Chapter 5

Significance of Agricultural Residues in Sustainable Biofuel Development

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Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.78374

Abstract

Bioenergy resources are considered clean and are an integral part of efforts to address the menace of climatic, economic, environmental, and social security challenges consequential from the utilization of fossil fuel, which is currently the main energy source. Bioenergy and biofuel utilizing biomass such as biorefinery, plant materials and manure, and waste resources for application as renewable fuels for transportation and for power generation can ensure a sustainable, low-carbon alternative to fossil fuels. Bioenergy is among the major plan to strategically phase out electricity generation from coal as well a comprehensive climate plan through carbon capture and other measures. Biomass selection sustainably has been advocated over time and reaction pathways are the other area of intensified effort for an economical and environmentally synthesized process. Besides, the use of agricultural residues and manure to produce bioenergy offers a significant opportunity for local and regional economies. In this chapter, various agricultural biomass residues which are an important energy resource are presented and the several studies where they have been explored in various locations of the world considering different approaches had been presented. Crop residues, in particular, are one of the largest biomass resources globally and the best options for use to produce bioenergy depending on local factors, including the type and scale of resources in each location are therein enumerated. It is observed that agricultural residues are an important resource for future biofuel and bioenergy generation sustainably.

Keywords: agricultural residues, bioenergy, biofuel, bioelectricity, future prospects

1. Introduction

As at 2012, world basic energy supply touched 560 EJ, corresponding to about 19,000 Mtce [1]. Of this energy supply, more than two-third is made up of fossil fuels, nuclear power was made up of 5% while 3% was renewable energy comprising hydropower, geothermal, solar, wind, and tidal. The balance is made up almost entirely of biomass and waste, which amounted to 10% of the world market. This portion of the energy considerably provided about 56EJ/y of the energy supplies; an amount, which is equal to three times the energy contributed by all other renewable energies in totality. However, considering resource report and reserves, biomass did not comparatively attract desired interest and data are not as extensively available as those for oil, gas, and coal, although reasonably good data are available for the demand and supply of biomass [2, 3].

Of importance is the renewable energy resources meant for locomotion and generation of electric power to curb the menace of climatic, economic, environmental and political concerns associated with the combustion of fossil fuel. Bioenergy, which is the utilization of bio-based materials, including plant materials and manure, to produce renewable fuels for transportation and to generate electricity sustainably. This fuel is characterized with low-carbon emission compare to fossil fuels while communities also stand to benefit immensely from the sale of this local resource [4]. Bioenergy is among the various policies put in place to reduce the dependence on the use of fossil fuel and it has been propose to cut US. oil use in half by 2030, and consequently, this practice will ensure the propensity of phasing out coal as electricity producing feedstock. An important key to exploring biomass resources sustainably is to focus on the right ones, and to develop them in holistic ways and at appropriate measures [5].

Cellulosic biomass may be derived from agricultural sources, such as crop residues and perennial energy grasses, as well as forest sources, such as forest residues and woody biomass. Crop residues mainly include corn stover, wheat straw, and rice straw. Because these resource is by-products of crop production, their collection and utilization ensures sustainable practice and does not result in food energy feud and land competition. Therefore, the negative effects of cellulosic biomass production from crop residues on food prices can be expected to be negligible. Although cellulosic feedstocks differ significantly in their environmental performance [5], they can provide commensurate advantage and prospect for various environmental benefits when compared with the coal they will substitute [6]. China is a major producer of corn, wheat, and rice. It produced about 20% of the world's corn and wheat, and 26% of the world's rice, in 2010 [7]. Therefore, China is among the nation that can ensure universal practice of potential production of a large amount of crop residues, which can reduce the nation's reliance on coal as a major energy source.

The union of concerned Scientists evaluated the magnitude of biomass resource potentially feasible from the united states production capacity in a bid to possibly comprehend the main biomass feedstock as well as the operational scales in order that the synthesized biofuel carefully balances the energy and environmental trade-offs. It was discovered that the nation could harness nearly 680 million tons of biomass resources annually up to 2030 [8]. This resource was sufficiently observed to be suitable to generate well above 10 billion gallons of ethanol, or 166 billion kilowatt-hours of electricity, which is equivalent to about 4% of total US. power consumption in 2010. Agricultural biomass has been earmarked to be an important energy resource in this wise [9]. Among the feedstocks available in abundance to the US are the crop residues and the choice of selecting the appropriate agricultural biomass and manure for bioenergy production is a measure of some factors, which may include the type and scale of resources in each location. The use of agricultural residues and manure to produce bioenergy offers a significant edge for local and regional economies.

Currently, 17% of the global population remains without electricity an amount, which is estimated to be about 1.2 billion people [10]. The climatic and geographical hindrances prevent easy accessibility to rural or remote areas where mainstream of this estimates reside; this constraint hampers the extension of power grids to these locations. An alternative to this problem is the exploration of renewable energy sources, which are increasingly the source of electricity for isolated systems in rural areas [10]. The physicochemical characteristics of biomass make it an attractive source to be harnessed for energy generation [11].

2. Agricultural residues

Agricultural residues are carbon-based materials generated as a byproduct during the harvesting and processing of agricultural crops. Agricultural residues which are produced during harvesting are primary or field-based residues while those produced along with the product during processing are secondary or processed based residues. Agricultural residues are heterogeneous, varying in bulk density, moisture content, particle size and distribution relative to operational handling. They are usually fibrous, low in nitrogen and vary with geographical location [12]. These field residues are occasionally utilized as fertilizer, for erosion control and as fodder for livestock. Almost half of these resource are combusted on the farm prior to the commencement of another farm season.

Process residues offer high prospect as an energy source. Chemical composition of any crop residue varies depending on several factors among, which may include species, age of residue or period of harvest, physical composition including length of storage and harvesting practices [13, 14]. Agricultural residues are produced as a waste product from food crops such as maize, wheat, sunflowers, and so on. Currently, only small proportion of these residues are being used by farmers as feed for livestock and the rest of these are plowed back into the soil or burned to get rid of the huge volumes of biomass before planting the next crop. The biggest advantage of utilizing agricultural residues is that it does not compete with the production of food, and if it can become a by-product that can be utilized economically for the production of energy, it will result in lower food prices. It is estimated that roughly one ton of residue is produced for every ton of grain harvested [15].

2.1. Crop residues

Apart from the grains of crops such as corn, wheat, and rice which as sourced for food, the remnants or left over from the processing of these grains also serve as an important resource.

These residues generally makeup at least 50% by mass of the biomass in US grown crops. Over time, these resources have been sourced for animal bedding, combusted, or allowed to decay on farmlands. The recent development for use of the biomass residues for ethanl production or electricity generation sequel to scientific discovery has raised hope for the resource for both economical and environmental benefits. Significantly, the US agriculture can probably support up to 155 million tons of residues for producing bioenergy in 2030 [8]. Without the need of additional land requirement since these residues is by-product of major crops [16].

Residues are known to offer a lot of advantages ranging from erosion prevention and mitigation against soil carbon depletion, their use for soil bioenergy production may adversely impact on these benefits, therefore, their utilization should be subject to certain circumstances, and even then, only at a predetermined magnitude. The amount of residues that can be collected is subjective and depends on several conditions relative to the farmland, this should be considered sustainably as removal of too much resdiues may cause exposure of the land to excessive erosion while too less or no removal of the residues can inadvertently prevent soils from drying in spring, thereby affect the planting season.

Removal of residues for bioenergy potential and application can impact negatively on other agricultural practices. The environment could be worsen as a result of excessive exposure of the farmland. In order to minimize the effect of this, farmers can employ various strategies to curb the effect. For instance they can use no-till farming and indulge in cover cropping to decrease soil erosion and water pollution. This will enhance agricultural production sufficiency while also provide abundantly the amount of residues for bioenergy biofuel production [17].

In corn-growing regions, large quantities of corn stover—leaves and stalks left over after corn is harvested—are available to produce ethanol. Corn residues are abundant near existing facilities fitted to produce and distribute ethanol made from corn grain. Indeed, companies are building the first three commercial-scale efforts to produce ethanol from agricultural residues near such existing facilities in Iowa and Kansas. Producing ethanol from corn grain and corn stover at the same location can reduce the use of natural gas and electricity by the combined facility, curbing the environmental footprint of the fuel [18].

2.2. Waste from livestock

Livestock raised in very large confined animal feeding operations generate an enormous amount of manure, which can be used for bioenergy, but also frequently pollute water supplies in many locations. Fortunately, on the smaller end of the livestock production scale, farmers convert manure into biogas with the aid of anaerobic digesters resulting in both economic and environmental paybacks. The biogas can be employed to provide heat and power on the farm, or it can be further purified and sold as renewable natural gas for use elsewhere. Prospect of anaerobic digesters for biogas production from manure can enhance water quality, reduce obnoxious greenhouse gas from manure, and assist farmers to fixate nutrients to the soil. In the United States, reports show that almost 60 million tons of manure can be adopted to produce bioenergy in 2030 [8].

This resource is best used close to where livestock produces it, and would ideally be integrated with crop production. Crop residues do not usually appear in official statistics hence an estimate of the amount of crop residues produced are usually deduced based on production data [19, 20]. Available data for processing residues is generally poor, due to a wide variety of processing techniques producing an array of different stocks of residues [21, 22]. The ratio between main product and residue vary depending on a set of factors including variety, moisture content, nutrient supply, and use of chemical growth regulators among others. In reality, there are factors which limit the use of certain residues for bioenergy production such as scattered abundance, technical constraints, ecosystem functions, and other demands such as animal fodders, fertilizer, domestic heating, and cooking for which the application of the resource is being explored for.

Bentsen et al., presented a report relative to the production data of some crops which were combined with the residue-to-product ratios (RPR) of the different crops to obtain the amount of residues for each annual crop and from perennial plantation crops. The analysis showed that the estimated total amount of crop residue that is potentially available for energy was 150 million tonnes. Using 30% conversion that is typically obtained in biomass to energy conversion systems efficiency and the heating value data, these residues can generate about 0.60 EJ, which is equivalent to 34% of the current energy consumed in Nigeria.

3. Bioenergy potentials

In accordance to the report of World Health Organization (WHO), United Nations Development Program (UNDP), 1.5 billion people, implying an estimated one-quarter of the world's population, do not have access to electricity [23]. In order to meet the UNDP millenium development goals, modern energy service need be supply to about two billion people. Lack of accessible and uninterrupted electricity supply and liquid transportation fuels undermines undeveloped and developing countries deleteriously, where population density is high and access to resources is low. About 2 billion people require on solid fuels (**Figure 1**), which are employed primarily for cooking and heating purposes. This development of combusting biomass environmental pollution and health issues. In the long run, the effect incurs health costs, where the main victims are the woman and children, due to the burning of solid fuels in poorly ventilated housing [23–25].

Contrarily, developed nations sourced for bioenergy to combact the menace of environmental pollution due to CO_2 emission and possibly reduce it and provide domestic energy [26]. Energy crops with potential to generate high-yielding lignocellulosic biomass have been studied by [27]. Exploration of the special energy crops in developing countries may possibly displace food crops resulting in food-energy fued [28–30]. Food security, as well as energy provision from these crops, can be ensured when the degraded farmlands are used to grow crops after the deforestation, which can result in CO_2 emissions as a result of excessive land use [31]. Hence, opportunities abound from dual cropping process, which can enhance agricultural productivity by generating bioenergy from agricultural waste while food production is ensured.

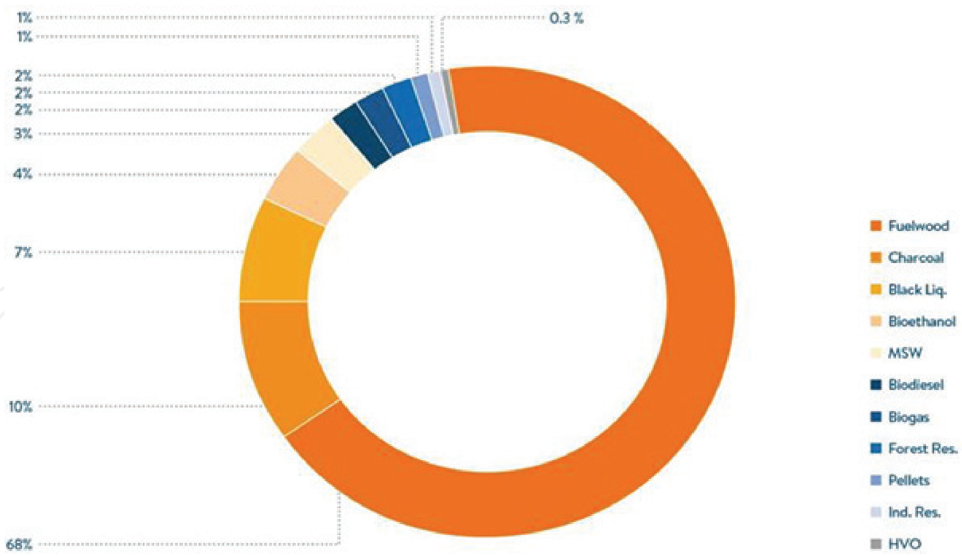

Figure 1. Primary energy supply of biomass resources globally in 2013 (WBA Global Bioenergy Statistics 2016). Source: Based on data from World Bioenergy Association (2016).

Albeit the enormous advantages of using agricultural residues as a waste stream [32], Kim and Dale opined that clearing the farm of some types of agricultural residues may result in some serious environmental concerns [26]. For instance, recurrent continual harvesting of total above ground biomass from annual cereal crops can ultimately reduce soil organic matter, causing long-term degradation of soil fertility, and rapidly promoting CO_2 emissions [33]. However, an example of removing partial residues has been demonstrated for rice (*Oryza sativa*) grain husks in India, which are gasified in small-scale ecofriendly units to produce electricity for users spending approximately $2 a month for energy [34]. Such a model for renewable energy could serve globally as an inexpensive decentralized energy mechanism.

In exploring parallel circumstances, environmental factors such as temperature, rainfall, and altitude affect the production of crop from different locations. Thus, identification of source feedstocks suitable for dual-use cropping and that are available in regions with energy scarcity is imperative. In this regard, an existing dual-use feedstock that is underused is endocarp tissues from horticultural fruit crops. For instance, the endocarp of a drupe fruit is the inedible shaft of the fruit that encloses the seed, and which is mostly thrown out after processing. The hardened drupe endocarp is made up of predominantly lignin content of any woody feedstock which can be as high as 50% wt/wt [35, 36].

In biofuel synthesis, lignin offers much higher energy content compared to cellulosic biomass [37, 38]. In practice these crops are majorly horticultural crops. The geographical distribution of selected crops and their individual potential for bioenergy synthesis was studied by Mendua et al. [35] The considered crops include coconut (*Cocos nucifera*), mango (*Mangifera indica*), olive (*Olea europaea*), walnut (*Juglans* spp.), pistachio (*Pistacia vera*), cherry (*Prunus cerasus*, *P. avium*), peach (*P. persica*), plum (*P. domestica*, *P. salicina*), apricot (*P. armeniaca*), and almond (*P. dulcis*). The focus of the study was to determine the relationship between diversity of endocarp and the proliferation of energy insufficiency by investigating the potential of endocarp biomass for energy [39].

http://dx.doi.org/10.5772/intechopen.78374

The prospect of biomass feedstock for synthesis of biofuel and as starting materials for industrial processes cannot be overemphasized, following this development; experts forecast the potential of agricultural residues in augmenting the energy need globally in the near future thereby accounting for a significant part of international agricultural transactions in the nest few decades. However, the cost of petroleum product is usually the yardstick for evaluating the economic viability of bioenergy, although social ane environmental concerns are possible factors that can possibly fast track the schedule [39].

3.1. Biomass conversion processes

3.1.1. Biochemical conversion process

Typically, biomass composition is usually considered from three major components namely, cellulose, hemicellulose, and lignin (**Table 1**). The process of biochemical transformation processes of biomass is aimed at the disruption of the hemicellulose part in order to enable easy reachability to the cellulose, however, there is no alteration done to the lignin component [21]. Nevertheless, the lignin fraction can be converted to important fuel using a thermochemical conversion mean. Anaerobic digestion and fermentation are the two biochemical methods where biomass is converted into a valuable substance (**Table 2**).

Anaerobic digestion is an important conversion method appropriate for bioenergy synthesis from agricultural residues and some other organic products [40]. It has been researched

Crop	Residues	Residue	Composition	(Dry weight basis)
		Cellulose	Hemicellulose	Lignin
Rice	Straw, husk, stalk	0.36	0.24	0.16
Maize	Cob, husk, stalk, stover	0.35	0.23	0.19
Soybean	Husk, stalk	0.40	0.16	0.16
Groundnut	Husk	0.30	0.30	0.40
Hazelnut	Husk shell	0.30	0.16	0.53
		0.26	0.30	0.43
Tobacco	Stalk, leaf	0.36	0.34	0.12
Sunflower	Stalk, head	0.48	0.35	0.17
Almond	Shell	0.51	0.29	0.20
Wheat	Pods, stalk	0.38	0.27	0.18
Sugar cane	Baggasse, top and leaves	0.44	0.32	0.24
Cotton lint and cotton seed	Boll, shell, husk, stalks	0.80	0.20	—
Grasses	Straw	0.40	0.50	0.10
Barley	Straw	0.46	0.23	0.16

Table 1. Some crop residue and their lignocellulosic composition [71, 72].

Conversion processes		Biomass	Components	
	Fat and oils	Protein	Sugar and starch	Lignocellulosic
Direct combustion	✓			✓
Anaerobic digestion	✓	✓	✓	Cellulose only
Fermentation		✓	✓	Cellulose only
Transesterification	✓			
Pyrolysis	✓	✓	✓	✓
Gasification	✓	✓	✓	✓

Table 2. Primary biomass conversion process and processed biomolecules [21].

extensively in the production of bioenergy for both domestic and industrial applications [41]. The process involves the utilization of microorganism for conversion of moist organic substance in an anaerobic environment to generate CO_2, biogas and some other impurities such as hydrogen sulfide [21]. Along the product a waste stream digestate is generated which are usually utilized as manure of the farmland. The generated biogas is characterized with high-energy content of one-third of the lower heating magnitude of the feedstock from which it is produced [42]. In the quest for renewable energy production in the form of biogas, this method has been studied succinctly. Moreover, there is inherent advantage of carbon capture for CO_2 mitigation [39, 41]. Among the various biomass resources that has been investigated, algae stand prominent as an agricultural residue producing significant amount of biogas in many locations of the world [39].

Besides, another vital approach of biomass conversion is an enzymatic controlled anaerobic process [43], which is employed in the synthesis of bioethanol from lignocellulosic biomass. In this process, the first action is the pretreatment of the raw biomass and subsequent hydrolysis prior to fermentation process. The cellulosic component of the biomass is transformed into glucose via enzymatic hydrolysis converts the cellulose component of the biomass into glucose while the hemicellulose part affords pentose and hexoses. Microorganism then converts the glucose into ethanol. This is affected by the action of biological catalysts to turn fermentable sugars to important chemicals (usually alcohols or organic acids). The most essential product of fermentation has been ethanol; however, there are some other useful substances such as hydrogen, methanol, and succinic acid that are generated. The major fermentation substrates are hexoses, which are mostly glucose, while modified fermentation organisms are used to convert pentose, glycerol, and other hydrocarbons to ethanol [44].

Furthermore, fermentation process is a conventional and extensively considered method in the treatment of waste streams, as well as for ethanol synthesis from agricultural residues, such as corn cobs and sugar beets [43]. Using fermentation sugars in sugarcane as feedstock, Brazil established a successful bioethanol plant. In 2011, about 5.57 billion gallons of ethanol is generated as fuel from this program, an equivalent of about 24.9% of the world's total ethanol utilization in form of fuel [21].

http://dx.doi.org/10.5772/intechopen.78374

Transesterification reaction is used to synthesize biodiesel by employing the ethanol along with large branched triglycerides into smaller straight-chain molecules usually in the presence of a catalyst [40]. The biodiesel produced is used in diesel engines either pure or in blend with fossil diesel. In spite of the success recorded in various part of the world, biodiesel production in commercial scale is still at evolving stage in Africa [40, 45] despite the myriad of feedstock available and the potential of this important biofuel.

3.1.2. Thermochemical conversion processes

Various other methods of thermochemical conversion processes for biomass conversion abounds, which are carried out at supercritical temperature and pressure and are usually at higher reaction condition compared to biochemical processes [46]. This process has been employed to generate a number of important bio-based products. These methods include direct combustion, pyrolysis, gasification and hydrothermal liquefaction (**Table 2**).

An important method for biomass conversion via thermochemical route is direct combustion methods is employed to produce the major bioenergy resource of the world accounting well above 97% of world bioenergy index [43]. It is the most common way of extracting energy from biomass. Direct combustion methods produce energy only in the form of heat and electric power as such it is not employed for biofuel production [47] and it considered several feedstocks such as energy crops, agriculture residues, forest residues, industrial and other wastes [48].

Another production process is pyrolysis, which is an important biomass conversion method that heralds the combustion or gasification of solid fuels. It comprises of thermal degradation of biomass feedstock at temperatures of about 350–550°C, under pressure, in air tight compartment [21]. This approach affords three fractions: liquid fraction (bio-oil), solid (largely ash), and gaseous fractions. Pyrolysis has been useful over time in charcoal production, however, it is only been recently considered due to the mild temperature and short residence time [49]. The product generated from the fast pyrolysis technic is known to be made up of more than two-third of the feedstock in liquid content and is suitable for use in engines, machinery and myriads of other applications [49]. An integrated approach where fast-pyrolysis can be co-processed with fossil fuel in conventional refinery is the current trends in research in which refined hydrogen can be utilized for blend to upgrade the oil into locomotive fuels and, in turn, some gases of pyrolysis are employed in the refinery [42, 50]. The feasibility of this approach is a measure of the comparable cost of natural gas, biomass feedstock, and incremental capital costs. Co-processing of petroleum with renewable agricultural residues offers advantages from both technological and economic considerations.

Subject to sustainable practices and advocacy as well as the availability of feedstock, the utilization of biomass feedstock in biofuel and bioenergy production promise to be prominent approach and the generated biofuel products are known to be comparative in characteristic feature with petroleum products. The first large-scale plant facility employing fast pyrolysis and bio-crude refining method in the United States amounting to about $215 million projects is the KiOR Inc. plant situated in Columbus, Mississippi [50].

Pyrolysis of biomass and their direct liquefaction method with water are often used mistaking to mean the same thing; however, there exist a striking difference between the two processes. Although they are both thermochemical conversion methods that involve the alteration of various components of biomass into liquid products. Whence liquefaction involves decomposition of macro-molecule feedstock into smaller fragments of light molecules where an appropriate catalyst is employed in the conversion. Subsequently, the unstable smaller fragments are re-polymerized into oily constituent with comparable molecular weights with fossil equivalent. Whereas in pyrolysis, the generated fragments are instantaneously merged to an oily compound and the use of catalyst is predominantly may be subject to necessity [43].

4. Global biofuel and bioenergy scenarios

The potential for bioenergy generation from agricultural residues is being studied intensively and many studies have been conducted on both a regional and a global scale. In most cases, the outcomes of these studies vary considerably because of factors, such as the residue to product ratio and the sustainable removable amount of residues, used to calculate potentials range substantially.

So far, a lot of studies in different countries have been conducted for the assessment of availability of residual biomass. Scarlat et al. [51] assessed the availability of residual biomass of agricultural and forest crops suitable for bioenergy synthesis in Romania. Crop yield, variation multi-annual yield, environmental and economic constraints, and competitive uses were the various measures utilized to estimate agricultural residues. A comparable work was developed by Shonhiwa [52] who explored the magnitude of biomass available for energy production using thermochemical conversion technologies in Zimbabwe. Besides, Iye and Bilsborrow [53] evaluated the propensity of agricultural residues in Nigeria based in six areas; three situations were considered subject to the collection and availability of biomass proportion.

Moreover, in Argentina energy potential of residual biomass derived from herbaceous and horticultural crops was studied by Roberts et al. [54]. In Colombia, several studies were carried out to determine the features of residues from agriculture, animal, forestry, and municipal solid waste in order to evaluate its energy potential [11, 55]. Subject to the geographical location of Colombia tropics, Colombia has comparative advantages in the production of agricultural and forest biomass and its potential is sufficient to satisfy the energy demands [56].

As an example, Hiloidhari assumes a RPR of 2 for maize [57], whereas the IEA considers a RPR of 1.5 [58] while Kim et al. adopted a ratio of 1 [59]. Similarly, the fraction of the produced residues that can be detached in a sustainable manner is in the range of 20 [60] to 50% [61] although 70% is recorded in some studies [62]. Apparently, this has a huge impact on the resulting propensity for bioenergy production.

Furthermore, numerous works have assessed the technical feasibility of crop residue production in China. Jiang et al. [63] used a GIS-based approach to examine the availability of crop residues in China. A number of cereal crop were considered and the findings demostrated China potential to provide about 506 million dry biomass metric tons of the residues annually. In another study, Qiu et al. [64] adopted remote sensing data and reported about 729 million MT crop residues in 2010, of which about 20–45% of this amount could substitute coal subject to regional utilization and customary needs of crop residues. Liu et al. [65] discovered that about 630 million MT of crop residues was harvested annually over a decade between 1995 and 2005. The observable dicotomy is as a result of the several factors such as considered crops, assumptions relative to crop-to-residue ration, and residue collection methodology, which is evidence in the estimated technical availability of crop residues available in the results.

In estimation of the technical potential of crop residues production, production cost of the residues and the cost of feedstock were never considered in past reports. In certainty, farmers' preparedness to collect crop residues rely significantly on the yields and production costs of crop residues as well as on the biomass prices provided in the market. Specifically, the biomass prices offered must cover the costs of collecting crop residues. In this regard, Chen [66] examined the potential yield of each type of crop residue in China at various prices and subsequently, estimated the collective supply of crop residues at these prices. As regards the crop residues, different residues were considered as potential residues and due to the inherent yield and cost uncertainty, they derived the supply curves of the crop residues using alternative assumptions about the production costs of crop residues and residue collection technology.

In Tanzania, the major commercially sourced after agricultural crops include sugar, cotton, tea, cashew nut, tobacco, coffee, and sisal. Significant amounts of residues from these crops have been utilized for the cogeneration of electricity in the sugar sector. Convesely, only a small amount of sisal residues had been utilized as substrate in a pilot biogas plant to generate electricity since 2008. Moreover, almost all biomass can be converted into energy; crop residues are not an exception. The types of residues available for energy generation in the commercial crop sector in Tanzania were bagasse, coffee husks, cashew nut shells, tobacco stems and sisal pulp [67].

The energetically available share of these residues was determined by the termed non-energy applications, whence the energy content of residues is influenced by the plant structure and the moisture content of the residue. Considering the account of these different parameters, the heating value for every tonne of dry matter had been reported. Although they submitted to probability of the estimation due to expedient losses during collection and transportation, the upper bound demonstrated that all residue types contain a incredible energy propensities. The combined potential of 6053 TJ is equivalent to 1680 Gigawatt hours (GWh). This estimated maximum potential is equivalent to over 37% of the country's electricity generation of 4553 GWh in 2008 [68].

5. Future prospects

Significantly, the role of biofuels and bioelectricity as an important sustianble fuel in today's fuel and electricity grid cannot be underestimated due to their presumed potential to revolutionize the bioenergy sector. Researchers in various research institutions around the world are engaging in unprecedented investigation on converting biomass into biofuels and other chemicals and products. For instance, reserachers of diverse field of specialization at the Biocentury research farm, Iowa State University are currently investigating new approaches for conversting agricultural residues and other advanced feedstocks into biofuels, while social scientists are preoccupied with the analysis of the economic blueprint of bioenergy on Iowa agriculture.

In developing the technological practices and policies, there is the need to use agricultural biomass resources responsibly to ensure that communities across the every location and agencies benefit both financially and environmentally while the nation abates its oil and coal use and global warming emissions. However, achieving this quest will require private investment and smart public policy.

The IEA World Energy Outlook [69] suggested that renewables could form an integral proportion of the global primary energy mix in the near future, up to a fifth of demand (**Figure 2**), while coal could provide a quarter by 2040. A great deal of this renewable energy could be from hydroelectricity, solar PV, and wind power while cofiring practices of biomass could augment these sources while not requiring the premature retirement of coal assets, many of which are still in the early days of operation in places Asia. Cofiring solid fuel with coal is a relatively low-cost, relatively safe method of adding biomass capacity without a major

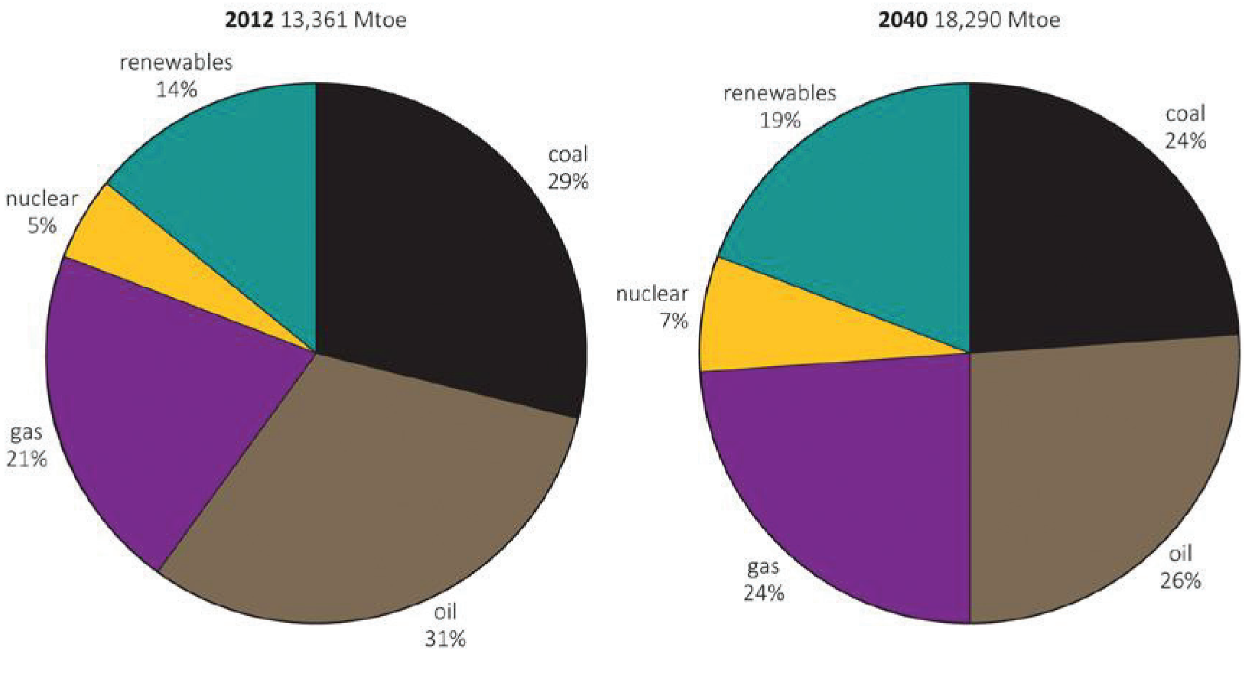

Figure 2. A comparable projection of the primary energy demand in the world in 2040 (Source: [70]).

disbursement of capital expenditure compared to a dedicated biomass plant. In an effort to compare the different global biomass resource, a presentation of specific types of biomass that exist and identification of those best suited for combustion for power generation is imperative. Numerous practices have been suggested to ensure a sustainable practice. This biomass resource can be combined with any fossil-fuel in any of the following practice, such as:

- Cofiring solid biomass particles with coal;
- Mixing with synthesis gas; and
- Landfill gas or biogas with natural gas.

6. Conclusion

Bioenergy is derived from biomass, which can be deployed as solid, liquid, and gaseous fuel for a wide range of uses including heating, electricity, and cooking. It can also provide substantial climate change mitigation benefits when developed appropriately, and therefore, can be instrumental in working toward the attainment of the Paris Agreement goals. Among the variously available resource, agricultural wastes are biomass considered in on-going research for biofuel and bioenergy production as well as synthesis of important chemicals for industrial applications. These resources are relatively abundant around the world and can serve a dual purpose of energy production and environmental protection.

Moreover, the quantity of residues originating from the food processing is usually huge, and their exploration for energy generation can provide a considerable volume of renewable energy. Nevertheless, current application of these residues includes utilization as livestock feed, promoting the production of highly valued meat and dairy products. These commodities are important sources of protein in the human diet, and cannot be left out without affecting the quality of food consumption. Hence, exploring residues for non-feed purposes such as biofuel and bioelectricity requires adaptations in the food system to compensate for protein losses. Therefore, based on the available reports in literature and the various policies for sustainable practices that is geared toward pollution mitigation. Hence, these residues are important feedstocks of immense potential for sustainable biofuel and bioenergy production.

Acknowledgements

The authors would like to express our gratitude to Dr. Olorunnisola Kola Saheed for his effort in taking time to read through the manuscript and providing his valuable technical inputs.

Conflict of interest

The authors declare that there is no conflict of interest in the chapter whatsoever.

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