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Waste management practices in Jordan (AlGhoor region) and potential for implementation of biogas technology

MASTER'S THESIS

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Declaration

I hereby declare that I have done this thesis entitled “Waste management practices in Jordan (AlGhoor region) and potential for implementation of biogas technology” is my own work, all texts in this thesis are original, and all the sources have been quoted and acknowledged by means of complete references and according to Citation rules of the FTA.

In Prague 22/4/2021

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Haya Suleiman

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Abstract

Biogas production through anaerobic digestion process is an appropriate technology to be implemented at AlGhoor region for farm waste management and cooking activities within rural areas and farms (replacing traditionally used LPG and electricity), and it's considered cost effective, providing many benefits including reduction of greenhouse gas emissions, organic waste management and production of fertiliser. Therefore, this study attempted to center the attention on the waste management techniques that are used by farmers in Jordan and the potential of implementing of biogas technology or building a biogas plant (BGP).

The primary data were collected in AlGhoor region, Jordan, in August 2020, including semi structured interviews with farm owners who are using different methods of waste management, and their willingness to implement the biogas technology as solution to discard the farm wastes instead of different inefficient and has a negative impact on the environment (n=70). Using a logistic regression analysis of various cross-sectional data (with SPSS software).

The findings showed that the farmers are welling to adopt a new technology if it was cheaper and more efficient than their current method of discarding their farm waste, as well as the need of a foreign fund to support such project of building a BGP in the region, it also shined the light on the government approach and regulations when it comes to the waste management techniques that has been used all this time by farmers in the area.

Most of farmer's residues are derive from crops, due to it being an agricultural area with less farmers who owns any livestock. In accordance of findings of the study, it can be concluded that that the adoption of planting a biogas technology in AlGhoor region leads to a better positive impact on the surrounded environment as well as the understanding of using the technology properly which might in return change the farmers behavior towards abandoning the biogas plant for more available and more common options like the LPG and electricity.

Key words: Jordan; AlGhoor; Biogas; waste management techniques; Biogas technology

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RPR	Residual Production Ratio
MSW	Municipal Solid Waste
SWM	Solid Waste Management
GHG	Green House Gases
BGPs	Biogas Plants
LPG	Liquefied Petroleum Gas
GWh	Giga watt per hour
WWTPs	Waste Water Treatment Plants

1. Introduction

AlGhoor region (Jordan valley) is a low-lying strip which cleaves down the western border of Jordan, it is warmer than the rest of the country, has a year-round agricultural climate, fertile soils and water supply have made AlGhoor the food bowl of Jordan. (Al-Hamamre, et al., 2014) Unfortunately, there were no reports really convincing that using biogas technology would be profitable, and biogas was not fully utilized to its maximum extend.
The biogas/electricity is only output, and it is barely used in Jordan (Al-Hamamre et al. 2014). Jordan, with an-add up to the range of approximately 88,780 km2, lies to the East of the Jordan Waterway. Rural arrive (% of arrive region) in Jordan was measured at 11.29% in 2011.
This incorporates the share of arrive region that is arable, beneath lasting crops, and beneath changeless pastures. Besides, 9.61% (% of add up to rural arrive) re-presents a rural inundated arrive. These lands allude to rural regions given with water and arrive watered by controlled flooding. Irrigation speaks to a key calculate to preserve the steady generation of any edit in Jordan. Subsequently, the generation of absolute rain encouraged arrive is so shifted each year; subsequently, it could be troublesome to deliver any edit when the precipitation is unusually moo. In arrange to preserve a steady generation of any edit, an economical water supply and request adjust must be secured.
A wide assortment of vegetables counting tomatoes, cucumber, potato, melon, eggplants, cauliflower, squash, lettuce, onion, cabbage, pepper, peas & beans are created for household utilization, nearby markets, and export. Vegetables are primarily developed on flooded lands found within the middle of nation and within the Jordan Valley. Difficult climate conditions such as dry season and solidifying may contribute to the moo edit yield from time to time. (Al-Hamamre et al. 2016).

Citrus, olives, grapes, peach, apple, and banana are the most natural products delivered within the nation and available for neighborhood markets and export, Olive tree is the foremost critical natural product tree grown in Jordan. Olives covers almost 107,000 hectares which speaks to 72% of the whole region planted with fruit trees and 36% of the whole developed zone within the nation. The whole number of olive trees within the nation is evaluated at evaluated 17 million olive trees with a development rate of 1 million olive trees per year. The created olive natural product re-present around 33% of the entire sum of a natural product created. The average yearly generation for a long time in 2007–2012 is assessed at 136.49 thousand tons. The two fundamental creating ranges are the western mountains (rain nourished) and the northeastern area (irrigated). Citrus trees (oranges, lemons, and grapefruit) are developed over almost 6.882 hectares speak to the 2nd major natural products created within the nation. Citrus ranches are conveyed within the Jordan Valley, in the northern AlGhoor, and within the flooded range in center side of the nation. The normal yearly generation is evaluated at 104.05 thousand tons accounting for 25.3% of the whole sum of natural products created. This can be taken after by banana (10.2%), apple (8.2%), grapes (7.8%), and peach (5.0%).
The most natural product created in Jordan for the years 2007–2012, the assessed residues delivered, and their energy potentials. Residues gotten from natural product trees and natural products can be classified into two bunches. The primary bunch speaks to residues that are produced within the field at the time of collector field-based residues such as wood, branches, and take off. The moment gather is of those residues that are co-produced amid preparing (by-product or residues) such as olive cake, citrus natural products peels, and banana peels, etc. For most natural products residual production ratio (RPR) esteem of 2.0 was detailed, In addition, for an olive tree esteem of 1.4 was chosen for (RPR), and for Banana, the (RPR) values detailed extended between2.0 and 3.0. (Al-Hamamre et al. 2016)

2. Literature Review

Biogas generation is one of key arrangements to meet family vitality request of provincial regions in Southeast Asia, because it could be a promising innovation for ranchers who depend on animals farming. Organic matter is processed in biogas plants (BGPs) and the item – biogas can be utilized in families for cooking in biogas stoves. Within the handle of biogas generation, the natural residues digestate is considered as a by-product and can be utilized as normal fertilizer. Utilize of fertilizer as a feed stock for biogas plants is an suitable arrangement, as it enables to oversee squander that seem possibly hurt the environment. Biogas as a vitality source in provincial Vietnam replaces customarily utilized fuel charm and light-petroleum gas (LPG). Utilization of biogas comes about in financial benefits. Another advantage of biogas is the lessening of the wellbeing chance of ladies and children, caused by indoor fuel charm burning. Anaerobic assimilation (Advertisement) makes a difference to oversee natural waste, otherwise possibly hurtful to the environment, which because it is produced continuously in the cultivate range, serves as a feedstock to the digester. (Abu-Hamatteh et al. 2010)

With acknowledgment that oil and gas supplies are limited, increasing consideration has been paid to the wide extend of renewable vitality sources. All fossil vitality devoured today (coal, oil and common gas) came from the sun's energy, which was put away in biomass for millions of years. These changed biomasses cannot be regenerated on a human time scale.
Waste-to-Energy and Solid Waste Management (SWM) is a "win-win" choice as application of progressed squander management hones and methods makes a difference not as it were to reduce the amount of squanders at source but moreover encourages their treatment and transfer in naturally inviting manner other than making a difference in era of significant amount of vitality. With capacity of 3.5MW as of now installed inside Jordan, the utilization of biogas as a source of renewable vitality makes a major commitment to the Jordan's commitment to handling the issue of climate alter. (Abu-Hamatteh et al. 2010)

The ever-growing Environmental pollution has had several direct and indirect causes and Instigators; the continues growth in human population, the under developed processes of Collecting, moving and managing the waste “solid rubbish, organic waste, recyclable rubbish And hazardous waste” and mainly organic waste, as well as the continues search for automation in the industrial and agricultural sectors; which lead to the exponential growth in the produced waste amounts, while on the other hand environmental advocates have increase in numbers “due to the development of human civilization” which in-turn has pushed for people to approach organic agriculture, adopt and further develop it.
Farmers have had the constant and everlasting aspiration to seek and approach secondary methods and ways to generate revenue for themselves as well as use the secondary agricultural products in ways that are both economically and environmentally safe, and by adopting clean technologies, which can produce energy in a feasible price would be an extraordinary usage for the agricultural organic waste produced from and cow breeding and rearing farms which are estimated to be 140,000 tons per year, in the regions of Al-Dlayl and Khaledeyah in Jordan** (Al hammad et al. 2019)

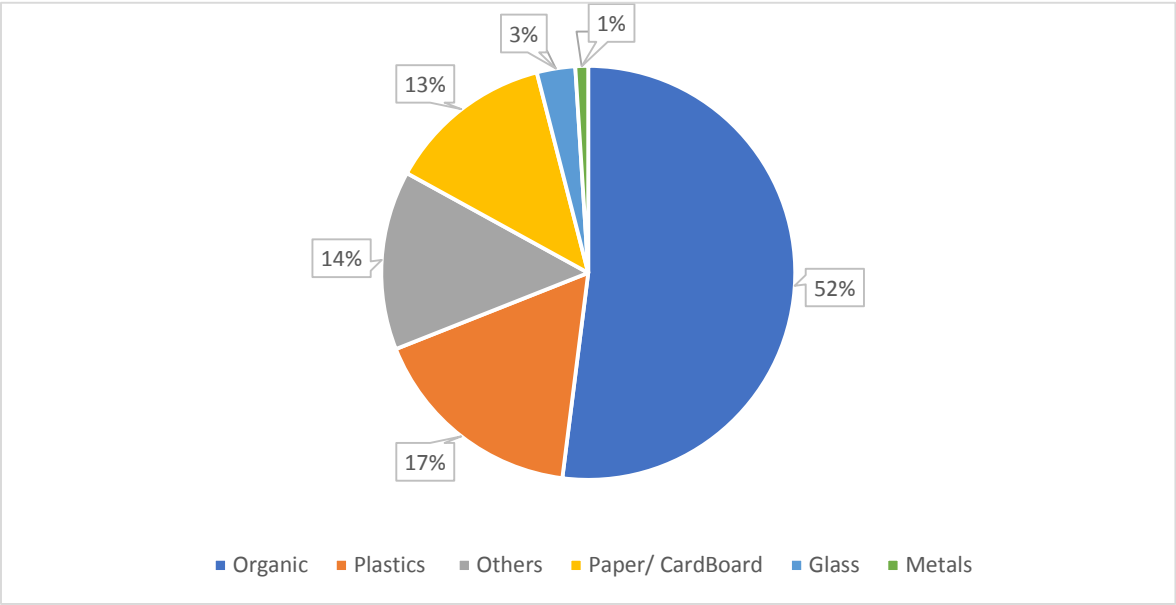
Anaerobic decomposition happens wherever tall concentrations of damp natural matter amass within the absence of broken up oxygen. This handle is common in the foot dregs of lakes and lakes, in swamps, peat marshes, and intestine of creatures and within the profound layers of landfill sites. (Abu-Hamatteh et al. 2010)

Anaerobic decomposition experienced a few forms as particular organisms feed on certain organic materials. In the introductory stages, acidic microscopic organisms disassemble the complex organic atoms into peptides, glycerol, liquor and the simpler sugars. When these compounds have
been produced in adequate amounts, a moment sort of bacteria change over these middle items into hydrogen and carbon dioxide, which are at that point changed into methane and water concurring to the equation:

$$CO2 + 4H2 \longrightarrow CH4 + 2H2O$$

Municipal solid waste (MSW) is waste that is that is produced by families and the commercial educate and industrial sectors. The squander fabric incorporates plastics, materials, glass, metal, and biodegradable materials such as paper and cardboard, wood, nourishment squander, and garden squander. There's a relentless increment within the volume of the strong squander divisions in Jordan particularly within the final three decades as a result of populace development; social, social and financial improvements, current advanced living measures, as well as, due to the constrained movements brought about due to the territorial clashes and related to individuals relocations. (Al-Hamamre et al. 2016).

In Jordan, there are around 2.7 million tons of (MSW) sums produced and collected by the significant specialists in 2014; considering 6.7 million nearby populaces in addition to around 1.0 million of the Syrian outcasts live within the refugees' camps and have communities within the year of 2014 (in add up to of7.7 million of populations). The duty for collection and transport of MSW to the ultimate goal destinations lies on neighborhood regions. An exemption is Aqaba City, where squander is collected by a private company contracted by the Aqaba Uncommon Financial Zone Specialist (ASEZA). Be that as it may, transfer is the obligation of the Joint Administrations Boards (JSCs).(Al-Hamamre et al. 2016).



(Figure 1) The physical composition of MSW in Jordan
Source: Al-Hamamre et al. (2016), adjusted by author

2.1 Agrarian land in Jordan

Jordan, with add up to range of around 88,780 km2, lies to the East of the Jordan Waterway, Agrarian arrive (% of arrive region) in Jordan was measured at 11.29% in 2011. This incorporates the share of arrive region that is arable, beneath lasting crops, and beneath lasting pastures. Moreover, 9.61% (% of add up to agrarian arrive) re-presents a rural watered arrive. These lands allude to rural regions given with water and arrive inundated by controlled flooding.
Irrigation speaks to a key calculate to preserve steady generation of any trim in Jordan. Hence, the generation of simply rain encouraged arrive is so shifted each year; thus, it may be troublesome to create any edit when the precipitation is strangely moo. In arrange to preserve steady generation of any edit, a feasible water supply and request adjust must be secured. (Al-Hamamre et al. 2016).

The capability of biogas creation is the strong waste gathered from the Malvar Open Market and urban barangays setting off to the Materials Recuperation Office (MRF) [3]
The late increment in oil and gas costs in Jordan has demonstrated the need to look for elective wellsprings of customary vitality [6]. It was discovered that domesticated animals waste (dairy animal's compost and waste) contained an enormous extent of natural substances that could be utilized to create Energy; it was found to contain 65% of methane.

2.2 Biomass availability

Jordan has exceptionally constrained nearby inborn vitality assets that contribute as it were with 2.4% to the in general vitality utilization. The government has set up a technique to differentiate the energy sources and increment the commitment of the nearby and renewable energy sources within the energy blend. This can be accomplished by implementing and creating existing advances by expanding its efficiency within the various segments. The Renewable Vitality and Energy Proficiency Law embraced in 2010 in Jordan may be a major step forward. The law sets motivations to advance renewable energy utilization in Jordan as well as building up the Jordan Renewable Energy and Energy Efficiency Fund (JREEEF), but is still not operational, however. Be that as it may, a few imperative issues are not addressed directly by the law and cleared out for future choices and informational to be issued by important substances.

2.3 Field crops waste

Most crops generation in Jordan are concentrated in irrigable arrive (within the Jordan valley), in conjunction with a few rain nourished zones within the center and northern side of the nation where the precipitation can be as tall as 400–600 mm/a. Trim development without water system on dry lands depends completely on the precipitation that frequently happens within the winter and early spring, i.e. late October to April. Most crops on these lands are planted within the October–November period and harvested in Eminent of the following year.

2.4 Biomass vitality potential

Vitality appraisals of biomass assets can be considered as an improvement methodology for the change of the quality of life and the environment. The annually reachable biomass residues are shifted depending upon a few nearby conditions; among which climatic variables, cultivate generation, the sort and assortment of animals and crops planted and their yields. One of the key obstructions to biomass advancement is the need of information on the asset potential. Exact gauges of biomass sources are essentially required to bolster the approach and choice making forms.

2.5 Municipal solid waste (MSW)

It is a waste that is generated by households and the commercial institutions and industrial sectors. The waste material includes plastics, textiles, glass, metal, and biodegradable materials such as paper and cardboard, wood, food waste, and garden waste. (Al-Hamamre et al. 2016).
The natural division of MSW can be changed over in to valuable vitality (power, heat) or into a more adaptable vitality source (gaseous and fluid fills) by means of thermo-chemical (combustion, pyrolysis, and gasification), and biochemical (anaerobic or high-impact assimilation and aging) transformation processes, Waste to Energy (WtE) plants have been worked by burning waste and changing over the coming about warm into energy and most plants still utilize this innovation to date. There unused sorts of WtE have been created as of late such as gasification, pyrolysis, thermal de-polymerization and plasma gasification, and landfill gas (LFG) utilization. In Jordan, there are right now two active administrative WtE ventures which are 6 MW LFG recuperation and control era framework at the Al Ghabawi landfill, in Amman and another pilot LFG recuperation plant within the ancient Ruseifah MSW dumpsite worked by Jordan Biogas Company.
There's a steady increment within the volume of the solid waste divisions in Jordan particularly within the final three decades as a result of populace development; social, social and financial improvements, current present day living guidelines, as well as, due to the constrained relocations brought about due to the territorial clashes and related to individuals relocations.

2.6 Biogas Technology

Biogas plant is a proficient, well-illustrated innovation for utilization of natural waste for generation of power, heat vitality and organic fertilizer without discharging nursery gas to the climate. Biogases produced amid anaerobic assimilation (Advertisement) are generally methane and carbon dioxide. The presentation of the biogas as an elective source of vitality has found significant adequacy in Jordan. This leads to methane emanation lessening and produces clean renewable power and tall quality fertilizer. Biogas burns with a clear blue fire encompasses a temperature up to 800 °C and a calorific esteem 5650kcal/m3. Anaerobic digestion is the breakdown of natural fabric by micro-organisms within the nonappearance of oxygen.

Waste management is one of the major challenges that face society, especially in developing countries. In several countries, waste management and reduction climbed to the top of their priorities' list because of their negative environmental effects, representing a very important share of the common responsibilities and efforts in the endeavor to reduce the pollution and greenhouse gas emissions that cause global climate change.

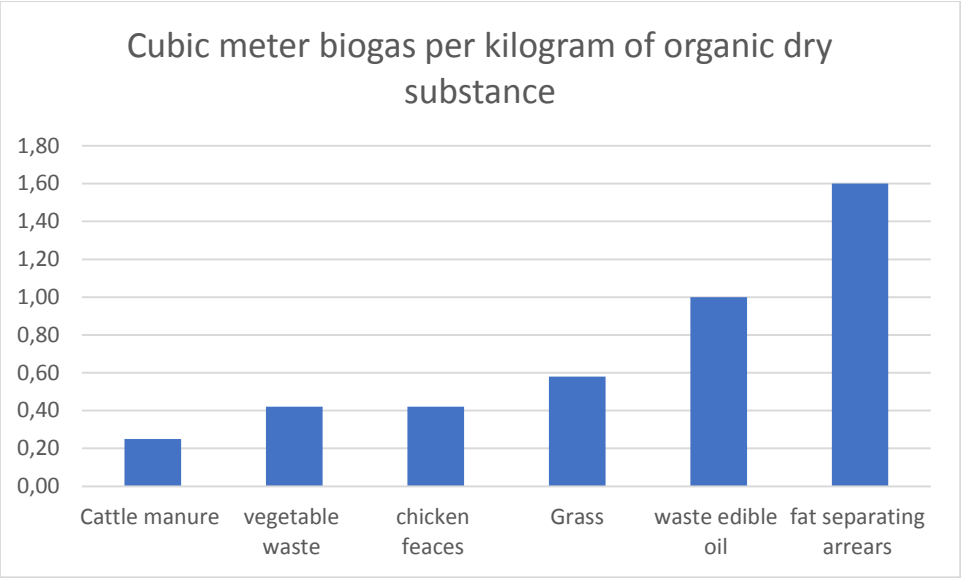
The old way of disposing wastes is unacceptable today; because of its undesirable effects, even using landfills for controlled waste disposal is not considered an optimal practice, as environmental standards call for the utilization of waste management through the recovery process, recycling nutrients, and using organic matter to produce biogas (Alkhalidi et al. 2019). Jordan has considerable biomass assets within the shape of metropolitan strong squanders, sewage, mechanical squanders and creature fertilizer. Municipal solid waste speak to the leading source of biomass in Jordan. Strong squander era within the nation is roughly 2 million tons per annum, with per capita of nearly 1 kg per day. The day by day waste era surpasses 6,000 tons which is characterized by tall natural substance (more than 50 percent). Nourishment waste constitutes nearly 60% of the full waste at most transfer locales. In expansion, more than 2 million cubic meter of sewage slime is created each year from treatment of sewage water in more noteworthy Amman zone which can be an awfully great source for biogas era.

2.7 The development

Biogas may be a gas blend of methane, carbon dioxide and little amounts of hydrogen and hydrogen sulfide which is made beneath discuss avoidance through the maturation of natural substances with microorganism help. Biogas blend comprises of around 40 to 75% methane (CH4), 25 to 60% carbon dioxide (CO2), and roughly 2% of other gasses (hydrogen, hydrogen sulfide and carbon monoxide). The assessment of input materials in a biogas prepare depends on their potential achievable abdicate.

The biogas could be a flexible source of vitality, which is presently ideally changed over into power and warm. In later a long time, a few hundred biogas plants were taken in operation in Europe, where creature excrement and natural squanders from industry and Households are fermented, moreover grass can be aged due to advance within the maturation strategy. Agriculturists ended up "vitality has" due to the maturation of green fabric. The clean vitality from meadows can be effectively transported and contributes to the diminishment of nursery gasses. Aging of grass can give a biologically and financially shrewd commitment to energy generation of long haul.

Biogas can too be provided specifically through pipelines into a biomass warming plant. By doing so, the client can maintain a strategic distance from the execution of a larger than usual kettle and the establishment of an extra warm source. Methane could be a nursery gas thirty times more harming than the comparable sum of carbon dioxide. In the event that one tone of putrescible nourishment squander comprises of 77 per cent water and 23% solids, the digester will change over roughly 75% of the solids to biogas. The greatest conceivable abdicate of biogas is 400 m3, in any case, in hone it is closer to 100 m3, this has a vitality esteem of around 21-28 MJ/m3. Between 20-50% of the vitality delivered will be utilized to run the plant. Biogas may be utilized specifically or as a substitution fuel for furnaces ،boilers and heaters found near to the Advertisement location. In the event that the gas is utilized in control era, gas clean-up is required to remove corrosive trace gases, moisture and vapors. (Abu-Hammatteh et al. 2010).



(Figure 2) Biogas and Organic matter
Source: Abu-Hamatteh et al. (2010)

2.7.1 Biogas Potentials

The Hashemite Kingdom of Jordan has experienced rapid population growth, as well as improved living standards, improvements in the industrial and agricultural sectors, and the introduction of stricter environmental regulations by authorities, in the last five years. (Assaf et al. 2019)

Biogas is a viable renewable energy source that not only provides much-needed energy but also aids in the reduction of greenhouse gas (GHG) emissions. Anaerobic digestion is more common in modern waste water treatment plants (WWTPs). This process decreases sludge volume and generates biogas, which is used to power the WWTP site. (Assaf et al. 2019)

The potential for biogas production through the construction of anaerobic digestion plants in South Amman WWTPs is assessed in this study. The amount of biogas and future energy generation are used in the feasibility analysis. According to the findings, anaerobic digestion will generate 6,942,869 kWh/a, of biogas, which will cover 66 percent of the energy demand in South Amman WWTPs, in addition, the anaerobic digestion unit would reduce the greenhouse gas (GHG) emissions of WWTPs by 29662 tons per year of CO_2.(Albatayneh et al. 2019)
The possibility of producing renewable fuel from organic waste and as an alternative to waste treatment, the use of bio digesters to generate biogas by anaerobic digestion may play an important role in local economies [14]. There is currently only one WWTP in Jordan that uses biogas generation technology, which is the AS-SAMRA WWTP. (Albatayneh et al. 2019)

The waste created in Jordan is comparable to most semi-industrialized countries. The per capita of waste produced in Jordan is around 0.9 kg/day. The entire era of waste in Jordan is assessed at 3.5 million tons per year.

2.7.2 Small-Scale Biogas Plants in Jordan

The previous biogas plants in Jordan gets day by day 60 tons of unadulterated natural waste comprises fundamentally of:
1. Slaughterhouse waste.
2. Nourishment squander from cafés and lodgings.
3. The focal market for vegetables.
4. Blood.
5. Yeast wastewater, dairy industry wastewater.

Biogas is produced using well-established technology in a process involving several stages, with two main components which are called the digester, Gas holder:
1. Bio-waste is crushed into smaller pieces and slurrified to prepare it for the anaerobic digestion process in the Digester. "Slurrifying" means adding liquid to the biowaste to make it easier to process.
2. Microorganisms need warm conditions, so the bio-waste is heated to around 37 °C (only the ones working in mesophilic conditions).
3. The actual biogas production takes place through anaerobic digestion in large tanks (the digesters) for about three weeks.
4. In the final stage, the gas is purified (upgraded) by removing impurities and carbon dioxide, and stored in the gas holder for distribution or personal usage.

After this, the biogas is ready for use by enterprises and consumers, for example in a liquefied form or following injection into the gas pipeline network.
There is a clear usefulness of use of digestate from an anaerobic codigestion process as a fertiliser, due to its improvement of soil properties (Alburguerque et al., 2012) and increased yields (Šimon et al., 2015)
It is additionally conceivable to apply little biogas vitality and manure supply frameworks in the provincial and urban territories to improve the way of life and lessen trouble being forced on ladies and youngsters degassing and settling of civil natural strong waste through anaerobic treatment is broadly utilized innovation in the created nations, execution of this innovation in Amman end up being effective. It has been understood that the job of the private part is conceivable.
The establishment of the biogas venture has changed the entire circumstance were many negative effects have been wiped out. The pilot biogas plant has contributed vigorously to take care of major natural and social issues.
The Biogas Plant features a critical impact on the financial perspectives of economic advancement and will be helping Jordan towards assembly its Kyoto commitments by accomplishing noteworthy fossil fuel investment funds and to change over organic waste as a renewable vitality source and to urge advantage from other by-products such as composting and reusing. The taking after reduces have been accomplished:
• Landfill gasses must be controlled for as they are anticipated to be created.
• The framework embraced at Amman plant demonstrated to be effective and may be received in other Center East nations.
• Biogas misuse has triple benefits as critical renewable vitality source, progressing the environment and the advantageous esteem of the bio fertilizer generation. A beat quality fertilizer that ensures way better crops.
• It is additionally conceivable to apply little biogas vitality and fertilizer supply frameworks within the rustic and urban ranges to progress the standard of living and diminish burden being forced on ladies and children.

• Degassing and stabilizing of metropolitan natural strong waste through anaerobic treatment is broadly utilized innovation within the created nations, execution of this innovation in Amman demonstrated to be effective.
• It has been realized that the part of the private sector is conceivable.
• The establishment of the biogas extend has changed the entire circumstance were numerous negative impacts have been killed. The pilot biogas plant has contributed intensely to fathom major natural and social issues.

From the natural point of view, the treatment of waste speaks to the extreme arrangement to the contamination and odor issues that undermine the populace and the eco–system at both neighborhood and worldwide levels. Biogas plant has been sensibly fruitful in Jordan in giving clean and renewable source of vitality, utilize of biomass vitality has numerous one of a kind qualities that give natural benefits.

2.8 Landfills in Jordan

Landfilling is the simplest and normally cheapest method of disposing of waste (R. Taylor 2003). Despite waste reduction and recycling policies, and waste pretreatment programmers to lower the proportion of waste going to landfill, at the end of the day landfills will still be required to accommodate residual wastes. However, although the proportion of waste to landfill may be decreasing, the total volumes of MSW being produced are still increasing significantly (Allen et al.2000; Beigl and Lebersorger et al. 2009).
Landfills in Jordan are worked by CSCs (which ordinarily serve more than region within the same governates) with double supervision of the Environment and Districts Service.
Jordan has seen a huge increase in population amid the past five decades as a result of high population growth rate and constrained migrations.
Economical and social advancement has progressed the standard of living and changed buyer propensities within the community, resulting in an increase within the volume of Civil solid waste (MSW) with time.
Landfilling, practiced in Jordan, is simply dumping the waste in trenches or cells with leveling and compacting by trash compactors to reduce the size and the thickness of the layers, and finally cover the waste with soil.

Table (1) Landfills in Jordan

No.	Received Waste (Tons / day)	Area in Square Meters	Location	Region
1.	350	80000	Akaider	North
2.	100	38000	Mafraq	North
3.	90	71000	Kufrinja	North
4.	100	78000	Northern Shuneh	North
5.	30	60000	Taybeh	North
6.	80	55000	Saro	North
7.	30	40000	Um Qutain	North
Sum	**780**			
1.	2200	12000	Russeifa	Middle
2.	150	80000	Madaba	Middle
3.	140	27000	Humra	Middle
4.	70	70000	Dhuleil	Middle
5.	20	30000	Thiban	Middle
6.	30	20000	Dier Allah	Middle

7.	10	48000	Azraq	Middle
Sum	**2620**			
1.	80	50000	Aqaba	South
2.	50	60000	Maan	South
3.	85	50000	Karak	South
4.	50	45000	Tafila	South
5.	20	26000	Shobak	South
6.	20	28000	Eil	South
7.	20	27000	Qoura	South
8.	15	10000	Husania	South
9.	40	10000	Southern Shonah	South
10.	20	15000	Ghor safi	South
Sum	**400**			
Total Sum	**3800**			

Source: Daradki et al. (2008)

The total estimated daily generation of municipal solid waste in Jordan is about 3800 tons/day, disposed at 24 sites. The northern region contributes about 780 tons/day, the middle region totals about 2620 tons/day, and the southern region contributes about 400 tons/day, see table (1).

2.8.1 Biogas Plant at Rusaifeh Landfill

The Government of Jordan, in collaboration with UNDP, GEF and the Danish Government, built up 1MW biogas plant at Rusaifeh landfill close to Amman in 1999. The plant has been effectively working since its commissioning and has as of late been expanded to 4MW. The venture comprises of a framework of twelve landfill gas wells and an anaerobic absorption plant based on 60 tons per day of natural squanders from inns, eateries and slaughterhouses in Amman. The effective establishment of the biogas venture has made it a part demonstrate within the whole locale and a few enormous cities are endeavoring to reproduce the show.

The Rusaifa plant comprises of two parts: a biogas from biowaste plant (bookkeeping for 1/3thof biogas delivered), and a biogas from landfilling plant (bookkeeping for 2/3th of biogas delivered). The speculation share of the biodigester was almost 2.2 million US dollars. The biodigester isn't a portion of the CDM extend movement. "The generation of biogas by the bioreactor confronted misfortunes and JBC was constrained to cease its full-scale operation in 2005, as the inward film of the gas capacity tank was found to be flawed and spilled gas.In expansion the coming about slurry was exceedingly saline and contained other contaminants as well,and seem not be utilized as fertilizer or compost, as initially arranged. Not one or the other may it be landfilled.

Other potential biomass assets within the nation are as follows:

1) Organic wastes from slaughterhouse, vegetable advertise, inns and restaurants.
2) Organic waste from agro-industries, animal manure, primarily from dairy animals and chickens.
3) Olive mills.

4) Natural organic waste, either fluid or solid, are a great substrate for biogas era by making utilize of anaerobic absorption prepare.
5) Anaerobic absorption of natural mechanical waste is quick picking up ubiquity worldwide as one of the most excellent waste management strategy.
6) The utilization of anaerobic absorption innovation for organic industrial waste would be a significant step in Jordan's rise as a renewable vitality center within the MENA locale. Jordan is arranging to execute 40-50 MW of waste-to-energy ventures by 2020.

The landfill opened in 1989 and closed 2003. The location is 70 ha in add up to, of which the transfer location is 54 ha. Amid the time of its operation, the landfill gotten 1800 ton/day of Municipal solid waste (MSW) on the common, it is evaluated that an entire of 12 million parcels of waste has been dumped at the landfill, of the following composition: 56 % natural, 16 %paper and paper board, 13 most moldable, 7 % glass, 5 Brass and three to 1 another. The tallness of the dump is between 10 - 25 m. "By wells biogas from the landfill is gotten. Once in an exceedingly exceptionally whereas a greenhorn well is penetrated. It has been evaluated that the landfill will create gas until the year 2033. This biogas from the landfills goes straight to the generators, as treatment is apparently not essential. The biogas from the biodigester was treated, apparently by a biofilter or bio streaming filter since the diagram of JBC (microscopic organisms, water) is closest to a biofilter or bio streaming filter portrayed by the Danish Technological Institute, Expected is that the H2S expulsion was done to a degree secure enough to run the Jenbacher (inside combustion) motor, and not lower. (L. Allegue et al. 2014)

(Figure 3) Rusaifeh Biodigister out of operation
Source: Sam Staps et al. (2016)

2.8.2 Al Ghabawi Landfill Project

Al Ghabawi landfill is the primary of its kind in Jordan because it is planned and built with gas collection frameworks with monetary help from the World Bank. The extend operation is the primary municipal carbon fund organization within the middle East. The power created from landfill gas will be conveyed to the national network, uprooting power delivered by grid associated power plants that customarily utilize heavy fuel oil.

It's a comprising of three cells, begun accepting waste in 2003. Cell 1 has come to full capacity. Cell 2 is developed, operational and is being filled with waste. Cell 3 is a built amid 2013. As of now the location gets approximately 3,000 tons of waste per day but LFG recovery framework is however to be executed. (Yamin et al. 2019)

It gets more than 50% of the volume of the produced solid waste in Jordan. The area of this landfill was chosen after conducting an natural affect appraisal for best location choice (Al-Tarazi et al. 2008). It was moreover outlined and designed concurring to universal measures whereas developed. The rest of the landfill that gets 40% -50% of the volume of waste within the Kingdom are not outlined concurring to universal benchmarks for landfills in terms of well being or natural necessities. Linings need and the strategies of dumping practiced might lead to defilement of groundwater, soil and air. (Aljaradin et al. 2014).

(Figure 4) AlGhabawi urban waste landfill (Gas to Energy)

Source: IDOM project

2.8.3 Energy from Landfills

Al Rusaifah Biogas Company was established in 1997 on the landfill, its main goal was to cut down greenhouse gas (GHG) emissions coming down from the landfill and to use the organic waste to produce the methane gas to initiate power, and the plant had two parts. The first part is to obtain the biogas from the wells of the closed landfill, whilst the second part get the biogas from the digester, where the organic waste is obtained and digested anaerobically. The plant is anticipated to decrease 1.4 million tons of carbon dioxide emissions yearly, and to produce 20,000 megawatts hourly of electricity when it's completely functioning, it will

minimize the methane emission of 5000 tons, and it will save around 6000 tons of diesel for producing electricity. (Aljaradin et al. 2014)

As you can see in (Table 2), the change in electrical energy supply in Jordan for the years 2004-2007 is presented. the expansion rate in biogas production for electricity generation is large, but still the proportion of the overall power supply from non-fossil sources is little. The biogas contribution for producing electricity has increased slightly from 2004 to 2007. The biogas as a renewable source of energy is welcome in Jordan for producing clean renewable electricity; the increasing of production in 2007 will encourage the govt. to speculate more during this sector, However, Nothing much are exhausted this regards after.

Table (2) Electrical energy production in Jordan (GWh)

Year	2004	2005	2006	2007	2006/2007
Electricity sector	8471	9138	10646	12609	18.40
Steam units	7168	7524	5731	6525	13.90
Gas Turbines /diesel	464	341	67	32	-52.2
Gas Turbines /Natural	776	648	943	916	-2.9
Diesel Engines/HFO	1	2	4	1	-75
Hydro Units	53	57	51	61	19.60
Wind Energy	3	3	3	3	_
Bio Gas	**6**	**5**	**6**	**10**	**66.70**
Combined Cycle	0	558	3841	5061	31.80
Industrial Sector	496	516	474	392	-17.3
Steam Units	422	445	446	379	-15
Diesel Engines/HFO	74	71	28	13	-53.6

Source: Aljaradin et al. (2014)

2.8.4 Landfills Environmental effect

The pollution that is caused by the solid waste landfills, uncontrolled landfills, open dumping and partial combustion was recognized by the Jordanian government around the 70s, all of these environmental issues could affect surface water, soil and ground water.

Still many landfills represent a highly threaten to environment. However, many studies have been conducted to investigate some of these threats; the effect of the leachate from the landfill Alakidr was investigated in 2001. Physical and chemical parameters were estimated within an area of 6 km from the landfill site and the impact on the ground water flow direction was covered. The result from that study showed that the landfill constitute a serious threat to the local aquifers (Abu-Rukah et al. 2001).

Physical and chemical parameters were estimated within an area of 6 km from the landfill site in Alakidr landfill and the impact on the groundwater flow direction was covered. The result of that study showed that the landfill constitutes a serious threat to the local aquifers, and thermodynamic analysis of subsoil pore water indicates that Fe, Cu, Zn, and Pb exist as metal hydroxides were at the landfill site and the area around it. Open dumping is still the only practice

at the landfill, so it is strongly affected by sludge accumulation, odor, insects, and rodents. The generated leachate contaminates soil, groundwater, and surface water, the leachate contains very high levels of BOD (36,900mg/L) and COD (157,920 mg/L). (Aljaradin et al. 2014).

2.8.5 Reducing the Environmental effect

In order to develop sustainable energy systems, relations between energy and environment must be understood. In general, all energy systems and human activities have environmental impacts. Extraction of natural resources, materials processing, production processes, transportation and disposal processes produce an enormous amount of wastes and emissions.

Energy products are usually re-leased in the environmental media (water, air, and soil). These products often cause severe problems concerning the standard air, ecosystems, biodiversity, and fresh water. Therefore, the employment of renewable natural resources and also the use fossil fuels with cleaner technologies can help reduce the environmental effects of energy use.

Nevertheless, the accumulations of a huge amount of agricultural, domestic, and industrial wastes generated thanks to human activities and/or improper handling and disposal of these solid wastes have potentially harmful effects both on the environment and human health, managing these wastes from generation to their safe disposal may be a major requirement, Incineration of those wastes targets to scale back their volume, cost of land-filling and to recover energy, either for heating or electricity generation.

However, incineration is often applied for residues with a water content of less than 50% otherwise oil or gas must be added to fuel the combustion process. Besides, incineration produces CO_2, CO, NO_X and volatile organic compounds, which cause environmental pollution, while an outsized amount of ash and residues from off-gas treatment requires further treatment.

3. Aim of the thesis

The Master's Thesis is focused on waste management practices in AlGhoor region. The main object was to provide an understanding about the waste management practices among rural farms and their attitude towards implementing biogas technology at AlGhoor region.

Specific objectives:

- To identify waste management practices currently in-use by farmers and households in the AlGhoor region in Jordan.
- To provide an overall understanding of the general knowledge acquired by local farmers regarding the different methods for utilizing and managing their waste "Biowaste" in specific.
- To examine the factors affecting farmers' willingness to adopt anaerobic digestion (biogas) technology and other environmentally-friendly technologies to solve the farm's and household's waste.
- To create a detailed statistical reference for AlGhoor region for current and any future researchers, advocates and enthusiast regarding the topic of Biogas in farms and households.

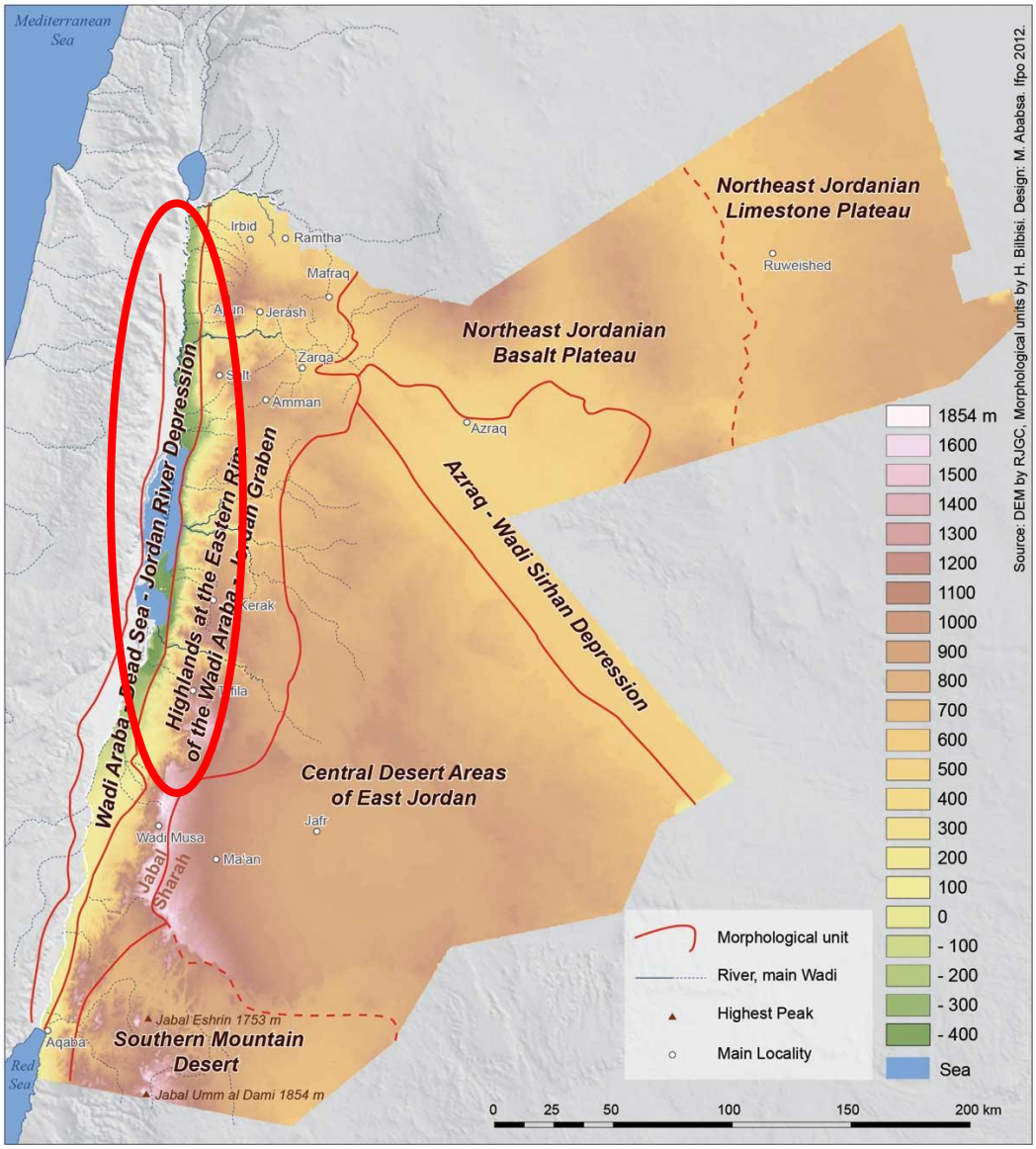
3.1 Reasearch Questions

- Do the local community, comprised by mainly farmers in AlGhoor Region, know about the Biogas technology, its different possible utilities, aspects and benefits?
- Did the Jordanian Government push or advocate for new eco-friendly guidelines, regulations and laws for the agricultural sector in Jordan?
- Can we properly and efficiently implement a working Biogas model within AlGhoor region, to be used and utilized by local farmers?
- Would the implementation of a Biogas model within Farms in AlGhoor Region help sustain the agricultural sector in the region, and push it towards long-term sustainability?

4. Methodology

4.1 Study area description

The research was conducted in AlGhoor region, in the western border of Jordan. (See the figure…) Solid waste management sector is now a priority and currently, Jordan generates about 2 million, 45,000, and 4,000 tons of MSW, MSW collection coverage is estimated at about 90% and 70% for urban and rural areas, about 50% of MSW is food waste, most of it ends up at dumpsites, incineration and sometimes as landfills.



(Figure 5) Map of Jordan with highlighted AlGhoor region (Jordan Valley).

Source: IFPO et al. (2012)

4.2 Data source

The thesis is divided into two main parts. The theoretical part will be based on the literature review derived from the scientific sources and articles, the second part will consist of primary data collection in the target area.

4.2.1 Primary data sources

Primary research data was collected through questionnaire survey with respondents from the target area of Jordan (AlGhoor region) - rural farmers. The provided methods of data collection will involve qualitative as well as quantitative approach.

It will focus on the data collection from the target area was consisting of observing the farms and farmers usual habits of getting rid of their farm waste, either they burn it or they move the pile somewhere far from sight which attracts rodents and insects, the main idea was to convince farmers that there's another safe way to get rid of the farm waste which is both eco-friendly and uncostly.

Respondents were requested to provide information about gas, electricity usage and farm waste in that area and also the approximate amount and sort of waste from farms (livestock, crops, etc.), as the variety and amount of waste affects the biogas production.

The questionaries' focal point is to find out local farmers' waste management practices and their awareness of how it can be used in small scale energy obtaining.

The collected data set from the questionnaire survey will be transcribed into the statistical program SPSS, where it has been sorted, coded, and categorized for further analysis.

4.2.2 Secondary data sources

This Part of the thesis will mainly be contain data from scientific articles and previous projects about the waste management and municipal waste control in Jordan in general and AlGhoor region in specific, Secondary data were searched in scientific databases as Web of Science, Science Direct, research gate and waste management book.

4.2.3 The Questionnaire

The apparatus for collection of essential information was chosen organized survey, questions were partitioned into a few segments:

Table (3) Questionnaire Essential Information

Section Name	**Content**
1. Personal details and socio-economic data	Gender, Age, Farm income, Owner of farm, Farm source of gas, Existence of livestock.
2. Farm Data	Total farm area, Types of crops in farm, Yearly production of crops, Total farm crop waste.
3. Knowledge about waste Management	The mechanism of waste management, Farmers information about waste management.

4. Waste Management Practices	Waste management practices known to farmers (Recycling, Sorting, Composting, and Incineration).
5. Additional Energy Related Information	The amount of money they spend on electricity and gas, the willingness of using a new technology, local government support with waste management, government interest in improving the environment.

Source: Author

4.2.4 Pilot Testing

Pilot testing of questionnaires was held with the help of Eng. Saleh Al yaseen, the farmers and food dealer's official, First version of the Questionnaires were tested in AlGhoor region, on 70 farmers, and observation of the targeted area to watch the farmers waste management behaviors.

4.2.5 Interviews

Along with the questionnaire pilot testing, there was interviews with the directorate of Dier Allah official, Northern-Shoneh resort director where I found the abandoned Biogas plant that was used instead of LPG gas in the resort main restaurant, visited the director of the National Agriculture Research Center (NARC), talked about the potential of applying a Biogas plant in the area, and I interviewed some local farm and restaurant owners in the area about their Farm waste and kitchen waste management.

4.2.6 Target Group

The main target in this thesis is on farmers who are living in AlGhoor region, the respondents of the Questionnaire survey must be:

- Worker/ owner of a farm.
- Live and work in AlGhoor district.
- To have a Jordanian nationality or have a work permit to work in Jordan.
- Number of respondents: 70 farmers in AlGhoor region.

4.3 Methods of data analysis

To achieve the objectives of this thesis, a mix of data analysis methods was employed. First, descriptive statistics was used to summarize the main characteristics of the sample, with information about farmer's background and household's features, farm characteristics, waste management practices being described in detail.

Second, we applied several statistical inference methods to investigate the factors influencing the farmer decisions to adopt biogas technology on their farms, ANOVA, Chi-square and independent sample t-test were used to test various associations between knowledge of waste management techniques, willingness to valorize waste management and age.

Furthermore, binary logistic regression was used to examine the factors influencing the willingness of farmers to adopt waste management technologies.

4.4 Description of explanatory variables

Explanatory variables were: gender, age, Farm management, number of workers, type of farm, and yearly income of the farm (JD per year).

Gender: it is nominal variable taking value 1 for female and 2 for male respondent. Gender of the respondent was included to see possibility of different perception of interest in farming and waste management between male and female respondents.

Age: The age of the surveyed person is an important factor affecting the interest in waste management. Generally, due to new trends and recent concerns about environmental protection, young respondents are often interested in waste managemen tand the environment. Older respondents tend to follow the customs of the previous generation and are not very interested in the environment.

Farm management: it is nominal variable taking value 1 for Yes and 2 for No.

Number of workers: Scale variable.

Type of Farm: it is nominal variable divided into three groups. First group, coded as 1 for Crops, second group, coded as 2 for Livestock, and last group, coded as 3 for Mixed (crops and livestock).

Yearly income of the farm: It is the yearly income of the farm (JOD per year) and it is a nominal variable taking value 1 for 0-1000; 2 for 1000-10,000; 3 for 10,000-100,000; and 4 for more than 100,000.

Table (4) Description of explanatory variables.

Variables	Definition	Type of variable
Gender	**Gender of respondent**	**Nominal variable (1 = female; 2 = male)**
Age	**Age of respondent (years)**	**Scale variable**
Farm management	**If the respondent managing the farm**	**Nominal variable (1 = Yes; 2 = No)**
Number of workers	**How many people work on the farm (total)**	**Scale variable**
Farm type	**The type of the farm**	**Nominal variable (1 = Crops; 2 = Livestock; 3 = Mixed)**
Income	**The yearly income of the farm(JOD per Year)**	**Nominal variable (1 = 0-1000; 2 = 1000-10,000; 3 = 10,000-100,000; 4 = more than 100,000)**

Source: Author (2021)

4.5 Limitations of the thesis

Limitation of survey include missing data, due to some respondents who weren't able or didn't answer some critical or private questions like farm income, less number of respondents or small number of collected sample. This might be due to the current COVID-19 situation.

Limitation of the study include the lack of awareness of farmers on the environmental issues and the importance of applying eco-friendly waste management techniques.

5 Results and Discussion

This chapter presents the main findings of the data analysis. Descriptive statistics, chi-square tests and binary logistic regression were used to gain insights about farmers waste management knowledge, crop and livestock production, their willingness to adapt a new technology, and the government support of adapting this new technology.

This chapter also includes the quantitative research analysis of the primary data analysis results of structured interviews with farm owners in AlGhoor region, and the results from the qualitative research that has been done through observing the area, visiting the farms and talking to the directorate of Dier Allah district and the one of member of the Supreme Agricultural Council Eng. Saleh Al yassin, for more understanding about the waste management techniques that has been done recently in the area , also the possibility of the existence of an abandoned biogas plan in AlShouneh district were we went to examine this abandoned biogas plant and find out about the reasons of abandonment.

5.1 Overview of existing biogas related regulations

With around 8900 Farmers in AlGhoor region and 195285 km2 of cultivable area (1) and yet Jordan has yet to put in place Biogas related regulations and policies, but there are no regulations to stop all farmers from using waste management practices.

Deposition of waste in unsanitary land filling causing severe environmental problems such as emissions of greenhouse gases (GHG) and other substances, toxic residuals, potential contamination of ground water, pollution of the waterways, odor and bad smell as well as possible fires and explosions due to the release of methane gas.
The installation of this project has changed the whole situation were many negative impacts have been eliminated. The pilot biogas plant has contributed heavily to solve major environmental and social problems. The biogas technology is considered as an efficient solution for serious local environmental problems. (Abu-Hamatteh et al. 2010)
In the light of the current financial despondency, as the oil and gas prices are sky rocketing by the minute, the indispensable need grew greater in hopes of finding alternative energy resources, as a result we decided to turn our heads to the eco-friendly direction as the natural resources deemed to be the least damaging to nature, take the solar and wind energy for an example on this and all the assistance they have offered even while the world is mainly still relying on oil for energy.
A recent feasibility study in Jordan that was conducted in cows farm proved that the increase in population naturally demands an increase on dairy and red meat production thus the growth of biogas production, so Biogas now stood up as an exemplary solution as it limits pollution and in the same time we make use of it instead of it being a wasted resource.
In that we reached a solution for the biggest of issues that faces us
Which are:
- The increase of oil prices globally.
- Limit the pollution that is caused by gas and farms waste.
- The markets need for investors, attracting them through investments in biogas to provide a Cheaper and a more eco-friendly gas.

These solutions are what many researchers confirmed in the terms of the possibility of biogas production to be applied as a project in many different areas inside Jordan, (AL Hamad et al. 2019) included these information in her research about the possibility of investing in the biogas that exists in the Zarqa governorate specifically in the Al Dlail and Al Khaldyeh area, as those two areas are known for their cow farms and dairy production, as the number of cows reached 40000 in 220 farm.

5.2 Overview of Waste Management practices in Jordan

Solid waste management in Jordan, and particular MSW, has been improved for the last 15 years since the mid-1990s, with improvement of legal framework and institutional capacity to be the main drivers of sector's development. With the adoption of government National Agenda (NA) for Sustainable Development which represents the government's policy for ten years (2006-2015), solid waste management sector is now a priority and will be addressed on par with water and wastewater issues. Currently, jordan generates about 2 million, 45,000, and 4,000 tons of MSW, hazardous industrial waste, and medical waste, respectively, per year. MSW collection coverage is estimated at about 90% and 70% for urban and rural areas, respectively, about 50% of MSW is food waste and 35% is packaging waste that would be potentially available for recovery. Most of MSW ends up at dumpsites and landfills, whereas only 7% are currently recovered informally in the kingdom, there are existing plans to develop an integrated treatment centre for hazardous industrial and medical wastes, that are now partially controlled either in Swaqa hazardous waste treatment and storage centre or in various incinerators attached to health care facilities. (GIZ, 2014).

Solid waste (SW) mismanagement is a global issue in terms of environmental contamination, Social inclusion, and economic sustainability, which requires integrated assessments and holistic
Approaches for its solution. Attention should be paid in developing and transition countries, Where the unsustainable management of SW is common. (Ferronato, 2019)

Fumble of solid waste leads to open wellbeing dangers, unfavorable natural impacts and other socio-economic issues. Typically self-evident in numerous creating nations around the world. Right now, a few nations have realized that the way they oversee their solid waste does not fulfill the goals of economic improvement. (Ferronato, 2019)

Subsequently, these nations, counting Jordan, which shapes the case think about displayed here, have chosen to move absent from conventional solid waste management (SWM) alternatives to more coordinates solid waste approaches. Shockingly, in numerous creating nations like Jordan, the need of satisfactory assets to actualize the vital changes is posturing a genuine impediment.

Essential energy needs are not always met in poor and rural areas of developing counties; therefore, natural energy sources are necessary to mitigate this problem.
Rural areas inhabitants utilize methane as a replacement for cooking gas to reduce their gas bill, methane gas can be produced from a biogas digester; however, operating a large digester in a densely populated village in Jordan can be challenging due to inefficient village waste management systems. On the other hand, using a small-scale portable biogas digester to generate biogas could overcome these problems. In this work, three biogas digester feed-stocks for a small portable biogas digester from natural sources available in Jordanian villages such as human and animal waste were designed and evaluated. The three feed-stocks are food waste, human waste, and a mixture of human and food waste. The parameters tested were the digester size and the biogas production. The results showed that the best digester for portable application was that which digested a mixture of human and food waste; for a five-member family, this type of digester provided 115% of the family's cooking gas requirements with a digester volume of 0.54 m3. This design, while applicable for a typical rural Jordanian family, can also be utilized globally. (Alkhalidi et al. 2019)
From the natural point of view, the treatment of waste speaks to a definitive answer for the contamination and smell issues that undermine the populace and the eco–framework at both neighborhood and worldwide levels. Biogas plant has been sensibly effective in Jordan in giving

perfect and inexhaustible wellspring of vitality. The utilization of biomass vitality has numerous interesting characteristics that give ecological advantages.(FAO, 2019)

5.3 AlGhoor region previous biogas plants:

In the visited site there was a previous biogas digester, was used in a small restaurant at a known resort in Al shouneh district for cooking and they used kitchen waste and vegetable remains as a main feed for the digester, But it was then abandoned for unknown reasons, but likely because of the common use of LPG around the country and specifically in the area, in (figure 5) it shows that the Biogas plant been abandoned for several years, even though as been researched that it was working perfectly before the mass number of tourists started coming to that area.

Abandoned Biogas plant in AlGhoor region.

(Figure 6) Abandoned Biogas plant in AlGhoor region.

Source: Author.

5.4 Descriptive statistics results

5.4.1 Demographic Indicators

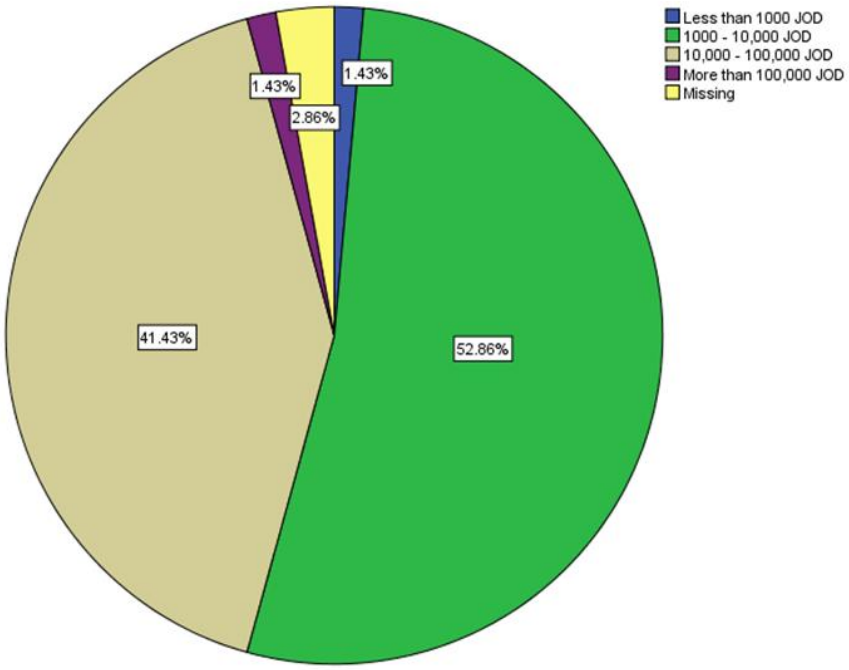
The result on the demographic backgrounds of respondents in study area are presented in Table (5). The results show that composition of gender was with a dominance of male respondents. Respondent's age ranges between 25-65 years, this range is considered to be the age of employed population in Jordan. All the respondents are the farm managers, and their workers range between 2-35 workers per farm which is also related to the income of the farm and how much the manager is generating an income, where the 2 workers farm has an income range between (0-1000) and the farm with a 35 workers has income that ranges between (100.000 and more). Most of the farmers has a crop type of farm while slightly less is the one with a mixed type of farm.

Table (5) Descriptive Statistics, Socio-economic indicators

	Min.	Max.	Mode	Mean	SD	%
Gender	-	-	2 (Male)	-	-	100% Male
Age (Years)	25	65	45	43.96	9.22	-
Are you the farm manager?	-	-	1 (Yes)	-	-	100% Farm manager
Yearly farm income	-	-	2 (1000 - 10,000 JOD)	-	-	52.9% (1000 - 10,000 JOD)
Farm size (Ha)	2	100	3	6.08	11.99	-
No. of workers	2	35	6	7.56	6.74	-

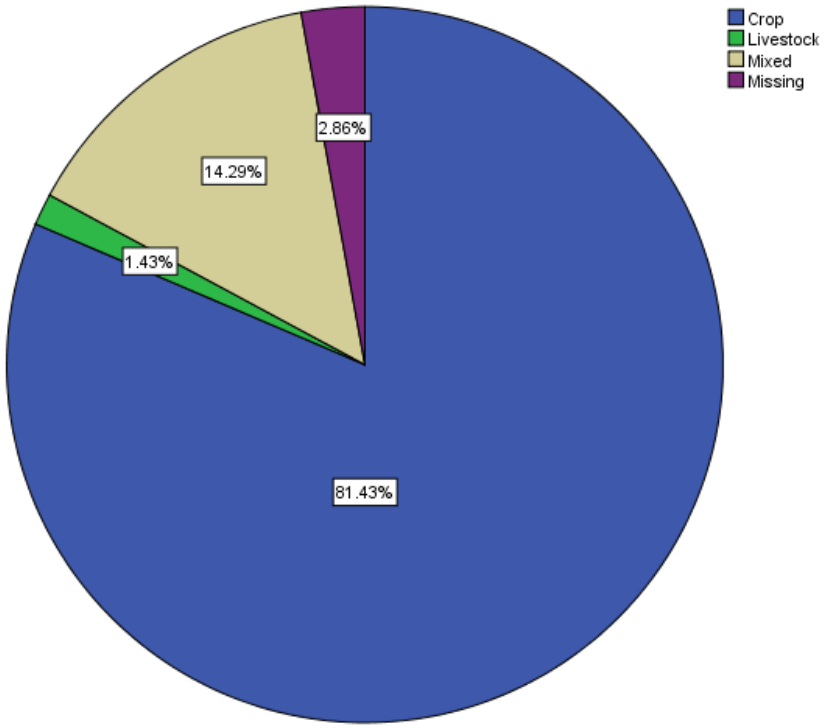
Source: Author.

Farm distribution based on income of each targeted farm in AlGhoor region. In figure (7) it shows that farmers with (1000-10.000 JOD) income range are the majority with a 52.86%, on the other hand farmers with an income range of (less than 1000 JOD) and (more than 100.000 JOD) are the minority with a 1.43% of farmers.



(Figure 7) Farms distributions based on income.
Source: Author.

Farm Types describes the classification of farms in AlGhoor region based on the data that was provided by respondents. Figure (8) shows the types of farm which are Crop, livestock, and mixed farms between crop and livestock. The result shows that the majority of farms are crop farms with the percentage of 81.43%, while the minority was a livestock farm with the rate the percentage of 1.43%.



(Figure 8) Farm Types.
Source: Author.

The main cultivated crops are (% of respondents): tomato (23.6%), cucumber (16.8%), paprika (10.6%) and potato (9.9%), the rest was (write other plants)

Regarding livestock, 11.4% of farmers reported that they own sheep, 4.3% own cattle and 1.4% own poultry.

5.4.2 On-farm Waste Management Practices in the Study Area

Plant Production Waste

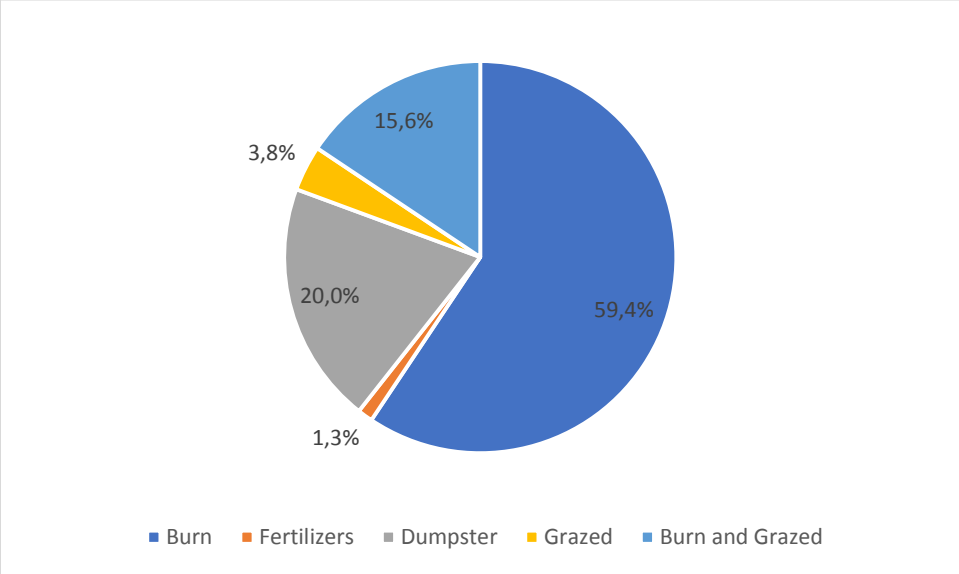
As shown in table (6), the descriptive analysis of each product has been produced in AlGhoor region and comparing it with the amount of waste produced in Tons per year and the technique they use to get rid of these wastes.

Table (6) Plant waste management techniques

Crop	Production Quantity (ton/year)	Waste Quantity (ton/year)	Plant Waste Management Techniques (%)				
			Burn	Fertilizers	Dumpster	Graze	Burn and Graze
Tomato	108.4	34.86	63,2	-	13,2	5,3	18,4
Cucumber	72.77	20.35	70.4	-	11.1	3,7	14.8
Paprika	63.24	18.29	52,9	-	23,5	5,9	17,6
Potato	72.81	23.94	75,0	-	12,5	-	12,5
Zucchini	45.45	19.82	72,7	-	18,2	-	9,1
Green bean	46.67	14.22	55,6	-	11,1	-	33,3
Okra	67.78	28.22	33,3	-	44,4	11,1	11,1
Carrot	200.63	28.57	50,0	-	37,5	-	12,5
Eggplant	40	15.63	25,0	-	62,5	-	12,5
Onion	66.67	10.83	83,3	-	16,7	-	-
Corn	72.5	38.75	25,0	-	-	25,0	50,0
Citrus	110	19	33,3	33,3	33,3	-	-
Grape	53.33	10	-	50,0	50,0	-	-
Palm	130	70	2,9	-	-	-	-

Source: Author.

Figure (9) summarizes the main waste management techniques used by farmers in AlGhoor for plant production.



(Figure 9) Plant waste techniques frequencies.
Source: Author.

Livestock Production Wastes

The result in table (7) shows the number of farms that uses animal's products and waste, the result shows that it's uncommon for farmers to own animals or use animals in the farm, the most common animal is used was Sheep, and it's waste was used mostly as a fertilizer, and the least used animal on farms was poultry which was also used as farm fertilizer.

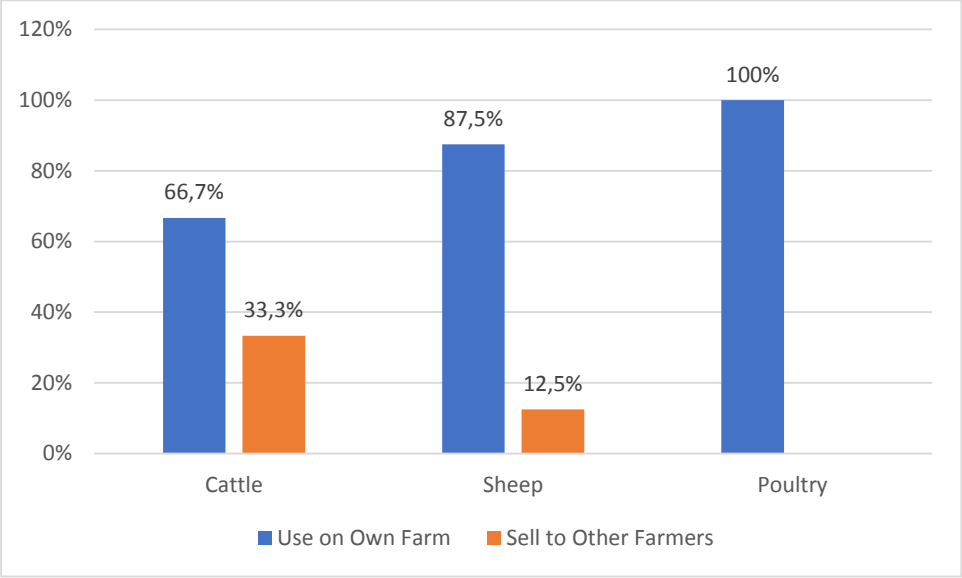
The main uses of livestock and the average number of heads are summarized in the table (6).

Table (7) Uses of livestock production waste

Livestock type	No. heads (Mean)	Uses (%)		
		Meat	Dairy/Eggs	Manure
Cattle	10.67	14.3	71.4	14.3
Sheep	49.38	50	50	-
Poultry	151	-	80	20

Source: Author.

Farmers who raise livestock use the livestock waste either on their farms as fertilizers, or they sell it to other farmers in the area (Figure 10).



(Figure 10) Usage of Livestock Waste.

Source: Author.

5.4.3 Farm Waste Management Techniques in the study area

The result on the waste management practices and techniques backgrounds of respondents in study area are presented in Table (8).

The results show that most of the farmers common waste management practice is the incineration and grazing of the waste where the they incinerate and graze around 30 to 200 Ton every season, while farmers who are using the incineration technique, they were incinerating around 80 Tons every season and sometimes once every year. On the other hand the use of waste as a fertilizer as the least common were it was around 10 Tons in total once every year, also grazing technique alone was rarely been done by farmers were it was only 1 Ton once a year and sometimes less.

Table (8) Farm waste management techniques

Practice	Used By Farmers (%)	How often? (Mode / %)	Waste Quantity (kg)	Reasons of Using this Practice (%)			
				Environ. reasons	Monetary reasons	No other way	Don't know
Solid Waste Sorting	13.2	Yearly (50)	1,955	28.6	14.3	28.6	28.6
Food Waste Sorting	17.6	Yearly (60)	7,610.3	80	10	10	-
Recycling	4.5	Yearly (100)	50,001.5	-	100	-	-
Composting	27.9	Seasonally (50)	6,858.29	60	40	-	-
Burning	80.9	Seasonally (60)	53,844.1	63	1.9	35	-

Source: Author

Respondents Knowledge about Waste Management

The result of the knowledge level about waste management between farmers are presented in table (9).

The result show the general knowledge about the different waste management techniques that are used or familiar to farmers in the area are mainly low or non-existent, for example the highest zero knowledge was in sorting the waste with 67,6 %, also it was the highest rate with the average knowledge about the waste with 10,3 %. If we look at the composting knowledge the percentage of excellent knowledge was recognized and it was the only percent level in the excellent knowledge level with 1, 5 %.

Table (9) level of knowledge about waste management between farmers.

Practice	Level of knowledge (%)				
	None	Poor	Average	Good	Excellent
Sorting	67,6	20,6	10,3	1,5	-
Recycling	66,2	25,0	8,8	-	-
Composting	58,8	25,0	7,4	7,4	1,5

Source: Author.

5.5 Overview of farmer's approach and acceptance

Farmers in AlGhoor region has shown great interest in waste management techniques and practices, once presented with the financial benefits. In terms of quantity per capita and constituents, the waste generated in Jordan is comparable to most semi industrialized nations. The per capita of waste generated in Jordan is about 0.9 kg/day. The total generation of Waste in Jordan is estimated at 3.5 million tons per year. (Abu-Hamatteh et al. 2010).
The results of farmer's acceptance in implementing and adapting a new technology shows that the factors affecting their decisions is not related to the government support or the previous knowledge of waste management techniques, as well as the income of the farm. In fact their willingness to apply such technology was due to the high energy expenses they spend on the farm, which means they are willing to accept and apply the new technology if it will save them money and effort, also if it was applied by the government or from a foreign investor.

The Chi- Square Test of valorizing and adaptation of biogas technology

The result of valorizing and adapting of the biogas technology are shown in table (10). The result shows that if there's a substitute energy with a lower cost than the farmers usually pay for to get rid of their farm waste, they were willing to apply it, especially if it will save the amount of money they spend on electricity and gas every month.

Table (10) Are you willing to use a new technology to produce your farm's energy? * Do you feel support from local government regarding waste management? Cross tabulation

			Do you feel support from local government regarding waste management?			
			Yes	No	I don't know	Total
Are you willing to use a new technology to produce your farm's energy?	Yes	Count	4	40	13	57
		% within Are you willing to use a new technology to produce your farm's energy?	7.0%	70.2%	22.8%	100.0%
	No	Count	1	4	5	10
		% within Are you willing to use a new technology to produce your farm's energy?	10.0%	40.0%	50.0%	100.0%
Total		Count	5	44	18	67
		% within Are you willing to use a new technology to produce your farm's energy?	7.5%	65.7%	26.9%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	18.203[a]	1	.000		
Continuity Correction[b]	11.784	1	.001		
Likelihood Ratio	12.374	1	.000		
Fisher's Exact Test				.002	.002
Linear-by-Linear Association	17.935	1	.000		
N of Valid Cases	68				

a. 2 cells (50,0%) have expected count less than 5. The minimum expected count is ,44.

b. Computed only for a 2x2 table

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	22.294[a]	.398	.703

a. Estimation terminated at iteration number 20 because maximum iterations has been reached. Final solution cannot be found.

5.6 The results of Binary Logistic Regression model analysis

The binary logistic regression model was used to analyse the possible effects of factors influencing the willingness to adapt a new technology. The results are presented in table (11) below. Results of analysis suggested that significant predictors used in model include the environment interest and gas spend, both are positively affect the decision of farmers in adapting a new technology, the farmers with the highest environmental interest the higher the willingness of adapting a new technology for waste management. The higher the gas spend the more they are willing to adapt a new technology as it shows in the table the significance is 0,028. It might be due to the fact that the gas prices are high and still increasing.

On the other hand, the higher the electricity spend the less they are willing to adapt to the new technology, and the result shows that the number is insignificant with 0,108. Even though that the electricity bills are approximately high in Jordan.

Table (11) Results of binary logistic model analysis

							95% C.I.for EXP(B)	
	B	S.E.	Wald	df	Sig.	Exp(B)	Lower	Upper
Step 1[a]	Age	-.168	.111	2.297	1	.130	.845	.680	1.051
	No_Workers	.297	.180	2.729	1	.099	1.346	.946	1.915
	Income	-.763	1.199	.405	1	.524	.466	.044	4.889
	FarmSize	-.052	.061	.729	1	.393	.949	.843	1.069
	Environ_Interest	5.468	2.215	6.094	1	.014	236.913	3.085	18194.025
	ElecSpend	.028	.017	2.589	1	.108	1.028	.994	1.063
	GasSpend	-.355	.162	4.810	1	**.028**	.701	.510	.963
	SubEnergy	21.990	22983.439	.000	1	.999	3548294699.604	.000	.
	GovInterest	2.576	2.351	1.201	1	.273	13.150	.131	1318.904
	Constant	-11.056	22983.440	.000	1	1.000	.000		

a. Variable(s) entered on step 1: Age, No_Workers, Income, FarmSize, Environ_Interest, ElecSpend, GasSpend, SubEnergy, GovInterest.

5.7 The previous knowledge of different waste management techniques

Table (12) shows the result of farmers' knowledge of different waste management techniques that they have been practicing in the farm when the survey was conducted. And comparing the knowledge with the ability or willingness to valorize the waste and using a new technology. The results shows insignificant numbers for all waste management techniques, which means that the previous knowledge of these different waste management techniques has no effect on the farmers willingness to adapt a new technology in the farm. It might be due to the lack of awareness and knowledge from farmers about the importance of applying or implementing these waste management techniques in the area.

Table (12) Knowledge of sorting * Are you willing to use a new technology to produce your farm's energy? Cross tabulation

Count

		Are you willing to use a new technology to produce your farm's energy?		
		No	Yes	Total
Knowledge of sorting	Zero knowledge	8	38	46
	Poor knowledge	1	13	14
	Average knowledge	1	6	7
	Good knowledge	0	1	1
Total		10	58	68

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	1.076[a]	3	.783
Likelihood Ratio	1.336	3	.721
Linear-by-Linear Association	.518	1	.472
N of Valid Cases	68		

a. 4 cells (50,0%) have expected count less than 5. The minimum expected count is ,15.

Table (13) Knowledge of recycling * Are you willing to use a new technology to produce your farm's energy? Crosstabulation

Count

		Are you willing to use a new technology to produce your farm's energy?		
		No	Yes	Total
Knowledge of recycling	Zero knowledge	9	36	45
	Poor knowledge	1	16	17
	Average knowledge	0	6	6
Total		10	58	68

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	3.095[a]	2	.213
Likelihood Ratio	4.147	2	.126
Linear-by-Linear Association	2.924	1	.087
N of Valid Cases	68		

a. 2 cells (33,3%) have expected count less than 5. The minimum expected count is ,88.

Table (14) Knowledge of composting * Are you willing to use a new technology to produce your farm's energy? Crosstabulation

Count

		Are you willing to use a new technology to produce your farm's energy?		
		No	Yes	Total
Knowledge of composting	Zero knowledge	6	34	40
	Poor knowledge	2	15	17
	Average knowledge	1	4	5
	Good knowledge	1	4	5
	Excellent knowledge	0	1	1
Total		10	58	68

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	.516[a]	4	.972
Likelihood Ratio	.650	4	.957
Linear-by-Linear Association	.007	1	.936
N of Valid Cases	68		

a. 7 cells (70,0%) have expected count less than 5. The minimum expected count is ,15.

5.8 ANOVA, Knowledge of waste techniques and age of respondents

The result of comparing the knowledge of waste management and the ages of targeted farmers as shown in table (15).the result shows that knowledge of only composting is significantly associated with age but knowledge of sorting and recycling were insignificant when associated with age of respondents. It might be due to the fact that composting knowledge is very common in AlGhoor farms and the high usage of fertilizers and compost between older farmers and it was the only old technique to enhance the production.

Table (15) comparing knowledge of waste management with Farmers age

		Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
Knowledge of sorting	Between Groups	14.695	26	.565	1.045	.440
	Within Groups	22.172	41	.541		
	Total	36.868	67			
Knowledge of recycling	Between Groups	10.910	26	.420	.971	.522
	Within Groups	17.722	41	.432		
	Total	28.632	67			
Knowledge of composting	Between Groups	36.493	26	1.404	1.894	.033
	Within Groups	30.389	41	.741		
	Total	66.882	67			

Source: Author

6 Conclusion

The objective of this diploma thesis was to provide understanding about the waste management practices among rural farms and their attitude towards implementing a biogas technology at AlGhoor region and to create a detailed statistical reference for AlGhoor region, for current and any future researchers, advocates and enthusiast regarding the topic of Biogas in farms and maybe households.

The results of questionnaire survey conducted in the frame of this Master's Thesis showed that age, locality and had significant influence on public approach to interest in waste management practices in connection to the environmental issue.Younger and middle age respondents tended to be more interested in helping the environment than respondents in older age category.

First of all, there was a previous usage of an old abandoned biogas plant in the region, and reasons of abandonment were due to the lack of usage and the local access to the LPG which is very common in Jordan.

The knowledge of the waste management techniques was irrelevant in accordance with the appliance of those techniques in farms, due to time and effort availability, lack of government interest and concern with the matter, which made the farmers care less about the environment and the effect that their bad waste management technique is making, so whether there is a support or non-governmental support from the government it doesn't really affect the farmers support of adapting the new technology.

Although the lack of farmer's awareness about the environmental issues even though a lot of farmers care about the environment and they were willing to adapt a new clean technology to manage their waste therefore we need the decision maker to shine a light on this issue for further studies.

Second of all, after the survey been conducted, most of the farmers were welling to adapt a new cheaper and effective technology to get rid of their waste; according to farmers the incineration and dumping the waste in an abandoned place, was the most efficient and cheapest way to get rid of their waste even though they knew about the environmental effect that this technique causes, and that the government did provide another solution nor they complained about their behaviour towards managing the waste, most of the young farmers were complaining about all the bad waste management behaviours and tries to use their waste in different ways as fertilizer and grazing but due to the huge amount of waste coming out of the farm each season it was inefficient and they needed a different method to get rid of the waste.

The previous knowledge of waste management techniques such as sorting the waste or recycling has no relation with the respondents age or the experience in farming field, they were mostly getting their information from various sources such as other farmers/ neighbouring farmers, media or from family members. Needless to say that the farmers needed the education on how to manage their waste, but the need of government care and regulations to forbid anti-environmental waste management techniques.

The proper and efficient implement of a working Biogas model within AlGhoor region, and to be used and utilized by local farmers is a slim chance due to previous model which were implemented before as well as previous landfill projects, and were closed or shut down to many previously mentioned reasons as the possibility of abandonment.

The implementation of a Bio-Gas model within Farms in AlGhoor Region would help sustain the agricultural sector in the region, and there's a possibility that it will push it towards long-

term sustainability but with the proper governmental regulations that might push the farmers for a better behavior towards their waste.

As seen from the recent changes in regulation specially when dealing with solid wastes, there has been a lot of improvements within the behaviors of people who live in AlGhoor region due to all the projects that has been done to aware citizen including farmers to the importance of dealing with the solid waste around the country.

It can be concluded that the adoption of planting a biogas technology in AlGhoor region leads to a better positive impact on the surrounded environment as well as the understanding of using the technology properly which might in return change the farmers behavior towards abandoning the biogas plant for more available and more common options like the LPG and electricity. The LPG prices and electricity bills are increasing and due to the Corona virus situation, the amount of production got decreased which also can be another reason for implementing a cheaper method to decrease the amount of farm expenditures. Specially that the biogas technology has its effective positive advantages.

Further research to identify the possibility of applying a biogas plant model in AlGhoor region, specifically in Dier allah is recommended due to the positive feedback of farmers in that area, and the main directorate's opinion about this project. It is necessary to ensure that the biogas plant will remain and won't be abandoned in the future, also increase awareness around farmers about the environmental effect of BGP, although the government support has no effect on changing the behavior or decision of farmers in conducting or their willingness to implement a new technology.

Finally, seeking foreign investment to apply a successful self-sustaining biogas technology can be achieved in the future with more users benefitting from biogas technology on small-scale and large-scale level might be possible but farmer's awareness about the importance of using the BGP and the reasons why it's an efficient technology is highly recommended.

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Appendices

List of the appendices

Appendix 1: Biogas and waste management questionnaire – Field survey AlGhoor 2020.

Biogas and waste management questionnaire – Field survey AlGhoor 2020

1. Personal details and socio-economic data:

Family name, first name	
Gender	☐ Male ☐ Female
Age	
District	
Village	

1.1. Are you head of the household? ☐ Yes ☐ No, my relation to head of household _____

1.2. How many people live in the household in total and their age?

1)_____ 2) _____ 3) _____ 4) _____ 5) _____ 6) _____ 7) _____ 8) _____

9) _____

1.3. What is your occupation? _____

1.4. Type of household:

☐ Regular household ☐ Household with business (small restaurant, shop) ☐ Farm ☐ other, specify _____

1.5. What is your household income in cash per month?

Main source of income _____

1.6. What is your household source of gas?

2. Farm data:

Total farm area	m^2	**What do you do with residues? (describe)**
Name of crops:	**How much waste comes out from this crop?**	
-		
-		
-		
-		

Do you own any livestock? ☐ Yes ☐ No

If yes, what kind of livestock do you own? _____

3. Knowledge about waste management

3.1. What mechanisms of waste management do you know?

Sorting of solid waste	1 (Know very well)	2 (moderate knowledge)	3 (Don´t know anything)
Recycling	1 (Know very well)	2 (moderate knowledge)	3 (Don´t know anything)
Composting	1 (Know very well)	2 (moderate knowledge)	3 (Don´t know anything)

3.2. Where do you get information about waste management?

☐ from mass media (TV, radio, newspapers) ☐ Local community ☐ Neighbors ☐ Other, please specify _____

3.3. Are you interested in environmental issues? ☐ Yes ☐ No

3.4. How do you get rid of your farm waste? Please specify _____

4. Waste management practices

Sorting of solid waste material **Why:** **How and how often:**	1 Yes	2 Sometimes	3 No
Sorting of food waste material **Why:** **How and how often:**	1 Yes	2 Sometimes	3 No
Recycling **Why:** **How and how often:**	1 Yes	2 Sometimes	3 No
Composting **Why:** **How and how often:**	1 Yes	2 Sometimes	3 No

4.1. What waste management practices do you do and why?

Burning waste **Why:** **How and how often:**	1 Yes	2 Sometimes	3 No

5. Additional Energy Related information

5.1. How much money you are spending on electricity/gas per month? _____

5.2. Are you willing to use a new technology to manage your waste?

☐ Yes ☐ No

5.3 If there's a substitute for your energy source with a lower cost would you want to apply it?

☐ Yes ☐ No

If you answered with No, please specify the reasons and concerns:

_____

5.4. Do you feel support from local government regarding waste management? ☐ Yes ☐ No ☐ I don´t know

5.5. Do you think that the local government is interested in improving the environment? ☐ Yes ☐ No ☐ I don´t know