Residual Biomass Resources in Kazakhstan

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Agricultural, animal and municipal solid waste are available to produce energy in Kazakhstan based on combustion technologies; however, animal waste and agricultural are the main potential sources with 61.02% and 38.34% of the theoretical total biomass potential energy analyses, respectively. Inadequate disposal of residual biomass can cause soil contamination, compromise the quality of water resources and promote environmental disturbances among species. As a consequence, the residual biomass before its final disposal needs to undergo an appropriate treatment process to reduce its potential environmental risk. Residual biomass from agricultural, animal and solid waste has been considered for energy production in Kazakhstan, to be incorporated into existing fuel storage and handling systems and be co-fired. Energy valorization from residual biomass would also be a key component in waste management into valuable products in a circular economy.

Keywords: energy potential ; Kazakhstan ; residual biomass

1. Agricultural Residues

Agricultural residues are formed directly during harvesting and the subsequent processing and sorting of agricultural crops. In Kazakhstan, crop production occupies a leading place in the structure of the agriculture of the country, accounting for 56% of all production [1]. Cereals account for 70% of all acreage [2]. Furthermore, Kazakhstan accounts for 21% of the acreage of grain crops in the Commonwealth of Independent States. As a consequence, millions of tons of agricultural waste are produced in Kazakhstan every year. Despite some of this waste being used as litter for farm animals, fertilizers or animal feed, it is principally burnt directly on the fields or in inefficient burners (with less than 10% efficiency) in small villages [3], resulting in a significant impact on the greenhouse effect in terms of gas emissions and air pollution [4]. In fact, during crop harvest, the elimination of waste is frequently carried out by farmers by burning it in the fields, crushing and mixing it with the soil or abandoning it in the field, because of the difficulty and high cost of removing [5]. The elimination of waste by burning during crop harvest makes possible the reincorporation of part of the necessary nutrients for the crop [6], however, open burning results in emissions to air of high concentrations of pollutants in the form of particles, CO_x, hydrocarbons, NO_x, SO_2, volatile organic compounds (VOCs), polycyclic aromatic hydrocarbons (PAHs), polychlorated compounds, dioxins and furans, that have a deleterious effect on air quality and human health [5][7]. On the other hand, the alternative of burying the straw in the soil generates between 2.5 and 4.5 times more methane than burning it [8]. Finally, the abandoned crop waste in the field sometimes may flow into the drainage during the rainy season, causing an obstruction of the drainage, but also providing a suitable place for the propagation of the bacteria [9].

Agricultural residues depend upon a wide range of local conditions and the primary factors influencing the amount of crop residue are the type and variety of crops planted and their yields [4]. In Kazakhstan, four globally important crops in terms of production quantities are wheat, barley, maize and rice, with their harvested area covering 35 million ha [10]. The annual collectible dry biomass (CB) production is calculated according to Equation (1), where CP is the annual production of crops, RF is the residue factor, defined as the ratio of a field weight of residue per mass unit of crop yield [11], WF is the dry weight factor, which is used to take into account the high percentage of water in crops and depends on the type of crop and the amount of water in its environment [12][13][14] and AF is the availability factor, which is evaluated considering various constraints and excluding the fraction that is already used for energy production [12][13][14].

$$C_B = C_P \times R_F \times W_F \times A_F \quad (1)$$

Table 1 summarizes the annual production of crops, as well as the calculated collectible dry biomass, in this research. It shows that despite an annual production of crops of 23.41 × 10^6 tons/year, the total annual collectible dry biomass calculated is 15.10 × 10^6 tons/year, of which 63.31% is from wheat, followed by barley, maize and rice with 16.89%,

16.69% and 3.11%, respectively. The comparison between the annual collectible dry biomass (CB) and the annual production of crops (Cp) shows how the type of crop and its residues and availability factors affect the collectible biomass. For example, wheat represents 53.40% of annual production but 63.31% of annual collectible dry biomass; however, in the case of maize, although it represents 30.75% of annual production, finally, the contribution in collectible dry biomass is reduced to 16.69%.

Table 1. Calculated collectible dry biomass (C_B) from crop residues available in Kazakhstan.

Crops	C_P [1][2]		R_F [11]	A_F [11]	W_F [12][13][14]	C_B	
	10^6 ton/Year	%				10^6 ton/Year	%
Wheat	12.50	53.40	0.85	1.00	0.90	9.56	63.31
Rice	0.51	2.17	1.43	0.80	0.80	0.47	3.11
Maize	7.20	30.75	1.10	0.60	0.53	2.52	16.69
Barley	3.20	13.67	1.90	0.70	0.60	2.55	16.89
Total	23.41	100.00				15.10	100.00

2. Animal Waste

The amount of farm animal waste varies depending on the type of animal, feeding methods, size of animal body, type of breeding and population density for each location and keeping time at day or night [15]. Nevertheless, the modernization of the confined animals breeding systems is intensifying the generation of waste, which causes environmental problems due to the concentration and scale of the activity.

The most important branches of livestock breeding in Kazakhstan in 2021 are summarized in **Table 2** and include sheep and goats, cattle, poultry and horse breeding [16]. Poultry breeding is the main branch of livestock production (55.26%), as many regions of Kazakhstan have favorable natural conditions for the development of poultry farming. The next branch of livestock production is sheep and goat, which is especially developed in East Kazakhstan, Akmola, South Kazakhstan and several other areas, where pastures of different seasons are successfully combined, representing 31.21% of the animals considered in this research.

Table 2. Livestock breeding and potential waste production.

Livestock	Population		Dry Matter (D_i) (kg/Head and Day) [16]	Collection Efficiency (η_i) (%) [16]	Animal Waste Production (AW)		
	Number (Million) [17]	Percentage (%)			Dry Matter (ton/d)	Dry Matter (10^6 ton/Year)	Percentage (%)
Cattle	8.20	9.47	3.5	80	22,960.00	8.38	50.00
Sheep and goats	27.00	31.21	0.45	60	7290.00	2.66	15.87
Horses	3.50	4.04	4.9	60	10,290.00	3.76	22.43
Poultry	47.80	55.26	0.15	75	5377.50	1.96	11.70
Total	53.40	100.00			45,917.50	16.76	100.00

Taking into account branches of livestock breeding, the potential mass of animal waste (AWi), in tons of dry matter/day, for each animal species *I* has been calculated using Equation (2). In this expression, Ni is the population of animals of species *I*, Di is the dry dung output per day for animal species *I* and ηi is the collection efficiency of i animal dung and depends on the dimensions and duration of stock farming per year of manure used for every type of animal. The values of Di and ηi are included in **Table 2** from [18].

$$AW_i = N_i \times D_i \times \eta_i \quad (2)$$

From the overview given in **Table 2**, it can be concluded that the potential dry waste production from animals included in this research is estimated to be 45,917.50 ton/d. Although poultry are the main branch of livestock production, cattle could have the greatest potential to be used as a source of clean energy, producing 50% of this waste, with horses in second place with 22.43% of the total production. According to official statistics, the uncontrolled handling and storage of animal waste in Kazakhstan produces 22.1 million tons of liquid waste annually [19], contributing to air pollution with harmful substances to humans, plants and animals, as well as a loss of organic matter [18][19][20][21]. The livestock sector is a significant contributor to global human-induced GHG emissions. Thus, Food and Agriculture Organization (FAO) has reported a total of 8.1 Gton CO_2-eq in 2010 (using 298 and 34 as global warming potential for N_2O and CH_4 respectively) from livestock supply chains [22]. In these emissions, methane (CH_4), nitrous oxide (N_2O) and carbon dioxide (CO_2) account for about 50, 24 and 26 percent of the total, respectively.

3. Municipal Solid Waste

Municipal solid waste (MSW) is defined as waste consisting of everyday items, such as product packaging, grass clippings, furniture, clothing, bottles and cans, food scraps, newspapers and other fractions. This waste comes from homes, institutions, such as schools and hospitals, and commercial sources, such as restaurants and small businesses. In production terms, generally, the more urbanized the area is, the higher the amount of waste generation per capita; therefore, a positive correlation exists between increased welfare and the generation of municipal waste [19][20].

According to the Ministry of Energy of the Republic of Kazakhstan, at the end of 2021, the population of Kazakhstan was 19,169,550 people [23], which produced 5.5 million tons of MSW [13], resulting in a production rate of 0.84 kg/(person and day). An overview of the typical composition of MSW in the country shows that organic waste is the main component, representing 40% of the waste produced. A major percentage of combustible waste is also produced, representing ~54% of the total waste produced (paper and cardboard, plastic and textiles) [24].

The typical composition of MSW in Kazakhstan's cities is shown in **Table 3** [25], where organic waste, composed by food and landscaping wastes, is the main component, representing 46% of the waste produced. Five percent of the material is denoted as 'other' and mainly includes construction and demolition debris and hazardous waste.

Table 3. Typical composition of municipal solid wastes in Kazakhstan cities, %. Data for table from [24].

Waste Composition	Percentage (%)
Paper	15
Food wastes	25
Landscaping wastes	21
Plastic	16
Metals	7
Textiles	4
Glass	7
Other	5

According to the Ministry of Energy of the Republic of Kazakhstan [26], in 2021, 9% of MSW was recycled, resulting in a disposal rate of 91% of MSW produced [27]. Consequently, more than 1000 hectares of land are occupied by this waste in the country, 98% of which is unsuitable and represents a potential hazard [27]. As a result, analysis of the existing state of accumulation of MSW in Kazakhstan shows that municipal waste management is one of the country's most significant environmental problems, so it is necessary to improve the waste management system and the application of advanced methods based on circular economy principles. This is further supported by the fact that it is planned by 2030 to increase the share of recycling to 40% [27].

4. Potential Inventories of Residual Biomass

The residual biomass inventory from the different categories of biomass production included in this research has shown that Kazakhstan currently has a sustainable annual production of 37.26×10^6 tons of residual biomass, which is capable of producing energy.

The highest residual biomass production came from animal residues, closed followed by agricultural waste; in fact, both residues contribute 85.51% of the country's biomass production. Finally, although urban waste represents only 14.49% of total production (5.5×10^6 ton/year), the foreseeable increase in population and the rate of generation of waste in the country could suggest an increase of this fraction in coming years; in fact, the annual increase of population in the last year was 1.55% [23].

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