Energy Sustainability: A Study of Solar Energy Installation in India

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ABSTRACT

The Energy sector has a direct impact on the economic development and growth of developing as well as developed countries, because energy is the major requirement for running any industrial units, agricultural activities, commercial sector, household and other activities. As far as sustainability is concerned, there are two sources of energy i.e. renewable and non-renewable energy. Renewable energy being a sustainable source is assuming importance in the context of non-exhaustible, future potentials and environmental friendly as compared to non-renewable/conventional energy sources. Sustainable energy growth is possible by adopting safe, clean and non-exhaustively source of energy. Solar energy, among other sources of RE is most safe and clean, having greatest potential. As per Intergovernmental Panel on Climate Change (IPCC) only a fraction of solar energy can meet the whole needs of electricity. The present research is an attempt to discuss about sustainable energy development through renewables. The focused concern of the research is trend analysis and scenario of solar energy in India. Data for the purpose has been used from various annual reports and publications of MNRE, Ministry of Power (MOP) and various institutions and agencies concerned with energy sector.

Keywords: Conventional Energy, Renewables, Solar Energy, Sustainable Energy, Trends.

Introduction

The Energy sector has a direct impact on the economic development and growth of developing as well as developed countries, because energy is the major requirement for running any industrial units, agricultural activities, commercial sector, household and other activities. Renewable energy is assuming importance in the context of negative environments externalities caused by non-renewable energy source. (MNRE-2011). The consumption of fossil fuels caused damage to the environments in different forms. Human activities dumps every year roughly 8 billion metric tonnes of carbons into atmosphere in which 6.5 billion tonnes from fossil fuels (Sood et-al-2002). Half of the country's carbon emission is caused by power sector.

As far as sustainability is concerned, there are two sources of energy i.e. renewable and non-renewable energy. Renewable energy being a sustainable source is assuming importance in the context of non-exhaustible, future potentials and environmental friendly as compared to non-renewable/conventional energy sources. According to MNRE estimated renewable energy potential in India is about 900GW assuming 3% waste land is available and which includes wind-102GW (at 80 meter height), small hydro-20GW, Bio-energy-25GW and 750GW solar power (assuming 3% wasteland available). Renewable energy sector has emerged as a significant player in the grid connected power generation. It is trying to fulfill the government's agenda of sustainable growth and meeting the nation's energy security need. During the last few years renewable energy has witnessed tremendous growth with supportive policy framework. Solar energy, among other sources of RE is most safe and clean, having greatest potential. As per Intergovernmental Panel on Climate Change (IPCC) only a fraction of solar energy can met the whole needs of electricity. Average intensity of solar radiation on India is 200MW/km square. On the basis of location, daily incidence ranging from 4 to 7kw/meter square and with 2300 to 3200 hours of sunshine in a year. India has solar radiation incidence for more than 5000 trillion kWh/year solar energy. Solar energy is easy safe, clean and sustainable method of generating power (Garud and Purohit- TERI).

Review of literature

Increased demand of energy forced India to move toward solar to fulfill the need of growing population. The solar trend in India has rapidly increasing from last few years due to police support (Saluja, 2018). Climate change mitigation, energy independence, rural development, and improved health is shifting renewable energy from fringe to mainstream of sustainable development (Meisen, 2011). Luthra-2014 in her interview with Manish Bopana, executive Vice-President and MD at World Resources Institute examines the steps India is taking towards sustainable energy future. He argues that while India has made progress to some extend with low carbon alternative and increased energy efficiencies, much of potentials in this area remain unrealized. Rosen-2009 discussed factors that must be considered to achieve energy sustainability such as harnessing sustainable energy sources, the thermochemical hydrogen production process, sustainable energy cerriers, energy efficiency, environmental impact and socio-economic acceptability. Elatamaly et.al, 2015 conducted a survey on integrated renewable

energy sources with smart grid system, which is the concept used in energy management, such as energy efficiency, maximization utilization, reducing cost and controlling emission and explored the challenges and technologies used in integrated smart grid with renewable energy. Lior-2010, state that disastrous global consequences, it would be impossible to engage in large scale activities without ensuring their sustainability. Mahender-2017**,** in their study "Customers' Willingness to Pay More for Solar Energy" identified some factors related to adoption of solar energy. In this paper, author proposed a conceptual model revealing that customers' willingness related to spending on solar energy is influenced by environmental concern, knowledge towards solar energy, socio-economic factor and government policies.

Aims of the research

The present research is an attempt to discuss about sustainable energy development through renewables. The focused concern of the research is trend analysis and scenario of solar energy in India.

Data and Methodology

In this study, we have tried to find out the trend of total solar energy production/installation i.e. grid connected and off-grid from 2000 to 2017. For the purpose, we have used Year Wise Percentage Change/growth, Annual/ Simple Average Growth Rate (AAGR), Compounded Annual Growth Rate (CAGR) function and Geometric Mean.

For growth function we have used:

$P_n = P_0 (1+r)^n$

Where P_n=value at the end of the period, P_0 = value at the beginning of the period, r= average rate of growth, n= is the number of year.

We have also used Simple linear Regression model to find out the line of the Best Fit of variables from 2000 to 2017. Least Square Method has been used to obtain regression lines by the following regression equations:

$Y = a + bX$ .... … (1)

$X = a_0 + _{b0}Y$…….(2)

In equation (1), a and b are constant which represents intercept and slope of the line. Here Y is the dependent variable which in the present study represents solar energy and X is the

independent representing time periods. Same in the equation (2), a_0 and b_0 are constant and X is dependent variable and Y is independent variable. We have also forecasted the value of solar energy production/installation by the year 2022 by using solar energy as dependent variable and time periods as independent variable.

Data source

Secondary data has been used related to solar energy potentials and installation in India and collected from the official websites of International Renewable Energy Agency (IRENA), website of Ministry of New and Renewable Energy (MNRE), website of The Energy and Resources Institute (TERI) and Solar Energy Corporation of India (SECI).

Renewable energy and sustainability

Brundtland Report of the World Commission on Environment and Development-1987, defined sustainable development as "development that meet the need of the present without compromising the ability of future generation to meet their own need". As per World Summit on Sustainable Development (WSSD)-2002, states that sustainable development stood on three pillars: economic development, social development and environment development. Energy factors in the all three components of sustainable development. Energy sustainability include provision related energy service in a sustainable manner, necessitate that energy services be provided in a manners that now and in the future sufficient to provide necessities, affordable and detrimental to environmental and acceptable to communities. Energy sustainability is taken as, not just limited to the sustainable energy sources, but more comprehensive. Energy sustainability is concerned with sustainable use of energy in the overall energy system where system include processes and technologies for harvesting of energy source, their conversion in the energy form, energy storage and transportation and utilization of energy to provide energy sources (Rosen, 2009). Fossil fuel based energy sources (coal, oil, natural gas, tar sands, oil shale, peat etc.) considered finite and environment disastrous while non- fossil fuel sources (solar, wind, wave, biomass, tidal, hydraulic energy etc.) considered renewable (when growth rate is not below the rate of use) having abundant potentials and environmental friendly. According to Intergovernmental Penal on Climate Change (IPCC) only a fraction of solar energy can met the

whole needs of electricity. If we harness only 5% of the solar energy source of RE, it will be 50 times more the energy world required (Rai-2000).

Trend analysis of solar energy

India has abundant solar potentials because of most of the states have been on or around cancer line where good solar radiation incident exist. Estimated solar potential of India is 5000trillion kWh per year (Panday and Singh, 2012). An average of 250-300 clear sunny days are there in India. Electricity needs of India can be harnessed on 0.1% of total land in India i.e. 3000square Kilometers. Solar radiation incidence over India is 4-7 kWh per square meter per day (Kumar and Kumar, 2010). Annual radiation in India is ranging between 1200-2300 kWh/m^2 (MNRE-2006).

Table: 1. Top ten states/UT of solar potentials and installed capacity of grid connected solar energy in India.

Solar energy potentials (Assuming 3% wasteland is made available)			**Grid connected Solar energy installed capacity as on 31-12-2017**		
Sr. No.	***States/UT***	***Potentials (MW)***	***Sr. No.***	***States/UT***	***Installed capacity(MW)***
1	Rajasthan	142310	1	Telangana	2990.07
2	Jammu & Kashmir	111050	2	Rajasthan	2310.46
3	Maharashtra	64320	3	Andhra Pradesh	2165.21
4	Madhya Pradesh	61660	4	Tamil Nadu	1819.42
5	Andhra Pradesh	38440	5	Karnataka	1800.85
6	Gujarat	35770	6	Gujarat	1344.69
7	Himachal Pradesh	33840	7	Madhya Pradesh	1210.11
8	Orissa	25780	8	Punjab	905.64
9	Karnataka	24700	9	Maharashtra	763.08
10	Uttar Pradesh	22830	10	Uttar Pradesh	550.38

Source: Annual Report MNRE-2017-18

Rajasthan, Jammu & Kashmir and Maharashtra have abundance potentials of 142310MW, 111050MW and 64320MW respectively. If talk about the installed capacity, Telangana is in top position with 2990.07MW followed by Rajasthan.

Table 2. Year wise Total (grid connected and off grid) installed capacity of solar energy from 2000 to2017

Sr. No.	years	Solar energy (MW)	Sr. No.	years	Solar energy (MW)
1	2000	1	10	2009	36
2	2001	5	11	2010	60
3	2002	5	12	2011	529
4	2003	6	13	2012	926
5	2004	6	14	2013	1336
6	2005	10	15	2014	3518
7	2006	7	16	2015	5396
8	2007	22	17	2016	9647
9	2008	25	18	2017	17873

Source: International Renewable Energy Agency (IRENA).

In the above table-2, the data has been taken from the official website of IRENA related to total solar energy (grid connected and off-grid) installation from the year 2000 to 2017. The sector is growing rapidly but if see the data and growth up to 2009-10 seems very gradual. But after 2010 and onward the sector has grown with very high growth rate due to implementation of Jawaharlal Nehru National Solar Mission (JNNSM) that was launched on 11th of January, 2010 with result of National Action Plan on Climate Change (NAPCC) that was released on 30th June, 2008.

Table: 3. Annual percentage growth, Average Annual Growth, Compounded Annual Growth and Geometric mean of solar energy from 2000 to 2017

Time Period (X)	Years	Solar Energy (MW)Y	Percentage (change/Growth)
1	2000	1	-
2	2001	5	***400.00%***
3	2002	5	***0.00%***

4	2003	6	***20.00%***
5	2004	6	***0.00%***
6	2005	10	***66.67%***
7	2006	7	***-30.00%***
8	2007	22	***214.29%***
9	2008	25	***13.64%***
10	2009	36	***44.00%***
11	2010	60	***66.67%***
12	2011	529	***781.67%***
13	2012	926	***75.05%***
14	2013	1336	***44.28%***
15	2014	3518	***163.32%***
16	2015	5396	***53.38%***
17	2016	9647	***78.78%***
18	2017	17873	***85.27%***
Simple/Annual Average Growth (SAG/AAG)			***57.59%***
Compound Annual Growth (CAG)			***77.88%***
Geometric Mean			***77.88%***

Source: As calculated in MS Excel.

Table-3 shows the year wise percentage growth, Simple/Annual Average Growth, Compound Annual Growth and Geometric Mean of growth of solar energy from 2001 to 2017. All the growth indicator (SAG, CAG and Geometric Mean) depicts a high degree of growth trends in solar energy especially from and above the years 2010.

Results of the regression function calculated in MS-Excel.

Simple regression analysishas been done taking solar energy (Y) as a dependent variable and time period (X) as independent variable. If see the regression results R square which is also known as coefficient of determination or percentage of the response variable variation explained by linear model is 0.47 which shows moderate responsiveness of the response variable. Multiple

R shows the correlation coefficient of variables which shows high degree of positive correlation between the variables.

Regression	Statistics
Multiple R	0.68
R Square	0.47
Adj. R Square	0.43
Stnd. Error	3518.67
Observations	18

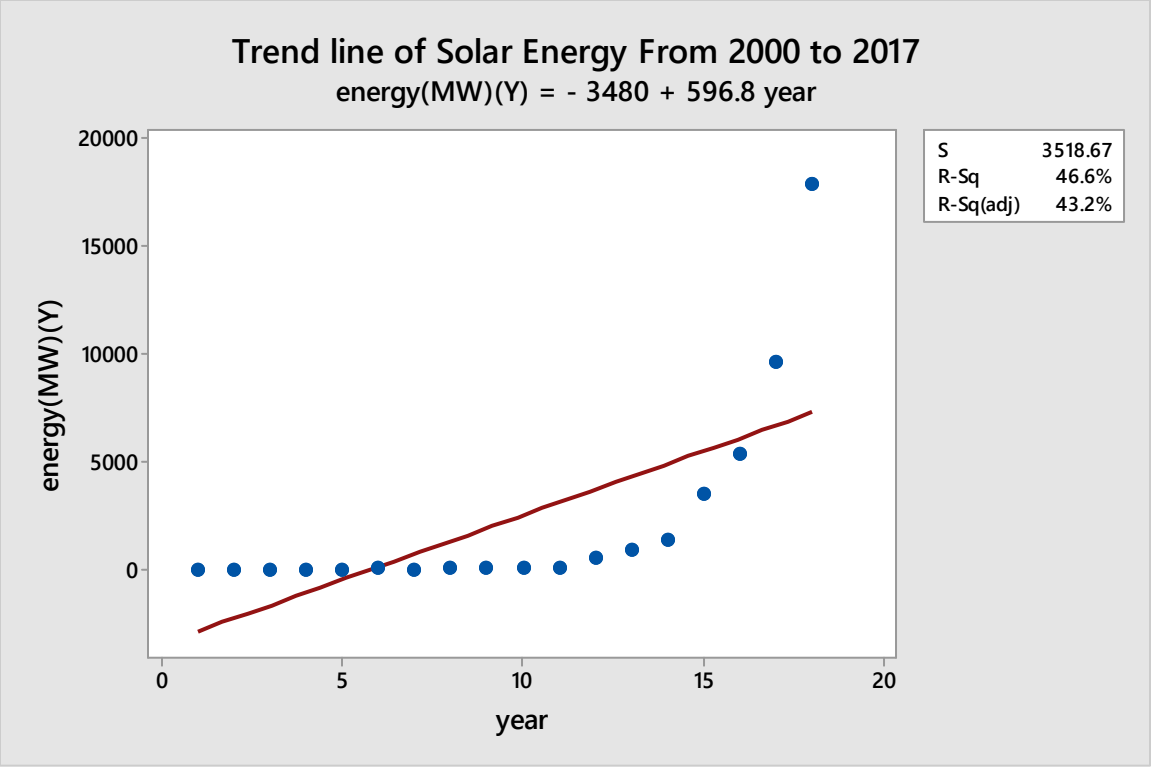
ANOVA

	df	SS	MS	F	Signif. F
Regression	1	172556603.61	172556603.61	13.937	0.002
Residual	16	198096516.39	12381032.27		
Total	17	370653120.00			

	Coeff's	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	-3480.137	1730.348	-2.011	0.061	-7148.312	188.038	-7148.312	188.038
X	596.786	159.857	3.733	0.002	257.905	935.668	257.905	935.668

Trend line of solar energy

Best of fit line has been drawn through least square method of regression which shows a high degree of positive growth of solar energy throughout the time periods.



Trend line also depicting that later the year has high degree of growth in the solar energy sector. A target of 175GW of RE capacity by the year 2022 has set down by the govt. of India which includes 100GW from Solar only. The 100GW target of solar energy includes 40GW Rooftop and 60GW through grid connected solar power projects. As of 31st December 2016, the gross installed capacity of RE stood at 50GW in India and contribute 16% of the total electricity installed capacity. In the total installed capacity of RE, wind energy contributes 57.4% (28700MW) as maximum followed by solar power, Bio-power and small hydro-power with 9013MW, 8021MW and 4334MW respectively. As per submission to the United Nations Framework Convention on Climate Change on Intended Nationally Determined Contribution stated that by the 2030, India will achieve 40% cumulative power capacity from non-fossil fuel energy resources. (Annual Report MNRE-2016-17).

Conclusion

Sustainability in energy sector has been concerned with the factors, economic development, social development and environment development and possible through renewable and non-fossil fuel sources of energy. India has abundance resources of renewable energy and can meet their energy need by harnessing very few of these resources. At present, renewable energy sector

has golden era in India and World and growing with rapid pace. Trends of solar energy in India shows high degree of positive growth.

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