Chapter 7
A Brief Review of Waste Generation in India and Biofuel Applications

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Abstract Waste generation is increasing due to population growth coupled with rapid industrialization. The scientific disposal of the waste is highly essential, and resource recovery through eco-friendly and economically viable processes is gaining significance. In addition to this, conventional fuels are depleting at a faster rate, and hence, the development of alternate fuels is very much crucial for sustainable progress. The biochemical approach is promising and sustainable and organic solid wastes such as municipal solid wastes, including food waste, animal manure comprising, cattle manure, poultry litter, and industrial wastes such as press mud, coffee pulp, fruit juice residues, wheat straw residues, etc. are suitable resources for the generation of multiple biofuels and bio-based products through a biochemical pathway. Therefore, this book chapter discusses waste generation in India and its biofuel applications.

Keywords Biofuel · Anaerobic digestion · Biogas · India · Waste

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P. Chowdhary et al. (eds.), *Bio-Clean Energy Technologies Volume 2*, Clean Energy Production Technologies, https://doi.org/10.1007/978-981-16-8094-6_7

7.1 Introduction

Waste generation has been increasing exponentially (Hoornweg and Tata 2012; Jalasutram et al. 2013) over the years due to population growth coupled with rapid industrialization. The scientific disposal of the waste is highly essential, and in this context, resource recovery through eco-friendly and economically viable processes is gaining significance (Taiwo 2011; Gangagni Rao et al. 2012). In addition to this, conventional fuels are depleting at a faster rate, and hence, the development of alternate fuels is very much crucial for achieving sustainability in terms of progress (Gaurav et al. 2017; Gangagni Rao et al. 2013). In this way, wastes that are produced in every nation could turn into an asset for the age of substitute powers. In the course of the most recent couple of years, extensive endeavors have been made to accomplish a reasonable switch for a bio-based economy to supplant fossil-based energizes with elective biofuels and worth-added bioproducts, particularly from natural squanders (Begum et al. 2016). There are various natural pathways accessible for the treatment of these natural squanders to create the ideal items; however, the biochemical methodology is promising and practical (Goud et al. 2010; Begum et al. 2017a, b). Henceforth, the natural strong squander like a natural part of metropolitan strong squanders including food squander (Muhammad et al. 2019; Kuruti et al. 2017) creature compost containing steer fertilizer, poultry litter, and mechanical squanders, for example, press mud, espresso mash, natural product juice deposits, wheat straw buildups, and so forth, which are appropriate assets for the age of numerous biofuels and bio-based items through a biochemical pathway called anaerobic digestion (AD). AD is a sequence of biological processes for the generation of hydrogen (H_2), volatile fatty acids (VFA), alcohols, etc. and biogas from organic waste during the acidogenic and methanogenic phases, respectively (Rubio-Loza and Noyola 2010; Savla et al. 2020; Gandu et al. 2020). The generation of biogas from animal manure through conventional digesters is a well-known technology and implemented widely (Rohjy et al. 2013). However, there is a recent interest in the generation of short-chain and medium-chain fatty acids from a wide variety of organic wastes via anaerobic fermentation in contrast to the generation of biogas (Komemoto et al. 2009). However, in the biorefinery approach, it is possible to produce VFA in the acidic phase and methane (CH_4) in the subsequent methanogenic phase from organic waste. In this approach, VFA may one of the main platforms to produce biopolymers, such as polyhydroxylalkanoates, the reduced form of chemicals (aldehydes, alkanes, esters, and alcohols) simultaneously, and biofuels such as bioethanol like CH_4 and H_2 (Khan et al. 2016). Presently, commercial production of VFAs is accomplished by chemical routes, and therefore, production of VFA and bioethanol using cheaper and abundantly available organic wastes can reduce the production cost. The development of a commercially viable process is still a hindrance due to a variety of technological reasons (Mustafa et al. 2013).

7.1.1 MSW Production in India

All around the world, the vast majority of the nations are waste administration challenges and the measure of municipal solid waste (MSW) created dependent on the pay of individuals, the size and sort of mechanical action, propensities for individuals, and season (Kaushal et al. 2012; Chowdhary and Raj 2020). India creates roughly 1, 33,760 tons of MSW each day, out of which around 91,152 tons are gathered (CPCB 2000)). MSW generating per capita in India is in the scope of roughly 0.17 Kg per individual in unassuming communities to 0.62 Kg per individual each day in urban areas (Kumar et al. 2009). The waste production on a variety of issues such as resident's density, financial condition, level of industrial production, ethnicity, region, habitation, etc. The waste generation data in India across various states are shown in Table 7.1 (CPCB 2012), and it shows MSW generation in Maharashtra is the highest whereas it is the lowest in Tripura.

7.1.2 Food Waste

MSW primarily contains organic waste to the tune of 50 to 60% and in which again 50 to 60% is food waste. An overwhelming 1300 million tons of cooking stuff (food) is spoiled each year in India. Data from the FAO says that one-third of the food manufacture worldwide is wasted due to inappropriate management of usage, with an assessment of the global budget around $750 billion or Rs 47 lakh crore. This worrying increase in food wastage is producing approximately 3.3 billion tons of greenhouse gases, thus persistently impacting the ecosystem (http://www.developmentnews.in/tackling-food-wastage-india/).

7.1.3 Agricultural Waste

A lot of rural squanders are accessible in India, while some of them are used as steer feed at the same time; colossal measures of rice straw, stick squander, and extra ranch squanders are handily burned in the field grounds (http://www.abccarbon.com/). Internationally, India is one of the main producers of paddy after China, which is around 98 million tons with a straw of roughly 130 million tons, in which around half is used as grub. Additionally, 350,000 tons of straw were created in India, which brings about around 50 million tons of garbage from straw (http://www.abccarbon.com/). The losses from agribusiness like maize, cotton, millets, sunflower, and different stalks, bulrushes, groundnut shells, coconut junk, and so forth could likewise be utilized as feedstocks for the biofuels. Ranchers are chiefly consuming these agribusiness squanders because of the requirements of yield cycles and using time effectively, and this is contributing intensely to a worldwide

Table 7.1 Status of MSW generation collection, treatment, and disposal in class 1 cities (CPCB, 2012)

S. no.	State	Cities (number)	Residents of municipality	Municipal solid waste (t/day)	Per capita, MSW generated (Kg/day)
1	Andhra Pradesh	32	10,845,907	3943	0.364
2	Assam	4	878,310	196	0.223
3	Bihar	17	5,278,361	1479	0.280
4	Gujarat	21	8,443,962	3805	0.451
5	Haryana	12	2,254,353	623	0.276
6	Himachal	1	82,054	35	0.427
7	Karnataka	21	8,283,498	3118	0.376
8	Kerala	146 (municipalities)	3,107,358	1220	0.393
9	Madhya Pradesh	23	7,225,833	2286	0.316
10	Maharashtra	27	22,727,186	8589	0.378
11	Manipur	1	198,535	40	0.201
12	Meghalaya	1	223,366	35	0.157
13	Mizoram	1	155,240	46	0.296
14	Orissa	7	1,766,021	646	0.366
15	Punjab	10	3,209,903	1001	0.312
16	Rajasthan	14	4,979,301	1768	0.355
17	Tamil Nadu	25	10,745,773	5021	0.467
18	Tripura	1	157,358	33	0.210
19	Uttar Pradesh	41	14,480,479	5515	0.381
20	West Bengal	23	13,943,445	4475	0.321
21	Chandigarh	1	504,094	200	0.397
22	Delhi	1	8,419,084	4000	0.475
23	Pondicherry	1	203,065	60	0.295
	Total	299	128,113,865	48,134	0.376

temperature alteration (http://abccarbon.com/biomass-turning-agricultural-waste-to-green-power-in-india/).

7.1.4 Predictions on Future Waste Growth

The generation of waste is expanding step by step across the world and hoping to arrive at 27000 million tons consistently by 2050; this significant commitment from China and India is almost 33% of the absolute waste produced from Asia (Modak 2010). The waste litter created in urban communities of the Indian subcontinent is approximately 1,70,000 tons each day, comparable to about 0.062 billion tons consistently, and this is expected to ascend by 5% each year because of floods in the populace and changing ways of life (Arranging Commission, Administration of India. 2014).

7.2 Energy Demand and Environmental Impact

The energy demand has been rising inexorably in the last 150 years due to industrial development coupled with population growth. It is known that 82% of the global power requirement is achieved via fossil fuel resources that are prominent to the reduction of traditional power supplies (http://news.bbc.co.uk). The transport sector alone consumes 56 to 63% of conventional fuels (https://www.globalpetrolprices.com/articles/39/). Furthermore, the broad utilization of petroleum products establishes a weight on the climate that causes a worldwide temperature alteration because of the ascent of carbon dioxide (CO2) and other ozone-harming substances/greenhouse gases (GHGs) in the climate. Most customers are found to contribute GHG releases inferable from the utilization of non-renewable energy sources (Kirkinen et al. 2008), which goes before different destructive results like environmental change, dissolving of icy masses, expansion in the ocean level, harm of biodiversity, and so on (Kirkinen et al. 2008). It is assessed that CO_2 emanations because of the utilization of ordinary energizes will ascend from 31 GT (gigatons) to 37 GT in the range of 25 years (2011 to 2035), affecting a long-term normal temperature increment of 3.6 °C (IEA 2012). Long-haul grouping of GHG is noticeable, 60% more noteworthy than the levels of the pre-modern period and a lot higher than the normal reach, in the course of the most recent 650,000 years (Martinez 2010). The world financial movement directly depends on the crude oil prices, which would also demand energy (He et al. 2010). In this perspective, there is a rising demand for unconventional types of power sources across the globe. In the present context, bioenergy plays a significant role in the energy supply chain, and it accounts for approximately 35% of energy demand (includes open burning of wood for cooking purposes in rural areas) in developing countries, which in turn accounts for 13% of the world's energy demand.

India is one of the incredibly growing countries with vast economic and industrial developments. The energy requirement is predicted to rise continuously to 50% by 2030, as fuel is the main for their rapid economic growth (IEA 2012). The consumption of energy in India by using conventional energy sources is about 151.3 gigawatt (GW) produced from thermal sources like coal, oils, and natural gas, about 4.78 GW produced by using nuclear energy sources, about 30.49 GW produced by hydropower sources, and approximately 27.54 GW of energy produced by using renewable energy sources (Kumar et al. 2015). This shows that the major sources for energy requirements in India are coal and oils, and the hardest part of it is that the oil requirement of India is fulfilled through imports. As a result, it is crucial to walk around the energy from sustainable resources. One of the nonconventional energy resources is energy produced from biomass. Biomass is one of the important renewable power resources composed of carbon complex, H_2, oxygen, and nitrogen. The composition of biomass results from the decomposition of fossil plant sources, by-products of crops cultivation, wood materials, and agro-industrial residue leachates into the earth (Martinez 2010). The agriculture sector is the backbone of economic growth and contributes about 25% of gross domestic products and delivers livelihood to approximately 70% of the population of the country. Hence, it can be assimilated that the consumption of energy from biomass in India has been in practice since ancient times. It has been utilized as the cake of cow dung, firewood, husk, and other abundantly available feedstocks. According to the 2011 census, in rural regions, the population is around 68.84% in India. There are 6,38,000 rural areas in India that are required to plan for electricity generation from biomass, which would be a key alternative as a renewable power resource. The ministry of new and renewable energy (MNRE), Govt of India, has planned to achieve an overall 4324.22 megawatt (MW) of energy production based on biomass. The MNRE has taken up an idea like vital financial support and financial encouragements for boosting the usage of bio-energy from agrodeposits, plantations, and various wastes of municipal areas and trades (Singh et al. 2010).

7.3 Biofuels

Biofuels are in different structures like fluid and gas principally framed by utilizing biomass. Various kinds of biofuels have the option to produce from biomass, for example, bioethanol, biogas, biomethanol, diesel, H_2, and CH_4 (Demirel et al. 2008). A raising of cutting edge and arising advances of bio-powers are pivotal to decrease reliance on imported oil and to get together supported formative targets (Fulton et al. 2004). Different countries have carried out various techniques to propose biofuels somewhere in the range of 1980 and 2005. The worldwide age of biofuels upgraded from 4.4 to 50.1 billion liters (Armbruster and Coyle 2006), and this is projected to build more in the impending years (Licht, F.O, HTTP:// www.agra-net.com/portal/puboptions.jsp.).

Bio-energizers have emerged as profoundly possibly environmentally friendly power energy assets and are accepted as a prevalent technique for development to obstruct GHG discharges and, in the end, further develop the air quality and discover new vivacious assets (Delfort et al. 2008). Biofuels are significant because they supplant petrol energizers and leave a low carbon impression on the climate. The funds of each biofuel contrast with the spot, feedstock, and various additional viewpoints, and sociopolitical arrangement and biological interests also have an influence as an essential part in the age and utilization of biofuels. In Walk 2007, the European board (EU) allowed a required point of a more noteworthy than 20% energy from as of late-developing fuel sources in worldwide energy ingesting by 2020 and a mandatory 10% least mean to be cultivated by all partner nations for the piece of biofuels in the transportation region by 2020. Biofuels could include

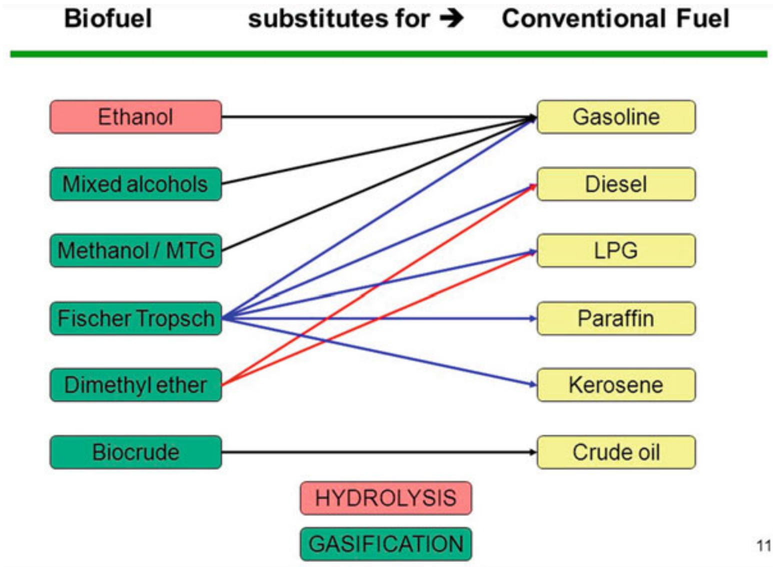

Fig. 7.1 Biofuels and alternative petroleum-derived fuels

moderately recognizable to regular strategies like ethanol created from sugar-based waste or diesel-like fuel produced using soybean oil and formaldehyde from the dimethyl ether (DME) or Fischer–Tropsch fluids (FTL) delivered from lignocellulosic biomass (Wiesenthal et al. 2009). It is feasible to substitute most oil-inferred powers with biofuels (Fig. 7.1), and subsequently, biofuels accept incredible importance in the current setting.

Biofuels are by and large sorted as two kinds of biofuels. The initial one is essential biofuels and the second one is optional biofuels (Fig. 7.2). The essential bio-energizes are used for warming, by utilizing fuelwood and wood chips. The optional bio-fills are ready by extravagance biomass, for example, bioethanol, diesel, methoxymethane, and so forth, that will be used in cars and various assembling strategies. The optional bio-powers are moreover isolated into the first-, second-, third-, and fourth-age (Fig. 7.2) biofuels dependent on natural material and skill used for their production. Biofuels are classified based on their substrate or waste type. Bio-energizes are solid, (kindling, wood coal, and lumber pellets) or fluid (bioethanol, diesel, and ignition/pyrolysis oils) or gas (CH_4, biohydrogen).

7.3.1 *First-Generation Biofuels*

The original biofuels were created from sugars (Love et al. 1998) or seed granules (Suresh et al. 1999) and required an unobtrusive technique to produce the fuel. The most appropriately perceived original biofuel is bioethanol, which is created by yeast

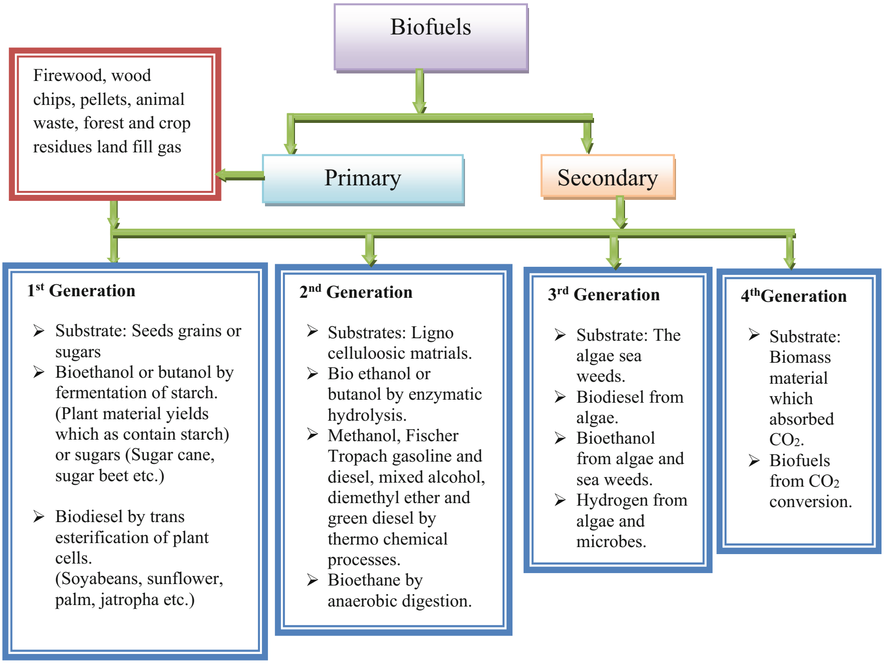

Fig. 7.2 Classification of biofuels

ageing of sugars extricated from plant yields, for example, sugar stick, corn seeds, or extra plants (Larson 2008). In this cycle, grains and starches are crude substances that convert into glucose via hydrolytic responses (IEA 2004). Comparable to the current presence, first-age biofuels are industrially delivered in quite well in numerous nations. Nonetheless, the practicality of the biofuels is questionable because of the food and human nexus (Patil et al. 2008). These sort of bio-powers have a higher age value inferable from challenges with foodstuff. The quick development of overall biofuel age from seed grains, sugar-delivering plants, and oilseed plants has expanded the cost of plants and groceries (Nigam and Singh 2014). These restrictions encourage the exploration of non-edible biomass for the manufacture of next-generation biofuels, reviewed in Table 7.2.

7.3.2 *Second-Generation Biofuels*

Second-generation biofuels are generating by two different strategies, for example, (1) organic or thermochemical treating, from rural lignocellulosic biomass, which is either non-palatable buildups of food crop produce or non-consumable complete plant biomass (for example, grasses or trees precisely adult for the age of energy), and (2) mechanical or metropolitan natural waste. The vital advantage of second-age

Table 7.2 First-generation biofuels

Advantages	Disadvantages
1. Modest and well-known manufacture techniques.	1. Feedstocks contend clearly with edible plants cultivated for food.
2. Traditional feedstocks.	2. Needs to address by-products marketing strategies.
3. Scalable to minor manufacture volumes.	3. Expensive feedstock sources cause higher price production rates.
4. Feasibility with current gasoline originated fuels.	4. Scarcity of land.
5. Practical knowledge with industrial manufacture and utilizes in numerous nations.	5. The uncertain net drop in fossil fuel utilization and greenhouse gas discharges with existing managing approaches.

biofuels from non-consumable feedstocks is that it limits the deficiency of food versus fuel contention connected with original biofuels. The feedstock used in the methodology can be sorted definitely for energy utilization, enabling progressed age per unit land region, and a bigger measure of over-the-ground plant source can be changed and used to create biofuels. Hence, this will extra accessibility of land-use skill differentiated to original biofuels (Nigam and Singh 2011). As said by Larson ED, it is perceived that the crucial quality of feedstocks holds the ability at lesser costs and considerable energy and is harmless to the ecosystem for most second-generation biofuels.

It is clear from the literature (Stevens et al. 2004) that the age of second-generation biofuel needs the most extreme modern tools, the extra cost per unit of fuel, and enormous scope administrations to restrict speculation cost to get financial matters. To achieve the conceivable energy and business parts of second-age biofuels, more exploration, headway, and application are required on feedstock and mechanical strategies need to be changed. FAuture production of ethanol is expected to include both the usage of regular grain/sugar crops and lignocellulosic biomass feedstocks (Aggarwal et al. 2001). Second-age biofuels add to the element of being produced from lignocellulosic biomass, empowering the utilization of minimal expense, non-palatable feedstocks, resultant in a breaking point between direct food and fuel challenge (Barron et al. 1996).

Second-age biofuels can be extra classified (Fig. 7.3) in states of the system or method used to change biomass over to fuel, for example, biochemical or thermo-chemical. Scarcely, any second-age biofuels, for example, ethanol and butanol, are produced using the biochemical interaction, while all extra second-age powers are created thermochemically. Various second-age thermochemical energizes are by and by being created industrially from petroleum derivatives. These thermochemical energizes contain methanol, refined Fischer–Tropsch fluids (FTL), and dimethyl ether (DME). Natural fills (for example, pyrolysis oils) are additionally produced thermochemically and, however, need critical purifying before they can be worked in motors (Larson 2008).

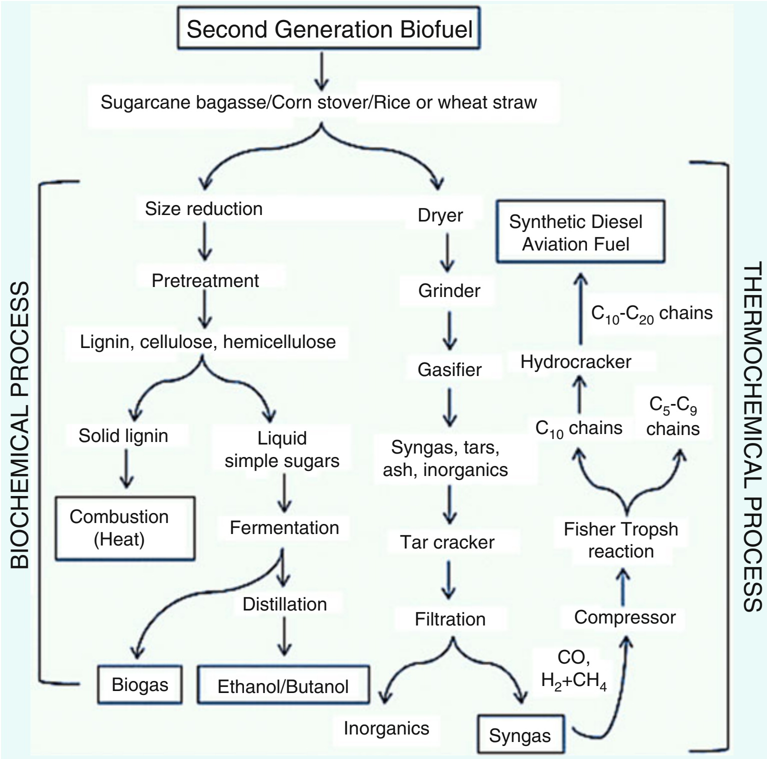

Fig. 7.3 Second-generation biofuel production pathways

Thermochemical biomass change incorporates methodology that needs a lot higher temperatures and pressure factors than biochemical transformation reactions. Explicit significant characteristics recognize the thermochemical methodology from the biochemical system, containing the adaptability in feedstock that can be adjusted with thermochemical strategies and the assortment of fuel items that are created (Farias et al. 2007).

Biofuels can be created thermally by pyrolysis and synthetically by gasification. This is for the most part additional speculation and includes a bigger scope that makes for a monetary benefit; however, the completing item is a clean-completed fuel that can be used immediately in motors. Fischer–Tropsch fluid (FTL) is a blend of significantly straight-tied materials of hydrocarbons, and these are part of the way refined crude oils can be shipped into petrol refining businesses for the production of clean oils, stream oils, or others by buildups (Farias et al. 2007). FTL is created by chemically changing CO and H_2, and in this way, any feedstock that can be changed to produce CO and H_2 can be used to produce FTL. The utilization of complete over-the-ground biomass in the age of second-age biofuels offers further developed land-use viability rather than original biofuels. In extra to that dependent on the lower cost of feed material and treatment of non-consumable biomass is the extra benefit for boosting the second-age biofuels.

7.3.3 Third-Generation Biofuels

The latest generations of biofuel researchers are now directing their attention to organic waste residues of plants, animals, and municipal solid waste through the anaerobic digestion process. Anaerobic digestion (AD) is one of the highly cost-efficient and ecologically welcoming technologies for energy generation. It can considerably drop greenhouse gas releases in contrast to fossil fuels by the consumption of easily accessible waste biomass. Also, the policy to boost biofuel use added to improving the usage of AD to attain energy generation and waste minimization. As the outcome, the innovation projections and the current logical confirmations give a thought that the third-age biofuels, which are inferred by microorganisms, are required to be a practical elective energy asset,which conquers the significant disadvantages that are related with the other biofuels. (Giuliano et al. 2010; Chowdhary et al. 2020).

7.3.4 Fourth-Generation Biofuels

Fourth-generation biofuels are designated at creating efficient power energy advancements and a way of catching and putting away CO_2. Biomass, which have been using CO_2 while grow, are changed into fuel applying comparative techniques as second-generation biofuels. This system shifts from second- and third-generation measures at all phases of age the CO_2 is caught utilizing the practices, for example, oxy-fuel ignition (Escobar et al. 2009). The CO_2 would then be able be geo seized seized by stowing it in old oil and gas fields or saline springs. This carbon catch accommodating fourth-era biofuel, carbon negative. This technique not just epitomizes and stores CO_2 from the climate yet additionally diminishes CO_2 discharges by subbing petroleum derivatives.

7.4 Conclusions

Presently, waste managing methods are gradually developing vital in the solid waste sector due to cleanliness and global warming issues, and it is pleasing to note that the government has brought essential programs. At present, different variations in methodology are produced for the treatment of natural strong waste, and at the same time, the age of biofuels is accessible on the lookout, and determination of proper innovation reasonable to the qualities of the natural waste is exceptionally basic in choosing the achievement and conservative viewpoint, moreover.

Acknowledgments We are thankful to the SERB-DST (India), Mahindra Group (India), and PBC (Israel) for constant support during this period.

Conflicts of Interest There are no conflicts of interest.

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