Green Chemistry: A Promising Route to Sustainable Agriculture

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Abstract:- Green chemistry is an innovative and eco-friendly process designed to reduce or eliminate the production and use of chemicals that are harmful to environment and human health and at the same time provide economic prosperity and social benefits. Today green chemistry represents a new paradigm in agriculture as it serve as a driving force for sustainable agriculture development. The present paper is focused on the main green chemistry technologies and process already in use are emerging in agriculture. The paper emphasize the benefits of bio fertilizers over conventionally used inorganic fertilizers. The novel control release fertilizer Including glass fertilizers, their working mechanism and impact on soil, health and environment are discussed. The type of bio-pesticides, their use and growth in Indian perspectives are also mentioned in the paper. Now a days, researchers are focused to use bio based material or use feed stock or raw material which are renewable such as agriculture waste products for bioenergy generation. The various forms of bio-energies (biogas, bio diesel, bioethanol), their generation techniques and total bioenergy supply and contribution, recent bioenergy development in India are discussed in the paper. Adoption of agricultural waste biomass as a fuel for energy production is not only reduces the problem of carbon emission but can ease the financial stream in developing country like India related to heavy burden of fossil fuel. They can also develop local source of revenue for the people within production chain. The paper deals with the various routes by which green chemistry plays an important rule for agriculture sustainability.

Key words: Agriculture sustainability, Green Chemistry, Bio- fertilizers, Bio-pesticides, Bioenergy.

INTRODUCTION

Sustainable Development is the development that meets the need of present (people) without compromising the ability of future generation to meet their own needs i.e. it is improving the quality of life of present generation without excess use of natural resources so that they can be preserved for the next generation. Environmental issues in the past were considered as part of economic system and the rapid exploitation of natural resources. It took many years to consider the established ways that materials were used (feedstocks), the initial design of chemical processes, the hazardous properties of products, the energy consumption and other parameters involved in the manufacture of products life cycle, recycling etc [1]. Green Chemistry is an increasingly prominent branch in the chemical industry. It attempts to quantify the environmental impacts and operational hazards of chemical processes using standardized metrics [2].

The idea of sustainable eco development was presented first in 1987 and now a days Green Chemistry plays an important role in the field of agriculture. In the last few years, for sustainable production of agriculture, use of renewable biomass resources increases to generate bio-based food products with low inputs, zero waste, sustainable social values and minimizing environmental impact [3]. The main goal sustainable agriculture as:-

- To satisfy human food and fibre needs.
- To enhance environmental quality and natural resources base upon which the agriculture economy depends.
- To make the most efficient use of nonrenewable resources and on farm resources and integrate where appropriate, natural biological cycles and controls.
- Sustain the economic viability of farm operations.
- To enhance the quality of life for farmers and society as a whole.

GREEN CHEMISTRY AND SUSTAINABLE AGRICULTURE

In 1998 Poul Ananstas and John C. Warner developed 12 principles of green chemistry. Green chemistry

starts with molecular level and eventually indicating the most important environmentally benign processes and products. In 2001, at University of Colorado, Boulder, IUPAC CHEMRAWN XlV Conference on Green Chemistry: Towards Environmentally Benign Processes and Products, was organized and in this conference a number of chemists discuss the effect of agricultural and industrial activities on atmospheric chemistry. They advised "design-for-environment " framework to work with consumers and assure the safety of foods and crops develop by green methods for green agriculture practice[4]. Now a days, Green chemists are trying to keep farmers how to tackle with contamination, removing pollutant, unwanted chemicals and manages use of recycled water. Researchers are focused on developing bio pesticides, bio fertilizers and bio catalyst. They are emphasizing the work to use bio based materials or use feed-stock or raw materials which are renewable e.g. agriculture waste product as well as transforming the agriculture materials into high value products and also enhancing their production and protection. Sustainability in agriculture is a core area which requires green chemistry strategies in agrochemical field for implanting the judicious use of pesticides and fertilizers.

ECO-FRIENDLY FERTILIZERS

Fertilizers are chemical substances supplied to the crops to increase their productivity The fertilizers contain essential nutrients required by the plants including nitrogen, potassium, phosphorus etc, They enhance the water retention capacity of the soil and also increase its fertility. Using the fertilizers in agriculture can be very useful for a food production, but on the other hand conventional inorganic fertilizers may be very dangerous for environment. The biggest issue facing the use of chemical fertilizer is ground water contamination. Nitrogen fertilizers break down into nitrates and travel easily through the soil, because it is water soluble and can remain in ground water for decades the addition of more nitrogen over the years has an accumulative effect. It is found to altered immune, endocrine and nervous system function in mice as well as influence on children's and foetus developing neurological, endocrine and immune system. One popular fertilizer urea produces ammonia, contributes to acid rain, ground water contamination and ozone depletion due to release of nitrous oxide by denitrification process[5]. The increase in water soluble nitrates creates an influx in plant life, which eats up oxygen and starves out fish and crust ocean. This has an impact not only on the aquatic eco system but on local societies who defend on food sourced from these areas[6]. Now days, demand for organic fertilizers are increasing continuously due to the following characteristics over inorganic synthetic fertilizers.

Organic fertilizers:- They are manufactured using organic substance which are bio-degradable i.e organic fertilizers are naturally occurring fertilizers and nutrients enhancers of the soil. These organic substances are further decomposed and broken into smaller and soluble particles by numerous microorganism. After being turned into soluble and simpler compounds, these fertilizers are taken in by the roots. Manure, slurry, worm casting. peat seaweed and sewage are green manure. Compost, blood meal, bone meal and seaweed extracts etc. are manufactured organic fertilizers. Crops are also grown by add nutrients to the soil [7]. The advantages of organic fertilizers are:-

1. They provides organic matter essential for microorganism.
2. They are slow and consistent at a natural rate that plants are able of use.
3. They do not leach out since the organic matter binds to the soil particles where the roots have access to it.
4. They won't build up harmful residues or cause pollution due to run off from irrigation or rain.
5. They encourage the soil life. Microbes converts the organic matter to the form of nutrients that plant need.

CHEMICALLY SYNTHESIZED CONTROLLED RELEASE FERTILIZERS

Controlled Release Fertilizers (CRF) have become increasingly popular and have gathered a great deal of attention growers and agronomists around the world. Applying lower amounts fertilizer is one solution to dealing with new regulations, limiting the amount of leached nitrogen. Scientific proof has shown that growers can achieve the goal of production and higher

quality with coated fertilizer [8]. These fertilizer achieve results which are as good as standard fertilization while using less fertilizer. CRF can produce the same yield with the rate 10-40%, less than conventional fertilizer. Sometime only single application is required which can reduce labour cost by 75%.

CRF are used in all agriculture and horticulture crop all over the world. Each application in a particular climate call for a specific fertilization strategy. Due to the differing length of time that each CRF granule takes to release nutrients inside. It is possible to fertilize on cycles as short as six weeks and as long as eighteen months.

CRF are fertilizers with one or more primary macro and micronutrients in a coated granule. There is different type of coating which gradually release the nutrients. Blends are often produced in order to achieve the correct nutrient levels for every crop. There is a wide range of 100% coated NPK with trace elements to partially coated blends (N/P/K) with or without trace element. The most important part of a CRF is coating itself. The difference in coating percentages affects the direct availability of nutrients to the plant as well as leaching during the growth season. The type of coating is also important, whether it is a resin coating, a sulphate coating with a higher initial release, or a coating of polymers. Each coating technology has its own specific characteristics. Factors influencing the release of nutrients are moisture content and soil temperature. In resin or sulphate coatings the release mechanism is primarily determined by the thickness of coating. There are also coated product available in which the microbiology within the soil affects the release pattern. In recent use there are different types of Controlled Released Fertilizers. Some of them are as follows -

- Sulfur coated urea
- Sulfur coated compound fertilizers
- Resin coated fertilizers
- Tower melt spraying granulation compound fertilizer
- Urea melt spraying granulation compound fertilizers
- Chemically modified biomass coating urea for controlled release
- bulk blend fertilizers
- Glass fertilizers

During the production process, the choice of nutrients combined with the type of coating are the key factors in the release of macro- and micronutrients. If the combination is not correct, not all the macro/micronutrients will be released. If the nutrients remain in the granule, they cannot benefit the plants. Working mechanism of CRF are given as given in diagram [9].

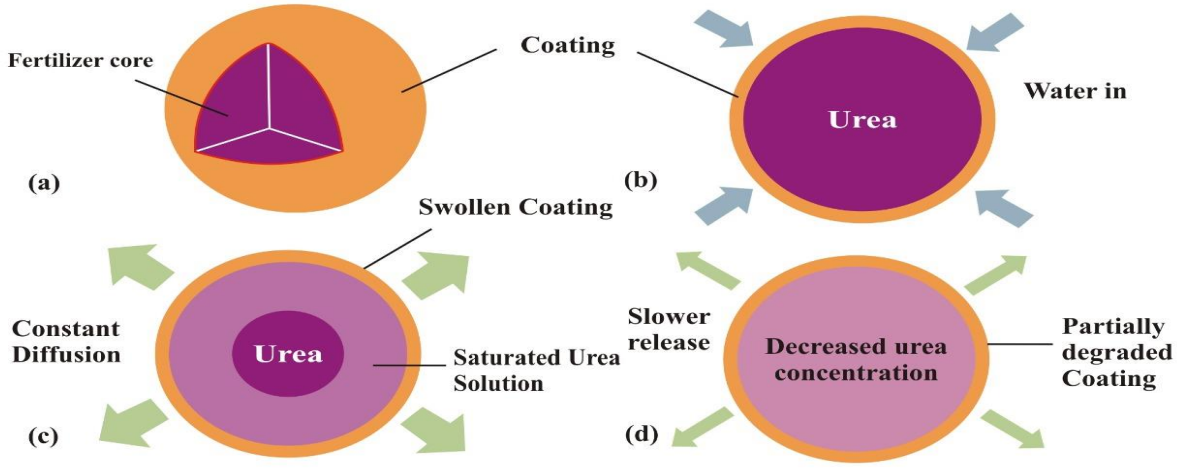

Figure 1. Mechanism of controlled release. **(a)** CRF granule. **(b)** A lag period where water penetrates through the coating to the core **(c)** The buildup of internal pressure results in constant release to the environment. **(d)** Decay state where concentration gradient and release rate decrease.

CRF HAVE MANY ADVANTAGES

1- Better plant growth due to the continuous and uniform availability of nutrients.
2. It is possible to reduce fertilizer application by 20-25 % as the risk of leaching is minimal. Even with a CRE, rain will wash away the minerals which are present in the root environment, but the CRF will immediately release new nutrients
3- The positive effect of CRF application induce higher yields, better quality distribution, more uniform grading, a higher tuber and greater plant weight. Because the plant glows evenly and gradually, It is less susceptible to damage and diseases such as aphids or powdery mildew and will show less deficiencies.

Glass fertilizers does not contain toxic substances since it does not have an acidic sulphate or chloricradical, glass fertilizers do not cause acidity to the soil, toxic gas or hydro sulpharic that can destroy plant roots [10]. The glass fertilizers are not water soluble, it lies with in soil and continues providing necessary nutrients for plants. The glass fertilizers not only helps increase the fertility of soil, suitable for many kinds of plant but also help to prevent lack of magnesium and other nutrients in the soil that support the plants growth. The experiments have shown a 25-50% increase in the crop production with the use of these micronutrient glass fertilizers and the benefits can be seen for over 20 years of each addition. Organic fertilizers work overtime to create a healthy growing environment they improve the structure of soil and increase its ability to hold water and nutrients

INDIAN PERSPECTIVES OF BIOFERTILIZERS

A report published by the Center for Science and Environment (CSE), New Delhi states[11] that the production of carrier based solid biofertilizers in India amounted to roughly 134,323 tons in 2000-21, this was an 83% growth over figures from 2018 -19. On the other hand Indian production of liquid biofertilizers in 2020-21 was at 26,442 kilo liters. The central government runs two kinds of programs to promote the use of bio fertilizers and organic fertilizers in the country, the first kind is aimed at farms as part of larger agriculture scheme such as Paramparagat Krishi Vikas Yojana, Bhartiya Prakritik Krishi Padhati and National Food Security Mission, the second kind of programs are aimed at manufactures the markets example of these are Capital Investment Subsidies Scheme and New National Biogas and Organic Manure Program. In order to increase the production and consumption of organic and bio fertilizers the report recommends a well-funded national program that promotes their use. The report advocates for a thorough quality checking mechanism and explicit commitments from state and central government to make bio fertilizers and organic fertilizers readily available.

ECO-FRIENDLY PESTICIDES OR BIO-PESTICIDES

Agriculture has to face the distinctive activities of numerous pests like fungi, weeds, and insects, leading to radical decrease in production and yield. With the advent of chemical pesticides this crisis was resolved to a great extent but the over dependence of chemicals pesticides and eventual uninhibited use of them necessitated for alternatives mainly for environmental concern . Degraded soil and ground water pollution has resulted in nutritionally imbalanced and unproductive lands. Violative pesticides residues also sometimes raise food certification for domestic and export crops [12]. Therefore, an equivalently alternative is a need of hour. Biopesticides or biological pesticides based on pathogenic micro organisms specific to a target pest offer an ecological sound and effective solution of pest problems They pose less threat to the environment and to human health. The interest in biopesticides is based on the advantages associated with such products which are **(i)** inherently less harmful and less environmental load,**(ii)** designed to effect only one specific paste or in some cases a few target or measure, **(iii) o**ften effective in very small quantity and often decompose quickly, thereby resulting in lower exposure and **(iv)** largely avoiding the pollution problem when used as a component of integrated paste management program (IPM). bio pesticides can contribute greatly. Table 1 shows the benefit of bio pesticides over chemically synthesized pesticides [13].

Table 1 Benefits of Biopesticides

Factors	Benefits
Cost effectiveness	Costlier but reduces number of applications.
Persistence and residual effect	Low, mostly biodegradable and self perpetuating
Knockdown effect	Delayed
Bulkiness and Handling	Bulky' carrier based, easy , liquid formulation
Paste resurgence	Less
Resistance	Less prone
Effect on beneficial flora	Less harmful and beneficial paste
Target specificity	Mostly host specific
Waiting time	Almost Nil
Nature of Control	Preventive
Shelf life	Less

Source(Ref.13 Gupta S. Dikshit A. k. 2010)

Biopesticides falls into three major categories (i) Microbial biopesticides contain a microorganism bacterium, fungus, virus, protozoans or alga as the active ingredient. Microbial pesticides can control many different kinds of pests, although each separate active ingredient is relatively specific for its target fixed. For example, there are fungi that control certain weeds and other fungi that kill specific insects. The most widely known microbial pesticides are varieties of bacterium Bacillus thuringiensis or Bt, which can control certain insects in cabbage, potatoes and other crops. Bt produces a protein that is harmful to specific insect pests. Certain other microbial pesticides act by out-competing pest organisms. Microbial pesticides need to continuously monitored to ensure they do not become capable of harming non- target organism including humans. Beauveria bassiana, Baculovirus, Nosema and chlorella are widely used microbial pesticides. (ii) Plant incorporated protectants (PIPs) are pesticidal substances that plants produce from genetic material that has been added to the plant. For example, scientists can take the gene from Bt pesticidal protein, and introduce the gene into plants own genetic material. Then the plant, instead of the Bt bacterium manufactures the substance that destroy the pest. Both the Bt protein and its genetic material are regulated by EPA. Insecticidal molecules employed in PIP technology are Bt Cry protein, toxic complex (Tc) protein from Xenorhabdus and photorhabdus, X-amylase inhibitors, protease from Baculovirus, double stranded ribonucleic acid ds RNA and Mir 1-CP from Maize (iii) Biochemical pesticides are herbal substances and also known as plant pesticides. They control pests by nontoxic mechanism. Conventional pesticides, by contrast, are synthetic materials that usually kill or inactive the pest. Biochemical pesticides include substance that interfere with growth or mating, such as plant growth regulators or substances that repel or attract pests such as pheromones. e.g., essential oils. The most consumed in India in 2019-20 (source GOI 2020) are listed in table 2 [14].

Table 2 Most Consumed Biopesticides in Indian Agriculture

Name of Biopesticides	% Consump.
Tricoderma Viride	26
Pseudomonas Fluorescens	18
NPV of Helicoverpa armigera	16
Tricoderma Spp.	9
Neem Based Insectisides	8
Beauveria bassiana	8
Azadirachin	6
Verticillium lecanii	5
Bacillius Thuringiensis	4

Source(Ref.14 Nayak P. Solanki H. 2021)

India stands 12th in pesticide use globally and 3rd in Asia after China and Turkey. India has a vast potential for bio pesticides. However, its adaptation for farmer in India needs education for maximizing gain. The Indian bio-pesticide market size was USD 64.73 million in 2021. The market is projected to grow from USD 69.62 million in 2022 to USD 130.37 million by 2029, exhibiting a CAGR of 9.38% during the forecast period. In the present time, the total consumption of

bio-pesticides is only 8%. For sustainable agriculture development and to protect environment from adverse side effects of chemical pesticides, formulation and utilization of bio-pesticides should be prompted [15].

CONVERSION OF AGRICULTURE WASTE AS ENERGY SOURCE

In India more than 70% population lives in rural area and adopt agriculture as me occupation. As a result, lots of agriculture waste are generated and remained non utilized. Globally 140 billion metric ton biomass is generated from agriculture, this includes sugar cane bagasse rice straw, wheat straw, grasses sawdust or chips, corn stalk, coconut shells and coffee husk depending on regional characteristics. In developing country like India, the direct burning of agriculture biomass is a common practice which lead to serious environmental impacts e.g. the emission of carbon dioxide, nitrogen oxide and other harmful gasses. India needs to burn approx. 92 million tons of agriculture biomass every year, leading to considerable impact on air quality and health. The improper utilization of agriculture waste contributes to global change, water and soil contamination and local air pollution. Beside this waste is of high significance with respect to material and energy recovery. Since energy crisis of the 1970s many countries are interested to develop biomass as fuel source. Up until recently, the interest in biomass has lessened due to the technological breakthrough that make fossil energy (energy from coal and petroleum etc.) become relatively inexpensive. However, the higher greenhouse emission, deadly air pollution, unstable fossil-based energy prices and strong growth of global transportation fuel demand have boosted extensive research efforts in developing bio energy. Bio energy is energy derived from any fuel that is originated from biomass. Biomass is a renewable resource and considered as an alternative feed stock to provide sustainable energy. Biogas, bio-char, bio-diesel, bio-hydrogen, bio-ethanol are the example of bio-energy [16]. The share of energy from renewable sources in European countries is growing every year. Over the last 15 years the share of energy of renewable sources has more than doubled and has amounted to 22.1% in 2020 (10.2% in 2005). The largest share of renewable energy is in Sweden 55.8%, Finland 42.7% and Latvia 40.9%. Conversely the lower share of energy from renewable source is in Luxembourg 7.0% Malta 8.2% and Netherlands 8.9%. Biomass in European Union countries currently accounts for 60% of all renewable energy source and 10% of all energy sources. The largest share of biomass in renewable energy is in Estonia 94% Latvia 92.4% and Lithuania 91.1%, a significant lower share of biomass in renewable energy is found in Malta 9.3% Cyprus 15.2% and Ireland 23.5%. Agriculture biomass accounts for 27% share of total biomass use of energy conversion. Countries such as Netherlands, Germany and Belgium produce the most energy from agriculture in European Union and the least amount of energy from this source is produced in Estonia, Sweden and Bulgaria 17,18]. India is the world's 3rd largest energy consuming nation .In India in 2019 renewable make up 22.6% of total energy supply. The renewable energy share in final energy consumption is 31 % (The difference between the share of renewable Energy in supply and consumption relates to unused heat from power plant which is counted in energy supply but not in final consumption). Around 85% renewable energy is from biomass. Table 3 and 4 shows total energy supply and contribution of different energy sources in India in 2019 (source IEA 2021-word energy balance and renewable information) [19].

Table 3 Energy supply and contribution in India with Distribution in 2019 from various enery sources

Name of energy source	Energy used in Exajoule EJ	% of Energy consumed
Coal	17.5	44.8
Oil products	9.9	25.3
Renewable energy source	8.8	22.6
Natural Gas	2.3	6.0
Nuclear Enegy	0.5	1.3

Table 4 Different Renewable energy forms consumed in India In 2019

Renewable energy source	% Consump.
Bio energy	19.8
Hydropower	1.6
Solar	0.6
Wind	0.6

Source(Ref.19 Implementation of Bio energy in India : Country Report ,IEA ,2021)

TECHNOLOGIES USED FOR PRODUCTION OF BIO-ENERGY

There are several technologies process options are available for biomass energy conversion, trans esterification technique is used for conversion of biomass to bio diesel and electricity. Two general techniques i,e. thermochemical and biochemical conversion are also used, conversion by means of thermochemical technique comprises the decomposition of organic components in the biomass using heat whereas biochemical conversion utilizes micro organism and enzymes to convert biomass waste into useful energy. Conversion by means by thermo chemical technology involves pyrolysis, gasification, liquification and combustion. Use of catalyst accelerate the reaction date and improve the quality and performance of energy. Biochemical conversion encompasses three process options known as anaerobic digestion, alcoholic fermentation and photo biological reaction. Figure 2 shows the production of a wide variety of bioenergy and their conversion techniques [20].

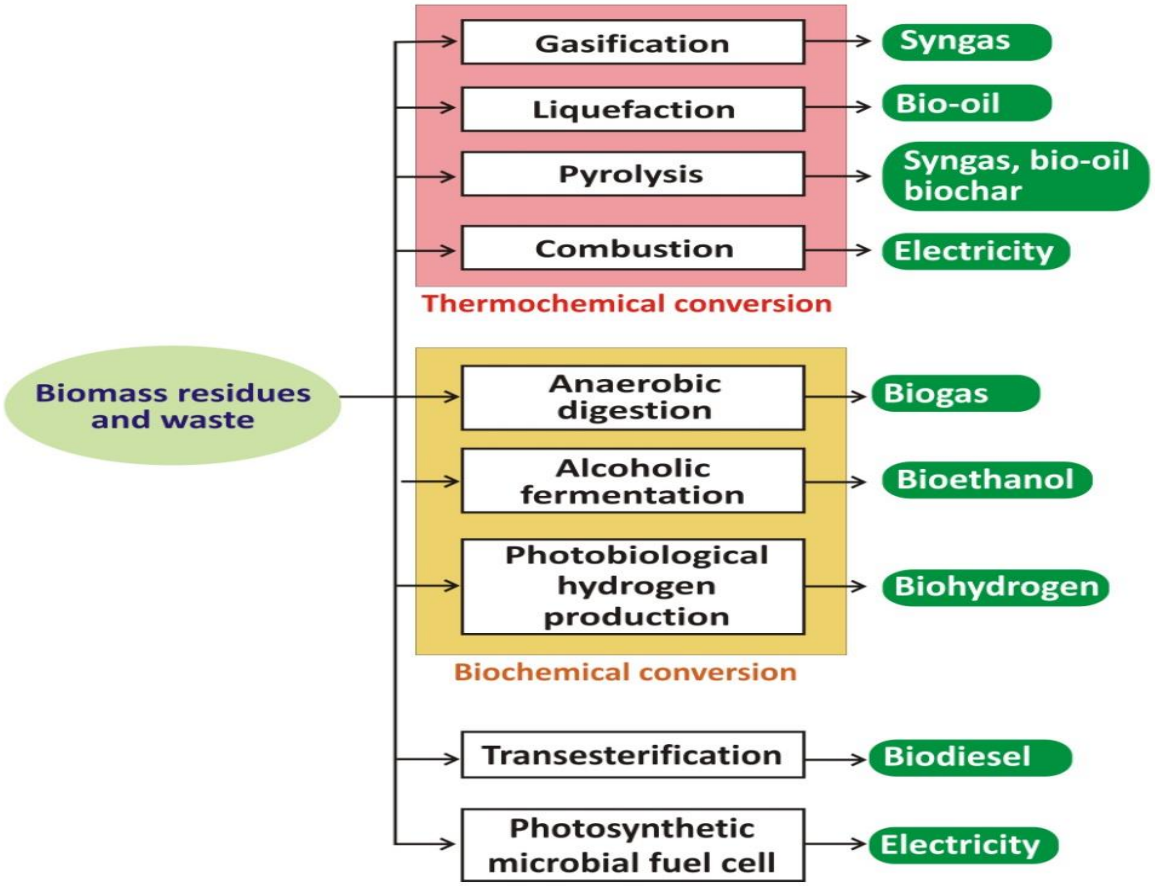

Figure 2. Diagram of Biofuel produced by biomass reridue and waste and their conversion pathways to produce a wide variety of bioenergy.

ELECTRICITY GENERATION FROM AGRICULTURE WASTE

Biomass used for electricity generation is a growing industry. It starts in a robust way with the installation of co-generation heat and electric power system by burning sugar cane baggage to produce all energy needed in the process, thus presenting another green alternative to lower the dependence of hydropower and fossil fuel power. From approx. 8GW of electric energy produced from biomass co-generation, 80% comes from sugarcane bagasse with the rest produce mainly by black liquor, wood chips, biogas and rice husks. Several other agriculture waste such as wheat straw, corn stalk, coconut shell, and coffee husks might be explored as fuel source depending upon reasonable characteristic. As mentioned earlier globally 140 billion metric tons of agriculture biomass is generated every year. Equivalent to approx. 50 billion tons of oil, agriculture biomass waste transfer to energy can significantly displace fossil fuel, decreases emission of greenhouse gas and supply renewable energy to some 1.6 billion people in developing countries which is still lack access to electricity [21].

CONVERSION TECHNIQUES

In biomass power plants biomass fuel is burnt in boilers the heat released from this process is used to heat and convert water into steam to turn a steam turbine, which runs a generator to create electricity. Biomass is sometime burned in combination with coal in boiler this is called co- firing. Certain critical engineering design norms of a gas application system were first developed on a laboratory scale model and then used to design a fully-fledged commercial scale system of thermal output of 1080MJ/h. This system comprises a reactor, a gas conditioning system, a biomass feeding system and instrumentation and control system. The system was extremely simple to operate, only two operators per shift of eight hours are required to operate the system including fuel and ash handling operations. The ministry of new and renewable energy has implementing biomass co-generation program since mid-nineteenths. Over 800 biomass power and bagasse/ non bagasse co-generation project aggregation to 1020 5.6 MW capacity has been installed in the different state of country for feeding power to grid. Some biomass gasifire based electric power installation are as follows:

(i) A 5 × 100 KW biomass gasifier installation on Gasaba Island in Sunderban of West Bengal is being successfully run on commercial basis to provide electricity through a local grid.

(ii) A 4x 250kW (1.0 MW) biomass project is commissioned at Khtrichera Tripura for village electrification.

(iii) A 7.5 MW Ravikiran power project is commissioned in Marlanhalli in Karnataka state (by Greenko in 2005).

(iv) A 10.15 MW agri-waste based power project has been set up jointly by Punjab Biomass Power, Barmaco energy, Archean Granites and Gammon Infrastructure Project Limited in Punjab. The project locally buy agriculture waste like rice straw and sugar cane trash for fuel. The total annual fuel requirement is around 120,000 tons of biomass, all of which will be acquired locally. Punjab has about 20 million acres under paddy yielding 100 million tons of rice straw. Rice straw is burnt by farmers in the field to make way for Rabi crop. But now these wastes are being used for generating electricity the project is expected to provide additional income to 15000 farmers from the sale of agri waste. It will also trim down the release of a smoke and other pollutant caused by burning 100 million tons of waste which could be used for earning carbon credit. [22]

ADVANTAGES OF BIOMASS FUEL

Sustainable utilization of biomass waste to produce energy can also solve the problem of pollution by burning and spoiling of agri waste, problem of ruler employment and utilization of wasteland. It is helpful to enhance the social and economic status of the farmers and people of rural areas. The table 5 shows a case study of 45 biogas plants and extrapolated for 163 project for the observation of overall impact of the program implementation.

Table 5 Case study : Benefits of Biogas plants

Total no. of Biogas plants	163
Annual Energy cost saving (in Rs lakhs)	787
Annual CO2 Saving (in tons.)	9587

Annual Bio manure production(in tons.)	32582
Direct Employment (Man- Days)	63484
Indirect Employment (Man- Days)	56894

Source https:/mnre.gov.in>current status

The picture clearly shows that the adoption of biomass a fuel for energy production is not only reduced the problem of carbon emission but can ease the financial stream in developing country like India related to heavy burden of fossil fuel. This can also develop local source of revenue for the people within production chain .Future of biomass energy depends on providing consistent energy service at competitive cost. In India, this will happen only biomass energy services can compete on a fair market policy priority should be to orient biomass energy services towards market and to reform the market towards fair competition.

RECENT MAJOR BIOENERGY DEVELOPMENT IN INDIA

(i) The government of India has advanced the target of achieving 20% blending of ethanol in petrol by 5 years to 2025 -26 .

(ii) The government of India has allowed to maize and surplus rice available with Food Corporation of India (FCI) to be used for ethanol production.

(iii) India is committed in developing and demonstrating technologies for bio-based renewable fuels, chemicals and materials to replace the petrochemical products contributing to greenhouse gasses emission reductions under mission innovation reductions.

(iv) Under Mission Innovation 2.0 India and US are co -leading the Mission Innovation Collaborative platform initiative on " Innovation for Sustainable Aviation Fuel" (ISAF).

(v) Galvanizing Organo -Bio- Agro Resources [GOBAR]- DHAN announced on February 01, 2018 is an effort to improve sanitation in India villages by processing livestock menu and solid agriculture waste to produce biogas.

(vi) In India's quest to promote hydrogen as a clean fuel for mobility sector, hydrogen blended HCNG is emerging as an excellent interim technology for achieving emission, reduction and import substitution. One compact reformer plant and trial run of 50 buses has been started on 20 October 2020.

(vii) Bio manures produced from CBG plants has now been included as Fermented Organic Manure and Fermented Liquid Organic Manure under fertilizer category for retail sale in the country [19].

CONCLUSIONS

Green chemistry seeks the goal towards form profitability community, prosperity and improving soil quality for reducing the dependence use of nonrenewable sources like synthetic fertilizers and pesticides minimizing the adverse effect on water quality, wildlife and safety. The use of bio fertilizers and bio pesticides are increasingly growing in all over the world as well as in India. The production of carrier based solid bio fertilizer in India amounted to roughly 134,323 tons in 2021. This was an 83% growth over figure from 2018-19. On the other hand, Indian production of liquid bio fertilizers in 2020-21 was at 26,442 kilolit. The Indian bio pesticides market size was USD 64.73 million in 2021, 69.62 USD million in 2022 and expected to 130.37 USD million by 2029. Use of agriculture waste for energy generation is a growing industry. In India in 2019 agriculture biomass make of 19.8% of total energy supply .The use of agriculture waste for energy and electricity production is a unique way for" Wealth from Waste". We can say that the green chemistry generates the new green inputs for sustainable agricultural production and protection.

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