MultiCraft

International Journal of Engineering, Science and Technology
Vol. 3, No. 1, 2011, pp. 265-271

INTERNATIONAL JOURNAL OF ENGINEERING, SCIENCE AND TECHNOLOGY

www.ijest-ng.com

Energy management using solar and fuel cell based appliances in rural areas of India

M.A. Mallick[1]*, I. Ashraf[2], M. I. Khan[3], S. Pandey[4]

[1]Department of Electrical and Electronics Engineering, Integral University Lucknow, INDIA*
[2] Department of Electrical Engineering, A.M.U., Aligarh INDIA [EED, College of Engineering ,TU, Madina, KSA]
[3]Department of Mechanical Engineering, Integral University Lucknow, INDIA*
[4]Department of Electrical Engineering, MMMEC, Gorakhpur, INDIA
[*]Corresponding Author: e-mail: mamallick@rediffmail.com, Tel +91-9838849825, Fax. +91-512-2890809

Abstract

In this paper, an attempt has been made to estimate the green house gases reduction potential using the diffusion models in rural areas of India which comprises of thousands of villages. Most of them has no grid connection and people depends on wood, gas and kerosene oil for their cooking and lighting purposes. The purpose of doing this diffusion models has been to forecast the demand of electricity and look for the measures that could be implemented to meet their energy demand. The demand of the energy could be met by using non conventional energy sources especially solar photovoltaic and solar thermal technologies. The green house gases have been considered as one of the major causes of the global climate change. The carbon dioxide emission during fuel consumption for power generation has also been considered. The carbon dioxide comprises major portion of the green house emissions. The results could be implemented by the policy makers in developing countries as an effort to reduce the emissions and maintain the growth rate of the country.

Keywords: Emission reduction, green house emissions, renewable sources, solar photovoltaic, solar thermal.

1. Introduction

India has already decided to cut the carbon intensity from 20% to 25% by 2050 against a 2005 base line .It can be achieved only when each individual is made aware of the need of energy so that a collective effort can be made by all so as to acquire the target as expressed by the minister of power at the Copenhagen meet at Denmark. Since India is a large country having many states which has many cities. The cities are slowly transforming into metropolitan as the villages are slowly changing into urban as the road and other facilities are increasing In India the rural places comprises more than 50% of the total population, so we can say that India is a rural country with most of its population living in the villages. Among such cities there is a city named Lucknow which has developed in the last decade with the construction of roads linking various parts of city consequently resulting in the improved transportation and hence increased green house gases emissions respectively.

In spite of such improvements there are hundreds of villages in India which are deprived of electricity and some do not have grid supply. These villages are located at a distance of ten kilometers from the main road and the villager's uses kerosene oil for lighting purpose and wood for cooking purposes.

In order to supply electricity the transmission line should be extended which is a costly option. Therefore the decentralized power supply is the best option. Since the people living in far flung places are small farmers and are based upon agriculture and animals for their livelihood so to set up a standalone plant is not the best option for such places. We should search for better option such as solar photovoltaic and solar thermal for such places for lighting, cooking, heating and agricultural purposes. In this paper, an attempt is being made to determine the rate of diffusion of the new technology based on solar power .The feasibility study of the solar power based technology is also done and the green house gases reduction by employing the new technology based on solar is estimated. The per capita consumption of the village people residing in such areas is far less as compared to those living in the cities, so a small power can suffice the need of the people living in such places. Providing solar lantern, solar cooker, solar home lighting system, solar pumps could cater their daily needs and at the same time it will reduce the green house gases (GHG)

emissions .The health problems due to cooking based on woods can also be avoided by solar cooker. Subsidies need to be given by the government as all the people are not able to purchase the solar pumps and the solar home lighting system .The subsidies are already given by the government agencies of about 55% on the home lighting system which cost Rs 13585 (subsidized cost).There is a facility to get the system installed by a payment of Rs 3585 and rest by paying in installments which can be easily paid by the consumers. The solar lantern cost about Rs 500 which can be easily managed by the consumer .The solar pump is costly so it will be used by the affluent people of the village. In India, the per capita consumption of electricity is 500.5 Watts/day.()

2. Literature review

Literature review is on of the important aspects of research (Hina et al., 2007) It gives the latest information pertaining to the various related issues and the latest developments in the global arena to solve the problem .A number of publications, journals, technical papers, seminar proceedings, research thesis are consulted to understand the power status in the rural places of India .The study has been carried under two sub headings as discussed below.

2.1. Energy status: This section deals with the power which is available in the rural places. In India, 70% of the people lives in 5, 87,258 villages. About 95% of the villages are electrified which comprises of 138 million households so 29363 villages still remains unelectrified .We can say that 300 million of the total population of the country mostly in rural areas have no access to electricity. Only 31% of the rural households are electrified as against 76% in urban households of the total living in the rural and urban place respectively .There is a rapid urbanization of the Indian villages which is found by survey the reason being the improvements in the road communication from villages to city, mobile communication, increase in the employment and the economy of the people as a whole. The electricity consumption in India has grown from 550 MU in 1999 to about 5555 MU in 2010 which implies that the energy consumption rate has been increased by 10 times which does not match with that of electricity generation rate which has increased by three times respectively in the same period .Thus this threefold increase need to be taken seriously for the sustainable growth of the country as the conventional sources will deplete by the end of this century. The consumption of the conventional sources can't be increased every year to meet the growing energy demand of the country, hence some alternative source for energy generation is needed which has large potential in India .In India, most of the people live in the rural areas and the country's economy is largely dependent on agriculture.The rural people uses small gas cylinder for lighting and cooking purposes and who are having some land for cultivation or literate to some extent. The liquid petroleum gas (LPG) is sometimes not available or they have to go far away to meet their needs. They thus have an alternative arrangement by depending on kerosene oil or wood in place of LPG. The kerosene oil is bought from the government shops at subsidized rate which is limited so most of the people need to depend on the private shops which sell kerosene at a higher rate of Rs 30 per litre. There is a risk of fire and health problems using the fuels based on oil and wood for cooking purposes.The main conveyance of the rural people is bicycle and about 10% of the people owns motorcycle operated on petrol based fuel for going to the shops or market in the city .About 5% have some vehicle such as tractor or trolley attached small vehicle. About 2% have cars or vans for transportation purposes. The vehicle for transportation uses diesel or petrol based fuel. The population of the villages is increasing at a rate of 10% per annum in India; thereby the energy demand is also increasing in the same proportion. There is a need of supplementing their energy needs by some alternative form of energy which is more feasible for the people living in those places in terms of cost and reliability. The demand for power has been recently increasing at a compounded annual growth rate of 9% per annum (Ghosh et al., 2005). Rural population is higher as compared to the urban population so its affect is more on the total population growth rate. Therefore by seeking solution of the energy needs in a decentralized manner will provide more effective solution.

2.2 Greenhouse Gases: In India generation of electricity is largely dependent on coal. It is the third largest coal producer and consumer in the world after China and US, respectively. The coal usage is 247.9 million metric tonnes (MMT) in 1990 in India which has increased to 550.7MMT in 2006 (EIA, 2006), as such it seen that the coal usage in increased two fold to meet the present energy needs .The expected life time of the coal resources is about 50 years (3).The high ash content causes technical difficulties at the power plants (IEA, 2000). This increase in coal consumption has lead to increase in the green house gases (GHG)emissions .In India, the GHG emissions is 583MMT in 1990 which has increased to 1293MMT by 2006 (EIA,2006). The coal contributes to 40% of the GHG emissions and the coal based power generation is mostly used which accounts for 66% of the total generation .The other sources of generation are hydro, nuclear, gas, oil and renewable respectively. India's CO_2 emissions due to consumption of energy were 1.1 Gt,of which emissions from combustion of coal were 0.7 Gt of CO_2 in 2004(IEA 2007).There is an annual rate of rise of 4.4% CO_2 emissions between the year 1990-2000 and 5.1% rise in between 2000-2005(Shukla et al.,2006). The per capita emissions of India is tenth in the world but the emissions annually stands fifth and likely to reach third place by 2012 if it goes on increasing at the present rate of increase. The major effect of these GHG emissions is the climate change which is a matter of concern all over the world and plenty of conferences are conducted throughout the world to obtain the solution. The Kyoto protocol, held at Japan is the first international agreement in 1997 among the developed and developing nations to find a solution to this climate change by the exchange of technology, financial support and sustainable growth respectively. However we see that almost no improvement is visible as most developed countries neither agreed to the Kyoto protocol and nor gave the financial support to the developing nations or the technology. Another international conference

at Bali, Indonesia in 2007 was organized to formulate a meaningful solution, but it also failed to combined effort of the developed countries which are not ready to slowdown their economic growth by checking the GHG emissions. In 2009 another international meet was held at Denmark to obtain a solution which could lessen the gap between the developed and developing nations. However the two week mind boggling exercise could not provide a solution to the developing nations like India. The countries like Maldives, Fiji, and Bangladesh etc. which were the sufferers of climate change effects although they do not generate large GHG emissions. Thus we see that the developed nations are more concerned about themselves and their own prosperity rather than about the developing and under developed nations, so to depending on their support for bringing a change in the GHG reduction in the world does not seems feasible . There is an urgent need to develop some model based upon the resources available in India which could fit for the rural areas of India and at the same time it could provide sustainable growth in the country.

2.3 Energy demand analysis and forecasting:

In rural India people mostly use kerosene oil for lighting purposes at home by means of lantern lamps and wood for cooking purposes and canals for irrigation purposes, diesel operated generators for pumping out water for irrigation when there is no water supplied from canals .The per capita consumption of people is 50.5 kWhr or units respectively. Since the people are illiterate so they do not need to wake up late at night. The lanterns are kept burning throughout the night though at its minimum and kept at one corner of room so that there is no need to light it again after putting it off. The continuous burning of the lamp leads to consumption of kerosene oil which accounts for half liters consumption approximately costing about Rs 15, so we see that there is an expenditure of Rs 450 per month for the oil for lighting purposes. It is observed that the people of the rural villages has the capacity to pay for the electricity charges which is paid by the people of electrified villages. The fuel for cooking is based upon wood which is collected mainly by women and children. Incorporating some other form of energy which is a sustainable source and non polluting that could be provided to help these remote villagers .Thus beside providing them light they can also contribute their efforts to reduce the greenhouse gases emissions. A reasonable knowledge of the present and past energy consumption and the future demand are primary requirements for energy planning .An accurate energy demand forecasts is primarily required to enable timely reasonable and reliable availability of energy supplies to ensure proper functioning of the economy. Errors in demand projections lead to shortages of energy, which may have serious repercussions on economic growth and development of the nation. Popular methodologies employed in energy forecasting include time series trend analysis, econometric multiple correlation forecasting, macroeconomic and input-output models, survey etc (Bargur et al.,1981). The simplest approach for energy demand modeling is time series trend analysis (Sharma et al.2000) Regression models are also employed for forecasting the consumption of various commodities like electricity, coal and petroleum products (Farahbalhsh et al.1998) (Rao et al.,1996). Econometric models that correlate the energy demand with other macro economic variables are effective for medium term forecasts as it relates the demand in physical terms to some socio-economic determinants(Ramprashad,1993) (Bernt et al.,1975). Econometric energy demand models are used to aid planners and policy makers in evaluating past experiences, studying the impact of future policies and forecasting demand for planning purposes. A widely used modeling approach is the two tag optimization procedure in which the optimal amount of aggregate energy is first determined followed by choosing the optimal amount of fuel (Halvorsen.R, 1977), (Elkhafif, 1993) (Bass, 1969).There are various model which are used for the adoption of new technology .One such model is used for estimating the rate of adoption of consumable durables (Fernandez,2008). The pearl model is being used to estimate the wind potential in India .The bass model and pearl model is used for the estimation of the solar photovoltaic potential in the island of lakhsdeep (Ashraf et al., 2007). The technological forecasting in India first started in 2005(MNRE report, 2005). There are two aspects of conservation, in one of them less energy is used with no sacrifice on the part of the individual affect of economy and technology. The second aspect of energy conservation involves some forgo on the part of user. There is a limit beyond which conservation measures may become too costly in terms of foregoing other resources or useful outputs thereby causing more harm than good (Dhingra,1999). Energy conservation is the demand of the time and it means to save man's "fuel-powered" ecosystem .Improvement in energy efficiency brings environmental and economic benefits at the same time. It weakens the link between energy demand and economic growth and delays the need for new capacity(Fleming,2000) ,(Maniwala et al.,1996), (Munnasinghe,1983). Demand supply management (DSM) is a broad term often used in place of energy efficiency and vice versa. It covers all means of influencing the magnitudes and pattern of energy consumption. Two types of tools namely, hard and soft are used for DSM .The hard policy tools like physical controls, technical methods and directed investment are more effective in short period of time. The soft policy tools include pricing, financial incentives, education and propaganda and have a greater impact on a longer period of time. Both the techniques need to be carefully coordinated (TERI report, 2006).

3. Energy Management

The population is growing at a rate of 10% annually so we can conclude that the energy need is also increasing accordingly. The family is also splitting due to the transfer from joint family concept to the nuclear concept which is adopted at present. The numbers of the houses are increasing as a result of nuclear family concept and therefore the energy need is also increased accordingly. The energy shared by the family members in the joint family concept is favorable from energy conservation point of view.

3.1. Lighting: The energy needs can be partially fulfilled by adopting new technologies based on solar photovoltaic (SPV) or fuel cells (FC) .In villages there is a need of light in homes and street during night. For lighting purposes, both the solar photovoltaic and fuel cell based technology are feasible. If both the technologies are hybridized then it would be more effective .The SPV panel collects the solar energy from the sun and transformed it directly into electrical energy which can be used to charge a battery .The battery stores the electrical energy in the form of charges. These charges can flow through a load such as LED torches, CFL lamps, dc fans etc. The charge that can be collected in a battery depends on the size of the battery (ampere hours) and the size of the SPV panel area respectively. The SPV technology can be incorporated for pumping water for irrigation purposes but at the stake of larger incurring cost.

3.1.1. Cost analysis for grid based lighting:

No. of villages still unelectrified= 29363

Average no. of houses/village=100

Total no. of houses still unelectrified=2.94 million

Minimum electricity consumption /capita (in India) =50.5units

Total energy consumption =50.5*2.94 million units =148.3 million units

Cost of generation (including transmission and distribution with the existing power system in India) =Rs 95 per Watt

Tariff=Rs 3.50 per unit

Tariff per month=Rs 3.50*30 units (say)
=Rs 105.00

Each household requirement (Minimum as given by National Policy Act) =1KW

Total power required for village electrification=2940 MW

Cost of total village electrification (Using Grid supply)=Rs 27930 Crores(approx.)

3.1.2. Cost analysis for SPV-FC based lighting:

Cost of solar home lighting system (SHLS) =Rs 13585/household

Total cost of SHLS (Unelectrified villages) =Rs 13585*2.94 million =Rs 3994 Crores

Cost of one solar lantern=Rs 1440

Total cost of solar lantern (Unelectrified villages) =Rs 1440*2.94 million=Rs423.36 Crores

Transportation +Installation+ other charges=Rs 450 Crores
National Saving's (Using SPV-FC systems for unelectrified villages of India) =Rs 23062.64 Crores (approx.)

Recovery period for the installed systems=5 years

Monthly payment=Rs 234.75/household

Daily payment=Rs 8/household

This amount is easily payable even by a laborer.

3.1.3. Cost analysis for kerosene based lighting:

Kerosene consumption per day by a rural household = 180.6ml (approx.)

Monthly consumption of kerosene oil=5.42 litre

Cost of 1litre kerosene=Rs 30(approx.)

Total cost of kerosene/household=Rs 162.50/month

3.2. Green house gases emissions:

The solution for getting light in a typical rural household is discussed in the previous section. Now we analyze the important aspect that is, emissions that occurs due to different methods

TABLE 1. Green house gases emissions by different fuels used for rural lighting

S.No.	Comparison of different lighting system in rural home areas		
	Source	Cost(Rs.)	GHG Emissions/year (million metric tonnes)
1.	Grid supply	504.00	70.56
2.	Solar Photo Voltaic	234.75	-
3.	Kerosene Oil	162.50	0.4916

4. Forecasting

The forecasting models can be implemented for the solar photo voltaic and other renewable based appliances to analyze the rate of adoption by the consumers in a specific period of time.

.

4.1 Rate of Adoption

The widely used diffusion theory discussed by [26] states that innovations are diffused over time in a pattern that resembles as S-shaped curve. Rate of adoption postulates that an innovation goes through a period of slow, gradual growth before experiencing a period of relatively dramatic and rapid growth. The theory also states that following the period of rapid growth the innovator's rate of adoption will gradually stabilize and eventually decline.

4.2 Pearl model

As per this model, the following expression can be used for cumulative number 'N (t)', of the renewable energy based technology disseminated up to the t^{th} year. The coefficients 'b' and 'k' determined from the earlier data. The forecasting for any period of time can be evaluated using the expression (1).

The least square estimators of the logistic growth curve parameters are as follows

$b = e^{b0}$; $k = -b_1$; $b_0 = Y - b_1T$; $Y_i = \ln (1/R_i - 1)$; i= 1, 2, 3,…

$Y = 1/N (Y_0 + Y_1 + Y_2 + \ldots..)$ (1)

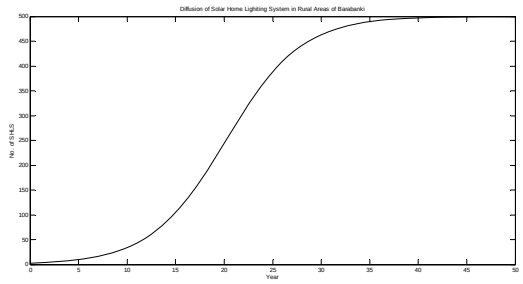

Fig 1. Adoption of solar home lighting system in Rural areas of Barabanki since 2008.

5. Result and Discussions

In this paper, we considered the cost of the fuel as a result of greenhouse gases emissions. It was observed that although the grid based supply of electricity cost per household is a small yet the installation cost of the power system based on coal based generation is very high and is not practicable for India keeping the high growth rate of the country. Moreover it is contributing much to the GHG gases which will add up to the global warming which will be harmful for the world climate. The SPV-FC based lighting system is having higher unit charges but the installation charges are much lesser as compared to the grid based system. It is environment friendly as compared to other sources. The kerosene based lighting is having moderate cost but it is also adding to the GHG emissions as well harmful for health. It estimated that about 352.8 MMT GHG gases can be mitigated per annum by implementing the SPV-FC technology in India.

6. Conclusions

We conclude that the SPV-FC based lighting system is the best option to provide proper illumination to the rural households. However care should be taken that awareness among the rural people should be made by proper education though media, schools, training etc. The entire exercise should be taken in two steps; the first one may be for short term up to five years. Whereas the other should a long term, taking into account of the sustainable development in the area which could be planned for a period of 50 years. The application of SPV-FC technology to the transport sector and agriculture sector could also be done to verify the feasibility of the technology in the rural area so that the development of the villages could be done alongside.

Nomenclature

DSM Demand supply management
GHG Green house gases
Gt Giga tonnes
KW Kilowatt
MMT Million metric tonnes
SHLS Solar home lighting system
SPV-FC Solar photovoltaic fuel cell

.

Acknowledgement

The author expresses his gratitude to their family members for their patience and help during the preparation of this paper. The author also expresses his thanks to all those who had helped in any way.

References

Bargur and Mandel, A.1981.Energy consumption and economic growth in Israel trend analysis (1960-1979), *Proceedings of the 3rd International Conference on Energy Use Management*, Berlin, Vol.4, pp A1-A8.

Berndt.E.R, Wood.D.O. 1975, Technology, price and the derived demand for energy, *Review of economics and Statistics*, Vol.6, pp259-268.

Bass, New product growth model for consumer durables1969, *Management Science*, pp.215-227.

Chikkatur, A.P. (2005). Making the Best Use of India's Coal Resources, *Economic and Political Weekly* (Dec.2005):5457-5461.

Dhingra.K.K, 1999, Impact of energy conservation in energy sector development, Financing of Energy Sector in Developing Countries,

pp.203-210.
Elkhafif.M.A, 1993, Energy forecasting models, simulations and price sensitivity, new formulations, *International Journal of Forecasting*, Vol.9, pp.203-210.
Energy Information Administration, EIA (2006).World Per Capita Energy Consumption.U.D.EIA.2007.
Farahbalhsh, H.Ugursal.V.I, Fung.A.S, 1998.,A residential end-us energy consumption model for Canada., *International Journal of Energy Research*, Vol.2, pp.1133-1143.
Fernandez, "Estimation of CDM wind potential in India," *Energy Policy*., 2008, Elsevier.
Flaming.S.W, 2000, Developmnt of energy efficiency and DSM service experience of US utilities, *Sustainable Energy supply in Asia*, pp.356-365.
Ghosh, D. 2005. Assessment of Advanced Coal based Electricity Generation Options for India: Potential Learning from US Experiences.BCSIA *Discussion Paper Series*, Harvard University.
Halvorsen.R, 1977.Energy substitution in US manufacturing, *Review of Economics and Statistics*, pp.381-388.
Hina, V.Devadas, Energy Management in Luck now city, *Energy Policy*, 2007, Elsevier.
I.Ashraf, M.A.Mallick, M.S.Ansari, A. Chandra, "Renewable Energy for Power Generation in Androth Island: Projected level Dissemination Using Technology Diffusion Models", *International Conference on renewable energy*, New Delhi, 2007].
International Energy Annual Report, IEA, (2000).
Mallick.M.A, Ashraf Imtiaz, 2010, Technology Diffusion Models as tools for demand supply management, *IE(I) Journal*, India.
Maniwla.M.J, Prasad, 1996).S.S.R., 1996, Energy management strategies in Indian Industry, *EnergyManagement*, Vol.3, pp.2-12.
MNRE Annual Report, 2005. GOI, India.
Munasinghe and Schramm, 1983, Ramprasad.S. 1993. Energy modeling for India towards a policy for commercial energy,' Study *Report of planning Commission*, Government of India, New Delhi.
Rao .R.D, Parikh, 1996, Forecast and analysis of demand for petroleum products in India, *Energy Policy*, 24(6), 583-592. Delhi.
Sharma.D.P, Nair, Rao.B, 2000, Residential demand for Electrical energy in the state of Kerala: an econometric analysis With medium range projections, *Proceedings of IEEE Power Engineering Society*, 2000, Singapore; 23- 27January.
Shukla, P.R. (2006). "India's GHG emission scenarios: Aligning development and stabilization paths."*Energy policy*. Elsevier.
TERI report ;(3i Network,2006).
TERI report, 1997.

Biographical notes

M . A. Mallick received BSc.Engg and M.Sc.Engg degree from Aligarh Muslim University, Aligarh, India in 1994 and 1998, respectively. He has submitted his PhD thesis in the year 2011 in Integral University, Lucknow.He is working as Asstt. Professor and as Head of the Department of Electrical and Electronics Engineering, Integral University, Lucknow, India. His research interests include renewable energy systems, power system modelling, instrumentation, electrical machines and drives. He is a Member of IE (India), Associate member of IETE (India).He has many publications in national and international conferences.

I.Ashraf received his M.Sc. Engg from Aligarh Muslim University(AMU), Aligarh and PhD degree from Indian Institute of Technology, Delhi in 1993 and 2005 respectively. He is working as Associate Professor in the Electrical Engineering Department, AMU, Aligarh, India. Presently he is on leave and working as Assistant Professor in Taibbah University, Madina Munawwarah. His research interest includes ANN based modelling, Renewable energy Power system optimization, etc.

M.I. Khan received his M.E. and PhD degree in 1966 and 1979 from Roorkee University (IITR).He has worked as associate professor in MNREC, Allahabad and IITRoorkee.Thereafter he had worked as professor in mechanical engineering department in an engineering college in Lybia for 10 years. Presently he is working as professor in the Mechanical Engineering department since 2000.He has large number of publications in international and national journals. His field of interest is under water welding, renewable sources, production engineering etc.

S.Pandey received her B.Tech degree in Electrical and Electronics Engineering from Integral University in 2010 .She is presently doing M.Tech in power electronics and drives from MMMEC, Gorakhpur .Her field of interest is electric drives, renewable energy sources, machines and power electronics.

Received February 2011
Accepted March 2011
Final acceptance in revised form June 2011