# RENEWABLE ENERGY OPTIONS IN PUNJAB STATE OF INDIA

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**ABSTRACT**

*There is a tremendous scope for deployment of renewable energy appliances. Solar energy, an inexhaustible source, potentially capable of meeting significant portion of human energy needs with a minimum of adverse environmental consequences, is the most promising of the unconventional energy sources. The renewable energy appliances that are appropriate at rural level are solar passive heating gadgets like solar cookers, solar water heaters, solar dryer, solar desalination etc., solar photovoltaic based gadgets like solar lantern, solar home lighting system, solar street light, solar water pump, solar inverters etc., the biomass based cook-stoves, gasifiers for direct thermal applications and bio-gas plants at domestic as well as at large scale i.e. at dairy farms, poultry farms, stray cattle yards or 'gaushala's' etc. Biomass based cook-stoves can be used where appropriate feedstock is available. To meet the energy requirement and uplifting the rural livelihood, the renewable energy is one of the options. Considerable government incentives and provisions of cash payments in phased manner have been earmarked for the popularizing these among the rural masses. But due to certain techno-economic reasons, discussed in the paper, these appliances have not been accepted by rural people.*

***Keywords: Renewable, Sustainable, Energy, Solar, Biomass, Appliances***

## 1. INTRODUCTION

Punjab, land of five rivers, is land locked state of Independent India. The present Punjab is inhabited by 2.77 crore people with 62.52 per cent living in 12581 villages. The gross state domestic product at current prices is 3.176 lakh crores with average annual compound growth rate of gross income is 5.76 per cent whereas 4.74 per cent is at national level. The per capita income at current prices of Punjab is Rs.92,350/- whereas Rs.74,380/- is at national level. The Punjab is at 14$^{th}$ position as of income of its inhabitants out of 33 states and union territories. The geographical area of Punjab is 50.36 lakh hectares whereas of union of India is 3287.26 lakh hectares. The total cropped area of Punjab is at 79.05 lakh hectares out of 41.79 lakh hectares of cultivable area making cropping intensity of 189.2 per cent whereas of union of India, the total cropped area of 1952.46 lakh hectares and 1555.17 lakh hectares cultivable area, cropping intensity is 125.5 per cent [3]. This make Punjab predominantly an agrarian state as agriculture being the largest occupation of people.

In recent years a stagnant productivity has been observed mainly due to falling fertility of the soil due to excessive use of fertilisers and pesticides over the years. Another worry is the rapidly falling water table on which almost 90% of the agriculture depends; alarming drops have been witnessed in recent years [10]. With the agriculture of the state being almost at par with various developed countries with consequential pros and cons, there is not much improvement in livelihood security at rural household as a whole. With the large scale burning of crop residue along with ongoing problems, the situation worsens day

by day. Today, the society is experiencing a transmutation and alteration due to climate change concerns, crude oil price fluctuations in world vis-a-vis with country, increased electricity and fuel demand for raising living standards epitomized shift to renewable and sustainable use of available resources.

Renewable energy sources such as solar and biomass are emerging as viable options for meeting energy requirements of various sectors especially at rural level in an economically, environmentally and sustainable way. Household kitchen waste and sewage to municipal and industrial wastes as biomass source are also useful sources of energy. During the previous years, adequate infrastructure has been developed in the country as well as in state for carrying out research/development, testing, demonstration, manufacture and sell different renewable energy gadgets. Ministry of new and renewable energy of government of India, state energy development agencies, state agricultural universities, state departments and private entrepreneurs and companies are encouraging development and promotion of all available types of renewable energy gadgets [16].

There is an urgent requirement of energy security for everyone especially at rural level. Renewable energy sources and appliances are therefore, not only increasingly more relevant but also call upon us to attempt maximize and generalize their use as quickly as economically viable to each one. This paper symbolizes the potential usability, economics and government incentives for popularizing the renewable energy gadgets for sustaining rural livelihood in Punjab state as a whole.

## 2. SOLAR ENERGY GADGETS

Solar energy experienced by us as heat and light can be used through two routes: thermal and photovoltaic. The thermal route uses sun's heat for water heating, cooking, drying, water desalination etc. and the photovoltaic route transform the light energy of sun in to electric energy through different gadgets which further can be used for lighting, water pumping and power requirements etc.

### 2.1 Solar water heating systems

Solar water heaters uses solar thermal energy for heating water circulated inside the gadget. The solar water heating systems are based on different systems for heating water with or without heat exchanger type, heating of working fluid or direct water type, natural convection pressurised type, natural convection non-pressurised type, forced convection type, etc. The natural convection or thermosiphon type systems are the simplest and economical. These systems are suitable for domestic and small institutions. The components of the simplest systems are solar collector, insulated storage tank and insulated pipes and auxiliary electrical connections. The solar water heating system work well during sunny days. In case of prolonged foggy or cloudy condition, there is a provision of heating water with auxiliary electrical supply. These systems can installed on the rooftops of houses or at any obstruction free areas near the usage point. The solar collector's inclination with horizontal surface is fixed at $45^{o}$ with south facing. The common commercial models are of two main types; flat plate collector (FPC) type and evacuated tube collector (ETC) type solar water heaters. The FPC and ETC type devices can heat water upto $80^{o}$C temperature in a sunny day. For hot water requirement up to $80^{o}$ C, these gadgets can be used.

*2.1.1 Flat plate collector (FPC) type*: The solar radiation is absorbed by Flat Plate Collectors which consist of an insulated outer metallic box covered on the top with glass sheet, Fig. 1. Inside there are blackened metallic absorber (selectively coated) sheets with built in channels or riser tubes to carry water. The absorber absorbs the solar radiation and transfers the heat to the flowing water.

*2.1.2 Evacuated Tube Collectors (ETC) type*: Evacuated Tube Collector is made of double layer toughned glass tubes evacuated for providing insulation. The outer wall of the inner

tube is coated with selective absorbing material. This helps absorption of solar radiation and transfers the heat to the water which flows through the inner tube.


Fig. 1: The flat plate collector type device.

Fig. 2: The evacuated tube collector type device.

Solar water heating is now a mature technology. Wide spread utilization of solar water heaters can reduce a significant portion of the conventional energy being used for heating water in homes, factories and other commercial and institutional establishments. Internationally the market for solar water heaters has expanded significantly during the last decade. A fuel savings with 100 litres capacity gadget can be made on replacing an electric geyser for residential use and saves 1500 units of electricity annually. Environmental benefits of using a 100 litres capacity gadget can prevent emission of 1.5 tonnes of carbon dioxide per year. A life of 15 to 20 years is expected with normal use. The cost and central financial assistance on the gadget is given in Table 1.

**Table 1: The approximate cost and central financial assistance on different type of gadgets.**

| Sr. No. | Type of system | Approximate cost | Subsidy |
|---|---|---|---|
| 1. | Flat plate collector type | Rs.25000/- for 100 LPD* | Rs.6600/- for LPD* |
| 2. | Evacuated tube collector type | Rs.15000/- for 100 LPD* | Rs.4500/- for LPD* |

*Liters of hot water provided per day at 60-70C

The overall financial assistance is 30 % of the benchmark cost of the gadgets and Rs.110-150 per installed litre for higher capacity systems. The payback period is 3-4 years when electricity is replaced, 4-5 years when furnace oil is replaced and 5-6 years when coal is replaced [15].

### 2.2 Solar cookers

This is a device which uses sunlight as its energy source. Box type solar cookers are suitable for the boiling type of cooking. The cooking temperature is around 100$^{o}$C. The solar cookers can be single or multi-reflector type or concentrating type. A rectangular type solar cooker for domestic use is shown in Fig. 3.

### 2.3 Solar dryers

Solar drying is the oldest method of food articles preservation. People learned to dry the different raw food articles when they observe that food articles, kept in open under the sun, become dried, kept in safe custody, last longer than the fresher ones. The different type of dryer are given below.

*2.3.1 Domestic solar dryer*: Domestic solar dryer is a small sized, natural circulation, solar dryer. Most of the products that are used in powder form in domestic kitchen, e.g. chilies, garlic, ginger, mango powder, coriander, onion, fenugreek leaves etc., are used in small quantities of the order of a few kilograms per year. It has aperture area of 0.36 $m^2$ and it is capable of drying about 2-3 kg of fresh product in 2-3 days. The domestic solar dryer is shown in Fig.4.

Fig. 3: The rectangular solar cooker.

Fig. 4: Domestic solar dryer.

*2.3.2 Multi-product solar dryer*: For drying agricultural product, drying air temperature should be below its maximum allowable temperature because temperature above this limit causes quality deterioration of dried product. In multi-product solar dryer, drying air temperature is maintained below maximum permissible temperature limit of drying product. The multi-product solar dryer is modular in design and one module of this dryer has loading capacity of 20-30 kg of agricultural product. A photograph of one module of this solar dryer is shown in Fig.5.

Fig. 5: Multi-product solar dryer.

**2.4 Solar lantern**

This is an emergency light charged with sunlight and works for 3 to 4 hours. The approximate cost of the gadget varies from Rs.500/- to Rs.1800/- depending upon light intensity and panel power. The solar lantern to be used at domestic level is shown in Fig.6.

**2.5 Solar home lighting system**

The system consist of one 37 watt capacity solar panel, one 40 Ah battery, one charge controller, one fan and two lights. It works for 4 to 6 hours. The approximate cost of

the gadget varies from Rs.6,000/- to Rs.12,000/- depending upon work required. The solar home lighting system is shown in Fig.7.

Fig. 6: Solar lantern.

Fig. 7: Solar home lighting system.

**2.6 Solar street light**

The gadget consists of one 40 $W_p$ capacity solar panel, one 12V/26Ah battery and one LED light source/bulb of 9 to 18 watts. It automatically works from sunset to sunrise. It has inbuilt controller for the activity. The approximate cost of the gadget varies from Rs.16,000/- to Rs.22,000/- depending upon power of light required. The system is shown in Fig.8.

**2.7 Solar water pump**

The gadget earlier comprise 1600 to 2400 watt DC motor and equal power solar panels. It now comes with AC motor. The power available varies from 1600 watts to 7500 watts. The discharge pipe or bore diameter varies from 2 inches to 4 inches. The pump discharge varies from 1,20,000 liters to 3,60,000 liters and works satisfactorily at 35 to 90 feet water level. The approximate cost of the gadget varies from Rs.2,30,000/- to Rs.12,00,000/- depending discharge depth requirements. The solar solar water pump system is shown in Fig.9.

Fig. 8: Solar street light

Fig. 9: Solar water pump

**2.8 Solar inverter**

The solar inverter is available in three different capacities and requirements i.e. 600VA, 800VA and 1400VA. The system comprises one or two batteries charge controller/inverter and matching capacity solar panels. The system is capable of taking two to five rooms electrical load for 3 to 8 hours or so, depending upon load and power consumption situations. The system cost varies from 37,500/- to 1,25,000/- depending upon power load matching requirements. The solar inverter schematic is shown in Fig. 10.

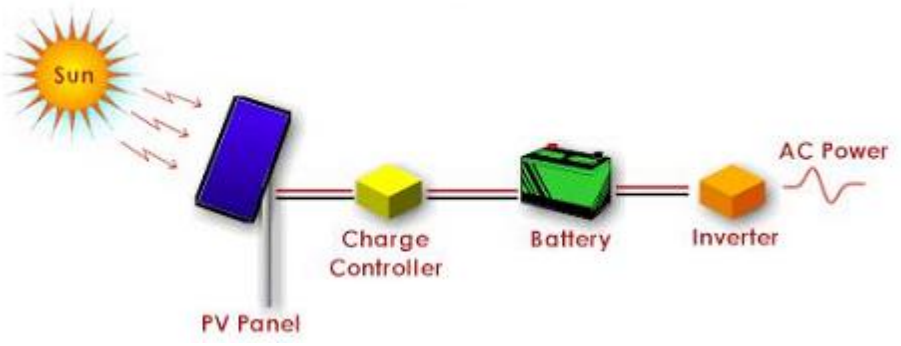


Fig. 10: Solar power inverter

## 3. BIOMASS BASED ENERGY

Agricultural biomass is a domestic energy resource, and farmers have the chance to extend their function from a supplier of raw material to managers of domestic energy resources. Agricultural and forestry residues, energy crops, dairy-house, piggery, poultry, domestic and industrial waste based biomass will play a pivotal role in the replacing the fossil fuels with renewable resources. Biomass will contribute 83% to the increased use of renewable resources, [5]. Agricultural biomass is readily available and can be used to drive energy continuously. Rural or regional energy systems of the future will have to be based on renewable sources to a much larger extent [6].

### 3.1 Biomass cook stoves

Key biomass based energy strategy may largely involve innovative technological investment, which use biomass more efficiently to produce modern renewable fuels to meet energy needs in various sectors. Such technological investment requires biomass conversion to non-solid form and more efficient use of solid biomass fuel using modern cooking stove technologies. These potential advantages include: reduction in indoor air pollution, decreased per capita energy consumption and various other societal welfare benefits [4]. The National Biomass Cook-stoves Initiative (NBCI) was launched in India in late 2009 to extend the use of clean energy to all of India's households through the development of "the next-generation of household cook-stoves, biomass-processing technologies, and deployment models" [8]. There are now number of solid-biomass-using stoves available, which produce emissions per meal that are less than one-fifteenth that of traditional stoves in lab tests, with greater reductions seemingly possible [17].

Biomass cook-stove is basically a combustion device which burns biomass fuel more efficiently with reduced emissions and offers cleaner cooking energy solutions. Biomass cook-stoves are of two types; fixed type and portable type. The portable cook-stoves are also of two types; natural draft and forced draft. Advanced cook-stoves utilizing fans are more efficient cook-stoves compared to natural draft ones. Each type of cook-stove can be used for domestic as well as community cooking applications. Different types are shown in Fig. 11.

Fig. 10: Different type of improved biomass cookstoves

The improved cook-stoves may be made with metal, ceramic and terracotta/ pottery (durable type) and combination thereof. With this, the stoves will be categorized as metallic (MS, SS, cast iron and combination thereof), metal clad ceramic/ pottery and ceramic types. The standard performance parameters for cook-stoves are given in Table 2.

**Table 2: The standard performance parameters for different types of cook-stoves.**

| Sr. No. | Type of Biomass Cookstove | Standard Performance Parameters | | |
|---|---|---|---|---|
| | | Thermal Efficiency (%) | CO(g/MJd) | PM(mg/MJd) |
| 1 | Natural Draft Type | Not less than 25 | ≤ 5 | ≤ 350 |
| 2 | Forced Draft Type | Not less than 35 | ≤ 5 | ≤ 150 |

The central financial assistance is provided through state energy development agency (PEDA) on the family sized /domestic cook-stoves/earthen cook-stoves upto 50% of cost of cook-stoves with maximum ceiling of Rs.400 for natural draft and Rs.800 for forced draft cook-stove for the years 2013-14 and 2014-15, and upto 40% of cost of cook stoves with maximum ceiling of Rs.300 for natural draft cook stoves and Rs.600 for forced draft cook-stoves for the years 2015-16 and 2016-17 under $12^{th}$ five year plan.. At present, there are a total of 41 nos. of cook-stoves approved by MNRE on the basis of their performance testing conducted by Improved Cook-stove Test Centres and satisfying stipulated performance parameters, which include 20 nos. natural draft domestic cook-stoves, 12 nos. forced draft domestic cook-stoves, 2 nos. of natural draft community cook-stoves and 7 nos. of forced draft community cook-stove with total 26 nos. of manufacturers [8].

### 3.2 Biomass gasifiers

Thermal gasification involves partial combustion (oxidation in restricted quantity air/oxidant) and reduction operations of biomass to produce combustible mixture of gases known as producer gas. In a typical combustion process generally oxygen is surplus, while in gasification process fuel is surplus. The combustion products, mainly carbon dioxide, water vapour, nitrogen, carbon monoxide and hydrogen pass through the glowing layer of charcoal for the reduction process to occur. During this stage both carbon dioxide and water vapour, oxidize the char to form CO, $H_2$ and $CH_4$. A typical composition of the gas obtained from wood gasification on volumetric basis is as; CO is 18-22 %, $H_2$ is 13-19 %, Methane is 1-5%, heavy hydrocarbons is 0.2-0.4%, $CO_2$ is 9-12 %, $N_2$ is 45-55 % and water vapour at 4 %. Gasifiers are broadly classified as per; i) the direction of gas flow and ii) the output or capacity of the gasifiers. The gasifier are also classified as per the type of fuel bed i.e. (i) Fixed bed and (ii) Fluizised bed [11].

*3.2.1 Selection of gasifiers***:** An extensive review of gasifier manufacturers offering 'commercial' gasification plants from which: 75% of the designs were downdraft type, 20% of the designs were fluidized bed systems, 2.5% of the designs were updraft type, and, 2.5% were of various other designs, [7]. However, there was very little information on cost aspects, emissions, efficiencies, turn-down ratios and actual operating hours experience. Above all, no single manufacturer was ready to give full guarantee for technical performance of their gasification technology, [9].

For meeting the thermal and electrical requirements of rural households, downdraft gasifiers have been developed in the range of 5-60 kW, as given in Table 3. A 5 kW gasifier will be suitable for a family of 4-6 persons. After cleaning producer gas through filters, diesel engine gen-sets can be operated and up-to 70% of diesel savings can be made. Annual savings of up-to Rs.20,000/- can be achieved by operating the system for 1500 hours and one can recover the cost of gasification system in 3 years, [12].

**Table 3: Performance of biomass gasifier-diesel engine system*.**

| Sr. No. | Capacity, kW | Application | Fuel and its size (mm) |
|---|---|---|---|
| 1 | 5 | Water pumping | Rice Husk, As such |
| 2 | 10 | Water pumping or electricity generation | Wood chips, maize cobs, cotton and pulses sticks, (50) |
| 3 | 25 | Electricity generation | ----same as above----, (100) |
| 4 | 40 | Electricity generation | ----same as above----, (120) |
| 5 | 60 | Electricity generation | ----same as above----, (150) |

* Moisture content of fuel: Less than 15%; Engine de-rating: 15 - 25%;

* Diesel replacement: 70-75 %; Fuel consumption: 1 to 1.3 Kg/kWh.

### 3.3 Bio-gas plants

In a country like India, where about 68.8% of the total population lives in rural areas, [1], one such alternative is the use of biogas. Biogas, a product of anaerobic digestion in the absence of air of cellulosic biomass, like cattle dung, poultry droppings, pig excreta, human excreta, crop residues etc., abundantly available in rural areas, is suitable fuel for providing heat and operating stationary engines. This oxygen deficient digestion results in the production of a combustible gas called biogas, which contains 50-60% methane, 30-40% carbon dioxide, 1-5% hydrogen and traces of nitrogen, hydrogen sulphide, oxygen, water vapours etc. [14]. Anaerobic digestion not only provides valuable fuels and enhances the fertilizer value of the waste, but also provide a conventional, safe, aesthetical and economical waste disposal method. A biogas plant is a device for conversion of fermentable organic matter, in particular cattle dung, into combustible gas and fully matured manure. The design of a biogas plant is directly linked to its hydraulic retention time (HRT), which may be defined as the time period during which the mixture of cattle dung and water stays in the digester to produce the gas before being exhausted of its biochemical potential. The HRTs of biogas plants are different for different regions of India. For the majority of the regions in Indian, including Punjab, it is 40 days.

*3.2.1 Design models of biogas plant*: Biogas plants are mainly classified as; (i) batch type and continuous type, (ii) brick masonry dome and steel drum type. Biogas plants are classified as per use i.e. (i) Domestic level, (ii) Institutional level and (iii) Community level [11].

*3.2.2 Selection of size of biogas plant*: The size (capacity) of a biogas plant means the quantity of biogas ($m^3$), which we can get from it on a 24 hour basis. The selection of the size of biogas plant to be installed depends upon the number of persons to be served or the quantity of cow dung available. Taking one parameter as the criterion of selection, the other can be calculated. Per person, 0.34–0.42 $m^3$ of biogas is required for cooking food, and 1 kg of cattle dung has a potential of producing about 0.04 $m^3$ of gas. Hence, once the process is set in, 25 kg of dung is required per 1 $m^3$ of biogas production. Normally, 10–20 kg of dung is collected from ordinary cattle, [14]. The calculations, hence made, are shown in Table 4.

*3.2.3 Cost of installation of biogas plants*: The costs of civil construction including cost of steel required for each type of biogas plants was taken as per criteria adopted by Singh K J and Sooch S S, [14]. The cost of installation of different family size biogas plants that includes material and labour cost at the prevalent market rates is given in Table 5.

**Table 4: Number of persons served, requirement of dung and number of animals for different sizes of biogas plants.**

| Sr. No. | Capacity of biogas plant ($m^3$) | No. of animals required | Quantity of dung required (kg) | Cooking for number of persons |
|---|---|---|---|---|
| 1 | 2 | 3-4 | 50 | 4-5 |
| 2 | 3 | 5-6 | 75 | 7-8 |
| 3 | 4 | 7-8 | 100 | 10-11 |
| 4 | 6 | 10-12 | 150 | 4-16 |

**Table 5: Installation costs of different types of biogas plants.**

| Sr. No. | Biogas plant models | Plant Capacity | | | |
|---|---|---|---|---|---|
| | | 2 $m^3$ | 3 $m^3$ | 4 $m^3$ | 6 $m^3$ |
| 1 | KVIC type | 30,000/- | 37,000/- | 43,000/- | 55,000/- |
| 2 | Janta type | 26,000/- | 30,000/- | 32,000/- | 40,000/- |
| 3 | Deenbandhu type | 20,000/- | 25,000/- | 30,000/- | 35,000/- |

The Government of India, for promoting the use of biogas, is providing a fixed amount of financial assistance in rupees, as given in Table 6, [2].

**Table 6: Central Financial Assistance under the National Biogas and Manure Management Programme, w.e.f. 08.05.2014.**

| Sr. No. | Financial Assistance for different regions of India | Capacity of family type biogas plants | | Contacting Agency |
|---|---|---|---|---|
| | | 1 $m^3$/day | 2 to 6 $m^3$/day | |
| 1 | NER States, Sikkim (except plain areas of Assam) | 15,000/- | 17,000/- | District level or Nodal officers of State level Energy Development Agency |
| 2 | Plain areas of Assam. | 10,000/- | 11,000/- | |
| 3 | Jammu & Kashmir, Himachal Pradesh, Uttrakhand, Niligiri of Tamil Nadu, Sadar Kurseong & Kalimpong Sub-Divisions of Darjeeling, Sunderbans (W.B.) and Andaman & Nicobar Islands. | 7,000/- | 11,000/- | |
| 4 | Scheduled castes / Scheduled Tribes of other than above regions | 7,000/- | 11,000/- | |
| 5 | All Others | 5,500/- | 9,000/- | |
| 6 | Additional for toilet linked Biogas Plants | 1,200/- | | |

Punjab is all set for leading change in renewable energy sector due to a large scale investment in solar power projects, net metering policy and farm-level solar power projects. Punjab was rated as the number one State in India for progress in solar energy by World Bank. The state aims to accomplish the goal of generation of 15% power requirement through renewable energy by 2022 [13].

## 4. CONCLUSIONS

There is huge potential in converting incident solar energy into useful energy either through thermal route or through photovoltaic route but the cost factor is keeping the general users at distance.

Thermal gasification of biomass is a promising technology to displace use of fossil fuels and to reduce $CO^2$ emissions. Among other renewable energy conversion systems, it has great potential because of its flexibility to use a wide range of feedstock, and to produce energy vis-à-vis wide range of fuels and chemicals. Abundant quantities of crop/forestry based biomass is available, it can be optimally used for thermal and power requirements of villages by empowering village co-operatives with technical know-how of the technology along with convincing incentives that may change the overall energy scenario at rural level.

Biogas plants are successful in outer peripheries of villages or in fields. Biogas contains mainly CH4 (≅60%), which is the same as in natural gas. So, biogas and natural gas can be used for same application. Methane can be burnt for cooking or lighting the house. It can also be used to power combustion engines to drive a mechanical motor or generate electricity. Biogas has two types of economic benefits one is it saves the energy cost to be purchased and on the other hand extra money can be earned by selling biogas to the neighbours. Biogas units are less successful in the interiors of villages, due to difficulties in arranging for land, water and feedstock required for the plants.

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