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Application of Renewable Energy in Indian agriculture

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Abstract

Energy plays a key role in agricultural production, post-production, rural domestic and livestock raising sectors, both directly as different forms of energy and fuel inputs for various purposes like operation of machinery, equipment, lighting, etc., and indirectly, for seed, fertilizers and chemicals production used in rural activities. India needs a secure, affordable and sustainable energy system to power effective economic growth well supported with renewable energy sources. Engineering interventions for effective (functionally, energetically and economically) systems is utmost needed for rural India. There is need for a revolution in mechanized agriculture, so that new energy efficient systems and machines can be recommended and introduced for small and marginal farmers. There is need to enhance the power availability and optimize the energy input to the rural sector to obtain the better income to agro-rural producers, traders and industrialists.

Energy interventions are needed to use the locally available energy sources curtailing the use of fossil energies. The major targets in Indian perspective are the use of available and developed renewable and conventional energy sources & gadgets in rural society and agro-industry using all kinds of available biomass resources including solar electricity, heating and pumping at decentralised mode. We need to employ recent advanced technologies like plasma technology, nano-technology, IoT, artificial intelligence and robotics for effective generation of energy and valued products from rural local renewable resources. Research on solar energy use for production agriculture is challenging due to fluctuating need of torque depending on the agricultural field conditions. The use of batteries for storing and releasing power is another concern for long term use of solar photovoltaic (SPV) gadgets. Bio-CNG has emerged as an option for ex-situ management of crop residue. Thermo-chemical and bio-chemical conversion based electrical power routes are available and there is a need to promote these with better incentives. Energy efficient functionally improved mechanical systems to be introduced in the Indian farms need to be evolved.

Key words: Renewable energy, Thermo & Bio chemical conversion, energy efficiency, nanotechnology, solar electricity & pumping,

Introduction

Farm power availability and energy input has significant positive impact on the agricultural productivities. There is need to precisely regulate the inputs like, water, labour, seed, fertilizer, machines, prime movers and agricultural land to enhance the yield. Energy optima can impart the yield maxima. But in present scenario, the use of inputs is not optimal which is leading to higher cost of production and energy input. Further, India needs to enhance the income to the farmers, which can be achieved by properly managing all the input resources to reduce the cost and to use the optimum energy input. Economic growth, urbanisation, rising incomes, Agricultural and Industrial activity are the drivers for increased energy consumption in India. The sectoral energy consumption by industry is 42.7% followed by Domestic (24%), Agriculture (17.7%), and Commercial (8%), Traction and railway (1.5%) and others (6.1%). The farm power availability is nearly 2.08 kW/ha which is to be increased by 4.0 kW/ha by 2025 to increase the productivity. Renewable energy is having important role for augmentation of grid power, to provide energy access, to reduce the consumption of fossil fuels and to support Indian economy to pursue its low carbon development path. India has a target to increase the share of renewable based installed electric capacity to 40% by 2030. India is also encouraging the establishment of a solar based economy across the globe. With France partnership, India promoted the establishment of the

International Solar Alliance (ISA) in 2015. In 2018, ISA was transformed into a treaty-based organisation having head-quarter in India.

In India agriculture provides livelihood to two-thirds of the total working population. The contribution of agriculture to Gross Domestic Product (GDP) is 15%. Indian agro-positive climatic conditions make India as one of the top producers of cereals, pulses, fruits, vegetables, milk, meat and fish. In India, due to Green Revolution in the 1960s, there was an increase of 45% in per capita food production till now. Tremendous growth in Indian agriculture in the last 75 years due to various efforts and initiatives has improved food security and raise agricultural output. But this has not resulted in the income enhancement of farm households. About 20 % of rural households primarily engaged in agriculture have income less than the poverty lines. To increase the farmer's income, the Government of India tried a strategy in 2018 - Doubling Farmers' Income. The strategy aimed to double the income by 2022 with yearly growth rate of 10.4%. About one fifth of the total electricity consumed in the country, is used for agriculture practices, mostly for irrigation. As the climatic conditions are erratic and irrigation is dependent on monsoon, the dependence on groundwater has increased. Presently 90% of country's groundwater is consumed for irrigation. For this, the farmers are using 12 million electricity connections and 9 million diesel pumps sets to take out the groundwater for irrigation use. Solar energy can play a significant role in addressing this critical issue. Ministry of New and Renewable Energy (MNRE) has launched PM KUSUM (Kisan Urja Suraksha Evam Utthaan Mahaabhiyan) scheme to support farmers for; (a) Setting-up of 10 GW of decentralized ground mounted grid-connected renewable power plants upto 2 Mega Watt (MW) capacity, (b)Installation of 1.75 Million stand-alone solar agriculture pumps, and (c) Solarisation of 1 Million grid-connected agriculture pumps. Solar pumps are a reliable power source for irrigation with almost negligible cost to run in the long term. Their uses also cut down the diesel cost, and reduce the pollution caused due to burning fuels. The decreasing cost of solar modules has made solar pumps a viable solution for farmers. Solar pumping holds great potential to save 4 billion litres of diesel yearly and 5% of total greenhouse gas emissions. Besides, using grid-connected pumps, cultivators can sell surplus power back to the grid, creating a good income to them.

Another approach to the farmers is the raw material needed in biofuels production - Biomass. National Policy on Biofuels, 2018 and Biomass based cogeneration plants, mentions to produce biodiesel and ethanol utilising sugarcane and its by-products, surplus rice, maize, damaged food grains and non-edible seeds. This is a straight forward opportunity for farmers to increase their income using un-utilised organic waste. Further, this will also reduce the emissions to an extent, as burning of agricultural residue will be reduced.

Energy availability and supply in agriculture is imperative to ensure agriculture sustainability. The changes in farm power and usage of energy resources in Indian agricultural over time have taken place in different magnitudes, accordingly influencing the energy productivity & profitability. The dynamic nature of energy demand and consumption scenario in the agriculture mostly depends on the primary sources of energy such as diesel, petrol and electricity. The dependency on such conventional sources energy not only brings burden on the foreign reserves but also creates huge environments hazards. Hence, India needs a secure, affordable and sustainable mechanised energy system to power effective economic growth. This can be achieved by developing the methodologies, technologies for precise use of renewable energy sources for better energy and grain productivity management.

Renewable Energy Sources

These energy sources are inexhaustible and are renewed by nature itself. Solar, wind, tidal, geo-thermal, hydro and biomass are examples of non-conventional energy sources.

Solar energy: Solar energy is the basic energy source available in abundance and provides food, feed and fiber through photosynthesis. The surface of the earth receives about 1014 kW/m^2/day from sun in the form of solar energy which is approximately five orders of magnitude greater than that currently being consumed from all resources. Solar energy can be used for heat and electricity generation. When converted to thermal (or heat) energy, solar energy can be used to heat water (for use in homes, buildings, or swimming pools), heat spaces (inside homes, greenhouses, and other buildings) and heat fluids (to high temperatures to operate a turbine to generate electricity). Solar energy can be converted to electricity through Photovoltaic (PV devices) or "solar cells" and concentrating Solar Power Plants.

Wind energy: Wind is simply air in motion. It is caused by the uneven heating of the Earth's surface by the sun. Because the Earth's surface is made of very different types of land and water, it absorbs the sun's heat at different rates. The main advantages of wind energy are that wind is renewable and free of cost, pollution free and can be installed in remote locations. Electrical energy can be generated from wind by converting its kinetic energy. Wind can be used to run a wind mill which in turn drives a generator to produce electricity. Wind mills are classified into horizontal axis and vertical axis wind machines. Horizontal axis machines have to be orientated towards the direction from which the wind is flowing, thus requiring a mechanism for yaw, whereas vertical axis machines are omnidirectional meaning they can operate independent of the direction of flow the wind.

***Tidal energy*:** The periodic rise and fall of water level of sea, which is carried by the action of the sun and moon on water of the earth is called "tide". A barrage is a barrier constructed across the sea to create a basin for storing water. During high tide, water will flow from sea to tidal basin through turbine, thus producing electricity. During low tide, water will flow from tidal basin to sea through turbine again producing electricity.

Geothermal energy: Geothermal power plants derive energy from the heat of the earth's interior. There are five general categories of geothermal sources namely hydrothermal convective systems (vapour dominated or dry steam fields, liquid dominated or wet steam fields and hot water fields), geo-pressure resources, petro-thermal or hot dry rocks, magma resources and volcanoes. The main advantages of geothermal energy include cheaper cost and can be used as space heating for buildings, industrial process heat and are inexhaustible in nature. They have lower overall power production efficiency (about 15%) and require large areas for its exploitation.

Ocean thermal energy: Ocean thermal energy conversion systems (OTEC) use the temperature difference of the seawater at different depths to generate electricity. It utilizes the temperature difference that exists between the surface waters heated by the sun and the colder deep (up to 1000 m) waters to run a heat engine. Such a small temperature difference makes energy extraction difficult and expensive. Hence, typically OTEC systems have an overall efficiency of only 1 to 3%.

Hydroelectricity: Hydroelectricity is the term referring to electricity generated by hydropower; the production of electrical power through the use of the gravitational force of falling or flowing water. It is the most widely used form of renewable energy.

Biomass energy: Biomass is organic material and contains stored energy from the sun. Plants absorb the sun's energy in a process called photosynthesis. Biomass is a renewable energy source because we can always grow more trees and crops, and waste products in the form of plant mass will always exist. Some examples of biomass fuels are wood, crops, manure, and some forms of garbage. When burned, the chemical energy in biomass is released as heat, which in turn can be used directly for thermal applications or for conversion to electricity using suitable conversion systems. Indian agriculture sector is largely deficient in energy and power supply in both quantitative and qualitative terms, whereas, agriculture is itself an effective source of energy generation using bio and thermo-chemical processes of biomass. In India, biomass of agriculture origin in the form of surplus straw and stalks is available abundantly. The total annual production of different types of biomass in the country is around 1000 million tonnes derived mainly from agriculture & forestry. The effective use of this locally available biomass for energy conversion is the best strategy to cope up with energy requirement in Indian Agriculture & Rural Sector. This would enable the agriculture sector to self-reliance in energy for production and processing of agro products. In relation to agricultural sector, the biomass energy is very important not only for energy generation but also for purposeful utilization of agro-biomass effectively for value addition and income generation to farmers coupled with saving of the environment.

Biomass availability and its supply chain

Biomass energy is essentially solar energy captured by green plants in photosynthesis and then stored chemically, usually as carbohydrate, and hydrocarbon, etc. It is probably oldest source of energy after the sun. The resource includes several terrestrial and aquatic plant species, various agricultural, forestry and industrial residues, process waste, sewage and animal wastes. Some grasses (e.g., miscanthus, elephant grass) and plants like jatropha are now grown as energy crops. The forest residue like leaves and other herbaceous plant are also a source of biomass Concern over depletion of fossil fuel, studies has suggested that biomass-derived energy will provide a greater share of the overall energy. The characteristics and properties of each source are different hence the utilization of biomass in from of energy is diversified. The use of biomass a source of energy is very attractive, since it can be a zero net CO_2 energy source, and therefore does not contribute to increased greenhouse gas emission.

Biomass is potentially an infinitely renewable resource. Biomass contributes over a third of primary energy in India. Biomass fuels are predominantly used in rural households for cooking and water heating, as well as by traditional and artisan industries. Biomass delivers most energy for the domestic use (rural - 90% and urban - 40%) in India. Surveys were carried out by different agencies over period of time to estimate the biomass availability, utilization and surplus however the estimates found to be very variable. The quantity of recoverable biomass from cropland, grassland, forest, roadsides, and agro-forestry and estimated total available crop residues in India ranges 500-600 Mt/year and surplus as 90-130 Mt/year. The residues of most of the cereal crops and 50% of pulses are used for fodder. Coconut shell, stalks of rapeseed and mustard, pigeon pea and jute & Mesta, and sun flower are used as domestic fuel. A major residue goes to more competitive use as cattle feed, animal feed, packing material, heating and cooking fuel. Among all the crops, rice was found to contribute highest crop residue. MNRE [Ministry of New and Renewable Energy] made an effort to bring out a Nationwide Biomass Atlas for different sources of biomass with a development of web enable data base on biomass based on GIS and Remote sensing techniques. The ratios of various residues were recorded to estimate the total state wise and crop wise biomass production.

Biomass supply chain

Biomass technologies aimed at transformation of different types of non-food biomass into valuable chemicals and energy are recognized as one of the effective ways to decrease fossil fuel usage. The availability of this biomass is diverse in nature and hence additional cost and technologies are required in collection, transport and storage. The low bulk density is limiting factor during handling of biomass. Locational constraints reflect the physical difficulties of harvesting, collecting and transporting biomass from the point of production to the place where it will be burned. The gathering and transport of biomass is influenced by the terrain and the distance over which the biomass is transported, and also by the availability of biomass in a determined area. **Figure 1** shows the elements and machines needed for biomass supply chain for Ex-situ biomass management.

Figure1: Process and mechanical systems for biomass supply chain

Rivers, steep slopes, areas of marshland and so on, all act as barriers to access. The different means of collection of biomass are includes Chopper and Rakes Balers, Straw combines etc. Two types of balers, viz., high capacity round balers and low capacity square balers are normally used in India. However, most common balers are square because of their low cost. The normal sizes of bale are 0.36 m x 0.46 m and 1.25 m for square and round bale respectively. The average field capacity and field efficiency of conventional field baler are 1-1.2 ha/h and 70-75% respectively. The baling could increase the bulk density of straw to about 110-140 kg/m and makes its handling and storage much easier. To collect the straw tractor operated chopper is being used to cut the straw because the baler cannot collect straw standing especially in combine harvested field. A rake is used to gather the crop into a swath that not only helps to facilitate drying, but windrows the crop so that it can be picked up by the baler. Straw output is almost 2 times more in with raking condition than that of without raking. The field capacity of the baler is almost doubled and energy required per ton of baling is almost half in case of baling with raking.

Long-term storage of biomass fuels is necessary to avoid a time gap between production and utilization. Considering the fact that biomass fuels generally have a relatively low energy density, the design of the storage facilities is quite important in order to keep fuel costs low. Short-term storage with an automatic discharge system is needed for feeding the fuel to the conversion plant. The most common way of storing biomass is to pile it. When applying this method several aspects have to be taken into account. First, some general points have to be considered when long-term storage of straw in a pile is performed. Biological and biochemical degradation as well as, in some cases, chemical oxidation processes result in heat development, which can cause deterioration and self-ignition in certain cases. Second, dry-matter losses, changes in moisture content, and health risks (growth of fungi and bacteria) should be taken into consideration.

In order to strengthen the Indian agriculture and to enhance the farmer's income, the biomass supply chain management is utmost needed so that the market value of agro-residues can be enhanced which will ultimately lead to increased economic gain to farmers and also sustainable rural energy security.

Briquetting

Briquetting is high level densification process which uses two main high pressure technologies namely ram or piston press and screw extrusion machines. Briquettes can be produced with a density of 1000-1300 kg/m^3 from loose biomass of bulk density 80-120 kg/m3. Transportation, storability and use of loose biomass are enhanced by briquetting. In fact, the briquetting process includes collection of biomass, storage, drying, particle size reduction and homogenization, mixing of binding agent, pressing, cooling and storage. Briquetting process could be either binderless (no external binders are added) or with binder (such as molasses, clay, soil, sodium bentonite, bitumen etc.). The agro-residues were dried before grinding in the hammer mill coupled with blower and cyclone separator. The optimum moisture content of the biomass may be 8-12% for grinding and briquetting purpose. In binderless process, the hemicellulosic and cellulosic bonding collapse due to the high temperature (170-200 °C) and very high pressure (1.2-1.4 x 108 N/m^2) and lignin is fluidized dispersing evenly throughout the granular mass. The energy density of fuel is increased in both the cases. Binder can be used during briquetting. Small plunger type or screw type manually operated machine can be used to produce the briquettes from biomass char. Char produced is normally mixed with cattle dung or soil in the ratio of 10: 1 by weight. Adequate amount of water is added to the mixture to obtain the moisture content in the range of 30-35%. The density of char produced through pyrolysis of biomass is quite low (300-600 kg/m^3). A tractor operated briquetting machine developed at CIAE, Bhopal is shown in **Figure 2**.

Figure 2. Briquetting (With binder) machine

Bio-chemical conversion

Biomass can be used through two methods which are bio-chemical conversion and thermochemical conversion, for wet and dry biomass, respectively. The biogas generation is most promising and used method for wet biomass especially for cattle waste. Bio-methanation is a process of conversion by which organic material is microbiologically converted to biogas under anaerobic conditions. Animal dung is a major substrate used for biogas production. Along with cow dung, lignocellulosic material in the form of crop residues from agricultural field, kitchen waste, agro-industrial wastes can also be used for biogas production. Biogas comprises of 50 - 70% methane, 28 - 48% carbon dioxide and 1 - 2% H_2S, N_2, H_2, CO. The digested mass contains about 1.5 - 2%, 1.0% and 1.0% nitrogen, phosphorous and potash, respectively, depending upon the feed material used. The entire biogas production process (anaerobic digestion) may be considered as a three-stage process namely hydrolysis, acidification and methanogenesis. A biogas plant consists of digester, gas holder/ gas storage space, influent inlet, outlet, slurry mixing tank, gas outlet pipe and stirrer, etc. The optimum pH range for methane production is between 7.0 - 7.4. Total solids content of in-fluent between 8-12% is suitable for smooth operation of biogas plants. Satisfactory gas production can be achieved in the range of carbon to nitrogen ratio of 20:1 to 30:1. Biogas technology has been implemented since the 1970 through many programs. On the basis of construction, the rural household digesters are classified as floating drum and fixed dome plants.

Floating drum biogas plants: This type of plant consists of a well-shaped digester, movable cylindrical gas holder, mixing tank, inlet and outlet. Collected cattle dung is mixed into the mixing tank with equal quantity of water and fed into the digester through inlet. It remains there for certain specified period of time and digested mass comes out through the outlet. With the increase in gas production, gas holder rises up and with the use it moves down. Small family type biogas plants have also been started in rural areas, which can produce 1 to 10 cubic meters of biogas per day.

Fixed Dome Biogas Plant: In case of fixed dome biogas plants there is no separate gas holder and gas holding space is constructed as an integral part of the digester. It is entirely a masonry structure and both digester and gas holder form an underground combined unit. The volume of dome is generally kept 60% of plant capacity. When the gas is formed, it rises upwards and gets collected in the dome, by pushing the slurry into inlet and outlet chambers. The gas is liberated at variable pressure from 0-90 cm of water column. The volume of gas stored in the dome at any time is equal to total volume of slurry displaced in inlet and outlet chambers. Besides, there are some flexible dome biogas plants in which external storage like balloons are used for gas storage. For industrial biogas production, vertical column type biogas plants are used with stirrer system, temperature control system to increase biogas production.

Crop residue-based bio-methanation: Crop residue-based bio methanation gives integrated approach of ex situ management as well as conservation agriculture. This process involves collection of crop residue from farm, transportation of material to the biogas plant, pre-treatments of the crop residue, one stage, two stage digestion or co-digestion. Utilization of lignocellulosic material like crop residue requires pre-treatment for loosening the bond between the complex fiber structures of the material. Biogas production efficiency varies based on the pre-treatment type. Combination of two or more pre-treatments can produce higher amount of biogas. There are various pre-treatments chemical, microbial, thermal, mechanical treatments etc. These treatments have different effect on the increase of surface area of substrate, solubilization of hemicellulose, solubilization of lignin and alteration of lignin structure etc. **Figure 3** shows sold state digestion concept used for paddy straw biomethanation using co-digestion of paddy straw and cow dung.

The produced biogas can be further utilized for thermal or power generation purpose and the digested slurry can be used in farm as a fertilizer. Biogas is commonly used as domestic cooking fuel in rural areas and to a limited extent, it is used for illumination (lighting using mantle lamps.). On industrial scale, biogas is being used for steam generation, shaft power applications and power generation. SI engines can run completely on biogas. The use of biogas in SI engines requires modification in air inlet manifold for entry of gas and of air cleaner pipe for provision of a metering device to throttle combustion air. Test results indicate that SI engines develop 85% of maximum brake power on biogas and the ignition timing should be advanced to 25° BTDC to get the best results. The brake thermal efficiency of engine is slightly higher on biogas and the specific gas consumption is 0.9 m^3/kWh.

Bio CNG (Compressed Bio Methane) is produced in the bio-digestion process. The earlier standard IS 16087:2013

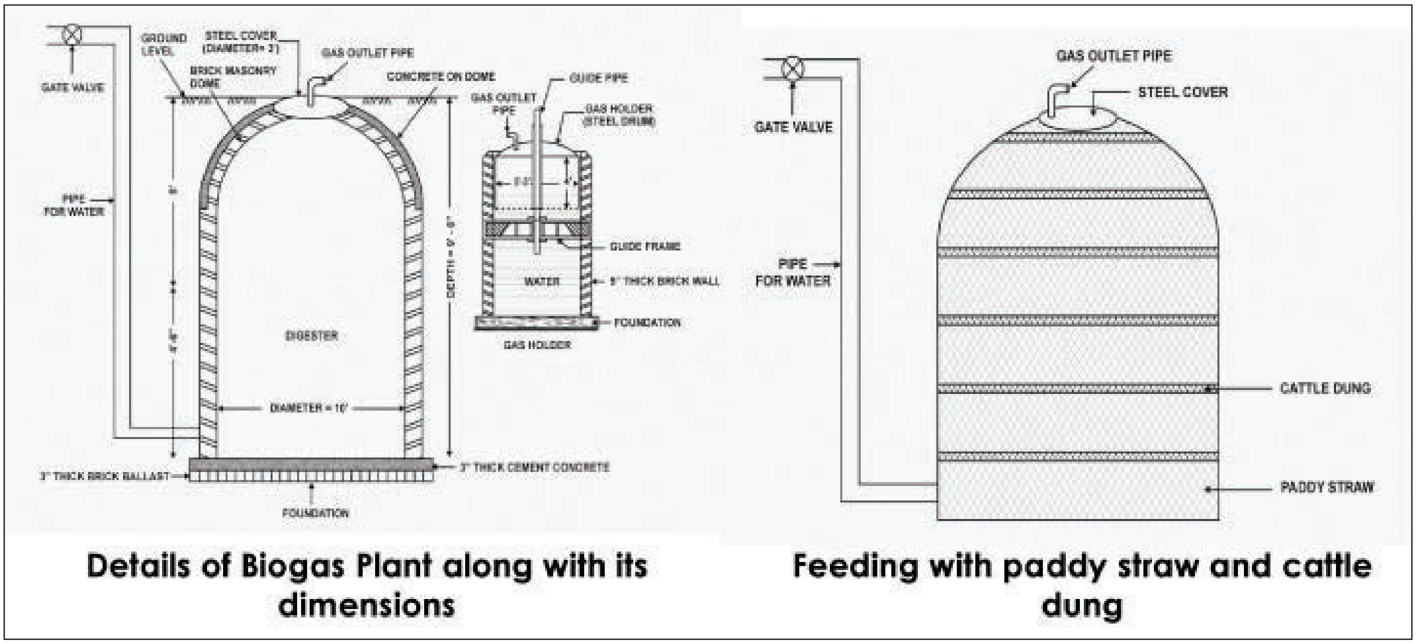

Figure 3: Paddy straw based biogas plants (PAU, Ludhiana)

was replaced by IS 16087:2016 to incorporate significant changes in specifications to bring Bio CNG at par with fossil CNG used in vehicle applications. Compressed Bio Methane is derived from cow dung as well as crop residue-based biogas. Generated biogas passes through scrubbing process where CO_2 and other non-combustible gases are removed and pure methane of more than 95% concentration is achieved and then compressed in to the cylinder.

Composting

Composting is controlled decomposition and natural breakdown process of organic residues by micro-organisms. Organic materials such as residues and by products from crops, food and industrial processing, enhance their suitability for application to the soil as a fertilizing resource, after having undergone composting. Composting has been practiced in rural areas for centuries. Physical, chemical, and biological nature of substrate determines the progress of composting process by given microorganisms. Quantity and the balance of nutrients, as well as degree of availability of nutrients to various microorganisms are essential. Composting may be divided into two categories by its nature of the decomposition, breakdown process and oxygen use. Compost could be produced either aerobically (with oxygen) or an-aerobically (without oxygen). Aerobic composting is the most efficient form of decomposition and produces finished compost in the shortest time. In anaerobic composting, decomposition occurs where oxygen (O2) is absent or in limited supply. Anaerobic micro-organisms dominate and develop intermediate compounds including methane, organic acids, hydrogen sulphide and other substances. The different parameters affecting composting process are carbon and nitrogen ratio, surface area of substrate, aeration, moisture, temperature and pH. Carbon and nitrogen are the two fundamental elements in composting, and their ratio (C:N) is significant. Bacteria and fungi in compost digest or “oxidize” carbon as an energy source and ingest nitrogen for protein synthesis. Carbon can be considered the “food” and nitrogen the digestive enzymes. Surface Area of substrate allows the microorganisms to digest more material, grow more quickly, and generate more heat for decomposition. Insects and earthworms also break down materials into smaller particles that bacteria and fungi can digest. The decomposition occurring in the compost pile takes up all the available oxygen. Micro-organisms can only use organic molecules if they are dissolved in water, so the compost pile should have a moisture content of 40-60 percent. If the moisture content falls below 40 percent, the microbial activity slows down or becomes dormant. Microbes generate heat as they decompose organic material. A compost pile with temperatures between 32 and 60°C is composting efficiently. Temperatures higher than 60°C inhibit the activity of many of the most important and active organisms in the pile. Some microorganisms like cool temperatures and continue the decomposition process, though at a slower pace. The most advantageous pH range for most of the biological reaction is between 5.5 and 8.0. During the process of decomposition, the pH increases and at the lower pH, fungi facilitate the decomposition. Bacteria dominate at 6.5 to 7.5 pH and ammonia gas may be generated, which may cause adverse odor, microbial population decline resulting into poor quality of compost.

Thermo-Chemical Conversion of Biomass

The processes of converting biomass into liquid, gaseous or solid fuel using oxidation, partial oxidation and anaerobic oxidation are known as thermo-chemical conversion processes.

Combustion: Combustion is the process of complete oxidation of the fuel. The fuel may be solid, liquid or gas. Theoretically, carbon and hydrogen in the fuel are oxidized to generate the heat and the products of combustion are carbon dioxide and water. Complete oxidation of biomass by burning to produce heat is called combustion. The rate of heat release is very rapid in combustion.

Gasification: Gasification is partial oxidation of biomass. Biomass gasification is the process in which solid biomass is converted by a series of thermo chemical reaction to a combustible gas called producer gas, liquids (tar and oils) and solids (char and ash). The supply of oxygen is reduced to do the gasification of biomass. Nearly 1 kg of biomass can produce about producer gas volume of 2.5 m^3 at standard temperature and pressure. During gasification, about 1.5 m^3 of air is needed. For complete combustion of wood, the requirement of air is about 4.5 m^3. Therefore, for gasification about 33 per cent of theoretical stoichiometric ratio for wood biomass is needed. The average energy conversion efficiency of wood gasifiers is about 60–70 per cent. The reactions are carried out in the reactor which is called gasifier. The combustible gas comprises mainly of carbon monoxide (18-22%); hydrogen (15-20%); methane (1-5%); carbon dioxide (8-12%) and nitrogen (45-55%). The calorific value of producer gas is 4.2-5.0 MJ/Nm^3 whereas the conversion efficiency is 80%. About 10 to 30 % energy of the solid fuel is lost in the conversion process. Producer gas can be generated from charcoal, coke, wood, peat or from agricultural residues such as corn cobs, groundnut shells, rice husks, soybean stalk, saw dust, bagasse, cashew shells, etc. In addition, char and tars are also produced. Sulphur compounds and nitrogen along with tar vapour, water vapour, dust and mineral vapour may also be present which are pollutants and can be corrosive. Tar content may be 1-180 g/Nm^3 in the producer gas and varies depending on of fuel, the oxidizing agent, reactor type. This concentration has to be lowered to only 50-500 mg/Nm^3 depending on the application or, even brought to practically zero for integrated gas power generation system and fuel cells.

Gasifier systems: The gasifiers can be used to generate the producer gas for use in thermal and shaft power applications. Thermal applications mean the producer gas is being burnt to generate the heat at utility point. Shaft power applications mean that producer gas is being used to generate the power from engine. The engines can be used for electricity generation, water pumping, running gas vehicles, and operating some machines taking power from flywheel, etc. A gasifier system consists of (a) a gasifier, and (b) a gas cleaning and cooling unit. For thermal applications, a suitable burner is needed to burn the gas to generate the heat. Gasifier system is to be integrated with an engine generator set for electricity generation. The gasifiers are usually classified on the basis of direction of fuel and air or gas flow in the reactor as Up draft, Down draft, Cross draft and Fluidized bed. A natural draft gasifier developed at CIAE, Bhopal having thermal capacity of 100 kW is shown in **Figure 4**.

Figure 4. CIAE 100 kW natural draft gasifier

Pyrolysis of Biomass

Pyrolysis is defined as destructive distillation of organic material heated to more than 200°C in the absence of air or oxygen. In practice, a restricted quantity of air is allowed for partial combustion to achieve the temperatures required for pyrolysis. During pyrolysis solid char, liquid tar, organic liquids, and combustible gases are produced. Carbonization of wood at temperature above 280°C liberates energy (exothermic process). The process of breakdown continues until only the carbonized residue, called charcoal, remains in the pyrolyser. The process stops and the temperature reach a maximum of about 400°C. This charcoal contains a lot of volatile matter. Further heating increases the carbon content by driving off and decomposing the tars. The rate of temperature change, temperature of pyrolysis, chemical composition of the biomass and residence period are the important factors which determine the nature and relative proportion of various products of pyrolysis. Slow heating rates and low temperature favor the formation of char, whereas rapid heating promotes the formation of liquids. Control of air in the process is required to ensure that the wood / biomass do not burn away to ash but is decomposed chemically to form charcoal. In the traditional method of charring, some of the biomass is burnt to generate the heat required for maintaining the process temperature of pyrolysis. In this method all products of pyrolysis, except char, are lost to the atmosphere. In the advanced methods, the reactor is externally heated in a controlled manner. The pyrolysis gases produced during the process are normally used as fuel for heating the reactor. The charring conditions best suited are temperatures of 150°C for 6 h for rice husk and 200 - 250°C for 2.0 - 2.5 h for maize / sorghum stalk. Lignin content of biomass is important and lower lignin content results in lower char recovery. The temperature of piloted and spontaneous ignition of wood is typically about 350°C, and approximately 600°C, respectively.

Charring Equipment: Biomass pyrolysing system is for three different levels of application, i.e. domestic unit, community level unit and commercial unit. Based on material used for fabrication, three different types of kilns are used for charcoal production. The oldest method of charcoal production has been earthen mounds and pits. Properly constructed and operated brick kilns give high quality charcoal with fairly high yield. The size of kilns may be decided depending upon the requirements. Large size kilns are used for commercial operation while the small kilns may be made for domestic / community use. The performance of the brick kiln was found between 25-60% depending upon the type of biomass and the operating variables. Portable and stationary metallic kilns are also available. The portable kilns are useful for producing charcoal for domestic uses whereas the stationary metallic kiln are used for community and commercial charcoal production. The char produced using pyrolysis can also be used as biochar. The biochar term is used for char when it is used for soil amendment and for carbon sequestration. CIAE has developed several pyrolysis systems for different applications. Annular core biochar production system developed by CIAE is shown in **Figure 5**.

Figure 5. Annual core biochar production system developed by CIAE, Bhopal

(Cost: 1.6 lakhs for 100 lit capacity and 10 kW system; License fee: 1.25 lakh; Recovery 30-38 %; room temperature to 700 °C; Dominant convective two side Radial heating of biomaterial bed for uniformity)

Activation of char: The char produced through thermochemical conversion process, is often activated, or modified using different activation methods such as physical, chemical and impregnation method to improve its effectiveness. The type of raw feedstock, its compositions, pyrolysis process conditions and activation parameters have significant influences on the properties of resultant activated biochar. Activation of char increases the surface area of the raw biochar to many folds. The activation process is mainly done to improve the surface area, pore volume, and porosity of the biochar for a specified application. Physical and chemical activation are the most widely used techniques for the preparation of activated char. In the physical activation process, the raw material is subjected to pyrolysis at higher temperature and then activated using steam or CO_2. The physical activation is also called dry activation method. Whereas in chemical activation, i.e., wet oxidation, char or precursors are impregnated by chemical activating agents and then heated at high temperature under inert atmosphere. Chemical activation can be either in the form of acid activation or alkali activation mode, which induces acid functional groups, oxygenated functional group, and removes impurities. Chemical activation is preferred over physical activation method due to its low process time and activation temperature.

Thermal degradation at lower temperature in absence of air is called torrefaction which is process to generate the bio-coal or torrefied biomaterial from crop residues to impart the hydrophobicity, brittleness and other beneficial storage properties in the material. Torrefaction is lower segmental treatment in pyrolysis zone for biomass. One torrefaction unit having biomass capacity of 200 kg per batch developed by CIAE is shown in **Figure 6**.

Figure 6: Electrically controlled torrefaction system developed by CIAE, Bhopal

Compared with traditional activated carbon, activated biochar appears to be new potential cost-effective and environmentally-friendly carbon materials with great application prospect in many fields such as water pollution treatments, CO_2 capture and energy storage. Activated char is efficient, cost effective and environmentally friendly material. It has distinctive features over raw biochar such as large surface area and increased adsorption capacity. At present, crop residues based activated biochar are gaining worldwide popularity due to its wide application in waste water treatment, supercapacitors and in fuel cell technology.

Due to rapid industrialization, industry waste water becoming a dominant source of water contamination. There is an urgent need to find out the alternative, environmentally friendly, and cost-effective material to remove the pollutants, heavy metals. Activated char is considered as a green remediation material for removal of heavy metals, inorganic contaminants due to its higher adsorption capacity. Use of activated biochar in supercapacitor as an electrode material can be justified with the cost associated for the use of commercial activated carbon, carbon nanotube, and graphene. As compared to these materials activated char-based electrode material shows higher surface area, porous structure, high electrical conductivity, which is requirement for ideal electrode material. Supercapacitor as an energy storage device is superior over conventional capacitor owing to its high-power density, higher chemical stability, quick charge and discharge ability and its long-life cycle. The activated char has been used as a material for direct carbon fuel cell for conversion of carbonaceous material into electricity.

Other important aspects pertaining to renewable energy utilization in Indian agriculture

The Drone based mapping for agricultural fields is needed to find the real time generation, uses, availability of agro-biomass area-wise, crop-wise and season vise. IoT based artificial e-system need to be established at national level using national e-portal which can receive wide range of problem and suggest solutions with respect to agro-mass utilization for enhancing the income of farmers. Our efforts to develop technologies for site-specific application is need to be intensified. Energy systems should be designed using the 95th percentile of biomass availability data which demand a national wide pertinent survey, assessment and measurements. The whole value chains of energy mechanization covering farmers, KVKs, researchers, engineers, small and medium manufacturers, and traders, is to be established in different states. There is need to evolve a complete system which can take needed systems to farmers with minimized cost and time.

Water scarcity problems in irrigated agriculture also need the solar pumping intervention at massive scale. By switching over from traditional surface irrigation to improved and efficient irrigation techniques, powered by solar energy, such as sprinkler and drip irrigation to produce more crops per drop of water, is giving multi facet advantages and benefits. It is therefore, development of quality solar based micro-irrigation products, systems and their applications through use of sensors and other advanced techniques such as drones and IoT. Decentralized solar pumping system is a concept of using more water to agricultural fields with minimum energy load on itself. For that, the solar coupled micro irrigation systems are best suited. Agro-voltaic is also being promoted in Gujarat state to produce the crop and energy from same field. This technology also tries to tap the rain water falling on the solar panels and this collected water can be channelized for irrigating the crop being grown there itself.

Conclusions

Renewable sources of energy (RES) are major contributors to provide energy security by reducing dependence on fast depleting fossil fuels with a positive environmental impact. Solar, wind, geo-thermal, bio-mass energy can fulfill around 33% of India's energy needs and 75% of the rural energy needs. According to the Central Electricity Authority of India, about 50% of the country's power supply will be generated by renewable energy sources by 2030. The nation needs effective use of renewable sources for enhanced energy use efficiency.

The major targets should be to use of available and developed renewable and conventional energy sources & gadgets for rural productive activities and agro-industry using existing local renewables covering solar electricity, heating and pumping. Research on solar energy use for production agriculture needs fluctuating torque demand depending on the agricultural field conditions. The use of batteries for storing and releasing power is another concern for long term use of solar photovoltaic (SPV) gadgets. The battery operated systems including vehicle are facing few threats like, replacement cost of battery, safe disposal of discarded batteries and its components, quick and safe charging, solar based prompt charging, etc.

Compressed clean biogas and Bio-CNG have also emerged as an option for ex-situ management of crop residue. Biomass based power generation has already in place in several state. They need to be promoted by giving adequate incentives as they are supporting the green electricity generation. However, the cost of electricity generation for each unit in biomass based power generation is high in comparison to that obtained in new solar electricity generation technology. Thermo-chemical and bio-chemical conversion based electrical power routes are available and there is a need to promote these with better incentives.

The development of energy efficient machinery, use of nano-lubricant for fuel saving in different agricultural systems, energy management in agriculture, energy optimization with yield maximization, input cost reduction with maximized yield, energy cost optimization, biomass utilization for energy and value addition, development of process and protocol for second and third generation biofuels, crop residues management, bio-hydrogen generation, bio-ethanol and butanol production, bio-crude generation and its downstream processing, etc., are prime theme areas for renewable energy research and applications in near future.

Energy efficient and cost effective mechanization systems for rural activities covering crop production, post-harvest, rural domestic operations and livestock raising are to be provided with energy supply security. We need to focus to introduce and implement the recent advanced technologies like plasma technology, nano-technology, IoT, artificial intelligence and robotics for enhanced effectiveness of processes for generation of energy and valued products using rural local renewable resources.