small thermal power is also present with hydro electricity. But, there is no contribution of other renewable sources in power generation.

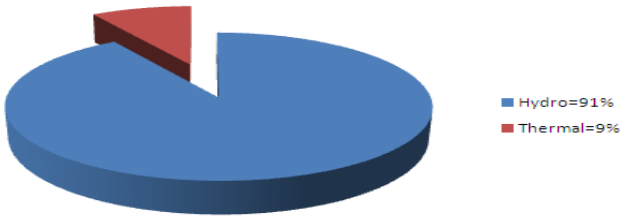

Fig.9. Source wise electricity production in Nepal

Nepal's electrification rate is 40%, among which 90% is urban population [3]. Per capita electricity consumption of this country is 80.4 kWh/year, which is very low in the world as well as in the South Asia [12]. The overall quality of Nepal's electricity infrastructure is very bad and is frequently attacked by moisture. So huge amount of power is lost on the way to the consumers, and the transmission and distribution loss is 21.6%. Nepali people have to face load shading of up to 20 hours per day [38].

4.6 Bhutan

Bhutan's hydropower potential is estimated as 30,000 MW [3]. All of its hydro potential cannot be harnessed due to lack of technological advancement and economical support. Bhutan's total power installed capacity is 445 MW [26]. Hydro is the only source power production. 50% population of Bhutan still remains without electricity [3].

4.7 Maldives

Maldives is the smallest country in South Asia. It has basically no primary energy reserve. The country has to depend on imported primary energy for power generation.

5 RENEWABLE ENERGY OVERVIEW

To fight against the present crisis, the practice of renewable energy has been adopted by some developed countries. The renewable energy technology decreases the dependence on the electricity sources. International energy association has defined three generation of renewable energy:

1) First-generation technologies are biomass, Hydroelectricity, geothermal power.
2) Second-generation technologies include solar heating, photovoltaic, wind power, solar thermal power station and modern form of bio-energy.
3) Third-generation technologies include advanced biomass gasification, bio-refinery technology and ocean energy [27].

5.1 Hydroelectricity

Hydroelectricity is generated by using the potential energy stored in water by creating a dam. This kind of plant has long life. Low cost power can be generated and no harmful emission is created by this type of power plant. However, the main disadvantages of hydroelectric power plant are – it may harm social and environmental system, monsoon dependent and located far away from the load site.

5.2 Geothermal power

The earth has a molten core of high temperature which produces huge amount of steam. When the steam comes out through the earth vents can be used for power production. Geothermal power plants can operate 24 hours per day, providing base load capacity [27]. The main disadvantages of this plant are its cost and high technology. So it is difficult to afford this plant for developing countries.

5.3 Wind power

Wind power can be generated for using where wind at suitable velocity is available. Wind power has high potential and relatively low production costs. Wind power supplied 1.3% of global electricity consumption in the past [27]. Wind power is region and monsoon sensitive. It is economic for only those countries that have sufficient amount of coastal area and suitable wind velocity.

5.4 Tidal power

Ocean waves and tides contain large amount of energy. This energy can be used in power generation. The world's first Tidal power station was installed in 2007 in Ireland (1.2 megawatt) [27]. The main disadvantages of this power is that it is highly technological, costly, power supply is not constant and is located far from the load site.

5.5 Solar Power

5.5.1 Photovoltaic cell

Photovoltaic (PV) cells, also called solar cells, convert sunlight into electricity. The cell acts like a photodiode. Here light is converted into current according to semiconductor

principle. The world largest photovoltaic (PV) power plant is Olmedilla Photovoltaic Park (Spain, 60 MW) [27].

5.5.1 Solar thermal power stations

The heat energy contained in the sun rays is utilized here to boil water and generate steam which is used to drive a prime mover to generate electricity. The largest solar thermal power station is in USA (80 MW) [4],[33].

6 ADVANTAGES OF RENEWABLE ENERGY OVER CONVENTIONAL FOSSIL FUEL

1) For renewable energy generation, once the infrastructure has to built but fuel is free of cost, that means only capital cost, no operating cost.
2) The fuel amount for the renewable energy plant operation are limitless and never be ended.
3) There is no environmental pollution for this power generation which is caused due to fossil fuel power generation.
4) If locally generated then transmission and distribution cost can be eliminated.
5) In the day of increasing electricity demand, renewable energy can eliminate the need for commercial source which is used in many other industries to grow economic condition of a country.
6) Once is installed minimum maintenance and operating person is required.
7) Renewable energy technology gives relief a country, which has less fuel reserves, from fuel import and helps the economy to rise.
8) Renewable energy reduces the global emission of carbon dioxide and keeps the environment cool.
9) A PV panel with wiring system costs $100 which can charge a car battery and after that provide power to run a fluorescent lamp or a small television for a few hours a day [30].

7 SUITABILITY OF RENEWABLE ENERGY IN SOUTH ASIA AND ITS EFFICIENCY

The advancement of renewable energy increases the diversity of sources and decreases the dependency on traditional commercial fuel which is finish able. Renewable energy is particularly suitable for developing countries. Transmission and distribution of energy generated by fossil fuel is difficult and expensive. Production of renewable energy locally can eliminate this problem. By considering all possibilities, solar power is the most suitable among all renewable energy for Asian countries. The region has abundant probabilities of solar power. For their geographical situation the region receives on an average or more than eight hour bright sunlight per day and 300 such sunny day per year [28]. Photo voltaic cell efficiency is very poor. So people think that, this power has no significant importance. A commercial solar cell has an average efficiency of 11-15% in developed countries like USA and other cold countries [18]. The sunlight that we get in the South Asian countries can generate average 200MW power per square km area [29]. The largest photovoltaic cell power plant is situated Olmedilla, Spain, 60 MW [27] which uses almost 270,000 [32] conventional solar panels, made with silicon wafers, [31] to facilitates 40000 homes [31]. The total construction cost was 384 million Euros (US$530 million). [32] Concentrate solar thermal power plant works on the principal of heat engine [4]. There is a hot body which is sun rays reflection receiver and a cold body, here it is the atmosphere. This system generally use mirror or lens to track sunlight in a small place, the receiver to produce heat energy, this heat energy is then used for running conventional power plant. A power generating element is set between the hot body and cold sink. It takes heat from the hot body, do the necessary work and then release remaining heat in the cold sink. The largest solar thermal power plant situated at Harper Lake, United States, Solar Electric Generating Station (80 MW), uses parabolic through reflector to concentrate the sunrays after reflection [4],[33]. The plant is capable to support about 230000 homes by using 900000 mirrors as concentrator [34] and the installation cost is 3000 USD/kW [35]. The geographical location of South Asian countries has made it a suitable place for tracking huge amount of sunlight falls almost perpendicularly throughout the year. The estimated nominal value of solar constant on the earth surface is about 137 MW/cm2 [39], but it differs from place to place. It depends up on the Latitude of the specific place. The sun does not remain constant directly overhead on any particular place of the earth surface throughout the year. The declination as well as the incident solar energy constant can be calculated by using the following equation where α is declination of sun, ΔT is number of days counted from the vernal equinox (March 21) when α =0^0 at equator [40].

$$\alpha = 23.5\ \mathrm{Sin}\theta\left(\frac{\Delta T}{365.25} \times 360\right)^0 \text{ [40].}$$

TABLE 2:
THE DECLINATION OF SUN ON DIFFERENT DAY OF THE YEAR AFTER CALCULATION

Day	Declination α in degree
1st May	14.924
1st June	22.079
1st July	23.17
1st August	17.97
1st September	7.78
1st October	-4.172
1st November	-15.35
1st December	-55.13
1st January	-23.075
1st February	-17.612
1st March	-8.4
1st April	4.023

Table 2 shows the declination of sun on different day of the year. By using the equation given below, we can easily find out the solar constant for a particular day for a particular place where L is the latitude of the site.

$$\sigma D = (137 \mathrm{mW/cm^2}) \times \cos(L - \alpha) \text{ [39]}$$

Table 2 shows the declination of sun on different day of the year (see appendix). Table 3 gives the comparison of solar power intensity in different South Asian countries and the places where the world's largest solar power plants are situated for the first day of each month of the year. Fig. 10

shows the solar power intensity of different south Asian Country and Olmedilla, Spain and Harper Lake, United States

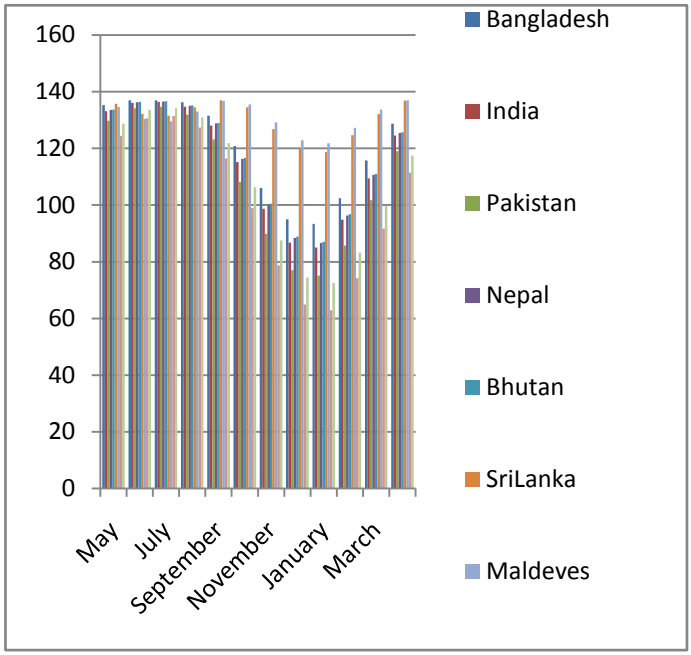

Fig.10. Solar power intensity of different south Asian Country and Olmedilla, Spain and Harper Lake, United States

From the above Fig. 10, it is clear that the solar intensity is higher in almost all south Asian countries than Olmedilla, Spain and Harper Lake, United States, where the world's largest solar power plants are situated.

8 ROLE OF RENEWABLE FOR SUSTAINABLE ENERGY SECURITY IN SOUTH ASIAN COUNTRY

Energy plays a great role in our economy. Sustainable energy security is the key to the development of a country. One country must try to build up its economy to support the population by its own energy reserve. Imported energy use deteriorates the economic condition. Electricity produced by imported energy sources is very costly. Fossil fuel reserve of one country is limited. So it is not wise to expend all of these rapidly. The South Asian countries have a limited commercial energy reserves and a vast population. Due to the increasing population the energy demand as well as the demand of the electricity is increasing. To meet the increasing demand the region has to import huge amount of primary energy which creates a negative impact on the economic growth. One country is how much developed and rich is measured by per capita electricity consumption. So poverty is inversely proportional to electricity access of people. If there is no sustainable energy security, electricity production cannot be sustainable; access to electricity cannot be assured and poverty elimination and economic growth will be a matter of joke for South Asian countries. South Asia has abundant potential of renewable energy especially solar energy which is higher than that of many countries of the world. All of the countries are in a geographical area where sun shines directly most all of the days in the year which can produce huge amount of heat. So renewable technologies can provide alternative sources of electric power in these countries and can meet the growing demand of electricity. In many circumstances, these investments can be less expensive than fossil fuel energy systems. Per kWh fossil fuel power plant initial capital cost is £750–£1000 and per kWh wind power plant initial capital cost is £1500 [37]. Table 4 shows various costs of different types of power plants. It shows that though the installation costs are higher in solar power plant but the variable operating and maintenance cost is zero as fuel can be got free. The use of renewable energy will diversify the dependence on sources and lessen the importance of commercial energy. This will give a sustainable security of energy for the country's population and raise economic growth. This will result in poverty elimination. For example, Denmark is moving towards wind energy but USA and European countries are developing solar energy technology and geothermal power etc [38]. South Asian countries have to move in the same direction, especially in solar energy to get energy security.

9 RECENT WORLDWIDE DEVELOPMENT OF RENEWABLE ENERGY

Ancient CO2 emitting electricity production by burning fossil fuel should be reduced to 50% by 2050 [27] to reduce global warming. Developed world is looking forward to renewable energy with advance technology for sustainable economy, energy and environmental security. World's renewable energy capacity has changed from 10% to 60% between 2004 and 2009 and in 2008, first time renewable energy contribution became higher than conventional energy in European Union and United States [27]. Japan is the biggest users and Iceland will 100% user by 2050 of renewable energy. World's largest bio-fuel industry is in Brazil and geothermal power plant is in USA (3.1 GW) along with Philippines, Indonesia, Mexico, Iceland, Japan and New Zealand of total capacity 10 GW [27]. In USA, Germany, Spain and Portugal, large photovoltaic power plants, in China 27 million rooftop solar water heaters, in Egypt, Mexico and Morocco, solar thermal power plant, in Denmark wind energy plant and in Ireland, tidal power station are situated [27].

10 NECESSITY OF RENEWABLE ENERGY IN SOUTH ASIA:

Developing countries have more than half of global renewable power capacity [27]. In many respect it is important for developing countries like South Asian to advance in renewable energy but very few necessary steps have taken. Renewable energy can be especially suitable for low income South Asian countries [19]. Long transmission and distribution line construction for rural and remote electrification is difficult and costly and huge amount of power is lost on the way as transmission loss. Local renewable energy production is free from this problem. Sunil Ghose, a senior project manager at Nexant, an international energy and consulting firm, said that – people suffer in Nepal, Maldives and Sri Lanka despite of having abundant renewable energy resources like Bangladesh has solar energy and biomass and Bhutan has 30,000-megawatt hydro potential [38]. Visiting South Asia, Secretary General of World Wind Energy Association, told

after finding 30% renewable sources of total energy that- if harnessed properly, it can supply a good percentage of energy and an official of anti-poverty Action Aid International added that solar energy is better and workable option in South Asian countries as they have about 300 clear sunny days a year [38]. South Asia can be world leader in renewable energy and India alone has the capacity of generating 65,000 MW wind power [38]. However, small steps have taken in South Asia such as rural electrification program by solar PV cell in India [19], 100-kilowatt solar power plant In Bangladesh [15], and cooperative work of Swedish government and Bangladesh in developing Solar Energy [2].

11 CONCLUSION

Development of a country depends upon electricity consumption. South Asia is the lowest per capita electricity consumption region in the world and its 50% are still in dark [3]. Those who can access electricity are suffering from chronic load shading. All proven reserve of limited primary energy, mostly in India, Pakistan and Bangladesh, cannot be harnessed due to poor technological support. Besides it has other uses in industries and transportation. In Bangladesh, only 45% gas can be used in power generation. Instead of having enormous renewable potential, it is not justified to burn out finite primary energy (coal, oil, natural gas) in power production. As nuclear power production needs enrich uranium supply and hydroelectric power is monsoon dependant, so the best solution for South Asian countries to fight against growing energy demand and to electrify all deprived population is to do the best utilization of solar energy. Lack of consumer awareness, political and governmental policies, high installation cost and low efficiency are the main obstacles in developing solar power in South Asia. These obstacles can be neutralized by considering several positive effects like it has only installation cost but no fuel cost. It can be set into the remote area to supply electricity to the rural people. No distribution and transmission line have to be built, power can be locally generated and distributed. So, bulk transmission loss is saved. Considering all above advantages, it is the best solution for electrifying rural South Asia.

APPENDIX

TABLE 3

CALCULATED SOLAR POWER INTENSITY ON THE SURFACE OF SOUTH ASIAN COUNTRIES AND OLMEDILLA, SPAIN AND HARPER LAKE, UNITED STATES.

Country	Bangladesh	India	Pakistan	Nepal	Bhutan	Sri Lanka	Maldives	Olmedilla, Spain [36]	Harper Lake, United States, [41]
Latitude	24	28.6	33.7	27.72	27.47	6.93	4.17	39.62	35
May	135.286	133.120	129.717	133.601	133.732	135.670	134.596	124.482	128.684
June	136.923	136.115	134.195	136.337	136.395	132.244	130.368	130.636	133.535
July	136.986	136.386	134.695	136.569	136.615	131.539	129.544	131.398	134.093
August	136.243	134.651	131.875	135.023	135.123	134.467	133.049	127.345	130.999
September	131.552	128.063	123.232	128.795	128.998	136.985	136.728	116.405	121.843
October	120.786	115.215	108.174	116.340	116.654	134.439	135.552	98.931	106.240
November	105.971	98.670	89.835	100.117	100.524	126.782	129.134	78.693	87.466
December	94.985	86.765	77.002	88.383	88.838	119.770	122.833	64.911	74.413
January	93.344	85.006	75.124	86.645	87.107	118.658	121.816	62.913	72.507
February	102.463	94.843	85.684	96.350	96.774	124.635	127.228	74.208	83.238
March	115.694	109.440	101.685	110.692	111.043	132.130	133.720	91.679	99.577
May	128.765	124.601	119.048	125.460	125.699	136.824	137.000	111.424	117.480

TABLE 4
VARIOUS COSTS OF DIFFERENT TYPES OF POWER PLANTS

		Capital cost	Fixed operating and maintenance cost	Variable operating and maintenance cost	Fixed operating and maintenance cost in 20 years	Variable operating and maintenance cost in 20 years	Total cost
Solar power plant	Solar PV cells	144.9	7.7	0.0	154	00	298.9
	Solar thermal power plant	204.7	40.1	0.0	802	0	1006.7
Cole based power plant	Advanced Coal with CCS	93.3	9.3	36.8	186	736	1015.3
	Conventional Coal	65.8	4.0	28.6	80	572	717.8
Nuclear power plant		88.8	11.3	11.6	226	232	546.8
Wind power plant		300.6	22.4	0.0	448	0	748.6
Hydro electric power plant		76.9	4.0	6.0	80	120	276.9
Gas Turbine power plant	Conventional Combustion Turbine	46.0	2.7	79.9	54	1598	1698
	Advanced Combustion Turbine	31.7	1.9	44.4	38	888	957.7

REFERENCES

[1] Golam Mustofa Sarowar (editor), "Bangladesh Energy Sector: Crisis Compounding", Energy Bangla, http://www.energybangla.com/index.php?mod=article&cat=SomethingtoSay&article=2803Sweeden-- , published October 13, 2010,

[2] Golam Mustofa Sarowar (editor), "Sweden to Support Bangladesh in Developing Solar Energy," http://www.energybangla.com/index.php?mod=article&cat=GreenPage&article=2789, published October 08,2010,

[3] "South Asia Regional Overview," eia, Independent Statistics and Analysis, U.S Energy information administration, http://www.eia.doe.gov/emeu/cabs/nepal.html, October, 2004

[4] "Concentrated Solar Power," Wikipedia, the free encyclopedia, http://en.wikipedia.org/wiki/Concentrated_solar_power, January,2013,

[5] "Nepal energy profife," eia, Independent Statistics and Analysis, U.S Energy information administration, http://www.eia.doe.gov/country/country_energy_data.cfm?fips=NP, June, 2010,

[6] "Bangladesh energy Profile," eia, Independent Statistics and Analysis, U.S Energy information administration, http://www.eia.doe.gov/country/country_energy_data.cfm?fips=BG, June 30,2010,

[7] "Bhutan energy profile," eia, Independent Statistics and Analysis, U.S Energy information administration, http://www.eia.doe.gov/country/country_energy_data.cfm?fips=BT, June 30,2010,

[8] India energy profile," eia, Independent Statistics and Analysis, U.S Energy information administration, http://www.eia.doe.gov/country/country_energy_data.cfm?fips=IN, June 30,2010,

[9] Maldevies energy profile," eia, Independent Statistics and Analysis, U.S Energy information administration, http://www.eia.doe.gov/country/country_energy_data.cfm?fips=MV, June 30,2010,

[10] "Pakistan energy profile," eia, Independent Statistics and Analysis, U.S Energy information administration, http://www.eia.doe.gov/country/country_energy_data.cfm?fips=PK , June 30,2010,

[11] "Sri lanka energy profile," eia, Independent Statistics and Analysis, U.S Energy information administration,

http://www.eia.doe.gov/country/country_energy_data.cfm?fips=CE, June 30,2010,

[12] "Country Comparison > Electricity – consumption", Indexmundi, http://www.indexmundi.com/g/r.aspx?v=81&l=en, October,2010,

[13] "International Total Primary Energy Consumption and Energy Intensity," eia, Independent Statistics and Analysis, U.S Energy information administration, http://www.eia.doe.gov/emeu/international/energyconsumption.html, October,2010,

[14] "Country Comparison > GDP - per capita (PPP)," Indexmundi, http://www.indexmundi.com/g/r.aspx?c=mv&v=67, October,2010,

[15] Golam Mustofa Sarowar (editor), "Bangladesh's Biggest Solar Power Plant goes into Operation," http://www.energybangla.com/index.php?mod=article&cat=GreenPage&article=2768, published October 04,2010,

[16] "Country Comparison > Population," Indexmundi, http://www.indexmundi.com/g/r.aspx?c=bt&v=21, October,2010,

[17] Nimal Shantha,Herath Mudiyanselage Wijekoon," Time Dependent Transmission Losses In National Network, Sri Lanka," Ceylon Electricity Board (Sri Lanka), October 23,2010.

[18] Dev Llorens, "Solar Pannel Efficiency and the factors affect it ", One Block of the Grid, http://howsolarworks.1bog.org/solar-panel-efficiency/, October, 2010

[19] "Renewable energy in developing countries," Wikipedia, the free encyclopedia, http://en.wikipedia.org/wiki/Renewable_energy_in_developing_countries, October 24,2010,

[20] "Country Comparison > Oil – production," Indexmundi , http://www.indexmundi.com/g/r.aspx?t=0&v=88&l=en, October ,2010,

[21] "Country Comparison > Natural gas - proved reserves", Indexmundi, http://www.indexmundi.com/g/r.aspx?t=0&v=98&l=en, October, 2010

[22] "Electricity sector in India", Wikipedia, the free encyclopedia, http://en.wikipedia.org/wiki/Electricity_sector_in_India, October, 2010

[23] "Electricity sector in Pakistan", Wikipedia, the free encyclopedia , http://en.wikipedia.org/wiki/Electricity_sector_in_Pakistan, October, 2010,

[24] Annual report 2009, Bangladesh power development board, 2010.

[25] "Energy in Srilanka", Wikipedia, the free encyclopedia , http://en.wikipedia.org/wiki/Energy_in_Sri_Lanka, October,2010,

[26] "Hydro-Electric Power Projects of Bhutan," Updated on May 05, 2005, www.bhutannewsonline.com/hydro_power_project.html

[27] "Renewable energy commercialization", Wikipedia, the free encyclopedia, http://en.wikipedia.org/wiki/Renewable_energy_commercialization, October,2010

[28] Athar Parvaiz, "South Asia-Harness Untapped Renewable Energy Sources' – Experts", IPS, inter press service, http://ipsnews.net/news.asp?idnews=49906, published January 07,2010

[29] G.R Nagpal, Power Plant Engineering, 15th edition, Delhi, Khanna Publishers, 2006, pp. 1-10.

[30] "Solar cell", Wikipedia, the free encyclopedia, http://en.wikipedia.org/wiki/Solar_celll, October, 2010

[31] "Olmedilla Photovoltaic Park," Wikipedia, the free encyclopedia , http://en.wikipedia.org/wiki/Olmedilla_Photovoltaic_Park, January, 2013

[32] "Olmedilla power plant Data sheet", NOBESOL-Solar plant, http://www.nobesol.com/?seccion=4&subseccion=2&contenido=40, January,2013

[33] "Solar Electric Generating Station IX", National Renewable Energy Laboratory, http://www.nrel.gov/csp/solarpaces/project_detail.cfm/projectID=36, January, 2013,

[34] "Solar Electric generating System," Next Era energy resources, http://www.nexteraenergyresources.com/content/where/portfolio/pdf/segs.pdf, January, 2013,

[35] San Diego regional renewable energy study group, "Potential for Renewable Energy in San Diego region" National Renewable Energy Laboratory Report, August 2005, Appendix E, http://www.renewablesg.org/docs/Web/AppendixE.pdf

[36] "Soalr Energy Generating Syatem," Wikipedia, the free encyclopedia , http://en.wikipedia.org/wiki/Solar_Energy_Generating_Systems, January, 2013,

[37] "Fossil-Fuel power station", Wikipedia, the free encyclopedia, http://en.wikipedia.org/wiki/Fossil-fuel_power_station, January,2013,

[38] Motiram Phuval (moti), “In 100 years of Nepalese Hydroelectricity, People still Suffer Scarcity ,Increasing Load-shedding remains at least for five more years”, Oh my news international, http://english.ohmynews.com/ArticleView/article_sangview.asp?menu=c10400&no=386090&rel_no=1, published may 25,2010,

[39] Therasa M Scott, “Calculating the Energy from Sunlight over a 12-Hour Period, LTP, http://www.grc.nasa.gov/WWW/k-12/Numbers/Math/Mathematical_Thinking/sun12.htm, August 2012

[40] Richard Perez, Sam Coleman, “PV module angle”, Home Power, August 1993. pp. 14-16