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Final Report:

Extension of waste transfer station "ET SUR" in Quito, Ecuador

Feasibility Study and business planning to set up value chain "organic waste – biogas – energy"

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Content

1 Summary

The Ecuadorian Foundation SEMBRES through its affiliate Optrasembres has been running for the last six years the waste transfer station in Quito. Daily, average 540 tons of domestic waste are transferred from smaller trucks to big trailers at ET Sur and brought to the landfill 45km away. This feasibility study shall clarify the following key questions:

- Can a sustainable business model ("value chain organic waste – biogas - energy") be established based on the processing of approximately 300 tons of organic material for energy production?
- Is there a local market to absorb the output materials (electricity, heat and/or cold energy; organic fertilizer)?
- Can the output materials be sold at a prize that would allow running the plant self-sustainable?

Following the most important findings of this study in a nutshell:

- The existing site of the transfer station is not suited for a low-tech biogas plant to process 300 tons of organic waste per day (static reasons, insufficient space, no consumer of heat or cold);
- The market to absorb the output (organic fertilizers) of a biogas plant to process daily 300 tons of waste does currently not exist and has to be developed;
- The study presents a financially viable business model for a pilot biogas plant to process 32 tons of organic waste per day aiming at producing electricity and feeding to the grid, developing a market for organic fertilizer and avoiding high costs for waste transport and disposal in the remote landfill;
- The study makes clear the high potential for saving (transport and disposal of waste) for the City of Quito. Accordingly, the funding of the pilot plant shall be mixed (private AND public) but cannot be assured without the commitment of the City of Quito (reinvestment of savings);
- There is a new legal framework for the construction and operation of a biogas plant in the country that defines subsidies prices for renewable energies;

With the realization of the project of a pilot biogas plant it can be proved that there are environmental-friendly solutions to the organic waste problem in Quito and more general in Ecuador where domestic waste still consists of more than 60% organics.

More profitable and impactful than biogas production only would be the processing and sale of recyclable materials in the ET Sur. As a next step a comprehensive business model will be developed based on this feasibility study comprising recycling and biogas production and presented to the Municipality of Quito and the National Financial Corporation (CFN), a national credit line to finance projects of renewable energy.

2 Introduction

SEMBRES, an Ecuadorian foundation which is supported by the Swiss association Pro Pomasqui, has been executing a recycling project for almost 10 years in Pomasqui near Quito, Ecuador. Based on a successful pilot project to introduce separation of waste at source (households and schools), the project has been continuously scaled up and includes today approximately 55’000 people as well as local schools and companies. Roughly 20 tons of material is recycled monthly. The ambition is to further develop this development project towards a self-sustaining small social enterprise. Currently, the project has a degree of self-sustaining of about 80%. To continuously improve the effectiveness of this recycling project, SEMBRES is carrying out an environmental education campaign, which is aimed at schools, households and companies. Centre pillars of this campaign are the environmental education bus, the environmental educational trail and a manual for environmental education which were basis to sensitize and train thousands of habitants of the sector.

With this successful track record, SEMBRES through its affiliate Optrasembres Ltd. has been awarded a contract by the Municipality of Quito to operate the waste transfer station in Southern Quito (Estación de Transferencia SUR – ET Sur) for 16 years. In summer 2008 the construction of the plant was finished and the station was set into operation. Daily, approximately 540 tons of waste are collected (average), transferred from smaller trucks to big trailers at ET Sur and brought to the landfill 45km away. During the operation of both projects, SEMBRES regularly analyses the composition of waste and has set up a comprehensive database. Roughly 75% of the waste are recyclable, 65% is organic material (see 4.1.1).

Ecuador intends to put more emphasis on the production of renewable energy in the future. The production of more energy of renewable sources forms part of a national plan (“Plan national del buen vivir”) and has been integrated as a target in the strategy of the local power supplier.

3 Objectives

Based on the long-term pilot experience and learnings with processing and commercialization of recyclable materials, SEMBRES intends to scale up the pilot-project and add a recycling module to use the high potential of unused recyclable organic and inorganic waste transferred at ET Sur. This scaling up process is planned in two phases:

- 1st phase: using the organic material as major fraction to:
  - Produce energy AND organic fertilizer by means of a biogas plant
  - Reducing costs for disposal at the landfill as well as transport cost
- Second phase: installation of a recycling module to separate and commercialize other recyclable materials

Against this background, the feasibility study at hand shall clarify the following key questions:

- Can a sustainable business model (“value chain organic waste – biogas - energy”) be established based on the processing of approximately 300 tons of organic material for energy production:
  - Is there a local market to absorb the output materials (electricity, heat and/or cold energy; organic fertilizer/humus)
  - Can the output materials be sold at a prize that would allow to run the plant self-sustainable
- Could the organisation to run the biogas plant be set up as a social entrepreneur with maximal ecologic and societal impact?

The following illustration sums up the originally planned social business model to be verified by the feasibility study:

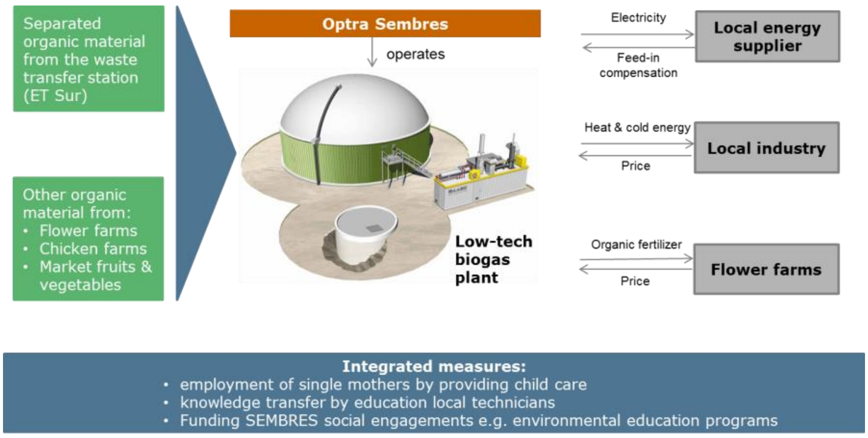

Figure 1: Business model of biogas plant to be verified

4 Results

Involved Partners

In the context of this feasibility study and the implementation oft he biogas plant the following partners are respectively will be involved:

- First Biogas International AG (following referred to as “FBI”): a Swiss company with expertise in the field of biogas plants, which will ensure technical feasibility and knowledge transfer;
- BHP – Brugger and Partner Ltd.: a Swiss consultancy with expertise in the fields of strategy development, (corporate) sustainability as well as start – up support for social purpose organisations, responsible for the coordination and management of the project;
- SEMBRES Foundation (following referred to as SEMBRES): Ecuadorian NGO with expertise and track-record in recycling projects and environmental education;
- Optrasembres Ltd: Affiliate of SEMBRES and operator of the waste transfer station ET Sur
- Pro Pomasqui: Swiss NGO, which is providing financial and conceptual support for SEMBRES

Today, both the SEMBRES Foundation and Optrasembres are led respectively owned by Herman Moser.

4.1 Technical feasibility of biogas plant

4.1.1 Composition of waste transferred in ET SUR

The analysis of the composition of the waste transferred at ET SUR during the past 4 years is summarized in Table 1.

Componente	2010 (%)	2011 (%)	2012 (%)	2013 (%)	Promedio
Orgánico	64.71	62.27	63.22	67.85	64.51
Plásticos (Alta y Baja Densidad, PET)	12.00	12.91	12.22	12.54	12.42
Papel y Cartón	5.41	7.28	9.49	6.59	7.19
Pañales	5.44	5.40	5.38	5.47	5.42
Telas	5.89	5.54	5.37	1.84	4.66
Latas (Al)	0.91	0.76	0.50	0.57	0.69
Vidrio	1.60	1.90	2.12	2.32	1.99
Residuos Peligrosos	1.51	1.31	0.26	0.48	0.89
Residuos Electrónicos	0.59	0.35	0.12	0.22	0.32
Escombros	0.90	0.37	0.00	0.00	0.32
Icopor o Poliestireno expandido	0.41	0.77	0.35	0.44	0.49
Polipropileno	0.30	0.48	0.46	0.65	0.47
Tetra pack	0.23	0.23	0.30	1.03	0.45
PVC y caucho	0.09	0.00	0.00	0.00	0.02
Caucho	0.00	0.15	0.00	0.00	0.04
Madera	0.00	0.00	0.00	0.00	0.00
Porcelana	0.00	0.15	0.02	0.00	0.04
Hierro	0.01	0.01	0.00	0.00	0.01
Caucho	0.00	0.10	0.04	0.00	0.04
Esponja	0.00	0.02	0.00	0.00	0.01
Metal	0.00	0.00	0.15	0.00	0.04
	100.00	100.00	100.00	100.00	100.00

Table 1: Composition of waste in ET SUR 2010 – 2013 (Source: SEMBRES 2014)

The average percentage of organics is 65%. This corresponds to a potential of 390 tons of organic material per day to be processed in the biogas plant, whereas this amounts varies about 5% during the year.

➔ **Based on our analysis of waste composition and taking into consideration the planned technical solution (see 4.2.1), ET Sur has the following potential for a biogas plant:**
- **Organic input material up to 300t/d (75% efficiency factor);**
- **output material: 40 ton/day solid fertilizer, 230'000l liquid fertilizer/day**
- **potential energy production of 17 GWh/a**

Further potential
Based on the reference values (source: 10 years experiences of SEMBRES made in the recycling project in Pomasqui), this analysis confirms as well the high potential to recycle high density plastics and PET that can be easily separated and cleaned after transport. The following table calculates potential incomes (75% efficiency factor; 540/tons/d during 6 day per week) by commercialising plastics on the local market. The comprehensive calculation of potential incomes by processing recyclables is provided in annex 9.2.

Components	%	t/a	USD/t	USD/a
HD plastics	2.87%	4835	150	2'175'919
PET	0.06	9418	200	1'883'606

Table 2: Potential of plastic recycling

4.1.2 Separation of organics
The analysis makes also clear that the incoming waste is highly polluted and mixed after the recollection and transport to ET Sur, thus several process units are necessary to separate the organic waste from all other components, especially the low density plastic bags and the batteries that are a risk factor for the operation of the biogas plant. Roughly 50% of organic waste is wrapped in low density plastic bags. A "bag opener[1]" or similar manual step is needed to process maximum percentage of the organic material. However we assume receiving enough organic material without complex separation equipment to run the planned pilot plant (10% of potential material processed).

4.1.3 Site of the biogas plant
Our analysis of ET SUR as site to build the biogas plant unfortunately shows that the transfer station is not suited for the originally planned biogas plant to process 300 tons of organic waste per day. First of all, there is simply not enough space to put all buildings and the digesters. And if the design approach shall be a low-tech one there is even more space needed because of the laguna digesters. Secondly, the small land strip has steeply slopes on both sides. For static reasons, a construction of high volume digester tanks is not feasible. Additionally, there is no local heat or cold energy demand next to the ET Sur that would allow selling outputs to improve the profitability of the plant.

➔ **The current site of ET SUR is not suited for a biogas plant to process 300 tons of organic waste per day applying a low-tech approach.**

During this feasibility study, several alternative sites have been identified and analysed trying to optimize framework conditions for the biogas plant, such as:
- Organic material available
- Transportation of organic material
- Additional sources of organic material
- Selling the cold
- Selling the heat
- Selling fertilizer
- Land costs

The entire matrix applied to identify potential alternative sites is enclosed in annex 9.1.

[1] type "schlitz-o-mat";http://www.brt.info/en/products/schlitz-o-mat.html

Three potential sites were analysed:

Site	Distance to ET Sur	Cost USD/m^2	Comments
Site 1 „landfill“	45 km	30	+ synergies to disposal + low land cost - no local market for cold/heat - no transport savings (km/CO_2)
Site 2: „airport“	30	85	+ high demand for cold (storehouses for flowers) - high land cost - limited transport savings
Site 3: „ET Sur“	5	40	+ limited additional transport cost - no local market for heat/cold

Table 3: Alternative sites for biogas plant

Assuming that a biogas plant to process 300t/d of organics would need a site of at least 7500m^2 additional costs of minimal USD 225’000 (site 1) and USD 637’500 (site 2) would incur. Furthermore, the investment costs for infrastructure would be much higher as there would not be any synergy effects with ET Sur. Last but not least, social impact would be weakened as transport savings would decrease. Having in mind the potential benefit of a biogas plant of 300t/d (see Annex 9.2), the economic viability of the plant is no longer given.

Against this background, the project team decided to analyse the feasibility of a pilot plant with reduced scale that can be built on the site of the existing ET SUR with the key figures defined in chapter 4.1.6.

➔ **The option to construct the biogas plant outside the transfer station is economically not viable.**

4.1.4 Market

The outlined business model to be analysed (see chapter 3) as part of this feasibility study makes clear that the profitability of the biogas plant depends heavily on a threefold revenue stream [sale of electricity, heat or cold (as secondary outputs of the biogas production) and additionally the sale of organic fertilizer (solid or liquid)].

a. Market for electricity

Following the most important findings regarding the sale of electricity that have changed significantly during the conduction of the feasibility study:

- CONELEC (El Consejo Nacional de Electricidad) is the governmental department in charge of the regulation and control of the energy sector. The Ecuadorian Government delegates the generation, transmission, distribution and commercialization of electric energy to licensed parties through CONELEC.
- The Ecuadorian Government established in 2013 a new regulation (Regulacion No CONELEC – 001/13) defining the legal framework for the construction and operation of a biogas plant in the country. Following the most important parts of this regulation with regard to the planned biogas plant in Quito are summarized:
  - Contracts with licensed parties are established for a period of 15 years;
  - Private companies contracted by CONELEC before 31 December 2016 to generate renewable energy are reimbursed with a “subsidized” price/kWh for biogas fed into the grid: 0,1108 USD/kWh
  - Whereas this price seems to enable a profitable operation of a plant, it has to be considered that a provider of renewable energy has to pay 2,86 Cents/kWh (production < 5MW) to the Government (Estado del Buen Vivir Territorial); the net value per kWh would be 11,08 cents – 2,86 cents = 8.22 ct/kWh
  - Private entities intending to produce renewable energy have to provide the following documentation to CONELEC:
    - Legally recognized, national company dedicated to the production of energy;

  - Proof of feasibility of connectivity of planned production site to the grid (executed by the power distribution company but paid by the power producer [USD 5'000 – 10'000];
  - Project description
  - Pre-feasibility study of project
  - Environmental impact assessment of the production site and – if needed – along the power line carrier(s)
  - Business plan including assurance of financing
- Furthermore, the following conditions have to be met:
  - At least 50% of the technicians involved in the project and 100% of the persons in charge of non-qualified works have to be Ecuadorian Citizens.
  - A concept for the continued capacity building and knowledge transfer during the operation of the plant has to be presented
- The regulation defines a cap for the amount of energy produced of biomass and biogas subsidized by CONELEC at 100MW

The originally planned LoI with the local Electricity Company is no longer needed as the new regulation led by CONELEC as national entity defines the exact procedure to be followed.

➔ **There is a legally fixed compensation for renewable electricity fed into the Ecuadorian grid.**
➔ **There is a clear process to follow to have access to this subsidized compensation led by CONELEC (El Consejo Nacional de Electricidad)**

b. Market for heat or cold

There are no major consumers of heat or cold in a distance to the transfer station that would allow selling heat or cold. This important income parameter was considered during the identification of alternative sites (see Table 3).

c. Market for organic fertilizers

Our explorative study on the market potential to absorb the planned output material (organic fertilizer) concludes that unfortunately today there is not yet enough demand and even considerable scepticism by the agricultural sector to take advantage of the organic output material to substitute chemical fertilizers – not even thinking about buying the organic material as fertilizer which would help to run the biogas plant sustainably. Although we presented chemical studies on the expected composition of the organic material derived from comparable plants, most of the potential buyers remain critical about the fact that such a high-quality fertilizer shall be produced out of “domestic waste”. This fact was important to scale down the biogas plant to a demonstration plant that can be visited and would allow making pilots as well with the output material based on a real basis and not based on empirical data provided.

4.1.5 Current cost of waste management in Quito

To calculate the overall cost of the biogas plant, the current cost of waste management has to be taken into account:

	unit	Cost (USD)
Transport ET Sur to landfill (45km x 2)	t/km	0.15
Final disposal of waste	t	5.60

Table 4: Potential savings for Municipality of Quito

The construction of the biogas plant can help to reduce these costs as the amount of waste transferred to and disposed at the waste disposal is reduced. Chapter 4.3 is dealing with this aspect in depth.

4.1.6 Interim summary: construction of a “pilot plant”

Based on these findings, the project team decided to elaborate the technical concepts and economics for a smaller plant, which is referred to as “pilot plant”. The parameters of the pilot plant are the following:

Parameter	Unit	Annual value	Unit	Daily value
Organic waste input	[t/a]	12‘000	[t/d]	32.9
Separated liquid digestate output	[t/a]	6‘742	[t/d]	15.5
Separated solid digestate output	[t/a]	4‘097	[t/d]	11.2
Electricity production	[kWh/a]	2‘257‘800	[kWh/d]	6186

Table 5: Key figures pilot biogas plant

4.2 Details Technical solution of the pilot plant

Based on chapter 4.1.6 the following paragraphs refer to the pilot plant with an organic input of 32.9 tons per day.

4.2.1 Applied fermentation system

The organic waste fraction after the separation process at ET SUR is mostly coming from households and restaurants. This input material is rich in energy and protein. In a conventional single step digester this feedstock causes problems due to a fast acidification. If there are no other organic materials available that can balance out this load, it is common practice to have a hydrolysis pre-treatment process. The hydrolysis unit is then used as a mixing pit, too. The solid feedstock is mixed with liquids and can easily be pumped to the digester. Thus, an imported and expensive solid feeder is not necessary and the whole plant design can be kept simple. First Biogas International AG (FBI) has more than 20 years of experience with hydrolysis technology and has developed its own systems. For the ET SUR pilot plant it’s best to take the low air-aerobic hydrolysis technology for pre-treatment. With the presence of some air bacteria that have more energy for their metabolism. Thus, the formation of volatile fatty acids (VFA) is diminished and the unwanted propionic acid is quickly turned into acetic acid. Additionally, more fatty acids are turned directly into acetonic acid because the acetic forming bacteria can work in aerobic and anaerobic situations. But too much air would have a negative impact on the biogas yield because too much organic matter is becoming decomposed and turned into CO_2.

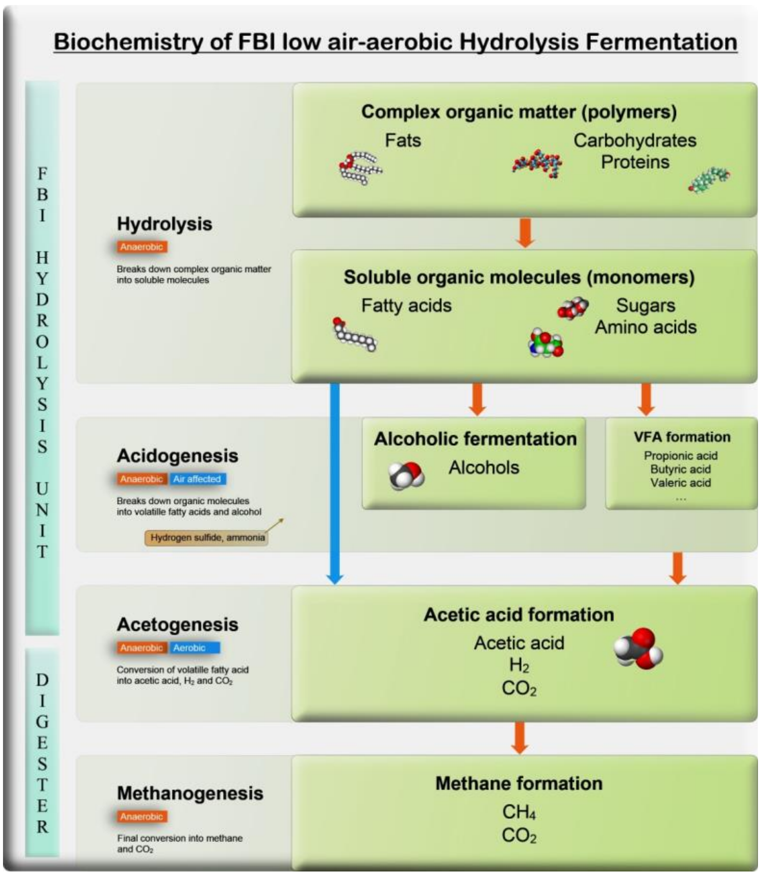

Figure 2: Biochemistry of FBI low air-aerobic Hydrolysis Fermentation

For the pilot plant it makes no sense to bring in other feedstock such as waste from the flower farms outside of Quito. This would mean further transportation cost and more traffic at the transfer station. The objective of the pilot plant shall be the successful demonstration of turning organic waste into energy and fertilizer. So for reasons of simplicity just the waste available at ET Sur is used at a scale that a profitable plant operation is feasible. With an additional higher investment for a low air-aerobic hydrolysis system a stable plant operation with the planned organic waste can be achieved. From a biological point of view the operators can manage and run the plant easier and need less knowhow than with a single step fermentation system.

For the flower farms biogas plants would also make much sense. They can turn their flower waste into energy and fertilizer. Nevertheless, the challenge with flower waste is that it has a high content of cellulose and hemi-cellulose which cannot be digested in a single step fermentation system. Here’s also a (semi-aerobic) hydrolysis system is necessary to get satisfactory gas yields. The advantage of having a pilot plant with a low air-aerobic hydrolysis is to be able to demonstrate temporarily the use of flower waste to the farmers.

4.2.2 Pilot Plant description

The biogas pilot plant consists mainly of one hydrolysis tank (1), one digester (2) and a one final storage (4). A CHP unit (3) will burn the biogas and generate electricity and heat.

After the separation of the incoming waste part of the organic fraction (12’000 t/a) will be fed directly and regularly into the hydrolysis tank by a conveyor belt. This tank is made of concrete and has a volume of 90 m^3. The organic waste is mixed with separated liquid digestate (9’000 t/a) from the separation unit in order to make it liquid at a TS-content of about 11%. The mixture is stirred regularly and kept at a temperature of 38°C. Inside the tank there is a membrane aeration system. Once per hour a pump discharges 2.5 m^3 of the pre-treated organic mixture to the digester for fermentation. The digester is also made of concrete and has a net volume of 1’076 m^3.

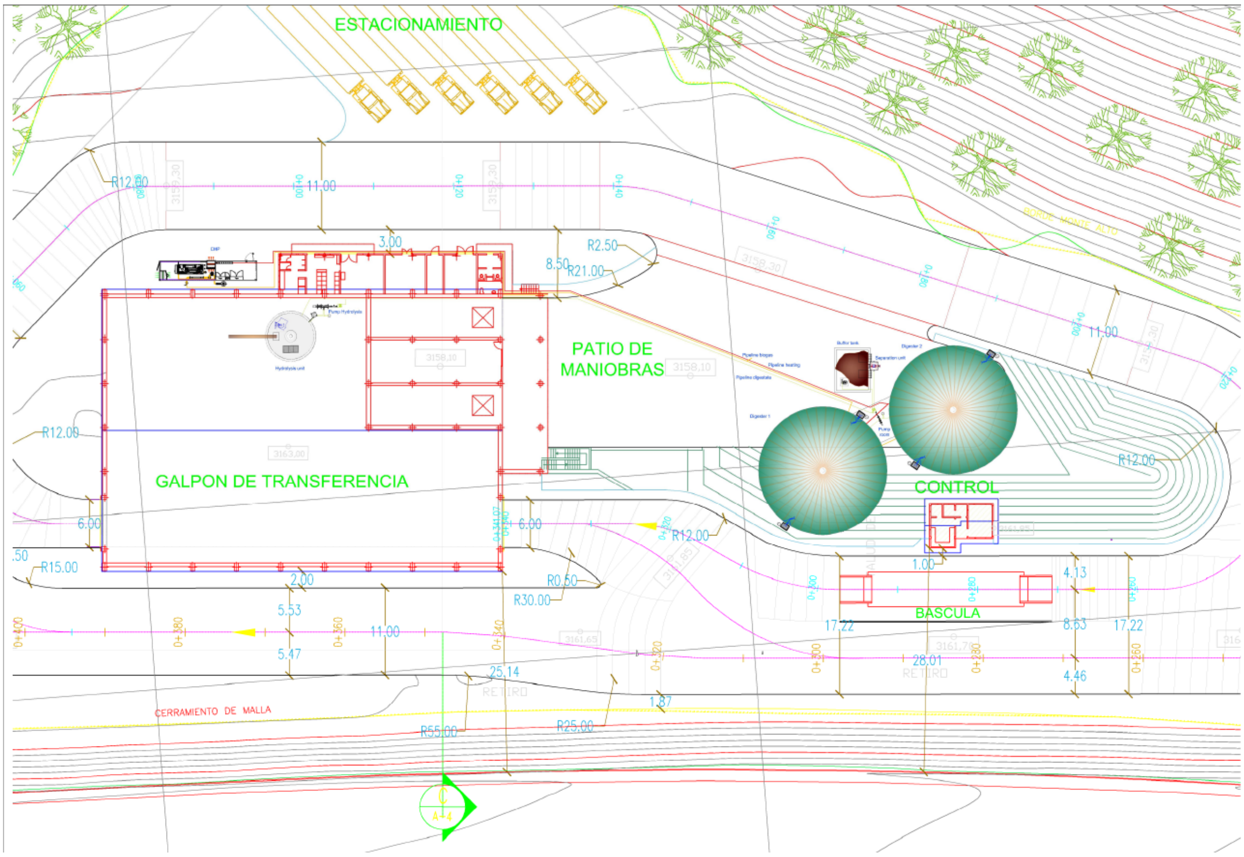

Figure 3: Layout of the pilot biogas plant

An internal heating system keeps the content at 42°C and agitators keep it stirred. Methane bacteria produce biogas that is temporarily stored in a gas holder on top of the digester. From there, the CHP with an electric power of 265 kW sucks the gas into its combustion engine and generates electricity and hot water. The electricity is fed into the grid and the hot water is used to heat the hydrolysis tank and the digester. With the excessive heat the liquid and/or solid left-overs of the biogas plant can be dried. After the digester the fermented substrate is pumped into the final storage. This storage has the same characteristics like the digester but has no heating system. This tank is used for further biogas production and can be filled up in case the digester needs cleaning. From the storage tank a pump feeds the separation unit (5) that separates the digestate into a liquid fraction (3.5% TS) and a solid fraction (25% TS). The liquid digestate is temporarily stored in a concrete buffer tank beneath and the solid digestate on top of the buffer tank.

The pilot biogas plant is well integrated into the existing transfer station ET SUR. Thus, no extra land is needed and process ways are short. The plant is not a low tech biogas plant. Low tech would mean taking laguna digesters instead of concrete tank digesters, for instance. But laguna systems need much more space which is not available at the transfer station and are less efficient. Thus, the focus of design is more on a well-integrated and efficient system. Ecuador should have state of the art technology and design. In the waste industry, Ecuador can afford and implement efficient technologies like the success of ET SUR itself has proven. Biogas plants shall not only dispose organic waste in an environmentally friendly and cheaply way. They shall also produce renewable energy and organic fertilizer for which both a demand already exists (renewable energy) or can be developed (organic fertilizer) in the country. In addition, the digestion of food waste, cellulose rich materials and abattoir waste demands a certain level of technology and are not really suited for low tech plants. But design and technology applied for the pilot biogas plant can be realized in Ecuador.

Following table gives the overview of the planned figures of the pilot biogas plant:

Parameter	Unit	Annual value
Gas production		
Biogas quantity	[Nm^3/a]	969‘000
Methane content	[%]	60
Methane quantity	[Nm^3/a]	581‘400
Methane quantity	[Nm^3/h]	67
Energy production		
Electricity production	[kWh/a]	2‘257‘800
Plant own consumption	[kWh_{el}/a]	270‘936
Heat production	[kWh/a]	2‘138‘910
Plant own consumption	[kWh_{th}/a]	320‘837
Hydrolysis unit		
Number	[-]	1
Liquid volume	[m^3]	90
Temperature	[°C]	36
TS-content	[%]	10.9
Hydraulic retention time	[d]	1.2

Digester		
Number	[-]	1
Liquid volume	[m^3]	1‘076
Temperature	[°C]	40
TS-content	[%]	7.9
Hydraulic retention time	[d]	18.4
NH_4-N estimated	[g/l]	4.2

Volume load	[kg oTS/m^{3}d]	5.0
Post-digester/storage		
Number	[-]	1
Liquid volume	[m^3]	1'076
Temperature	[°C]	30
TS-content	[%]	7.3
Hydraulic retention time	[d]	18.4

Table 6: Figures biogas pilot plant

4.2.3 Components

Most of the equipment and labors come locally from Quito and Ecuador. Thus, a big value creation stays in the country and will drive acceptance. However, some specific components have to be imported from abroad in order to guarantee proper function and this has nothing to do weather a system is of low tech or high tech nature. These are the imported components:

CHP The plant site is at an altitude of about 3'000 m above sea level. Because of the low air pressure at this height combustion engines run at a much lower power. FBI used CHPs both gas and dual fuel engines at sea level and in mountainous regions. It showed that dual fuel engines (based on diesel engines) that use a little bit of diesel decrease much less in power than pure gas engines. Thus, a dual fuel CHP with an electric power rate of 265 kW is imported from Germany. It is estimated that in order to operate at its nominal power a 20% increase in biogas consumption is necessary. These CHPs have a high electric efficiency (42%) and are packed in a container, including diesel tank and electric cabinets. Thus, transportation is easy and the whole installation is done within the container in an excellent quality.

Agitators The hydrolysis unit and the digester need special agitators that have been proven in biogas plants. That's why they are imported from Germany.

Pumps The same for the pumps.

Separator The same for the separator.

Piping, valves, gauges, cabinets as well as all civil works can be purchased locally.

4.2.4 Mass balance

The following figures describe the mass balance of the pilot biogas plant. Table 7 sums up the annual inputs and outputs of the plant.

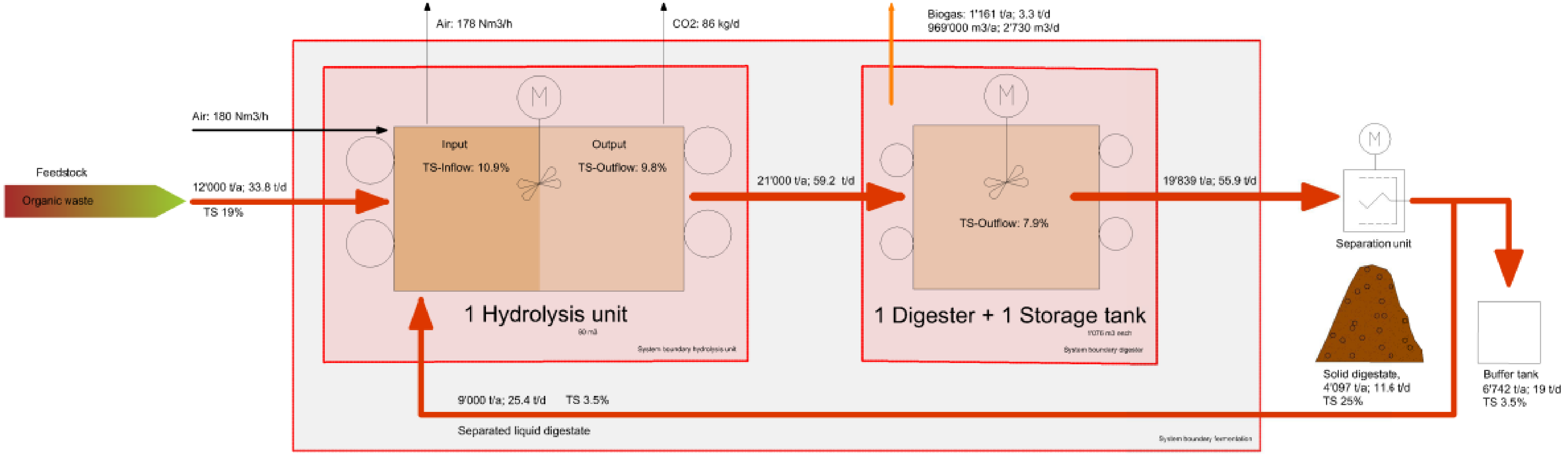

Figure 4: Mass balance

Parameter	Unit	Annual value
Mass balance		
Organic waste input	[t/a]	12‘000
Separated liquid digestate input	[t/a]	9‘000
Separated liquid digestate output	[t/a]	6‘742
Separated solid digestate output	[t/a]	4‘097

Table 7: Mass balance

4.2.5 Digestate management

The outflow of the biogas plant is 10’839 t/a. Whereas 6’742 t/a are liquid and 4’097 t/a are solid. Both can be used as fertilizer. It is assumed that the City of Quito can take 3’650 t/a liquid fertilizer for their parks etc. This liquid fertilizer is odourless and has a balanced nutrient composition.

There is an annual excessive heat from the CHP of 1’818’073 kWh. This heat can be used to evaporate water and to increase further the fertilizer quality.

Fertilizer production

Basically, 3’092 t/a at 3.5% TS and/or 4’097 t/a at 25 % TS can be dried. This means a water loss of 1’652 m^3/a.

Variation 1:

One way to use the heat is to dewater the liquid fraction down to 1’440 t/a at 7.5% TS. This can be done with proven evaporation systems that have to be imported from Germany. As a consequence transport and dumpsite cost can be reduced.

Figure 5: Evaporation system for liquid outflows of biogas plants

Variation 2:

The other way to use the heat is to dewater the solid fraction: dewatering down to 2’445 t/a at 41% TS. This can be done with container systems that use hot air to dry the material on internal conveyor belts.

Figure 6: Evaporation system for solid left-overs of biogas plants

4.3 Economic feasibility

4.3.1 Investment costs

Table 8 sums up the expected investment costs for the pilot biogas plant.

CHP	220‘000 $
Digester	148‘270 $
Final storage	117‘800 $
Hydrolysis unit	78‘627 $
Buffer tank	29‘200 $
Hydraulics	34‘132 $
Separation	38‘500 $
Gas and heating installation	15‘600 $
Electric equiment and installations	80‘000 $
General civil works	75‘490 $
Equipment (truck trailer)	20‘000 $
Engineering, project management and commissioning	245‘000 $
Total investment costs	**1‘102‘619 $**

Table 8: investment costs pilot biogas plant

Investment costs for the concrete digester and final storage tanks are rather high. The costs were calculated by a local architecture company. A cheaper solution hereby could be to im-port steel tanks from China as used by FBI in Chinese projects. They are cheap and have a sufficient quality. Other than that, costs seem rather high in general for Ecuadorian conditions. But it’s deceptive. All installations and components are state of the art and according to safety standards. We’re not talking here of a self-made back yard biogas plant in a third world country. This would not be accepted by the City of Quito and the modern equipped flower farms. This pilot biogas plant shall demonstrate to Ecuador a state of the art and profitable solution to turn organic waste into energy and fertilizer.

4.3.2 Capital cost

Amortization

The effective useful life of the equipment differs significantly. The digester is expected to last at least 20 years, whereby some parts have to be replaced sooner, in particular the gas membrane, which is expected to last some 5 years. The agitators will last some 10 years; the heating system lasts approx. 20 years except for the pumps. The CHP engine requires rebuilding after 30'000 to 60'000 hours, depending on the manufacturer.

All components and services are divided into 4 categories:

Category	Amortization period	Abbreviation
Mechanical components 1	5 years	T5
- CHP engine - Pumps - Gauges - Compressors - etc.		
Mechanical components 2, Building equipment 1	10 years	T10
- CHP without engine - Agitators - Gas storages - Heating systems - etc.		
Electrical equipment, Building equipment 2	20 years	T20
- Digester		

- concrete pits - electric cabinets and installation - civil works		
Land, utility connections	No amortization period	TX

For the pilot biogas plant the amortization list looks like this:

T5	88'323 $
T10	280'805 $
T20	733’492 $
TX	0.00

This means that every 5 years components for 88’323 USD have to be replaced, for instance.

Annuity
At 5% capital interest the following annual capital cost arises:

T5	20'328 $
T10	36'530 $
T20	58’640 $
Total	115'498 $

4.3.3 Cost of operation

Amount of work and manpower
For the labour, an hourly wage of $ 8.-/h is used. The labour consists of the following works:

- Controlling of the pilot plant
- Maintenance and service of the biogas plant and the components
- Journalizing the data
- Oil change of CHP every 400 running hours

The running of the pilot plant needs approximately 2 hours a day.

Maintenance of the pilot biogas plant
With our experience and knowledge, repairing and material cost of the pilot plant are approximately 1 to 1.2% of the investment costs per year.

Service and repairing costs of the CHP
The provider of the CHP has a fixed value to calculate the cost of this service. The costs depend on the power of the engine and the hours of operation. A CHP unit with a power of 265 kW costs € 7.02/h. For bigger engines the costs are higher.

The dual fuel engine of the CHP needs a little bit of fuel oil. Consumption: 2 lt/h at 0.14$/lt.

Costs for active coal
The needed amount of active coal to clean the biogas is dependent on the biogas production and the concentration of the hydrogensulfate in the biogas. A 265 kW electric biogas plant needs approx. 450 kg/a. One kilo costs about $ 4.0.

Biotechnical support
It is recommended analysing the digestate regularly to check the situation in the digester for the biology. FBI offers support in the first year with training including analysis and consulting. The analyses have to be done by a laboratory in the region of the plant.

Insurance
The yearly insurance costs depend on the provider but are estimated based on enquiries.

Table 9 sums up the expected operational expenditures (opex):

Cost	$ per year
Labour	5’840
Maintenance	11’000
CHP	25’000
Fuel oil CHP	2’386
Active coal	1’800
Support	15’000
Insurance	6’000
Administration	4’000
Total	71’026

Table 9: operational expenditures (opex)

4.3.4 Incomes

The main income is the sale of the generated electricity to the grid at a net price of 0.0822 $/kWh. With a total net production of 1’986’864 kWh/a the income is 161’731 $ per year.

During the pilot phase, no further income from sales of fertilizers or energy is calculated.

Savings
As already mentioned in chapter 4.1.5, the reduced costs of waste disposal for the City of Quito can also be regarded as incomes for the biogas plant. Normally, the 12’000 t/a of organic waste has to be transported and disposed at the landfill. The distance from the transfer station to the landfill site is 90 km (return at 0.15$/km) and the cost per ton of waste to be dumped is 5.6$. Thus, 1 ton less of disposal saves 19.1$!

Due to biogas production the annual mass loss is 1’161 t. This means savings of 22’175 $/a (avoided costs for transport and final waste disposal) for the Municipality of Quito and can fully be regarded as income for the biogas plant.

4.3.5 Economics of pilot biogas plant

Table 10 sums up the economics of the pilot biogas plant.

Initial Economics	
Object	$ per year
Outgo	
Capital cost	115’498
Opex	71’026
Income	
Electricity	161’713
Savings	22’175
Balance	- 2’636

Table 10
Economics pilot biogas plant

The pilot biogas plant is not profitable at first calculation. Mainly the low feed-in tariff of renewable electricity caused partly by taxes and the missing opportunity of using the excessive heat keep the income low resulting in a loss of USD 2’636/a.

Improvements of economics
Following, several alternatives to improve the result are presented:

Reduced annuity and opex
At 4% capital interest the following annual capital cost arises:
With this lower interest rate about 7’000 $ can be saved annually.

T5	19’800 $
T10	34’563 $
T20	54’242 $
Total	108’605 $

Table 11: Reduced annuity (4%)

Realistic would be to have a mixed funding, whereas the City of Quito contribute 30% of the costs (reflecting the expected savings), international (Corporate) Foundations 30 – 40% and up to 70% could be financed by the National Financial Corporation (CFN) for promoting renewable projects 6% interest. The annuity in such an alternative would be 110’695 $.

Cost	$ per year
Labour	5’840
Maintenance	11’000
CHP	15’000
Fuel oil CHP	2’386
Active coal	1’800
Support	15’000
Insurance	6’000
Administration	2’000
Total	59’026

Table 12: Optimized opex

Opex can be reduced by having an employed engineer from the existing transfer station trained in Germany for the maintenance of the CHP. Thus, about $ 10’000/a can be saved. Administration cost can also be reduced by taking advantage of the existing administration of the transfer station.

Optimized economics	
Object	$ per year
Outgo	
Capital cost	110’695
Opex	59’026
Income	
Electricity	161’713
Savings	22’175
Balance	**+ 14’167**

Table 13: Optimized economics of pilot biogas plant

Reduced annuity and optimized opex results in a positive balance of the pilot biogas plant (see **Fehler! Verweisquelle konnte nicht gefunden werden.**).

Further savings
The City of Quito can take advantage of 3’650 t/a liquid fertilizer for their parks. This would not only reduce existing costs but would contribute to considerable lower landfill cost of 20’440$/a (3’650 t/a at 5.6$/t). Transportation costs still incur to bring out the fertilizer.

Further savings through additional investments
Besides the reduction of landfill costs which occur due to the usage of the liquid fertilizer as output of the pilot biogas plant for their parks, there is an opportunity to create additional savings through two different variations. For these two variations further investments are necessary as follows.

With **variation 1** (evaporating water from liquid digestate) the investment would be about $150’000. The annuity at 5% interest and 10 year amortization is 19’500 $. Opex are at $ 5’000/a. Thus, the total annual costs are 24’500 $. Savings come from the evaporation of 1652 t/a of water and thus, there are 31’553 $/a less disposal cost. This means a further profit for the biogas plant of 7’053 $/a.

With **variation 2** (evaporating water from solid digestate) the investment would be about $220’000. The annuity at 5% interest and 10 year amortization is 28’600 $. Opex are at $ 7’000/a. Thus, the total annual costs are 35’600 $, it results a loss for the biogas plant of 4’047 $/a.

	Pilot plant incl. variation 1	**Pilot plant incl. variation 2**
Object	$ per year	$ per year
Outgo		
Capital cost	110’695 +19’500 = 130’195	110’695 + 28’600 = 139’295
Opex	59’026 + 5’000 = 64’026	59’026 + 7’000 = 66’026
Income		
Electricity	161’713	161’713
Savings	22’175 + 20’440+ 31’553 = 74’168	22’175 + 20440 + 31’553 = 74168
Balance	**+ 41’660**	**+ 30’560**

Table 14: Optimized economics of biogas plant

Both variations can be run profitable. But variation 2 would produce a solid fertilizer of 41% TS that flower farms in our experience are most interested in. The solid fertilizer of variation 1 has a TS-content of 25% which is rather wet to use.

Variation 2 offers furthermore the opportunity to realize additional savings due to organic fertilizer that can be delivered for free to flower producers: as this material does not have to be disposed at the landfill, 19.1USD/t can potentially be saved or used to develop the market for organic solid fertilizer.

So in order to convince the farmers during the pilot phase of operations (“market development”) of the quality of the organic fertilizer variation 2 should be realized.

➔ **Due to the high disposal and transport cost for domestic waste there is a good opportunity to make the biogas plant profitable and produce a high quality organic fertilizer. With the realization of a pilot biogas plant it can be showcased that there are environmental-friendly solutions to the organic waste problem in Quito and more general in Ecuador where domestic waste still consists of more than 60% organics.**

4.3.6 Comprehensive recycling plant

Although out of scope of the feasibility study at hand, the authors would like to draw the attention to the high profitability of the recycling of plastics and other recyclable materials.

In parallel to this feasibility study focusing on the value chain “organics to energy”, the project team analysed economics of a module to recycle all possible materials such as plastics, metals, paper etc.

Annex 9.5 sums up the business plan of such a recycling plant characterized by the following figures:

Object	$
Investment costs	2’841’853
Object	$ per year
Capital cost	510’612
Opex	1’289’199
Income	
Recyclables	2’928’838
Savings (non-disposal)	118’938
Balance	> +516’000

Table 15: Economics of recycling plant

Although the investment costs are much higher and the amount of material that do not have to be cost-intensively disposed at the landfill, the potential benefit is much higher compared to the pilot biogas plant.

4.4 Funding of the pilot plant

Two factors had been most relevant for the project team for the financing of the project:

- Venture philanthropists/social/impact investors do not only support their investees financially but also and often more important by means of non-financial support (HR, strategy management, investor relation)
- The planned biogas plant has a clear profile of a social entrepreneur

The following chart sums up the preferred model to be established for the funding of the pilot biogas plant.

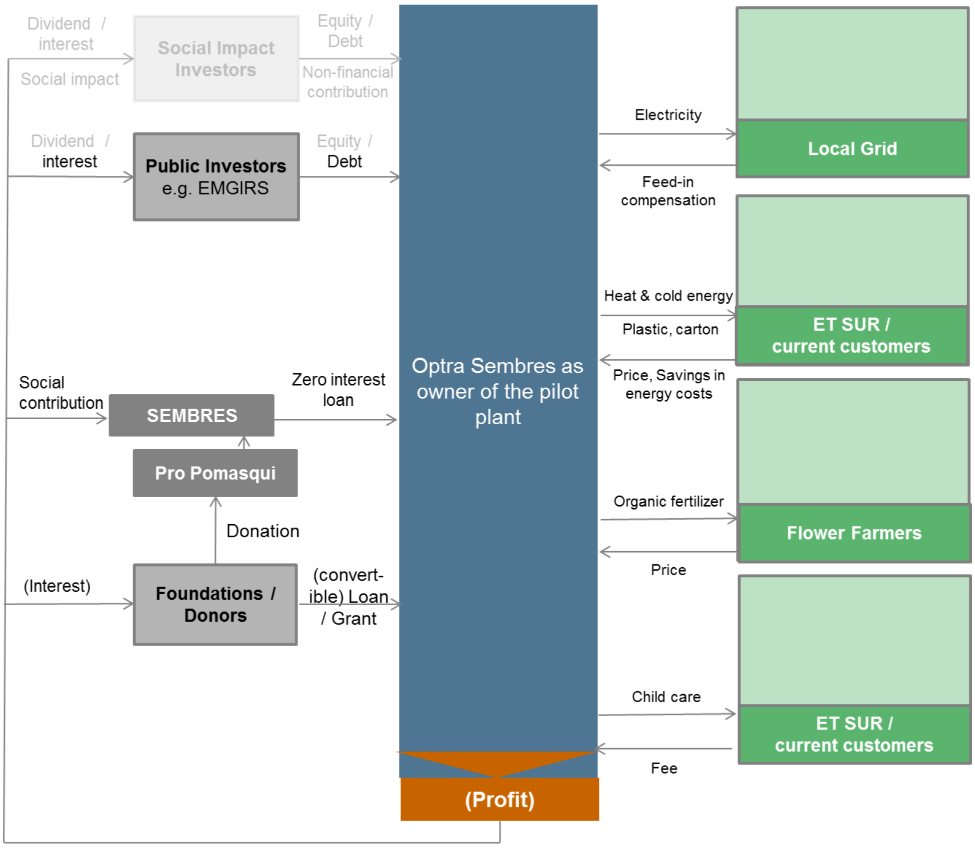

Figure 7: funding model for pilot biogas plant

To exploit synergies regarding the waste transfer station ET Sur it makes sense that Optrasembres is the owner or at least the longterm operator of the pilot biogas plant. The latter can be based on a long-term Operating Agreement between the owner of the pilot biogas plant and Optrasembres.

As mentioned in chapter 4.3.4 we do not consider gaining further income by the sale of heat and cold energy or the organic fertilizers. The aim is to develop a respective market and to gradually increase income from these sources. This is illustrated by the dark green (current market) and light green (potential market).

In the course of the feasibility study, several potential impact/social investors were approached. Whereas the market of social impact investments or venture philanthropy is rapidly growing in Europe, there are only few of them that focus their investments to projects with a similar risk - benefit profile as the project at hand. A growing number of them focus on a later stage investing (lower risk profiles) focussing on scaling up phases and do not invest in early-stage projects (LGT Venture Philanthropy, Alphamundi). The change in the character of the biogas plant is another reason why social and impact investors are not the right investors to address in the pilot phase.

Therefore, in the second phase of the conduction of the feasibility study, the approach to finance the project has been adapted to the pilot plant profile. Optrasembres has been very active in promoting the pilot idea within the municipality (EMGIRS) and met also important politicians aiming at a financial contribution to the project. EMGIRS should not only be attracted by the direct benefits but as well by the savings (see 4.3) and the fact that this project will offer a new perspective for the Municipality of Quito to manage its waste by pushing innovative energy projects and support the market development in Ecuador.. To date, we have not received a final confirmation of the Municipality to support the project financially. But the personalities in charge agreed on an on-site visit in Europe or China to see and understand a running biogas plant.

We could explore interest of more than 10 international foundations that are interested in receiving the proposal to partner up with SEMBRES (The Coca-Cola Foundation, Inc. A Spark, Belgian Investment Company for Developing Countries (BIO), Elea Foundation, Hivos, Inter-American Development Bank (IDB), Lotex Foundation, SwissRe Foundation). Other potential funders need to be approached once an anchor donor/investor is identified (Multilateral Investment Fund (member of the IDB Group, Pomona Impact).

As a next step, we intend to present the project to

a. the Citiy of Quito (funding AND acceptance to re-allocate the savings)
b. the National Financial Corporation (CFN), a national credit line to finance projects of renewable energy. CFN finances such projects with loans (6% fixed interest during 15 years) up to 25 million and up to 70% of the project amount.

In case of a successful pilot phase and a scaling up of the plant as mentioned in chapter 8 in phase 3, the funding model would have to be adapted. Please see Annex 9.7 for further information.

4.5 Knowledge transfer

The feasibility study has made very clear that a key element of the planned pilot phase would be a comprehensive knowledge transfer to follow up on the continuous work done during this feasibility study. It is not sufficient to focus this knowledge transfer to the technical operation of the biogas plant. Additionally, we plan a knowledge transfer approach in a broader sense on four key dimensions as success driver for the project:

- Assure appropriate technical operation of biogas plant
- further develop the organizational capacities of the SEMBRES team especially in the following dimensions:
  - Managing processes (effectivity of SEMBRES to manage a major social investment by an international social/impact investor)
  - Marketing and communications
  - Organizational structure (how is SEMBRES organized and supported to deliver?)
  - Legal organisation to assure that social investments can be done
- market development for organic fertilizer
- creation of ownership by the local municipality

Accordingly, the knowledge transfer concept reflects these four dimensions:

Objective 1: Assure appropriate technical operation of biogas plant		
A1.1	On-site presence of FBI during construction phase and bringing into service of biogas plant. The strong focus on a low tech approach simplifies the technical operation of the biogas plant. The new regulation on the production of biogas determines that at least 50% of the technicians involved in the project and 100% of the persons in charge of non-qualified works have to be Ecuadorian Citizens. A concept for the continued capacity building and knowledge transfer during the operation of the plant has to be presented. To ensure the envisaged impact regarding knowledge transfer, we focus on the following groups: • Engineers: the biogas plant will be managed by Optrasembres, owner of the transfer station. Herman Moser, CEO of Optrasembres, is part of the project	FBI

	team to execute the feasibility study at hand. Additional technical engineers are involved from the municipal authority (EMGIRS) and one leading Ecuadorian consultant that is planned to be the technical lead manager should the project come to the implementation phase. • The operational knowhow would be transferred during the construction and operation of the plant led by FBI to local engineers that will run the plant as employees of Optrasembres. Optrasembres is already professionally running the waste transfer station and production of organic fertilizers (compost) on pilot level (SEMBRES Foundation), the biogas plant will be managed as additional unit of the company. FBI is used to implement this biogas production system in similar settings (e.g. China). • Two technicians in charge of the plant will be trained on-site on an operating biogas plant in Europe or China to assure an effective knowledge transfer and optimize opex (see 4.3.5).	
A1.2	Backstopping of Optrasembres by FBI Once the plant is running FBI will backstop the technicians via web-based solutions. Further on-site trainings are planned to optimize operations of the biogas plant.	FBI
Objective 2: Further develop organisational capacities of SEMBRES		
The feasibility study made clear that the organisational capacities of Optrasembres have to be professionalized to meet the expectations of impact investors. Exploring interviews with impact investors helped us to identify major areas that need optimization (organizational effectiveness). Without these institutional improvements, Optrasembres would not overcome the challenging due diligence processes upfront to impact investments (e.g. LGT Venture Philanthropy).		
A2.1	Strengthening organizational capacities based on the OCAT2.0 methodology	BHP
A2.2	Bring in external expertise by means of a local capacity builder, an external senior expert volunteer (e.g. Swiss Contact Senior Expert Corps) or a professional of a Venture Philanthropy organisation that would bring in the needed expertise as non-financial contribution additional to a financial contribution.	BHP & Optrasembres (OS)
Objective 3: Market development for organic fertilizer		
A3.1	Identify 3 producers of cut roses as partners (future clients) to jointly run a pilot project “organic fertilizers” accompanied by the University San Francisco de Quito; Investigate on-site results of organic fertilizer compared to chemical fertilizers;	Optrasembres & UNSF
A3.2	Ongoing chemical analysis of product as basis for promotion	OS
A3.3	Promote product (organic fertilizer) focussing on cut flower producers (free of charge)	OS
A3.4	Organize on-site visits to understand process of biogas production and create confidence in product	OS
A3.5	Introduce product first to other cut roses producers, than to a wider agriculture sector (prizing)	OS
Objective 4: Create ownership by the local municipalities as basis of financial commitment		
A4.1	Present results of feasibility study including longer-term business model to key personality within municipality of Quito	OS, FBI
A4.2	Organize and conduct study tour to a similar operating biogas plant with 2 – 3 decision making powers of the municipalities and the designated operating team of Optrasembres.	OS, FBI

5 Progress at the end of the project

Objectives	Achievement	Reference, comments
Technical concepts for building the biogas plant are determined and the technical regulations are clarified	100%	4.2
Business model and business plan for a sustainable operation of the biogas unit are developed	100%	4.3
MoU with the local energy supplier regarding the feed in of the power produced	Not applicable There is a new regulation for the feeding of renewable energy to the grid (CONELEC)	4.1.4
MoU with the concerning department in Quito (EMGIRS) regarding the expansion of ET Sur	Not achieved Formal MoU pending but intense partnership during feasibility phase. On-site visit planned to running biogas plant in EU or China	
Letter of Intent with potential buyers of the organic material (for at least 25% of the expected output material)	Not achieved Finding: Market to be developed to absorb this amount of fertilizer; key: sensitization AND product presentation; project design has been adapted due to inexistent market for organic fertilizer	Measures: 4.5
2 Letters of Intent with potential investors	Funding strategy adapted: Based on the adapted business model, we intend to finance the pilot phase with a mixture of donations and governmental support; impact investments are not appropriate in this early stage but shall be attracted for the scaling up phase.	
Concept “knowledge-transfer” elaborated	100%	4.5

6 Impacts

6.1 Impacts of the present feasibility study

The main impacts of the present feasibility study conducted are the following:

- Sensitization of the municipality of Quito regarding renewable energy production
- Sensitization and basic knowledge transfer to locals regarding renewable energy production
- Employment creation, there were 5 local people involved to conduct this study
- Learnings regarding social impact investors being useful for a later stage of the biogas plant

6.2 Impacts of the pilot plant

The project leads to several positive impacts. First of all the quantity of waste brought to the landfill is reduced. This leads to less methane gas emission on the landfill and approximately half of the transports to the landfill can be avoided. Second, the waste separation at ET Sur and the operation of the biogas plant will create employment, especially for the vulnerable members of the Ecuadorian society. Third, as potentially 65% of the transports from ET Sur to the landfill can be avoided, there is a huge cost-saving potential. Figure 9 illustrates expected impacts of the biogas social enterprise.

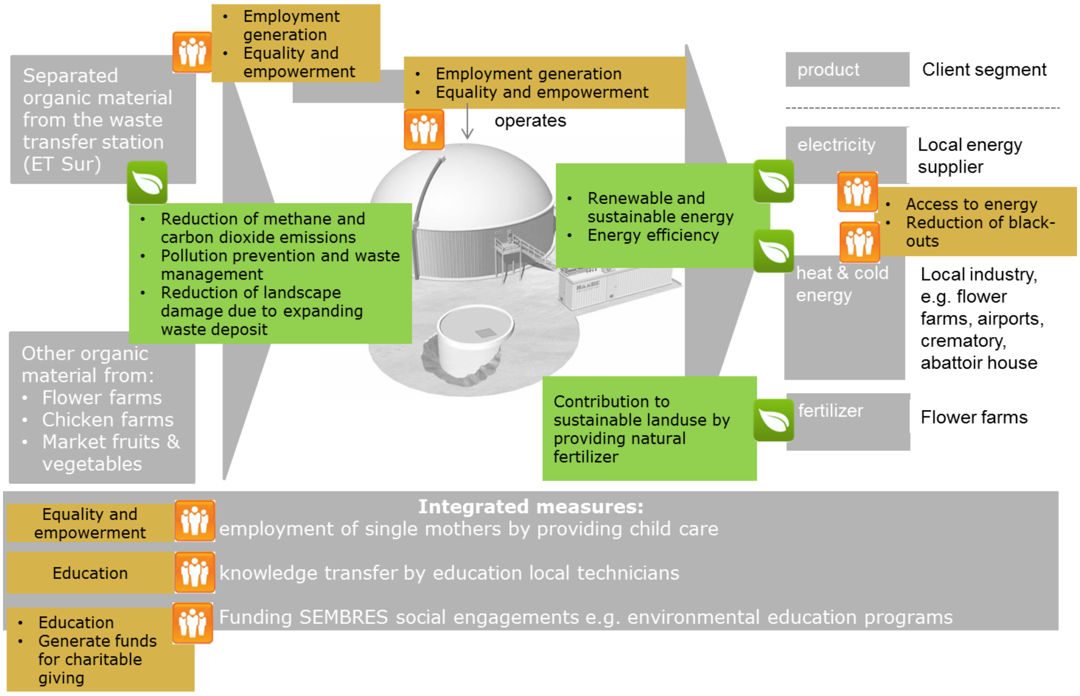

Figure 8: Expected impacts of the pilot biogas plant

Additional, we see following important impact dimensions:

- Due to the ongoing collaboration with EMGIRS and decision-making powers and politicians of the Municipality of Quito, important personalities expressed their interest to visit a running biogas plant to better understand and learn on the technological approach to be implemented in Quito.
- First cut flower producers started to look deeper into the pros and cons of organic fertilizers. Still there is a long way to go to develop a market for organic fertilizers. Our knowledge transfer concept reflects this fact.

Some of these impacts can be quantitatively estimated as visible in Table 16:

Impact	
Environmental	
pollution prevention (reduction of waste to landfill in t)[2]	12'775
Reduction of transport emissions [t CO2e/a]	19
Reduction of methane gas emissions at landfill [t CO2e/a]	35'000
Number of people provided with electricity	1'806
Social	
Employment generation	23, depending on realization of recycling module
Number of people educated	tbd

Table 16: Specific impacts of biogas social enterprise

If the market of organic fertilizer is developed a further impact would be the replacement of synthetic by organic fertilizer, which is approximately 10'900 t per year.

[2] This figure considers that the organic output material of the biogas plant is also brought to the landfill.

7 Conclusions and Recommendations

This feasibility study makes clear that the originally planned biogas plant is not feasible at the site of the ET Sur. Although this unexpected negative interim result caused a lot of discussion and challenged all of the team members, we managed to scale down the project to a level that still makes a lot of sense from an economically, social and ecological point of view and can be implemented at the site of ET Sur. Beside this challenge of the location, we had underestimated the fact that a biogas plant only makes sense and can be self-sufficiently operated when output materials can be sold. The missing market for organic, high-quality fertilizers surprised us and made us downscale the project to a demonstration plant that still has the potential to be run self-sustainingly but does not anymore offer the aspired higher profit that would have allowed attracting impact investors.

Although we have focussed during this feasibility study on the organic fraction of the waste transferred at ET Sur, we have learned that in a first phase we should implement a recycling module on-site taking advantage of all recyclable materials available and locally saleable. The high profits could be saved in an earmarked fund to assure financing of the biogas module to be added during a second phase. Both phases can be run as social enterprises with impressive social impacts.

During this feasibility study we have experienced what “investment readiness” means although we had intended to attract social impact investors and not traditional investors. Investment readiness challenges traditional aid-driven implementing partners in developing and emerging countries to further develop from “aid-administrators” towards a more entrepreneurial type of organisation optimizing not only social impact but at the same time as well economic figures – a truthfully challenging change process. We have elaborated the knowhow transfer concept accordingly.

We are all grateful that we have been given the opportunity to conduct this feasibility study that helps us enormously to define next steps.

8 Future Prospects

Following up the feasibility study and the parallel analysis of the recycling business opportunity will focus on three work streams:

1. Elaboration of a comprehensive proposal “sustainable waste management” based on the findings of the feasibility study and the business plan “recycling plant” to be implemented in following 3 phases:

Phase 1 (year 1 – 3) Construction and running of recycling module; set up of fund to finance phase 2
Phase 2: Construction of biogas pilot module to process 32t/d and develop market for organic fertilizer
Phase 3: Scaling up of biogas plant to process 300t/d

2. Present project (“pilot plant”) to
   a. The Municipality of Quito (EMGIRS)
   b. National Financial Corporation (CFN)
   c. Identified International Foundations and start-up funds such as the Seco Start-up Fund (SSF) as donors

3. Organise study tour with municipal bodies to a running biogas plant to understand better potential of proposed pilot biogas plant;