This book reviews different ways of energy generation from different resources like agricultural waste, municipal solid waste, and municipal sewage sludge, by producing biogas through anaerobic digestion system and converting it to heat or electricity, or even into cool energy. The potential energy recovered from all these resources decreases the energy price and keeps the environment save from pollution, diseases, etc. The potential electricity generation from the anaerobically digestion of organic solid waste in Palestine is around 325 MWh/day which is enough to cover at least 15000 households. Also the potential energy recovery from cow and chicken manure is around 110542 MWh annually. Applying such a project in Palestine needs between 12-15 years to recover its capital costs. Such a project will save environment, create new jobs for engineers and other skilled labours, and encourage the industries to expand & large their investments.

Ziad Tareq Abdo

Issam A. Al-Khatib

Potential of Biogas Production from Biomass and Organic Waste Material

Eng. Ziad Tareq Abdo has a master degree in Water and Environmental Engineering from the Institute of Environmental and Water Studies, Birzeit University, Palestine. Prof. Dr. Issam A. Al-Khatib has an extended research and professional work experience in water resources management, engineering hydraulics, medical & solid waste and climate change.

978-613-8-38862-3

LAP LAMBERT Academic Publishing

Ziad Tareq Abdo
Issam A. Al-Khatib

Potential of Biogas Production from Biomass and Organic Waste Material

Ziad Tareq Abdo
Issam A. Al-Khatib

Potential of Biogas Production from Biomass and Organic Waste Material

LAP LAMBERT Academic Publishing

Imprint
Any brand names and product names mentioned in this book are subject to trademark, brand or patent protection and are trademarks or registered trademarks of their respective holders. The use of brand names, product names, common names, trade names, product descriptions etc. even without a particular marking in this work is in no way to be construed to mean that such names may be regarded as unrestricted in respect of trademark and brand protection legislation and could thus be used by anyone.

Cover image: www.ingimage.com

Publisher:
LAP LAMBERT Academic Publishing
is a trademark of
International Book Market Service Ltd., member of OmniScriptum Publishing Group
17 Meldrum Street, Beau Bassin 71504, Mauritius

Printed at: see last page
ISBN: 978-613-8-38862-3

Potential of Biogas Production from Biomass and Organic Waste Materials in the West Bank of Palestine

Table of Contents

Forward

The state of Palestine is extremely dependent on importing energy from Israel as fossil fuels with high taxes while there are many resource of renewable energy are neglected which may decrease the total amount of imported energy as electricity or fossil fuels.
This book will review many different way to generate energy from different resources like agricultural waste includes agricultural residues and animal manure, municipal solid waste, and municipal sewage sludge, by producing by producing biogas through anaerobic digestion system and converting it to heat or electricity or even into cool energy.

The potential energy recovered from all these resources will decrease the energy prices and will keep the environment save from pollution, diseases, etc. the amount of electricity available only from digesting solid waste anaerobically in Palestine is around 325000 kWh/day or 325 MWh/day which is enough to cover at least 15000 household as the Palestinian central bureau of statistics (PCBS) mentioned. Also the potential energy recovery from animal manure by cow, and chicken manure only, is around 110542 MWh annually.

Also the financial analysis will take under consideration through this book, to evaluate the recovering period and maximize the net profits, to make it possible to upgrade this project. Applying this project in Palestine needs between 12-15 years to recover its capital costs which is approximately 90,000,000$, this project will save environment save and create new jobs for engineers and other skilled labours, will encourage the industries to expand and large their investments, also in the agricultural way like what Al-Jabrini did.

Introduction

The state of Palestine is a geographical region in western Asia between the Mediterranean Sea and the Jordan River. It is under the control of the Israel Zionist occupation since 1948. The Palestinian central bureau of statistics (PCBS) has estimated the population between the Jordan River and the Mediterranean, wide-ranging of the west bank, the Gaza strip and Israel, amounted to 6.08 million people in 2014 [1]. The Palestinian population in the west bank is amounted to 3008770 with a growth rate of +2.50% and 1943398 in Gaza strip with a growth rate of +3.3% in 2017 [2]. This continuously increased population are followed by increasing the economics growth which means more energy requirements.

Palestinian energy demand had grown-up quickly, growing by 6.4% annually from 1999 to 2005 [3]. The expected energy consumption in Palestine is 8400 gigawatts by 2020 as the consumption rate 6% annually [4]. All energy consumed is imported from Israel and it heavily taxed. The cost and customer prices of electricity in Palestine are the most expensive when compared with other countries in the region as shown in Fig. 1.

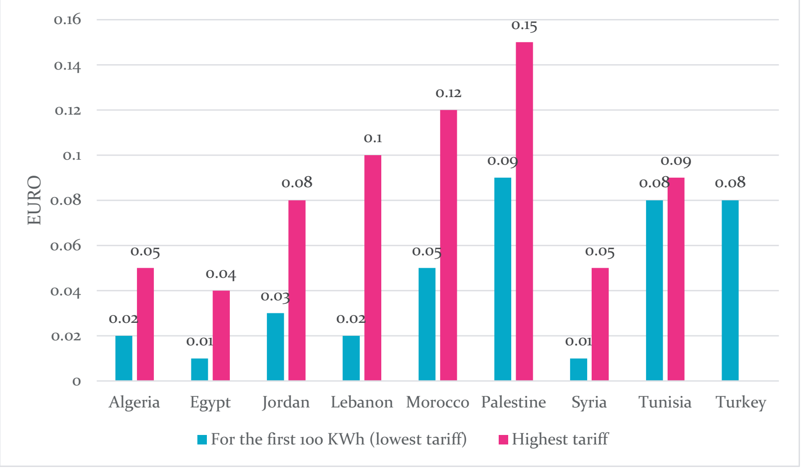


Figure 1: Tariffs of electricity in EURO [5]

Further to the increase of the primary energy required due to high economic growth and increase in population as well as standard of living in the future. The amount of petrol or fossil fouls required to meet the worlds energy demand will keep on increasing if no alternatives applied. Many countries had decided to shift from fossil fouls to renewables to sustain their industries. Now the studies are focusing to use anaerobic digestion (AD) of biomass from deferent wastes (municipal, agricultural, industrial) to produce energy (bio-gas) in Palestine.

Principles of Anaerobic Digestion

Anaerobic digestion (AD) is a collection of processes by which the microorganisms break down the biodegradable material in the absence of oxygen [6]. This process or technique is used to manage wastes from industrial, agriculture, municipal and to produce energy. Anaerobic digestion occurs naturally in some soils and in lake and oceanic basin sediments, where it is usually referred to as “anaerobic activity” [7; 8]. This is the source of marsh gas methane as discovered by Alessandro Volta in 1776 [9; 10].

The digestion process starts through the bacterial hydrolysis of the input materials. Insoluble organics, like carbohydrates, are broken down to soluble matter for other bacteria. Then Acidogenic bacteria turn the sugars and amino acids into hydrogen, carbon dioxide, ammonia, and organic acids. These bacteria will also turn the resulting organic acids into acetic acid along with additional carbon dioxide, hydrogen, and ammonia. As a final phase, the methanogens turns these products into carbon dioxide and methane. Anaerobic digestion is used widely as a source of renewable energy. The anaerobic digestion process is producing biogas which consists of methane, carbon dioxide and other contaminant gas. This biogas can be used directly as energy source by heat and power gas engines or improved to natural gas quality bio-methane, also other nutrient-rich products are formed which can be used as fertilizers. [11]

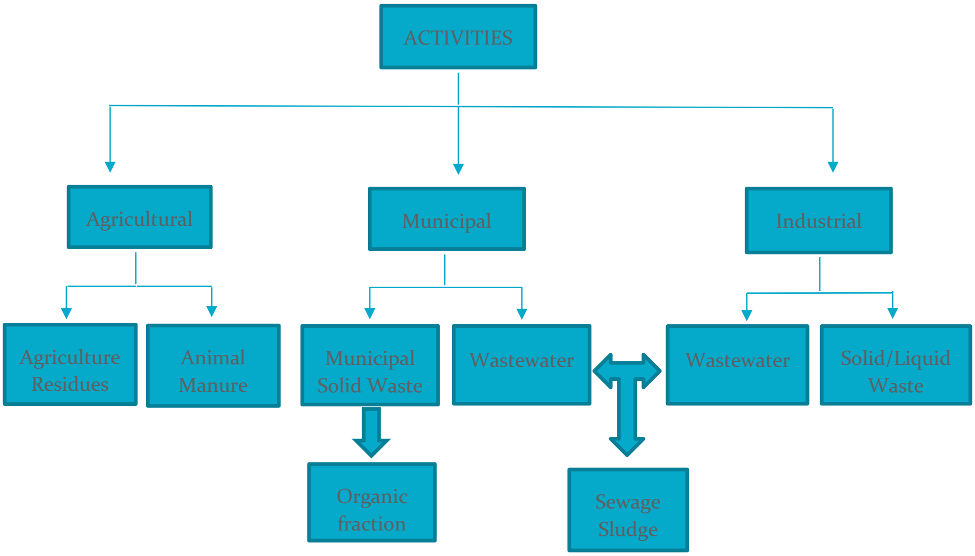


Figure 2: Potential biomass/waste for anaerobic digestion in Palestine [13].

Methodology

The mesophilic AD only considered in this review. The Chemical oxygen demand (COD) concentrations, total solids (TS), volatile solids contents (VS) for the deferent biomass were found in past studies in literature. The biomass / wastes that are identified to the Mauritian context, VS and TS contents were determined affording to the procedures formulated by VanWychen and Laurens with slight tuning that VS content was determined after 3

h in muffle furnace instead of the 24 ± 6 h computed by Van Wychen and Laurens [12].
The total CH4 produced are calculated by the following equations (1) or (2):

Total CH4 produced = (the amount of biomass / wastes available locally {tons/year} × TS (%) × VS (%) × Mesophilic CH4 yield got from literature {m^3/kg VS}) as the following Eq.

V= (M × TS content × VS content × Q1 × 1000)
Eq. (1) [14]

Or by the second equation Eq. 2
Total CH4 produced = (the amount of biomass / wastes available locally m^3/year × total oxygen demand of the biomass/ waste (COD content) {Kg/m^3} × Mesophilic CH4 yield got from literature {m^3/kg COD}) as the following Eq. [14].

V= (M × COD content × Q2)
Eq. (2) [14]

The electrical and thermal energy produced from the CH4 ignition through the consumption of the anaerobic digestion of the biomass / wastes by using the spark ignition engine in a CHP unit is calculated as the following equations [14]:

Electrical energy (TJ/year) = Total CH4 produced {m^3/year × density of CH4 at room temperature and pressure, 0.656 Kg/m^3 × the maximum heating value of CH4, 55568 {KJ/Kg} × electrical

efficiency of the CHP unit system, average of 34.6%) ÷1000000000
As the following Eq. [14].

$E_{\mathrm{electrical}}$ = (V × ρ_{m} × $\mathrm{H_C}$ × $\eta_{\mathrm{electrical}}$) ÷ 1000000000
Eq. (3)

Thermal energy (TJ/year) = Total CH4 produced {m^3/year × density of CH4 at room temperature and pressure, 0.656 Kg/m^3 × the maximum heating value of CH4, 55568 {KJ/Kg} × thermal efficiency of the CHP unit system, average of 42.0%) ÷1000000000
As the following Eq. [15-18].

E_{thermal} = (V × ρ_{m} × $\mathrm{H_C}$ × η_{thermal}) ÷ 1000000000
Eq. (4)

Combined heat and power (CHP) system

CHP system is a technique which converts the biogas from deferent resources like agriculture waste, sewage and sludge gas, and landfills gas into a heat and power or even into cooling energy (CHPC) [19]. The following figures are illustrates the different ways in producing bio-energy using (CHP) [19].

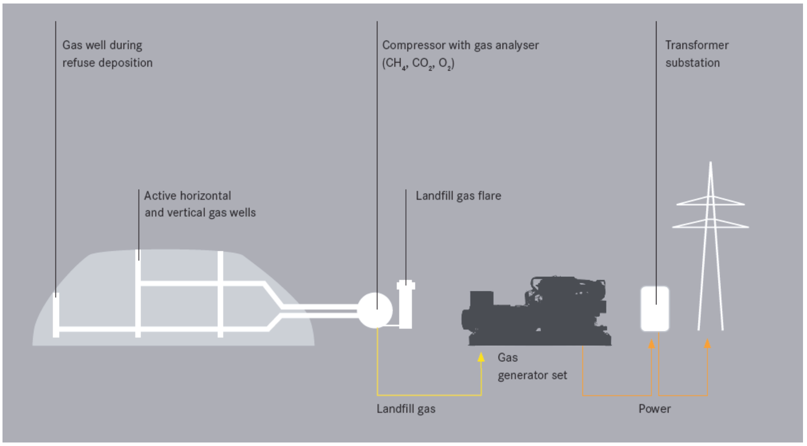


Figure 3 LANDFILL GAS AS FUEL: GAIN FROM GARBAGE [19]

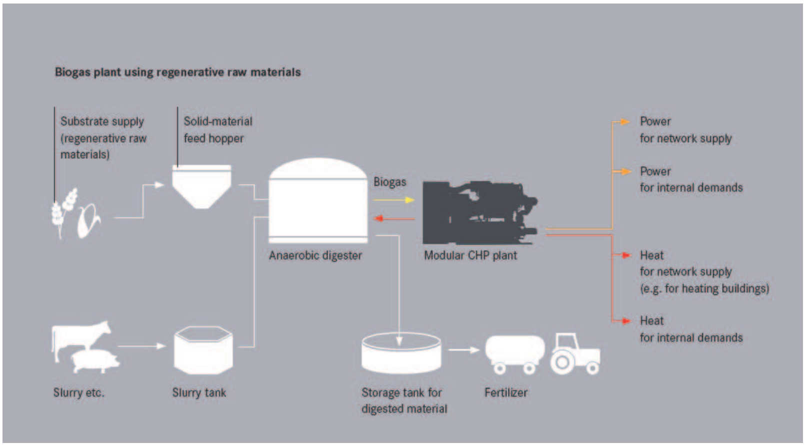


Figure 4 utilizing agricultural raw and waste material [19]

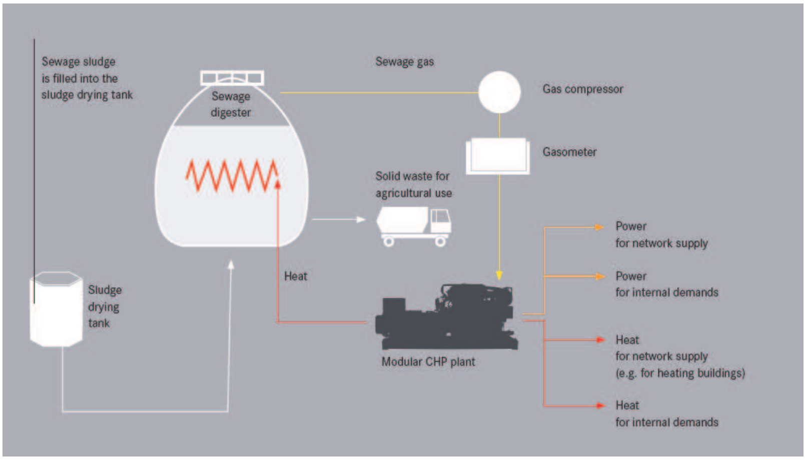


Figure 5: sewage and sludge gas as fuel; energy from effluent [19]

The CHP system components are [19]:

- Gas engine
- Generator
- Ignition system
- Mixture cooler
- Knock detection
- Crank-case ventilation

Agricultural waste

Agricultural waste is playing a main character to produce CH4 which is divided into animal manures and agricultural residues [20].

Animal Manure

One of the main agricultural activities is livestock farming which consist of Cattle, Sheep, Goat and Poultry. Alongside to the major source of food presented by livestock farming, it generates considerable amount of waste as animal manure. Animal manures are highly loaded by organic matter, so it causes a potential pollution through the release of CH_4 gas in the atmosphere if missed untreated [20; 21]. Based on one of the biggest farms in Palestine “Al-Jabrini” they harvest about 30 tons of dung daily by their cows which can be recycled to generate 380 Kilowatt hours [22].

Manure can be found in different types (liquid, solid, dried or treated and fresh manure), and the nutrient composition of these types varies with animals, bedding, storage and processing [24]. The main nutrients found in a manure are nitrogen, phosphorus, potassium, phosphate (P_2O_5) , potash (K_2O) and many others in addition to organic matter and moisture content as shown in the table(1) below [25].

Table 1: shows the percentage of nutrient composition of manure [25]

	Nitrog en (N)	Phosphorous (P2O5)	Potassium (K2O)	Calciu m (Ca)	Magnesiu m (Mg)	Organic matter	Moisture content
Fresh manure	%	%	%	%	%	%	%
Cattle	0.5	0.	0.	0.	0.1	16.	81.3
Sheep 3	0.9 5	0. 3	0.8	0. 7	0.3	30.	64.8
Poultry 5	0.9	0.5 2	0.8	0.4 7	0.2	30.7	64.8
Horse	0.5	0.	0.	0.	0.12	7.0	68.8
Swine 3	0.6 6	0.5 3	0.4	0.2	0.03	15.5	77.6
Treated – Dried manure	%	%	%	%	%	%	%
Cattle	2.0	1.5	2.2	2.9	0.7	69.9	7.9
Sheep	1.9	1.4	2.9	3.3	0.8	53.9	11.4
Poultry	4.5	2.7	1.4	2.9	0.6	58.6	9.2

A small fraction of the nitrogen in the manure is found in the ammonium/ammonia or inorganic form. The ammonium nitrogen form is a readily available fraction. Other inorganic forms such as nitrate and nitrite can also exist, but their quantities are usually very low [24].

Some research has shown that manure may lose approximately one-third of its fertilizer and organic matter value in three months, one-half in six months and even more over a longer period. When manure is exposed to the weather, ammonia gas is released and nitrates leach out with the rain, phosphorous is washed or drained away with the liquid portion, and potassium is either washed away or carried off in the urine, and organic matter is rotted away. In order to reduce these loses; the following steps are recommended [26]:

1- Ample bedding should be used to absorb liquid manure.
2- Manure should be stored in straight, well packed piles.
3- Manure should be stored in an area that has a water tight bottom and provide overhead protection from weather.
4- Livestock should be kept on pasture as much as possible in summer months.
5- Phosphate should be added to manure pile to trap nitrogen.
6- Plenty of bedding should be used and manure should be accumulated in stables until it can be hauled and spread directly in the fields. [26]

“The following table (2) compares the production amount and energy potential for the deferent feedstock’s that can be utilized for biogas production” [27; 28].

Table 2: Comparison of biogas yield and electricity produced from different potential substrates [27].

type	Biogas yield per ton fresh matter (m3)	Electricity produced per ton fresh matter (Kwh)	Manure production (kg/day)	Manure production in Palestine ton per day
Cattle dung	55-68	122.5	-	-
Chicken manure	126	257.3	0.06 for 1 kg chicken weight	1997.52
Horse manure	56	114.3	-	-
Pig slurry	11-25	23.5	1-4 kg/day [28]	-
Cow manure	-	89.7	37 kg/day [28]	1257.26

According to the Palestinian central bureau of statistics (PCBS) and table (2) above the number of cows in Palestine is 33980 in 2013 and the number of chicken is 33292161 in 2012/2013, the amount of electricity can be produced in Palestine per annual from cow manure is about 14,302MWh/y and from chicken is about 96,240.513MWh, the total amount of electricity can be produced in Palestine only from cow and chicken manure is about 630 MWh per day which is about 110542 MWh annually. These are calculated by the Eq. [1, 3, and 4] as mentioned previously in the methodology.

Note: sample calculation will be showed in the appendix.

Agricultural Residues

There are many deferent crops in Palestine like olives which may play a main role to produce a biogas. The olive oil industry produces in addition to oil, two types of waste: pomace, resulting from olive pulp, and mill wastewater, essentially constituted by process water and olive aqueous fraction. [23]

But the problem with olive pomace, exemplified by high concentration of polyphenols, affects the digestion process due to its inhibitory influence which has to be solved. [23]

Anaerobic digestion system for olive pomace

The anaerobic digestion are consist a series of technical units connected together, to achieve its purpose [23];

A. Olive pomace storage
B. Washing and mixing unit
C. Filtration system includes;
    1. Decanter; pomace and water separation sub-unit.
    2. Ultrafiltration sub-unit.
D. Anaerobic digestion unit

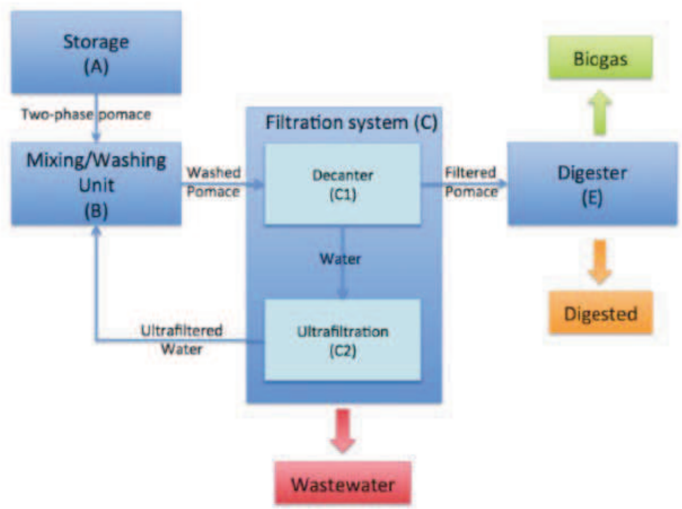


Figure (6): anaerobic digestion system for olive pomace [23].

The two-stage pomace, before to be nourished to the digester has been washed and weakened 1:4, by utilizing olive factory wastewater, already treated to decrease the high convergence of polyphenols: along these lines, it is conceivable to treat, in the meantime, olive pomace and plant wastewater. As schematically appeared in Fig. 6, the pomace is pulled back from the capacity and sent to a tank of blending and washing. Here, it is blended with the ultra filtered water from the filtration framework, which is created by two sub-units: decanter and ultrafiltration. The water, leaving the decanter, is encouraged to the ultrafiltration sub-unit and afterward returns in the past tank of mixing, while the washed pomace is acquainted with the digester [23].

The solids (olive mash) are hydrolyzed to solvent natural issue, which is additionally aged to Volatile Fatty Acid (VFA), butyrate and propionate. Acidic acid is acquired from the change of butyric and propionic acids lastly methane is created from acidic corrosive, hydrogen and carbon dioxide. The speculation of the model is accounted for next [23]:

- to begin with arrange energy can be expected for the hydrolysis of the solids
- straightforward Monod energy for transformation of dissolvable natural issue to VFA and acetic acid derivation and hydrogen to methane
- changed Monod energy including hydrogen restraint for the corruption of butyric and propionic acids to acetic acid derivation
- thermodynamical balance between hydrogen in fluid stage (produced from aging of solvent organic matter) and gas-stage;
- superbly mixed digester
- Consistent pressure and temperature.

Municipal solid waste

MSW is valued renewable resource with an ability to produce biogas for a combined heat and power (CHP) by using appropriate technologies to convert MSW into energy [29]. These technologies should be selected upon the waste composition and economics which is not an easy task due to the waste production are depends on the seasonality and socioeconomic level of producers [29].waste to energy technologies can be characterised into biochemical and thermochemical processes while MSW can be classified as biodegradable and non-biodegradable, which are suitable for biochemical and thermochemical processes [30; 31]. Anaerobic digestion technologies are depending on biochemical processes to produce biogas [32].incineration, gasification and pyrolysis technologies are depending on thermochemical processes [29]." In the Pichacay Landfill, Cuenca, for example, 1.6 MWh of energy is estimated to be generated by biogas recovering and driving a thermal power plant "[33].

Solid Waste Generation, Physical Characteristics and Management

Identifying the composition and properties of MSW is important for the selection of treatment method to recover energy from heterogeneous mixture of organic and inorganic municipal waste [34]. MSW can be characterized upon its biodegradability nature: organic and inorganic based to Landva and Clark [35]. The MSW generation can be getting from technical reports, sanitary landfill and transfer stations reported by the public corporation of integrated management of solid waste. As a solid waste generation is influenced by the season and the socioeconomic level of the producers, it will be also necessary to provide a stratification of the city, based on the territorial grouping, the field studies to be carried out [29]. Socioeconomics are classified as follow: A-High, B-Medium, C-Medium Low, D-Low [36].

Estimation of Energy Generation Potential

Many techniques have been developed to estimate the potential energy from waste, some are depends on empirical models and some on the experimental approaches such as estimation of biochemical methane potential test system for biogas production and calorimetric measurement for heat recovery [29]. The energy recovery potential (ERP) of MSW is estimated by Chakraborty, and the power generation potential (PGP) is estimated by using Rafat [37; 38]. Table (3) illustrates the equations used to calculate the potential biogas production from waste.

Table 3: Equations to estimate energy generation from municipal solid waste [29].

Energy generation potential	Equation	#	Reference
Biochemical potential	ERP = $\frac{BG \times NCV}{0.042}$	Eq.1	[39]
	PGP = $\frac{[BG \times NCV \times \eta]}{1000}$	Eq.2	[40]
	BG = $[\sum_{I=1}^{N} KL_0\, M_i (e^{-kt})] \times (T_{msw/y})^{-1}$	Eq.3	[41]
Thermochemical	ERP = $1.16 \times NCV \times MSW_q$	Eq.4	[39]
	PGP=$\frac{[0.048 \times NCV \times MSW_q \times \eta_{Th}]}{1000}$	Eq.5	[40]

Where ERP = energy recovery potential in kWh/tMSW, PGP= Power generation potential MW/tMSW, BG= biogas generation in m3 of CH4/y, NCV=net calorific value (Kcal/kgMSW); for biochemical potential, NCV is between 0.194/0.242 Kw/m3 of biogas, Ƞ= conversion efficiency of biochemical process at 30%; k=methane generation constant, L_0=methane generation potential; Mi = mass of wastewater, ti = age of the i increment; TMSW/y = total production of MSW per year; MSWq= Municipal solid waste dried quantity (tonnes/day); ȠTh= conversion efficiency of thermochemical process considered at 30% [29].

According to the Palestinian central bureau of statistics the average waste production ton/day in west bank the average waste produced by Palestinian families kg are viewed in the following table (4) [42].

Table 4: Quantity of waste generated per day (tons), the average household waste production in Palestine by region 2015 [42].

Region	Total daily waste production (ton)	Average waste production from Palestinian families
Palestine	2551	2.9
West bank	1835	3.2
North of the West Bank	711.5	3.2
Middle Of West Bank	563.5	3.4
South of the West Bank	560	3.0
Gaza strip	716	2.4

The municipalities of Palestine especially in the west bank, are currently produces about 1835 ton/day which is transported to a different landfills located in Palestine like Zahrat Al Finjan in Jenin, Al-Menya , Jericho sanitary landfill, and another landfill in Abu Dis for an area of east Jerusalem on the west bank side [43; 44].

MSW Composition

Waste composition data in Palestine is very limited. Based on the available data it's found that the organic waste are forms 59% of the waste, and recyclables materials (paper, plastic, glass, metals) are forms about 29.4% of the waste. These details are plotted in figure (6) [44]:

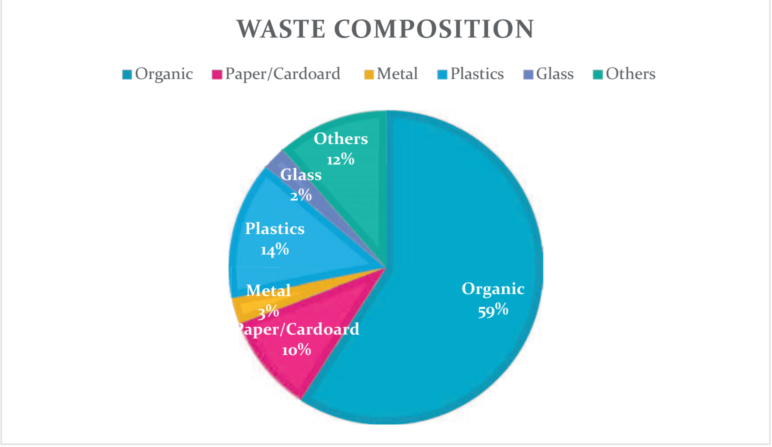


Figure 7 : waste composition in Palestine [44].

Potential Energy Recovery from Waste

The amount of energy produced by AD, will be differentiated by different waste material and the type of digester used. Digesting 1 tonne of food waste can produce about 300 kWh of electricity. According to the renewable energy association, if all the domestic food waste is digested by AD, it will generate enough electricity for 350000 household [52].

According to the table (4) the amount of food waste produced in Palestine per day is 1835 × 59% = 1082.65 ton. So the amount of generated electricity by AD is around 324.795 MWh per day. The following table (5) are showing the average household energy consumption of electricity by region; Jan-2015 [53].

Table 5: Average household energy consumption in Palestine regions [53].

REGION	ELECTRICITY (kWh)/ Month
Palestine	306
West Bank	328
North of the West Bank	272
Central West Bank	442
South of the West Bank	294
Gaza strip	265

By assuming the electricity consumption at the peak month is around 600 kWh, the produced energy (electricity) will cover around 16240 household.

Municipal Sewage Sludge

The potential use of sludge is as a biomass, fertilizers and biodiesel. The Analysis of dried sludge shows that the organic content is about 40% of the weight. The percent of extracted lipids from sludge is around 25% of the weight, so a 1.4 ton can be produced of a biodiesel daily. The calorific value of the remaining sludge is 12.7 MJ/Kg, by mixing it with saw dust it can raise the heating value up to 15 MJ/kg. Burning of the sludge produced can generates 1.52 times than the electricity consumption at the wastewater treatment plant as heat energy [45].

Many studies are confirms that the biodiesel is one of the most alternatives are inserting of using the vegetables oil and wastewater sewage sludge. The use of the sewage sludge was interested by researchers to produce lipids from activated sludge and produce a biodiesel from lipids, also phosphorous extraction from ash sludge to produce high quality fertilizers [46; 47; 48].

Biodiesel Production

The biodiesel production has five major processes [45];

1. Lipids extraction
2. Titration
3. Transesterification
4. Separation and purification

Lipid Extraction

Lipid extraction is the first phase of the biodiesel production from the sewage sludge. The lipids can be extracted by using these tow solvents (ethanol, hexane) in a different ratios, either by using only hexane or by mixing it with ethanol, next step is to treat the extracted amount of lipids by heat for 15 minutes to remove the excess amount of water, finally the treated lipids were filtrated [45].

Transesterification

It's a conventional and the most common way to produce a biodiesel. In this process, the fatty acid alkyl esters (biodiesel) are produced by the reaction of triglycerides with alcohol, especially with methanol or ethanol, in the presence of alkali, enzyme catalyst or acid. The potassium hydroxide or sodium hydroxide whish dissolved in alcohol is used as a catalyst in transesterification reaction. Excess amount of alcohol with adequate catalyst are leads to the reaction equilibrium to the biodiesel products glycerol and esters [49].

The first step of transesterification is to determine the amount of catalysts by titration. When two samples are titrated with 1 g/l NaOH, the first sample are consisted of 2 mL isopropyl alcohol with some phenolphthalein drops, the second sample consisted of 2 Ml of isopropyl alcohol and 0.2 Ml lipids with some phenolphthalein drops. The sodium hydroxide are obtained in the samples (V1, V2), the acid value can be calculated by the following equation [49]:

$$\text{FFA}\ \left(\frac{mg}{g}\right) = (\text{V2} - \text{V1}) \times \frac{1.4}{doil} \qquad [49]$$

The constant value of 1.4 is a mass coefficient to convert the sodium hydroxide to KOH; doil is the density of lipids. Based on this the required sodium hydroxide (lye) for transesterification are calculated by the following equation [49]:

Lye $(\frac{g}{L}) = V2 - V1 + 5.0$

Separation and Purification

A boiled water are poured into the produced biodiesel to wash it out from contaminants like excess methanol, catalyst, glycerol, and soaps whish are dissolved better in hot water.

The volume of wastewater generated in Palestine is viewed in the following table (5) (mcm/year) [51].

Table 6: wastewater generation in Palestine (mcm/year)

Year	Palestine	West Bank	Gaza Strip
2006	89.0	49.5	39.5
2007	91.6	50.7	40.9
2008	94.3	52.1	42.2
2009	97.0	53.4	43.6
2010	99.8	54.8	45.0
2011	102.8	56.2	46.6
2012	105.9	57.7	48.2

mcm = million cubic meter*

CHP Plant Technology Converts Biogas from Sewage Sludge into Heat and Power Energy

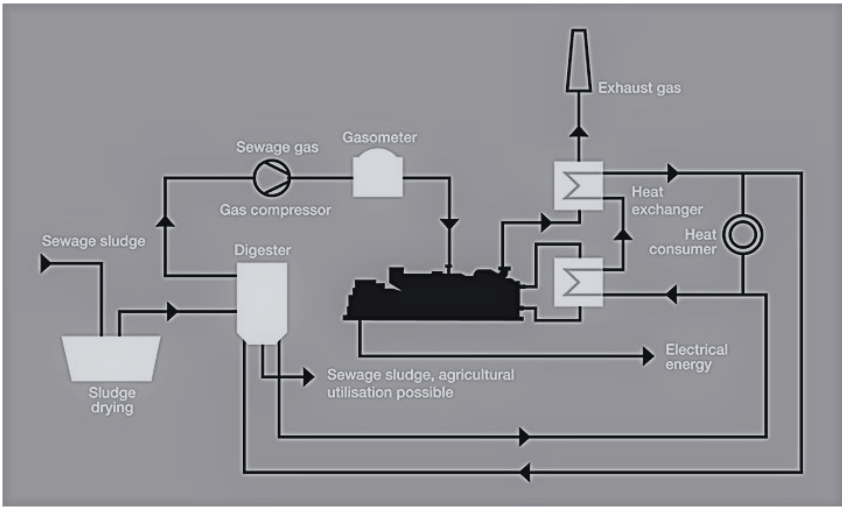
Waste treatment processes are includes many operations with high energy consumption like aeriation and pumping. So the wastewater treatment plant requires high energy consumption. By the increase of the electricity prices, the plant operators are facing high energy costs to meet the discharge permit requirements. The second expense to WWTP owners is energy cost only behind employers. For plants which uses anaerobic digestion to treat bio-solids, the process of combusting digester gas to produce electricity and heat by CHP which may provide a solution for a high operational costs [50].

The Benefits of CHP for Sewage Treatment is [50]:

- Generates renewable energy from waste materials by combined heat and power system (CHP)
- Limit of carbon dioxide emissions especially in comparison with aerobic sewage treatment plant
- Produce economic electricity power onsite, and reduces the losses of transmissions
- Produce fertilizers with low carbon / soil improver

The following figure shows how CHP system works [50]:

Figure 8: CHP system converts biogas into power & heat [50].



Many wastewater treatment plants worldwide do not recovering back the expenses and costs of treating sewage through electricity and heat. But the renewable energy source "sewage gas" can be converted into heat and power by using gas engines, which recovering about two third of the plants electricity demand, So there's no need to import fossil fuels for plant heating process [50].

Steps To Convert Sewage Gas into Renewable Energy

The steps of the biogas generation processes are divided into [50]:

1. Input material preparation and contamination removal.
2. Digestion (fermentation) consists of hydrolysis, acetogenesis, acdiogenesis and methanogenesis.
3. Convert biogas into renewable heat and electricity through Combined Heat & Power System (CHP)
4. Post-treatment of the digestate.

“Sewage is gathered in city sewage frameworks and sent to the waste water treatment plant. From here it is arranged and sent to the sewage digesters. In the absorption tanks a progression of organic procedures are saddled with a specific end goal to create biogas. Hydrolysis is where the organic material is solubilized into the absorption fluid. It at that point experiences the transitional strides of acidogenesis and acetogenesis which make the forerunner atoms for methanogenesis. Methanogens nourish off these antecedents and create methane as a cell squander item. The biogas containing this naturally inferred methane is contained and caught in a gas stockpiling tank which is ordinarily found independently to the primary digester. The gas stockpiling tank goes about as a cushion with a specific end goal to adjust variances in the generation of gas in the digesters. Where gas creation levels are low or exceedingly factor, double fuel blending can be utilized to supplement the sewage gas with flammable gas from the mains conveyance network.” [50]

Advantages of Sewage Gas CHP [50]

1. High electrical efficiencies
2. LEANOX controls with turbocharger bypass
3. Longer overhaul schedule

Costs of Anaerobic Digestion

A financial analysis should be taken before deciding to set up an AD plant, which includes [54]:

- Capital cost
- Operating cost
- Sources of income

Factors like plant size, waste composition, and plant location are affecting into the capital costs. So the plant requires a specification to be accurate while determining the costs. Cost related with staff, insurance, transference, pollution reduction and control, annual authorizations, and maintenance are counted in the operational costs. Finally the source of income includes the revenue from the recovered energy even as electricity or heat [54].

The operator of AD plant should be ensuring that the feedstock materials are sufficient to operate the plant at the optimum capacity. There are some difficulties to arrange for accurate costs due to different categories include the type of waste, and the size of plant (capacity). Following are some examples [54]:

- The capital cost for AD digester plant with capacity of 3000 tons/year is between 140000 $ and 270000$. And the operational cost without labour is about 2700$.

- The capital cost for AD digester plant with larger capacities are vary from 675,000$ with a capacity of 10000 tons/year to 6,750,000 $ with a capacity of 200000 tons/year of wastes from different farms. The operational costs is between 40,000$ to 715,000$
- The capital cost of AD digester which treating the MSW organic fraction is vary from 4,000,000$ for a capacity of 5,000 tons/year to 17,000,000$ for a capacity of 100,000 tons/year. The operating costs are ranging between 170,000$ to 1,300,000.

The following parameters shown in table 7 are used for electricity calculation [54].

Table 7: Parameters used for electricity calculation [54].

Feedstock	Total solids TS (%)	Volatile solids VS (% of TS)	Biogas yield (m3/kg VS)	CH4 content (%)
Pig slurry	3-8	70-80	0.25-0.50	70-80
Cow slurry	5-12	75-85	0.20-0.30	55-85
Chicken slurry	10-30	70-80	0.35-0.60	60-80
leaves	80	90	0.8-0.95	n.a
straw	70	90	0.35-0.45	n.a
Garden waste	60-70	90	0.20-0.50	n.a
Organic waste	10	80	0.50-0.60	70-80

In Palestine the amount organic solid waste generation per year is approximately 550,000tons/year [42], the amount of electricity produce is calculated below:

The parameters

TS= 10%

VS= 80% of TS

Biogas yield= 0.55 m^3/kg VS

TS= 550000 × 10%= 55000 ton/year of solids

VS content is: 55000 × 80% =44000 ton/year of volatile solids

Biogas yield = 44,000,000 kg/y × 0.55= 24,200,000 m^3 biogas /y

The biogas produced annually is 24,200,000m^3, which is 2760 m^3/h

Electricity and heat generation amount is

Note: the calorific value of biogas is 22MJ/m^3

$\frac{2760 \times 22 \times 10^6}{3600}$ = 16,866,666 W or 16,866Kw

The available power for the CHP unit is 16,866Kw, and if the CHP unit has conversion efficiency of 30% for electricity and 55% for heat so:

16,866 × 0.3 =5,059.8 Kw

5,059.8 × 24 × 365 =44323 MWh/y

The generated electricity is 44,323 MWh/y

$16,866 \times 0.55 = 9,276.3$ Kw

$9,276.3 \times 24 \times 365 = 81,260$ MWh/y

The generated amount of heat is 81260 MWh/y

The generated heat could be used due to the process (digester heating, purification) and for other needs.

The total revenues from the electricity by assuming the unit price of the Kwh is 0.49 NIS

Is 21,718,270 NIS annually, which is around 6,000,000$ USD

This project requires 5 AD plants according to amount of organic solid waste produced in Palestine

So the capital cost is $17,000,000 \times 5 = 85,000,000$ $

Revenues minus the operational cost is

21,718,270 – 1,300,000 =20,418,270 NIS OR 6,005,373 $

$\frac{85000000}{6005373} = 14$ years

So the project will recover its capital cost after 14 years and will start gaining profits.

Conclusions

Applying this technology (AD) will back to Palestine with many benefits, it will increase the size of investments, encourage the agricultural sector by decreasing the water price, provide the farm with electricity like what Al-Jabrini did, also the final material form the process can be used as a fertilizers due to its nutrient rich like nitrogen, phosphorous, carbon. AD plants will create new sector of clean energy, and will save the environment from the contaminants.

AD plant requires CHP unit to convert biogas into energy (electricity, heat, or cooling energy), CHP unit are able to provide the locality with enough power coverage to about 14,000 household through the AD resulting biogas as mentioned previously, which is around 14,000 MWh/year of electricity, and 26,000MWh/year of heat energy.

References

1. Elhanan Miller,'Right-wing annexation drive fueled by false demographics, experts say,' The Times of Israel5 January 2015.
2. Palestinian Central Bureau of Statistics (pcbs). Retrived from; http://www.pcbs.gov.ps/site/881/default.aspx#Population
3. West Bank and Gaza Energy Sector Review" Sustainable Development Department, United Nations. May, 2007.
4. Marei, Ibrahim (2016). "Developments in law and policy: The promotion of green energy in the electricity sector of Palestine". Journal of Energy and Natural Resources Law. 35 (1): 47–67. Retrieved 2 June 2017.

5. (Questionnaires MED-ENEC workshops Egypt/Syria – may/june 2007); retrieved from; https://www.slideshare.net/rcreee/session2-solar-thermal-applications-in-palestine-abdallatif-kharouf-pec-anwar-attawneh-niroukh-industries-afif-akel-birzeit-university.
6. National Non-Food Crops Centre. "NNFCC Renewable Fuels and Energy Factsheet: Anaerobic Digestion", Retrieved on 2011-11-22.
7. Koyama, Tadashiro (1963). "Gaseous metabolism in lake sediments and paddy soils and the production of atmospheric methane and hydrogen". Journal of Geophysical Research. 68 (13): 3971–3973.
8. Pamatmat, Mario Macalalag; Bhagwat, Ashok M. (1973). "Anaerobic metabolism in Lake Washington sediments" (PDF). Limnology and Oceanography. pp. 611–627.
9. *Zehnder, Alexander J. B. (1978). "Ecology of methane formation". In Mitchell, Ralph. Water pollution microbiology 2. New York: Wiley. pp. 349–376*
10. MacGregor, A. N.; Keeney, D. R. (1973). "Methane formation by lake sediments during in vitro incubations". Journal of the American Water Resources Association (JAWRA).
11. SusGlobal Energy. Retrieved from; http://susglobalenergy.com/technology/anaerobic-digestion/. Accessed on 1-15-2018.
12. Van Wychen S, Laurens LML. Determination of Total Solid sand Ash in Algal Biomass. Laboratory Analytical Procedure (LAP) 2013:5100–60956.
13. Z. Bundhoo; Renewable and Sustainable Energy Reviews 56 (2016) 1087–1100.

14. German Solar Energy Society (DGS), Ecofys. Planning and Installing Bioe- nergy Systems: A Guide for Installers, Architects and Engineers. James & James/Earthscan; 2005.
15. Lübken M, Wichern M, Schlattmann M, Gronauer A, Horn H. Modelling the energy balance of an anaerobic digester fed with cattle manure and renewable energy crops. Water Res 2007; 41:4085–96. Retrieved from; http://dx.doi.org/10.1016/j.watres.2007.05.061.
16. Dutt G. Methane Density, MGM International; 2003. Retrieved from; http://cdm.unfccc.int/methodologies/inputsconsmeth/MGM_methane.pdf. Accessed November 24, 2014.
17. Avallone EA, Baumeister III T. Marks' Standard Handbook for Mechanical Engineer. 10th ed. New York: McGraw-Hill; 1996.
18. EEA/ICF. Technology Characterization: Reciprocating Engines. 2008.
19. MTU onsite energy, a Rolls-Royce power system brand, retrieved from; https://www.mtuonsiteenergy.com/fileadmin/fm-dam/mtu_onsite_energy/media-all-site/pdf/en/brochure/3061531_OE_Biogas_GB_ES.pdf
20. Visvanathan C, Chiemchaisri C. Management of Agricultural Wastes and Residues in Thailand: Wastes to Energy Approach; 2006.
21. Steed J, Hashimoto AG. Methane emissions from typical manure management systems. Bioresour Tech 1994; 50:123–30.
22. The new arab & agencies, creating power with cow dung in Palestine; 12 April 2017. Retrieved

from: https://www.alaraby.co.uk/english/society/2017/4/12/creating-power-with-cow-dung-in-palestine
23. Marco Milanese, Arturo de Risi, Andrea de Riccardis, Domenico Laforgia. Numerical study of anaerobic digestion system for olive pomace and mill wastewater; 2013
24. Using manure and compost as nutrient sources for fruit and vegetable crops. Retrieved from: http://www.extension.umn.edu/garden/fruit-vegetable/using-manure-and-compost/. Accessed January 3, 2016.
25. Manure is an excellent fertilizer. Retrieved from; http://www.ecochem.com/t_manure_fert.html. Accessed January 15, 2018.
26. Cooperative extension service. University of alaska fairbanks; Animal manure as fertilizer. Retrieved from; https://www.uaf.edu/files/ces/publications-db/catalog/anr/LPM-00340.pdf
27. A Spyridon, A Vasileios, J Gerrit/ Engineering 3. A Technological Overview of Biogas Production from Biowaste. 2017:300
28. H nancy. Environment accounts and staistics division; A geographical profile of livestok manure production in canada;2006.
29. M diego, A clay, J David, J Esteban; Waste-To-Energy Technologies: an opportunity of energy recovery from Municipal Solid Waste, using Quito - Ecuador as case study; 9th International Conference on Sustainability in Energy and Buildings, SEB-17, 5-7 July 2017, Chania, Crete, Greece
30. M. S. Korai, R. B. Mahar, and M. A. Uqaili, "The feasibility of municipal solid waste for energy generation and its existing management practices in Pakistan," Renewable

and Sustainable Energy Reviews, vol. 72, pp. 338-353, May-2017.
31. U. Di Matteo, B. Nastasi, A. Albo, and D. Astiaso Garcia, "Energy Contribution of OFMSW (Organic Fraction of Municipal Solid Waste) to Energy-Environmental Sustainability in Urban Areas at Small Scale," Energies, vol. 10, p. 229, 2017.
32. L. A. Hadidi, M. M. Omer, "A financial feasibility model of gasification and anaerobic digestion waste-to-energy (WTE) plants in Saudi Arabia," Waste Management, vol. 59, pp. 90-101, Jan-2017.
33. INER. (2013). Use of biogas in the Pichacay landfill (Aprovechamiento del biogas en el relleno sanitario de Pichacay). Retrieved from; http://www.iner.gob.ec/wp-content/uploads/downloads/2013/05/EMAC_Aprovechamiento-del-biogas-en-el-relleno-sanitario-de-Pichacay_Galo_Vasquez.pdf
34. M. Korai, R. Mahar, and M. Uqaili, "The feasibility of municipal solid waste for energy generation and its existing management practices in Pakistan," Renewable and Sustainable Energy Reviews, vol. 72, pp. 338-353, May-2017.
35. A. O. Landva and J. I. Clark, "Geotechnics of waste fill," in Geotechnics of waste fills—Theory and practice, ed: ASTM International, 1990.
36. INEC. Encuesta de Estratificación Del Nivel Socioeconómico. (2016, 13 March). Retrieved from; http://www.ecuadorencifras.gob.ec/encuesta-de-estratificacion-del-nivel-socioeconomico/
37. M. Chakraborty, C. Sharma, J. Pandey, and P. K. Gupta, "Assessment of energy generation potentials of

MSW in Delhi under different technological options," Energy Conversion and Management, vol. 75, pp. 249-255, 2013.

38. A. Rafat, K. Omar, and A. Syed, "Potential value of waste to energy facility in Riyadh city, Saudi Arabia.," in 8th Jordanian international mechanical conference at Amman, Jordan; 2014., 2014.

39. M. Chakraborty, C. Sharma, J. Pandey, and P. K. Gupta, "Assessment of energy generation potentials of MSW in Delhi under different technological options," Energy Conversion and Management, vol. 75, pp. 249-255, 2013.

40. A. Rafat, K. Omar, and A. Syed, "Potential value of waste to energy facility in Riyadh city, Saudi Arabia.," in 8th Jordanian international mechanical conference at Amman, Jordan; 2014., 2014.

41. H. Scharff and J. Jacobs, "Applying guidance for methane emission estimation for landfills," Waste Management, vol. 26, pp. 417-429, 2006.

42. Palestinian Central Bureau of Statistics (pcbs); retreved from; http://pcbs.gov.ps/Portals/_Rainbow/Documents/HHE%202015%20a%205.htm; accessed on 26/12/2017

43. Middle east eye; The machinations behind a delayed yet urgent landfill project in Ramallah highlight how when foreign donors contract with their own national companies, there are often little benefits for the Palestinian economy; retrieved from; http://www.middleeasteye.net/essays/landfills-become-pits-foreign-aid-west-bank-1373293510. Accessed on 12/29/2017

44. German cooperation; Country report on the solid waste management in Occupied PALESTINIAN Territories; Retrieved

from http://www.environment.pna.ps/ar/files/Country%20report%20on%20the%20solid%20waste%20management.pdf. Accessed on 12/29/2017

45. SH. Mays, T Mohamad, A Hala, E Amer, E Yazan, K Ala'a, B, Nojod; The Potential of Utilizing the Sewage Sludge Produced from Nablus West Wastewater Treatment Plant as an Energy Source and or a Fertilizer; Department of Chemical Engineering, An-Najah National University.
46. Xu, Huacheng; Recovery of phosphorus as struvite from sewage sludge ash. Journal of Environmental Sciences 24.8 (2012): 1533-1538.
47. Revellame, Emmanuel; Biodiesel from activated sludge through in situ transesterification. Journal of chemical technology and biotechnology 85.5 (2010): 614-620.
48. Olkiewicz, Magdalena; Evaluation of different sludges from WWTP as a potential source for biodiesel production. Procedia Engineering 42 (2012): 634-643.
49. J., M Canakci and Van Gerpen; Biodiesel production via acid catalysis. Transactions of the ASAE, 1999, Vol. 42, pp. 1203-1210.
50. Clarke energy; Kohler company.sewage gas; Retrived from: https://www.clarke-energy.com/sewage-gas/
51. European Environment Agency; Horizon 2020 Mediterranean report annex 5 : Palestine 2014; page 6-7
52. The official information portal on anaerobic digestion. Retrieved from; http://www.biogas-info.co.uk/about/faqs/; Accessed on Jan-2018.
53. Palestinian Central Bureau of Statistics (pcbs); Retrieved from; http://pcbs.gov.ps/Portals/_Rainbow/Documents/HE-%20AA12%202015.htm ; Accessed in 26/12/2017

54. Remade Scotland Report; **An Introduction to the Digestion of Organic Wastes**; Fabian Monnet, November 2003. Retrieved from: http://www.remade.org.uk/media/9102/an%20introduction%20to%20anaerobic%20digestion%20nov%202003.pdf

Appendix

Calculation sample

Feedstock	Total solids TS (%)	Volatile solids VS (% of TS)	Biogas yield (m3/kg VS)	CH4 content (%)
Cow slurry	5-12	75-85	0.20-0.30	55-85
Chicken slurry	10-30	70-80	0.35-0.60	60-80
leaves	80	90	0.8-0.95	n.a
straw	70	90	0.35-0.45	n.a
Garden waste	60-70	90	0.20-0.50	n.a
Organic waste	10	80	0.50-0.60	70-80

Total CH4 produced = (the amount of biomass / wastes available locally {tons/year} × TS (%) × VS (%) × Mesophilic CH4 yield got from literature $\{m^3$/kg VS$\}$) as the following Eq.

V= (M × TS content × VS content × Q1 × 1000)
Eq. (1) [14]

Total CH4 produced from cow manure is

V= 458900 × 0.085 × 0.8 × 0.25 × 1000

=7,801,298.3 m^3 biogas/year

Which is equal to 890.5 m^3/h

The electricity and heat production is:
With a calorific value of biogas of 22MJ/m3,

890.5*22*10^6/3600= 5,441,944 W that is approximately 5,441 kW

So the power available for the CHP unit is 5,441 kW. Assuming that the CHP unit has a conversion efficiency of 30% for electricity and 55% for heat:

5,441*0.3= 1,632.5 kW

1,632.5*24*365= 14,301 MWh/y

The production of electricity will be 14,301 MWh/y.

5,441*0.55= 2,992.55 kW

2,992.55*24*365= 26,214.7 MWh/y

The production of heat will be 26,214.7 MWh/y. This heat could be used for the routes (digester heating, purification) and for other applications.