CLEAN ENERGY SOLUTIONS

In association with

R2E2

Task 3 – Biomass supply assessment for Armenia
Task 4 – Outline of assistance and training needs
Task 5 – Definition of outcome indicators

Fact finding for the project “GAF – Renewable Energies Programme Phase V” in the Republic of Armenia

Client

KfW

KFW
Bank aus Verantwortung

Document date

14.06.2022

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DOCUMENT CONTROL SHEET

PROJECT NUMBER 52x210128

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DATE: 14.06.2022

Date	Revision No.	Editor	Checked by	Approved by
01.06.2022	**Rev. 0**	Ali, Akh	Bac	Bac
14.06.2022	**Rev. 1**	Ali, Akh	Bac	Bac

CONTENT

TABLES

FIGURES

1. EXECUTIVE SUMMARY

Overall goal of this market assessment is the identification of biomass projects in Armenia. In previous tasks relevant sectors and their potential were evaluated. The aim of this task was the identification of feasible biogas projects in Armenia.

One challenge in this project was the allocation of suitable resources for biogas production as agricultural areas and residues are mainly used for production purposes or sold to other farmers/ sectors. The Identification of consumers with constant energy demand was another challenge of project allocation in Armenia. Farms and greenhouses were finally identified and screened as potential substrate suppliers as well as consumers of generated energy.

Three potential biogas projects were identified and evaluated under this task. Finally, a biogas plant at the site of Arax poultry farm, located western of Yerevan, was selected as the most promising project for further project development. Arax poultry is one of the largest poultry farms in Armenia and is interested in further investigations.

The concept of the project is an anaerobic digestion of poultry manure in combination with crop waste for biogas production. Poultry manure at Arax is currently sold as fertilizer. Crop waste from a greenhouse 30 km away, which is currently composted on-site, is considered as a potential co-substrate in the biogas plant. In the current concept, approx. 2,6 MW of biogas will be produced and utilized in a CHP plant. The project generates about 7,200 MWh of electricity which will be fed in the public electricity network. Additionally, about 4,300 MWh of heat will be produced which can be used for heating of poultry barns on-site. Therefore, adaptations in the heating system of the farm will be required and are included in the project. Digestate from the biogas plant can be sold as fertilizer at the end. Alternatively, a smaller biogas plant was considered for direct gas supply of the poultry farm (without CHP).

The investment costs of the biogas plant including CHP were estimated by about 3.9 mln. EUR. The cost for operation is estimated by about 210,000 EUR/year. Levelized cost of heat (LCOH) were calculated by 40 EUR/MWh and an IRR of 2.7% was calculated without grant. Including 30% of grant gives LCOH of 38 EUR/MWh and an IRR of 5.9%. Additionally, this project reduces CO_2 emissions by 3,990 tons per year[1].

[1] assumed emission factor of 433 g/kWh for electricity and 204 g/kWh of natural gas

2. IDENTIFICATION AND SELECTION OF BIOMASS PILOT PROJECT LOCATIONS

Potential energy consumers and biomass supplier were identified and mapped in the first step of the project. Therefore, following sectors were considered as potential fuel suppliers:

- Unused straw from cereal production
- Greenhouses
- Cattle, sheep, and poultry farms

Furthermore, the following sectors were screened as potential heat consumers:

- Meat processing
- Milk processing
- Fruit and vegetable production
- Beer production

Additionally, the main energy consumers of industrial and commercial sector were identified. All identified and screened locations are shown in the following figure.

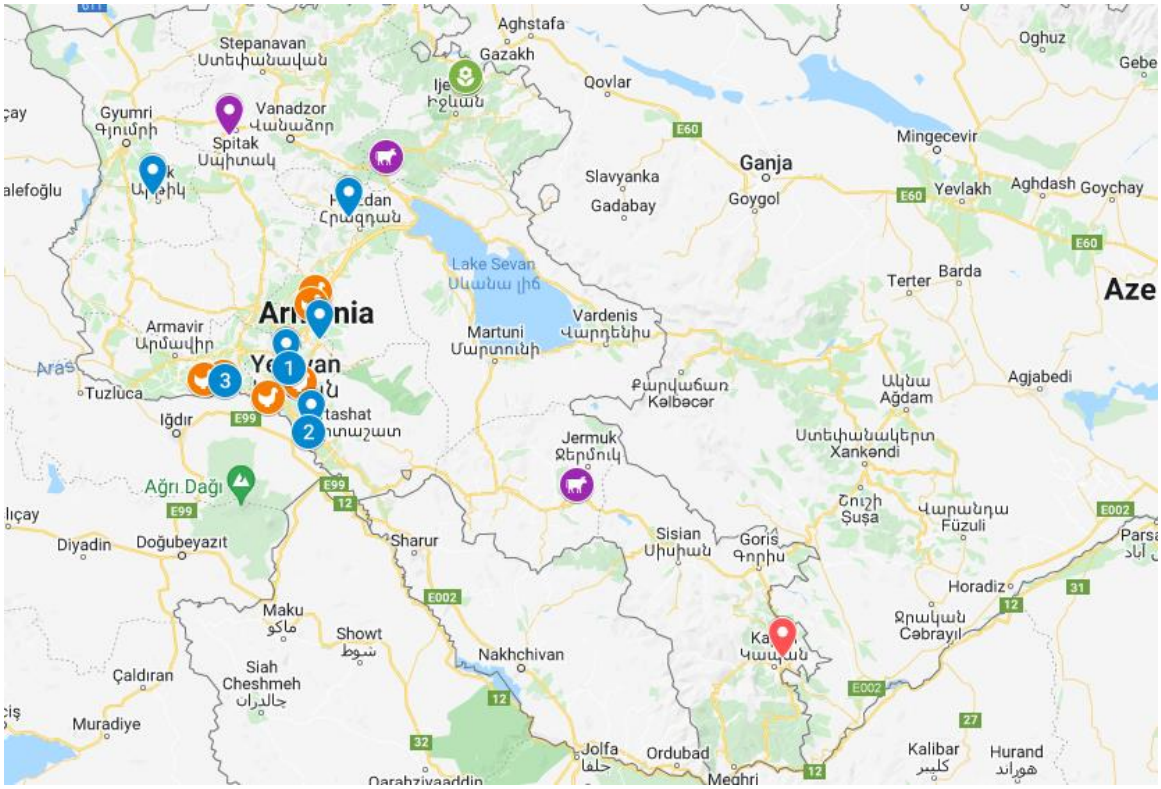


Figure 1 – Biomass supply and energy demand potential of Armenia

2.1. POTENTIAL BIOMASS SUPPLIERS

The Armenian agriculture sector is very diversified and small scale, except some sub-sectors which are highly developed and automated. Thus, 11 greenhouses and 18 farms were selected and interviewed through usage of questionnaires and direct phone conversations.

2.1.1. Farms

The following farming companies were interviewed regarding their biomass supply and heat consumption potential:

- Agroholding Armenia LLV
- Porkprod LLC
- Combined Feed Factory after Vladimir Hakobyan
- Agrotechinvest LLC
- Yeghegnut LLC and Gndevaz LLC
- Lusakert Elite LLC
- Variant Group LLC
- Arax Poulty Farm CJSC
- "Arzni Poultry, Cattle and pig-breeding farm OJCS"
- Bandivan Kat LLC
- Spitak Poultry Farm LLC
- Shahumyan Poulty CJSC
- Ashtarak Dzu LLC
- Getamej Poultry 2016 LLC
- Lusakert Elite
- 6 small lifestock farms in Kotayk region

The following map shows the location of the screened farms in Armenia.

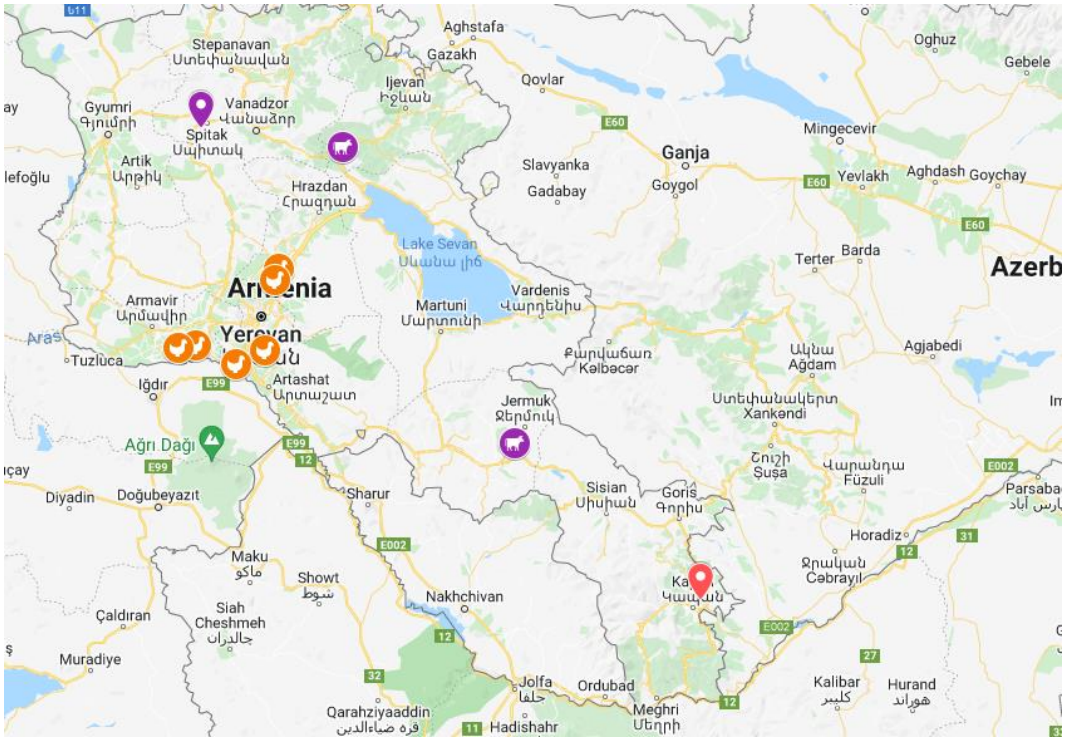


Figure 2 – Location of screened farms in Armenia

The total amount of available manure was identified to be around 136,000 tons per year. An overview of the available amounts per company is shown in the following figure.

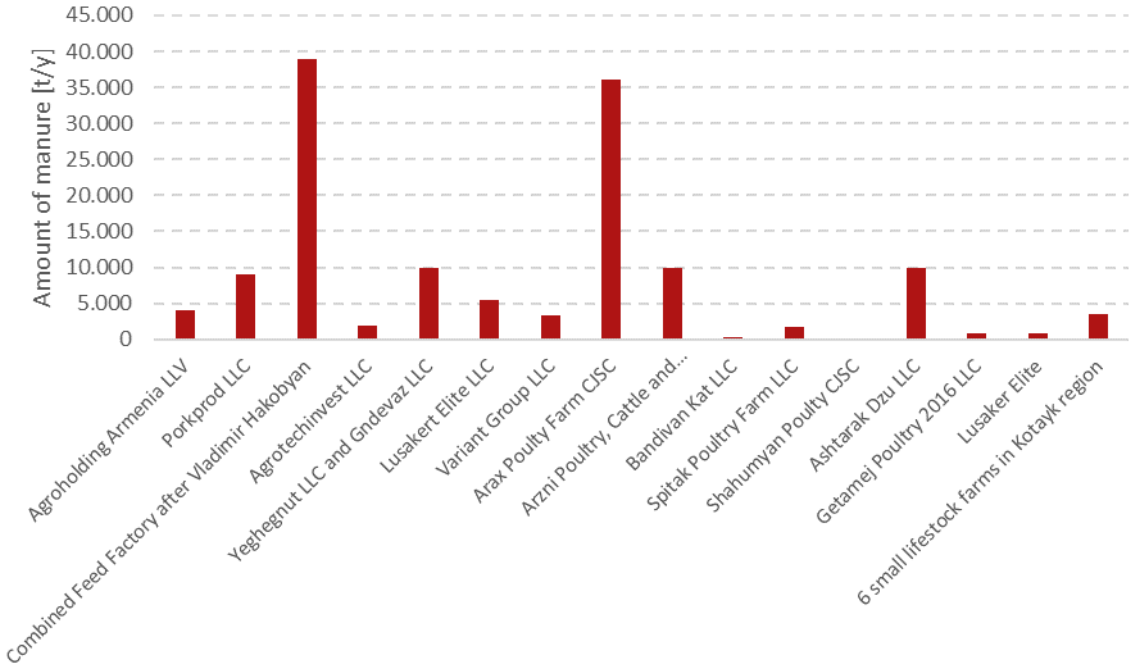


Figure 3 – Identified manure amounts

The questionnaires sent to each company and their responses can be found in the annex of this report.

2.1.2. Greenhouses

Following greenhouses were selected for identification of available biomass potential in the greenhouse sector:

- Spayka LLC
- Green Farmer LLC
- Ecoland LLC
- Green Food LLC
- Green House LLC
- Eco Fruit LLC

Location of the screened greenhouses is shown on the following map.

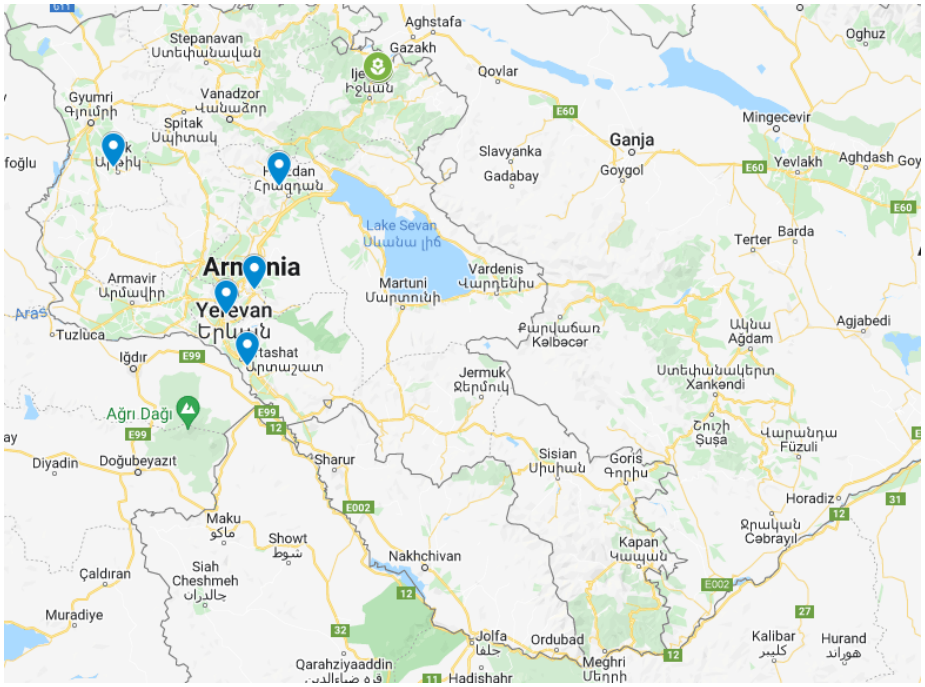


Figure 4 – Location of screened greenhouses

Only 3 companies responded and showed interest for delivery of biomass. The available potential was identified to be around 20,000 tons per year. The results are shown in the following figure.

Figure 5 – Biomass residues - greenhouses

2.2. POTENTIAL BIOMASS PROJECT SITES 1 AND 2 - SPAYKA LLC (YEREVAN)

2.2.1. Project sites

Spayka LLC in Yerevan produces tomatoes and cucumbers in about 60 ha of greenhouses. A biogas plant would be built on the site of Spayka LLC in Yerevan. The following figure shows the location of the potential biomass project site 1.
Spayka LLC in Artashat, province Ararat, produces tomatoes and cucumbers in about 55 ha of greenhouses. The following figure shows the location of the potential biomass project site 2.

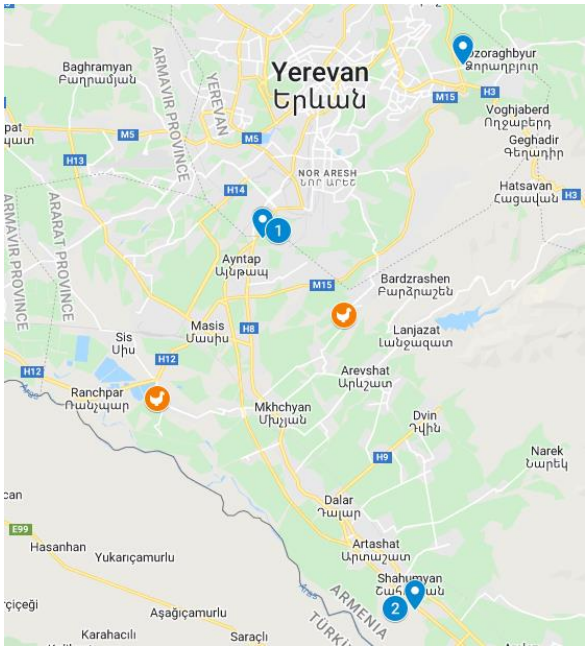


Figure 6 – Potential project locations 1 (Spayka Yerevan) and 2 (Spayka Artashat)

The greenhouses are currently heated with natural gas fired boilers. The total gas consumption of Spayka (Jerevan & Artashat) is about 30 mio. m³ in 2019 and 36 mio. m³ in 2020. The required gas consumption would partially be replaced with the heat from the biogas plant.

2.2.2. Biomass supply options

The main resources required for biogas production, would come from Spayka LLC. Cultivation of tomatoes and cucumbers implies significant amounts of organic waste. The waste amount, mainly leaves and plant residues, is estimated to 130-150 t/ha. Currently, this amount is composted and not further utilized. The company uses mineral fertilizer for the plants and thus can provide the waste for free.

In order to provide additional biomass, other sources would be needed. The Erebuni poultry farm in Nubarashen started in 2010 and has 14 poultry houses with about 245.000 chicken. The yearly production capacity is about 2.000 tons of meat. Currently 4 new poultry houses are built for production of eggs. Animal waste is stored and available for usage. The estimated yearly poultry

manure is 39.000 t/a. The transport distance to the potential biogas plant is approx. 19-24km, depending on the potential biomass project site.

A second biomass stream located in the area was identified at Variant poultry farm. The Variant Group operates a poultry farm in the Noramarg community with about 50.000 chicken. The yearly manure amount is estimated to approx. 2.300 tons. Currently, this waste is sold as fertilizer to other agricultural farms. The transport distance to the potential biogas plant is about 12-21 km, depending on the potential biomass project site.

Additional biomass could be supplied by Arax Poulty Farm, the leading poultry meat and egg producing enterprise in Armenia with about 654.230 chicken. The waste is currently stored on landfills and sold to other farms. Based on average numbers, the amount of manure is estimated to approx. 30.000 t/a. The transport distance to the potential biogas plant sites is between 44km and 30 km, respectively.

2.3. POTENTIAL BIOMASS PROJECT SITE 3 - ARAX POULTRY FARM

2.3.1. Project site

The third potential biomass project site is located at the Arax Poultry Farm in Jrarbi, province Armavir. The farm manages about 655 tsd. animals. The following figure shows the location of the potential biomass project site 3.

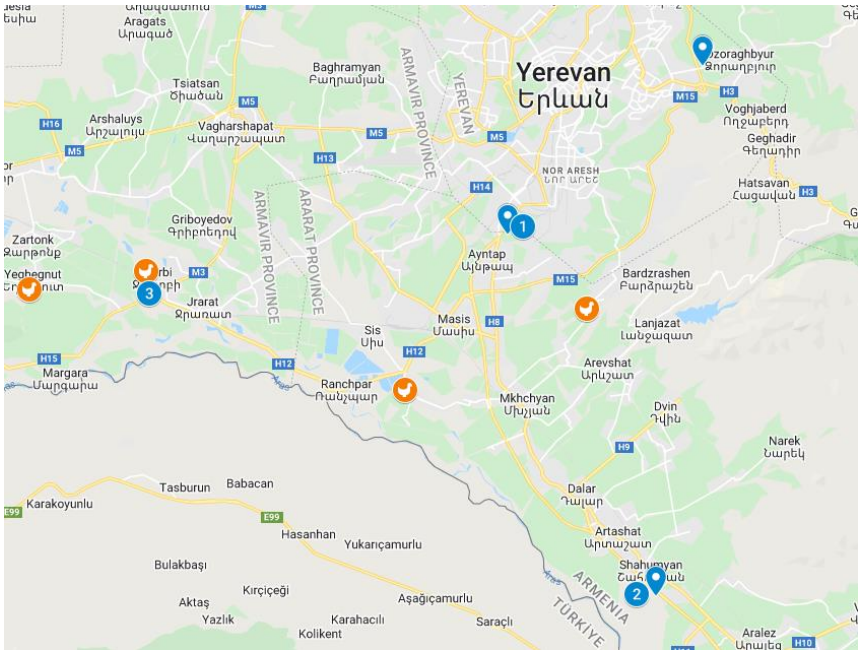


Figure 7 – Potential project location 3 – Arax

Heat is currently generated by a gas fired boiler and gas fired heaters. The natural gas consumption of the company was 1,5 mio m³ in 2020. Gas consumption shall be reduced by heat of the project.

2.3.2. Biomass supply

The main biomass amounts will be provided by Arax Poultry Farm. The waste is currently stored on landfills and sold to other farms. Based on average numbers, the amount of manure is estimated to approx. 30.000 t/a.

Furthermore, Yeghegnut LLC, a poultry farm in Yerevan managing about 108.000 chickens, could be an additional biomass supplier. Approx. 3.000 tons of waste are produced and sold as fertilizer to agricultural farms and individual farmers.

Variant Group and Spayka, described in the previous chapters, are in the area (ca. 30km distance) and can also be considered as potential biomass suppliers.

2.4. PROJECT COMPARISON AND SELECTION

A comparison of the projects was done by calculation of the technical potential based on reported data. A summary of reported data as well as the biogas potential of the certain projects is shown in following table.

Table 1 – Potential biogas projects

	Potential Project					
	1		2		3	
	2019	2020	2019	2020	2019	2020
Waste supply						
Vegetable waste						
Supplier 1						
Name	**Spayka LLC (Yerevan) Tomato and cucumber**		**Spayka LLC (Artashat) Tomato and cucumber**			
Annual amount of waste	7.800 t/a		7.150 t/a			
Type of waste	Tomato and cucumber		Tomato and cucumber			
Distance	0 km		0 km			
Cost of transport	0 AMD		0 AMD			
Current utilisation	composting		composting			
Fertilizer	mineralic		mineralic			
Price of waste	0 AMD		0 AMD			
total cost of waste	0 AMD		0 AMD			
spec. Cost [EUR/MWh]	0 EUR/MWh		0 EUR/MWh			
Supplier 1						
Name	**Spayka LLC (Artashat) Tomato and cucumber**		**Spayka LLC (Yerevan) Tomato and cucumber**			
Annual amount of waste	7.150 t/a		7.800 t/a			
Type of waste	Tomato and cucumber		Tomato and cucumber			
Distance	27 km		27 km			
Cost of transport	17.678.571 AMD		19.285.714 AMD			
Current utilisation	composting		composting			
Fertilizer	mineralic		mineralic			
Price of waste	0 AMD		0 AMD			
total cost of waste	17678571 AMD		19285714 AMD			
spec. Cost [EUR/MWh]	12 EUR/MWh		12 EUR/MWh			
Total amount from vegetables	***14.950 t/a***		***14.950 t/a***			
TS	*12.693 t/a*		*12693 km*			
oTM	*11.258 t/a*		*11258 km*			
Gas production	*4.503.317 Nm³/a*		*4.503.317 Nm³/a*			
CH4	*2.431.791 Nm³/a*		*2.431.791 Nm³/a*			
Energy	*24.172 MWh/a*		*24.172 MWh/a*			
Produced heat	*8.158 MWh/a*		*8.158 MWh/a*			
Produced electricity	*6.526 MWh/a*		*6.526 MWh/a*			
Livestock waste						
Supplier 2						
Name	***"Erebuni" Nubarashen Poulty factory***		***"Erebuni" Nubarashen Poulty factory***		***Arax Poulty Farm CJSC***	
Annual amount of waste	39.000 t/a		39.000 t/a		30.095 t/a	
Type of waste	Poultry		Poultry		Poultry	
Distance	19 km		24 km		3 km	
cost of transport	67.857.143 AMD		85.714.286 AMD		6.889.785 AMD	
Current utilisation					storage, disposal, selling	
Fertilizer					organic waste	
Price of waste					0 AMD/t	
total cost of waste	67.857.143 AMD		85.714.286 AMD		6.889.785 AMD	
spec. cost [EUR/MWh]					1 EUR/MWh	
Supplier 3						
Name	***"VARIANT GROUP" POULTRY FARM LLC***		***"VARIANT GROUP" POULTRY FARM LLC***		***Yeghegnut LLC***	
Annual amount of waste	2.300 t/a		2.300 t/a		3.000 t/a	
Type of waste	Poultry		Poultry		Poultry	
Distance	12 km		21 km		8 km	
Cost of transport	2.527.473 AMD		4.423.077 AMD		2.197.802 AMD	
Current utilisation	Fertilizer		Fertilizer		storage, disposal, selling	
Fertilizer					organic waste	
Price of waste	0 AMD/t		0 AMD/t		0 AMD/t	
total cost of waste	2.527.473 AMD/t		4.423.077 AMD/t		2.197.802 AMD/t	
spec. cost [EUR/MWh]	5 EUR/MWh		9 EUR/MWh		4 EUR/MWh	
Supplier 4						
Name			***Arax Poulty Farm CJSC***			
Annual amount of waste			30.095 t/a			
Type of waste			Poultry			
Distance			44 km			
Cost of transport			121.260.212 AMD			
Current utilisation			storage, disposal, selling			
Fertilizer			organic waste			
Price of waste			0 AMD/t			
total cost of waste	0 AMD/t		121.260.212 AMD/t			
spec. cost [EUR/MWh]			20 EUR/MWh			
Total amount from Poultry	***41.300 t/a***		***71.395 t/a***		***33.095 t/a***	
FM	*6.195 t/a*		*10.709 t/a*		*4.964 t/a*	
oTM	*4.646 t/a*		*8.032 t/a*		*3.723 t/a*	
Gas production	*348.779 Nm³/a*		*602.927 Nm³/a*		*279.484 Nm³/a*	
CH4	*226.706 Nm³/a*		*391.903 Nm³/a*		*181.664 Nm³/a*	
Energy	*2.253 MWh/a*		*3.896 MWh/a*		*1.806 MWh/a*	
Produced heat	*761 MWh/a*		*1.315 MWh/a*		*1.219 MWh/a*	
Produced electricity	*608 MWh/a*		*1.052 MWh/a*		*488 MWh/a*	

Specific substrate costs per biogas production were calculated for certain projects based on this energy balance. The results are shown in following table.

Table 2 – Project comparison

Project	1		2		3	
Name	***Spayka LLC (Yerevan) Tomato and cucumber***		***Spayka LLC (Artashat) Tomato and cucumber***		***Arax Poulty Farm CJSC***	
Electricity consumption	14.294.740 MWh/a	15.686.074 MWh/a	14.294.740 MWh/a	15.686.074 MWh/a		
Heat consumption	299.725 MWh/a	363.474 MWh/a	299.725 MWh/a	363.474 MWh/a	20.975 MWh/a	15.529 MWh/a
Share of heat supply	**3,0%**	**2,5%**	**3,2%**	**2,6%**	**5,8%**	**7,8%**
Total cost of resources	70.384.615 AMD		211.397.575 AMD		9.087.587 AMD	
Spec. resource costs	7.892 AMD/MWh		22.316 AMD/MWh		7.456 AMD/MWh	
	13,9 EUR/MWh		39,3 EUR/MWh		13,1 EUR/MWh	

Discussion of project ideas and identification of interest for project participation in the companies was evaluated in meetings. During these meetings, the interest in project implementation was shown by Arax but not from Spayka. Additionally, Arax is one of the largest poultry producers in Armenia and thus has a high energy demand. Based on these arguments, a biogas plant at the site of Arax poultry was considered for further investigations.

3. LOCATION OF THE BIOGAS PLANT

3.1. ARAX POULTRY

Arax is an Armenian poultry farm, in Jrarbi community of Armavir Province (Marz), located approx. 38 km west from Yerevan. The province is in the western part of Armenia in the Ararat plain. It shares a 72 km long border with Turkey on the south and west. The capital town of the province is Armavir, while the largest city is Vagharshapat[2].

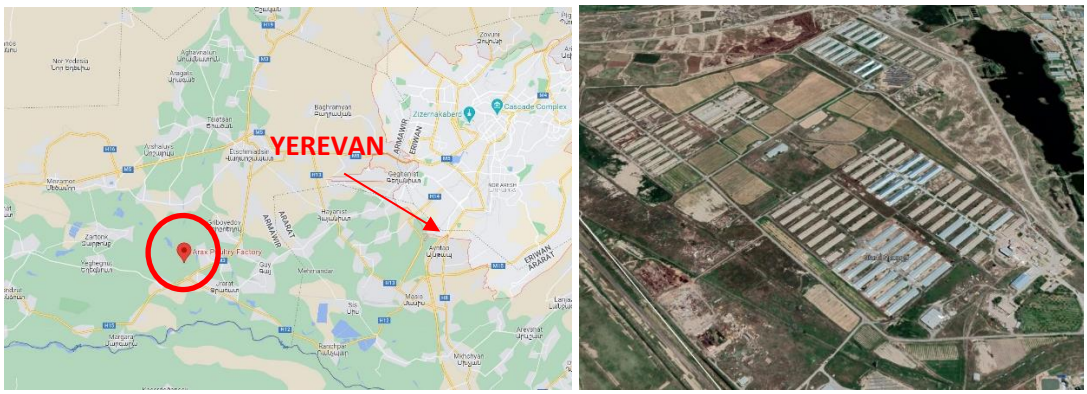


Figure 8 – Location of Arax poultry farm (left) and aerial image of Arax poultry farm

With an area of 1,242 km^2 (about 4.2% of the total area of the country), Armavir is the smallest province of Armenia.

Araxsk Poultry Farm was established in 1997 based on Jrarat Poultry Farm, which was the largest poultry farm in Armenia during the Soviet era. The Jrarat Poultry Farm reopened in 2001 after being incorporated into the X-Group.

Considerable work has been done by the company to restore production volumes, as well as development of a new mother herd of Cobb broiler in Armenia. Due to large investments, already in 2002, the factory was producing and selling 1,600 tons of chicken meat and meat products.

The production capacity allows the poultry farm to carry out the whole process, from the breeding of one mother chick per day to the broiler skin sale, as well as egg production. The broiler mother bird is kept in poultry houses equipped with German equipment, separately from the broiler birds. The factory operates the recently acquired Dutch incubator equipment.

[2] www.wikipedia.org

Broilers are slaughtered at the poultry farm with a capacity of 3,500 heads per hour. Meat is stored in a cold storage. Besides the chicken meat, farm produces eggs and semi-finished poultry products. The company cooperates with many foreign and local organizations, purchasing feed raw materials, feed additives and equipment[3].

The company is present on the local market under different brands such as "Jrarat", "Yerevan Poultry Farm", "Teghakan", "Nature Food". Chicken meat and eggs are produced mainly under the brand "Eco".

Figure 9 – Packages of chicken eggs and meat produced by Arax Poultry Farm

The total land area of the farm is about 205 ha. Poultry houses and other structures occupy less than 50% of that territory.

3.2. ENERGY DEMAND OF ARAX POULTRY PLANT

The main energy sources used in the company are natural gas and electricity. In average Arax requires about 1.8 million m³ of natural gas and about 4.5 million kWh of electricity per year. Peak load of electricity consumption is about 1,5MW and peak load of gas is about 12MW (assuming a simultaneity factor of 0,7). Natural gas is mainly used for space heating of the poultry houses and hot water preparation.

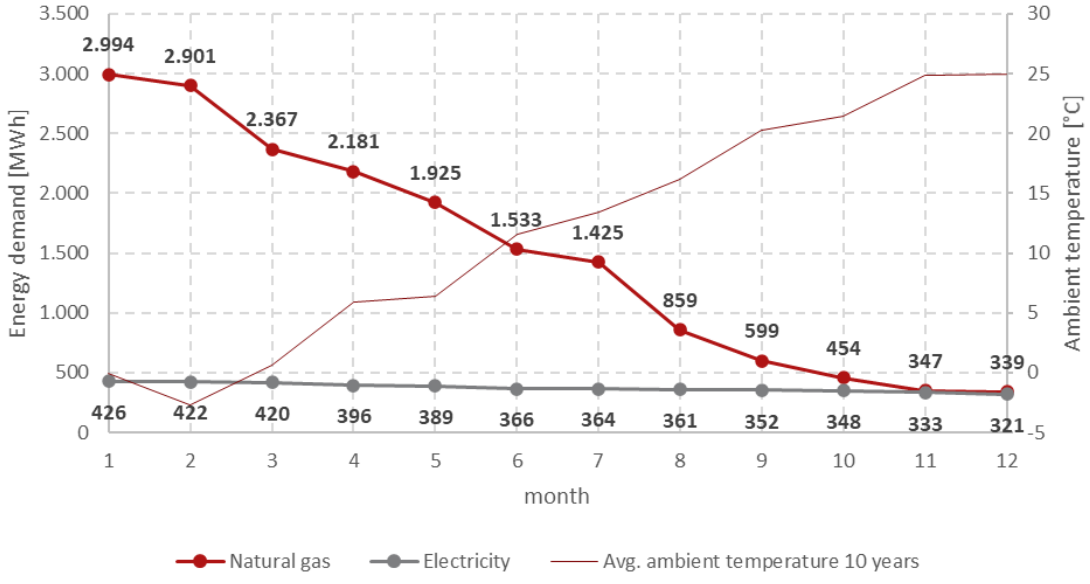


Figure 10 – Sorted energy demand of Arax

[3] www.xgroup.am

The sorted monthly energy demand for the last 3 years shows an almost constant electricity demand throughout the year. The heat demand is dependent on the outside temperature with a constant demand of about 340 MWh per month (450 kW).

3.2.1. Electricity consumption

Electricity is currently used on site for water supply, illumination, operation of machinery, equipment of the slaughterhouse, etc. In case of electricity generation via the biogas plant, it is most likely that it will be supplied to the national grid, while some part of it will be consumed on-site.

Grid power in the connection point is 504 kW. Voltage level is 10 kV (fifteen 10kV substations are located on the territory of the farm). Day-time tariff for electricity is 42 AMD/kWh (0.08 EUR/kWh) and night-time tariff is 32 AMD/kWh (0.061 EUR/kWh). Peak load is 1,500 kW. Total installed capacity of back-up diesel power generators is 1,300 kVA.

There are two PV power plants constructed on the territory of the farm to cover the electricity demand. One PV power plant with installed capacity of 500 kW is integrated into the national grid with two-directional electricity meter. The net-metering system allows to cover own demand and supply excess electricity to the national grid.

Figure 11 – On-site solar power plant 500kW

The second PV power plant with installed capacity of 300 kW is operated in off-grid mode, i.e. it is not integrated to the national grid and all electricity generated by the plant is consumed by the farm.

Thanks to the installation of PV power plants, the company managed to reduce its annual electricity consumption from the national grid by approx. 850.000 kWh/a. At the same time, the company needs an additional 1 MW to cover the electricity demand. This demand may be covered with a new off-grid PV plant to be constructed by the owner.

3.2.2. Heat demand

Natural gas is used for heating of the poultry houses and for hot water preparation in the slaughterhouse (mainly cleaning). Therefore, gas-fired boilers are installed on-site. The average cost of natural gas is about 139 AMD/m^3 (0.265 EUR/m^3).

Poultry houses are heated with self-regulating gas heaters with individual installed capacity of 45kW (20 heaters) and 75kW (132 heaters). The total installed capacity of heating systems available at the farm, including the above-mentioned heaters as well as several gas boilers is 17.2 MW.

In case of broilers, the heating regime is as follows: 33°C with a gradual, weekly decrease of the temperature by 2-3°C. The average temperature maintained in poultry houses in winter and summer is 27°C, with high consumption in winter and relatively low consumption in summer (mainly at night-time).

Figure 12 – Direct gas fired heaters (example)

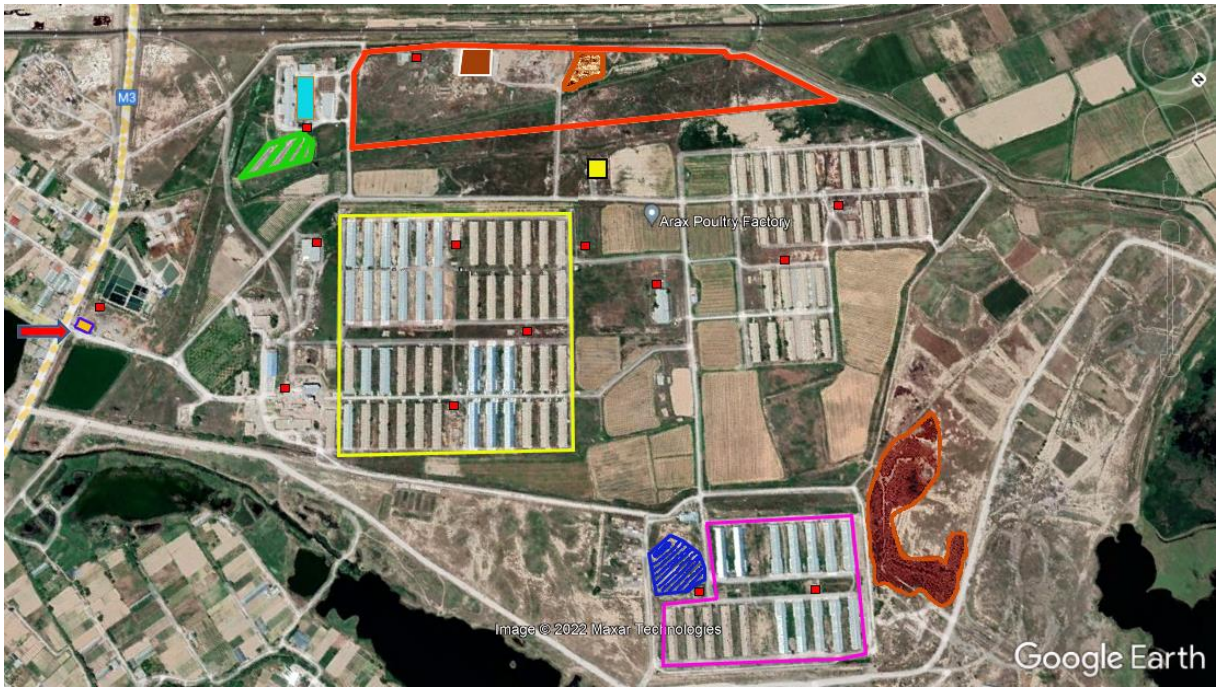
There are no other consumers of thermal energy in the vicinity of the farm, and it is not possible (reasonable) to organize district heating for nearby settlements.

4. PLANT DESIGN

4.1. PROJECT SITE AND INFRASTRUCTURE

4.1.1. Project site

The location of poultry houses and other facilities, as well as the space proposed by the company for construction of a biogas power plant can be seen on the figure below.



LEGEND

- *Checking point at the main entrance*
- *10 kV substations of farm*
- *35 kV substation of HVEN*
- *Slaughterhouse and facilities*
- *Former WWT facility (dismantled)*
- *300kW off-grid PV power plant for own use*
- *500kW on-grid PV power plant for own use*
- *Are proposed for construction of biogas plant*
- *Storage of poultry waste from laying hens*
- *Storage of poultry waste from broilers*
- *Poultry houses for broilers (floor keeping)*
- *Poultry houses for laying hens (cage keeping)*

The land plot proposed by the farm for construction of the biogas plant is located on the southwest side of the farm. The plot of about 16 hectares is located along the fence and the railway passing next to the farm. On the site there is a 10kV substation, infrastructures of the currently not operational and mainly dismantled wastewater treatment plant (WWTP), as well as an outdoor open storage for poultry waste mixed with straw.

Figure 13 – Former WWTP (left) and solid poultry manure storage (right)

The site proposed for construction of the biogas plant is currently empty and overgrown with vegetation (mainly grass-like Scirpus, i.e. Bulrush). Some parts of the territory are covered with construction debris left after the dismantling of some previously operated infrastructures, including wastewater treatment plant (WWTP), as well as unused and dilapidated buildings.

The land plot is owned by the farm. The zoning is industrial without special constrains for construction.

The farm has a well-developed internal road infrastructure that allows access to the biogas plant site from several directions. A 35kV substation is about 150-200 m from the site, which connects the farm to the public electricity grid.

Figure 14 – Images of proposed land plot for biogas plant

4.1.2. Infrastructure

Electricity supply

The farm is fed from 35/10 kV substation owned and operated by Electric Networks of Armenia CJSC, the national distribution grid operator. The substation is located within the territory of the farm, quite close to the plot proposed for construction of the biogas plant.

There are fifteen 10/0.4 kV substations owned by the company itself located throughout the territory of the farm. These substations supply electricity to the poultry houses and other facilities. Substations are connected by underground and overhead power lines.

Water supply

Technical water supply is available at the site, and the current capacities of the water supply system are sufficient to ensure operation of the biogas plant. There are several sources of water supply (artesian wells equipped with pumps) and all of them are located on the territory of the factory.

Wastewater

There is no existing sewage system on site (no contract with the sewage service provider is signed). Wastewater generated on the farm is discharged to a nearby channel.

Accessibility

There are 6 other access roads to the farm and the closest one can be used for shipment of equipment to the project site. The main access road allows traffic of up to 24-ton trucks. The site itself has internal road infrastructure that provides access to different areas and facilities.

4.2. FUEL SUPPLY AND LOGISTICS

The main substrate used for the biogas plant is poultry manure from Arax. The poultry manure is currently stored in a remote place in an open way for up to 6 months. Manure is sold for a price of about 10.000 AMD per ton (19-20 EUR/ton). Co-substrate is required for stable operation of the plant. Currently a share of about 70% poultry manure was considered in this assignment. Therefore, either corn or plant silage plant residues are suitable. In the questionnaires sent to greenhouses Spayka responded about the availability of tomato/cucumber residues from their greenhouses. The available amounts of substrate were reported as follows

Table 3 – Available substrates for project

Amount [t/a]	Description	Moisture content [%]
18,000	Manure from laying hens	46
7,200	Manure from broilers	74
5,000	Tomato and cucumber residues	92

Following literature values were used for this assessment as no detailed analysis of the available substrate was available.

Table 4 – Literature analysis of substrates

	DS	VS	C	N	S
	[m %]	[m %]	[m %]	[m %]	[kg/m³ FM]
Tomato and cucumber residues	92%	83%	37,3%	1,8%	
Poultry manure	43%	78%	21,6%	5,5%	0,54

Poultry manure from laying hens is generated and collected daily. This feedstock can be directly fed-in the plant with a loader. Manure from broiler production is collected at the end of a cycle (~11 weeks). This amount can be stored in a storage and constantly fed into the plant. Tomato and cucumber are available after harvesting. The distance between Arax and Spayka is around 30km. The required amounts can be transported regularly to the project site by trucks.

4.3. BIOGAS PLANT

4.3.1. Biogas plant with CHP

The considered process is based on a single stage wet digestion for a stable operation of the plant. Fresh poultry manure is directly put in a mixing tank. Manure from broilers as well as tomato and cucumber residues are delivered discontinuously and therefore stored in a feedstock storage. The balanced amounts are inserted in the mixing tank in combination with recycled process water by a loader. As poultry manure has a high nitrogen content, a carbon rich co-substrate is required.

Corn silage is often used for biogas plants, but in this case tomato and cucumber residues are available and can be used. A dry mass content of <10% is aimed to keep the pulp suitable for pumping. Pulp is transported in the wet digesters with pumps. For continuous operation, the digesters are split in 2 units with 7,800m³ each. Decomposition of feedstock is done in the digesters. The digesters are operated continuously at about 40°C which is favourable for biogas production. The digesters are covered with a leak-tight double layer membrane which acts as gas storage. The nominal capacity of biogas produced is about 2.6 MW or about 431 m³/h. After a retention time of about 30 days, the digestate is pumped in a storage tank and separated by a screw extruder. Process water is recycled for dilution of new substrate and filtrate is stored in a lagoon. This filtrate can be used as fertilizer on fields. A symbolic process scheme is shown in following figure.

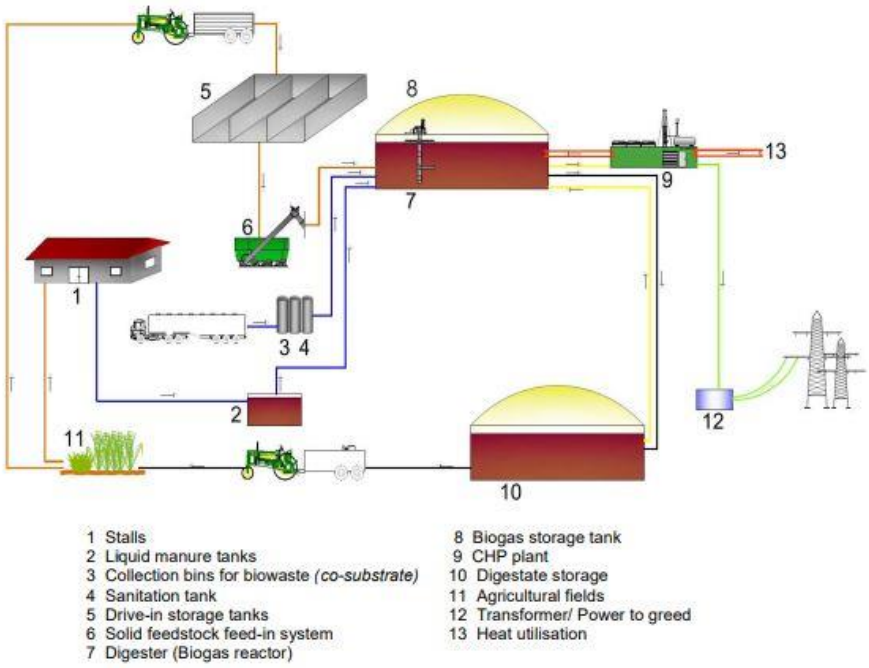


Figure 15 – Scheme of the biogas plant (Source: Source: biogas handbook, p. 62)

Biogas contains a larger amount of sulphur which must be reduced with a cleaner. The cleaned biogas is compressed and used for a CHP plant. Therefore 2 Jenbacher Innio J312 CHPs were considered. These machines are designed for biogas operation and their nominal parameters of the CHPs are shown in the following table

Table 5 – Nominal data of Innio Jenbacher J312 CHP unit(s)

	CHP Performance Data		**Efficiency [%]**
Type		Innio Jenbacher J312	
Energy Input	1,315	kW	84,1
Electrical capacity	548	kW	41,7
Thermal capacity	558	kW	42,4

The main components of the considered biogas plant are

- 1 mixing tank (400m³)
- 2 digesters (2 x 8,000m³)
- 1 buffer storage tank for filtrate (8,000m³)
- 1 lagoon (1,500m³)
- 1 water storage tank (400m³)
- 2 CHP (2 x 550kW)

A potential layout plan of the described project is shown in the following figure. Thus, a total area of about 1 ha is required.

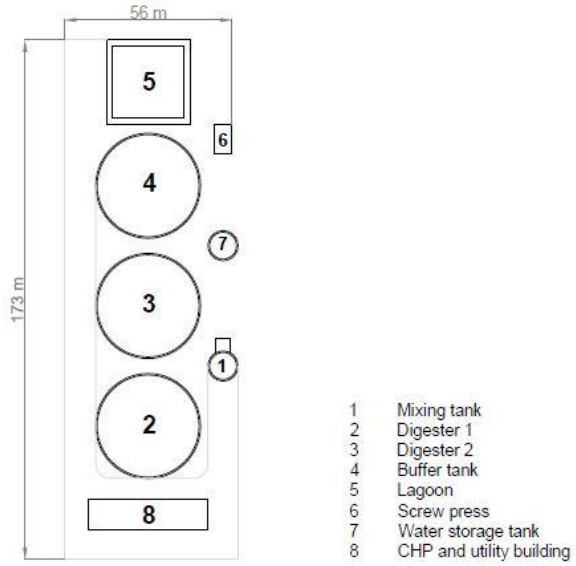


Figure 16 – Potential project layout plan

The plant is operated by one trained and experienced person who is responsible for operation and repair works in the plant. The plant operates fully automated, but the process must be controlled. Maintenance of plant components and CHP is done by technology suppliers/experienced partners. Digestate in liquid form can further be sold as fertilizer to other farms.

4.3.2. Biogas plant with direct gas usage

Additionally, the case of direct biogas usage by Arax poultry farm was considered. The direct usage of biogas for the installed heaters requires further detailed analysis (e.g. feasibility, emissions, etc.). Currently, it is assumed that natural gas can be replaced with biogas without any major adaptations. In this case, the capacity of the biogas plant is reduced to 30% of the CHP case due to the low gas demand during the summer period.

The main characteristics of this project are:

- Nominal power 800kW resp. 130 m³/h of biogas
- 120 m³ mixing tank
- 2x 1,900m³ digesters
- 1,900 buffer storage tank
- 600m³ lagoon

4.4. ENERGY CONSUMERS

4.4.1. Electricity

Electricity demand of the plant is covered by the generated electricity. Excess supply can either be used at Arax of fed into the public electricity grid. The demand of Arax was reduced already in the last years with 2 photovoltaic plants which cover a certain amount of demand. Additionally, the feed-in tariff for electricity from biomass is higher than the consumption price. Thus, in this consideration electricity is supplied in the public grid. A transformer for feed in the 10kV network is foreseen for the CHPs.

4.4.2. Heat

CHPs offer medium and low temperature heat. Hot water supply temperatures of up to about 105°C are possible. Preferably, hot water preparation or water-based heating systems can be supplied with this heat. The total installed heat capacity is 17,2MW. Thereof about 10,8MW are direct heaters in the barns and the rest is unknown.

Based on the monthly heat demand during summertime, a continuous heat demand of around 400kW can be seen. This could be either hot water preparation or conditioning of barns. The detailed amounts must be identified in further stages of the project and are not part of this report. Hot water preparation would require less investments in the existing heating system and therefore should be preferred.

In case of usage for heating purposes, water-based heaters should be installed in the barns. In European countries, such heating types are a standard and can heat up halls up to 25m. They can either be installed on the roof or on sidewalls, reach nominal capacities of up to 130kW and can operate in recirculating or fresh-air mode. Examples of heating systems are shown in the following images

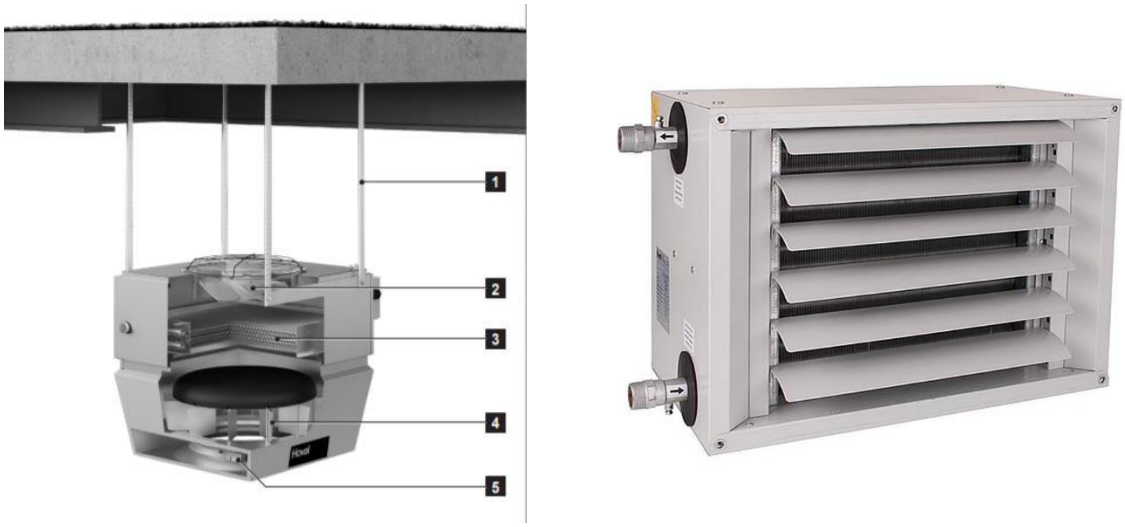


Figure 17 – Examples of hot water hall heating systems

Hot water pipes are normally insulated and laid underground for prevention of freezing. Additionally, glycol are electric trace heating systems could be used for prevention of freezing.

4.5. ENERGY AND MASS BALANCES

Biogas is produced by degradation of poultry manure and plant residues. The main share of process water of the plant is recycled. A certain share is discharged by digestate respectively must be replaced for process reasons. The mass balance of the considered biogas plant is shown in following table

Table 6 – Mass balance of the biogas plant

Input		
Poultry manure (laying hens)	9,000	t/a
Poultry manure (broilers)	4,680	t/a
Tomato and cucumber residues	5,000	t/a
Fresh water	29,200	m^3/a
Recycled process water	91,200	m^3/a
Output		
Fertilizer	5,600	t/a
Filtrate	9,300	t/a

The energy balance of the biogas plant is shown in following table. It is assumed that the energy demand of the biogas plant is covered by the CHP which is shown in the difference of gross and net production amounts.

Table 7 – Energy balance of the biogas plant

	Biogas produced	*Gross electricity generation*	*Net electricity generation*	*Gross heat generation*	*Net heat generation*
	[MWh]	[MWh]	[MWh]	[MWh]	[MWh]
January	1,761	734	603	747	255
February	1,591	663	544	675	253
March	1,761	734	603	747	325
April	1,704	710	583	723	353
May	1,761	734	603	747	399
June	1,704	710	583	723	425
July	1,761	734	603	747	466
August	1,761	734	603	747	467
September	1,704	710	583	723	417
October	1,761	734	603	747	378
November	1,704	710	583	723	311
December	1,761	734	603	747	275
Total	**20,737**	**8,641**	**7,096**	**8,799**	**4,324**

As mentioned above, electricity is fed into the public grid and heat is delivered to Arax farm. The monthly amounts are shown in following table.

Table 8 – Energy balance of Arax after project implementation

	electricity demand of Arax	*electricity replaced by CHP*	*natural gas demand of Arax*	*heat replaced by CHP*
	[MWh]	[MWh]	[MWh]	[MWh]
January	396	0	2,901	255
February	348	0	2,367	253
March	364	0	1,925	325
April	352	0	1,533	353
May	366	0	859	399
June	422	0	454	425
July	426	0	347	347
August	420	0	339	339
September	361	0	599	417
October	321	0	1,425	378
November	333	0	2,181	311
December	389	0	2,994	275
Total	4,498	0	17,923	4,077

5. COST ESTIMATES

5.1. INVESTMENT COSTS (CAPEX)

A concept design of the main components was done. Base on this design the investment costs of the main components were estimated. The costs are based on realized projects and literature values.

5.1.1. Biogas plant with CHP

An estimation of the project related costs for a biogas plant with gas utilization in a CHP is shown in the following table.

Table 9 – Project CAPEX estimation CHP

	Amount	Price	Total	
Engineering	7%		214,215	7%
Soil works	6,204	10	62,042	6,204
Building	400	1,000	400,000	400
Civil works	2,112	500	1,055,855	2,112
Pumps	8	5,000	40,000	8
Sand removal	1	60,000	60,000	1
Gas processing	1	110,000	110,000	1
Gas membrane	1	200,000	200,000	1
Gas cleaning system	1	15,000	15,000	1
Gas burner	1	40,000	40,000	1
CHP	2	336,162	672,324	2
Hydraulic installation	1	70,000	70,000	1
Electric installation	1	100,000	100,000	1
Transformer	1	60,000	60,000	1
Automation	1	45,000	45,000	1
SCADA	1	130,000	130,000	1
Contingencies	10%		327,444	10%
Total CAPEX			**3,601,880**	

As mentioned in the previous chapters, investments in the heating system of the company are required. Therefore, costs of about 140,000 EUR are estimated for pipes, heaters, and hydraulic integration.

5.1.2. Biogas plant with direct usage of biogas

The estimated costs for this case are shown in following table. It is assumed that the biogas can directly be used in the existing heaters (must be proofed in detail).

Table 10 – Project CAPEX estimation direct usage

	Amount	Price	Total	
Engineering	7%		96,580	EUR
Soil works	1,651	10	16,513	EUR
Building	83	1,200	100,000	EUR
Civil works	872	600	523,195	EUR
Pumps	8	5,000	40,000	EUR
Sand removal	1	60,000	60,000	EUR
Gas processing	1	110,000	110,000	EUR
Gas membrane	1	200,000	200,000	EUR
Gas cleaning system	1	15,000	15,000	EUR
Gas burner	1	40,000	40,000	EUR
CHP	0	0	0	EUR
Hydraulic installation	1	70,000	70,000	EUR
Electric installation	1	80,000	80,000	EUR
Transformer	1	0	0	EUR
Automation	1	45,000	45,000	EUR
SCADA	1	80,000	80,000	EUR
Contingencies	10%		147,629	
Total CAPEX			**1,623,916**	**EUR**

Due to the smaller size the specific CAPEX is significantly higher than the CHP case.

5.2. OPERATIONAL COSTS (OPEX)

Costs of operation were split in variable and fix costs. Variable costs include the substrate costs and maintenance costs. Chicken manure was considered as free of charge. Crop residues are included with about 4 EUR/t for transport and 4 EUR/t of substrate costs. Willingness for delivery and price negotiations were not part of this project and should be investigated in further stages of the project. Pumping costs are considered for water as the water is provided on-site. Unforeseeable costs for repair works are included. About 50% of the fixed costs are related to maintenance of the CHP. A detailed cost breakdown is shown in following chapters.

5.2.1. Biogas plant with CHP

Table 11 – Project OPEX estimation (biogas plant with CHP)

		Amount	Price per unit	Total	
Variable costs					
Chicken manure	t/a	13,680	0	0	13,680
Tomate and plant residues	t/a	5,000	8	40,000	5,000
Electricity	MWh	1,459	0	0	1,459
Water	[m³/a]	26,280	0,2	5,256	26,280
Repair		3,325,623	1,0%	33,256	3,325,623
Total variable costs				**78,512**	
Fixed costs					
O&M CHP	[h/a]	7,884	10	78,840	7,884
O&M biogas	[EUR]	2,653,299	1,0%	26,533	2,653,299
Staff	[PAX]	1	10,000	10,000	1
Insurance	[EUR]	3,601,880	0,4%	14,408	3,601,880
Total fixed costs				**129,781**	

5.2.2. Biogas plant with direct usage of biogas

Table 12 – Project OPEX estimation (biogas plant with direct usage of biogas)

		Amount	Price per unit	Total	
Variable costs					
Chicken manure	t/a	3,060	0	0	EUR/y
Tomate and plant residues	t/a	2,000	8	16,000	EUR/y
Electricity	MWh	1,459	68	99,412	EUR/y
Water	[m³/a]	8,213	0	0	EUR/y
Repair		1,510,824	1,0%	15,108	EUR/y
Total variable costs				**130,520**	**EUR/y**
Fixed costs					
O&M CHP	[h/a]	0	0	0	EUR/y
O&M biogas	[EUR]	1,510,824	1,0%	15,108	EUR/y
Staff	[PAX]	1	10,000	10,000	EUR/y
Insurance	[EUR]	1,623,916	0%	6,496	EUR/y
Total fixed costs				**31,604**	**EUR/y**

6. FINANCIAL ANALYSIS

6.1. COSTS AND TARIFFS

The economic calculations are based on the following parameters:

General	
Inflation rate	2%
Increase of energy tariffs (natural gas and electricity)	1%
Interest rate	
Cost of carbon rich co-substrate	8 EUR/t
Cost of water	0.2 EUR/m³
Electricity feed-in tariff	44 EUR/MWh
Price of fertilizer	5 EUR/t
Financing	
Share of equity	0%
Grant	0%
Upfront fee	0,5%
Interest rate	2%
Repayment period	12 years

6.2. COST-BENEFIT ANALYSIS (CBA)

6.2.1. Biogas plant with CHP

Table 13 – Cost-benefit analysis biogas plant with CHP (no grant)

	year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Revenues																						
	Heat		109,999	111,099	112,210	113,332	114,466	115,610	116,766	117,934	119,113	120,304	121,507	122,723	123,950	125,189	126,441	127,706	128,983	130,272	131,575	132,891
	Electricity Arax		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Electricity grid		316,005	319,165	322,356	325,580	328,836	332,124	335,445	338,800	342,188	345,610	349,066	352,556	356,082	359,643	363,239	366,871	370,540	374,246	377,988	381,768
	Fertilizer		46,485	47,415	48,363	49,330	50,317	51,323	52,350	53,397	54,465	55,554	56,665	57,798	58,954	60,133	61,336	62,563	63,814	65,090	66,392	67,720
	Total revenues		472,489	477,678	482,929	488,242	493,618	499,057	504,561	510,130	515,766	521,468	527,238	533,077	538,986	544,965	551,016	557,140	563,337	569,608	575,955	582,379
Costs																						
	Investment	-3,737,613																				
	Grant	0																				
	Credit costs	-18,688	-56,064	-52,327	-48,589	-44,851	-41,114	-37,376	-33,639	-29,901	-26,163	-22,426	-18,688	-14,950	-11,213	-7,475	-3,738					
	Variable costs		-78,512	-80,082	-81,684	-83,318	-84,984	-86,684	-88,418	-90,186	-91,990	-93,829	-95,706	-97,620	-99,572	-101,564	-103,595	-105,667	-107,780	-109,936	-112,135	-114,377
	Fixed costs		-129,781	-132,376	-135,024	-137,724	-140,479	-143,288	-146,154	-149,077	-152,059	-155,100	-158,202	-161,366	-164,593	-167,885	-171,243	-174,667	-178,161	-181,724	-185,359	-189,066
	Total costs	-18,688	-264,357	-264,785	-265,297	-265,893	-266,576	-267,348	-268,210	-269,164	-270,211	-271,355	-272,596	-273,936	-275,378	-276,924	-278,575	-280,335	-285,941	-291,660	-297,493	-303,443
CF		-3,756,301	208,132	212,893	217,633	222,349	227,042	231,709	236,351	240,967	245,554	250,113	254,642	259,141	263,607	268,041	272,441	276,805	277,396	277,948	278,462	278,936
DCF			208,132	204,705	201,214	197,667	194,076	190,448	186,792	183,115	179,424	175,726	172,027	168,333	164,648	160,979	157,328	153,700	148,104	142,691	137,457	132,395

NPV	-413,824 €
IRR	2.7%
LCOH	40 €/MWh

Table 14 – Cost-benefit analysis biogas plant with CHP (30% grant)

	year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Revenues																						
	Heat		109,999	111,099	112,210	113,332	114,466	115,610	116,766	117,934	119,113	120,304	121,507	122,723	123,950	125,189	126,441	127,706	128,983	130,272	131,575	132,891
	Electricity Arax		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Electricity grid		316,005	319,165	322,356	325,580	328,836	332,124	335,445	338,800	342,188	345,610	349,066	352,556	356,082	359,643	363,239	366,871	370,540	374,246	377,988	381,768
	Fertilizer		46,485	47,415	48,363	49,330	50,317	51,323	52,350	53,397	54,465	55,554	56,665	57,798	58,954	60,133	61,336	62,563	63,814	65,090	66,392	67,720
	Total revenues		472,489	477,678	482,929	488,242	493,618	499,057	504,561	510,130	515,766	521,468	527,238	533,077	538,986	544,965	551,016	557,140	563,337	569,608	575,955	582,379
Costs																						
	Investment	-3,737,613																				
	Grant	1,121,284																				
	Credit costs	-18,688	-72,883	-69,146	-65,408	-61,671	-57,933	-54,195	-50,458	-46,720	-42,983	-39,245	-35,507	-31,770	-28,032	-24,294	-20,557					
	Variable costs		-78,512	-80,082	-81,684	-83,318	-84,984	-86,684	-88,418	-90,186	-91,990	-93,829	-95,706	-97,620	-99,572	-101,564	-103,595	-105,667	-107,780	-109,936	-112,135	-114,377
	Fixed costs		-129,781	-132,376	-135,024	-137,724	-140,479	-143,288	-146,154	-149,077	-152,059	-155,100	-158,202	-161,366	-164,593	-167,885	-171,243	-174,667	-178,161	-181,724	-185,359	-189,066
	Total costs	-18,688	-281,176	-281,604	-282,116	-282,713	-283,396	-284,167	-285,029	-285,983	-287,031	-288,174	-289,415	-290,756	-292,198	-293,743	-295,395	-280,335	-285,941	-291,660	-297,493	-303,443
CF		-2,635,017	191,313	196,074	200,813	205,530	210,222	214,890	219,532	224,147	228,735	233,294	237,823	242,322	246,788	251,222	255,622	276,805	277,396	277,948	278,462	278,936
DCF			191,313	188,533	185,663	182,715	179,699	176,624	173,499	170,333	167,134	163,909	160,665	157,407	154,143	150,877	147,615	153,700	148,104	142,691	137,457	132,395

NPV	484,522 €
IRR	5.9%
LCOH	38 €/MWh

6.2.2. Biogas plant with direct usage of biogas

Table 15 – Cost-benefit analysis of biogas plant with direct usage (no grant)

	year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Revenues																						
	Heat		162,981	164,611	166,257	167,919	169,599	171,295	173,008	174,738	176,485	178,250	180,032	181,833	183,651	185,487	187,342	189,216	191,108	193,019	194,949	196,899
	Electricity Arax		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Electricity grid		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Fertilizer		12,133	12,375	12,623	12,875	13,133	13,395	13,663	13,936	14,215	14,499	14,789	15,085	15,387	15,695	16,009	16,329	16,655	16,988	17,328	17,675
	Total revenues		175,113	176,986	178,879	180,795	182,731	184,690	186,671	188,674	190,700	192,749	194,822	196,918	199,038	201,182	203,351	205,545	207,763	210,007	212,277	214,573
Costs																						
	Investment	-1,623,916																				
	Grant	0																				
	Credit costs	-8,120	-24,359	-22,735	-21,111	-19,487	-17,863	-16,239	-14,615	-12,991	-11,367	-9,743	-8,120	-6,496	-4,872	-3,248	-1,624					
	Variable costs		-130,520	-133,131	-135,794	-138,509	-141,280	-144,105	-146,987	-149,927	-152,926	-155,984	-159,104	-162,286	-165,532	-168,842	-172,219	-175,663	-179,177	-182,760	-186,415	-190,144
	Fixed costs		-31,604	-32,236	-32,881	-33,538	-34,209	-34,893	-35,591	-36,303	-37,029	-37,770	-38,525	-39,295	-40,081	-40,883	-41,701	-42,535	-43,385	-44,253	-45,138	-46,041
	Total costs	-8,120	-186,483	-188,102	-189,785	-191,535	-193,352	-195,238	-197,194	-199,221	-201,322	-203,497	-205,748	-208,077	-210,485	-212,973	-215,544	-218,198	-222,562	-227,013	-231,554	-236,185
CF		-1,632,035	-11,370	-11,116	-10,906	-10,740	-10,621	-10,548	-10,523	-10,547	-10,622	-10,748	-10,927	-11,159	-11,447	-11,791	-12,193	-12,654	-14,799	-17,006	-19,276	-21,611
DCF			-11,370	-10,688	-10,083	-9,548	-9,078	-8,669	-8,316	-8,015	-7,761	-7,551	-7,382	-7,249	-7,150	-7,081	-7,041	-7,026	-7,901	-8,730	-9,515	-10,258

NPV	-1,726,821 €
IRR	/
LCOH	/

Table 16 – Cost-benefit analysis of biogas plant with direct usage (30% grant)

	year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Revenues																						
	Heat		162,981	164,611	166,257	167,919	169,599	171,295	173,008	174,738	176,485	178,250	180,032	181,833	183,651	185,487	187,342	189,216	191,108	193,019	194,949	196,899
	Electricity Arax		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Electricity grid		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Fertilizer		12,133	12,375	12,623	12,875	13,133	13,395	13,663	13,936	14,215	14,499	14,789	15,085	15,387	15,695	16,009	16,329	16,655	16,988	17,328	17,675
	Total revenues		175,113	176,986	178,879	180,795	182,731	184,690	186,671	188,674	190,700	192,749	194,822	196,918	199,038	201,182	203,351	205,545	207,763	210,007	212,277	214,573
Costs																						
	Investment	-1,623,916																				
	Grant	487,175																				
	Credit costs	-8,120	-31,666	-30,042	-28,419	-26,795	-25,171	-23,547	-21,923	-20,299	-18,675	-17,051	-15,427	-13,803	-12,179	-10,555	-8,932					
	Variable costs		-130,520	-133,131	-135,794	-138,509	-141,280	-144,105	-146,987	-149,927	-152,926	-155,984	-159,104	-162,286	-165,532	-168,842	-172,219	-175,663	-179,177	-182,760	-186,415	-190,144
	Fixed costs		-31,604	-32,236	-32,881	-33,538	-34,209	-34,893	-35,591	-36,303	-37,029	-37,770	-38,525	-39,295	-40,081	-40,883	-41,701	-42,535	-43,385	-44,253	-45,138	-46,041
	Total costs	-8,120	-193,791	-195,409	-197,093	-198,842	-200,659	-202,545	-204,501	-206,529	-208,630	-210,805	-213,056	-215,385	-217,792	-220,281	-222,851	-218,198	-222,562	-227,013	-231,554	-236,185
CF		-1,144,861	-18,677	-18,423	-18,213	-18,048	-17,928	-17,855	-17,831	-17,855	-17,929	-18,055	-18,234	-18,467	-18,754	-19,098	-19,500	-12,654	-14,799	-17,006	-19,276	-21,611
DCF			-18,677	-17,715	-16,839	-16,044	-15,325	-14,676	-14,092	-13,568	-13,101	-12,686	-12,318	-11,996	-11,714	-11,470	-11,261	-7,026	-7,901	-8,730	-9,515	-10,258

NPV	-1,336,508 €
IRR	/
LCOH	/

7. ANNEXES

7.1. ANNEX 1 - FEEDBACK FROM FARMS

1	Name of company	Agroholding Armenia LLV	Dili LLC	Ecofarm LLC	Porkprod LLC	Combined Feed Factory after Vladimir Hakobyan	Agrotechinvest LLC	Yeghegnut LLC and Gndevaz LLC	Lusakert Elite LLC	Variant Group LLC	Arax Poulty Farm CJSC
	Type of managed animals	Pig and cattle	Cattle	Cattle	Pig	Poultry	Poultry	Poultry	Poultry and Pig	Poultry **and Pig**	Poultry
	Number of managed animals		700	800	3000	2450000	2000000	1080000	160800 and 123	50000 **and 3000**	654230
	Annual amount of animal waste, per type of animals, t/a										
	Poultry					39000	2000	**10000**	5400	2300	**30000**
	Pig				9000				54	**1000**	
	Cattle	**4000**	not specified	not specified							
	The current animal waste management system per type of animals	Solid storage for cattle waste, waste storage for pig waste is not specified	Solid storage for cattle waste	Solid storage	Liquid / slurry	Solid storage	Solid storage	Solid storage	Other: Semisolid	Other: Semisolid	Solid storage
	Would you be interested in the sale of animal waste generated at your farm as a "fuel" for a biomass or biogas power plant?	Yes, fully (100%) Yes, partially (50%)	Yes, fully (100%) Yes, partially (50%)	Yes, fully (100%)	Yes, fully (100%)	Yes, fully (100%) Yes, partially (50%)	Yes, fully (100%)	Yes, fully (100%)	Yes, fully (100%)	No	Yes, fully (100%)
	Would you be interested in signing a long-term contract for sale of the animal waste to a biomass or biogas power plant?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Type of heating system of farms	Gas heaters, electric heating, SWH based heating	Gas heaters and electric heating	Gas heaters and electric heating	Gas-fired boiler and gas heaters	Gas-fired boiler and gas heaters	Gas-fired boiler and gas heaters	Not specified	Gas heaters	Gas heaters with automatic control system	Gas-fired boiler and gas heaters
	Annual energy consumption for heating				2019: 150 MWh/a and 25000 m3/a 2020: 170 MWh/a and 32000 m3/a	2019: 1100000 m3/a 2020: 970000 m3/a	2019: 1100 MWh/a and 756000 m3/a 2020: 1200 MWh/a and 869000 m3/a	2019: 205810 MWh/a and 65242 m3/a 2020: 855101 MWh/a and 491175 m3/a	2019: 623816 MWh/a and 73482 m3/a 2020: 573329 MWh/a and 39692 m3/a	2019: 1019500 MWh/a and 518250 m3/a 2020: 1232600	2019: 2074446 m3/a 2020: 1535789 m3/a

										MWh/a and 543129 m3/a	
	Would you be interested in the possibility of alternative heating of your farm(s) with thermal energy produced by a biomass or biogas power plant, provided that heat energy is supplied directly to the farm(s), and the price is on the same level or lower compared to your current heating supply?	Yes	Yes	Yes	Yes (Acceptable purchase price of heat energy in AMD for 1 MWh: 40000 incl. VAT)	Yes (Acceptable purchase price of heat energy in AMD for 1 MWh: 30 incl. VAT)	Yes (Acceptable purchase price of heat energy in AMD for 1 MWh: 25-28 incl. VAT)	Yes (Acceptable purchase price of heat energy is not specified)	Yes (Acceptable purchase price of heat energy in AMD for 1 MWh: 28-30 incl. VAT)	Yes (Acceptable purchase price of heat energy in AMD for 1 MWh: 28-30 incl. VAT)	Yes (Acceptable purchase price of heat energy is not specified)
	What is the final use of the organic waste generated in your farm?	Fertilizer for agricultural needs by the owner of the livestock farm.	Fertilizer sold by the owner of the livestock farm to other agricultural farms	Fertilizer for agricultural needs by the owner of the livestock farm.	Fertilizer for agricultural needs by the owner of the livestock farm.		Fertilizer sold by the owner of the livestock farm to other agricultural farms	Fertilizer for agricultural needs by the owner of the livestock farm.	Fertilizer sold by the owner of the livestock farm to other agricultural farms	Fertilizer sold by the owner of the livestock farm to other agricultural farms	Long-term storage or disposal at landfills and sold by the owner of the livestock farm to other agricultural farms
	Is the organic waste processed somehow by the owner of the livestock farm before usage as fertilizers for own use or for sale?	No processing	No processing	Yes: dehydrated	No processing		Yes: dehydrated	No processing	Yes: dehydrated	No processing	No processing
	How is the transportation of the organic waste generated in your facility carried out in cases when it is used as fertilizer by the owner or sold to other farms?	By special transport for liquid waste	By usual tracks for transportation of dry materials	By usual tracks for transportation of dry materials	By usual tracks for transportation of dry materials		By usual tracks for transportation of dry materials	By usual tracks for transportation of dry materials	By usual tracks for transportation of dry materials	By usual tracks for transportation of dry materials	By usual tracks for transportation of dry materials
	At what price (AMD/ton or AMD/m3) organic waste is sold as fertilizer or fuel?	16,000 AMD for 10 m3	15,000 AMD for 5 ton		3000 AMD for 1 ton		40,000 AMD for 5 ton	free charity	very cheap	**20,000 AMD for a track (4-5 ton)**	

7.2. ANNEX 2 - FEEDBACK FROM GREENHOUSES

1	Name of company	Spayka LLC	Green Farmer LLC	Ecoland LLC	Green Food LLC	Green House LLC	Eco Fruit LLC
2	Contact information	Arevik Atikyan/ Greenhouse Project Chief Manager/ arevik.atikyan@spayka.com/ +374 41 100647	Tatevik Fidanyan, International relations specialist, +374 60 500570	Araqelyan Marina, export@ecoland.am	Armen Davtyan Financial manager, davtyan.arm@gmail.com, +374 91 438451	Sevada Kokobelyan, Director, greenhouse.arm@gmail.com, +374 99 569000	Anzhela Khachatryan, Director ecofruitarmenia@gmail.com +374 99 569000
3	Location(s) of greenhouse(s)	1. Artashat greenhouses- Artashat avenue 51/2, Yerevan 0007, RA 2. Noragavit greenhouses- Yerevan-Yeraskh Highway 4, Ararat reg. 0732, RA	RA, Kotayq region, Hrazdan, Djrarat district 999	Dzoraghbyur village	Shirak region, Artik, Armenia , Str. Sasunci David34	111/1 street, village Achajur, region Tavush	Tavush Region Achajur village 1st street 111, 111/2
4	Cultivated crops	Tomato and cucumbers	Tomato	Strawberry, tomato, cucumber	Strawberry	Dutch roses	Roses
5	Surface of greenhouse(s), ha	105	20	15	9,6	2	3,5
6	Type of greenhouse(s)	Plastic	Plastic	Glass	Plastic	Glass	Both (2 ha Venlo type, 1.5 ha plastic)
7	Type and annual amount of organic waste generated by the greenhouse, t/a	Mainly leaves and other organic residues of the plants, annual amount-130-150 t/ha	7000 t	Biomass (not specified)	750 t/a	Not estimated	Not estimated
8	The current practice of utilization of organic waste generated by the greenhouse	Composting	Disposal at landfill	Disposal at landfill	Disposal at landfill	Disposal at landfill	Disposal at landfill
9	Type of heating system	Not specified	Gas-fired boiler, gas heaters, passive solar heat	Gas-fired boiler	Gas-fired boiler	Gas heaters and diesel	Gas heaters and diesel
10	Annual energy consumption for heating	2019: 14294740 MWh/a and 29643100 m3/a 2020: 15686074 MWh/a and 35947986 m3/a	2019: 2620000 MWh/a and 8454700 m3/a 2020: 2260680 MWh/a and 7000000 m3/a	2019: 68285 MWh/a and 522677 m3/a 2020: 101500 MWh/a and 807493 m3/a	2019: 0.228 MWh/a and 928000 m3/a 2020: 0.68 MWh/a and 2216000 m3/a	2020: 418,580 MWh/a and 227700 m3/a	2019: 332.0475 MWh/a and 855550 m3/a 2020: 79.9196 MWh/a and 820267 m3/a
11	Do you have plans for expansion of the greenhouse?	Yes (100 ha)	Yes (10 ha)	Yes (20 ha)	Yes (3 ha)	Yes (3.5 ha)	Yes

12	Would you be interested in the possibility of alternative heating of your greenhouse(s) with thermal energy produced by a biomass or biogas power plant, provided that heat energy is supplied directly to the greenhouse, and the price is on the same level or lower compared to your current heating supply?	Yes	Yes (acceptable purchase price of heat energy in AMD for 1 MWh: 3000)	Yes	No	Yes	Yes
13	Would you be interested in the supplying the organic waste generated at your greenhouse(s) to a biomass or biogas power plant regardless of whether you buy the generated heat or not?	Yes (130 t/ha)	Yes (7000 t/ha)	No	No	Yes	Yes
14	What types of fertilizers are used for the crop cultivation in the greenhouse?	Mineral	Mineral	Mineral, complex	Complex	Complex	Complex
15	Would you be interested in the purchase and use of organic fertilizers produced by a biogas power plant?	Yes	Yes	Yes	No	No	No

7.3. ANNEX 3 – PRELIMINARY E&S SCREENING

See attached document.

7.4. ANNEX 4 – IDENTIFICATION OF NECESSARY TECHNICAL ASSISTANCE (TA)

The following Technical Assistance (TA) needs have been identified among the main stakeholders:

GAF	
	• Support in conducting project due diligence (obtaining documentation, review of documents, confirmation of legal compliance, minimum programme requirements, overview of financing and costs) • Capacity building events to understand the available / potential capacities on the market / in the region (construction companies, designers, financial institutions, governmental institutions, etc.), for specific areas (e.g. technical, health and safety, environmental) focused on international best practices, typical issues in design / construction / financing / operation, etc.
MINISTRIES / GOVERNMENTAL INSTITUTIONS	
	• Conduct interviews among key figures in the relevant ministries on the topic of biomass / biogas projects, specifically in agriculture / livestock companies • Awareness raising event related to benefits of biomass / biogas technologies (technical, financial, environmental, etc.) • Training on best practices in regulation in EU countries ion the biomass/biogas area • Examples of successful projects across Europe / Caucasus / Asia, etc. • Support consultant to provide input / guidance in revision of legislation (e.g. feed-in tariffs, environmental laws, energy related laws, etc.) to create favorable market conditions for development of projects
LOCAL FINANCIAL INSTITUTIONS & AGRICULTURE/LIVESTOCK COMPANIES	

	• Awareness raising event / networking event to:
	  ○ Initiate communication between the financial sector and potential investors
	  ○ Identify potentially interested stakeholders for realization of projects
	  ○ Explain potential of biogas projects in agriculture/livestock companies
	  ○ Improve understanding of the applicable technologies
	  ○ Explain benefits of similar projects

RE - INVESTOR	

	• Feasibility study
	• PIU support consultant
	  ○ tasks related to preparation and support with KfW required documentation and design
	  ○ preparation and support with documentation required for national procedures (depending on the chosen project components), E&S procedures and documentation (if required by local legislation, to be clarified in the FS)
	  ○ preparation and support with tender documents and procurement process
	  ○ supervision of work and contracts
	  ○ support during commissioning and verification
	  ○ support with ensuring appropriate O&M, insurance, plant operator, etc.)
	• Staff training (equipment provider), on the job training

7.5. ANNEX 5 – OUTCOME INDICATOR(S)

OUTCOME

Awareness on the benefits of biomass/biogas plants among projects stakeholders, agriculture and livestock companies is raised.

Outcome indicator 1 *Awareness raising training for RE investors and local banks with the aim to improve understanding of the potential for biogas projects coupled with agriculture/livestock companies, improve technology understanding and benefits of biogas projects*		
Unit *Number of participating institutions*	**Baseline (start of project)** *0*	**Target value** *5*
Means of verification: • *Event report* • *Participation lists*		

Outcome indicator 2 *Awareness raising training for relevant ministries with the aim to improve understanding of the potential for biogas projects coupled with agriculture/livestock companies, improve technology understanding and benefits of biogas projects*		
Unit *Number of participating ministries*	**Baseline (start of project)** *0*	**Target value** *2*
Means of verification: • *Event report* • *Participation lists*		

Outcome indicator 3 *2 agriculture and/or livestock companies have expressed their interest in biomass/biogas projects and participating in the GAF programme*		
Unit *Number of projects*	**Baseline (start of project)** *0*	**Target value** *2*
Means of verification: • *Letter of intent from agriculture/livestock companies* • *Written information of GAF*		

Outcome indicator 4 *1 biomass/biogas project has been prepared and accepted for funding under the GAF*		
Unit *Number of projects*	**Baseline (start of project)** *0*	**Target value** *1*
Means of verification: • *Application documents* • *Written information of GAF*		

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