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Desirable Impact on Environment of Solar Energy use in Domestic Sector

KEYWORDS: Solar energy, environment, dynamic equilibrium,urbanization, domestic sector

I. Nawaz	M. Emran Khan	M. Rafat
Department of Mechanical Engineering, Faculty of Engineering & Technology,Jamia Millia Islamia, Jamianagar, New Delhi	Department of Mechanical Engineering, Faculty of Engineering & Technology,Jamia Millia Islamia, Jamianagar, New Delhi	Department of Applied Sciences and Humanities, Faculty of Engineering & Technology,Jamia Millia Islamia, Jamianagar, New Delhi

ABSTRACT *Concern for healthy environment is a priority today. The environment is a holistic system whose basic components are constantly recycled. It is in a state of dynamic equilibrium, subject to various influences. Undesirable influences are clubbed under the term of pollution. It means the presence of abnormal quantities of any material. Of course, human beings are responsible for this abnormality. High CO_2 concentration is a glaring instance of it. To reduce CO_2 level in the atmosphere, there is an urgent need to utilize solar energy in preference to fuel sources; particularly in domestic applications. With this in mind, a mathematical model has been suggested in the present study; to optimize the share of solar energy and reduce thermal sources' share.*

Introduction:
Eelectric power is an essential input for industrial growth and a necessary condition for all round development of any region. There is a strong corelation between energy use and quality of life. It is not surprising that major advances in civilization have often coincided with enhanced energy consumption. To be specific, Figure 1 shows that Human Development Index (HDI) tends to increase with the growth of electricity consumption (HDI 2010). Turning our attention to Indian domestic sector; its energy needs continue to be a major challenge for india's progress. At present energy consumption in this sector is 21.79% (Energy Statistics 2013); while the total energy consumption in India is 940 kWh per capita per year, (which is quite low as compared to developed world) (Livemint 2014). It is projected that annual energy demand in India will soon increase to about 10,000 MW to accomodate a GDP growth of 8-9% (Power Sector at a Glance 2014).To meet India's energy needs and at the same time keep environment pollution free; the share of renewable energy sources particularly solar energy, must increase. Some basic questions to be answered in this copntext, are the following:

i. How much energy is potentially available in natural environment?
ii. For what purpose, can the harnessed renewable energy be conveniently used?
iii. Is it economical in comparison to other conventional sources?

Electricity and Development:
Share of electricity in total energy scenario generally tends to increase; since electricity is convenient and relatively clean. The Human Development Index (HDI) has already been mentioned. HDI values are compiled by the United Nations Development Programme in its "Human Development Report".

HDI is specifically linked to electricity consumption per capita. In 2010, India had a HDI of 0.56 and an average electricity consumption of 700 kWh/capita/year. Globally the average HDI was 0.7 (HDI 2010).

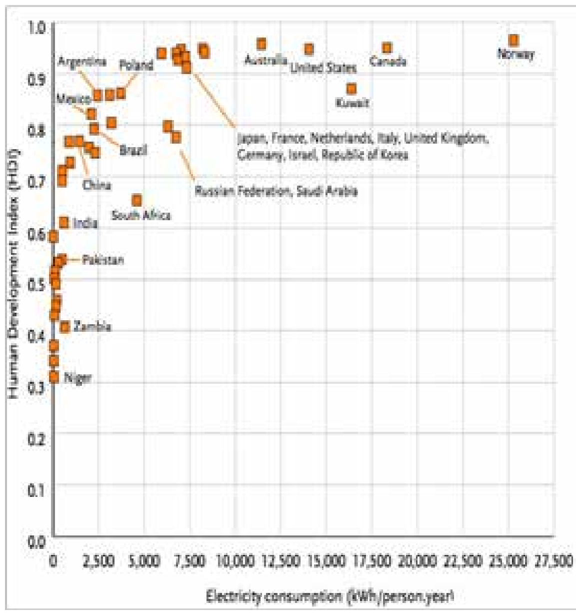

Figure 1:Graph of HDI and Electricity Consumption/ Person

Potential of Renewable Energy Sources:
The renewable energy sources include solar energy, wind energy, biomass, biogas, small hydro power and geothermal. Among them, biomass and biogas are less preferable as they emit CO_2 and other pollutants. Small hydro and wind energy have other disadvantages. Solar energy has the unique quality that it does not emit any gas or pollutants at all.

India is blessed with bountiful renewable sources. An estimate of the potential of important renewable energy sources is given in Table 1.

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Table1: Estimated potential of important renewable energy sources (MNRE 2013)

Sources/Systems	Potential
Solar Energy	50,000 MW
Wind Energy	47,000 MW
Biomass	30,000 MW
Biogas Plants (Nos.)	12 Million
Small Hydro Power	15,000 MW
Geothermal	10,000 MW

Renewable Energy Installed Capacity in India:

Table 2 shows the actual plants and installations for producing power from renewable energy sources.

Table 2: Renewable Energy Installed Capacity in India (as on31 May 2014) (MNRE 2013)

Type	Technology	Installed capacity in (MW)
Grid Connected Power:	Wind	21,262.23
	Small Hydro Power	3,803.65
	Solar PV Systems	2,647.00
	Bagasse Cogeneration	2,512.88
	Biomass Power & Gasification	1,365.20
	Waste to Power	106.58
Total - Grid Connected Power:		31,697.54
Off-Grid /Captive Power:		
	Bagasse Cogeneration	517.34
	SPV Systems (>1 kW)	159.77
	Biomass Gasifiers – Industrial	146.40
	Waste to Power	119.63
	Biomass Gasifiers – Rural	17.63
	Water Mills/Micro Hydel	10.18
	Aero generator / Hybrid Systems	2.18
Total - Off-Grid / Captive Power:		973.13
TOTAL:		32,670.67

Solar Power in India and its utilization:
Solar energy is readily available; it is a free source of energy since prehistoric times. India receives daily average of solar energy, in the range of 4-7 kWh/m^2 depending upon region. There are approximately 300 sunny days in a year in India. Even if 1% of energy incident on the total land area is used to generate electricity, at an efficiency of only 1% it will be possible to produce 3,00,000 MW of power. This is sufficient to meet the country's energy requirement (EAI).

Solar energy can be converted into thermal energy with the help of solar collectors and solar-thermal devices such as solar cooker and water heater. Alternatively, solar photovoltaics may use it to produce electricity for lighting and running electric appliances. The available thermal energy, besides being used directly, may be converted into mechanical or electrical energy. Three relevant temperature ranges of available thermal energy are low grade (< 100^0 C), medium (100^0 to 300^{0}C) and high (> 300^{0}C).

Utilization of Solar Energy in Domestic Sector:
In domestic sector, India has launched systematic programmes to promote solar thermal applications thus reducing the conventional electricity demand and conserving fossil fuels. Solar thermal systems are mostly used in residential applications such as domestic water heating, heating of swimming pools, space heating and cooking. The devices are reliable; they have high technical standard and low temperature demand. Some systems are mentioned below.

a) Solar Water Heating Systems:
A solar water heater successfully replaces conventional electric geyser. It is estimated that installation of 1000 solar water heaters with 2000 m^2 collector area each, may contribute to peak load saving of 1 MW (Solar Power in India). The gross, realizable techno-economic potential for solar water heating systems in India is estimated to be140 million m^2, corresponding to 40 million m^2 of collector area. On the other hand, a total of nearly 5 million m^2 collector area has presently been installed in the country (Ministry of MNRE). Solar energy may be used to heat water for at least four different applications; potable water, service use, floor heating and swimming pools.

b) Solar Air Heating:
Solar air heating is a solar thermal technology in which the energy from the sun is captured by an absorbing medium and subsequently utilized to heat air. The scheme involves the use of solar flat plate collector. It has applications in industries which require hot air at low temperature (50-80^{0}C); for instance leather, textile, chemicals, rubber, paper and pharmaceuticals. Large volume fish drying plants have also been developed based on solar water heating systems.

c) Solar Cooker:
Use of solar cooker is extremely suitable for Indian rural areas. The cooking temperature is about 100^{0}C. On a clear sunny day an oven of size 50 cm×50 cm×10 cm requires two to three hours to cook three food items; rice, meat/fish and pulses; they may serve a family of five to seven members.

The cooker directs the intercepted solar radiation towards the focal point thus creating cooking conditions, similar to traditional open fire cooking. It may be used right after one hour from sunrise until an hour before sunset. The heated area is located within the dish, therefore burning and blinding are avoided. Gradual cooking preserves nutrients while the taste of food is considerably improved. It has the following desirable features:

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- Environment friendly
- Free of health hazards
- Higher productivity
- Higher economic feasibility
- Faster cooking and easier operation
- Durability and reliability
- Ease in transport
- No supervision is required
- Foodstuff may be kept warm even after sun set

d) Solar Passive Architecture:

Solar Passive Architecture is an innovative climate responsive architecture concept. The appropriate design strategies may be classified on the basis of regional climate and the need of heating or cooling. This also includes strategies for optimal use of day light. The idea is to promote energy efficient buildings by suitable utilization of available solar energy and building materials. A few such buildings are currently under construction in the states of Himachal Pradesh and West Bengal in India.

Solar Photovoltaic Technology:

Solar photovoltaic technology converts solar energy into useful form of energy forms by directly absorbing solar photons; which are bundles of energy. Solar energy is converted into electricity by a photovoltaic (PV) cell. Solar energy photovoltaic is one of the key energy programmes in India; it is relevant particularly for rural and remote areas. It is a simple, reliable and environmentally benign technology. Some of its applications are lighting for commercial buildings, outdoor (street) lighting and water pumping. Solar electric power systems potentially offer independence from conventional utility grid and serve people during extended power failures.

The atractive features of solar energy systems is that they have no adverse impact on the environment, thus they are cleanest power-generating decices available today. They produce no air pollution, hazardous waste, or noise. Solar energy may also play an important role in lowering greenhouse gas (GHG) emissions. Such reduction will improve air quality and reduce the harmful impact on climate change.

Mathematical Model for Achieving CO_2 Reduction:

We now present our mathematical model, which may be used to plan a reduction in CO_2 emissions. The strategy is to increase the share of solar energy and correspondingly decrease the share of thermal sources of energy; in total power generation. This should be done in such a way that the CO_2 emissions are reduced, over a specified period of time e_i.

We describe the method of calculation in Appendix-A. Only the results are presented here. Let the relative shares of various sources of power generation be denoted by e_i, such that $\sum e_i=1$.

We suppose that the total power being generated presently is P and the power expected to be generated, after a given interval of time (say one year) is P. Let us aim at a relative reduction of η in CO_2 emissions, over the same period. This will be done by decreasing the share of thermal sources by a factor of α and at the same time increasing the share of solar energy by a factor of β. The required values of the parameters and are given by:

$$\alpha = \frac{(1-\eta)P}{P'} - \left[1 - \frac{(1-\eta)P}{P'}\right]\left[\frac{(c_6 e_6 + c_7 e_7)}{(c_1 e_1 + c_2 e_2 + c_3 e_3)}\right] \qquad (1)$$

Here , C_1 C_2 and C_3 refer to CO_2 emissions by thermal sources while C_6 and C_7 refer to biomass and biogas respectively

$$\beta = 1 + \frac{(1-\alpha)(e_1 + e_2 + e_3)}{e_{solar}} \qquad (2)$$

An example of calculation of the parameters αand β is included in Appendix-A

Conclusion:

Our requirement of energy is increasing continuously with increase in population. For obvious reasons, it is not possible to reduce energy consumption; the only feasible alternative is to increase the energy supply. This requires action on at least two fronts: (a) rationalization of energy prices to provide incentives for promoting efficiency and (b) introducing of other initiatives (not related to price) to push the economy towards greater energy efficiency. The use of super critical and ultra-super critical technologies of solar power generation can reduce the rate of coal in electricity production. If in the context of the declared goal of "Energy for All", the total amount of required electricity is generated from fossil fuels, the level of green house gases and other pollutants will rise enormously. To keep the environment relatively pollution free and simultaneously meet the energy demand, the use of renewable resources is certainly a better choice. Thus continuous emphasis should be placed on renewable resources, especially on solar thermal and solar photovoltaic alternatives. The government of India is systematically promoting the use of solar energy by providing substantial subsidy on various solar appliances, in rural and urban areas. We need to remind over selves that renewable sources of energy are conducive to cleaner and greener environment and hence constitute a wise and economical choice. We have suggested in our study a mathematical model to plan optimal use of solar energy. The model is flexible and may be used in a variety of circumstances.

APPENDIX-A

Let total electric power being produced now be*P*

Table A1: Sources of electricity and CO_2 emissions factor (DECC UK)

Table A1 (a): Conventional sources:

S. No. (i)	Source of electricity	Share ofelectricity produced by a particular source (e^i) in%	CO_2 emitted by a particular source (kg per kWh)
i.	Coal	e_1 =59.60	c_1 =0.98
ii.	Gas	e_2 =9.00	c_2 =0.52
iii.	Oil	e_3 =0.50	c_3 =0.77
iv.	Hydro	e_4 =16.30	c_4 =0.00
v.	Nuclear	e_5 =1.90	c_5 =0.00

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Table A1 (b): Non-Conventional, CO_2 emitting:

vi.	Biomass	e_6 =0.51	c_6 =0.35
vii.	Biogas	e_7 =1.00	c_7 =0.25

Table A1 (c): Non-Conventional, CO_2 non-emitting:

viii.	Wind & hydro(small)	e_8 =9.60	c_8 =00
ix.	Solar	e_9 =0.88	c_9 =00

Obviously $\sum_{i=1}^{9}(e_i = 1)$

Let CO_2 being emitted at present be H

$$H = P\sum_{i=1}^{9}(e_i c_i)$$

Suppose we plan to increase the total power P to a new value P'. The various shares e_i of different sources are suitably varied to new values e_i'. After these changes, amount of CO_2 emitted will become: $H' = P'\sum(e_i' c_i)$

Let H' be less than H and let the relative decrease be η.

Then

$$(1-\eta)P\sum_{i=1}^{9}(e_i c_i) = P'\sum_{i=1}^{9}(e_i' c_i)$$

where $\sum e_i = 1$, also $\sum e_i' = 1$

Let the share of thermal sources be reduced thus $e_1' = \alpha e_1$, $e_2' = \alpha e_2$ and $e_3' = \alpha e_3$, where $\alpha < 1$.

We let e_4 to e_8 remain as they are.

Finally we increase the share of solar energy and let $e_9' = \beta\, e_9$, where $\beta > 1$

Using the constraint

$$\sum e_i' = 1,$$

We get the following results

$$\beta = 1 + \frac{(1-\alpha)(e_1 + e_2 + e_3)}{e_{solar}}$$

$$\text{Where; } \alpha = \frac{(1-\eta)P}{P'} - \left[1 - \frac{(1-\eta)P}{P'}\right]\left[\frac{(c_6 e_6 + c_7 e_7)}{(c_1 e_1 + c_2 e_2 + c_3 e_3)}\right]$$

Example:

Let P' be 10% greater than P and let CO_2 reduction be 10%.

$$\text{Thus, } \eta = \frac{10}{100} = 0.1$$

$$\text{and } \frac{P'}{P} = 1.1$$

We use the data of Table A1to get

α=0.816(share of thermal sources is to be reduced by 18.4%) and

β=1.12(share of solar energy should be increased by 12%)

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