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Adaptation of renewable energy technologies along with non-renewable energy technologies for sustainable use of energy resources

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ABSTRACT

The history of economic development is on the cost of ecology rather than sustaining environment and development. The countries that became centrally located in the stream of economic exchanges among people around the world impacted the environment in the long run. Newspapers and editorials include environmental horror stories almost on a daily basis and demand better management of natural resources (Jangu, 2014). But who is listening? The environment is not just lush green trees, threated plant and animal species. It is the entity on which humans primarily exist, and agricultural and industrial development depends. Development on the cost of the environment can never be sustainable rather it would take us to a point causing enormous ecological losses and human sufferings primarily because of the present rate of development in developing countries. In order to contribute to the overall development in India, access to modern energy and cleaner fuel for rural households is important. The Brundtland Commission in its 1987 report 'Our Common Future' coined the most quoted definition of the term sustainable development, *i.e.*, development that meets the needs of the present without compromising the ability of the future generations to meet their own needs (Mathur and Goswami, 2016). Sustainable production and consumption of resources helps to satisfy necessities of life such as nutritious food, good health, clean water and sanitation, clean energy, education, employment creating sustainable communities while combating climate change. Having a negative energy balance for decades, India is forced to purchase energy from other countries to fulfil the needs of the entire country. Hence, energy access is an important component of poverty alleviation and an indispensable element of sustainable human development. Government of India has initiated numerous development programmes focussing on providing sustainable energy solutions to rural communities often deprived of clean and uninterrupted energy supply for their daily energy requirements. The study entitled 'Renewable Energy Options among Rural Households' was conducted in Haryana and Himachal Pradesh states. The outcomes of the study provide a roadmap for future programmes promoting the use of clean, efficient and modern energy technologies, to be implemented more effectively. Findings would further benefit the primary and secondary key stakeholders involved in research and

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development, formulation of policies and regulations, promoting sale and purchase and provide financial assistance to future energy programmes meant to popularize the use of Renewable Energy Technologies.

Key Words : Renewables, Sustainable energy, Rural households, Energy-use pattern, Solar energy

INTRODUCTION

Energy is fundamental to survival of life in any part of the globe. The pervasive nature of energy related activities have vast impact on the environment world over. With the current pattern of energy production, distribution and consumption, the resources will be exhausted much faster that would cause accelerated environmental degradation and slow down the progress dramatically. The energy sector has to play a critical role, especially in developing countries due to the huge investments required to meet the growing energy needs.

For the present research the categorization of energy resources used is Non-Renewable and Renewable energy resources. Non-renewable Energy Resources refer to those sources of energy that are derived from finite and static stock of energy. They cannot be produced, grown, generated or used on a scale that can sustain its consumption rate. The fossil fuels such as coal, petroleum, natural gas, nuclear power are examples of non-renewable sources of energy. Renewable Energy Resources refer to those resources which are available in abundance, are infinite and environment friendly in nature. These resources include solar, wind, biomass, wave and tidal energy (Varun and Chauhan, 2014).

Energy access to rural households in India :

India has transitioned from being the world's seventh-largest energy consumer in 2000 to fourth-largest within a decade and is the fifth largest power generators worldwide. India's energy basket has a mix of all the resources available including renewable energy resources (Pawar and Kaur, 2014).

Among the various sectors that use energy, household sector is the largest consumer of energy. Rural Households (HHs) in developing countries are often dependent on the use of traditional biomass resources such as fuel wood, crop residue and dung cakes for activities such as cooking, domestic lighting, water heating, cattle-feed preparation and indoor space heating. It provides for a minimum life-supporting energy service and also represents a high financial cost, negative effects on human health and stress on environmental resources.

There are many impediments to energy access for the rural masses despite the launch of several programmes and policies by the Government that aim to improve quality of life of people living in the remote and rural areas of the country. Some of these barriers are geographically-dispersed villages that are difficult to reach and hence, providing electricity (through conventional electric grid) becomes difficult. There is inadequate focus to explore local energy resources either due to lack of funds, technological know-how and appropriate organization. Adequate financial models to tap resources through Public-Private Partnership (PPP) are inadequate. Private sector investment is not sufficiently facilitated by the Government through an appropriate mix of subsidies and grants; incentives and tariff policies; and risk sharing. Due to low population density and fewer households in rural areas there is

high transmission cost along with severe transmission and distribution losses. The lack of facility for domestic connection in initial stages, uncertainty of power, load has impacted the demand for power in rural area due to poor quality and unavailability. Long and cumbersome procedures for getting a connection, distant location of facilities for paying bills and repair affect acceptability of renewable energy resources (Kumar, 2012).

Need to shift to renewable energy technologies (RETs) :

Traditional solutions often comprise relatively low efficiency and much of the energy output gets wasted due to use of age-old (inefficient) technologies. Therefore, sustainable energy services are seen as a necessity for improving the standard of living, facilitating development and reducing environmental impact. Use of decentralized and small-scale technologies that make use of new, locally available, renewable resources such as sun, biomass, wind, water etc. appear to be the ultimate solution. RETs can provide universal modern energy services which drive development and improve living conditions, particularly in rural communities (Mahapatra and Dasappa, 2012).

As mentioned by Kumar *et al.* (2010), to meet the energy requirement for such a fast growing economy, India will require an assured supply of three to four times more energy than the total energy consumed today. RETs are being progressively adopted as an alternative to conventional energy resources to ensure a sustainable future. In India there has been vigorous pursuit of activities related to production, application, research and development, demonstration and awareness for a variety of RETs to be used in different sectors. The benefits of access to clean energy resources for rural areas are many, including reduced deforestation and carbon emissions; improved healthcare services due to reduced consumption of raw water and smoke from open fire cooking; clean energy generated from renewable resources; decreased use and dependency on kerosene, wood and coal; improved agricultural output and access to potable and clean water. Renewable energy sources create a momentum for increasing time available for productive, income generating tasks and wealth creation over time. This can help in poverty reduction in rural communities (Chaurey *et al.*, 2004).

METHODOLOGY

The study was conducted in villages/hamlets from four districts of two states, viz-a-viz., Faridabad and Panchkula districts (Haryana); and Hamirpur and Bilaspur districts (Himachal Pradesh). The selection criterion for villages/hamlets for study was the presence of residents using RETs, *i.e.*, either possessing or benefitting from RETs (since two or more than two years). The villages/hamlets from Haryana and HP were selected as the locale of the study because ofpresence of HHs using similar types of RETs in both the states, there was availability of solar grid in Haryana for electrification of HHs that provided an opportunity to the researcher to understand the effect of electricity on their quality of life. Few hamlets that were close to the border of HP, also benefitted from the solar electrification programme of Haryana. This gave an opportunity to compare the ownership and usage of RETs in both the states.

The ex-post facto research design included qualitative analysis and interview of the stakeholders, *vis-à-vis*, RET users, village representatives and RET programme

implementation officers from *AkshayUrja (AU)* shops. Purposive Sampling Technique was used to select the key stakeholders for the study (*i.e.,* RETs programme implementation officials, RET users and village representatives).To get an insight about the location of houses using RETs, community service and facilities, sources of biomass collection etc., resource maps were prepared by involving the village representatives, residents and programme implementation officials (field staff from *AU* shops and local repair technicians).

Significance of the study :

Achievement of goals at an individual, community and world level are possible only if access to affordable and reliable energy for rural areas is available. This would help to strengthen jobs, enhance security, provide hygienic food, increase income, help in betterment of health and education. United Nations have been working with Governments to ensure the sustainable development across the countries. Millennium Development Goals (MDGs) launched in 2000 primarily focussed on ensuring environmental sustainability by integrating the principles of sustainable development into country policies and programmes and reverse the loss of environmental resources (Goal 7A). Though there was no MDG specifically mentioning energy access and security. Building on the success and momentum of MDGs a smooth transition to the new global goals, *i.e.,* Sustainable Development Goals (SDGs) launched in 2015 had proposed to confront the energy issues directly. These cover the three dimensions of sustainable development, namely, economic growth, social inclusion and environmental protection. In addition, these 17 SDGs are universal and apply to all countries, unlike MDGs that were intended for action in developing countries only. Each goal has specific targets that have to be achieved over the next 15 years. Goals that focus specifically to energy access and mitigation of climate change are Goal 7 (Ensure access to affordable, reliable, sustainable and modern energy for all) and Goal 13 (Take urgent action to combat climate change and its impacts).

In India almost 68.84% of the population resides in rural areas (Census Report, 2011). Also, India has highest percentage (35.4%) of population in the world that does not have access to the modern energy. Most of this population is from the rural areas of India. In addition, rural India is a power house of natural energy resources and provides great opportunity for production of renewable energy that can be utilized for the rural households, community at large and improving their built-environment such as schools and health centres. Also, improving the overall quality of life of residents w.r.t providing power to small businesses or cottage industries, income generation, financial security, health, education and reduction in drudgery of women. The research entitled Renewable Energy Technologies among Rural Householdsstudied the energy use pattern in rural HHs of Haryana and HP; pointing towards two broad categories of resources used by rural households to fulfil their day-to-day energy requirements for various HH activities. These were Non-Renewable Energy Technologies (NRETs) and Renewable Energy Technologies (RETs).In light of this, the study proposes a Sustainable Development Model for Co-existence of NRETs and RETs that can helpto integrate efficient use of RETs and conservation of NRETs, to achieve the Sustainable Development Goals (SDGs). At the same time provide solution to the existing barriers in adoption and sustenance of new and modern technologies in rural communities.

RESULTS AND DISCUSSION

Non-Renewable Energy Technologies (NRETs) and Renewable Energy Technologies (RETs)used by selected rural HHs of Haryana and HPhave been classified as follows:

NRETs used by residents for various HH activities included :

– Biomass- It primarily comprised of fuelwood (used along with a combination of crop residue and dung cakes).

– Fossil fuels- These include LPG, kerosene, coal and candles.

– Electricity (from conventional grid) was used to power various electrical and electronic devices owned by rural HHs.

RETs used by residents for various HH activities included :

– Solar-based Technologies- SPV (Solar Photovoltaic) Technologies such as home lights, lanterns, torch and street lights; Solar Thermal Technologies such as solar water heaters (Flat Plate Collector type and Evacuated Tube Collector type), solar cookers (Box type and parabolic type) and solar grids (up to 10KW).

– Biomass-based Technologies- Rural HHs in Haryana and HP were only using family size biogas plant up to $1m^3$.

Energy use pattern for household activities :

The energy use pattern highlighted that rural HHs used multiple energy resources for accomplishing various HH activities. RETs seemed to be a promising solution to the increasing needs of rural residents and the willingness to improve their quality of life. RETs were recognized as an important way to enrich the energy supply to rural HHs, reduce their financial burden from commercial energy consumption and was a boon for the environment. The major activities for which NRETs and RETs were used were Household Cooking; Household Lighting; Water Heating; and Indoor Space Heating, Ventilation and Cooling.

Energy resources used for household cooking :

The most popular energy resources used for HHs cooking were a combination of LPG and firewood/biomass. In Haryana, most of the HHs (52%) used a combination of fuelwood/ biomass as primary resource and LPG as secondary energy resource for cooking. In HP, majority of the respondents (57%) preferred a combination of LPG as primary and fuelwood as secondary cooking resource.Only 6% respondents from Haryana and 2% from HP indicated the use of RETs as secondary energy resource along with using LPG while none of the biomass users preferred using RETs.

The main reasons mentioned by the respondents for selection of fuelwood/biomass were low cost (96% from HP and 62.50% from Haryana) and familiarity with the use of biomass (80% from HP and 78% from Haryana) followed by ease of availability (67% from HP and 33.3% from Haryana) and ease to use (30% from HP and 12.5% from Haryana).

Few respondents indicated that fuelwood was easy to use, which was conversely the main reason for the selection of LPG (86% from Haryana and 81% from HP). Ease of availability was another important factor for almost 66.5% respondents from Haryana and

52% from HP to choose LPG over other resources for cooking purposes. There were respondents who considered LPG as affordable (40% in Haryana and 33% in HP) in view of the ease and comfort it provided in form of reduced drudgery of women and reduction in associated health risks.

Energy resources used for household lighting :

Respondents shared that along with taking maximum advantage of sunlight they used multiple energy resources. Majority of the respondents used electricity (from conventional grid) as their primary energy resource for HH lighting (74% from Haryana and all the residents from HP) followed by RETs that emerged as popular lighting resources for 64% HHs from Haryana and 60% from HP). Kerosene was used by 48% HHs from Haryana and 25% from HP) and usage of candles was practiced by 34% from Haryana and 35% from HP, respectively. The most popular combination of lighting energy resources was electricity (from conventional grid) as a primary energy resource with RETs as secondary (54% from HP and 47% from Haryana) followed by kerosene (28% from Haryana and 25% from HP) and candles (25% from Haryana and 21% from HP). Electricity and RETs were preferred because of ease of usage and availability.

Energy resources used for water heating :

Rural families used a different combination of energy resources including biomass, LPG, coal, electricity and RETs. The most popular energy resources for water heating were fuelwood/biomass (62% from HP and 59% from Haryana) and electricity (55% from HP and 41% from Haryana). Majority of the respondents using fuelwood as a primary resource for water heating chose) chose electricity as the secondary energy resource along with it (54% from Haryana and 29% from HP). The study findings also indicated the popularity of RETs along with fuelwood (37%) followed by LPG (35%) while in HP, LPG was a popular alternative resource used in combination with fuelwood (31%) followed by 12% candle users. Almost 29% biomass users from HP and only 7% from Haryana did not make use of any other fuel for water heating.

On the other hand, all the respondents using electricity as a prime resource also utilized alternative resources to fulfil their daily water heating requirements. The most popular combination being electricity and LPG, preferred by 43% respondents from Haryana followed by 38% fuelwood users and 19% using RETs. In HP, preference was shown towards a combination of electricity with RETs (66%), LPG (53%) and fuelwood (25%). None of the respondents mentioned using only electricity for water heating in both the states.

Energy resources used for indoor space heating, ventilation and cooling :

In rural HHs, the need for indoor heating, ventilation and cooling was fulfilled mainly by electricity (from conventional grid). The preferred combination used was electricity (from conventional grid) as the primary energy resource along with fuelwood/biomass (36% from Haryana and 19% from HP) followed by coal (10% from HP and 8% from Haryana). Coal was used by few rural HHs in a traditional device called *sigri* for space heating mainly in hilly terrains.

Sustainable Energy Model for Co-existence of Non-Renewable Energy Technologies (NRETs) and Renewable Energy Technologies (RETs)

RETs were necessary for fulfilling rural energy requirements for daily activities as well as a solution to the sustainability issues related with NRETs w.r.t economic, social and environment. Access to modern and clean energy services especially for rural poor is essential to achieve the Sustainable Development Goals (SDGs) to end all forms of poverty, fight inequalities and tackle climate change, while ensuring that no one is left behind. Based on the research, a sustainable development model has been proposed for rural development by adaptation of RETs along with efficient use of NRETs (Fig. 1).

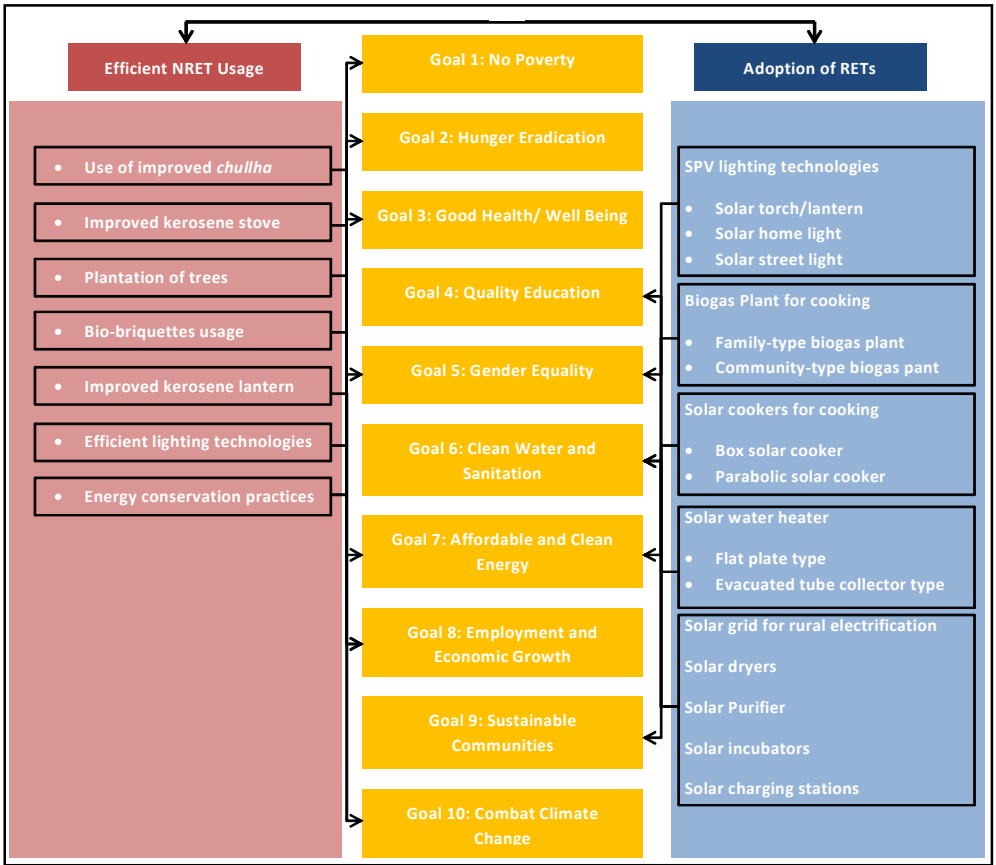

Fig. 1 : Sustainable development model

The research findings revealed that biomass (such as fuelwood, crop residue and cow dung) and fossil fuels (such as LPG, kerosene, petrol, candles) and electricity (from conventional electric grid)were an essential component of every rural HH and their existence is likely to continue in the near future as well. On the other hand, RETscan play an important role in reducing dependence on traditional/conventional technologies and increase access to modern energy services in an appropriate and environmentally sound way. Rural areas are blessed with huge amount of renewable natural resources that can be developed and utilized

to reduce energy poverty and enable sustainable development. RETs are the best solution to answer the energy accessibility and poverty issues because they cause less environmental impact than the conventional fuels, cannot be depleted unlike fossil fuels reserves and fuel wood, and are available as decentralized and independent solutions.

The sustainable development model suggests that the use of renewable energy resources combined with efficient use of biomass and electricity, can help in reducing the environmental effects of energy use and enable rural residents to supplement and complement the existing conventional energy resources to achieve the three components of sustainable development, namely, economic growth, social development and environmental safety or protecting the eco-system. Since, the traditional biomass is drawn directly from the environment it requires a sound management of these resources to be sustainable. In addition, their usage affects the environment. For example, Green House Gas (GHG) emissions with inefficient and incomplete combustion of biomass impacts the environment and contributes to climate change.

Since, every energy resource causes some impact on environment, efficient use of conventional energy resources along with the use of RETs to supplement NRETs, can help to overcome many of the concerns regarding the limitations imposed on sustainable development. RETs have the potential to achieve many sustainable development goals. These have been discussed as follows-

GOAL 1-Poverty alleviation :

The use of RETs provided rural residents with income generation opportunities. They enabled new start-ups and increased profitability/ productivity from existing work. New livelihood opportunities w.r.t RETs included setting-up shop for repair of RETs, solar charging stations, manufacturing of improved *chullhas*, opening small businesses such as beauty parlour, boutique, petty shops. Solar PV technologies and solar grid had positive implications in the lives of rural poor. In addition, RETs such as solar thermal technologies and biogas plants also enabled regularity to existing work by saving time in the morning.

GOAL 2- Zero hunger:

Clean and modern energy access enabled financial security that can help to provide three-time meal for the family. RETs such as SPV and solar grids enabled income-generation activities while solar cooker, water heater and biogas plant had the potential to provide hygienic food and water for the users.

GOAL 3- Good health and well-being:

It was evident from the research findings that access to clean and renewable sources of cooking and lighting energy had positive health impacts on the lives of rural residents. The users/beneficiaries reported that they felt positive change with respect to better healthcare services such as availability of doctors, medicines and midwives, along with better healthcare at home and reduced indoor air pollution that resulted in better health of women, children and elderly.

GOAL 4- Quality education:

The research findings highlighted that rural HHs with school-going children, had access

to lighting that was facilitated through solar PV technologies such as solar torch, lantern, home lights. Residents also benefitted from solar grid and street lights that led to positive change in education. They reported that the use of RETs enabled education as the students could spend more time studying, complete their homework, prepare for exams, participate in co-curricular activities, achieve better grades and increased regularity to school.

GOAL 5- Gender equality :

RETs had positive implications in terms of reduction of women drudgery and saving time for more productive HH activities such as cooking meal for family, helping children with their homework and exam preparation, increased leisure time, enable conducting HH activities with ease and enhanced family relationships. Women reported that biogas plants, solar cooker (box-type and parabolic-type) led to reduction in their work load and hardships in procuring fuel wood, better indoor environment and health of inhabitants. Also, the girl child who usually accompanied her mother for fuel wood collection, now had a better chance for education hence, reduced early drop-outs. The research pointed towards more involvement of rural women in use, operation and maintenance, decision making and governance. Residents reported that product design of RETs required improvement to ensure ease of usage by women without assistance of the male member, e.g. the solar cooker was usually operated by the male member in rural HHs.

GOAL 6- Clean water and sanitation:

The research findings pointed out towards the use of solar thermal technologies including water heaters and solar cookers for water purification. Also, residents mentioned about better sanitation in the surrounding areas with the deployment of solar street lights that helped to increase the sense of security and safety among rural residents. Open defecation near the households was common as residents were scared to go at distant location due to darkness. Also, with the support from Government's Total Sanitation Programme, toilets had been constructed in many rural HHs.

GOAL 7- Affordable and clean energy :

RETs were seen as a clean and modern form of energy and were reliable because of their inexhaustible nature. The affordability was an issue especially in rural areas primarily because of the high initial cost, additional (hidden) charges and low-purchasing capacity of the rural poor. Government is making necessary efforts to address this by provision of loans, rebates and subsidies. Also, many stand-alone RETs had been distributed free-of-cost to rural poor who were deprived of minimal electricity services. The continuance and more provisions of such financial incentives would go a long way to ensure the adoption and sustainability of RETs in rural areas.

GOAL 8- Decent work and economic growth:

The residents in selected rural areas reported that RETs had facilitated regularity to work as presence of electricity enabled completion of household chores. Increased productivity and profitability were experienced by residents who possessed shops in main (local) markets

or those who operated petty businesses from home. New start-ups were taken up by few rural residents that helped to enhance their household income. The subsidiary occupation such as opening of small shops, pursuing skills commercially such as beauty parlour, tailoring, etc. were taken up by women and elderly. Additional interventions were demanded by the residents (women-centric schemes) to empower them with skill that could enable them to earn additional income and improve their quality of life.

GOAL 11- Sustainable cities and communities:

RETs are the best alternative to ensure sustainability of cities and communities due to their clean and inexhaustible nature. They can be used for supplementing and complementing the NRETs which are becoming scarce.

GOAL 13- Combat climate change:

RETs have the potential to combat the ill-effect on the climate that are caused due to the extensive dependence on NRETs resulting in depletion of their reserves and inefficient usage (incomplete combustion of fuels leading to indoor air pollution and health hazards to the inhabitants especially women and children). Next generation technologies such as fuel cell, transparent solar panels etc. are sustainable alternatives and clean energy solutions.

Conclusion :

Rural residents in India primarily use RETs to supplement NRETs. This has brought positive and significant change in the lives of residents of selected villages/hamlets, especially the ones with paucity of conventional energy resources and poor quality power supply. The shift to clean and modern technologies was noticeable though it was slow. The penetration of RETs is picking up and a perceptible improvement in the quality of life of RET users would take its due course after usage of these technologies for a significant period of time, due to their novel nature as compared to the familiar and well-established conventional technologies. It was not possible to draw out the importance of NRETs from the lives of rural residents. Hence, rural energy programmes should integrate improvement of existent NRETs by providing awareness towards energy-efficient practices and importance of energy conservation. Furthermore, introduction of RETs was essential so that rural residents could enhance their quality of life by supplementing and complementing RETs with the NRETs particularly biomass technologies.

Recommendations :

For RETs and NRETs to co-exist, it is important to ensure their sustainable consumption. This section provides some simple tips to ensure the proper usage of RETs and NRETs.

Best practices for proper usage of RETs :

Solar photovoltaic technologies :

Slow system performance:

- Prevent shading from plantation or trees, for good system performance.
- Recharge battery on a regular basis even if the system is not in use.
- Periodically check the battery for electrolytic level and loose connections of battery

terminal.

– Solar lantern/torch should be kept in shade when charging to have maximum charge.

General care instructions :

– Clean the solar panel periodically with a damp cloth, prevent scratches.

– The luminaries of solar lights and contacts of the battery should be cleaned periodically for better performance.

Solar water heater :

No water in the tap :

– Check that the wall of cold water supply is open.

Water not heated at all, although cold water flow is normal :

– Check the consumption pattern and adjust the usage accordingly.

– Check for shading of PV modules.

– Collector might be checked for choking due to scaling.

Water not hot enough or insufficient quantity of hot water :

– Clean the collector with water and do not scratch or use harsh detergents.

– Check the collector for vapour locking (partial choking), allow it to cool and drain the system.

Insufficient quantity of boiling hot water, slow system performance :

– Check the glass for any breakage as this impacts the heat transfer from the collector.

– Clean the glass of any bird droppings or dirt periodically.

– Check for the absorber coating, if it is coming off heat collection will be slow.

– If the collector box is corroded or there is wetting of insulation, contact the repair staff.

General care instructions :

– Do not cover the collectors when the system is in use.

– Do not put up any objects which can cast shadow on the collectors

– Check solar tank, collector and piping insulation for any leakages, using proper sealants.

– Drain the system once in a year by opening the top end of cold water outlet hose.

– The pipes should be monitored for air lock.

– Do not draw the hot water when the temperature booster is on.

– The stored hot water from SWH should be used once a day for a minimum period of 1 hour.

– The water tank of the SWH should always be full and never dry.

Parabolic solar cooker :

Food not cooked evenly :

– Use appropriate size of pot for cooking which can fit well in the support provided

with the lid on.

– Reflector should be properly adjusted in the path of the sun to take maximum advantage of the sun and ensure that the food cooks evenly.

General care instructions :

– Replacement of reflecting sheets has to be done once in five years.

– Clean the reflective panels on parabolic solar cookers after every use with a soft cloth, do not scratch the surface of the reflector sheets as this will dull the shine and reduce the temperature at which it cooks.

– Use cloth or oven gloves for touching the pots.

– Always stand in the shade while putting on or checking the pots.

– Never look into the reflector with bare eyes. Use sunglasses for precautionary measures while working.

– Covers for parabolic solar cookers to extend their life span.

Box-type solar cooker :

Food is not cooked evenly even on a sunny day :

– Check for the black coating of cooking box and pots. If faded or peeled off, paint them with jet black paint.

– Replace the glass lid, mirror or the silver if broken or spoilt.

– Find out for any heat leakage point and seal them.

– Ensure that no dust is collected on the glass lid or mirror.

– Minimize the opening of the lid while the food is cooking to avoid heat loss.

– Always keep the cooker facing the sun so that the reflected rays from the mirror falls on the cooking box and cover its whole area.

Biogas plant :

Slow system performance :

– The feed material in biogas has to be mixed till harmonious slurry is formed.

– The cooking stove should be near to the plant for best performance.

– The inlet pipe has to be checked for choking to allow proper discharge of substrate into the digester.

– The biogas should be kept operational so that the slurry does not dry up.

– The livestock family has to be renewed to maintain regular supply of dung and continue benefitting from the system.

– The gas pipeline should be periodically checked for any damage or leakage.

Best practices for proper usage of NRETs :

Energy efficient practices :

– Fluorescent tube lights (FLTs) and Compact Fluorescent Lights (CFLs) convert electricity to visible light up to five times more efficiently than ordinary bulbs and also save about 70% of electricity for the same lighting levels.

– Light Emitting Diodes (LEDs) should be used for energy efficient lighting.

– Electronic ballasts can reduce power consumption by 20%.

– All the electrical appliances should be checked for standardization marks such as ISI, BEE 4-star label etc.

– Replace conventional regulators with electronic regulators for ceiling fans.

– Use of bio-fuels instead of traditional biomass.

– Energy saving devices such as pressure cookers and lid on the cooking vessel should be practiced.

– Promote the use of improved kerosene lantern.

– Reduce unsustainable use of fuel wood and thus, conserving trees and preserving the local environment.

– Reduction in the use of fossil fuel such as kerosene, LPG, coal etc.

– Using improved *chullha* (with chimney) can reduce indoor air pollution and the ill-effects caused due to it.

– Provision of windows and door could reduce indoor air pollution.

– Cut down consumption by 10%-50% with T-5, slim tube lights that are star rated by BEE.

– Draperies on windows help reduce energy loss.

– Electronic ballast instead of conventional ballast for fans should be used to save electricity.

– Set the washing machine temperature right (cold or warm and not too hot) and the rinsing temperature as cold to save energy.

– Each wash cycle uses up to 60 to 90 litres of water. To save water use washing machine on full load, plan washing periodicity and do not add too much detergent.

– Soak or pre-wash the clothes for effective cleaning.

– The plugs of TV, charger etc. should be removed from socket to save energy.

– Either switch-off the television or set to standby mode to save energy.

– Start-up and shut-down does not utilize any extra energy. Thus, once you are finished working practice this to reduces system wear and save energy.

– Setting computer monitor to sleep-mode when not in use helps cut energy costs by approximately 40%. Activate and standardize 'power down' on new and existing PCs.

– Use an optimal temperature setting of water heater, *i.e.*, from 60°C to 50°C. This could save over 18% of the energy used at the higher setting.

– To help reduce heat loss, always insulate hot water pipes, especially where they run through unheated areas.

– A dripping faucet wastes water and if it is dripping hot water, it's wasting energy too. Fix any dripping water faucet to reduce wastage and save energy/water bills.

Appropriate use and operation :

– Wall-mounted lights should be located at lower height, *i.e.*, not higher than 2 meters for higher light output.

– Light coloured interior surfaces for the walls, ceiling, curtains, floor and the table-surfaces for greater efficiency as they reflect more light resulting in higher illumination levels.

– All lamps should be shaded for better light quality.

– The distance that a fan should be mounted form the ceiling is directly correlated with its air moving potential; no fan should be mounted with its blade closer than 24 inches to the ceiling.

– Do not apply dark colours on the external surfaces (roof and walls) of the house. Dark colours absorb more heat than light colours and leads to increased need for indoor air cooling.

– Allow enough space for continuous airflow around refrigerator as motors and compressors generate heat that should be able to escape for the cooling system to work efficiently.

– Do no put uncovered liquids in the refrigerator. The liquids give off vapours that add to the compressor workload.

– Allow hot food to cool off before putting it in the refrigerator.

– Develop the habit of 'lids on' cooking to permit lower temperature settings.

– Carefully measure water used for cooking to avoid having to heat more than is needed.

– Microwaves cook food from the outside edge toward the centre of the dish, so if you're cooking more than one item, place larger and thicker items on the outside.

Proper care and maintenance :

– Dirty tube lights and bulbs reflect less light and can absorb 50 per cent of the light; dust your tube lights and lamps regularly.

– Make sure that refrigerator's rubber door seals are clean and tight.

– Clean the coils regularly to make sure that air can circulate freely.

– Defrost freezer compartment regularly for a manual defrost refrigerator.

– While using an LPG stove blue flame should be checked as it depicts efficient burning.

Implications of the study :

The findings of the study brought forth a number of implications. To ensure the sustainability of energy supply and sustainable economic development in rural areas, the Government needs to intensify implementation of RETs and energy efficiency programs. In addition, the existing research and development centers, and technology development institutions should be further strengthened to support the shift towards increasing the use of RETs. Human resource development, transfer of knowledge and technical know-how should be focused for project development, management, monitoring and evaluation. Accreditation of RETs through preparation of standards and codes of practices, maintenance manuals for efficient usage, life cycle costing and cost-benefit analysis tools should be undertaken on urgent priority. Sustainability of RETs through training programmes and better infrastructure is necessary.

Some of the challenges with respect to RETs such as high cost, repair and maintenance and training of staff had been addressed with the help of various initiatives by the Government through provision of financial incentives (in the form of subsidies, provision for loans, rebate

on electricity), *AkshayUrja*shops to enable promotion, sale, repair of RETs and *Surya Mitra* Program for training of local volunteers especially unemployed youth and rural women to provide repair and maintenance services for RETs.

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