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FRIEDRICH EBERT STIFTUNG

The Climate Effect of Biomass And A Roadmap for Development of Bioenergy Projects in Jordan

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Table of Contents

List of Tables

List of Figures

Acronyms

a	Annum
(C/N)	Carbon to Nitrogen ratio
CH4	Methane
CHP	Combined heat and power
CO2	Carbon dioxide
CSTR	Continuously stirred tank reactor
d	Day
DM	Dry matter
eq	Equivalent
EDCO	Electricity Distribution Co
el	electrical
GHG	Greenhouse gas
HRT	Hydraulic retention time
IDECO	Irbid Distribution Electricity Company
JEDCO	Jordan Electricity Distribution Company
KTBL	Kuratorium für Technik und Bauwesen in der Landwirtschaft
kWh	Kilo Watt hour
L/a	Liter per annum
MW	Megawatt
MSW	Municipal solid waste
NERC	National Energy Research Center
RSS	Royal Scientific Society
SH	Slaughterhouse
t	Tonne
TS	Total Solid
th	Thermal
WSP	Wastewater Stabilization Ponds
WWTP	Wastewater treatment plant

1 Summary

The Royal Scientific Society (RSS) / National Energy Research Center (NERC) prepared this study in cooperation with Friedrich-Ebert-Stiftung. The study aims at guiding the government and different stakeholders to develop a strategy to protect the environment from the negative effect of the targeted types of biomass, through stocktaking, identifying potential and suggesting green technologies to treat the biomass and generate energy.
Through the study, a comprehensive assessment has been conducted for the annual amount of organic waste (Biomass) that is produced from several targeted sources in Jordan for 2018 as an inventory year. These types include:

- Animal manure.
- Slaughterhouse wastes.
- Peat from olive oil.
- Sludge from Waste Water Treatment Plants.

The annual amount of targeted biomass was obtained from the relevant authorities in Jordan through site visits and meetings.
The annual amount of biomass that was assessed for the targeted types of biomass was used for calculating the annual Greenhouse Gas (GHG) emissions depending on Intergovernmental Panel on Climate Change (IPCC) guidelines. The study illustrated that 627,929.2 t CO_2 equivalent (eq) of GHG was generated from the targeted types of biomass.
The study also assessed the potential of generating bioenergy from the targeted types of biomass depending on the obtained information for 2018. The total potential power generation as electricity by using biogas technology is around 37.02 Megawatt (MW) as CHP unit in Biogas plants, which can generate about 100,454.7 MWh/a as electrical energy and 612,107.4 MWH as thermal energy from Olive Oil Peat.
The potential of producing biodiesel was calculated from the peat from olive oil, because of its high oily content. The annual expected amount of biodiesel that can be generated from the peat from olive oil in 2018 is 28,253,184 liter of biodiesel. With the ability to install biodiesel production plants and facilities at capacity of 14,715.2 liter per hour. Moreover, the study provides a roadmap to treat the annual amounts of the targeted types of biomass by suggesting different green technologies that can generate different products.
The study also mentions the possibility to use the peat from olive oil as a source of thermal energy.
Recommendations and guidelines for the local authority or experts are also provided

2 Introduction

The world generates around 2.0 billion tons of municipal solid waste annually, with at least 33% of which is not managed in an environmental sound manner[1]. Referring to the same report, 44% of the waste component is organic and food residue, which has negative effects on the climate and environment.
Locally, organic waste consists mainly of waste from the municipalities, like animal manure, peat from olive oil, slaughterhouse waste and sewage sludge. Organic waste in Jordan is

[1] World Bank – Trends in Solid Waste Management.

generally sent to dumpsites/landfills or direct incineration for heating purposes in rural areas. Internationally, many organic waste treatment processes have been utilized, such as chemical treatment aimed at producing biofuels, and biological treatment (fermentation) to produce biogas. A complete organic waste treatment process is considered as the main ambition of many countries worldwide.
Jordan plans to reduce GHG emissions by 14% from different sectors by 2030[2], and increase the share of renewable energy to 10% by 2020[3]. Therefore, managing and utilizing bio waste will aid achieving both targets of reducing GHG emissions and used as an energy source. in addition to it contributing to the targeted Scenario and Priority Initiatives in the Sustainable Consumption and production strategy for Jordan[4].

Waste management is still inefficient in Jordan, especially for waste being produced in small and medium scale (such as animal manure and agricultural residue). Using the untreated bio-waste directly as fertilizer for agricultural activities and disposing of waste in open places are some of the negative manifestations of the handling organic waste. These problems are the result of the absence of polices and plans for managing and treating the different types of the generated organic wastes.

3 Study Implementing Body

RSS/NERC have implemented this study in fulfilment of its role in serving the Jordanian society.
RSS is the largest applied research institution, consultancy, and technical support service provider in Jordan, and functions as a regional leader in the fields of science and technology. RSS provides expert testing services via more than 38 specialized locally and internationally accredited laboratories and prides itself on offering both the public and private sectors a unique scientific resource and a wide range of project expertise. Supported by more than 500 scientists, researchers, technical support staff, highly skilled management and faculty, the RSS has always been recognized as a local, regional and international research and development hub.
NERC is a part of RSS has been established for the purposes of research, development, training in the fields of new and renewable energy. And raising the standards of energy use in the different sectors and to promote the utilization of renewable energy in Jordan.

4 Study Objectives

The study aims to help the government and different stakeholders to develop a strategy to protect the climate and the environment from the negative Effect of the targeted types of biomass by stocktaking, identifying potential and utilizing green technologies to treat the biomass and generate energy especially in urban areas.
Moreover, the study includes a roadmap to propose different technologies for treating the annual amounts of targeted biomass by using appropriate green technologies.

[2] Jordan Intended Nationally Determined Contribution (INDC)
[3] Jordan energy strategy 2020.
[4] National Strategy and Action Plan for Sustainable Consumption and Production in Jordan (2016 – 2025)

5 Study Preparation Phases

The study was implemented through two main phases namely; Data collection phase and data analysis.

5.1 Data Collection Phase

The data for the biomass from livestock breeding's, olive milling, wastewater treatment and slaughterhouses were collected from the following relevant authorities:

- Ministry of local Administration, for Municipal Slaughterhouses.
- Greater Amman Municipality Slaughterhouse.
- Ministry of Agriculture, for private slaughterhouses
- Ministry of Agriculture, for livestock breeding's slaughter sector.
- Jordan water companies (Miyahuna Water Company, Al-Yarmouk Water Company and Aqaba Water Company) for WWT sludge.
- General Syndicate of contemporary owners of olive producers for Peat from Olive Oil.

All the data was collected for the year 2018. The data was used to calculate the annual amount of GHG and to estimate the potential of bioenergy from each type of biomass.

5.1.1. Annual Production of Biomass

Livestock Breeding
According to the Ministry of Agricultural, in 2018 the total number of livestock counts was about 11,535,997 (Cows, Sheep and Poultry) distributed in governorates as detailed in table 1.

Governorate	Cows (Head)	Poultry (Head)*	Sheep (Head)
Irbid	6,420	306,876	333,096
Amman	7,633	3,522,865	839,397
Jarash	1,614	132,925	63,662
Ajloun	978	0	79,570
Al-Mafraq	5,915	1,769,344	992,880
Al-Zarqa	34,435	455,484	246,537
Madaba	1,082	278,700	252,290
Karak	1,185	374,615	721,962
Tafilah	167	31,830	215,202
Maan	116	21,700	267,340
Al-Aqabah	10	85,000	179,888

Al-Balqa	1,091	204,400	99,787
Total	**60,646**	**7,183,739**	**4,291,612**

Table 1: *Number of Livestock breeding Head (poultry, sheep and cows).*[5]

* The total number of poultry heads was calculated based on the capacity of the poultry farms in Jordan.

Facts about livestock breeding in Jordan:

– Based on the Ministry of Agriculture, in 2018 the total number of sheep and cow heads was 4,352,258, but the actual number was less than 4,352,258 by 1 million head from cows and sheeps according to the same Ministry.

The annual amount of manure was calculated based on the annual number of livestock breeding heads in 2018 as shown in table 3 below:

Type of manure	Amount of biomass
Poultry	2.4 (t/100 hens) per annum
Cow	30 (kg/ day)
Sheep	1.5 (kg / day)

Table 2: *Manure production factors.*[6]

By using the factors in table 3, the total annual amount of manure produced in 2018 was about **3,186,139.7** tons, distributed in different governorates as detailed in Table 3:

Governorate	Cows (t/a)	Poultry (t/a)	Sheep (t/a)
Irbid	70,299.0	7,365.0	182,370.1
Amman	83,581.4	84,548.8	459,569.8
Jarash	17,673.3	3,190.2	34,855.2
Ajloun	10,709.1	0.0	43,564.8
Al-Mafraq	64,769.3	42,464.3	543,601.6
Al-Zarqa	377,063.3	10,931.6	134,978.8
Madaba	11,847.9	6,688.8	138,128.8
Karak	12,975.8	8,990.8	395,274.2
Tafilah	1,828.7	763.9	117,823.1
Maan	1,270.2	520.8	146,368.7
Al-Aqabah	109.5	2,040.0	98,488.7

[5] Ministry of Agricultural 2018.
[6] Jordan – GIZ report: 4th report biogas roadmap Jordan 2010.

Al-Balqa	1,1946.5	4,905.6	54,633.6
Total	**664,073.7**	**172,409.7**	**2,349,657**

Table 3: *Distribution of amount of manure that was produced in Jordan, 2018.*

Facts about the manure in Jordan:

- 25% of poultry manure's content is wood shavings.
- The water content of the manure (moisture content) in winter is higher than in summer, because most of the farms are not well designed to prevent water leaks to the farms.

Sheep manure represents 73% of the total animal manure generated in the kingdom, followed by cows as demonstrated in Figure 1.

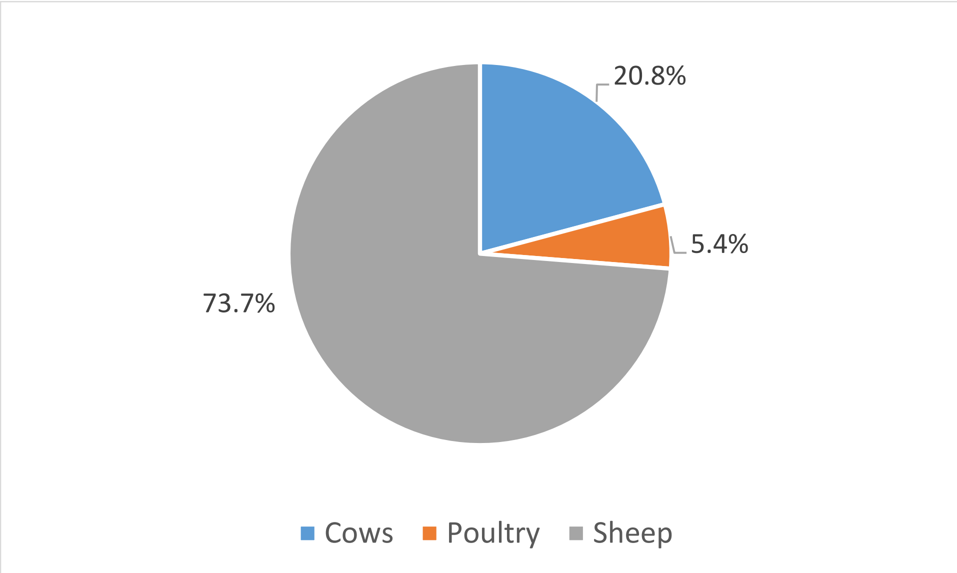

Figure 1: *Share of each type of animal manure in the total amount of manure in Jordan for 2018.*

Olive Oil Solid Residue

The olive oil industry is one of the major agricultural industries in Jordan. It produces olive oil seasonally, and Zibar (Liquid waste from olive oil Industry) as well as the Peat as by-products of the olive oil milling industry.

Zibar is the liquid that is produced within this industrial milling process and it is not targeted in this study.

The peat is the solid product from the olive oil industry, which is produced in huge amounts and can be used as fuel.

Facts about the olive oil industry and its by-products:

– Peat from olive oil was used in cement industry as a raw material to produce the clinker.
– Most of the produced olive peat were dried and used in direct incineration for heating in households.
– Each ton of olive pellets contains 35% of peat, 17% of oil and 48% of Zibar.[7]
– In 2018, each line for olive oil milling produced about 200 tons of peat.[4]
– Most of Olive oil plants/factories have more than milling line to produce oil from the olives.

Based on the facts and the mentioned data, the total annual amount of olive peat for 2018 was around **59,480** tons and distributed as shown in table 4 below:

Governorate	No of olive oil Plants[4]	No of olive oil production Lines[4]	Annual Amount of olive peat (tonne/a)
Irbid	48	107	21,870.8
Amman	10	22	4,496.8
Jarash	15	32	6,540.8
Ajloun	15	30	6,132
Al-Mafraq	12	27	5,518.8
Al-Zarqa	7	11	2,248.4
Al-Balqa	10	25	5,110
Madaba	6	14	2,861.6
Karak	5	12	2,452.8
Tafilah	2	3	613.2
Maan	4	7	1,430.8
Al-Aqabah	1	1	204.4
Total	**135**	**291**	**59,480.4**

Table 4: *Annual amount of olive peat in Jordan, 2018.*

Sludge from WWTPs

The third type of biomass that is targeted in this study is the sludge from wastewater treatment plants (WWTPs) in Jordan. WWTPs are under the supervision of the Jordan Water Authority and operated by three water companies:

– Miyahuna Water Company.
– Al-Yarmouk Water Company.
– Aqabah water Company.

[7] General Syndicate of contemporary owners of olive producers. 2018.

The annual amount of solid sludge produced in 2018 are illustrated in table 5 below:

Governorate	Name of WWTP	Sludge (T/a)
Al-Aqabah	Aqabah Mech.	2,782.7
	Aqabah W.S.P	1,902.7
Al-Balqa[6]	Salt	2,190.0
	Fuhis	357.7
	Tall-Mantah	167.3
	Baqa'	3,620.8
Al-Karak	AL-Lajjoun	297.0
	Mu'tah	293.5
	Karak	357.7
Al-Mafraq[9]	Elkader	0.0
	Mafraq	146.0
Tafilah	Tafilah	340.0
Al-Zarqa[8]	As-Samra	0.0
Amman[6]	Abu-Nusir	66.4
	AL-Jiza	68.5
	Wadi AL Seer	1,213.4
	South Amman	1,625.0
Irbid[9]	Irbid	2,903.4
	Wadi Arab	7,570.0
	Ramtha	1,204.2
	N.Shoneh	219.0
	Wadi-Shalala	0
	Wadi Hassan	280.0
	AL-Mansourah	49.9
Jarash[9]	Jarash	1,208.9
	AL-Marrda	1,252.0
Maan	Ma'an	632.9

[8] Miyahuna Water Company
[9] Al-Yarmouk Water Company

	Shobak	18.8
	Wadi-Mousa	719.5
Madaba	Madaba	711.8
Ajloun[9]	Kofranjeh	3,032.0
Total		**35,230.8**

***Table 5:** Annual amount of solid sludge that was produced from WWTPs in Jordan, 2018.*

Facts about the biomass from WWTPs:

– Part of the data for biomass generation from WWTPs were calculated based on the design capacity for the plant (just the stations under the management of Aqaba Water Company). The additional data is/was provided by the responsible water Companies.

– Wadi Al-Shalaleh and Al-Samrah WWTPs include a station for anaerobic treatment, so that the annual amount of untreated solid sludge is zero.

Slaughterhouse Waste

The fourth type of biomass that was targeted in the study is the slaughterhouse waste in Jordan. The slaughterhouses are under the responsibility of three authorities:

– Ministry of Agricultural for Poultry (private) slaughterhouses.

– Ministry of Local Administration for municipal slaughterhouses.

– Grater Amman Municipality has one slaughterhouse.

According to these Authorities the slaughterhouses distribution in 2018 can be summarized in table 6 below:

Governorate	Number of cows and sheep Slaughterhouses	Number of chicken Slaughterhouses
Irbid	4	0
Amman	1	4
Jarash	1	1
Ajloun	1	0
Al-Mafraq	1	2
Al-Zarqa	2	3
Madaba	1	0
Karak	1	0

Tafilah	1	0
Al-Balqa	4	1
Maan	1	0
Al-Aqabah	1	0
Total	**19**	**11**

Table 6: *Number of slaughterhouses in Jordan, 2018.*

Every head of livestock or poultry that is slaughtered produces blood, internal intestines and inorganic materials such as wool and feathers. The study evaluates the annual amount of internal intestines and blood that is produced from slaughtering (table 7).
The annual amount of bio-waste from the slaughterhouses was calculated upon the following bio-waste production factors:

Type of animal	Blood (litre)	Internal intestines (kg)
Cows	30	32
Sheep	4	2.5

Table 7: *Amount of organic waste that can produced from animal slaughters in Jordan[10].*

The average weight of each poultry in Jordan is about 1.5 kg[11], and produces 0.0905[10] kg of organic waste and 0.0275[12] litre of blood.
The annual amount of the organic waste and blood from slaughterhouses in Jordan are distributed by the governorates as shown in table 8 and 9 below:

Governorate	Poultry's Slaughtering organic waste (t/a)	cow's Slaughtering organic waste (t/a)	Sheep' s Slaughtering organic waste (t/a)
Irbid	0	297.76	96.1
Amman	6497.8	799.04	345.2
Jarash	8.1	116.8	36.5
Ajloun	0	35.04	9.1
Al-Mafraq	4,208.3	81.8	45.6
Al Zarqa	4,511.0	116.8	77.6

10 Ministry of local Administration, 2019
11 Assumed by RSS/NERC team.
12 Average numbers for more than 2 studies.

Madaba	0	11.7	31.9
Karak	0	58.4	91.3
Tafilah	0	23.4	22.8
Al-Balqa	0	106.8	72.1
Maan	0	0	0.0
Al-Aqabah	0	4608	33.8
Total	**15,225.1**	**1,652.0**	**862.0**

Table 8: *Annual amount of organic waste from slaughterhouses in 2018 in Jordan.*

Note: Maan Slaughterhouse did not operate in 2018.

Governorate	Poultry blood (liter/a)	Cows blood (liter/a)	Sheep blood (liter/a)
Irbid	0	279,150	153,780
Amman	1,866,217.4	749,100	552,280
Jarash	2339.3	109,500	58,400
Ajloun	0	32,850	14,600
Al-Mafraq	1,208,648.4	76,650	73,000
Al-Zarqa	1,295,593.1	109,500	124,100
Madaba	0	10,950	51,100
Karak	0	54,750	146,000
Tafilah	0	21,900	36,500
Al-Balqa	0	100,114.2	115,340
Maan	0	0	0
Al-Aqabah	0	4,320	54,020
Total	**4,372,798.2**	**1,548,784.2**	**1,379,120**

Table 9*: Annual amount of blood that was produced from slaughterhouses in 2018 in Jordan.*

Facts about the slaughterhouse industry in Jordan:

– The cow's and sheep slaughterhouses in Jordan are under the supervision of the Ministry of Local Administration.
– All the poultry slaughterhouses in Jordan are private and supervised by the Ministry of Agriculture.
– GAM has its own slaughterhouse, which is used for slaughtering cows, sheep and poultry.

– Aqaba Special Economic Zone Authority has its own slaughterhouses for cow and sheep as well
– All the organic waste that is produced from the slaughterhouses is sent to landfills and the blood for special liquid treatment facility in Al- Al Akeder Landfill.

The annual amount of biomass from the targeted sectors in 2018 illustrates that there is a high potential of bioenergy production in the most of the governorates in Jordan. The most potential of biomass production in Jordan can be seen in the manure of animals which represents about 96% from the total amount of biomass. Figure 2 below illustrates the share of each targeted type of biomass based on data from 2018:

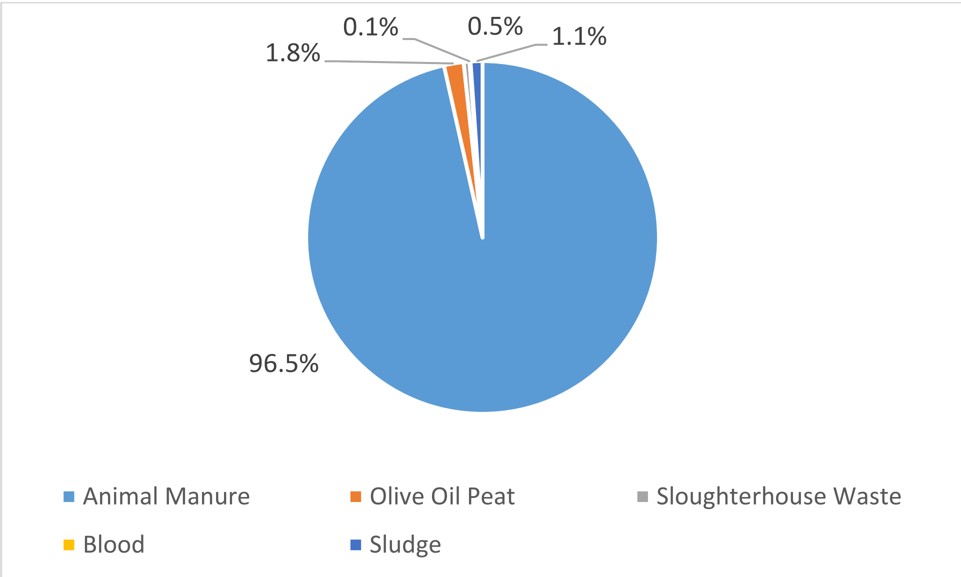

Figure 2: *Share of producing biomass from each targeted type of biomass, 2018.*

The second main potential for producing biomass offers the olive oil industry, which represents 1.8%.
Note: The share of blood in figure 3 above was calculated in tons per annum.
Each targeted type of biomass are disposed of through landfilling or dumping into open lands, so that these annual amounts of biomass that are produced have direct negative effects on the environment and climate through the emissions of GHG. The total amount of GHG emission that was emitted from the targeted biomass in 2018 were calculated in the second phase of the study.

5.2 Phase Two: Data Analysis

The second phase was conducted based on the results of phase one. All the annual amounts of biomass that were calculated in phase one were used for calculating the annual GHG emissions that were emitted in 2018 and the potential of bioenergy from each targeted type of biomass.

5.2.1. Annual Greenhouse Gas Emissions

Greenhouse gas is a gas that absorbs and emits radiant energy within the thermal infrared range and causes the greenhouse effect. The primary greenhouse gases in the earth's atmosphere are water vapour, carbon dioxide, methane, nitrous oxide and ozone.

This section provides information about the annual emission contribution of the targeted biomass that was emitted to the atmosphere.

The emission factors which were used in this study are derived from the IPCC guideline. The GHG emissions of biomass were calculated based on the emissions of methane gas (CH_4) from biomass which were converted to CO_2 eq emissions according to the equivalence “1 tn CH_4 = 25 tn CO_2 eq”.

Some of the emission factors for bio-waste are not included in the IPCC Guideline. The study depends on the Kuratorium für Technik und Bauwesen in der Landwirtschaft (KTBL) database for bio-waste emission factors to calculate the annual amount of GHG emission for the targeted bio-waste in 2018. Table 10 illustrates the emission factors that were used for calculating the 2018 GHG.

Type of bio-waste / biomass	Emission factor
Cows manure[13]	38 kg methane / head per year
Poultry manure[8]	0.02 kg methane / head per year
Sheep manure[8]	0.15 kg methane / head per year
peat from olive oil[14]	155 m3 Methane/ t VS
Sludge[9]	0.98 L Methane/ kg VS
Organic waste of Chicken[9]	0.57 L Methane/ kg VS
Organic waste[9] of cow and sheep	1.001 L Methane/ kg VS
Blood[15]	0.65 m^3 methane/ kg VS

Table 10: *Methane emission factors for the targeted biomass.*

Notes:

- KTBL database gives the Total Solid (TS) and Volatile Solid (VS) for each type of biomass in table 10.
- The standard density used for calculating the methane content in volume unit per annum is 0.656 kg /m^3 at (25 °C, 1 atm)[16].

[13] IPCC Guideline, 2006.
[14] KTBL Biomass database
[15] Feedstock’s for Anaerobic Digestion, Steffen, R, University of Agricultural Sciences Vienna, 1998.
[16] Gautam Dutt, MGM International, 2003.

The annual amount of the GHG emissions from the targeted biomass was calculated in tons CO_2 eq per annum. The distribution of the GHG for each governorate based on the type of the illustrated kinds of biomass:

GHG from Livestock Breeding

Table 11 shows the annual amount of GHG emission (**tonne** CO_2 **eq /a**) from the manure in the livestock breeding sector for 2018 in Jordan.

Governorate	cow manure (t CO_2 eq/a)	Poultry manure (t CO_2 eq/a)	Sheep manure (t CO_2 eq/a)
Irbid	6,099.0	230.2	1,249.1
Amman	11,053.9	2,642.1	3,147.7
Jarash	2,337.3	99.7	238.7
Ajloun	1,416.3	0.0	298.4
Al-Mafraq	8,565.9	1,327.0	3,723.3
Al-Zarqa	49,867.8	341.6	924.5
Madaba	1,566.9	209.0	946.1
Karak	1,716.1	281.0	2,707.4
Tafilah	241.8	23.9	807.0
Maan	168.0	16.3	1,002.5
Al-Aqabah	14.5	63.8	674.6
Al-Balqa	1,580.0	153.3	374.2
Total	**87,825.8**	**5,387.8**	**16,093.5**

Table 11: *GHG emission from manure in Jordan, 2018.*

The emissions from cows manure constituted about 80% of the total emissions, which is mainly due to the high organic content. The share of poultry manure emission in the total GHG emission of the manure in 2018 has the lowest share because of the low organic content. The diagram in figure 3 below illustrates the share of each type of manure and the total GHG emissions for Jordan in 2018.

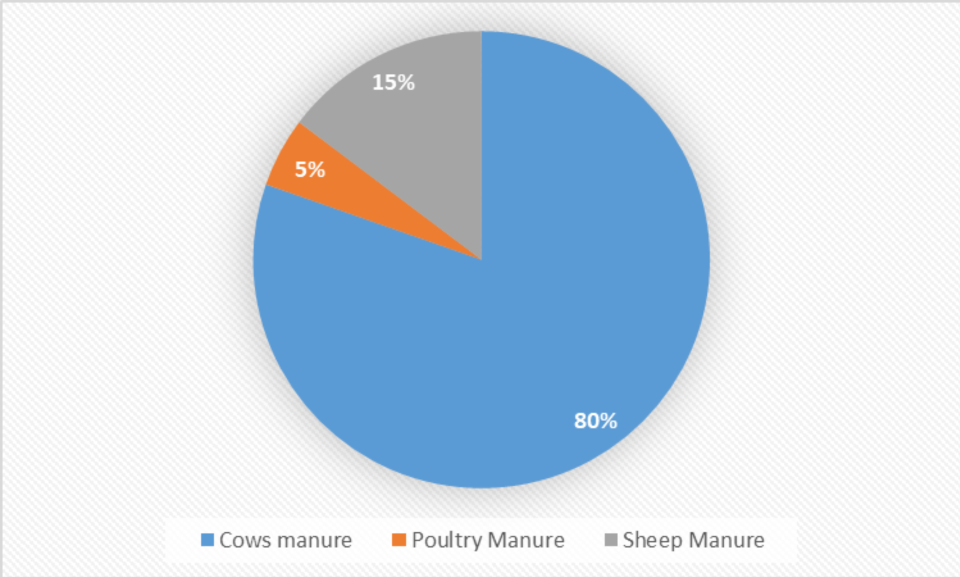

***Figure 3:** The share of different types of manure in the total GHG emission, 2018*

GHG from Olive Peat

Table 12 shows the annual amount of GHG emissions (**tonne CO_2 eq /a**) from olive peat resulting from the olive oil industry for Jordan in 2018.

Governorate	GHG (t CO_2 eq / a)
Irbid	48,387.3
Amman	9,948.8
Jarash	14,471.0
Ajloun	13,566.5
Al-Mafraq	12,209.9
Al-Zarqa	4,974.4
Al-Balqa	11,305.5
Madaba	6,331.1
Karak	5,426.6
Tafilah	1,356.7
Maan	3,165.5
Al-Aqabah	452.2
Total	**131,595.4**

***Table 12:** Annual GHG emission from solid peat in Jordan, 2018.*

Most of the emissions produced are in the Northern part of Jordan, which is due to the fact that the area houses the largest number of plants (Figure 4). Emissions are minimal at the Southern part.

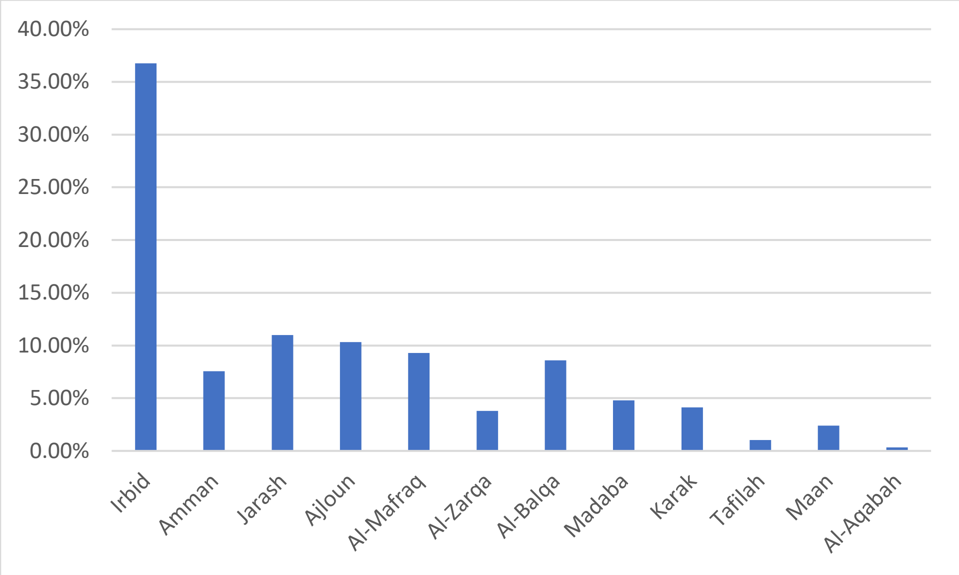

Figure 4: *Share of each governorate for GHG emission from olive peat, 2018.*

GHG from Slaughterhouses

Table 13 shows the annual amount of GHG emissions (**tonne CO_2 eq /a**) of organic solid waste and blood that was produced from slaughterhouses in 2018 in Jordan.

Governorate	Cows slaughtering (t CO_2 eq /a)	sheep slaughtering (t CO_2 eq /a)	Poultry slaughtering (t CO_2 eq /a)
Irbid	4,888.5	1,723.9	0
Amman	13,118.4	6,191.2	1,976.1
Jarash	1,917.6	654.7	2.5
Ajloun	575.3	163.7	0
Al-Mafraq	1,342.3	818.3	1,279.8
Al-Zarqa	1,917.6	1,391.2	1,371.9
Madaba	191.8	572.8	0
Karak	958.8	1,636.7	0
Tafilah	383.5	409.2	0
Al-Balqa	1,753.2	1,293.0	0
Maan	0.0	0.0	0

Al-Aqabah	75.7	605.6	0
Total	**27,122.7**	**15,460.2**	**4,630.3**

Table 13: *Annual GHG emission from animal slaughtering according to governorates, 2018.*

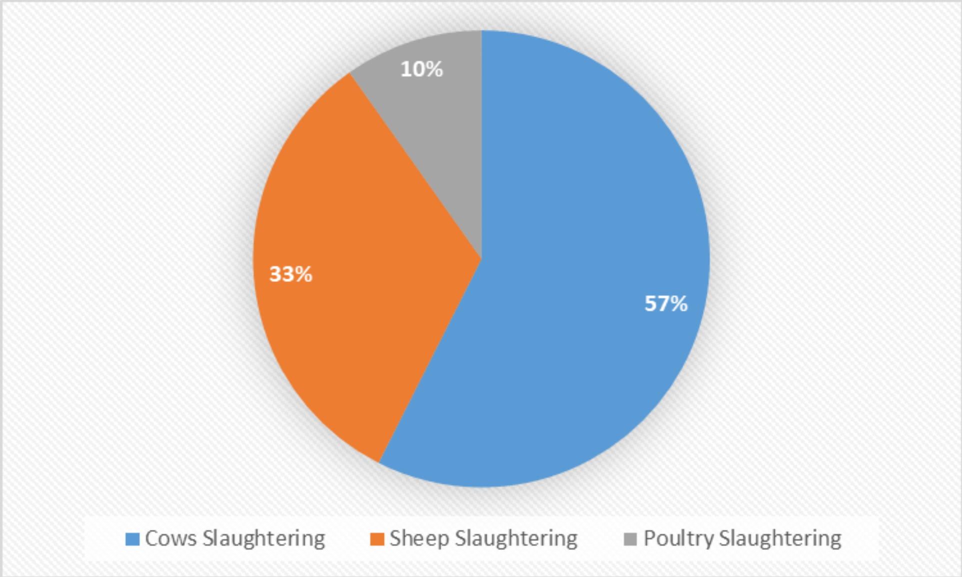

Figure 5: *Share of GHG from slaughtering for each type of animal in Jordan, 2018[17].*

Figure 5 shows that poultry slaughtering contributed least in GHG emissions while cows slaughtering has the highest share 57%.

GHG from WWTPs

Table 14 below shows the annual amount of GHG emission from dry sludge that was produced from WWTPs (**tonne CO_2 eq /a**) in 2018.

Governorate	GHG Emissions (t CO_2 eq /a)
Al-Aqabah	56,437.9
Al-Balqa	60,058.9
Karak	2,815.0
Al-Mafraq	1,384.0
Tafilah	3,222.9
Al-Zarqa	0.0
Amman	28,184.2

[17] Table 13

Irbid	115,897.8
Jarash	23,326.9
Maan	12,997.9
Madaba	6,746.9
Ajloun	28,741.1
Total	339,813.5

Table 14: *Annual GHG emission from sludge in WWTPs according to governorates, 2018.*

Figure 6 shows the GHG emissions from sludge of each governorate in Jordan. The share for Al Zarqa governorate in the total GHG from WWTPs is zero because the WWTP in Al-Zarqa (Al-Samra WWTP) treats the sludge by anaerobic treatment, while highest percentage is from Irbid governorate

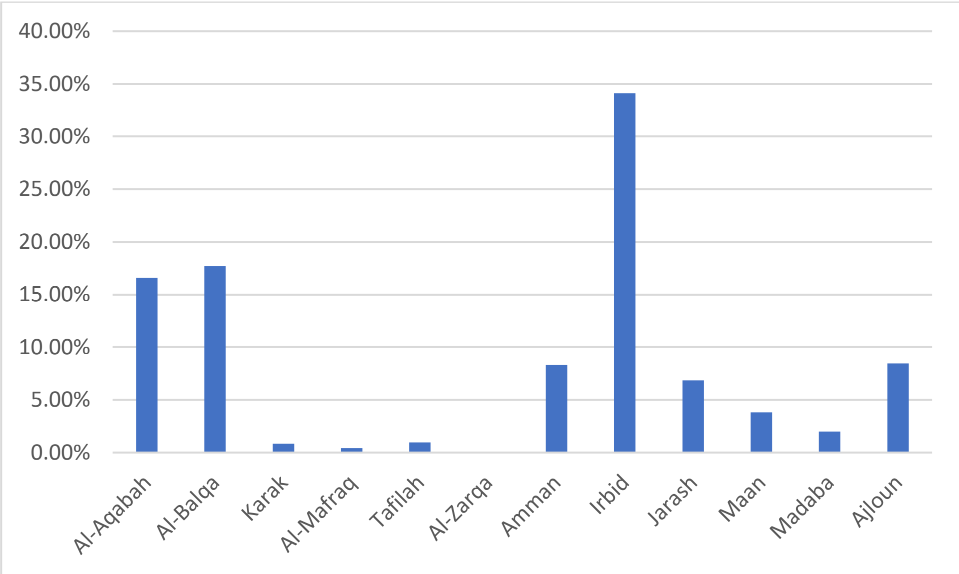

Figure 6: *share of GHG emission from sludge in each governorate in Jordan, 2018.*

6 Energy Solutions for Biomass

Treating organic waste in the Arab region is generally based on burying the bio-waste in landfills/ dumpsites, or direct incineration for heating purposes in rural areas. Internationally, many bio-waste treatment processes have been utilized to treat the organic component of biomass, such that the chemical treatment process, which is used to produce biofuels and biological treatment (fermentation) producing biogas. A comprehensive bio-waste treatment process is considered as the main ambition of many countries worldwide.

Jordan plans to reduce GHG emissions by 14% from different sectors by 2030[18], and increase the share of renewable energy to 10% by 2020[19]. Therefore, managing and utilizing bio waste will aid achieving both targets of reducing GHG emissions and used as an energy source. In addition to it contributing to the targeted Scenario and Priority Initiatives in the Sustainable Consumption and production strategy for Jordan

There are many green solutions for treating the organic component for the targeted bio-waste or biomass and reduce the GHG emission. This study will focus on the following feasible solutions:

- Anaerobic Fermentation Technology.
- Direct Incineration.
- Biodiesel Production.

6.1 Anaerobic Fermentation Technology

The anaerobic fermentation technology uses the anaerobic conditions to treat the biomass and produces a mixture of gases consisting of methane (**CH_4**) and Carob Dioxide (**CO_2**). This mixture of gases is called Biogas.

A biogas plant converts fermentable organic matter into a combustible gas. It works by subjecting the material to microbial decomposition in the absence of oxygen and with a source of heat, yielding finally, a mixture of methane and carbon dioxide, which is called Biogas. The whole process is called anaerobic fermentation and is known to occur naturally.

Biogas can be used directly for heating and lighting purposes, or in an engine driven generator to generate electricity. The effluent released from the biogas plant is an excellent fertilizer, which improves the physical properties of soil such as aeration, moisture-holding and water infiltration capacities.

The organic material needs to undergo certain processes to enable a stable biogas production and to avoid failure of the anaerobic fermentation process. The processes for anaerobic fermentation are detailed hereunder.

6.1.1. Preparation of Biomass

The digestion process is selected based on the substrate and its decisive properties such as solid concentration. Liquid waste such as sewage sludge with total solid concentrations between (4-15) % can be treated in a wet fermentation process.

If the liquid waste contains large size of biomass particles, pre-treatment process such as shredding and crushing is necessary. Subsequently, liquid waste and pre-treated organic waste can be mixed to obtain a desirable solid concentration which is (4-15)%.

Furthermore, biomass may need other pre-treatment depending on local conditions such as separation of impurities, e.g. plastics or sand.

[18] Jordan Intended Nationally Determined Contribution (INDC)
[19] Jordan energy strategy 2020.

6.1.2. Anaerobic Digester

The fermentation of the biomass under anaerobic conditions takes place in a digester. The common type of digester used for wet fermentation is a Continuously Stirred Tank Reactor (CSTR)(figure 7). CSTRs are characterized by regular mixing of the digester content through a mechanical agitator system. Efficiency of the biogas production is further enhanced through the installation of a heating system to keep the substrate at Mesophilic (around 35°C) or thermophilic (around 50°C) temperature ranges. Other factors such as the pH value and pressure need to be controlled as well to ensure a stable biogas production.

Figure 7: *CSTR digester*

6.1.3. Digestate and Biogas Utilization

Biogas produced in the digester must be purified. The purification steps from raw-biogas to pure biogas include dehydration followed by desulfurization. Dehydration is the removal of water which is contained in biogas. This step is required to increase the efficiency of the desulfurization as well as to avoid corrosion and damage of engine components. The amount of water or water vapour that can be assimilated by biogas depends on the gas temperature. Inside the digester biogas has a relative humidity of 100%. Dehydration can be achieved by condensation, adsorption or absorption drying.

Hydrogen sulphide is toxic and forms sulphuric acid in conjunction with water vapour. The chemical compound damages engine components and decreases the performance of subsequent cleaning stages. Desulfurization can be categorized in biological, chemical and physical procedures. Depending on the application, a rough- or fine desulfurization is necessary.

6.2 Direct Incineration

Direct combustion is a thermochemical technique in which the biomass is burned in the presence of oxygen. In this process, the photo synthetically stored chemical energy of the biomass will be converted into thermal energy.

The thermal energy produced can be used for heating or electricity generation in large scale burning.

6.3 Biodiesel Production

Biodiesel is an alternative fuel similar to conventional or 'fossil' diesel; it can be produced from straight vegetable oil, animal oil/fats, tallow and waste cooking oil.
Biodiesel is the name given to fuel for diesel engines created by the chemical conversion of biomass. The process of producing biodiesel is known as trans-esterification. This process is achieved by adding methanol to vegetable oil by the presence of catalyst and heat.
The catalyst is needed to increase the rate of the chemical reaction between the two components/elements, the catalyst used in the creation of biodiesel is an alkaline(this can be either Potassium Hydroxide or Sodium Hydroxide). As for heat, it is needed to reduce the bond strength between hydrocarbon elements allowing alcohol to break down the bonds between carbon, oxygen and hydrogen as shown in figure 8 below:

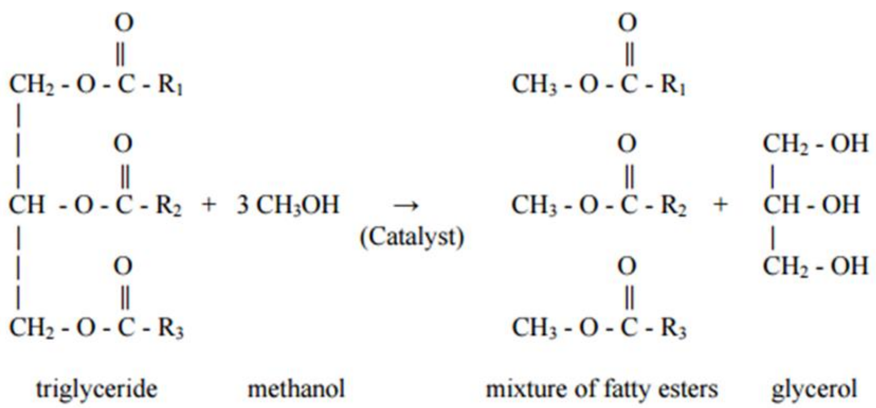

Figure 8: *Biodiesel Production Equation.*[20]

The product from the chemical reaction in figure 8 is an immiscible product consisting of glycerine and biodiesel. The biodiesel that is produced from this chemical reaction is not ready to be used directly, it needs additional treatment process aimed at removing the Plankton and corrosive chemicals.
The treatment of biodiesel consists of two steps, the first step is the treatment with acidified water, while the second step is drying the biodiesel in order to remove water particles. As for the Glycerine, it can be used for producing medicines and cosmetics.

7 Bio-energy Potential from Targeted Biomass

In this section, the assessment of producing bioenergy includes feasible solutions for treating the bio-waste and generating bioenergy are detailed.
The basic factors that were used in this study for calculating the potential of electrical energy from methane are illustrated in table 15 below:

[20] The Biodiesel Handbook, 2nd Edition

Heating value of methane[21]	Electrical efficiency	Operating hours annually[22]
kWh/m³	kWhel/kWhCH4	(hr / a)
9.97	0.35	7,800

Table 15: *Assumptions on methane and conversion efficiency*

Where calculating the annual energy was through the following equation:

Amount of energy (KWh) = amount of methane (m3/a) * methane heating value (kwh/m^3) * generator efficiency

The power for the biogas plant was calculated using the following equation:

$$Power\ KW = \frac{total\ amount\ of\ methane\ (m3) * heating\ value\ (\frac{kwh}{m3})}{operating\ hours\ (hr)}$$

7.1 Bioenergy from Livestock Breeding

The livestock breeding sector in Jordan produces a high amount of dry solid manure from poultry and sheep and semi-dry solid manure from cows. The best exploitation way for this biomass is to produce biogas from the solid manure by using dry process.

7.1.1. Energy from Cows Manure

The expected electrical energy that can be generated from cows manure based on the biomass data in 2018 is illustrated in table 16 below:

Governorate	Methane (m^3/a)	Expected Electrical Energy (Mwh/a)
Irbid	371,890.2	1,297.7
Amman	442,155.5	1,542.9
Jarash	93,493.9	326.2
Ajloun	56,652.4	197.7
Al-Mafraq	342,637.2	1,195.6
Al-Zarqa	1,994,710.4	6,960.5
Madaba	62,676.8	218.7
Karak	68,643.3	239.5
Tafilah	9,673.8	33.8
Maan	6,719.5	23.4

[21] Sustainable Heat Use of Biogas Plants handbook, 2ed edition.
[22] Assumed by the biogas experts.

Al-Aqabah	579.3	2.0
Al-Balqa	63,198.2	220.5
Total	351,3030.5	12,258.7

***Table 16:** Expected annual amount of methane and electrical energy from cows manure, 2018.*

7.1.2. Energy from Sheep Manure

The expected electrical energy that can be generated from sheep manure based on the biomass data in 2018 is illustrated in table 17 below:

Governorate	Annual Methane Emission (m^3/a)	Expected Electrical Energy (MWh/a)
Irbid	76,165.3	265.8
Amman	191,935.3	669.8
Jarash	14,557.0	50.8
Ajloun	18,194.5	63.5
Al-Mafraq	227,030.4	792.2
Al-Zarqa	56,372.7	196.7
Madaba	57,688.3	201.3
Karak	165,082.8	576.1
Tafilah	49,207.8	171.7
Maan	61,129.6	213.3
Al-Balqa	41,132.9	143.5
Al-Aqabah	22,817.3	79.6
Total	**981,313.7**	**3,424**

***Table 17:** Expected annual amount of methane and electrical energy from sheep manure, 2018.*

7.1.3. Energy from Poultry Manure

The expected electrical energy that can be generated from poultry manure based on the biomass data in 2018 is illustrated in table 18 below:

Governorate	Methane (m^3/a)	Expected Electrical Energy (MWh/a)
Irbid	9,370.3	32.7
Amman	107,568.4	375.4

Jarash	4,058.8	14.2
Ajloun	0.0	0.0
Al-Mafraq	54,025.8	188.5
Al-Zarqa	13,907.9	48.5
Madaba	8,509.9	29.7
Karak	11,438.6	39.9
Tafilah	971.9	3.4
Al-Balqa	662.6	2.3
Maan	2,595.4	9.1
Al-Aqabah	6,241.2	21.8
Total	**219,350.8**	**765.4**

Table 18: *Expected annual amount of methane and electrical energy from poultry manure,2018.*

The share of the expected potential of bioenergy from each types of manure is illustrated in figure 9 below:

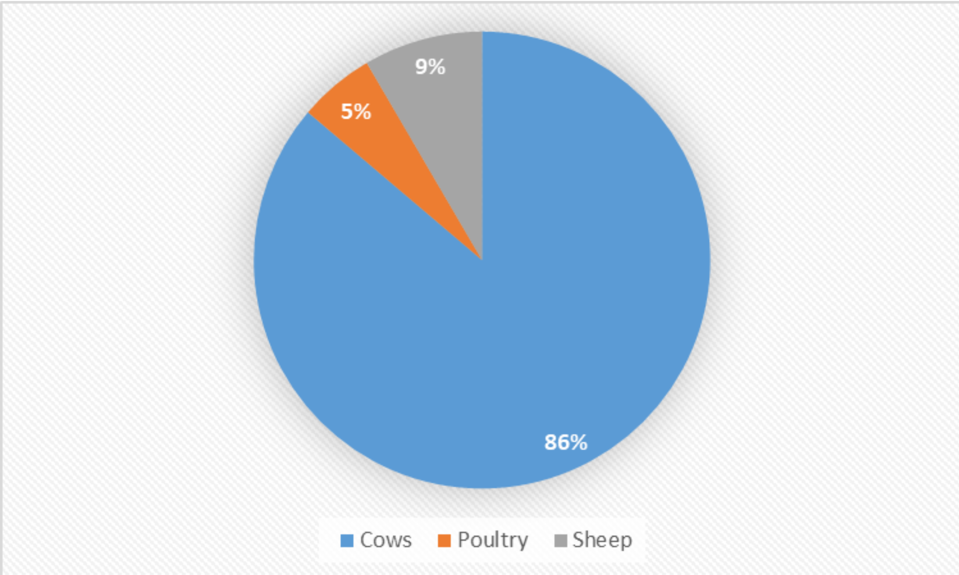

Figure 9: *Share of potential of bioenergy from the livestock breeding sector,2018.*

The largest potential of biogas from the livestock-breeding sector in Jordan in 2018 is in the cows manure.

7.2 Bioenergy from Slaughterhouses

Two main types of waste are daily produced in slaughterhouses: Blood and remnants of the intestines. The best technology for treating these types of waste is the mentioned anaerobic fermentation. In contrast to other treatments, but the anaerobic fermentation needs to reduce the organic content to appropriate for using of fermentation technology.
The expected annual amount of methane and electrical energy from slaughterhouses is discussed in the following section.

7.2.1. Expected Electrical Energy from the Cows' Slaughtering

Based on biomass data for 2018, the annual amount of methane and the expected electrical energy that can be generated from cows slaughtering are illustrated in table 19 below:

Governorate	Methane from waste (m^3/a)	Methane from Blood (m^3/a)	Total Methane (m^3/a)	Expected Electrical Energy (MWh/a)
Irbid	297,461.9	166.355	297,628.3	1,038.6
Amman	798,240.2	446.415	798,686.6	2,787.0
Jarash	116,683.1	65.255	116,748.3	407.4
Ajloun	35,004.9	19.576	3,5024.5	122.2
Al-Mafraq	81,678.2	45.678	81,723.8	285.2
Al-Zarqa	116,683.1	65.255	116,748.3	407.4
Madaba	11,668.3	6.525	11,674.8	40.7
Karak	58,341.5	32.627	58,374.2	203.7
Tafilah	23,336.6	13.051	23,349.7	81.5
Al-Balqa	106,681.6	59.662	106,741.2	372.5
Maan	0.0	0.000	0.0	0.0
Al-Aqabah	4,603.4	2.574	4,606.0	16.1
Total	**1,650,382.8**	**922.976**	**1,651,305.8**	**5,762.2**

Table 19: *Expected annual amount of methane and electrical energy from cows slaughtering, 2018.*

The potential of generating energy from cows slaughtering varies according to governorates . and illustrated in Figure 10 below.

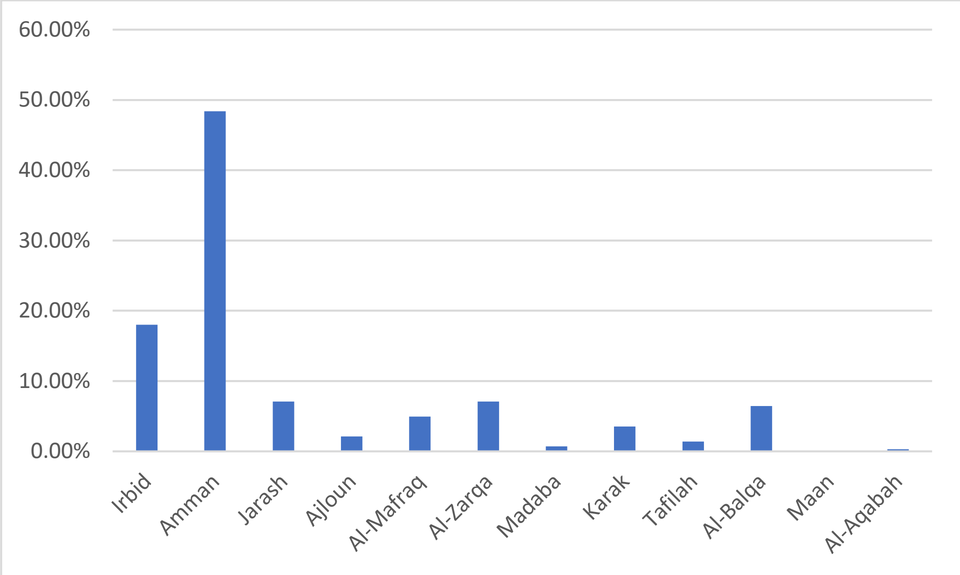

Figure 10: *The Share of each governorates in generating electrical energy from cows slaughtering, 2018.*

The potential of generating electricity from cows slaughtering depends on the daily amount of the slaughtering activities in each governorate. As stated in the tables and figures before, the potential of generating energy from cows slaughtering especially in Amman is high because of the high number of daily slaughtering.

7.2.2. Expected Electrical Energy from Sheep Slaughtering

Based on Biomass data for 2018, the annual amount of methane and the expected electrical energy that can be generated from sheep slaughtering are illustrated in table 20 below.

Governorate	Methane from waste (m^3/a)	Methane from Blood (m^3/a)	Total Methane (m^3/a)	Expected Electrical Energy (MWh/a)
Irbid	96,016.3	9,164.3	105,276.7	367.4
Amman	344,829.5	32,912.3	378,087.0	1,319.3
Jarash	36,463.5	3,480.3	39,980.2	139.5
Ajloun	9,115.9	870.1	9,995.1	34.9
Al-Mafraq	45,579.3	4,350.3	49,975.3	174.4
Al-Zarqa	77,484.9	7,395.6	84,958.0	296.5
Madaba	31,905.5	3,045.2	34,982.7	122.1
Karak	91,158.7	8,700.7	99,950.6	348.8
Tafilah	22,789.7	2,175.2	24,987.6	87.2

Al-Balqa	72,015.3	6,873.5	78,961.0	275.5
Maan	0.0	0.0	0.0	0.0
Al-Aqabah	33,728.7	3,219.2	36,981.7	129.0
Total	**861,087.2**	**82,186.7**	**944,135.8**	**3,294.6**

Table 20: *Expected methane and electrical energy from sheep slaughtering, 2018.*

The potential of generating energy from sheep slaughtering is approximately similar within the most of the Jordan governorates. An exceptional case with the highest expected energy is Amman. Figure 11 illustrates the potential of generating electrical energy in percentage for each governorate in Jordan.

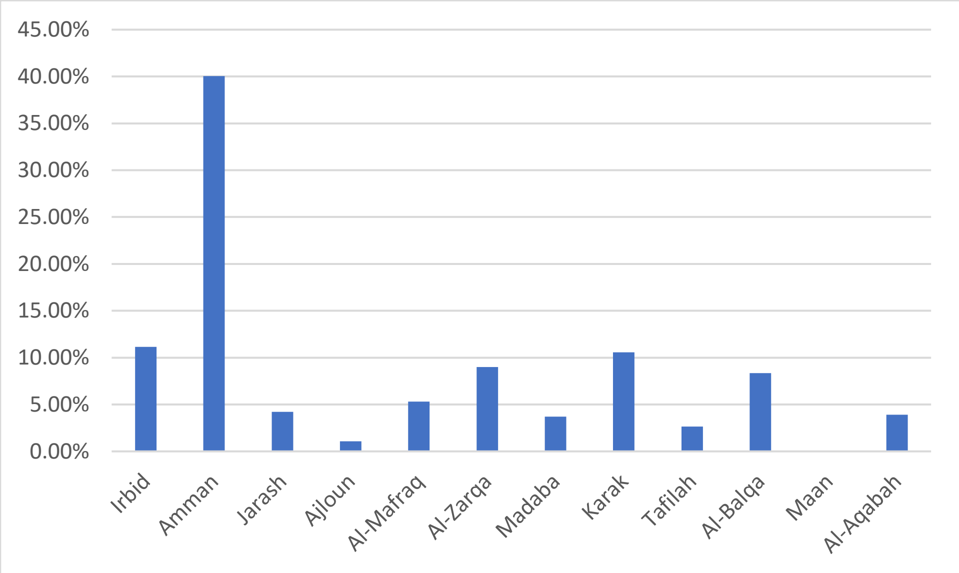

Figure 11: *The share of each governorate in generating electrical energy from Sheep slaughtering in Jordan.*

7.2.3. Expected Electrical Energy from Poultry Slaughtering

Based on the data of Biomass of 2018, the annual amount of methane and the expected electrical energy that can be generated from poultry slaughtering are illustrated in table 21 below:

Governorate	Methane from waste (m^3/a)	Methane from Blood (m^3/a)	Total Methane (m^3/a)	Energy (MWh/a)
Irbid	0	0	0	0
Amman	3,015.0	117,665.0	120,680.0	421.1
Jarash	3.8	147.5	151.3	0.5

Ajloun	0	0	0	0
Al-Mafraq	1,952.6	76,205.3	78,157.9	272.7
Al-Zarqa	2,093.1	81,687.1	83,780.2	292.4
Madaba	0.0	0.0	0.0	0.0
Karak	0.0	0.0	0.0	0.0
Tafilah	0.0	0.0	0.0	0.0
Al-Balqa	0.0	0.0	0.0	0.0
Maan	0.0	0.0	0.0	0.0
Al-Aqabah	0.0	0.0	0.0	0.0
Total	**7,064.5**	**275,704.9**	**282,769.4**	**986.7**

***Table 21**: Expected methane and electrical energy from poultry slaughtering, 2018*

The potential of bioenergy from poultry slaughtering in all governorates low, expect from GAM slaughterhouse, which has a feasible potential for bioenergy from poultry slaughtering according to table 21.

7.3 Bioenergy from Sludge

Wastewater treatment sector produces sludge with high water content. The best exploitation methodology is to produce biogas from the sludge by using wet process. Based on the biomass production from sludge results in section (5.1.1) and the methane emission, the electrical energy from biogas can be summarized as in table 22 below:

Governorate	Methane (m^3/a)	Energy (MWh/a)
Al-Aqabah	3,064,698.0	10,694.3
Al-Balqa[6]	3,662,127.0	12,779.0
Karak	171,646.4	599.0
Al-Mafraq[23]	84,388.6	294.5
Tafilah	196,519.9	685.8
Al-Zarqa[24]	0.0	0.0
Amman[6]	1,718,547.2	5,996.9
Irbid[5]	7,919,158.2	27,633.9
Jarash[5]	1,422,369.6	4,963.4
Maan	792,556.5	2,765.6

[23] Al-Yarmouk Water Company.
[24] Miyahona Water Company

Madaba[6]	411,394.3	1,435.6
Ajloun[5]	1,752,508.1	6,115.4
Total	**21,195,913.9**	**73,963.1**

Table 22: *Expected annual amount of methane and electrical energy from sludge, 2018.*

The different electrical energy produced from sludge according to governorates is demonstrated in Figure 12.

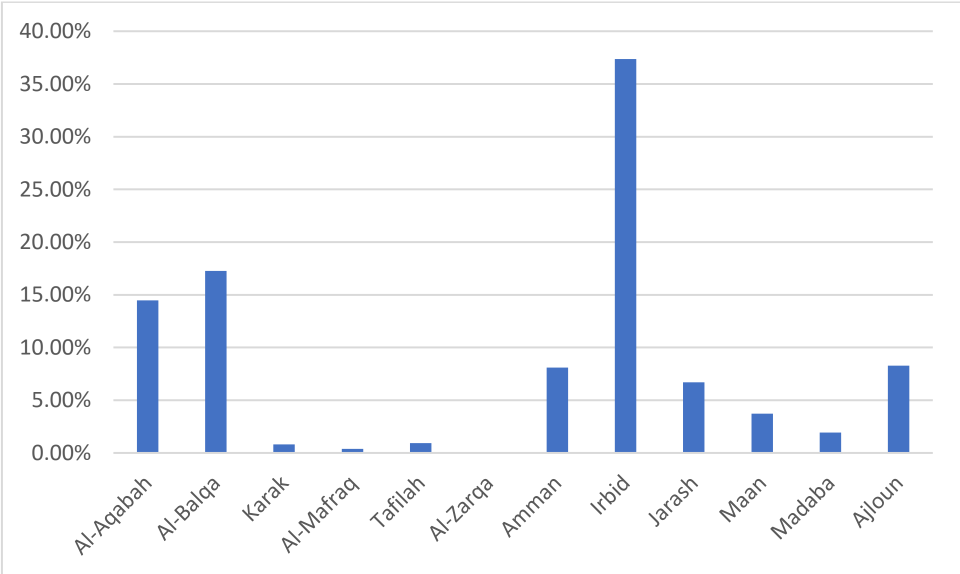

Figure 12: *The share of each governorate in generating electrical energy from sludge according to governorates, 2018*

Al-Samra and Wadi Al-Shalalah WWTPs are not included because they have already two biogas plants that generate electricity.

7.4 Bioenergy from the Peat from Olive Oil

The olive oil industry in Jordan produces a solid organic residue (peat) with high oily content. The best exploitation methodology to treat the solid organic component is by producing biodiesel using thermochemical process, or using direct incineration for heating proposes in small and medium scale.
Based on the biomass production within the olive oil industry (5.1.1), the study evaluates the expected amount of thermal energy and the potential of generating biodiesel from the peat from olive oil as illustrated in table 23 below:

Governorate	Biodiesel (l/a)[25]	Total thermal energy (MWh)
Irbid	10,388,630	225,070.4

[25] RSS/NERC pilot project results.

Amman	2,135,980	46,276.2
Jarash	3,106,880	67,310.8
Ajloun	2,912,700	63,103.9
Al-Mafraq	2,621,430	56,793.5
Al-Zarqa	1,067,990	23,138.1
Al-Balqa	2,427,250	52,586.5
Madaba	1,359,260	29,448.5
Karak	1,165,080	25,241.5
Tafilah	291,270	6,310.4
Maan	679,630	14,724.2
Al-Aqabah	97,090	2,103.5
Total	**28,253,190**	**612,107.4**

Table 23: *Expected annual amount of biodiesel and thermal energy from peat, 2018.*

Note: The thermal energy content in peat was assumed 5.66[26] kwh/kg of dry peat. The potential of generating biodiesel depends on the annual amount of the olive oil peat that can be generated by the olive oil industry. The highest potential of biodiesel production is located in the northern part of Jordan as shown in figure 13 below. Using the biomass to produce bioenergy in Jordan still weak and the number of projects that is working are low.

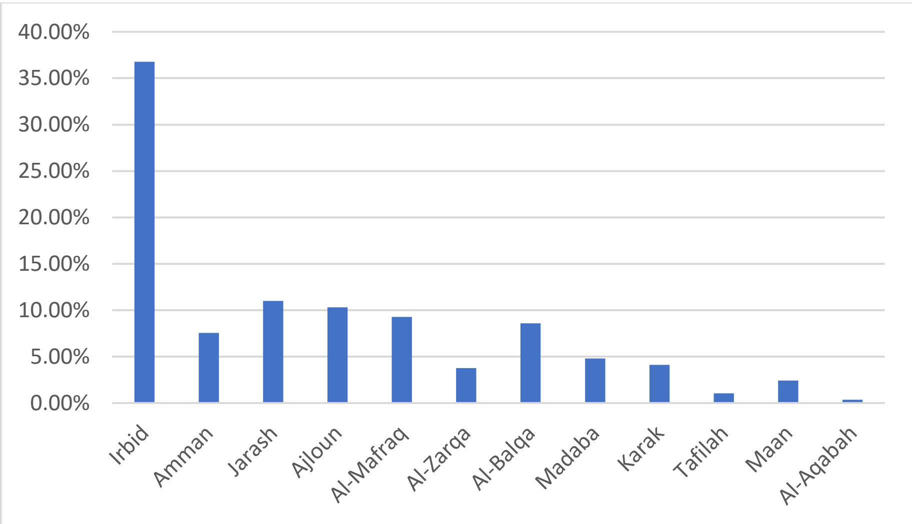

Figure 13: *the share of each governorate in producing biodiesel according to governorates, 2018.*

[26] Potential of using olive peat as a source of renewable energy for electricity generation in the Kingdom of Jordan, Oraib Al-Ketan.

8 Current Bioenergy Projects in Jordan

There are many successful projects for treating the organic component of biomass to produce biofuel and bioenergy. These projects were implemented as pilot projects to increase the awareness and knowhow about the bioenergy in Jordan.

8.1 Biogas in Al-Samra WWTP

Location: Al-Zarqa Governorate
Description: The Samra WWTP was built to replace the old, overloaded Samra Wastewater Stabilization Ponds (WSP), see figure 14. With a peak flow of 840,000m³ each day, the facility treats an average flow of 267,000m³ of wastewater, serving a population of 2.2 million located in the areas Greater Amman and Zarqa. The sludge in the station is used for producing electricity with a total capacity 6.5 of MW CHP unit and the produced digestate is sent to the landfill.

Figure 14: *Al-Samra WWTP.*

8.2 Biogas in Wadi Shalala WWTP

Location: Irbid Governorate
Description: The station started operating in 2013. The station has been designed to receive 13,700 m^3/day of wastewater, and the current flow of the plant is about 7,000 m^3/day of wastewater. Wadi Shalala WWTP houses a biogas plant to treat the sludge, with two digesters with 2,500 m^3 capacity each. The produced biogas is used for generating electricity by using CHP unit with total capacity of 0.58 MW (Figure 15).

Figure 15: Wadi Shalala WWTP.

8.3 Biogas in Al-Rusaifah Landfill

Location: Al-Zarqa Governorate
Description: The biogas plant in the Zarqa Governorate, funded by the United Nations Development Program (UNDP), was established in 1998 on the landfill dump Al-Ruaifah (see figure 16) to demonstrate the extent to which the central waste can be utilized to implement the project through the treatment of organic waste. In 2018 the electricity production stopped from the site due to the biogas emission run out, because the organic content in the bio-waste was decomposed, so the methane stop emission.
The biogas in the station was used for producing electricity with a total capacity of 3.5 MW CHP unit.

Figure 16: Biogas unit in Al-Rusaifah landfill.

8.4 Biogas in Gabawi Landfill

Location: Amman Governorate
Description: GAM works on collecting the biogas from Al-Gabawi landfill (see figure 17) to generate electricity. The total capacity of the CHP unit in Al Gabawi landfill is 5 MW and the electricity generation started in July 2019.

Figure 17: *CHP unit in Al-Gabawi Landfill.*

8.5 Biogas Small Scale Units

RSSNERC have installed many biogas units for livestock breeding farms in different locations in Jordan (Figure 18). The units use the animal manure for producing biogas by the wet process (TS is between (4-15)%) . The produced biogas is used for heating and generating electricity using small-scale biogas generators. RSS/NERC is the first organization, which has installed such technologies in Jordan.

Figure 18: *RSS/NERC's Small Scale Biogas unit.*

The mentioned biogas projects in Jordan don't cover all types of biomass and just use to the biogas production technology. That's why different types of technologies are needed, to use the whole potential of biomass.

9 Map for Expected Bioenergy Projects in Jordan

The potential of bioenergy projects classified according to the types of biofuel that will be generated, that is biogas, biodiesel and thermal energy from biomass.

9.1 Biogas Potential Project in Jordan

The potential of producing biogas from the targeted bio-waste illustrates that there are many opportunities to install biogas plants to treat the biogas in many governorates in Jordan.
The potential of biogas generation was calculated by assuming that the biogas plant operating hours are 7,800 (hr/a) and the electricity generator capacity is 35% (Table 24).

Governorate	Cows manure (MW)	Poultry manure (MW)	Sheep manure (MW)	WWTP (MW)	Cows SH (MW)	Sheep SH (MW)	Poultry SH (MW)
Irbid	0.48	0.01	0.10	9.0	0.38	0.13	0.00
Amman	0.57	0.14	0.25	2.2	1.02	0.48	0.15
Jarash	0.12	0.01	0.02	1.8	0.15	0.05	0.00
Ajloun	0.07	0.00	0.02	2.2	0.04	0.01	0
Al-Mafraq	0.44	0.07	0.29	0.5	0.10	0.06	0.10
Al-Zarqa	2.55	0.02	0.07	0.0	0.15	0.11	0.11
Madaba	0.08	0.01	0.07	0.5	0.01	0.04	0.00
Karak	0.09	0.01	0.21	0.2	0.07	0.13	0.00
Tafilah	0.01	0.00	0.06	1.2	0.03	0.03	0.00
Maan	0.01	0.00	0.08	1.0	0.14	0.10	0.00
Al-Aqabah	0.00	0.00	0.05	3.9	0.00	0.00	0.00
Al-Balqa	0.08	0.01	0.03	4.7	0.01	0.05	0.00
Total	**4.49**	**0.3**	**1.25**	**27.3**	**2.11**	**1.21**	**0.36**

Table 24: *Biogas plant potential based on type of targeted biomass.*

Figure 19 below compares the potential of biogas in each governorate of Jordan based on the type of biomass.

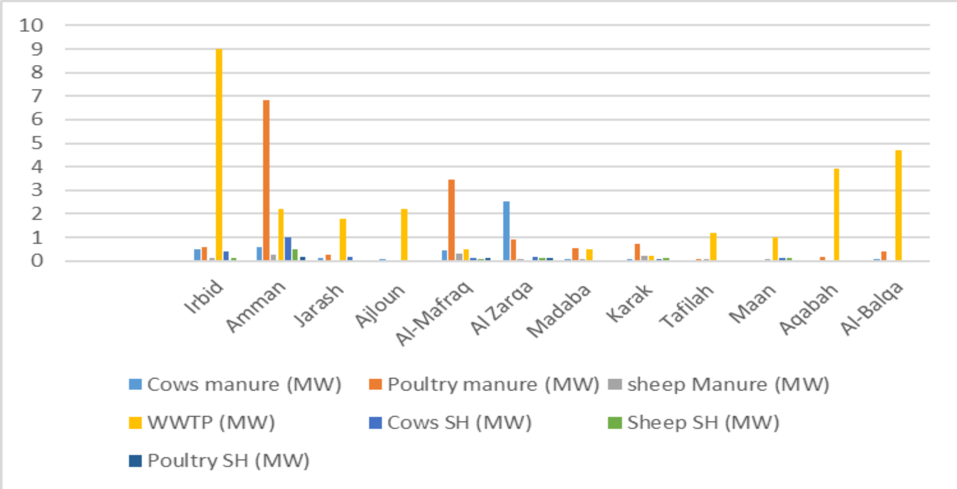

Figure 19: *Potential of installing biogas plants based on type of biomass for each governorate.*

The total potential of biogas units in (MW) that can be installed in each governorate utilizing different sources in Jordan is 37.02 MW as illustrated in table 25 below:

Governorate	Total (MW)
Irbid	10.1
Amman	4.81
Jarash	2.15
Ajloun	2.34
Al-Mafraq	1.56
Al-Zarqa	3.01
Madaba	0.71
Karak	0.71
Tafilah	1.33
Maan	1.33
Al-Aqabah	3.95
Al-Balqa	4.88
Total	37.02

Table 25: *Total potential of capacity of biogas plants that be installed in each governorate in Jordan*

Amman and Irbid have the largest potentials of biogas projects that can be installed to treat the amount of targeted types of biomass that are generated daily (Figure 20).

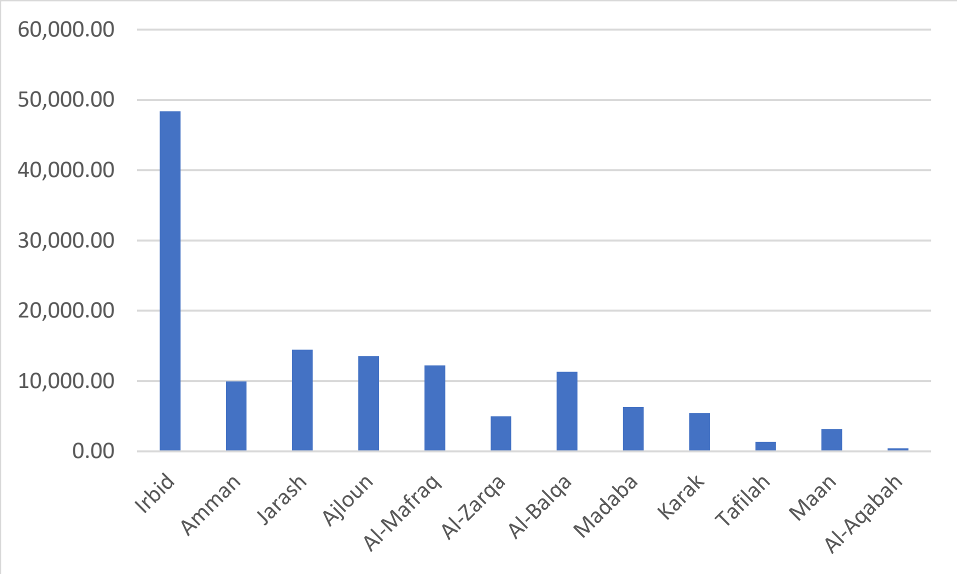

Figure 20: *Distribution the potential of biogas plant according to governorates, 2018*

9.2 Potential of Biodiesel Generation

The assessment of biodiesel production in the study was calculated for the peat from olive oil only. The potential capacity of biodiesel generation units in Jordan was calculated by assuming that each unit can produce biodiesel for 1,920 hrs/ annually. The result of the estimation is illustrated in table 26 below:

Governorate	Capacity of biodiesel unit (liter/hr)
Irbid	5,410.7
Amman	1,112.5
Jarash	1,618.2
Ajloun	1,517.0
Al-Mafraq	1,365.3
Al-Zarqa	556.2
Al-Balqa	1,264.2
Madaba	707.9
Karak	606.8
Tafilah	151.7
Maan	354.0
Al-Aqabah	50.6
Total	**14,715.2**

Table 26: Capacity of Biodiesel units based on governorate in Jordan.

Irbid Governorate has the largest potential of producing biodiesel in Jordan, and the Governorate of Madaba has the lowest potential, based on 2018 data as shown in figure 21 below.
The total annual amount of biodiesel that can be generated in Jordan according to the peat data in 2018 is 28,253,184 Liter.

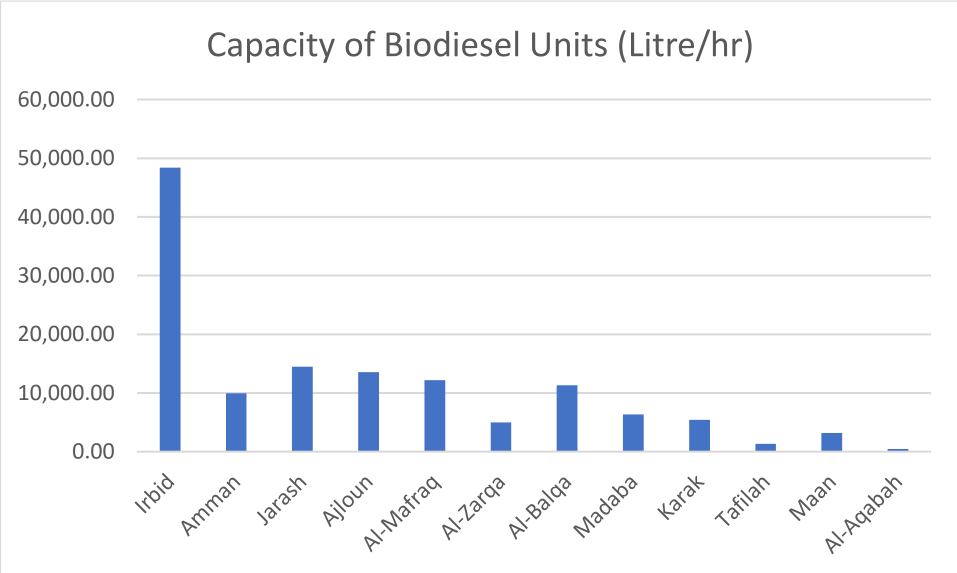

***Figure 21:** Distribution of capacity of the biodiesel units according to governorates, 2018*

9.3 Potential of Producing Thermal Energy

The potential of producing thermal energy from biomass requires huge amounts of biomass for ensuring the continuous operation of thermal energy production units. It would be better to use small and medium burners for heating purposes in households and medium size buildings with a capacity range of 5 KWth to 50KWth. The appropriate type of biomass for feeding such units is peat from olive oil because it has low moisture content.
In Jordan, most of the peat from olive oil is used for domestic heating in winter. It is dried and placed in a mold as shown in figure 22 below:

Figure 22: Olive mill peat dried and compacted to briquettes.

Most of the bioenergy production processes produce by-products such as the digestate in biogas technology and the ash in direct incineration. These by-products can be used as fertilizers for agricultural purposes.

9.4 Stakeholders Mapping

The investment or exploitation for the targeted types of biomass in generating energy has to be coordinated with reference authorities and stakeholders. Stakeholders are divided into two categories; primary stakeholders and specific stakeholders.
The stakeholders are classified depending on their role in the project as follows

9.4.1. Primary Stakeholders

Primary stakeholders are the stakeholder who must approve any project for utilizing the biomass to generate energy, which means that, no waste to energy project starts without following their laws and instructions. These stakeholders are:

- Ministry of Environment.
- Ministry of Energy and Mineral Resources.
- Ministry of Agriculture.

9.4.2. Specific Stakeholders

They are the stakeholders who involved in the waste to energy project according to the type of biomass that will be used to generate energy. These stakeholders are:

- **WWTP's Stakeholders**
  - Jordan Water Authority.
  - Jordan Water Companies (Al-Aqaba, Miyahuna and Al-Yarmouk)
- **Slaughterhouses stakeholders**
  - Greater Amman Municipality.
  - Ministry of Local Administration.
  - Aqaba Special Economic Zone Authority.
  - Local Municipalities.
- **Olive Oil Stakeholders.**
  - General Syndicate of Contemporary Owners of Olive Producers and Jordanians.
- **Livestock Breeding Stakeholders.**
  - Livestock Breeding Associations.

10 Considerations on Utilization of Bio-Fertilizers in Jordan

Most of the bioenergy technologies produce residues from using the biomass for generating biofuel. The residues that are produced from the bioenergy technologies can be used as bio fertilizer.

Bio fertilizers shall be hygienically safe; they shouldn't emit odours, attract flies, react during the storage nor shouldn't be saline.

Digestion of manures in liquid fermentation technologies requires dilution with water at a ratio of at least 1:1 to reduce the TS-concentration to 10%. After digestion, solids may be separated and the liquid part of the digested manure, a liquid compound NPK-fertilizer, can be introduced into drip irrigation systems. The exploration of successful penetration into the drip irrigation and fertilization market with the compound bio fertilizer may offer a great chance for liquid fermentation. An alternative dilution avoiding fermentation technology is dry fermentation, which operates with substrates with more than 25% TS.

One important criteria for bio fertilizers is a proper Carbon to Nitrogen (C/N) ratio. Bio fertilizers, in particular in digested manures, offer a very suitable ratio of about 10. Thus, for example in Germany, digested manures, crops and crop residues are being directly applied in the fields. Organisms in the soil require both carbon and minerals as fertilizers. The organic matter is slowly degrading and does not contribute to soil acidification or oxygen depletion.

Sewage however has a low C/N ratio. It is still recommended to remove fast degrading organic matter to avoid soil acidification or oxygen depletion. This can be done in anaerobic ponds. Thereby odours are being removed by digestion and the content in pathogenic flora. Both can be achieved by anaerobic digestion at long retention times, followed by UV-light treatment of the treated overflowing liquid.
The government of Jordan is preparing new regulations for the use of fertilizers and compost that is produced from the biomass treatment using aerobic and anaerobic technologies.
Until now, the regulations do not cover the utilization of the by-product in any bioenergy technologies.

11 Regulatory Framework

This section details some of the laws and regulations that govern the investment in bioenergy and biofuel in Jordan.

11.1 Renewable Energy Policy in Jordan

The bioenergy technologies are considered a part of renewable energy technology according to the Renewable Energy and Energy Efficiency law number 13 for 2012 and its amendments. Most of renewable energy projects in Jordan are focus on generating electricity.
In Jordan, power-generating plants with a capacity of up to 1 MW are allowed to operate without a license. Local supply networks with a capacity of max. 100 kW_{el} can be operated without a license, in the same way as all sizes of power plants that are used solely to generate electricity for self-consumption, so-called captive power. The users can't buy electricity directly from producers according to the electricity law in Jordan.
To develop renewable energy capacities, a number of support mechanism have been introduced. There are two promising business cases that enable investments in renewable energies:

- Direct Proposals for PPAs under consecutive rounds of "expressions of interest"
- Net-metering and Wheeling

The Government has been attempting for a long time now to conclude contracts with Independent Power Producers (IPP) with the aim to expanding the number of power stations in Jordan's electricity generating system.
The current energy strategy aims at reducing energy imports through diversification of the energy mix by using local resources such as shale oil, nuclear power and renewable energies. MEMR is currently updating its Strategy and aims to publish the updated one before the end of 2019. NEPCO is also conducting a set of studies to update their Master Plan; the additional capacities of power generation projects will be decided based on the results of the strategy and the studies performed by MEMR and NEPCO.
It is worth mentioning that in January 2019, a Cabinet Resolution was issued to temporarily stop giving the approvals for new electricity generation projects (based on both renewable and conventional sources) until the issuance of the above mentioned updated energy strategy and the studies performed by MEMR and NEPCO.

The feasibility of bioenergy projects are depending on the energy tariff. The electricity tariff structure in Jordan takes into account social aspects as well as the economic capacities of consumers.

11.2 Biofuel Instructions

There are two instructions; Biodiesel Instruction and Industrial fuel Instruction. These instructions were lunched by MEMR for licensing any facility that will produce biofuel. Through these instructions, any investor shall fulfil general requirements such as Environmental Impact Assessment, Feasibility Study, and Grid Impact Assessment before being granted an approval.

11.3 Legal Frame for Waste Management Law

The aim of this law is to provide the basic legal conditions to prevent and reduce the waste generation, recycling, treatment, extraction of the secondary raw materials and energy production, in addition to ensure safe disposal of waste for the purpose of protecting the environment, human health and sustainable development.
The law specifies the regulations and instructions for each authority in Jordan from the planning phase to waste transferring phase, along with the process of disposing or treating the waste. Additionally the law illustrates the sanction for illegal use or disposal of waste in Jordan.
The law includes the bioenergy technology as one of the organic waste treatment technologies, and the law mentioned for that using such technologies shall go through the regulatory frame for each governmental authority.

12 Limitations and Barriers for Waste to Energy Projects

The investment in bioenergy projects still weak in Jordan. There are some limitations and barriers that effect on the bioenergy sector which can be summarized as follows:

- The lack of a jointly bioenergy action plan among the stakeholders involved in the management of solid waste file in Jordan.
- Segmentation of responsibilities and approvals for local governmental authorities
- Lack of financing facility or programme specialised in financing the bioenergy projects in Jordan.
- The bioenergy tariff is low, which means that the annual income from the bioenergy generation is low in comparison to the cost of the initial investment for any bioenergy technology; additionally there is an operating cost higher than any renewable energy technology which makes the Investment's payback period very long.
- Using some types of biofuel such as biodiesel and bioethanol for transportation or still need some legal regulations from EMRC or MEMR to allow mix these types of fuel with the fossil fuel according to the international standards.
- There are no national technology providers for bioenergy in Jordan, which make the cost of installation for such technologies expensive in comparison to installing the same technology in origin country.
- The know-how for operating and maintenance of bioenergy facilities are not well known in Jordan.

13 Recommendations

The recommendations can be divided into three main aspects:

1. Publications of the results that was achieved using the collected data.
2. Establishing new regulation and instructions.
3. Enhancing the research studies.

13.1 Publications of the Results that was Achieved Using the Collected Data

The study recommends that Ministry of Agriculture, Ministry of Local Administration, Greater Amman Municipality, local water companies and General Syndicate of Contemporary Owners of Olive Producers in Jordan to cooperate with the Department of Statistics to develop a new approach or system for considering these data to calculate the annual amount of bio-waste that is produced from each targeted type of biomass.

Based on the results for the data analysis of the relevant authorities, it is highly recommended to record and publish these data annually, in order to monitor effect of untreated bio-waste on the climate. Also, these data can be used in estimating the potential of bio-energy that can be generated.

13.2 Establishing New Regulation and Instructions

The study recommends that Ministry of Agriculture, Ministry of Local Administration and Ministry of Energy and Mineral Resources to develop common regulations and instructions for waste management in order to regulate the wide range of aspects about using biomass for producing the bioenergy. It should be noted that all biomass treatment facilities usually include two kinds of products; bioenergy fuel for energy purposes and by-products can be used for the agricultural purposes.

The study also recommends that Ministry of Agriculture, Ministry of Local Administration, Ministry of Energy and Mineral Resources, and Ministry of Planning and International Cooperation to develop a National Bioenergy Action Plan which aims at support establishing the bioenergy projects in Jordan.

Furthermore, the study recommends that the Ministry of Energy and Mineral resources and Ministry of Environment to implement a capacity building programme in the field of waste treatment and waste to energy technologies such as biogas and biodiesel, due to lack of know-how in these fields

13.3 Enhancing the Researchers and Studies

The general recommendations targeted the researchers and the experts in the waste management field.

By calculating the annual greenhouse gas emission for the targeted types of bio-waste in the study, the results illustrate that there is a need for an accurate local GHG emission factors for different types of bio-waste, instead of using the IPCC or any international emission factors ,because there is a difference in the chemical component between local and international bio-waste.