Renewable Energy Options among Rural Households in Haryana and Himachal Pradesh: An Overview

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Abstract*—** *In developing countries the energy problems are both widespread and serious. Lack of access to sufficient and sustainable supplies of energy impacts around 90% of the population of many developing countries. People are compelled to live without regular and good quality electricity supply. The rural population remains dependent on fuels such as animal dung, crop residues, fuel wood and charcoal to cook their daily meals. Without efficient, clean energy, people are undermined in their efforts to engage effectively in productive activities and improve their quality of life (Barnes and Floor, 1996). India is home to the largest rural population in the world with approx. 68.84% of the total population residing in rural areas (Census, 2011). In order to contribute to the overall development in India, access to modern energy and cleaner fuel for rural households is important. There is a* ***need to bridge the access gap by expanding energy systems *to meet the energy requirements of the fast growing population and* ***mitigate the threat of climate change****.*

The best possible solution to the energy poverty challenges lies in the shift towards sustainable energy technologies. In the present scenario, the uncontrollable increase in use of non-renewable energies such as fossil fuel, oil, natural gas has led to fluctuation of demand and supply. This negative energy balance for decades has forced India to purchase energy from other countries to fulfill 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, focusing 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 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.*

Keywords*— *Renewable energy, Rural households, Energy access, Energy poverty, Solar energy.

I. 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

In the rural areas of India, energy access is an important component of poverty alleviation and an indispensable element of change in quality of life of rural residents. Despite the advances in the rural electrification, the number

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of people lacking access to energy services still remains relatively constant due to the increasing population. Many women and children face incapacitating illness or premature deaths due to dearth of energy services. The reason is that the basic social services such as healthcare are expensive which makes economic development harder to perpetuate. Energy poverty exists when the required infrastructure is not in place for energy delivery, especially electricity.

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.

Changes in Quality of Life through Renewable Energy Technologies (RETs)

Several studies have shown that energy access influence the quality of life of people living in rural areas. Rehling (2004) suggested that energy (particularly electricity) is required for meeting the basic needs such as health, education, agriculture, communication, information and other infrastructural services. He further stated that there is a correlation of per capita income with human development context. The United Nations Commission on Sustainable Development (CSD-9) identified renewable and rural energy among the key issues for sustainable development (Chaurey et al, 2004).

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).

II. 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 of**presence 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).

Two sets of interview schedules were administered, one on the RET programme implementation officials that gave an insight on aspects such as role of *AU* shops, use operation and maintenance of RETs. Second, an **interview schedule was administered on the rural residents (RET users)** thatfocussed on obtaining information concerning their socio-economic profile and energy-use practices concerning NRETs and RETs used. Interview schedules were supplemented with information obtained through informal discussions with residents and village representative. **Narratives** were recorded during informal discussions with the key stakeholders (with prior permission).**Observation schedule** helped to find out information about practices concerning RETs and NRETs.

The perception of RET users about the effectiveness of RETs and the resulting change in QoL with respect to RET usage was studied by using **two separate rating scales**. **Effectiveness of RETs** covered aspects concerning **ease of operation; repair and maintenance; product affordability; product design; reliability; and initiation and sustenance of RETs.** Rating scale for **Change in QoL of Residents** with respect to **RET Usage** was consistent with the other framework of QoL index already developed and included five dimensions i.e., **education of children; healthcare; convenience and social life; safety and security; and income-generation and financial security.** **SWOC analysis** was conducted to understand the perception of users towards the strengths, weaknesses, opportunities and challenges with regards to the use of NRETs and RETs.

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. In India, almost 68.84% of the population resides in rural areas (Census Report, 2011). 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 centers. A number of researches have been done on the RETs and QoL focusing on viability of renewable energy for rural people, Government policies and regulations, meeting targets (capacity of RETs installed and coverage of rural areas), measurement of effectiveness and barriers in RET implementation from researcher perspective. There is however, dearth of research study designed to take the overall view of user understand their knowledge about RETs and their perception towards effectiveness of RETs and change in QoL w.r.t its usage. Hence, a basic assumption to the study is that, to make an effective and efficient renewable energy programme for rural areas, it is necessary to obtain information directly from the rural resident about their needs and expectations from rural development programmes. This study was undertaken to explore in-depth understanding of the parameters that impact the effectiveness of RETs in rural areas and change in dimensions of QoL which the residents (RET users) desired the most to be improved with RETs usage to bring about an overall improvement in their QoL.

Objectives of the Study

1. To study the socio-economic profile and energy use practices in selected villages/hamlets.
2. To explore the types of renewable energy resources and the gap in technology transfer in selected villages/hamlets.
3. To investigate the effectiveness and adoption of renewable energy as an alternative resource.
4. To determine the change in the quality of life of the residents in selected villages/hamlets, with the use of renewable energy technology.

III. RESULTS AND DISCUSSION

I Profile of *AkshayUrja (AU)*Shops

- The *AU* shops had been established by the SNAs in the selected villages, i.e., HAREDA in Haryana and HIMURJA in HP. There were three *AU* shops in or near the selected villages/hamlets, i.e., one in Panchkula district (HR), one in Faridabad (HR) and one in Mandi district (HP).
- The shop provided repair and servicing facility for RETs installed /procured from either their shops or any other source as well. Display of relevant information available concerning RETs programmes and policies, energy saving practices, benefits of RET usage, price and subsidies etc. was insufficient. There was a need to improve the layout and service delivery system in *AU* shops.
- *AU* shops had proper timings and some staff was always available during the working hours. The shops were opened from 9 am to 5 pm from Monday to Friday. *Ea*ch shop had three to four staff members including a Project Officer, an Assistant Project Officer, a Technical Assistant and a Clerk. Paucity of staff was reported by the officers at all the shops as well as by the RET users. The officers posted at these shops felt burdened with excessive work load.
- The products available at the *AU* shops were accredited by MNRE. RETs had to conform to the minimal technical requirements laid down by MNRE. The shops that were operated and managed by the Government authorities were well maintained, clean,

had proper signage providing information regarding RETs, display boards and had good display of products. The shops managed by local entrepreneurs were not well-maintained, products that came for repair were stacked and there was no space to sit or move around.

- The customers were provided with a form (specific to the product). In case there were specified space requirements for installation of RETs such as solar power plant, solar water heateretc. a site visit was made by the technical staff or the project officer.
- The staff shared that for spurious or damaged products the channel partner (firm/company) was liable to repair or replace the product free of cost, if it was in the warranty period. *AU* shops provided support for repair even after the warranty period and charged a minimum fee to ease the customer from any extra burden.
- Awareness generation was done by setting up stalls in various camps (or*melas)* organized locally in different districts. Along with this, advertisements were published in newspapers and broadcast on radio. In addition, Block District Officer (BDO) had meetings with the village *sarpanch* every 15 to 20 days and provided them information about new schemes and programmes, to be disseminated among the rural masses.
- Training programs provided necessary knowledge and skills to the trainees (special focus on unemployed youth and women in rural areas) along with providing follow-up and refresher courses from time to time. The most popular being *Surya Mitra*Skill Development Programs conducted by National Institute of Solar Energy (NISE) that equipped the participants (youth and women) with necessary skills to install and repair RETs. There was a need for more *AU* shops in each block as the RET users from other blocks had to travel up to 16 to 25 kms to avail their services for purchase/repair/replacement of RETs.

II Profile of Stakeholders

(a) Profile of RET Users

- Study sample consisted of 66% males and 34% female respondents. In Haryana, 75% were male respondents and 25% were females. HP comprised of 56% male and 44% female respondents.
- Amongst the selected RET users, majority were from general caste (90%) followed by other backward castes (7%) and schedule castes (3%).
- In Haryana, majority of the respondents belonged to the age group of 35 to 64 years (46%) whereas in HP most of the respondents (42%) were above 65 years of age (elderly). The mean age of selected respondents was 48 years in Haryana and 54 years in HP. There were more young adults in Haryana (31%) as compared to HP (27%).
- Most of the houses in both the states were *pucca*(56%) followed by *semi-pucca*(33%) and *kuccha* (11%).
- The study comprised of HHs selected from different topographies, i.e. plains, low hills and high hills. Majority of the HHs were situated in low hills (52%) followed by 48% HHs from high hills and 29% HHs from plains.
- Most of the HHs had 4 to 5 rooms (46%) followed by 1 to 3 rooms (37%) and 6 or more rooms (17%).
- Majority of the rural HHs (42%) comprised of 4 to 6 members (nuclear families with one dependent member) while 30% HHs were joint families with 7 or more members. Nuclear families were relatively few (28%) consisting of 1 to 3 family members. Haryana had more joint families (35%) while in comparison HP had more nuclear families (35%).
- Majority of the respondents were educated up to secondary level, i.e., 44% from Haryana and 39% from HP. There were more graduates in HP (25%) as compared to Haryana (21%). Professionals that comprised primarily of ITI and polytechnic were 19% from Haryana and 22% from HP. Only 15% respondents from Haryana and 13% from HP had undergone primary education.
- Agriculture was the primary occupation in the selected rural areas (40%) while 30% respondents belonged to service category followed by homemakers (22%) and business personnel (8%). In HP, more residents were employed in services (35%) as compared to Haryana (27%).
- Family income ranged from Rs.5,000 or less to Rs.25,000 or more. Majority of the selected HHs (48%) had an income ranging from Rs.15,000 to Rs.25,000 per month followed by 29% HHs with Rs. 5,000 to Rs.15,000 per month, 12% HHs with less than or equal to Rs.5,000 per month while 11% with income above Rs.25,000 per month. The mean income in HP was Rs.25,352/month as compared to Haryana with Rs.24,750/month.
- Most of the families (44%) owned <1 hectare of land followed by 1 to 2 hectares (28%), more than 2 hectares (14%) and no landholding (14%).
- 40% HHs from HP and 22% HHs from Haryana did not own animals. The residents of Haryana owned more animals as compared to HP.

(b) Profile of Village Representatives

A total of sixteen village representatives were selected for interaction which included village representatives and energy committee members (responsible to operate and maintain the solar grids).

(c) Profile of RET Programme Implementation Officers

The RETs implementation staff comprised of project officer, assistant project officer, field staff and local technicians. Interview of three project officers; three field staff; and four trained local technicians were conducted. The employees were not only providing repair and maintenance for the products sold at the shop but also for other RETs installed/procured from other sources or shops. Apart from carrying out sale and providing repair and servicing of RETs, the employees were disseminating information on RETs and facilitating individuals and institutions to use RETs.

III Energy Use Pattern in Rural Households from Haryana and Himachal Pradesh

Rural HHs in Haryana and HP used both NRETs such as biomass, fossil fuels and electricity (from conventional electric grid) and RETs such as SPV technologies, solar thermal systems, solar grid and biogas plant to fulfil their daily energy needs.

(a) NRETs Used

(i) Biomass-based Energy Resources: These comprised of **fuelwood, crop residue and dung cakes**. Barter system was prevalent wherein residents with no landholdings were allowed to use the biomass (fuel wood and agriculture residue) and in return provided their services to the owners such as making dung cakes for them, maintaining their agriculture fields, helping in HH chores, assisting during functions and weddings, etc.

Fuelwood was popular because of its compact and long-lasting nature, familiarity, intense but steady heat production and accessibility. The most popular tree species used by rural residents were **kikar, aak, mango, jamun, eucalytus, kikar, amrood, and babul.** On an average 60-120 kg of fuel wood was bought every month that would cost Rs.180- 360 (approx.Rs.3/kg).

Crop residue was used primarily by rural HHs engaged in agriculture. It consisted of ***agricultural*** and ***process residue.*** It was used mainly as a start-up fuel to initially ignite fire which facilitated burning of fuelwood and also as fodder for animals.

On an average 15 trips/month were made by rural women to collect fuelwood. In most of the villages the distance travelled to procure wood was less than one kilometre. Average distance to collect the fuelwood was about 1.4 km (primarily by women accompanied by girl child). Hence, one person travelled about 21 km/month spending 1.7 hours per day to procure fuel (42.4 hours/month).

Dung cakes were predominantly used by rural HHs either for preparing farmyard manure by composting or directly preparing dung cakes to be used as a cooking fuel. After the deduction of these consumptions the surplus dung was used for biogas generation by user HHs. The findings revealed that the dung cakes were used by HHs where agriculture and dairy farming were their main occupation. The residents from HP reported that due to non-availability of members who were expert in making dung cakes and guard them from spoilage (due to drying), many families had discontinued its usage.

(ii) Fossil Fuel-based Resources: These comprised of Liquefied Petroleum Gas (LPG), kerosene, coal and candles.

LPG was available in 5 kg and 14.2 kg cylinders. Twelve subsidized cylinders every year were available to each HH. The average monthly consumption of LPG was approx. 9 kg, i.e., one cylinder (14.2 kg) was used for one and a half month or more, depending on the usage pattern and family size.

Kerosene was primarily used for HH cooking and lighting. Residents bought kerosene usually through the Public Distribution System (PDS), available at the kerosene depots. The families who did not possess ration card bought kerosene from the open market. The monthly quota for individual family was 20 litres/month for a family having no LPG cylinder; 3 litres/month for the family having a single LPG cylinder and nothing for families with two or more LPG cylinders. The existing price of kerosene in Haryana is Rs.14.8/litre and Rs.14.5/litre in HP. The demand fluctuated with season, usually being low in summers, medium in rainy season and higher in winters due to decreased fuelwood availability. Users shared that they used around six to seven litres of kerosene/month. The monthly expenditure by a HH on kerosene was Rs.85-100 (approx.@Rs.14.2/litre). The use of kerosene lamps, also known as *dibri or mittiketelkediye*as a make-shift lamp was prevalent in rural HHs of Haryana and some parts of HP since, there was not much initial investment.

Coal was used by rural HHs in both the states for water heating, space heating and sparingly for cooking. Equipment like *sigri and hamam* used coal (for space heating and water heating respectively). It was easily available in the local market at the cost of Rs.30/kg. The monthly expenditure on coal ranged from Rs.180-210/HH (for 6 to 7 kg of coal).

Candles were used by rural residents from both the states for domestic lighting. Frequency of use of candles was dependent upon irregularity of electricity supply and long power cuts which were quite common in villages of Haryana. A pack of 10 candles costed Rs.20 to 25 in rural areas.

(iii) Electricity (from conventional power grid): Electricity was used by rural HHs for various applications including domestic lighting; space heating, cooling and ventilation; cooking; water heating; powering equipment and appliances. The rate of electricity was higher in Haryana as compared to HP.

In rural HHs, **lighting** consumed a major portion of the electricity budget, i.e., 33-44.43 KWh per month of energy contributing 6-49% to the total energy cost in rural HHs. Research findings highlighted that *pucca*houses used efficient lighting devices such as CFLs, LEDs but their operational hours were more as compared to other HH categories while inefficient GLS usage was prevalent in *kucha*houses and hence, their energy share of lighting was quite high (33 KWh).For artificial lighting (indoors and outdoors) different types of lights were used including GLS (Incandescent Bulbs), CFL (Compact Fluorescent Lamps), fluorescent lights and LEDs (Light Emitting Diodes). Efficient and well-designed lighting technologies could yield HH energy savings. GLS used by HHs (two to three in number per HH) ranged 40W to 60W were operational for 1-4 hours in a day. CFLs that ranged from 9W to 20W were used for 2-4 hours per day and one to four systems were used per HH. 40W FLTs were found in most of the rural HHs (one to four in number) that were operational for 2-4 hours per day. LEDs in the range of 3W to 7W were used in some *pucca*houses (two per HH) for 2-3 hours per day.

Water Heating was another activity that utilized major share of electricity. Hot water was required for HH purposes and individuals utilized it for bathing, washing clothes, cleaning utensils, mopping the floor, rearing cattle etc. A 100 litres geyser (2 KW) and immersion rods (1.5KW) were the most common water heating devices used by HHs in both the states. It was found that water geysers were used by 37% HHs from Haryana and 36% HHs from HP respectively. Immersion rods were prevalent in HP (64%) and Haryana (20%). Since, the purchasing power of residents of *kuccha* HHs was quite low as compared to other HH categories they were primarily dependent on traditional energy resources (fuelwood/biomass) for heating water as these resources were low cost and readily available. In semi-*pucca* HHs, immersion rods were used for water heating (up to one hour per day) and consumed about 45KWh of energy per month. In *pucca* HHs, usually water geysers (100 litres) along with immersion rods were used for 1-2 hours per day consuming 45-240 KWh of energy per month depending on the usage pattern.

The need for **indoor space heating, ventilation and cooling** were fulfilled primarily with the help of ceiling fans, table fans and coolers (for indoor space cooling); room heaters (for indoor space heating); and (for ventilation) of spaces such as kitchen and bathrooms exhaust fans were used. Power consumption in rural HHs by HVC systems was 25.2 to 240.6 KWh per month contributing an energy share of 32% to 37%. In summers, residents (mainly elderly) took advantage of the shading from trees nearby the house or in agricultural fields to spent some relaxing time with family or friends, had food etc. In winters, sitting under the sun provided comfort to the residents from the cold weather.

The primary activity in all rural HHs was **cooking.** There were many conventional cooking devices used in rural HHs such as pressure cookers, mixer/grinder, microwave along with different cooking stoves that included traditional *kucchachullha*, improved *chullha* (with or without chimney), LPG stove, kerosene stove and biogas stove. Amongst the electrical cooking appliances, 28% from Haryana and 18% from HP possessed mixer/grinder (50W) whereas microwave ovens (50W) were possessed by only 11% HHs from Haryana and 10% HHs from HP.

HHs possessed different **HH equipment** such television (70W) and radio (11W), dish antenna (3W), cable box (2W); refrigerator (250W), washing machine (150W), computer (120W), iron (1100W), water pump (1.34 horse power) and provision for mobile charging (3W). It was noticeable that washing machine, iron and domestic water pump were possessed by *pucca* HHs and consumed a substantial share of energy (67.5 KWh per month) in spite of their limited usage (one hour).

(b) RETs Used

RETs used for fulfilling the daily energy and electricity requirements in the rural areas included both stand-alone and grid-integrated technologies such as solar power grids, Solar Photovoltaic (SPV), solar thermal and biomass-based technologies. Each of these technologies have been explained as follows-

(i) Solar Grids: Electrification using the conventional grid was economically not a feasible option, therefore, MNRE under the **Remote Village Electrification (RVE) programme** (2006) electrified these villages with decentralized systems, solar grids (5 KW) and hybrid solar-wind power plant (10 KW) to facilitate energy access to these HHs. Under this scheme the Central Government provided 90% financial assistance and the balance cost was borne by respective SNAs (HAREDA in Haryana and HIMURJA in HP) and village panchayat(s). Villages/hamlets that were not electrified with the conventional grid until 2012 were eligible for assistance under this scheme.

(ii) Solar Photovoltaic Technologies: The various SPV technologies used by rural residents in both the states had been explained in detail as follows-

Solar Torch: In rural areas, the Solar Lighting Programme started with the introduction of solar torch (CFL-based). Now, even the LED-based portable lighting device were available. Study findings revealed that CFL-based solar torch were used by 45% HHs from Haryana and 32% from

HP. LED-based torch were possessed by fewer HHs, i.e., 6% from Haryana as well as HP (each). Residents found them very useful as they were portable and could be carried while travelling in dark especially in hilly terrain.

Solar Lantern: The need for developing a solar lighting device much resembling a kerosene oil lantern was felt. The solar lantern was a portable device used by rural HHs of Haryana and HP. It consisted of a PV module, battery, lamp and electronics placed in a suitable housing, made of metal, plastic or fibre glass. There were two models of solar lantern used by rural HHs, namely, CFL-based solar lantern and LED-based solar lantern. Solar lantern served as room lighting in the non-electrified remote areas, emergency lighting in electrified areas, table lamp for reading; for income-generation activities; education of children at home and tuition centres; patrolling farms and cattle sheds. CFL-based lanterns were used by 53% residents from Haryana and 50% from HP as compared to 11% LED-based lantern users from Haryana and 8% from HP.

Solar Home Lighting System (SHS): SHS were one of the most popular RETs especially in the un-electrified hamlets of Haryana where residents had seen light for the first time in their life in past several years. SHS in comparison to solar lanternsoffered more facilities for lighting such as indoor cooling, entertainment and mobile charging. It was an independent unit made of one or more solar module(s), a battery charge controller and few loads usually in the form of light(s); television or a fan. The system was fixed unlike a hand-held solar lantern. CFL-based systems were more popular among rural residents of both the states. In Haryana, more CFL-based SHS were used, i.e., 73% HH as compared to 62% HH from HP while LED-based systems were used by only 6% HHs from HP and 5% from Haryana.

Solar Street Light: Solar street lights were standalone systems installed in the villages/hamlets of Haryana and HP. The system was an outdoor lighting unit used to illuminate the lanes and by-lanes; agricultural fields and open spaces. Solar street lights were amongst the most popular RETs and formed an essential part of almost all rural electrification programmes because of the ease and comfort provided to the rural community. In spite of being a community RET, solar street lights had been purchased by individual HHs in HP to keep the *verandhas* and agricultural farms well lit. Solar street lights were available in CFL and LED based models.

The common faults with the solar PV technologies included blackening of CFL, non-functional battery, problem with charge controller, no charging or under charged battery, solar panel not placed properly under the sun, system left in 'switch on-mode' during charging. *AU* shop officers shared that the systems worked well if the users maintained them properly. Lack of knowledge and ignorance on the part of users acted as chief constraint and impacted the performance of the systems. Hence, there was a need for better awareness about operation and maintenance in both the states.

(iii) Solar Thermal Technologies: Apart from the SPV modules, solar thermal technologies were used by the residents of Haryana and HP. These technologies took advantage of sun's energy to heat water and cook food. Ministry had been encouraging the use of various solar thermal devices since a long time under the Indian Solar Thermal Energy Programme. The solar water heater and solar cookers were used by the rural families.

Solar Water Heaters (SWH): The most common use of solar thermal technology in the rural areas was for domestic water heating. There were two types of solar water heaters used in the villages/hamlets, namely, **Flat Plate Collector (FPC)** which was the most commonly used water heater in the rural areas and **Evacuated Tube Collector (ETC)**which were characterized by low heat loss, high efficiency, less panel area to collect heat and suitability for cold regions. Since, the initial cost of the SWH was high, their users in rural areas were less as compared to SPV technologies. Study findings showed that usage of both FPC and ETC systems was higher in HP as compared to Haryana. In HP, 19% HHs used FPC and 13% used ETC while in Haryana, only 6% HHs possessed FPC and 4% ETC. User complaints included water not heated properly, slow system performance, water not hot enough or sufficient quantity of hot water not available.

Solar Cooker: Solar cooking technologies had been promoted by the Government as a simple, safe and easy method of cooking food. The two most common cookers available in the rural areas were the **box-type cooker** and the curved concentrated cooker commonly known as **parabolic cooker (SK-14)** that could cook faster at high temperatures as compared to box type that cooked at moderate temperature. *AU* shop staff shared that solar cookers were usually maintenance free systems that required periodic cleaning for smooth functioning. The average life span of the system was 10 to 12 years if maintained properly. It was observed that the parabolic cookers were placed in the *verandha* or roof-tops of the HHs. Even though people were aware of solar cooking, the usage of solar cookers was confined to few HHs in both the states, i.e., only 12.5% HHs owned a solar box cooker and just 5% were using solar parabolic cooker, due to their limited usage, slow cooking process and lack of knowledge.

(iv) Biogas Plant: Biomass energy was used for producing biogas for cooking in rural HHs. The family-size biogas plants were found in few rural HHs, i.e., 8% from Haryana and 3% from HP. The reasons recognized for such low acceptance were the low income level of the residents, lack of information and absence of well-established sustainable biomass supply.

Liquid and solid manure from cattle were one of the main substrates for the digestion process in a biogas plant. HHs also used organic waste including separately collected fruit and vegetable wastes, eggshells; plant waste that consisted of leftovers from the fields. The KVIC model (fixed-dome type) of capacities 1-2 m^3 were found in the study area.

IV. COMBINATION OF ENERGY RESOURCES USED FOR HOUSEHOLD ACTIVITIES

Rural residents in both the states were using multiple energy resources for fulfilling their daily energy requirements for different HH activities including cooking; domestic lighting; water heating; and indoor space heating, cooling and ventilation.

(a) 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.

The chi-square analysis indicated a significant association of energy resources used for HH cooking with the sample characteristics. Education exhibited significant association with NRETs such as biomass, electricity, LPG and RETs. Income was found to be significantly associated with biomass, LPG, kerosene, electricity and RETs. Topography exhibited significant association with biomass. Therefore, the findings focussed that choice of fuel for cooking was influenced by following variables-

- Respondents educated up to primary and secondary level preferred biomass as there was no technology barrier and these were familiar fuels.
- Majority of graduates and professionals used LPG, electricity and RETs for cooking as educated respondents preferred cleaner fuels.
- LPG was used mainly by respondents belonging to high income groups (Rs.25000 and above) as each cylinder costed quite some amount and these families could afford.
- Biomass was primarily used by HHs with low income, i.e., up to Rs.5000/month as this was available for free in nature, so they did not have to pay for the fuel.
- Electricity usage for cooking increased with rise in household income as it was expensive fuel and also, a clean fuel associated with better status.
- RETs were used for cooking by high income group families earning Rs.25000/month and above, as they were expensive and required an investment which only families earning well could afford.
- Biomass was preferred by respondents residing on high hills as it was easily available in abundance.

(b) 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.**

The chi-square analysis indicated the association of energy resources used for HH lighting with the sample characteristics. Education exhibited significance with RETs only; income was significant with kerosene usage; age with RETs and kerosene; and topography was highly significant with RETs and candles. The findings emphasized that, fuels selected for lighting were impacted by following variables-

- Higher education was associated with use of clean and modern fuels.

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- Higher income was associated with use of kerosene for HH lighting as it was an expensive fuel.
- Elderly and young adults preferred electricity and RETs for lighting as these were safer fuels.
- Majority of respondents residing on hilly terrains used RETs for lighting as conventional grid was not available.

(c)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.

The chi-square analysis indicated a significant association of energy resources used for water heating by rural HHs with the sample characteristics. Education exhibited significant association with the use of biomass, electricity, LPG and RETs. Income was found to be highly significant with biomass, electricity, LPG and RETs. Topography was found to be highly significant with biomass. Thus, findings highlighted factors for selection of fuels for water heating. These were as follows-

- Biomass was preferred by respondents educated up to primary and secondary level.
- Use of electricity was prominent among respondents who were graduates and professionals.
- LPG was used by respondents who were graduates, professionals and secondary educated.
- Electricity usage was more amongst graduates and professionals.
- Biomass was preferred for water heating by majority of HHs who earned income less than Rs.5000 up to Rs.15000 per month.
- Use of LPG for water heating was found associated with increase in income.
- Electricity and RETs were primarily used by HHs who earned income above Rs.15000 per month.
- Biomass was predominantly used by residents living on high hills.
- LPG usage was confined mainly to households situated on low hills and plains.

(d) 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.

The chi-square analysis indicated a significant association of energy resources used for indoor space heating, cooling and ventilation with the sample characteristics. Education was significantly associated with the use of biomass indicating that low level of education led to continued dependence on traditional fuels. Income exhibited significant association with the use of coal because of it high price as compared to biomass technologies, coal was used by high income HHs for indoor space heating.

V. EFFECTIVENESS OF RETs

Based on the overall mean scores concerning the effectiveness of RETs, **reliability** was perceived as the best dimension with a mean score of 72.21 while parameters **program initiation and sustenance**, **repair and maintenance** and **product design** were rated as poor. **Affordability** and **ease of operation** were perceived as below average. However, the scores on all the selected parameters did not vary too much (the range of scores being 59.11 to 72.21). The modal scores ranged from 37 to 50. The least modal score was for the parameter **program initiation and sustenance** and highest modal score was for **repair and maintenance** and **product design**.

Majority of users (55% from Haryana and 46% from HP) perceived the effectiveness of RETs above average; 41% and 44% as below average from Haryana and HP, respectively. Only 4% from Haryana and 2% from HP considered effectiveness as good and just 7% from HP perceived RETs as poor whereas none of the users from

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Haryana state considered RETs as poor with respect to their effectiveness.

Effectiveness of RETs parameters viz. 'reliability', 'affordability' and 'ease of operation' were rated above average while 'program initiation and sustenance', 'repair and maintenance' and 'product design' were rated below average. This indicated that RET users felt a challenge towards parameters that rated below average.

The state-wise ranking of six effectiveness of RETs parameter revealed that the mean scores for Haryana state were comparatively higher than HP. Parameters such as 'reliability', 'affordability' and 'ease of operation', 'program initiation and sustenance' and 'product design' were scored above 60 except for 'repair and maintenance' with mean score 57.50. In HP state, 'reliability', 'ease of operation', 'repair and maintenance' were considered better as compared to 'program initiation and sustenance', 'affordability' and 'product design' had mean scores 59.03, 54.17 and 58.18 respectively.

The comparative analysis (based on mean scores) between two states depicted that users felt that reliability contributed the maximum towards effectiveness of RETs in rural areas, with a mean score of 73.93 in Haryana and 69.35 in HP. **The residents in Haryana were more satisfied as compared to HP** probably because dependence on RETs was more due to depletion of conventional energy resources, power shortage and absence of electricity grid (in hamlets of Morni block, Panchkula district). In HP, RETs were valued for their non-polluting nature and supplement for NRETs to aid saving on electricity bills, reducing women drudgery to procure fuel and saving natural energy resources.

The association of user perception concerning effectiveness of RETs with their socio-economic characteristics revealed a significant association at 1% level of significance with education, occupation and family size. Graduates and professionals probably had better knowledge about various aspects of RETs, hence they were more satisfied with effectiveness of RETs. The primary and secondary educated respondents probably could not identify with the RETs due to lack of knowledge about their use, operation and maintenance. Respondents engaged in service and business noticed improvement in productivity and profitability as a result of RET usage, agriculturists wanted more RET options that could ease their work in the fields and increase production and profitability. Housewives were ultimate users of most of the RETs and probably had higher expectation but limited skills to operate these novel technologies. Since, the number of members in nuclear families were less, their energy needs could be fulfilled with fewer energy resources as compared to joint families whose energy requirements were more.

VI. CHANGE IN QUALITY OF LIFE OF RESIDENTS WITH RESPECT TO RET USAGE

Based on the overall mean scores on the change in quality of life dimensions, 'healthcare' was considered as the best dimension with a mean score of 66 while 'safety and security' and 'education' were perceived as below average. 'Comfort and convenience' and 'income generation' were rated as poor. However, the scores on all the selected QoL dimensions did not vary too much (the range of scores being 52 to 66). The modal scores ranged from 30 to 75. The least modal score was for the dimension 'education of children' and highest modal score was for 'healthcare'.

Majority of respondents (61% from Haryana and 66% from HP) perceived the change in QoL as below average. More residents in Haryana (36%) perceived the change as above average as compared to 21% users in HP. About 13% from HP perceived the change as poor whereas none of the users from Haryana state considered it as poor. Only 4% from Haryana considered change in QoL as good while none of the respondents in HP felt it as good.

'Healthcare' dimension was rated above average while other domains including 'safety and security', 'education of children', 'income-generation and financial security' and 'convenience and social life' were rated below average.

The state-wise ranking of five QoL dimensions indicated that, **change in Haryana state was higher as compared to HP.** Dimensions such as 'healthcare', 'education of children' and 'safety and security' scored above 60 while 'income generation and financial security' and 'convenience and social life' had mean scores 59.39 and 52.18. In HP state, only one domain i.e. 'healthcare' scored above 60 while all other dimensions scored below 60, these included 'education of children' (58.15), 'safety and security' (55.77), 'convenience and social life' (51.07) and 'income generation and financial security' (47.20).

The comparative analysis clearly indicated that residents of Haryana felt a better change in their QoL as compared to HP. In HP, better electricity supply and lesser tariffs were available as compared to Haryana. Moreover, RETs were predominantly used to supplement the existing electricity supply which was of good quality and adoption of RETs was a result of energy consciousness among rural residents of HP. In addition, HP state had abundance of natural resources and Government had been trying its best to preserve the same. These included measures such as introduction of LEDs at highly subsidized prices. In Haryana, the introduction and adoption of RETs was more need-based due to poor power quality in rural areas and the absence of electricity in many hamlets situated in remote locations (Morni block). Hence, RETs served as the sole source of energy for these HHs. Study results revealed that residents of Haryana appreciated the efforts of the Government as RETs had been a ray of hope

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for them, since, conducting many HH activities was difficult without access to electricity and paucity of resources.

The association of user perception of change in quality of life with their socio-economic characteristics revealed high association at 1% level of significance with education. Graduates and professionals had better knowledge about use, operation and maintenance of RETs that resulted in positive changes in their quality of life. Occupation, income and family size were associated with change in quality of life at 5% level of significance.

Service class respondent gave preference to RETs because of their busy schedule and responsibility to fulfil the needs of their family with limited financial resources. Housewives had monotonous HH tasks and were probably not very ambitious. Self-employed respondents and agriculturists associated change with increased profitability and new start-ups which was probably not up to their expectations. Low-income HHs were dependent on traditional NRETs which were low cost, readily available and familiar. Also, since they had received some RETs free of cost under various schemes their importance was not much realized by the recipients. High-income respondents expected more change since, RETs were one of most expensive durables and expectations with their performance were high. RETs were able to fulfil the energy needs of smaller families than joint families, due to less family members.

VII. REGRESSION ANALYSIS

Regression Analysis of Socio-economic Variables Influencing Effectiveness of RETs

The overall effectiveness of RETs scores were regressed with socio-economic characteristics namely gender, age, education, occupation, income and topography along with knowledge towards RETs, knowledge towards of NRETs, change in quality of life, effectiveness of NRETs, user acceptance of RETs and ownership of RETs. R^2 (0.677) indicated of 67.7% of the variance on the dependent variable, i.e., effectiveness of RETs was accounted by the independent variables mentioned above. t-value of age, education, change in quality of life, effectiveness of NRETs, acceptance of RETs and ownership of RETs were significant.

Regression Analysis of Socio-economic Variables Influencing Change in Quality of Life of Residents w.r.t RET Usage

Change of Quality of Life scores were regressed with variables such as gender, age, education, occupation, income, topography, knowledge towards RETs, knowledge towards NRETs, effectiveness of RETs, effectiveness of NRETs, acceptance of RETs and ownership of RETs. R^2 (0.558) indicated of 55.8% of the variance in the dependent variable, change in quality of life was accounted by the independent variables mentioned above. t-value of effectiveness of RETs, effectiveness of NRETs and ownership of RETs were significant.

VIII. SUSTAINABLE DEVELOPMENT MODEL FOR CO-EXISTENCE OF NON-RENEWABLE ENERGY TECHNOLOGIES AND RENEWABLE ENERGY TECHNOLOGIES

Based on the research, a sustainable development model has been proposed for rural development by adaptation of RETs along with efficient use of NRETs (refer Figure 1).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, RETs can 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.

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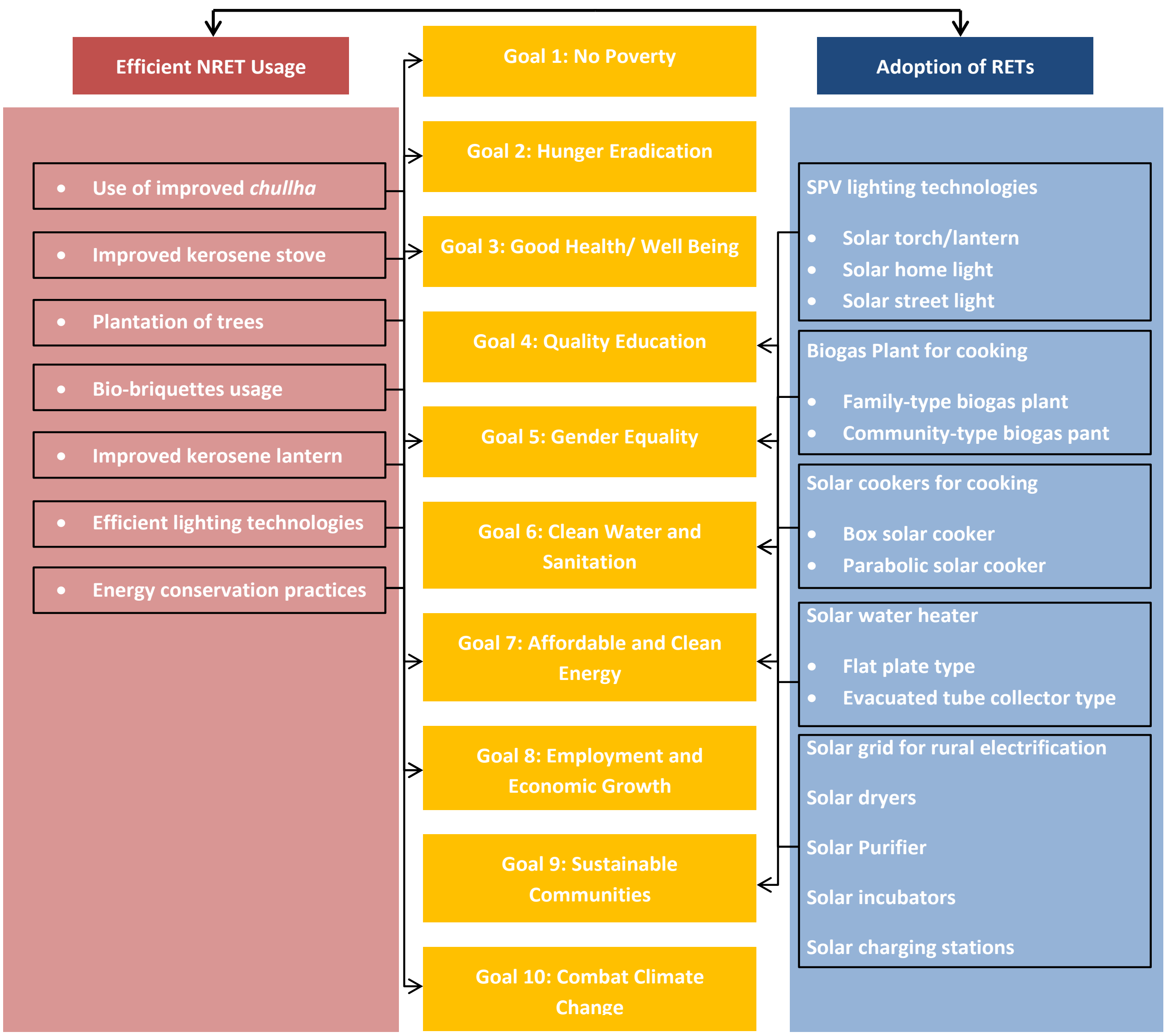

Fig.1: Sustainable Development Model

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.**

IX. 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. 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.

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.

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