# SOLAR ENERGY TECHNOLOGIES FOR AGRICULTURE AND ALLIED SECTOR


Compiled by

Dr. P. Subramanian

Dr. R. Mahendiran



THE DIRECTOR

STATE AGRICULTURAL MANAGEMENT AND EXTENSION TRAINING INSTITUTE

KUDUMIYANMALAI

# SOLAR ENERGY AND RENEWABLE ENERGY TECHNOLOGIES FOR AGRICULTURE AND ALLIED SECTOR

**Compiled by**

***Dr. P. Subramanian***

***Dr. R. Mahendiran***

***Tmt.T.Subathra***

*Jointly Organized by*

**State Agricultural Management and Extension Training Institute**
**Kudumiyanmalai, Pudukottai - 622104**

**&**

**Department of Renewable Energy Engineering**
**Agricultural Engineering College and Research Institute**
**TamilNadu Agricultural University, Coimbatore – 641003**

**MAY 2022**

# CONTENTS

# Role of Renewable Energy and Biomass Energy Conversion in Agricultural Applications

***P. Subramanian, J. Gitanjali and K.Karuppusamy Vikaraman***
Department of Renewable Energy Engineering,
Agricultural Engineering College and Research Institute,
Tamil Nadu Agricultural University, Coimbatore-641 003

Energy is the prime unit for all the activities in the world. It is an essential and scarce commodity; hence, it has to be spent judicially. The major source of energy supply is from conventional energy sources like coal, petroleum and natural gas, which are non-renewable. With a share of about 18% on global population, India consumes less than 6% ot total primary energy comparing world scenario. The depleting nature of these energy reserves and its resultant effect on environmental pollution, steering to focus towards renewable resources viz., solar, wind, biomass, etc. India has a contribution of about 35% of its power generation through renewable sources. Considering agrarian nature of our country, biomass have been a significant energy source which also has the advantage of net zero carbon emission.

## Biomass Energy

Biomass, as a fuel, has been in use for centuries all over world and produced locally almost everywhere. They are generally available in sufficient quantities and have lesser economic value at present. It has benefits such as lesser release of $SO_x$ and $NO_x$, maintaining water and soil quality, resultant biodiversity, rural employability and rehabilitation. Biomass provides the possibility of generation of solid, liquid or gaseous fuels. This versatility opens new opportunities for its use for different applications.

## Biomass - Indian Scenario

Biomass power generation potential is vast in a predominantly agricultural country like India. With an annual biomass availability of 680 million tonnes (surplus: 226 MT), the power generation potential is in the order of 18,000 MW. About 32% of the total primary energy use in the country is still derived from biomass and more than 70% of the country's population depends upon it for its energy needs.

Agricultural biomass is mainly applied to heat generation units with a regular automatic feed and used almost as a classical fuel due to its homogeneous dimensions. In the household and service sectors, agricultural biomass is burnt for space heating, domestic hot water production or cold storage through absorption equipment. In agro industry, applications range from drying to the simultaneous generation of thermal energy and electricity by means of steam turbines.

**Biomass energy conversion technologies**

A wide variety of biomass conversion technologies is available to produce various forms of renewable energy. Many factors affect the choice of the technology like biomass feedstock, desired energy form, environmental standards, economic conditions, and conversion efficiency. The key biomass conversion technologies are shown in fig.1. The thermochemical conversion of biomass into biomass into energy with respect to air supply and heat. The biochemical conversion of biomass into various fuels with the help of microorganisms. In chemical conversion process, various chemicals are added as reactants and catalysts with biomass to produce liquid biofuel.

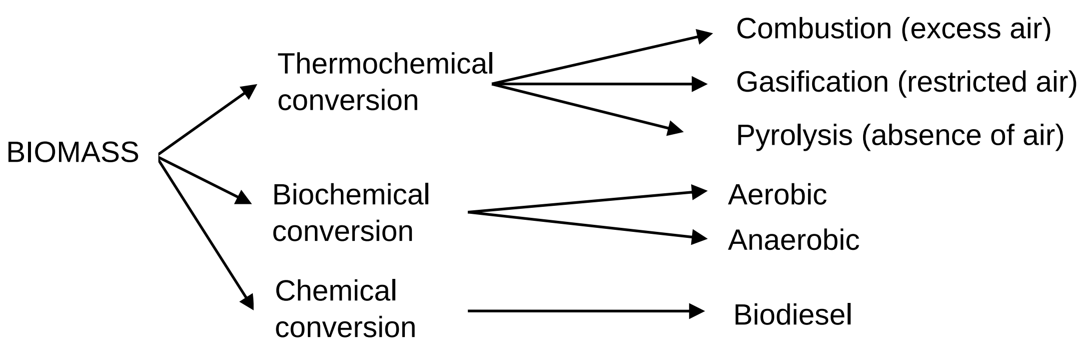



**Fig. 1. Biomass conversion technologies**

**Thermo Chemical Conversion**

Thermochemical conversion is an efficient method to convert biomass into various forms (solid, liquid and gas) of energy. In thermochemical conversion technologies, heat is used to initiate the thermal conversion process to convert complex chemical structure of biomass into convenient forms. The resultant chemical reaction will yield various end use forms of energy. They are further classified as combustion, gasification and pyrolysis, based on oxygen/air supply.

**Combustion**

Direct combustion in excess air is the best understood and most widely used energy conversion process. Combustion refers to the rapid oxidation of fuel accompanied by production of heat, or heat and light. Complete combustion of a fuel is possible only in the presence of an adequate supply of oxygen. Stochiometric air supply is the theoretical air requirement for the complete combustion of any fuel. Rapid fuel oxidation results in large amounts of heat. Solid or liquid fuels must be changed to a gas before they will burn. The goal of good combustion is to release all the heat in the fuel.

In India, 80 % of total population lives in villages. The major energy demand of rural population is for cooking which contributes to about 98 % of their total energy consumption. Wood, agricultural waste and biomass are used as fuel in rural kitchen. Conventional stoves waste a lot of energy and pose many pollution hazards. Most traditional stoves can utilize only 2 – 10 % of the energy generated by the fuel. Conventional stoves (chulha) take more time for cooking, more difficult to fire and consume more fuel and releasing pollution into the atmosphere. The pollutants are harmful to environment and to the health of rural women. It causes headache, watery eyes, common cold, sneezing and respiratory issues.

The growing gap between availability and demand for fire wood, poor thermal performance and pollution caused by traditional stoves forced to develop improved stoves with higher thermal efficiencies of stoves. The biomass is also used as fuel in boilers and furnaces for thermal applications in farm households, tea shops, steam generation and other agro-industrial applications.

**Gasification**

Gasification is the process in which the supply of oxygen is controlled and the biomass is converted into chemical product called producer gas. The reduced air of about 20-40% than stochiometric air requirement will result better production of fuel gas. Most gasification processes use air for oxidation. In combustion process, biomass is directly converted into heat energy, where as in gasification process, biomass is converted into an intermediate chemical product, which constitutes of mainly of carbon monoxide, and hydrogen.

The calorific value of producer gas is 950-1200 kcal $m^{-3}$. The main components of producer gas are carbon monoxide (18-24%), hydrogen (18-20%), carbon dioxide (9-12%), nitrogen (45-55%), methane (1-5%) and water vapour (4%). In gasification, the solid fuel is subjected to a series of thermochemical processes like drying, pyrolysis, oxidation and reduction. The resultant product is producer gas. It has a thermochemical conversion efficiency of about 70 to 90 %.

There are three main types of converter: up-draught, down-draught and cross-draught. In all these converters the solid biomass feed is in a vertical flow packed bed through which oxygen or air for combustion is passed downwards (down-draught), upwards (up-draught) or across (cross-draught) the bed.

In down-draught gasifier, biomass will be fed from the top, air enters near the oxidation/combustion zone and gas produced will be taken out through bottom. It is suitable for agricultural materials. As the biomass passing from the top to bottom, before reaching to the reaction zones, it will be dried and the tar produced will be brought to oxidation zone and tar is cracked in oxidation zone in high temperature. Thus, moist biomass like agricultural products can be easily gasified using down-draught gasifiers.

In up-draught gasifiers, gas produced in the reaction zones will be leaving out of the gasifier from the top. Air is passed nearer to the reaction zone, which provides a conducive environment for cracking of tar and gasification. Tar produced in the pyrolysis zone will be carried out by the outgoing producer gas, it also carries out dust particle from the reactor as well as from the incoming biomass and the moisture released in the drying zone will also be mixed with the outlet gas. Since, lesser moisture content, dust free and lesser tar producing biomass are suitable for updraft gasification like char coal etc.

The cross-draught gasifier usually has horizontal air entry. Air is provided nearer to the gas producing or reaction zone. Gas is produced nearer and horizontal to the air entry. As this has short air path for gasification reaction zone, these responding rapidly for changes in gas production.

Producer gas can be converted into mechanical, thermal or electrical energy. Applications such as cooking, water heating, grain drying, engine running etc. Thermal applications can be done using suitably designed burners for specified applications such as water heating, community level cooking, grain drying, gur making etc.  For engine running the producer gas is mixed with air in a selected ratio and sent to the engine inlet manifold.

**Pyrolytic conversion**

The principle pyrolysis reaction is the thermal decomposition of biomass to produce char, biooil and fuel gas in the absence of oxygen. The firewood, biomass residues, and municipal wastes can be pyrolyzed effectively. Gas generated by a pyrolytic converter can be used for heating and power generation. The char from the pyrolysis of wood and agricultural waste is widely used in the manufacture of charcoal briquettes.  The char can also be made into activated carbon, which commands a much higher price in the world market than ordinary charcoal.

Pyrolysis offers a flexible and attractive way of converting solid biomass into an easily stored and transported liquid, which can be successfully used for the production of heat, power and chemicals. The biooil has direct application as liquid fuels. These biooil can be used as fuels after various downstream processing. The pyrolysis process can be optimized for maximum release of volatile content to increase the biooil yield. Slow and fast pyrolysis are the two major processes through which boioil can be generated from agro residues.

Slow pyrolysis occurs at temperature 300 to 450 °C at slower heating rate with longer vapour residence time in minutes to hours. The slow pyrolysis yields 30 to 40 % char, 30 to 40 % biooil and remaining as non-condensable gases. Fast pyrolysis occurs at 400 to 750 °C with higher heating rate at lesser vapour residence time in seconds. This is mainly used for biooil production with less than 10 % or no char production. At an intermediate temperature and under relatively high heating rates, the main product is bio-oil.

**Biochemical conversion**

Biochemical conversion of organic waste materials involves the activity of microbes, to get converted into useful products. The biochemical technologies are as follows:

**Aerobic method**

The aerobic method of conversion of biomass is composting. Composting is a bio-process, in which diverse and mixed group of micro-organisms breakdown organic materials and transform into humus like substances in aerobic conditions. The organic material will normally have an indigenous mixed population of microorganisms derived from the atmosphere, water or soil. When the moisture content of the waste is brought to a suitable level and the mass aerated, microbial action speeds up. As well as oxygen and moisture, the microorganisms require for their growth and reproduction a source of carbon (the organic waste), macronutrients such as nitrogen, phosphorus and potassium and certain trace elements. In attacking the organic matter, the microorganisms reproduce themselves and liberate carbon dioxide, water, other organic products and energy. Some of the energy is used in metabolism; the remainder is given off as heat. The compost is made up of the more resistant molecules of the organic matter, breakdown products, dead and some living microorganisms, together with products of biochemical reaction.

### Anaerobic method

Anaerobic digestion involves the microbial digestion of biomass. The process takes place at low temperature upto 65 °C and requires a moisture content of at least 80 %. It generates a gas called biogas or gobar gas which consisting mostly of 55-65% methane ($CH_4$) and 35 - 45% carbon dioxide ($CO_2$) with minimum impurities of hydrogen sulfide. The biogas can be burned directly or upgraded to synthetic natural gas by removing the $CO_2$ and the impurities. The residue may consist of protein-rich sludge that can be used as animal feed and liquid effluents that are biologically treated by standard techniques and returned to the soil.

Bioethanol is produced through fermentation of sugar, starch and lignocellulosic materials. Fermentation is the breakdown of complex molecules in organic compound under the influence of ferment such as yeast, bacteria, enzymes, etc. fermentation is well established and widely used technology for the conversion of grains and sugar crops into ethanol. Ethanol can be mixed with gasoline to produce gasohol (90 % gasoline and 10 % ethanol).

### Chemical conversion

Depleted supplies of fossil fuel, regular price hikes of gasoline and environmental damage have necessitated the search for economic and eco-friendly alternative of gasoline. India's dependency on oil imports is increasing at faster rate. Hence, it is time to shift for alternate fuels like biodiesel, bioethanol and biobutanol, which are produced from biomass, renewable and abundantly available source.

Biodiesel is a chemical method of conversion of oil into diesel. Biodiesel is a variety of ester-based oxygenated fuels derived from natural, renewable biological sources such as vegetable oils through transesterification process. Biodiesel can be used as an alternate fuel for diesel engines.

### Conclusion

Biomass conversion technology has huge potential to fulfill the energy requirement. Biomass is available throughout a year, better other renewable energy sources like solar, wind, small hydro power, etc. that depends on climatic conditions. It has appropriate agricultural oriented electricity and thermal applications. The use of biomass conversion technology, based on thermochemical, biochemical and chemical conversion routes to produce solid, liquid, and gaseous fuels offering better efficiency and also sustainable energy solution.

# Recycling of Farm and Domestic Waste for the Production of Biogas and Organic Fertilizer

***D.Ramesh***
Department of Renewable Energy Engineering,
Agricultural Engineering College and Research Institute,
Tamil Nadu Agricultural University, Coimbatore-641 003

## Introduction

In the present scenario, energy demand is primarily fulfilled by fossil fuels which in turn are getting diminished at a very fast rate. Currently, coal alone is meeting around 61 % of India's electricity need though this is not an eco-friendly fuel. Global warming caused due to the emission of $CO_2$ which is further emitted by burning of conventional fuel like coal, is the major issue associated with coal's commercial application. Developing economy like India is feeling the heat of scarcity in meeting its own energy needs. It is a well-known fact that the non-renewable energy sources won't be last more than 40 years from now onwards. Hence renewable source of energy is the only option available which can cater the energy needs of a developing nation. India increases the targets of renewable energy about 175 and 275 GW (Giga watts) by the year 2022 and 2027 respectively. By 2030, 40% of electric power may be obtained from non-fossil fuel. Many technological development missions were carried out for time dependent commercial methods, which includes, in-situ gasification, carbon sequestration, thermal and photovoltaic solar system and biofuels like biogas, bio-diesel and wood gasification.

## Anaerobic digestion

The process of degradation of organic materials (animal waste, food waste, agro-waste etc.) to produce biogas in the absence of air is known as anaerobic digestion. There are four main processes in the anaerobic digestion process namely hydrolysis, acidogenesis, acetogenesis and methanogenesis. Biogas is majorly composed of methane (40–65% v/v) and $CO_2$ (35–55% v/v) with minute amounts of hydrogen sulphide ($H_2S$) (0.1–3% v/v), moisture, and other trace contaminants. Major factors affecting the anaerobic digestion process are pH, temperature, volatile solids (VS), total solids (TS), retention time (RT) and organic loading rate (OLR) of the feedstock. It can be used for cooking as well as for producing electricity or mechanical power using engines, as a vehicular fuel. The digestate produced from the biogas plant is an excellent manure rich in nutrients**.** Anaerobic digestion is an integrating step in cascading agro-waste system, where a renewable energy (biogas) is simultaneously produced with a digestate commonly called biofertilizer. This creates a closed loop wherein the agro-waste is transformed to value-added product streams, which are further used as the starting point for the production of new products and by-products, thus maximizing the energy, economic and environmental benefits.

## Current status of biogas production in India

India stands as one of the countries with the largest number of biogas plants ranking ninth in terms of biogas production. The country generates 2.07 billion $m^3$ of biogas per year but the potential has been identified to be still largely unexplored (despite its huge potential of 29–48 billion $m^3$ $year^{-1}$). Like in other Asian countries, the focus has been largely on small-scale cattle dung-based biogas plants for cooking purposes especially in rural areas and this model has attained substantial success. In general, the Indian biogas systems have mainly been fairly simple, cheap and robust family-type digesters that are easy to design and operate with locally produced materials. The feed used for the digesters are from the household and their small farming activities. These types of reactors typically is a humble underground tank with a floating drum to collect the biogas while the effluent is collected from the bottom of the reactor. As in 2012, 4.55 million such as biogas plants were operated in the country which carried a potential to mitigating global warming by 45 MT $CO_2$ eq $year^{-1}$. Such small family sized biogas plants generating 1–10 $m^3$ biogas daily can avail subsidies and financial aids from the government. A report presented by India's MNRE (Ministry of New and Renewable Energy) details the investment costs and the expected returns from such small-scale plants and the payback period is calculated to be between 1.6 and 3.2 years.

Currently, there is a gradual shift towards utilising different organic materials including crop leftovers, dairy wastes, chicken manures and kitchen wastes in medium-/large-scale biogas reactors to generate methane that can further be converted to electricity. In 2016, the Central Electricity Act was amended and the state electricity distribution companies were mandated to acquire 100% power generated from waste-to-energy plants. The country reported operating 56 biogas-based power plants (BPP) mostly concentrated in the states of Maharashtra, Karnataka and Kerala. Through 400 off-grid biogas power plants, a total power generation capacity of 5.5 MW has already been prepared for decentralised applications.

**The National Biogas and Manure Management Programme**

The government's National Biogas and Manure Management Programme (NBMMP) launched since the 1970s is the driving force for constructing biogas plants in the country. It has focussed on setting-up family-type biogas plants for cooking and lighting purposes. In 2018, the programme announced to support setting-up 65,180 biogas plants annually for cooking, lighting and small power needs targeting remote, rural and semi-urban areas. Meanwhile, the government's MNRE under the NBMMP, in collaboration with United Nation Development Programme (UNDP) also launched a project on 'Removal of Barriers to Biomass Power Generation in India'. This project has effectively supported the schemes concerning biogas production targeting wastes from industries, agricultural sector as well as the urban wastes. Implemented under the 'waste to energy mission', small-scale biogas plants (each with a potential of 1–25 $m^3$ $day^{-1}$), nearly five million family biogas plants could be installed in the rural areas focussing to provide clean cooking fuel.

**Biomass resources for anaerobic digestion**

**1. Animal waste**

India bears the largest population of animal in the world nearly 303.31million which includes buffalos, cows, goats, etc. Cattle and buffalo yield dung of 4.5 kg $d^{-1}$ and 10.2 kg $d^{-1}$ which makes a total 659 MT of wastes annually. This can be effectively utilized for biogas production.

## 2. Agricultural residues and crop waste

Since India is an agricultural country people mainly depends on farming. Due to increase in population, 35 – 40 % of production of grains, vegetables, fruits have increased. Using the sustainable residues for anaerobic digestion from crop waste which includes, sugarcane, rice, wheat, barley, oats, maize etc. will have a potential to generate 4000 tetra watthour (TWH) which can meet 6.5% of world population energy demand. The biogas potential of crop residues was estimated to be 103 and 172 billion $m^3$ $year^{-1}$ in 2040 considering low and high availability scenario.

## 3. Food waste

Approximately, 1/3 of the food generated (1300 MT) is being wasted without human consumption. Worldwide food waste was around 50%, 30% and 20% with fruits and vegetables, cereals and fishes and oilseeds respectively. Proper anaerobic digestion of these wastes mitigates the spreading of diseases, odors and thereby promoting healthy and hygienic sanitation.

## Process involved in anaerobic digestion

The four major mechanisms involved in anaerobic digestion of organic wastes is given below.

## Hydrolysis

The first step in the anaerobic digestion process is the hydrolysis of large organic molecules by extracellular enzymes produced by obligate anaerobic bacteria. Starch and glycogen are hydrolysed to disaccharides by the action of amylase. these enzymes attack polysaccharides from the non – reducing end of the chain cleaving alternate glycosidic bonds. These enzymes attack polysaccharides from the non – reducing end of the chain cleaving alternate glycosidic bonds. These enzymes attack polysaccharides from the non-reducing end of the chain cleaving alternate glycosidic bonds. Subsequently the disaccharides are cleaved to monosaccharides by a glycosidase. Cellulose is hydrolysed to cellobiose and subsequently to glucose by cellulase and cellobiose which include both exo and endo glucanases. Lipases and esterase's hydrolyse fats and lipids. Proteases catalyse the cleavage of peptide bonds of proteins. The microbial species fits with the family of *Streptococcaceae, Enterobacteriaceae,* genera of *Bifidobacterium, Lactobacillus, Clostridium, Eubacterium, Bacteroides* and *Butyrivibrio* were most important for this process.

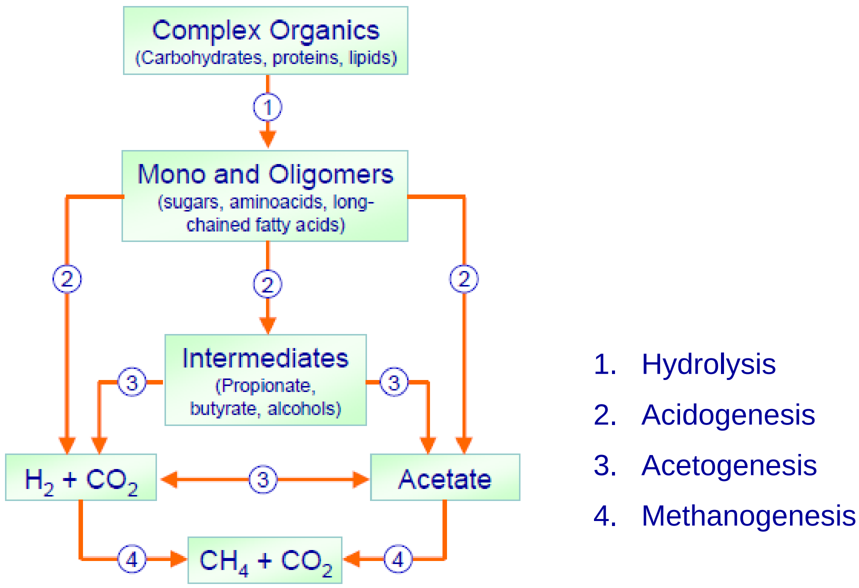



**Fig 1. Mechanism involved in anaerobic digestion**

**Acidogenesis**

This stage is called the fermentation stage where degradation of the soluble compounds from hydrolysis to form carbon dioxide and hydrogen with the help of $H_2$ producing acetogenic and $H_2$ consuming methanogenic bacteria (acidogenic bacteria). Acetic acid is formed in this reaction which is a major substrate for methanogens.

**Acetogenesis**

During this stage, hydrogen gas produced in acidogenic process inhibits the acetogeneic bacterial metabolism. Hence, this stage is otherwise called dehydrogenation stage. But this hydrogen is consumed by methanogens and converted into methane. The volatile fatty acids, produced in the acidogenesis are broken by homoacetogenic bacterias *Acetobacterium woodii* and *Clostridium aceticum* to facilitate the production of acetic acid, carbon di-oxide and hydrogen. The availability of water from acidogenesis acts as electron source for volatile fatty acid conversion.

**Methanogenesis**

This step is the final stage of the anaerobic process where conversion of acetic acid and hydrogen to methane and carbon di-oxide takes place with the help of methanogens. Methanogens are anaerobes survive in oxygen free environment and vulnerable to small quantity of oxygen. They are very important microbes and grows gradually and sensitive to changes in substrate.

**The efficiency of biogas generation depends upon the following factors:**

1. Acid formers and methane fermenters must remain in a state of dynamic equilibrium, which can be achieved by proper design of digester.
2. Anaerobic digestion of raw cow dung can take place at any temperature between 8 and 55°C. The value of 35°C is taken as optimum. The rate of biogas formation is very slow at 8°C. For anaerobic digestion, temperature variation should not be more than 2 to 3°C. Methane bacteria work best in the temperature range of 35 and 38°C.

3. A pH value between 6.8 and 7.8 must be maintained for best fermentation and normal gas production. The pH above 8.5 should not be used as it is difficult for the bacteria to survive above this pH.
4. A specific ratio of carbon to nitrogen (C/N ration) must be maintained between 25:1 and 30:1 depending upon the raw material used. The ratio of 30:1 is taken as optimum.
5. The water content should be around 90% of the weight of the total contents. Anaerobic fermentation of cow dung proceeds well if the slurry contains 8 to 9% solid organic matter.
6. The slurry should be agitated to improve the gas yield.
7. Loading rate should be optimum. If digester is loaded with too much raw material, acids will accumulate and fermentation will be affected.

**Table 1. Composition of biogas**

| **Name of the gas** | **Composition in biogas (%)** |
|---|---|
| Methane ($CH_4$) | 50-70 |
| Carbon dioxide ($CO_2$) | 30-40 |
| Hydrogen ($H_2$) | 5-10 |
| Nitrogen ($N_2$) | 1-2 |
| Water vapour ($H_2O$) | 0.3 |
| Hydrogen sulphide ($H_2S$) | Traces |

**Table 2. Properties of biogas**

| **Properties** | **Range** |
|---|---|
| Net calorific value ($MJ/m^3$) | 20 |
| Air required for combustion ($m^3/m^3$) | 5.7 |
| Ignition temperature ($^0C$) | 700 |
| Density ($kg/m^3$) | 0.94 |

**Types of biogas plants**

Biogas plants basically are two types.

- Floating dome type - Eg. KVIC-type (KVIC- Khadi Village Industries Commission)
- Fixed dome type - Eg. Deenabandu model

**KVIC type biogas plant**

This mainly consists of a digester or pit for fermentation and a floating drum for the collection of gas. There is a partition wall in the center, which divides the digester vertically and submerges in the slurry when it is full. The digester is connected to the inlet and outlet by two pipes. Through the inlet, the dung is mixed with water and loaded into the digester. The fermented material will flow out through outlet pipe. The outlet is generally connected to a compost pit. The gas generation takes place slowly and in two stages. In the first stage, the complex, organic substances contained in the waste are acted upon by a certain kind of bacteria, called acid formers and broken up into small-chain simple acids. In the second stage, these acids are acted upon by another kind of bacteria, called methane formers and produce methane and carbon dioxide.

**Gas holder**

The gas holder is a drum constructed of mild steel sheets. This is cylindrical in shape with concave. The top is supported radically with angular iron. The holder fits into the digester like a stopper. It sinks into the slurry due to its own weight and rests upon the ring constructed for this purpose. When gas is generated the holder rises and floats freely on the surface of slurry. A central guide pipe is provided to prevent the holder from tilting. The holder also acts as a seal for the gas. The gas pressure varies between 7 and 9 cm of water column. Under shallow water table conditions, the adopted diameter of digester is more and depth is reduced. The cost of drum is about 40% of total cost of plant. It requires periodical maintenance.

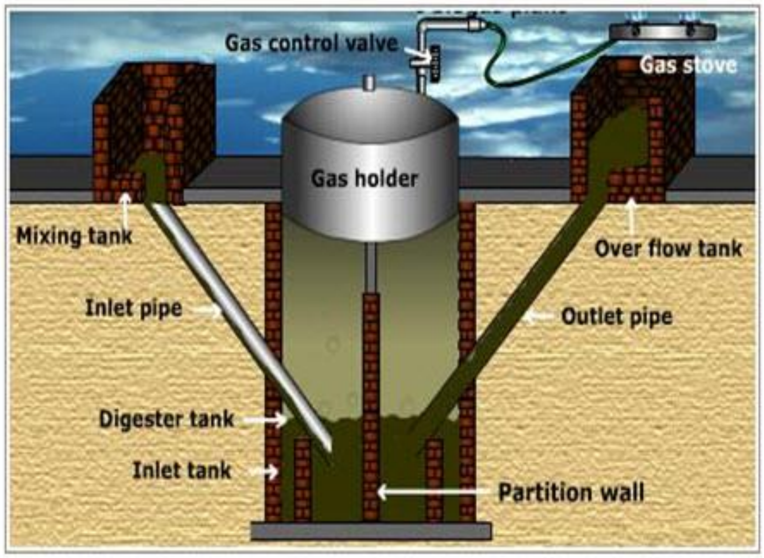



**Fig. 2. Schematic diagram of a KVIC biogas plant**

**Deenabandhu biogas plant**

Deenabandhu model was developed in 1984, by Action for Food Production (AFPRO), a voluntary organization based in New Delhi. The Deenabandhu biogas plant has a hemispherical fixed-dome type of gas holder. The dome is made from pre-fabricated ferrocement or reinforced concrete and attached to the digester, which has a curved bottom. The slurry is fed from a mixing tank through an inlet pipe connected to the digester. After digestion, the biogas collects in the space under the dome. It is taken out for use through a pipe connected to the top of the dome, while the sludge, which is a by-product, comes out through an opening in the side of the digester.

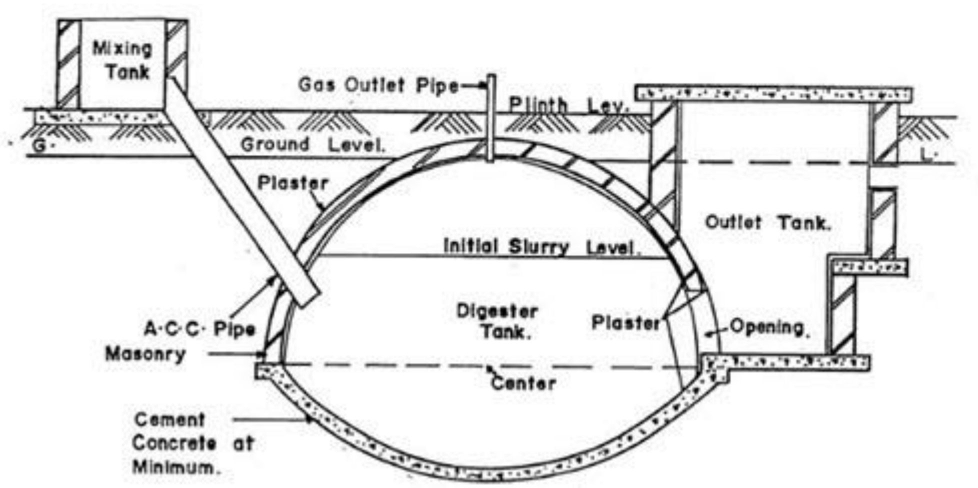


**Fig.3. Schematic diagram of a Deenabandhu biogas plant**

**Uses of biogas**

Biogas serves as a suitable alternate fuel for satisfying the energy needs of human society. It can be used for production of power, for cooking, lighting, etc.

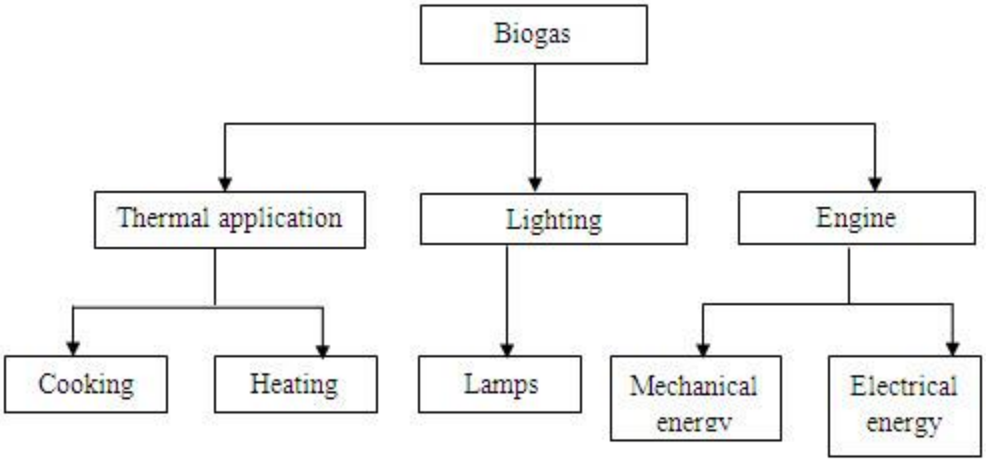



**Fig.4. Application of biogas**

**Cooking and lighting**

The primary domestic uses of biogas are cooking and lighting. Because biogas has different properties from other commonly used gases, such as propane and butane, and is only available at low pressures (4 - 8 cm water), stoves capable of burning biogas efficiently must be specially designed. Biogas burns with blue flame and without any soot and odour which is considered to be one of the major advantages compared to traditional cooking fuel like firewood and cow dung cake.

Lighting can be provided by means of a gas mantle, or by generating electricity. Biogas mantle lamps consume 2-3 cft per hour having illumination capacity equivalent to 40 W electric bulbs at 220 volts. This application is predominant in rural and unelectrified areas.

**Biogas as an Engine Fuel**

Biogas can be used as a fuel in stationary and mobile engines, to supply motive power, pump water, drive machinery (e.g., threshers, grinders) or generate electricity. It can be used to operate four stroke diesel and spark ignition engines. Electricity generation using biogas is a commercially available and proven technology. Typical installations use spark-ignited propane engines that have been modified to operate on biogas. Biogas-fueled engines could also be used for other on-farm applications. As discussed below, diesel or gasoline engines can be modified to use biogas.

IC engines (typically used for electricity generation) can be converted to burn treated biogas by modifying carburetion to accommodate the lower volumetric heating value of the biogas into the engine and by adjusting the timing on the spark to accommodate the slower flame velocity of biogas ignition systems. When biogas is used to fuel such engines, it may be necessary to reduce the hydrogen sulphide content if it is more than 2 percent otherwise the presence will lead to corrosion of engine parts.

In terms of electricity production, small internal combustion engines with generator can be used to produce electricity in the rural areas with clustered dwellings thus promoting decentralized form of electricity avoiding grid losses.

**Use of biogas as vehicular fuel**

Biogas is suitable as a fuel for most purposes, without processing. If it is to be used to power vehicles, however, the presence of $CO_2$ is unsatisfactory, for a number of reasons. It lowers the power output from the engine, takes up space in the storage cylinders (thereby reducing the range of the vehicle) and it can cause problems of freezing at valves and metering points, where the compressed gas expands, during running, refuelling, as well as in the compression and storage procedure. All of the $CO_2$ must therefore be removed from the raw biogas, to prepare it for use as fuel for vehicles, in addition to the compression of the gas into high-pressure cylinders, carried by the vehicle.

**Bio digested slurry**

Bio digestate is a potential alternative to expensive chemical fertilizers. The composition of digestate depends upon the composition of wastes, inoculum, operating conditions like pH, temperature, etc., and plant configuration. Generally, the digestate has slightly alkaline pH due to ammonia production and volatile fatty acids (VFAs) degradation. Organic matter (OM), total organic carbon (TOC) and ash content in the digestate are variable in concentration depending upon the composition of agro-waste. Usually, digestate is separated mechanically and then centrifuged into two fractions (i.e. solid and liquid), both having different modes of handling and application. Biogas digestate can be directly used on agricultural land as a fertilizer, dried to make animal bedding or processed and marketed as a commercial fertilizer for value addition and soil amendment. Apart from land applications: (i) liquid digestate can be used as a source of nutrients in algae production; (ii) solid digestate can be used for production of bioethanol or as a fuel in thermal processes such as combustion; (iii) solid digestate can be converted into added-value products (char or activated carbons) through a pyrolysis process. Further, the produced biomass was used as an alternative source for feeding aquatic animals or as a substrate for energy production.

**Uses of biodigested slurry**

The slurry after the digestion will be washed out of the digester which is rich in various plant nutrients such as nitrogen, phosphorous and potash. Well-fermented biogas slurry improves the physical, chemical and biological properties of the soil resulting qualitative as well as quantitative yield of food crops. Slurry from the biogas plant is more than a soil conditioner, which builds good soil texture, provides and releases plant nutrients. Since there are no more parasites and pathogens in the slurry, it is highly recommended for use in farming. The economic value of the slurry shows that investment can be gained back in three to four years' time if slurry is properly used. The cow dung slurry after digestion inside the digester comes out with following characteristics and has following advantages:

- When fully digested, effluent is odorless and does not attract insects or flies in the open condition.
- The effluent repels termites whereas raw dung attracts them and they can harm plants fertilized with farmyard manure (FYM).

- Effluent used as fertilizer reduces weed growth with about 50%. When FYM is used the undigested weed seeds cause an increased weed growth.
- It has a greater fertilizing value than FYM or fresh dung. The form in which nitrogen available can be easily assimilated by the crops.
- Biogas slurry can also be coated on the seeds prior to sowing. This acts as insecticide and prevents seeds or plants from insect attack. This helps in early germination and healthy growth of seedlings.
- The digested slurry is fed through the channel, flowing over a layer of green or dry leaves and filtered in the bed. The water from the slurry filters down which can be reused for preparing fresh dung slurry. The semi-solid slurry can be transported easily as it was in the consistency of fresh dung and used for top dressing of crops like sugarcane and potato.
- Biodigested slurry is also being used for fish culture, which acts as a supplementary feed. On an average, 15-25 litres of wet slurry can be applied per day in a 1200 sq. pond. Slurry mixed with oil cake or rice- bran in the 2:1 ratio increases the fish production remarkably. In general, organic manures about 10 t / ha, in the form of FYM or compost or biodigested slurry is recommended to be applied once in three years to maintain the organic content of soil, besides providing nitrogen, phosphorous and potassium in the form of organic fertilizers to the crop.

# Solar Energy Gadgets for Agrarian Applications

***R. Mahendiran, T. Ayisha Naziba, R.Kiruthika and P.Subramanian***
Department of Renewable Energy Engineering,
Agricultural Engineering College and Research Institute,
Tamil Nadu Agricultural University, Coimbatore-641 003

Climate change is the demanding concern of the 21st century, as the average surface temperature of the earth will cross 1.5°C in the next 20 years. With continuous rising global temperature, it is vital for each and every sector to concentrate on greenhouse gas emission and the amount of fossil fuels consumption. Warmer temperatures are causing havoc such as drought, floods and early frost. With such rising concerns, With such rising concerns, solar energy is proving to be a boom to mankind. Each and every sector is trying to adopt this renewable form of energy. Agriculture is one such sector, which can benefit hugely due to the adoption of solar energy. With the rising global population, the demand for agricultural products is increasing at an exponential rate.

India is an agrarian country, agricultural demand for electricity is one of the largest burdens on India's power sector as irrigation systems are largely undeveloped and farmers are dependent on electricity to power their pumps. Solar power can mitigate this entire portion of demand by generating power at the source and converting users into suppliers. Solar power is one of the most versatile forms of energy among renewable sources of energy, with boundless potential, if tapped wisely. Solar energy can be a game changer for the agricultural sector, saving the water resources, reducing dependency on the grid by utilizing their own clean power and even becoming an additional revenue stream for farmers.

## 1.1. India's Energy Scenario

India is the fourth-largest global energy consumer behind China, the United States and the European Union (EU). India will overtake EU as the world's third-biggest energy consumer, with the biggest share of energy demand growth at 25% by 2030. Over the last three decades, the country witnessed 10% of World industrial growth which might increase to 20% by 2040. This high energy demand forces the country to import fossil fuel as its domestic oil and gas production has been stagnant for years. Coal currently dominates India's electricity sector, accounting for over 60% of overall generation. Coal demand is seen rising to 772 million tonnes in 2040 from the current 590 million tonnes.

India's share in the growth in renewable energy is the second largest in the world, after China. As the world seeks ways to accelerate the pace of transformation in the energy sector, India is in a unique position to pioneer a new model for low-carbon, sustainable sources of energy with inclusive growth. The renewable power targets in India (Table 1) and category wise installed power capacity (Fig.1) are indicating the shine of growth in renewable energy sector.

Table 1. Renewable Power Targets in India

| Technology | Target |
|---|---|
| Renewable Power | 175 GW by 2022; 450 GW by 2030 |
| Bio-power | 10 GW by 2022 |

| | |
|---|---|
| Hydropower (small-scale) | 5 GW by 2022 |
| Solar PV | 20 million solar lighting systems added 2010-2022 |
| Solar PV and CSP | 100 GW by 2022 |
| Wind power | 60 GW by 2022 |

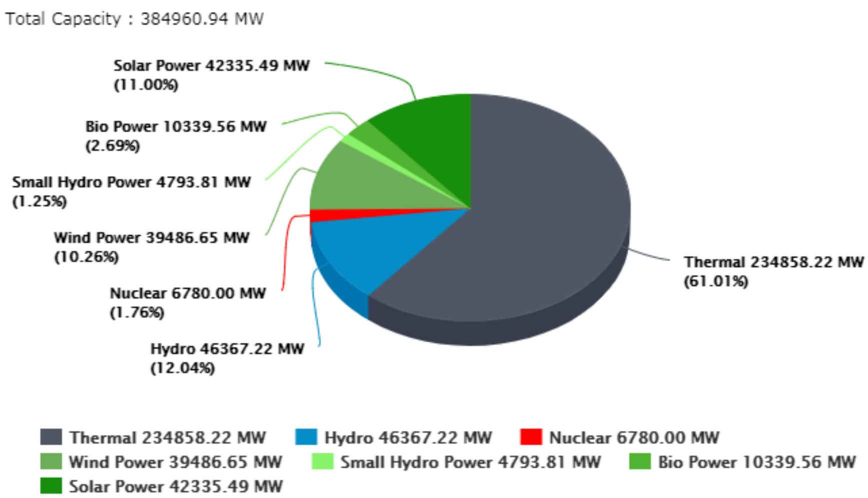



Fig 1. Category wise installed power capacity (as on 05.08.2021)

## 2. Solar Power in India

India is already a global leader in solar power, and solar combined with batteries will play a massive part in India's energy future. But India will need a whole host of technologies and policies to chart this new path. As new industrial sectors emerge and clean energy jobs grow, India will also need to ensure that no one is left behind, including in those regions that are heavily dependent on coal today.

India's power sector has a total installed capacity as on August 2021 as 385 Gigawatt (GW) of which 61% (234.8 GW) is coal-based, 37.2% (143.3 GW) is renewables including hydro and the balance is gas and nuclear-based power. Globally, India stands 4$^{th}$ in renewable power capacity, 4$^{th}$ in wind power, and 5$^{th}$ in solar power capacity. Fortunately, most parts of India receive 4-7 kWh of solar radiation per square metre per day with 300 sunny days in a year which can be used as solar power. India has abundant solar resources, as it receives about 3000 hours of sunshine every year, equivalent to over 5,000 trillion kWh. Today the contribution of solar power with an installed capacity of 42.3 GW, is nearly 44% of the total renewable energy installed 97.1 GW, excluding large hydro (Ministry of Power, August 2021).

The National Action Plan on Climate Change is being implemented through eight missions with focus on solar energy in the total energy mix of the country. Development of alternate energy has been part of India's strategy for expanding energy supply and meeting decentralized energy needs of the rural sector. The strategy is administered through India's Ministry of New and Renewable Energy (MNRE), Energy development agencies in the various States, and the Indian Renewable Energy Development Agency Limited (IREDA). MNRE has been facilitating the implementation of broad-spectrum programmes including harnessing renewable power, renewable energy to rural areas for lighting, cooking and motive power, use of renewable energy in urban, industrial, agriculture and commercial applications. In addition, it supports research, design and development of new and renewable energy technologies, products and services.

### 2.1. National Solar Mission

The National Solar Mission, is an initiative of the Government of India and State Governments to promote solar power in India. The objective of the mission is to establish India as a global leader in solar energy by creating the policy conditions for its deployment across the country with target of 100 GW of solar PV by 2022. NSM is to create conditions, through rapid scale-up of capacity and technological innovation to drive down costs towards grid parity. The Mission anticipates achieving grid parity by 2022 and parity with coal-based thermal power by 2030, but recognizes that this cost trajectory will depend upon the scale of global deployment and technology development and transfer. Among the number of schemes under NSM, PM KUSUM is a key solar energy policy for agriculture sector.

#### 2.1.1. Pradhan Mantri Kisan Urja Suraksha Evam Utthan Mahabhiyan (PM KUSUM)

PM-KUSUM scheme is one of the largest initiatives in the world to provide clean energy to more than 3.5 million farmers by solarizing their agriculture pumps. The scheme has three components A, B and C.

**A) Setting up of 10,000 MW of decentralized grid connected renewable power plants on barren land:**

Under this component, renewable energy based power plants (REPP) of capacity 500 kW to 2 MW will be setup by individual farmers / group of farmers / cooperatives / panchayats / Farmer Producer Organisations (FPO) / Water User associations (WUA) on barren / fallow land. These power plants can also be installed on cultivable land on stilts where crops can also be grown below the solar panels. The renewable energy power project will be installed within five km radius of the sub-stations in order to avoid high cost of sub-transmission lines and to reduce transmission losses. The power generated will be purchased by local distribution company (DISCOM) at pre-fixed tariff.

**B) Installation of 17.50 Lakh stand-alone solar agriculture pumps:**

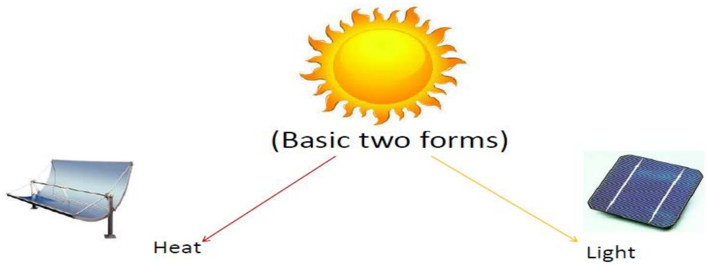
Under this component, individual farmers will be supported to install standalone solar agriculture pumps of capacity up to 7.5 hp for replacement of existing diesel agriculture pumps / irrigation systems in off-grid areas, where grid supply is not available. Pumps of capacity higher than 7.5 hp can also be installed; however, the financial support will be limited to 7.5 hp capacity.

**C) Solarisation of 10 Lakh Grid Connected Agriculture Pumps:**

Under this Component, individual farmers having grid connected agriculture pump will be supported to solarise pumps. The farmer will be able to use the generated solar power to meet the irrigation needs and the excess solar power will be sold to DISCOMs at pre-fixed tariff.

### 2.2. Solar Energy Technologies

There are two primary technologies by which solar energy is harnessed. Solar Photo-voltaics (PV) which directly convert light to electricity and solar thermal which uses the heat from the sunlight directly to drive the utilities. A solar collector used for converting solar energy to thermal energy (heat), typically used for domestic water heating but also used for space heating, for industrial process heat or to drive thermal cooling machines.




The applications of both Solar PV and Solar thermal technologies are summarized below.

| | | |
|---|---|---|
| Solar energy technologies and applications in agriculture | Solar thermal | Solar water heater |
| | | Solar dryer |
| | | Solar cooker |
| | | Solar still |
| | Solar PV (Photo-voltaics) | Solar lantern |
| | | Solar street light |
| | | Solar pumping system |
| | | Solar refrigeration |
| | | Solar sprayer |
| | | Solar powered equipment |

## 3. Solar Thermal Applications

### 3.1. Solar water heater

The water heating system works on the principle of greenhouse effect. A solar water-heating unit comprises a blackened collector with associated metal tubing facing the general direction of the sun. The plate collector has a transparent glass cover above and a layer of thermal insulation beneath it. A pipe to an insulated tank that stores hot water during cloudy days connects the metal tubing of the collector. The collector absorbs solar radiations and transfers the heat to the water circulating through the tubing either by gravity or by a pump. This hot water is supplied to the storage tank via the associated metal tubing. This system of water heating is commonly used in hotels, guesthouses, tourist bungalows, hospitals, canteens as well as domestic and industrial units.

There are two types of collectors used. Flat plate collector (FPC) - A flat metal plate with black selective coating for solar energy collection. The system with single solar FPC is designed for heating minimum 100 litre of water up to 60º C. **Evacuated tube collector (**ETC) - It consists of a number of rows of parallel transparent glass tubes in place of the blackened heat absorbing plate as in the flat plate collector. These glass tubes are cylindrical in shape. Therefore, the angle of the sunlight is always perpendicular to the heat absorbing tubes, which enables these collectors to perform well even when sunlight is low. The insulation properties of the vacuum are so good that while the inner tube may be as high as 150ºC, the outer tube is cooler to touch. This means that evacuated tube water heaters can perform well and can heat water to high temperatures even in cold weather when flat plate collectors perform poorly due to heat loss. Fig.2 shows solar water heater based on FPC and ETC.

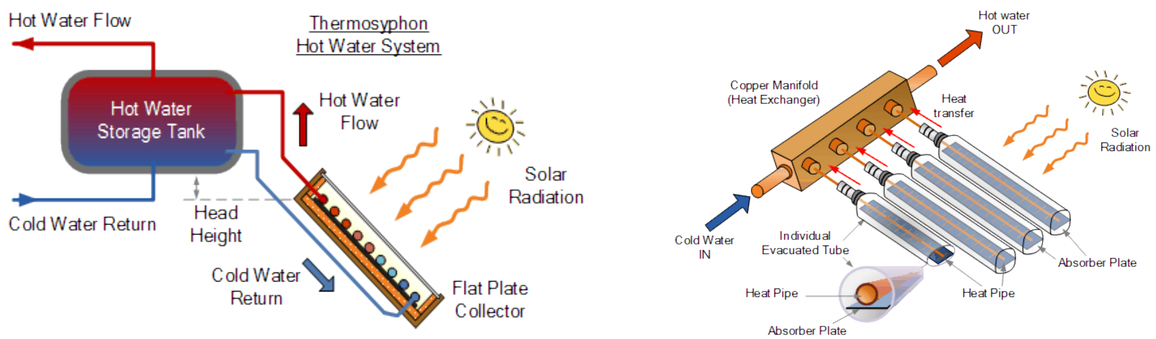



Fig. 2. FPC and ETC Solar water heating system

In order to heat water using solar energy, a collector, often fastened to a roof or a wall facing the sun, heats working fluid (water) that is either pumped (active system) or driven by natural convection or thermo-siphon (passive system) through it. Solar water heaters can provide hot water for cattle cleaning. Dairy operations can use hot solar water to warm and stimulate cow's udders.

### 3.2. Solar dryer

This is a traditional method of utilising solar energy for drying of agricultural products. Drying implies the partial removal of water from the material. Fuel fired drying and dehydration includes a supply of heat energy to evaporate the water and a supply of air to carry away the water vapour. In open air solar drying, heat is supplied to the material by direct absorption of solar radiation. The vapour produced is carried away by air moving past the material. In dehydration using fuel heat, the material being dried is placed in an enclosure and heated air is blown past the surface of the surface of the material to remove moisture.

The present practice of open drying on the floor not only requires a lot of open space and manual labour for material handling but it becomes difficult to maintain its quality and taste unless drying is done in a controlled atmosphere. Moreover, the products being sun dried very often get spoiled due to sudden rains, dust storms or by birds.

In solar dryer, the material is placed within an enclosure with a solar collector to accelerate the drying process through greenhouse effect. The solar radiation enters the dryer as shortwave as it gets scattered or reflected it turns out to be longwave radiation. The solar collector material is transparent to shortwave and opaque to longwave radiation).

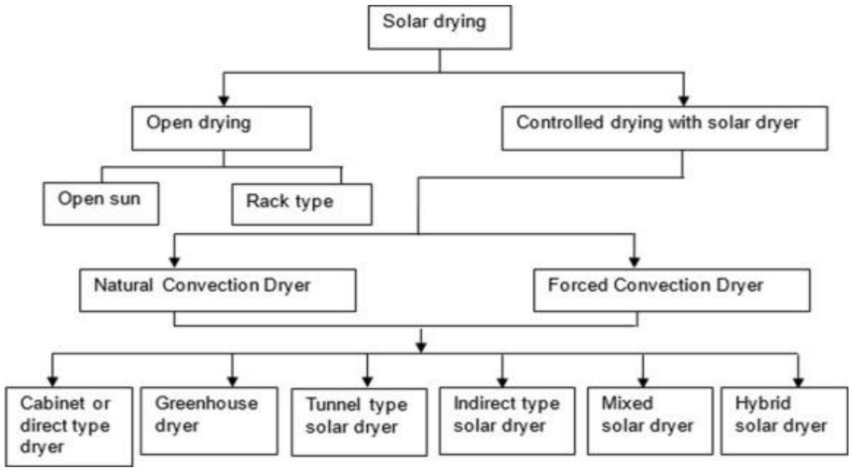


Fig.2. Classification of Solar drying

### 3.2.1. Solar Cabinet Dryer

Solar Cabinet dryer mainly consist of a drying cabinet. One side of the cabinet is glazed to admit solar radiation, which is converted in to low grade thermal heat thus raising the temperature of the air, the drying chamber, and the produce. Usually the sun light shines directly on the material being dried. The moisture evaporated by solar heat is removed by air circulation. This is accomplished either by designing to encourage natural convective air flow or by forcing circulation with fans or blowers. The material to be dried is placed in shallow layers on trays inside the drying cabinet. Proper air vents are provided for displacement of hot air.

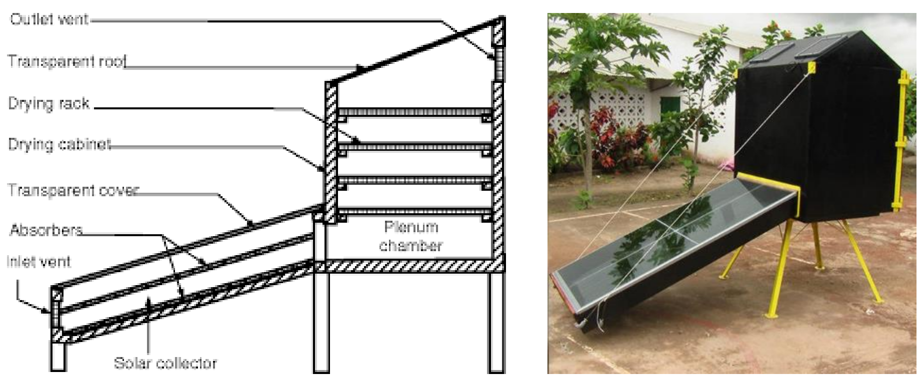


Fig 3. Solar cabinet dryer

### 3.2.2. Solar greenhouse dryer

Solar greenhouse dryers are characterized by having extensive glazing on their south facing side while the other sides are well insulated. Inside the enclosed area, some means are provided to store the daytime excess heat. Vents are strategically sized and positioned to control air flow. A well-designed greenhouse dryer permits a greater degree of control over the drying process than the solar cabinet dryers and should be used where relatively large quantity of product is to be dried.

### 3.2.3. Solar tunnel dryer

Solar tunnel dryer mainly consists of semi-cylindrical tunnel structure which covered with ultra violet (UV) stabilized polyethylene or polycarbonate as collector material. The floor of the solar tunnel dryer is constructed with cement concrete and coated with special black or kadappa flooring which ensures maximum absorption and temperature. Solar tunnel dryer is working based on greenhouse effect principle. The solar radiation is transmitted through transparent collector sheet to tunnel chamber. After reaching absorber surface, the shortwave radiation is converted into long-wave thermal radiation and reflected back to collector material. The transparent collector is opaque for long-wave radiation, hence heat is trapped inside the tunnel chamber. Solar tunnel dryer was adapted in Tamil Nadu region for drying of various agro-industrial products from 2003.

A success story indicates that the solar tunnel dryer installed at M/s. Supa farms, Chinniampalayam, Coimbatore with a capacity to dry 4500 to 5000 coconuts per batch. De-husked coconut was cut into two parts and spread over the drying yard with initial moisture content of 55 per cent and dried moisture reduction upto 6 to 7 per cent finally. The total drying time is 24 hours whereas 40 hours in conventional open sun drying method. Also, the firm confirms the increase in oil yield about 4-6%, shelf life of oil about more than 6 months due to elimination of dust, dirt and protect from fungal contimination.

A solar tunnel dryer was installed at Basuvanapuram, Sathyamangalam taluk, Erode district for farmers of rosemary growers' association. Rosemary (*Rosmarinusofficinalis)*, a medicinal and aromatic plant, commonly cultivated in hilly regions and has become a money-spinner for tribal farmers. Initial moisture content of rosemary was 66 %, reduced to 8-10 % in 13-15 drying hours whereas 30-34 hours in open drying method. The oil yield is observed about 1.5 per cent in solar dried herbs whereas it was only 0.78 % in open sun drying method. The solar tunnel dryer can be used for drying various agro-products such as coconut, chiilies, food (vadam) products and medicinal plants.

Fig 4. Solar tunnel dryer for drying agro products

**3.2.4. Indirect Solar Dryer:**

In this type of dryer, the produce is placed on trays inside an opaque drying chamber to which an air type solar collector is attached. The sun does not shine directly on the material to be dried, instead the air heated in solar collector is ducted to the drying chamber for dehydration. Air circulation can be by natural convection; however, it is often forced by blowers. These dryers result in higher temperature than the cabinet dryers or sun drying, and can produce higher quality product. Performance of solar dryer changes for different type of dryer operated at different temperature. Basic requirement for installation of a solar dryer is the open space free from any obstacle to the solar radiation.

Operation of solar dryers is very simple and it is considered to be maintenance free. However, for efficient performance general maintenance of cleaning of the glazing, regular coating of absorbing surface and instruments and controls can be installed to control the desired temperature and relative humidity.

### 3.2.5. Mixed-mode dryer

Mixed mode solar dryer composed of solar collector and a solar drying chamber. The flat plate collector is the most widely used solar collector for domestical and industrial purpose because it is simple and portable design and required less maintenance. The drying process uses only a solar energy. The air allowed in through air inlet is heated up in the solar collector channeled through the drying chamber where it is utilized in drying and removing the moisture from the agro-produce.

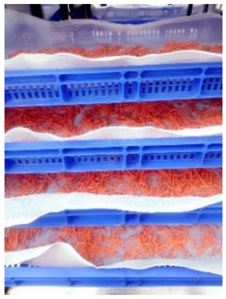


Fig 5. Mixed mode Solar CPC dryer for Vegetables

The mixed-mode solar dryer is highly preferred for value-addition of fruits, vegetables and high value crops. Mixed-mode Compound parabolic solar dryer (fig.5) is desiged, developed and tested for fruits and vegetables drying applications at Department of Renewable Energy Engineering, Tamil Nadu Agricultural University, Coimbatore.

### 3.2.6. Solar-Biomass hybrid dryer

Biomass hot air generation system integrated with solar tunnel dryer with auto-control system was developed at Department of Renewable Energy Engineering, Tamil Nadu Agricultural University, Coimbatore for drying coconut kernels, turmeric and other agro-products. Solar tunnel dryer is semi-cylindrical drying chamber covered with UV stabilized polyethylene / polycarbonate as collector and movable trays with trolleys for bulk loading. Biomass hot air generation system consists of combustion chamber, heat exchanger and air distribution ducts in the drying chamber. Auto-control system helps in regulating the constant drying environment in solar and biomass mode throughout the drying period, thus avoids the deterioration of the product quality.

Fig 6. Solar Biomass Hybrid Dryer for coconut kernels drying

**Salient features:**

- Drying capacity: 2 tonnes/batch (coconut kernels and turmeric)
- Solar mode can be used during sunshine hours and biomass mode can be used during off-sunshine and rainy hours.
- Coconut husk and coconut shell can be used as biomass fuel in this dryer
- Maintains desired temperature throughout the drying period
- Enhances product quality

**Economics:**

- Reduced drying time for copra, 48 hours (2 days) in solar-biomass dryer which is 4-5 days in solar tunnel drying and 6-8 days in open sun drying.
- Drying time for turmeric is 96 hours (4-5 days) which is 70 % lesser than open sun method (12-15 days)
- Cost of drying is Rs.1800 / tonne of copra and payback period is 3.6 years.

### 3.3. Solar cooker

A variety of fuel like coal, kerosene, cooking gas, firewood, dung cakes and agricultural wastes are used for cooking purposes. Due to the energy crisis, supply of these fuels are either deteriorating (wood, coal, kerosene, cooking gas) or are too precious to be wasted for cooking purposes (cow dung can be better used as manure for improving soil fertility). This necessitated the use of solar energy for cooking purposes and the development of solar cookers.

A simple solar cooker is the flat plate box type solar cooker. It consists of a insulated metal or wooden box which is blackened from the inner side. The solar radiations entering the box are of short wavelength. As higher wave-length radiations are unable to pass through the glass covers, the re-radiation from the blackened interior to outside the box through the two glass covers is minimised, thereby minimising the heat loss. The heat loss due to convection is minimised by making the box airtight. This is achieved by providing a rubber strip between the upper lid and the box for minimising the heat loss due to conduction, the space between the blackened tray and outer cover of the box is filled with an insulting material like glass wool, saw-dust, paddy husk etc. When placed in sunlight, the solar rays penetrate the glass covers and are absorbed by the blackened surface thereby resulting in an increase in temperature inside the box. Cooking pots blackened from outside are placed in the solar box.

The uncooked food gets cooked with the heat energy produced due to in-creased temperature of the solar box. Collector area of such a solar cooker can be increased by providing a plane reflector mirror. When this reflector is adjusted to reflect the sun rays into the box, then a 15°C to 25°C rise in temperature is achieved inside the cooker box.

The solar cooker requires neither fuel nor attention while cooking food and there is no pollution, no charring or overflowing of food and the most important advantage is that nutritional value of the cooked food is very high as the vitamins and natural tastes of the food are not destroyed. Maintenance cost of the solar cooker is negligible. The main disadvantage of the solar cooker is that the food cannot be cooked at night, during cloudy days. The concentrating type (focussing collectors) solar cookers are capturing direct normal irradiance (DNI) for generating steam at temperature range 150-350°C which is used for community cooking applications and agro-processing applications such as mushroom substrate pasteurization and dairy units.

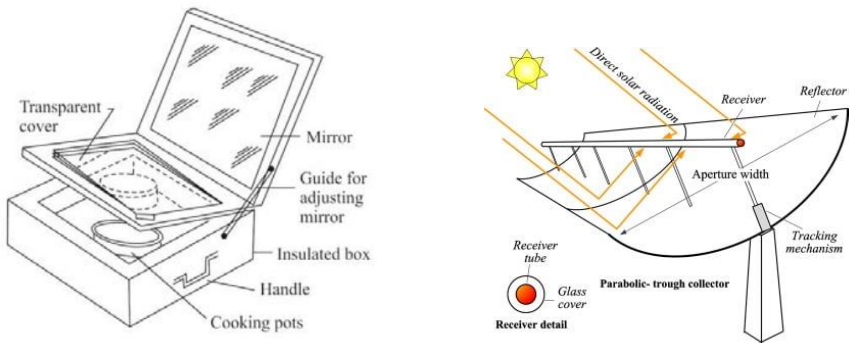


Fig 7. Solar Cooker (Box type and Concentrating type)

### 3.4. Solar Still

In arid semi and or coastal areas, there is scarcity of potable water. The abundant sunlight in these areas can be used for converting saline water into potable distilled water by the method of solar distillation. In this method, solar radiation is admitted through a transparent air-tight glass cover into a shallow blackened basin containing saline water. Solar radiation passes through the covers and is absorbed and converted into heat in the blackened surface causing the water to evaporate from the brine (impure saline water). The vapors produced are condensed to form purified water in the cool interior of the roof. The condensed water flows down the sloping roof and is collected in the troughs placed at the bottom and from there into a water storage tank to supply potable distilled water. Per liter-distilled water, cost obtained by this system is cheaper than distilled water obtained by other electrical energy-based processes.

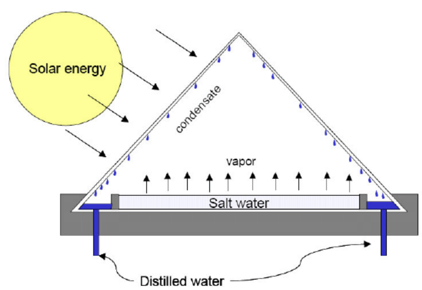


Fig 8. Solar Still

## 4. Solar PV Applications

### 4.1. Solar lantern

A Solar lantern is a simple application of solar photovoltaic technology, which has found good acceptance in rural regions where the power supply is irregular and scarce. A solar Lantern is made of three main components - the solar PV panel, the storage battery and the lamp. The solar energy is converted to electrical energy by the SPV panel and stored in a sealed maintenance-free battery for later use during the night hours. A single charge can operate the lamp for about 4-5 hours. The SPV modules are reported to have a service life of 15-20 years.

### 4.2. Solar street light

The components of solar PV street lighting systems are PV module, battery box, lamp with charge controller and lamp post. This system is designed for outdoor application in un-electrified remote rural areas and for street lighting. The system is provided with battery storage backup sufficient to operate the light for 10-12 hours daily. The system is provided with automatic On/Off time switch for dusk to down operation and overcharge / deep discharge prevention cut-off with LED indicators. The solar street light system comprises of 74 Wp Solar PV Module, 12 V, 75 Ah lead acid/lithium battery, Charge Controller, 11-15 W CFL Lamp/7 W LED with fixtures and 4m mild steel lamp post above ground level with weather proof paint and mounting hardware.

Fig. 9. Solar Lantern

Fig. 10. Solar Streetlight

### 4.3. Solar-powered pumping system

The solar water pumping system is a stand-alone system operating on power generated using solar PV (photovoltaic) system. The power generated by solar cells is used for operating pump set for lifting water from bore/open well or water reservoir for minor irrigation and drinking water purpose. The system requires a shadow-free area for installation of the solar array.

The solar water pump block diagram mainly includes a solar panel, water pump, electric motor, and controller. Generally, this pump works by using electricity from the solar panel. The solar panel receives solar energy and stores it. The motor is used to manage AC or DC and finally, the controller adjusts the speed and output power. Solar water pumps are classified into different types based on the application such as submersible solar pump and surface pump. These pumps are available in both AC & DC technology.

**Advantages**

- No fuel cost-uses abundantly available free sun light
- No conventional grid electricity required
- Long operating life
- Highly reliable and durable-free performance
- Easy to operate and maintain
- Eco-friendly
- Saving of conventional diesel fuel

#### 4.3.1. Universal Solar Pump Controller (USPC)

The Controller for Solar PV pumping system is the heart and brain of the system. The Solar PV pumping system deployed at huge cost to the farmer and the exchequer for the Government is currently utilised only for half of the days in a year (around 150 days per year) on an average. In order to optimally utilize the solar photovoltaic system that generates the electricity throughout the year during sunshine hours, the controller supplied for installation of solar pumping system should be able to perform several other tasks for agricultural and other needs of a farmer. This will increase the productivity of agriculture sector and income of farmer. With the use of USPC the solar system could be used effectively throughout the year.

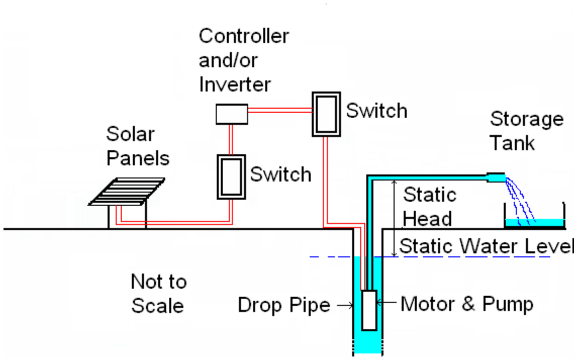



Fig 11. Solar PV pumping system

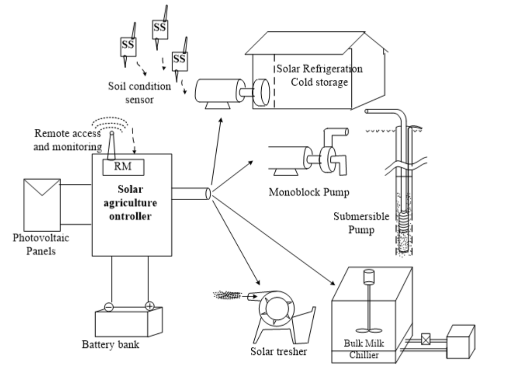



Fig 12. Block diagram of Universal Solar Pump Controller

### 4.4. Solar insect trap

The Solar light trap helps to kill the insects and replace chemical pesticides. The device consists of a bowl on a tripod, an LED bulb and a solar panel. It functions automatically with the help of solar power. The LED bulb will light from 6.30 pm to 9.30 pm and its blue light will attract the insects. When the flies come near the device, they will be trapped in the poison trap under the bulb, which ensures their instant death. Organic Farmers, who appreciate the beneficial pests are highly using the solar traps to kill the harmful insects. They prefer to use ordinary water and oil instead of poison liquids. It is a cost-effective pest control method.

Fig.13. Solar insect trap

### 4.5. Solar refrigerator

A solar-powered refrigerator is a refrigerator which runs on energy directly provided by sun, and may include photovoltaic or solar thermal energy. It is able to keep perishable goods such as meat and dairy cool in hot climates, and used to keep the farm produces at their appropriate temperature to avoid spoilage. Solar-powered refrigerators are typically used in off-the-grid locations where utility provided AC power is not available. Solar powered refrigerators are characterized by thick insulation and the use of a DC compressor. Traditionally solar-powered refrigerators and vaccine coolers use a combination of solar panels and lead batteries to store energy for cloudy days and at night in the absence of sunlight to keep their contents cool. Best application of solar refrigeration is cold storage for agro-produce such as fruits and vegetables.

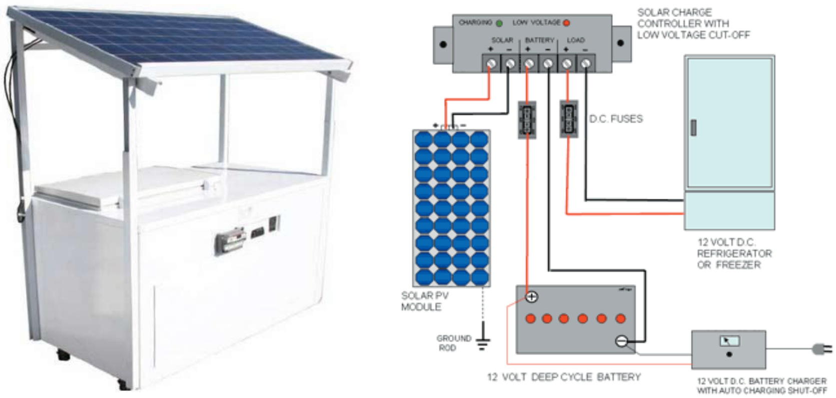



Fig 14. Solar Refrigeration System

### 4.6. Solar Sprayer

The Solar powered sprayer is demonstrated by the department of Renewable Energy Engineering for the visibility of operation. It is used to spray the plant protection chemicals for field crops and also used as sanitizing equipment during COVID-19 pandemic situation. It consists of a PV module (10W), battery and DC pump. The capacity (liquid volume) of the sprayer is 16 liters. The discharge rate is 72 lph with field capacity of 0.9 – 1.0 ha. The salient features of the sprayer include battery charging during operation, multi-nozzle with volume adjustment and easy to handle. The total weight of the sprayer is 8.0 kg, together with maximum chemical solution it weighs around 24 kg.


Fig 15. Solar-powered sprayer

### 4.7. Solar Fencing

A solar fence is a wired structure that works like an electric fence, which delivers a brief yet fierce shock when human beings or animals encounter the fence. The components of solar fencing are photovoltaic module, battery, charge control unit, energizer and fence wiring with voltage alarm unit. The direct current (DC) generated from solar module is used to charge the battery. Depending on sunlight hours and capacity, the system's battery can generally last for as long as 24 hours in a day. The output of the charged battery reaches the controller or fencer or charger or energizer. When powered, the energizer produces a brief yet sharp voltage. The primary function of the energizer is to produce pulses of nearly 8000 volts that are sharp and short-lived. These pulses are passed through the wires of the fencing system at a rate of around 1 pulse every 1-1.5 second with every pulse lasting for nearly 3 ms, thus ensuring that no physical harm is caused to the intruder who attempts to come in contact with the solar fence.

**Advantages**

- Easy construction and maintenance
- Low cost as independent of grid supply
- Does not cause fatal injuries
- Capable of being shifted, extended, modified and re-erected from one place to another without causing wastage of materials or labour
- Long-life due to the absence of any physical pressures causing wear and tear

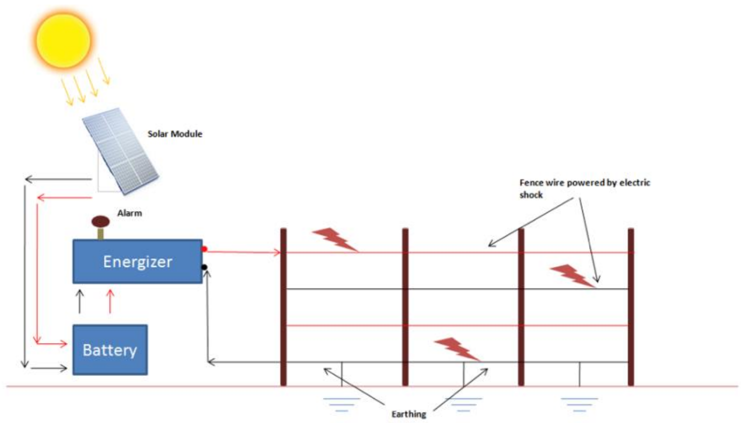



Fig. 16. Solar fencing

### 4.8. Solar farming

Solar farming uses power generated from solar energy to operate agricultural or farming tools thus reducing use of non-renewable energy. It is simple, cost effective, reliable and long lasting. Most common agricultural tools such as tractors, watering systems, rotavator, roller, planter, sprayers, broadcast seeder etc., work on battery power and fuel oil. Among the farming tools, solar electric fence, solar milking machine, solar mowers and tractors have been used by sparse population in India.

Fig 17. Solar-powered tractor

Fig 18. Solar-powered weeder

## 5. Advantages of installation of solar energy-based systems:

- ✓ The first and foremost advantage of solar energy is that it replaces conventional fossil fuel-based energy and abate Green House Gas emission by reducing carbon dioxide ($CO_2$) emission and other fossil fuel-based emissions such as $NO_x$, $SO_x$, etc.
- ✓ An average 1 $kW_p$ Solar PV power plant (off-grid/on-grid) can generate 5 kWh of electricity per day and it can reduce around 1 ton of $CO_{2e}$ per annum.
- ✓ A 100 LPD solar water heater system can save about 1500 units of conventional electricity and it can reduce 1.5 tons of $CO_{2e}$ per annum.
- ✓ It improves local air quality by replacing diesel combustion for energy generation.
- ✓ It offers decentralized power generation to all locations with available sunlight almost 300 days in a year in India.
- ✓ The technology advancement in solar energy devices have significantly reduces the cost of installation and become extremely cost effective in electricity generation.

## 6. Challenges & Constraints in solar energy technology

- ✓ **High Capital Cost:** Despite the fact that the price of Solar Photovoltaic technology has been coming down over the years it still remains economically unviable for power generation purposes. The average cost of Solar PV power plant is ranged from Rs.0.4 to 0.6 lakhs per kW. However, the estimated unit cost of generation of electricity from Solar Photovoltaic and Solar thermal route is in the range of Rs.2.5 – 3.5 per kWh and Rs. 5 - 6 per kWh respectively in India.
- ✓ **Manufacturing process:** Solar PV cell manufacturing is a technology-intensive process requiring high expertise and know-how. Besides, the technology landscape in the solar industry PV space is changing quite rapidly with innovations and R&D. It is challenging for new entrants to replicate the success of companies having a long standing in the Solar PV market.
- ✓ **Raw Material and waste products:** Some of the materials (like Cadmium) used for producing Solar PV cells are hazardous and other raw materials like plastics used for the packaging of the cells are non-biodegradable, thereby impacting the environment.
- ✓ **Environmental costs:** The large amount of land required for utility-scale solar power plants - approximately one sq. km for every 20-60 MW generated - poses an additional problem in India. Instead, Solar energy in particular requires unique, massive applications in the agricultural sector, where farmers need electricity exclusively in the daytime. This could be the primary demand driver for solar energy in India.

## 7. Conclusion:

India is a country, abundantly blessed with natural resources where 60 % of the population depends on agriculture. Utilizing these naturally available resources would help the nation to cut down the exploitation of non-renewable resources for energy consumption in agriculture and other sectors. Solar energy is one of the best alternatives to replace the energy consumption in agricultural sector. Agricultural energy consumption accounting for 27% of the total energy consumption could be completely replaced by solar potential which accounts for 40% of the total renewable capacity installed in India, to achieve self-sufficiency in energy consumption and increase the crop productivity.

# Production and utilization of briquettes for thermal applications

***P. Vijayakumary, P. Subramanian, J. Gitanjali and B. Prabha***
Department of Renewable Energy Engineering,
Agricultural Engineering College and Research Institute,
Tamil Nadu Agricultural University, Coimbatore-641 003

## Introduction

Biomass energy has been attracting attention as an energy source since zero net carbon dioxide accumulation in the atmosphere from biomass production and utilization can be achieved. Among several kinds of biomass, agro residues have become one of most promising choices. But it is generally difficult to handle them because of its bulky nature, low combustion characteristics and copious liberation of smoke. In its natural form, biomass is often an inefficient fuel because it is bulky, wet and dispersed. Among the options for conversion of biomass into energy intensive fuels, densification of biomass is a simple and economic technique. Densification yields an economically viable solution to the storage, handling and transportation problems of biomass. Baling, pelletizing, cubing, extrusion and briquetting are some of the densification technologies used to make biomass as a useful fuel.

## Biomass briquetting

Briquetting is the process of densification of low bulk density biomass to produce homogeneous, uniformly sized solid pieces of high bulk density for easy handling, transport, storage and uniform burning. In high-pressure compaction briquetting technologies, biomass is pressed together and forced through a die at an elevated temperature. The pressure and temperature make the material bond with the help of its own lignin. When temperature goes down, lignin solidifies and holds the briquettes intact in cylindrical form. These high-pressure compaction technologies are also called “binderless” technologies as briquettes can be produced without any binder using these technologies. But, a separate binding material may be added in lower pressure processes or processes which employ raw material of poor lignin content.

## Materials suitable for briquette production

All agricultural crop residues, woody biomass, saw dust from timber mills, dried leaves from orchards, shrubs and grasses along the road sides can be used for briquetting. Crop residues like rice and wheat straw are being burnt in the field for quick disposal in different parts of the country. They can also be briquetted. Moisture content in the range of 10-15% is preferred because higher moisture content will pose problems in grinding and more energy is required for drying. The ash content of biomass affects its slagging behavior together with the operating conditions and mineral composition of ash. Biomass feedstock having up to 4% of ash content is preferred for densification. The granular homogeneous materials which can flow easily in conveyers, bunkers and storage silos are suitable for densification.

## Unit operations involved in briquette production

There are four basic steps involved in the densification process namely, collection of raw materials, preparation of raw materials, compaction and cooling and storage.

### 1. Collection of raw materials

In general, any material that will burn, but is not in a convenient shape, size or form to be readily usable as fuel is a good candidate for briquetting.

**2. Preparation of raw materials**

The preparation of raw materials includes drying, size reduction, mixing of raw materials in correct proportion, mixing of raw materials with binder etc.

***a. Drying***

The raw materials are available in higher moisture contents than what required for briquetting. Drying can be done in open sun, in solar driers with a heater or with hot air.

***b. Size reduction***

The raw material is first reduced in size by shredding, chopping, crushing, breaking, rolling, hammering, milling, grinding, cutting etc. until it reaches a suitably small and uniform size (1 to 10 mm). For some materials which are available in the size range of 1 to 10 mm need not be size reduced. Since the size reduction process consumes a good deal of energy and hence this should be as short as possible.

***c. Raw material mixing***

It is desirable to make briquettes of more than one raw material. Mixing will be done in proper proportion in such a way that the product should have good compaction and high calorific value.

**3. Compaction**

Compaction process takes place inside the briquetting machine. The process depends on the briquetting technology adopted.

**4. Cooling and Storage**

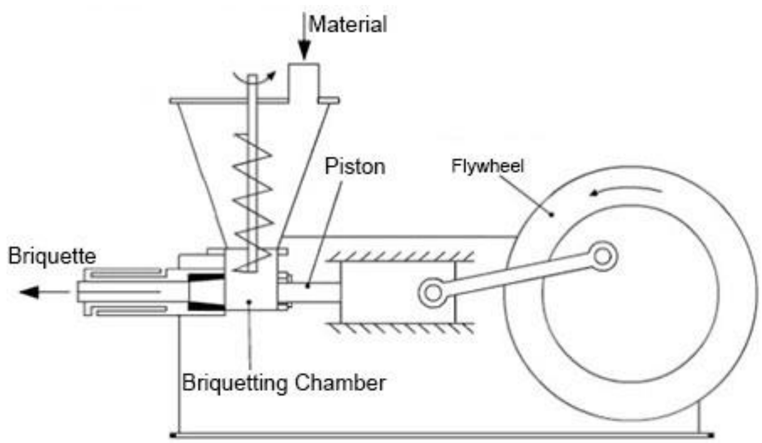
Briquettes extruding out of the machines are hot with temperatures exceeding 200 $^{o}$C. They have to be cooled and stored.

**Binderless biomass briquetting Systems**

The compaction of loose biomass without any binder is done using piston press, screw press and hydraulic press based technologies.

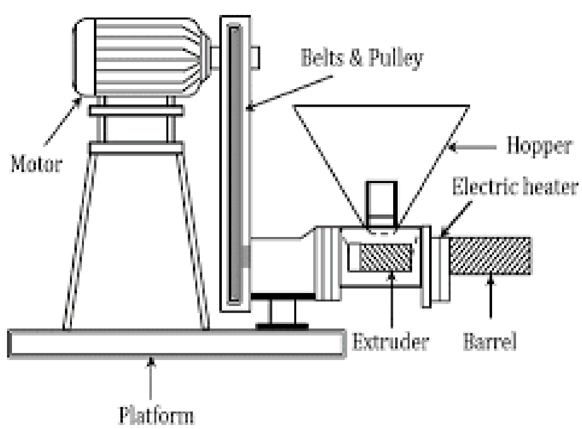
***a. Piston press technology***

In piston press technology, also known as ram and die technology, the biomass is punched into a die by a reciprocating ram with a very high pressure thereby compressing the mass to obtain briquettes. Diameter of briquettes is proportional to output of the machine. Commercial machines with 0.5-1.5 t/h capacity are available. They produce briquettes in the range of 50-90 mm diameter. The ram moves approximately 270 times per minute in this process. The power requirement of such briquetting machines varies from 25 kW to 60 kW.




*b. Screw Press technology*

In the screw press technology, the biomass is extruded continuously by a screw through a cylindrical die which is heated externally to reduce the friction (Fig.2). Material is fed continuously into a screw which forces the material into a cylindrical die, which is often heated to 250-300 °C to raise the temperature to the point where lignin starts flowing and pressure builds up smoothly. Briquettes produced from screw press are often of high quality than piston-press unit but the power requirement per tonne of briquette produced is also high. Briquettes produced by this machine have a hole in the center which makes it burn quickly. The wear and tear of screw is very high and requires frequent reconditioning.

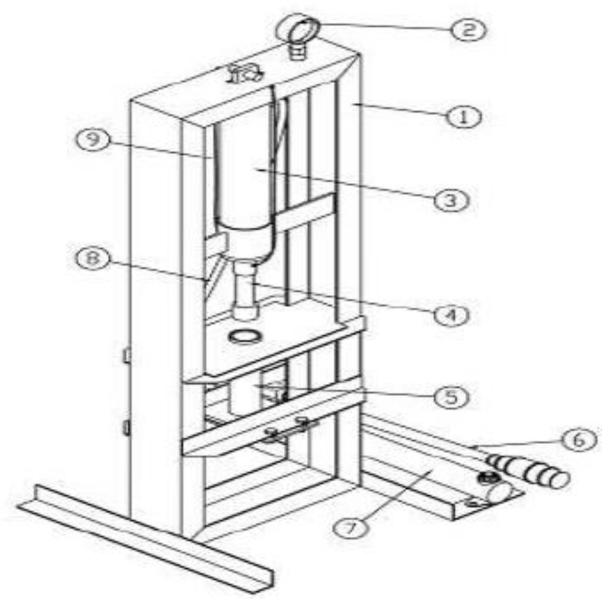



*c. Hydraulic press based technologies*

The hydraulic briquetting press consists of five main parts; main frame and mould, helical cylindrical tension spring, piston rod base plate, and a hydraulic system which include: fluid tank, cylinders and the hydraulic pipe. The main frame was made from 75 mm x 10 mm flat bar and 40 mm x 50 mm angle bars of various length all welded together to produce a rectangular shape of dimension
1155 mm × 300 mm × 80 mm. The mould is located at the lower part of the frame and is made from 10mm thick mild steel. There are two helical tension springs attached on both side of the frame. Steel wire of thickness 2mm is coiled to form a spring with free spring length of 350 mm.

The base plate is a rectangular structure made of mild steel with a thickness of 2 mm. It has an area of 130 mm × 120 mm.

The hydraulic system serves as a mechanism used in transmitting force/pressure. The hydraulic piston is pushed in a downward stroke, transmitting an enormous force to facilitate compaction of the material and also function in removing of compressed briquette from the mould. This material is available in sizes 0.8mm to 12mm. It has an operating range of 0 to 120ºC. The biomass is punched into a die by a reciprocating ram compressing it to obtain a briquette. The machine is operated manually by a hydraulic system to generate pressure required for compression. The hydraulic pump has a lever handle that drives hydraulic fluid to creates a pressure differential in the master cylinder. This pushes the piston that compresses loaded biomass in the mould.




| S/No | DESCRIPTION |
|---|---|
| 1 | Frame |
| 2 | Pressure gauge |
| 3 | Master cylinder |
| 4 | Compression piston |
| 5 | Mould |
| 6 | Hydraulic pump handle |
| 7 | Pump oil sump |
| 8 | Hydraulic hose |
| 9 | Cylindrical tension spring |

**Briquette Quality and Determining Parameters**

The quality of briquettes is dependent on the raw materials and the briquetting process. The desired qualities for briquettes as fuel include good combustion, stability and durability in storage and in handling, and safety to the environment when combusted. Combustion is measured by parameters such as calorific value, ease of ignition and ash content, while environmental concern is measured by the toxic emissions during combustion. The briquetting process, on the other hand, determines the durability and stability of briquettes. Compressive strength, abrasion resistance, impact resistance, moisture absorption, and density are basically the parameters that determine durability and stability. They are considered as the most important quality parameters of densified biomass.

***a. Combustion properties***

The combustion properties include percentage of volatile matter, fixed carbon, ash content and heating value. The percentage of volatile matter, fixed carbon and ash contents of four representative samples were determined based on ASTM Standard E711-87 (2004).

***b. Bulk density***

The volume and the weight of a briquette have to be measured in order to be able to determine the bulk density. Weight measurements were performed with a normal laboratory balance, the volume of the samples was determined by using a graduated cylinder. The average bulk density was calculated from three measurement series per sample.

***c. Water content***

The water content was measured by weighing a fuel sample before and after drying at 105 °C and calculating the loss in weight as a percentage of original weight.

***d. Water resistance***

Short-term exposure to rain or high humidity conditions during transportation and storage could adversely affect the quality of the densified products. Lindley and Vossoughi measured the water resistance as the percentage of water absorbed by a briquette, when immersed in water. Each briquette was immersed in water at 27 °C for one min.

***e. Impact resistance***

Impact resistance (or drop resistance or shattering resistance) test may simulate the forces encountered during emptying of densified products from trucks onto ground, or from chutes into bins. The drop resistance test to determine the durability of biomass pellets and briquettes. Pellets were dropped from 1.85 m height onto a metal plate 4 times. The weight retained as the percentage of the initial weight was taken as the pellet/briquette durability.

***f. Water stability test***

When the briquette is dipped into the water, if it falls to pieces in under 5 minutes, and that usually represents very low briquette quality. When the briquette falls to pieces in under 15 minutes, it shows medium briquette quality and in less than 20 minutes, it is sign of good briquette quality. However, this method is only of an informative character.

**Advantages of biomass briquettes**

- Ready availability and renewability of biomass make briquettes cheaper than coal
- Better feed handling characteristics
- Higher calorific value
- Improved combustion characteristics
- Clean and nearly pollution free
- More uniform size
- Low energy and capital requirements for production
- No fly ash when burning briquettes

**Disadvantages of biomass briquettes**

- High investment cost and energy input to the process

- Undesirable combustion characteristics such as poor ignitability, smoking, etc are often observed.
- Tendency of briquettes to loosen when exposed to water or even high humidity weather

**Utilization of briquettes**

Wood, coal, dung, cake and kerosene are at present most widely used fuels for domestic cooking. However, scarcity in coal and oil supplies is likely to continue in spite of the rising cost and more judicious use. Biomass briquettes are mostly used in the developing world, can be used in boilers, gasifiers, furnaces for thermal applications. They are used to heat industrial boilers in order to produce electricity from steam. The briquettes are co-fired with coal in order to create the heat supplied to the boiler. Briquettes of 60-90 mm size are being used in boilers and gasifiers. Producer gas obtained from briquette based gasifiers after cooling and cleaning of tar and dust can be used for running 100% gas operated electric generating sets. On an average 1 kg biomass briquette can produce 1 kWh of power. For domestic cook stoves 12-25 mm diameter briquettes are more suitable.

**Government incentives for briquetting plant in India**

The Indian government offers various incentives and relaxation on purchasing and setting up biomass briquetting Plant.

- 100% Depreciation: The total value of briquetting plant and machinery is allowed to be depreciated in the first year.
- Sales Tax Exemption: The various states have exempted biomass briquettes from sales tax.
- No Licenses: Renewable energy sources have been exempted for obtaining any license.
- Excise Exemption: The biomass briquettes are completely exempted from Excise duty. The Government is also considering exemption in the case of plant and machinery.
- Income tax holiday for first five years.
- Low rate of interest from government financial institutions

**Conclusion**

Everyone is now aware of the problems resulted by global warming and we are all thinking of ways to change our lifestyles in order to help stop this phenomenon and keep our world safe. The main source of energy for most areas of the world is fossil fuel, which usually make use of coal in order to power boilers to make steam for energy. Briquettes made from biomass are a great substitute for coal, since they are made of natural materials and do not add to the pollution in the world. Because of the production of briquettes, many companies use biomass briquettes since they found out about its benefits and how it can lower their carbon footprint while being affordable. These briquettes are cheaper than coal in the long run, and can be used for a long time. They are cheap compared to other fuels and are highly environment friendly. Excellent quality biomass briquettes are supplied by many plants. If managed properly their uninterrupted supply can be ensured throughout the year. The availability of biomass in abundance, good quality machine and equipment suppliers, Government incentives, huge demand and simple production process makes biomass briquetting a lucrative business for budding entrepreneurs.

## Biomass Chulha / Biomass Gasifiers / Biochar production

***S.Sriramajayam, B. Prabha, R.Kiruthika and P.Subramanian***

Department of Renewable Energy Engineering,
Agricultural Engineering College and Research Institute,
Tamil Nadu Agricultural University, Coimbatore-641 003

### Biomass Chulha

In India, 80% of total population lives in villages. The major energy demand of rural population is for cooking which contributes to about 98% of their total energy consumption. Wood, agricultural waste and biomass are used as cooking fuel in rural kitchen. The common cooking stoves used in rural houses, have very low thermal efficiency (10 to 15%) and hence per capita energy consumption in rural areas is much higher than that in urban areas. Conventional stoves waste a lot of energy and pose many pollution hazards. Most traditional stoves can utilize only 2–10% of the energy generated by the fuel. The growing gap between availability and demand for fire wood, poor thermal performance and pollution caused by traditional stoves forced the technologists to concentrate their attention on improving the thermal efficiencies of stoves.

### Single pot chulha

The single pot chulha has a double wall with a gap of 2.5 cm. It has a grate at the bottom of the combustion chamber and legs at the four corners of the chulha (5 cm height) as the ash can be collected below the grate. The outer wall has two rectangular secondary air openings at the lower portion on both sides for air entry. The inner wall has 1 cm diameter holes, which maintain a triangular pitch of approximately 3 cm. The secondary air enters through the rectangular opening in the outer wall gets heated in the annular chamber and while moving up it passes through the holes in the combustion chamber. The preheated air helps in proper burning of the fuel. The efficiency of single pot improved chulha is 24%.


**Fig. Single Pot Chulha**

### Double pot improved chulha

The TNAU double pot portable chulha (chimneyless) is made with two walls. Around the first pot, an annular chamber having a width of 2.5 cm is left and the outer wall is constructed.

The outer wall is also extended to cover the second pot in which case the annular chamber width is 3.5 cm, because of the smaller diameter of the second pot hole. Two secondary air inlets are made, one on the outer wall with rectangular shape (17 cm x 1 cm) near the combustion chamber and the other at the bottom of the second pot hole with round shape having a diameter of 5 cm. At the bottom of the first pot hole in the base, a hole of diameter 14 cm is made and a grate (C.I.) is placed over it. For the entry of secondary air to the first pot hole, 1 cm dia holes are made with a triangular pitch of 3 cm on the inner side of first pot hole and also on the tunnel projecting into the second pot hole. The efficiency of double pot improved chulha is 26%.

**Fig. Double Pot Chulha**

**Biomass gas stove**

The biomass gas stove has been developed for small scale thermal application in agriculture and allied industries. This stove widens the market for agro wastes, makes possible a higher efficiency and in some cases reduces the time and investment, all by comparison with combustion. The biomass gas stove is a natural convection type updraft gasifier consisting of a cylindrical body made of clay, sand and paddy husk with its top open and bottom closed. The diameters and height of the stove are 290 mm and 630 mm respectively. This can be reduced depending on the applications. An iron grate to hold the biomass is fixed at 50 mm from the base of the reactor. The bottom is provided with an air opening cum ash removal door. At the top, provision is made to place vessel for cooking, boiling etc. The biomass viz., wood chips, agricultural residues like coconut shell, groundnut shell, arecanut husk, tree barks and leaves can be used in this biomass gas stove. The feedstock materials used should preferably be in the form of small chips, splinters and small logs.

The stove can be ignited in two methods. One is igniting from bottom and other is from the top. In the first method, a bed of ignited charcoal (½ - 1 kg) to a depth of 50 mm is placed over the grate. Then the biomass used is dumped over the red hot charcoal. A white gas emanates first and the following the combustible gas is ignited. Whereas in the second method, it is ignited at the top Ash removal system Cooking vessel Air inlet Introduction to Renewable Sources of Energy 67 with diesel soaked waste cotton or by using easily combustible agricultural residues. Initially burning is started in combustion mode and then changes to gasification mode. The stove consumes 4 to 5 kg of biomass per hour. The quantity varies with the type of biomass used. The efficiency of biomass gas stove is 25%.

**Fig. Biomass gas Stove**

**Briquetting**

Briquetting machine is used to produce briquettes from biomass. A reciprocating piston pushes the material into a tapered die where it is compacted and adheres against the material remaining in the die from the previous stroke.

A controlled expansion and cooling of the continuous briquette is allowed in a section following the actual die. The briquette leaving this section is still relatively warm and fragile and needs a further length of cooling track before it can be broken into pieces of the desired length. The most common type of briquette press features a cylindrical piston and die with a diameter ranging from 20-125 mm. The die tapers somewhat towards the middle and then increases again before the end. The exact form of the taper varies between machines and biomass feedstock and is a key factor in determining the functioning of the process and the resulting briquette quality.

Biomass briquettes have a good thermal value and much lower ash content than coal. Briquettes can be used as fuel in boilers, gasifiers, furnaces and domestic cook stoves for thermal applications.

| | | |
|---|---|---|
| Capacity | : | 500 kg/ h |
| Type of machinery | : | Piston press |
| Power consumption | : | 50 kWh/ton |
| Diameter of ram die | : | 40, 50, 60 & 80 mm |
| Motor capacity | : | 40 Hp |

**Fig. Piston Press briquetting machine**

**Biomass Gasifiers**

The down draft gasifier is characterized by co-current flow of air or gas and the fuel. Fuel and air or gas move in the same direction. Gasifier requires drying of biomass fuel to a moisture content of less than 20%. Fuel and air or oxygen enters the top of the reaction chamber. Down-flowing fuel particles ignite, burning intensely and leaving a charcoal residue. The charcoal, which is about 5 to 15% of the mass of original fuel, then reacts with the combustion gases, producing CO and $H_2$ gases. These gases flow down and exit from the chamber below a grate. The producer gas leaving the gasifier is at a high temperature. Combustion ash falls through the grate. The advantage of the downdraft design is the very low tar content of the producer gas and it can be used as for power production.

A downdraft gasifier along with a gas cleaning system can be retrofitted with a diesel engine coupled with a water pump. Biomass gasification could provide clean fuel to a small engine and this renewable energy technology could be a sustainable option for water pumping in rural areas.

| | | |
|---|---|---|
| Gasifier capacity | : | 10 kg/h |
| Engine | : | 5 hp (Diesel engine) |
| Feedstock | : | Fire woods |
| Pump efficiency | : | 65% |

**Fig. Water pumping gasifier**

**Biochar production**

The biomass substances like agro and wood residues such as Prosopis, Casuarina, coconut shell and saw dust etc., are thermally degraded in the absence of oxygen condition at temperatures between 250–400°C to yield a solid product called biochar. The reactor used to produce biochar is called slow pyrolyzer. The biochar yield will vary between 30-35%. Biochar retains ~ 20% of the weight and 30% of the energy of the biomass and hence ~70% of the energy is released as usable vapours. The slow pyrolyzer consists of bottom chamber, top chamber and chimney

***Biochar production unit (1 kg)***

The bottom chamber is called combustion unit, where charcoal is used as the fuelling source. The top chamber is covered with the biomass materials where the pyrolysis process takes place to produce biochar. The heat is passed from bottom chamber to top chamber and volatiles were released through the chimney set up at the top. Once the reactor is cooled to atmospheric temperature, the biochar is collected.

Fig. **Biochar production unit (1 kg)**

***Biochar production unit (100 kg)***

The pyrolysis unit of capacity 100 kg is designed for non- electric charcoal production. The pyrolysis unit follows semi – indirect heating method. The volume of the pyrolysis chamber is 32.5 $m^3$ with the 60 cm diameter and height of 115 cm. The diameter and height of the combustion chamber are about 16 cm and 125 cm, which accounts to volume of 2.5 x $10^{-2}$ $m^3$. The bottom of the pyrolysis cylinder is provided with a grate of 65 holes (each hole of diameter 6 mm) to transfer the heat from combustion chamber to pyrolysis chamber. A chimney of 1 m height is provided on the top of the pyrolysis chamber for flue gas exhaust. The Charcoal yield efficiency of the developed reactor is around 34.84 %, whereas for conventional method is around 19.69 %.

**Fig. Biochar production unit (100 kg)**

The biochar is used as a substitute for solid fuels. It is also be used as a soil conditioner, and there by it mitigates green house gas emissions in the atmosphere. Furthermore, it is used as an adsorbent to treat wastewater by removing contaminants present in it.



Pub:No:AEC&RI/REE/SAMETI/20/2022