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ORIGINAL ARTICLE

Potential for the production of biofuels from agricultural waste, livestock, and slaughterhouse waste in Golestan province, Iran

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Abstract
The causes of global warming and the opposite solutions are among the issues discussed in scientific societies around the world. Also, one of the best options to take advantage of the huge potential of biomass is to use energy from biomass sources such as biogas. Biogas can be produced from anaerobic fermentation of organic waste, agricultural waste, and animal waste. The aim of this study was to investigate the production capacity of biofuels in Golestan province from agricultural crop residues as well as animal wastes including animal and poultry manures and slaughterhouse wastes. The results of research in Golestan province showed that 339.63 million m^3 can be produced annually from agricultural crop residues, 103.13–353.16 million m^3 from animal manure and poultry manure, and 362.61 million m^3 of slaughterhouse waste, respectively. Finally, a total of 2085.35 million kWh of electricity can be generated per year. The results of this study could be the beginning of further research and help to take a proper approach to government policies in the field of renewable energy.

Keywords Electricity generation · Biogas · Waste · Waste management · Biofuels · Agriculture waste · Animal waste

Nomenclature

$\mathbf{EC_{biogas}}$	Calorific value in biogas
m_{biogas}	Produced biogas
ε	The overall efficiency of converting biogas to electricity
M	The total amount of waste collected
$\boldsymbol{fc}$	Percentage of waste collected
TS	Ratio of solids content of total waste
EB_{TS}	The amount of biogas produced per kilogram of solid matter

1 Introduction

The declining fossil fuel resources, along with their increasing use, have raised growing concerns about greenhouse gas (GHG) emissions and global warming. The increase in CO2 levels, which is associated with the burning of fossil fuel sources, has been identified as more than 409 ppm [1, 2], which contributes to global warming [3]. Due to the increasing energy consumption, all countries in the world are facing the problem of energy supply. The limitation of nonrenewable energy sources such as oil and gas and the pollution caused by their consumption, which has many environmental effects, are among the problems facing all human societies [4].

The close relationship between economics and the environment has led to the development of new approaches in various fields, one of which is the issue of green economy. Among the goals of the green economy are reducing greenhouse gases, protecting natural resources, and achieving social and individual justice. In fact, green economy is a type of economy in which economic growth and development is based on the ecological balance of the environment in order to achieve the two goals of economic development and protection of natural resources at the same time; since the reduction of greenhouse gases is one of the most important goals of the green economy, the use of renewable energy can be a good option [5].

Among the advantages of using renewable energy are the reduction of greenhouse gases and the reduction of risks due to the increase in the price of fossil fuels [6]. In summary,

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Table 1 General properties of biogas [12]

Composition	55–70% methane (CH_4) 30–45% carbon dioxide (CO_2) Traces of other gases
Energy content	6.0–6.5 kWh m^{-3}
Fuel equivalent	0.60–0.65 L oil/m^3 biogas
Explosion limits	6–12% biogas in air
Ignition temperature	650–750 C (with the abovementioned methane content)
Critical pressure	75–89 bar
Critical temperature	−82.5 C
Normal density	1.2 kg m^{-3}
Smell	Bad eggs (the smell of desulfurized biogas is hardly noticeable)
Molar mass	16.043 kg $kmol^{-1}$

three of the benefits of renewable energy are the following: renewable energy sources have long life and natural cycles and, unlike nonrenewable energy sources, such as fossil fuels, are not finite and this ensures the continuation of energy consumption for future generations; renewable energy sources, especially wind and solar energy, due to their abundance and suitable geographical facilities, have significant capabilities in energy production and their use can save fossil fuel consumption; and unique use of fossil fuel power plants will create a focus on energy production areas, while renewable energy sources can easily be used to generate energy in any location with suitable geographical conditions. This leads to decentralized energy production in sparsely populated areas such as villages [4].

The development of renewable energy is an important part of global energy policy to reduce greenhouse gas (GHG) emissions from fossil fuels [7]. Organic wastes such as industrial wastes, municipal sewage sludge, solid wastes, agricultural wastes and poultry wastes, and fertilizers have the potential to be used to produce bioenergy [8]. There are several technologies and processes used in the extraction of bioenergy from biowaste, such as gasification, liquefaction, pyrolysis, anaerobic digestion, alcoholic fermentation, photobiological hydrogen production, sterilization, and fuel cell microbial photosynthesis. These technologies create the reuse of biowaste to produce energy and reduce their environmental burden [9].

Biomass is a promising source of renewable energy that can be used to produce biofuels, green electricity, and heat [10]. One of the best options to take advantage of the huge potential of biomass is to use energy from biomass sources such as biogas. Biogas can be produced from anaerobic

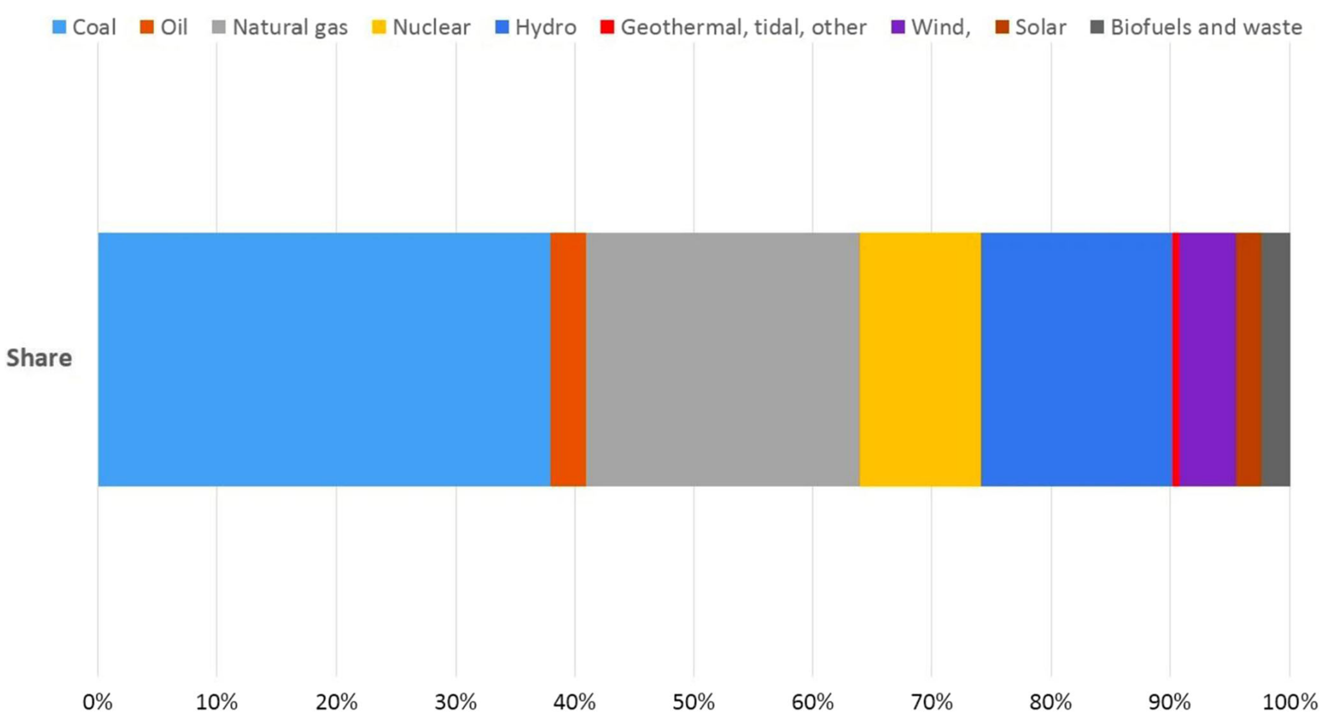

Fig 1 World gross electricity production, by source 2018 [22]

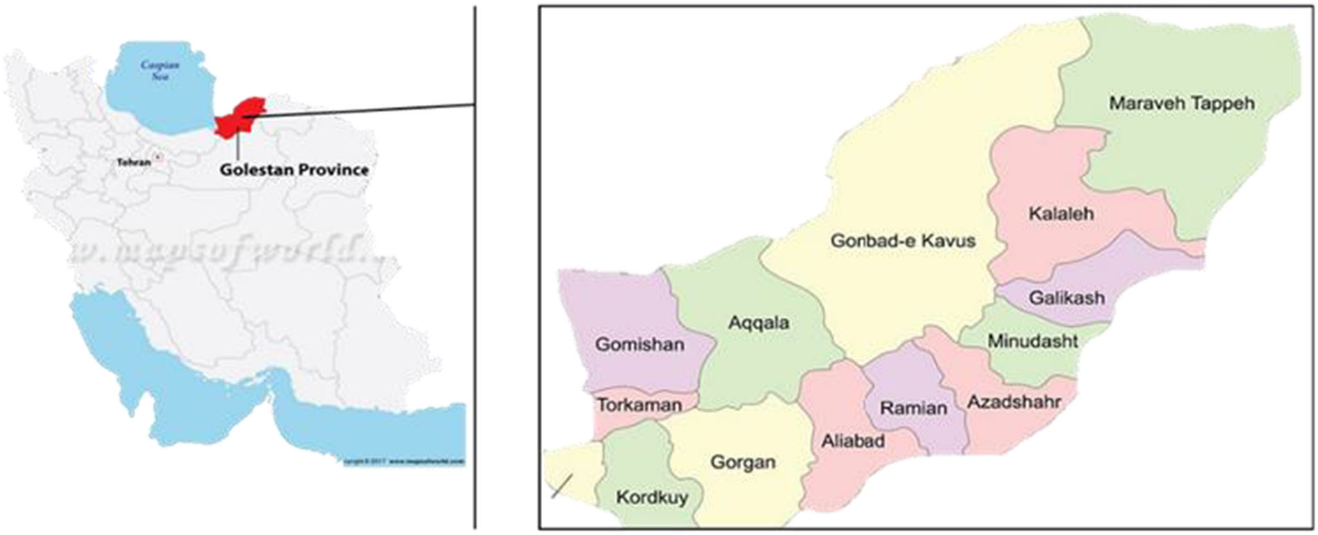

Fig. 2 Location of Golestan province in Iran

fermentation of organic waste, agricultural waste, and animal waste [11]. Biogas consists of an average of 65 to 70% methane gas and 30 to 45% CO_2 and very small amounts of other gases (H_2S, N_2, and H_2), which typically have a calorific value of 21–24 MJ.m^{-3} (Table 1) [13, 14]. Biomass, which is often organic waste, is commonly used around the globe to produce methane to convert it into energy. In recent years, the possible use of anaerobic digestion to produce bio-based products such as organic acids has been considered [15, 16]. Recently, the use of these materials for nonrenewable in the food industry for the production of biogas has been considered by scientists and governments. According to research, anaerobic digestion is the only fraction of the total potential energy that can be generated based on the amount of organic waste produced. One of the limitations of using anaerobic digestion to produce energy or chemicals is the lignocellulosic properties of different types of organic waste (e.g., agricultural residues) [16]. Lignocellulosic biomass, characterized by lignin, cellulose, and hemicellulose, is slowly biodegradable, which has so far limited its use as a raw material for anaerobic digesters. Many studies on the use of lignocellulosic biomass for fermentation purposes have pre-treated the raw materials before the fermentation stage [17]. The process of anaerobic digestion involves the decomposition and stabilization of complex organic matter by a group of microorganisms that lead to energy-rich biogas [18, 19].

Biogas production from biowaste is an alternative source of fuel in developing countries [20]. However, there are various obstacles in the implementation of this approach, for example, the main obstacles in the production of renewable energy are problems of policy, finance, technology, and lack of interest from people and governments [21].

According to Fig. 1, the share of biofuels from waste in electricity generation for the whole world in 2018 is approximately 2.4%. The share of renewable energy in the EU is expected to reach between 50 and 75% by 2050 [23]. It is also predicted that by 2030, the energy potential of fertilizers, grass, and straw will be about 1.2×10^3 to 2.3×10^3 PJ.Year^{-1} [24].

Today, of the total worldwide capacity for biogas (power plants with a capacity between 1.5 and 10,000 m^3.h^{-1} of crude gas), 15% is for biomass production [25]. The largest producers are Germany, Sweden, and the UK with an installation capacity of approximately 2 GW of biomass [25]. In 2018, for example, Germany generated 22.6% of the 224.7 billion kWh of electricity generated from renewable energy sources from biomass sources [26]. Research in Sudan also shows that agricultural residues in the country could be a good option for domestic energy production and reducing imports. According to the results obtained in 2016, there are 11.2 million tons of agricultural residues in this country, which is equivalent to 154,121,769 GJ.kg^{-1} [27].

Table 2 The amount of agricultural products in Golestan provinces and residue to crop (RCR) ratio

Crop	Area (ha)	Product (ton)	RCR	Reference
Alfalfa	1419	15,622.9	0.15	[38]
Sugar beet	530	14,892	0.7	[43]
Wheat	368,020.2	1,310,004	1.75	[44]
Potato	5164.9	130,428	1	[44]
Rice	60,118.9	294,583.2	1.757	[45]
Barley	83,906.7	171,598.8	1.2	[45]
Apple	428.4	2520.07	0.5	[45]
Citrus	6235.62	106,444.69	0.5	[46]
Fodder corn	6035.5	209,904	2	[47]
Total	531,859.22	2,255,997.66		

Table 3 Gaseous biofuels conversion factors from different agricultural residues [38]

Crop	Biogas ($m^3.ton^{-1}$)	Biobutanol ($liters.ton^{-1}$)	Biohydrogen ($m^3.ton^{-1}$)
Alfalfa	200	140.68	10.78
Sugar beet	397	79.24	6.22
Wheat	270	98.35	7.52
Potato	338	71.89	5.39
Rice	240	103.29	7.69
Barley	300	96.81	7.42
Apple	228	51.69	3.72
Citrus	610	92.65	6.92
Fodder corn	200	117.25	9.11

Research has shown that using biofuels to generate electricity instead of fossil fuels can prevent the production of 4.42 megatons of CO2. Therefore, using biofuels to generate electricity and use it in cooking is one of the potential suggestions [28, 29].

According to the statistics available in the agricultural sector and natural resources, and the capacity of the agricultural sector in the production of biogas fuels, and the importance of renewable energy in the coming years, In this study, with the aim of producing biofuel using waste from the agricultural sector in order to produce green electricity, capacity measurement has been done in Golestan province. It is hoped that using the results of the present study, an effective step will be taken in the field of waste management and renewable energy production, because not paying attention to this issue in the long run can be harmful to the environment and a good job can be lost.

2 Potential of biofuels in Iran

Iran is a developing country rich in renewable and nonrenewable natural resources. Iran has the second largest oil reserves in the Middle East after Saudi Arabia. In addition, Iran has the second largest reserves of natural gas in the world [30]. However, Iran is also trying to increase the production of renewable energy due to the reduction of fossil fuel consumption [31].

Taghizadeh et al. (2017) in a feasibility study on biofuel production from citrus waste in Iran concluded that using citrus waste can be 27 million liters of ethanol alone, 79 million m^3 of methane, 84.9 million liters of bio-oil, and 17.8 tons of coal equivalent to $ 28.60 million. The ethanol produced can be used as a clean fuel. Their results show that due to the lack of conversion industries and the lack of suitable storage conditions for biofuel production, it is a good suggestion [32]. They have also conducted research on the biofuel production capacity of pistachio waste. According to their results, Iran, with 300,000 ha of cultivated area, can ideally produce 47.6 million liters of ethanol per year, which will create a lot of added value for farmers [33].

Extensive studies also show that the Middle East is one of the most important producers of dates and consequently date waste in the world. Fruit, leaves, and seeds of dates have high potential in the production of biofuels, which can be a very

Table 4 Golestan potential for producing gaseous biofuel from agricultural wastes

Crop	Waste production (ton)	Biogas (MCM)	Biobutanol (Ml)	Biohydrogen MCM	Total energy from biogas (GWh)
Alfalfa	820.20	0.16	0.12	0.10	0.33
Sugar beet	3648.54	1.45	0.29	0.25	2.90
Wheat	802,377.45	216.64	78.91	67.04	433.28
Potato	45,649.80	15.43	3.28	2.73	30.86
Rice	181,153.94	43.48	18.71	15.48	86.95
Barley	72,071.50	21.62	6.98	5.94	43.24
Apple	441.01	0.10	0.02	0.02	0.20
Citrus	18,627.82	11.36	1.73	1.43	22.73
Total					
Fodder corn	146,932.80	29.39	17.23	14.87	58.77
Total	1,271,723.06	339.63	127.27	107.87	679.27

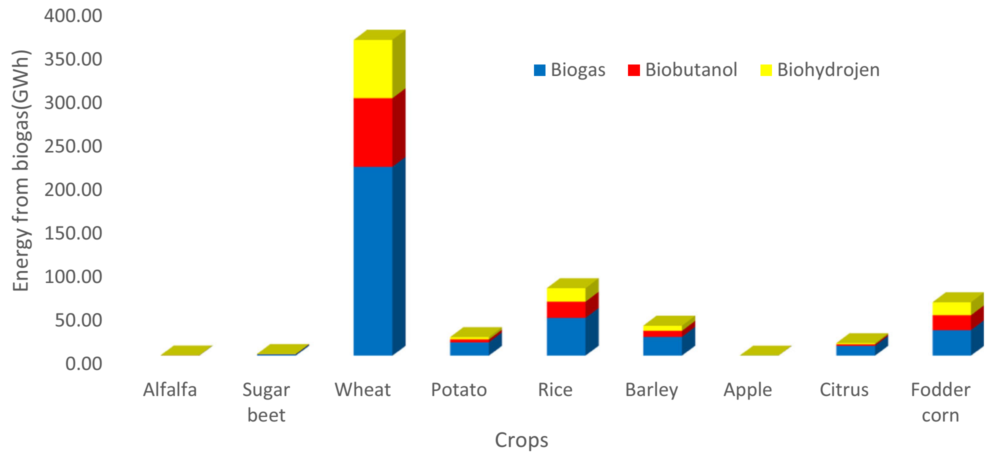

Fig. 3 Golestan potential for producing gaseous biofuel from agricultural wastes

good ground for the production of added value from agricultural waste. The results show that Egypt, Saudi Arabia, and Iran can produce 173.5, 438, and 401 million liters of ethanol per year from date waste, respectively [34], which requires special attention of governments to this issue. According to the obtained results, with the production of bioethanol from agricultural waste, 25% of the country's gasoline consumption can be provided [35], and for this reason, biomass can play a key role in the country's economy in the future.

Due to the diversity of climate and cultivation of various products, Iran is one of the top 5 countries in the production of 20 agricultural products and 30% of it becomes waste [36]. Wheat, corn, and barley are among the grain products that are potentially produced in Iran. Other products such as dates, pistachios, grapes, citrus, cotton, sugarcane, and sugar beet are other products that are grown in Iran. Their potential for biogas and biodiesel production has been investigated. According to the results of the research, the production potential of biogas, biobutanol, and biohydrogen from agricultural waste in Iran is 6542.65 m^3, 2443.779 million liters, and 2082.02 m^3, respectively, which produces a total of 13,085.29 GWh of energy.

But apart from the agricultural sector, there is also a large capacity for biomass production in the livestock sector, and due to the growing demand for meat and dairy, the livestock sector can be a good platform. In the slaughterhouse sector, 20,322.79 million m^3 of biogas can be produced using livestock waste, which is equivalent to 36,581.02 GWh.year^{-1}. Also, using livestock waste such as cattle, camels, buffaloes, goats, and sheep, an average of 5761.92 million m^3 of biogas can be produced annually. Given the capacity of the poultry sector, this sector can also produce an average of 2265.99 million m^3 of biogas per year [37].

Oilseeds are very important products in biodiesel production. Among those that are potentially grown in Iran are sesame, sunflower, soybean, rapeseed, cotton, olive, safflower, almond, walnut, and hazelnut. Researches show that ideally, only 35% of these products can produce 346.42 million liters of biodiesel per year, which can save 0.32 GL of diesel per year [38].

Our studies have shown that there is a high capacity in some areas. For example, Khuzestan province is considered one of the agricultural hubs despite many refineries. Researches have shown that 1030 million m^3 of slaughterhouse waste, 77 million m^3 of poultry manure, 303 million m^3 of animal manure, and 826 million m^3 of biogas agricultural residues can be produced annually. Using this volume of biofuels, 108 × 40 kWh of electricity can be generated annually [39]. Also, in this province, 11,624 MW of electricity can be generated annually by using municipal solid waste [40]. But biogas production and its growth have different obstacles in different sectors such as legislation, finance, research, government support, training, and working group that need planning and attention [40].

3 Potential of biofuels in Golestan

Golestan province is located in the northern part of the country, bordered by Turkmenistan to the north, Semnan province

Table 5 The average amount of livestock/poultry waste based on body weight [51]

Livestock	Body weight (kg)	Manure (kg/day)	Rumen content (kg/day)	Blood (kg/day)
Buffaloes, cattle, and camel	250	22.5	30	21
Goats and sheep	40	1.6	10	1.2
Poultry	1.5	0.045		

Table 6 Efficiency of biogas production from different sources

.Different substrates	TS (%)	Biogas (m^3kg^{-1} of TS)
Poultry	10–29	0.3–0.8
Sheep	18–25	0.3–0.4
Cattle	25–30	0.6–0.8
Rumen content	12–16	0.3–0.6
Blood	18	0.3–0.6

to the south, North Khorasan province to the east, and Mazandaran province and the Caspian Sea to the west (Fig. 2).

Out of 13 known climates in the world, Golestan province has 8 climates. This province has 14 township, 27 districts, 33 cities, 60 rural district, and 1049 villages. The area of the province is 20,438 km^2, which includes 1.3% of the total area of the country. There are 1,868,819 people living in this province, of which 53% are urban and 47% are rural [41].

This province, with 556 thousand hectares of arable land, 30 thousand ha of gardens, 911 poultry units, 482 thousand ha of forests, 862 thousand ha of pastures, and access to 110 km of the Caspian Sea coast, is responsible for 5% of the country's agricultural production. The agricultural sector accounts for 38% of the province's net employment. Golestan province is one of the agricultural hubs in the country due to its large rural population and fertile lands, so that it ranks first to fourth in cultivating 15 crops in the country. In soybean and rapeseed cultivation with 60.3 and 34%, respectively, is in the first place, and in wheat, with 10%, barley with 7.1%, and sunflower with 23% is in the second place [42].

3.1 Biofuels potential from agricultural wastes

Table 2 shows the area under cultivation and the amount of production of different agricultural products in the province. In order to obtain a realistic method of gas fuel capacity in the province, coefficients for different crops have been considered. Also, to prevent soil erosion, only 35% of waste products were considered for the production of biofuels [38].

According to Table 2, 2,255,997.66 tons of different crops have been cultivated in 531,859.22 ha of the province's lands, of which wheat has the highest amount with 1,310,004 tons. In this research, the coefficients of Table 3 have been considered to obtain the amount of biofuels from different products. Also, among the various gaseous fuels, biogas, biobutanol, and biohydrogen, which are used for different purposes, have been considered.

According to Table 4, using agricultural waste in this province can annually produce 339.63 million m^3 of biogas, 127.27 million liters of biobutanol, and 107.87 million m^3 of biohydrogen. According to Fig. 3, wheat, rice, and fodder corn have the ability to produce the most biofuels.

Biofuels are used in a variety of fields, including transportation, building heating, industry, and electricity generation. For example, due to increasing air pollution in large cities, biofuels can be used for public transport [48]. According to the results obtained in Table 4, assuming the extraction of energy equivalent to 2 kWh m^3 from biogas produced [49], up to 679.27 GWh of energy can be extracted from agricultural waste, which can be used in agriculture. For example, considering that the input energy per hectare of wheat cultivation for irrigated cultivation is equal to 0.017 $GWh.ha^{-1}$ [49], it is possible to provide the required energy for 39.95 thousand ha of wheat fields from renewable energy. Biohydrogen is also used in the production of ammonia and hydrogen peroxide [12]. Both are used for agricultural products and such wastes of the agricultural sector become valuable and useful materials.

3.2 Biofuels potential from livestock

Apart from the agricultural sector, the livestock sector can also have potential for biogas production. Livestock waste and slaughterhouse waste are materials that can be used in the production of biofuels [39]. Lack of proper management in this sector can cause damage to the environment and food health and cause social problems. Therefore, the management of this sector will both prevent these losses and create a platform for the production of added value from waste.

Golestan province with 911 poultry farms with a share of 5.09% is in the fifth place in the number of poultry farms in the country [50]. The province also has 470 industrial livestock farms and 22,580 sheep farms. With 667,000 ha of arable land and 30,000 ha of orchards, the province has a very high

Table 7 Biogas waste and fertilizer waste from different animals

Animal type	Sheep	Goat	Cow and calf			Buffalo	Camel
			Purebred	Hybrid	Native		
Number of animals (unit: thousand)	1179.551	210.547	15.305	56.065	69.328	2.1	7.5
Manure (Mt $year^{-1}$)	0.69	0.12	0.13	0.46	0.57	0.02	0.06
Biogas (million m^3 $year^{-1}$)	8.96	1.60	9.43	34.53	42.70	1.29	4.62

Table 8 Poultry production in Golestan province

Type	Capacity (thousand head)	Mature (Mt year^{-1})	Biogas (million m^3 year^{-1})
Broiler	90,563	1.49	341.65
Layer	2326	0.04	8.77
Broiler parent stock	90.039	0.00	0.34
Laying pullet	636.557	0.01	2.40
Total	600,661.1	9.87	353.16

potential for producing fodder for livestock. Also, Turkmen Sahara region has a very suitable capacity for camel breeding. Due to these statistics and the traditional nature of a large part of the province's livestock, by investing in this sector, this province has the ability to increase livestock breeding. Of course, the capacity of the red meat production sector in the province is 29,300 tons, which is ranked 11th in the country. Waste from livestock and animal rumen waste after slaughter has the capacity to produce biofuels using biogas reactors.

In order to calculate the amount of rumen and blood content, the statistics presented in slaughterhouses in Golestan province in 1396 were used. The amount of blood and rumen content of slaughter is proportional to the weight and age of the animal. Therefore, in this study, the amount of blood available was considered equal to 8.4% of the weight of large livestock (cattle, camels and buffaloes) and 3% of the weight of small livestock (sheep and goats) [51]. Also, ruminal weight (kg) was assumed to be 12% of body weight for large animals and 25% of body weight for small animals [52]. In this study, the average amount of feces was calculated based on the weight of livestock and poultry. Table 5 shows the average feces produced by livestock and poultry based on body weight.

The amount of biogas produced from animal and poultry waste depends on factors such as the type of animal feed, body weight, and the amount of solids in animal waste [53].

Theoretically, the amount of biogas production from animal waste can be calculated using Eq. 1:

$$Biogas\ potentioal = M*fc*TS*EB_{TS} \quad (1)$$

In this equation, M represents the amount of total waste collected, TS shows the ratio of the amount of solid matter from the total waste, fc represents the percentage of collectible waste, and ET represents the amount of biogas produced per kilogram of solid matter [52].

Table 6 shows the efficiency of biogas production from different sources.

In the present study, the TS rate was 25% for large and small cattle and 29% for poultry. Also, EB_{TS} for large, small, and poultry were 0.6, 0.4, and 0.8 kg^{-1}TS, respectively [51–53]. In addition, since in the ideal state, it is not possible to collect all the waste, so in this study, part of the amount of waste was considered a source of biogas production. FC levels were assumed to be 50% for large livestock, 13% for small livestock, and 99% for poultry, respectively.

In order to calculate the amount of biogas from blood and rumen lesions, it was assumed that all these lesions are transferred to the plant biogas without loss of moisture. The amount of biogas produced for blood and rumen was equal to 0.3 m^3.kg^{-1} of fresh waste [52, 53]. Tables 7 and 8 show the amount of animal waste as well as the potential of biogas extractable from animal and animal wastes in Golestan province.

The data in Table 7 show that the livestock sector has a good capacity. Of the 2.05 million tons of waste collected, 103.13 million m^3 of biogas is produced. Of course, the sum of this section with the poultry section (Table 8) shows a very high potential in the production of biogas from livestock and poultry waste.

According to Table 8, 353.16 million tons of biogas can be produced annually from poultry waste. By using this biofuel to heat poultry houses, gross profit can be reduced and exploitation can be increased.

But apart from the livestock and poultry waste sector, the slaughterhouse waste sector can also be used as raw material

Table 9 Livestock slaughter statistics in Golestan slaughterhouses

Type of animal	Number of animals	Blood (Mt year^{-1})	Biogas (million m^3 year^{-1})	Rumen (Mt year^{-1})	Biogas (million m^3 year^{-1})
Sheep	210,705	0.09	27.69	0.77	230.72
Goat	18,110	0.01	2.38	0.07	19.83
Cow and buffalo	14,280	0.11	32.84	0.16	46.91
Camel	402	0.00	0.92	0.00	1.32
Total	243,497	0.21	63.83	1.00	298.78

Table 10 Estimation of methane content, electricity generated, and potential heat value generated from agricultural and livestock waste

waste	Biogas (million m^3)	CH4	Heating value (10^9)	Electricity (kWh $year^{-1}$)
Slaughtered animals and poultry	362.61	217.57	6.66	652,698,621
Poultry waste	353.16	211.90	6.48	635,695,693.6
Animal waste	103.13	59.77	1.83	185,630,037.1
Agricultural residue	339.63	135.852	4.16	611,334,000
Total	1158.53	625.08	19.13	2,085,358,352

for biogas production. The data for this section are shown in Table 9.

According to this table, the sheep slaughter waste section has the highest capacity for biogas production and the camel has the lowest capacity for biogas production. From the total collected blood (0.21 million tons per year) 63.83 million m^3 and from the total collected rumen (1 million tons per year) 298.78 million m^3 of biogas can be produced. In total, the slaughterhouse sector has an annual production capacity of approximately 360 million m^3 of biogas.

3.3 Electricity potential from biogas

In various studies, the percentage of biogas produced from animal manures has depended on the type of fertilizer. For example, for cattle and poultry manure, this percentage is estimated at 50 to 70%. Also for sheep manure, this percentage is between 40 and 50. In the present study, 60, 60, and 45% were considered for cattle, poultry, and sheep manure, respectively [54, 55]. Also, the percentage of methane biogas obtained from slaughterhouses (rumen and blood) was assumed to be 60%. Also, in the researches, the average percentage of methane for organic wastes has been estimated between 40 and 75%, which in this research was considered 40% to present a real model [56]. Also, the heat conversion efficiency was calculated to calculate the calorific value of methane produced equal to 85% and the calorific value of 36 $MJ.m^{-3}$. The potential of the amount of electricity generated from biogas was calculated according to Eq. 2 according to the following [52]:

$$\text{Electric power genaration}_{biogas} = EC_{biogas} \times m_{biogas} \times \varepsilon \quad (2)$$

In this regard, EC_{biogas} is the calorific value in biogas ($kWh.m^{-3}$), m_{biogas} is the amount of biogas produced per year ($m^3.year^{-1}$), and ε (%) is the overall efficiency of converting biogas to electricity. The amount of EC_{biogas} was assumed to be 6 $kWh.m^{-3}$. Conversion efficiencies of 30% and ε for power plants with large turbine systems and small generators are considered to be 35–42 and 25%, respectively [52].

Table 10 shows the estimation of methane, electricity generated, and potential heat value generated from agricultural waste, animal waste, and also biogas from the slaughterhouse waste of Golestan province.

According to Fig. 4, the highest percentage of electricity production is for chicken and slaughterhouse waste sections, each with 31%. This shows that the livestock sector has a very high potential for biogas production. This sector alone can produce 1288.394315 million $kWh.year^{-1}$ of green electricity per year. The agricultural sector is also able to generate electricity with a very small difference compared to the livestock sector. This sector is able to generate 29% of electricity by producing 611.334 million $kWh.year^{-1}$.

Golestan province has consumed a total of 3043 million kW of electricity in 2016. According to Fig. 5, 467 million kW of this energy has been consumed for the agricultural sector and 487 million kW for the industrial sector.

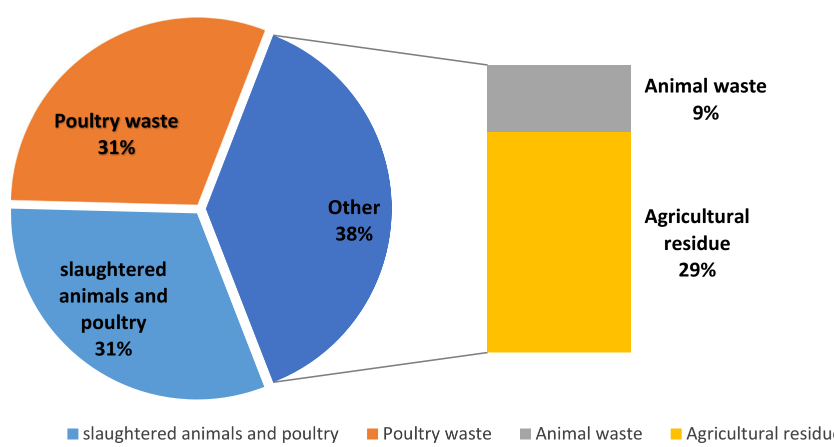

Fig. 4 Share of electricity generation for different sectors

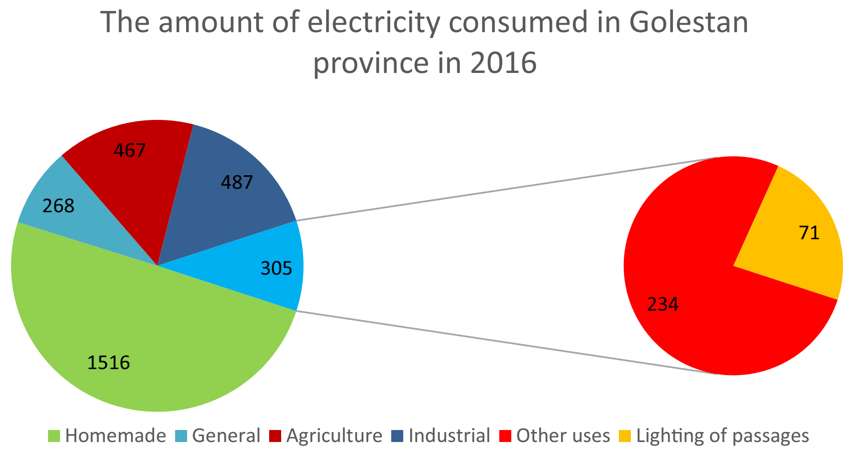

Fig. 5 The amount of electricity consumed in Golestan province in 2016

According to Fig. 5, electricity consumption in the home sector alone is 50% of the total electricity consumption in the province. According to the obtained data and Fig. 6, the generated green electricity can provide the energy needed by the domestic sector and the agricultural sector. This electricity can provide 69% of the total electricity consumption in the province. This indicates the very high and suitable capacity of this sector to supply electricity to the province. It is hoped that given these capacities, an effective step will be taken towards the use of clean energy.

4 Conclusion

Renewable energy is one of the most important sectors that are considered in many countries today. Countries' strategies in this area affect a number of factors, including food security, environmental protection, global warming, economic costs of production, and national security. Therefore, the issue of renewable energy is one of the favorite departments in the world's top universities and institutions in this field. This issue is also one of the most important issues in Iran due to the limitations of renewable energy and the nonresponse of the existing reserves forever. For this reason, in this study, the capacity of Golestan province as one of the leading provinces in the agricultural sector to produce biofuels has been considered.

In total, the province is able to produce 339.63 million m^3 of biogas per year in the agricultural sector, using the waste of some agricultural products. Also, livestock, poultry, and slaughterhouse waste can produce 103.13, 353.16, and 362.61 million m^3 of biogas, respectively. The use of fossil fuels to generate electricity is a common method in the world, but the environmental and geothermal effects have led to the production of this energy using renewable energy. Golestan province in total is able to generate 2085.53 million kWh of electricity annually, which can meet 69% of the province's electricity needs.

To achieve this ability to produce biofuels, various factors are involved, including government attention to this capacity, further research in the field of technology, government encouragement to producers, and the necessary training. According to the authors, the study of various technologies present, according to the existing fields, is one of the necessary needs to create a production environment in this province.

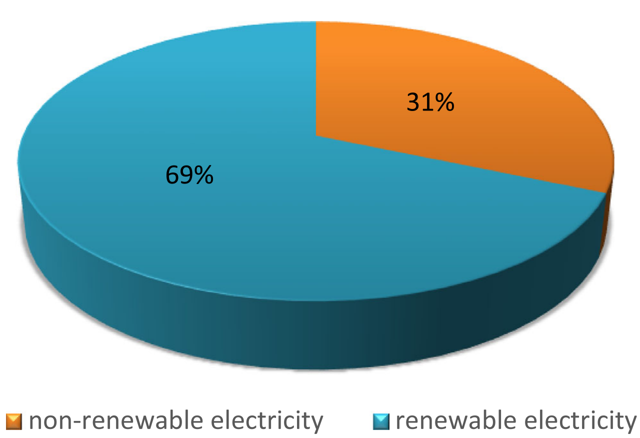

Fig. 6 Share of electricity generated from biomass in total electricity consumed

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