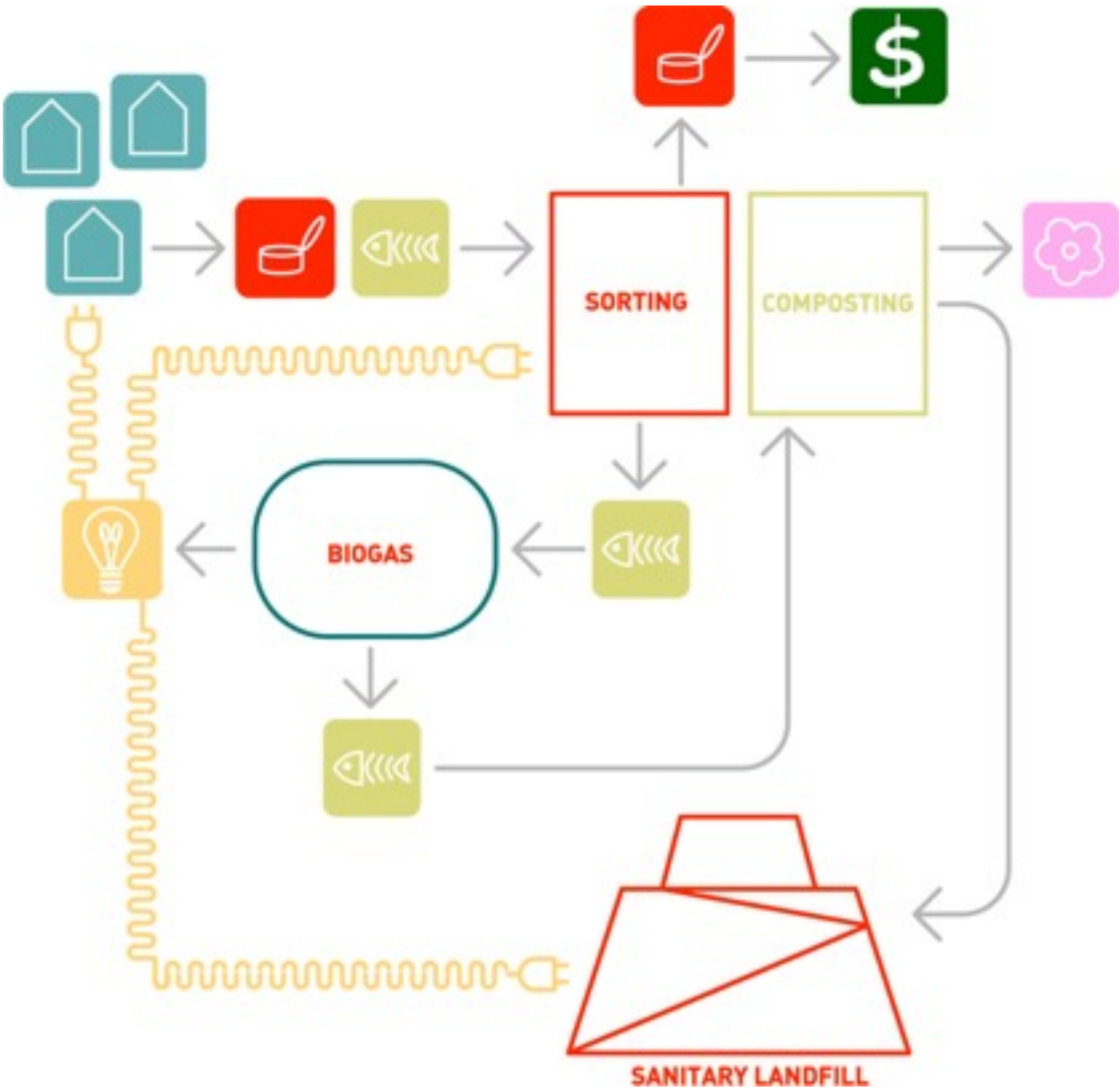
studioazue

FEASIBILITY STUDY
Design and Construction of a Biogas Digester - Baalbek



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Glossary of Terms

AD Anaerobic Digestion

OMSAR Office of the Ministry of State and Administrative Reforms

EIA Environmental Assessment

MSW Municipal Solid Waste

SCMF Sorting and Composting Management Facility

MOA Ministry of Agriculture

EDL Electricité Du Liban

CDR Council for Development and Reconstruction

WC Waste Compound, area of the site

OFMSW Organic Fraction of Municipal Solid Waste

WWTF Waste Water Treatment Facility

Nmc Normal cubic meter

METAP Mediterranean Environment Technical Assistance Program

CSTR Continuos Stirred-Tank Reactor

OLR Organic Loading Rate

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1.Scope of works

The purpose of this study is to chose and evaluate the more suitable anaerobic digestion technology to be inserted side by side to the SCMF under construction by OMSAR. On this purpose the need is to assess the viability and costs of digesting organic wastes generated in the Baalbek and Hermel areas and how this technology could be used to generate green energy. This feasibility study is to be considered as an amendment of the EIA produced by the company Geoflint in 2010 for the SCMF to be built by OMSAR. Therefore we consider main data regarding the general aspect concerning the area and the results of the Impact Assessment contained in the EIA to be valuable also for the BP, since the facility will be in direct connection with the SCMF. In the EIA and in the coming master plan there is also the full study of the assigned area (ANNEX 2, 3). In the annexes of the present documents only few additional maps have been inserted showing the topography of the plot and the position and dimensions of the facilities as agreed with OMSAR.

2.Baalbek Organic Waste Survey

Other than the EIA and to study more the waste production in Baalbek area a survey for organic waste has been conducted to check the availability of suitable and clean material to add to the biogas facility. The survey has been done during the month of July 2011 and it wanted also to give a picture of the type of organic material that can be easily kept separated at the source. Practices which need the full support of the project implementation body, local institutions and partners. MSW collected from the municipalities and delivered to the SCMF under construction by OMSAR will be sorted and a part of the organic component is going to be used by the biogas facility to produce at the final stage electricity. From the EIA and due to the lack of data about the quality of organic matter coming from the facility has not been possible to evaluate the biogas production of this type of waste. For that reason through the survey has been necessary to evaluate other sources in case the organic component coming from the SCMF will not be able to produce the desired quantity of gas and electricity.
As for the waste quantity the other sources described in the study, only estimation are available. The main cause is the lack of data and regulations which should force farms and waste producers to record their waste production.
The organic waste estimation has been done by interviewing the collection staff, the head of the Regional department of the Ministry of Agriculture and the responsible of some farmers associations.
At the end for each type of waste analyzed specific informations have been given about the theoretical biogas production for each type of waste analyzed. The data refers to the average rate of production considering the type of technology decided to be used. The estimation for the production of the Organic matter coming from the SWMF at this stage as been considered as the minimum production.

2.1.Waste management practices in Baalbek and Hermel area

In Baalbek and Hermel areas like all over Lebanon the collection of MSW is not different from the collection of other Special Waste Hazardous or Non Hazardous. Hospital waste only are collected or treated in separate system.
Several municipalities and mainly the most populated are using compactor trucks for waste collection and transportation. Small villages use mainly normal truck without compaction.

2.2.Organic component of MSW

The estimation of the organic material available from the MSW sorted in the SCMF has been conducted starting from the data available in the EIA.
Following the study the average quantity of organic waste in the MSW is around 49,468 ton/year. The quantity has been calculated by multiplying the total amount of coomingled waste for the 60% which is the average percentage present in Baalbek and Hermel MSW.
Based on the data available about the sorting in the SCMF is can be estimated that only an average of the 50% of this material will be sorted out reducing the available organic material to around 24,734 ton/year.
The quantities estimated are still sufficient to produce the amount of gas able to supply the electricity foreseen in the project.
A question mark is more about the quality of this organic material. The preliminary design of the SCMF envisage a screening at the beginning of the process with openings of 8 cm where the undersize material will be considered as the organic material sorted.
Due to this process the organic material available can not be considered clean while many inorganic objects and man made impurities can pass by the openings. During the design phase will be taken into consideration the possibility to add some clean and more suitable organic material.
Moreover the maximum size of 8 cm is not suitable for the fermentation which need smaller size. It might be necessary to add, after the screening process and before the fermentation, a shredder to reduce the particulate up to a maximum size.

For organic waste coming from source sorting collection can be considered an average biogas production of 450 - 700 m3/t, which should be considered a MEDIUM potential. The organic fraction from the SCMF with the sorting process foreseen can be estimated in a production of 100 m3/t

2.3.Agricultural waste

During the survey many types of suitable agricultural waste have been detected but the responsible of Baalbek department of the MOA told us that none of them are available since all are reused for different purposes: from the experience acquired on the area it is suggested to evaluate the agriculture condition right after the facility operation and ask farmers to provide for material directly.
The main agricultural waste detected are in table 1.

Table 1 - average yield on biogas of some agricultural waste

Product	waste	process	Alternative use	Biogas potential production
Olive	olive cake	waste coming from oil extraction	Sold by the farmers to extract the rest of the oil from using solvents and sold to be compacted and used for heating.	MEDIUM/HIGH depending on the oil quantity left inside. 400 - 800 m3/ ton
Olive	branches and leaves from pruning	yearly olives management	This material is not used.	NOT SUITABLE but important for the composting process of the digestate
Chicken waste	feather, manure broken eggs	chicken breeding	agricultural fertilizer	LOW 350 m3/ton
Cow manure	manure	cow livestock	agricultural fertilizer	LOW 270 m3/ton
Food processing industry	general waste production similar to kitchen household waste from source sorting collection systems	food preparation firms, like juice production, milk, frozen products preparation etc...	burned or dumped	MEDIUM 300 - 700 m3/ ton

2.4.Food waste and spent oil from restaurants

Spent oil is one of the most productive waste for biogas facility. The oil contains billions of carbon based chain which can boost the gas production. Mainly this type of waste is produced by restaurants or mess. In Baalbek the tourism sector is increasing and with it also restaurants. Following the interviews to the municipality employees responsible for the waste collection it

was discovered that the spent oil is used by several cement production company as fuel for their oven.
The employees informed that not all the spent oil goes to the cement factories but with a collection system a reasonable quantity of such a waste can be collected. During the starting of the facility it is suggested to set up a collection system for spent oil.
With the oil also the food waste from restaurant can be used for biogas and the production is the same of the clean organic component of the MSW.

Spent oil biogas production	1200 m3/ton

2.5.Waste from local markets

The vegetable markets are a very different source of material. In general this type of waste is collected using the general waste trucks and they end up to be mixed with the coomingled waste becoming a source of pollution and diseases. In side the markets there are placed several bins which if collected in separate trucks can be used, after a small sorting process, for the biogas production. The market collection system should be activated not only for the biogas facility but also to initiate a process of awareness toward a source sorting collection system. The collection of this type of waste need just a small awareness in coordination with the local institutions and the body partner of the WC to the shop owners.

Market waste biogas production	500 m3/ton

2.6.Green waste from management of municipal and private gardens

Such a type of waste is not suitable for the biogas production but it is recommended for the composting process of the digestate. As described in the following chapters the output product of the facility will be a compostable organic matter with a average density of 0,8 m3/ton and with the same features of the incoming material but impoverished of C, H and O and with a increase of the ammonia nitrogen at the expenses of the organic nitrogen. The green material coming from the management of garden and green spaces after the collection should be chopped and shredded to easier the reactivation of the digestate toward the oxidative process. A responsible of the collection system in Baalbek municipality informed that several trucks of material are collected from green public spaces every 2 months. It is suggested to the management of the SCMF to collect data about the quantities of such a material as soon as a weigh-bridge will be installed.

2.7.Slaughterhouse waste

The waste coming from the slaughtering of animals can give an important help on the process of biogas production since they are a source of proteins. Moreover such a waste including the blood are dangerous and are responsible of high leachate production if land filled. In most cases the blood is entering the civil sewage network ending up on rivers and see waters. While inserted in the fermenter mixed with other material can be stabilized and directed to the composting process.

Slaughterhouse waste biogas production	550 m3/ton

3.Rules and Regulations

3.1.Lebanese legal framework and regulations

The lebanese legal framework does not have specific regulations about waste management even if a master plan for waste from 2006 has been approve by the COM, Decision 1 and amended in 2010 (below in the table). The amendment is important since advocate waste-to-energy technologies in large cities. Suggesting between parenthesis " Generation of electricity from waste conversion technologies".
A draft Law on Integrated Solid Waste Management under METAP is still under review.

After that for the purposes of the project should be mentioned the electricity sector which is regulated by the Law 462/2002 and where no sustain has been given to support renewable energy intervention. Moreover the law is not applied yet.

Table 2 - Legal Framework

Law No. 64(dated 12 August 1988): regulating hazardous waste management. D**ecree 8735** (dated of 1974) assigning SWM as a municipal responsibility municipalities are responsible for the collection and disposal of house hold wastes. **Law No. 444**(dated 29/7/2002): Environment protection Law- fundamental principles and public rules, EIAs, Responsibilities, fines another institutional regulations. **Decree No. 9093** (dated 15 November 2002) provides financial incentives to municipalities for hosting SWM facilities or landfills. To date, the decree has never been implemented. **MoE Decision No 8/1** (dated 30/1/2001) setting standards for air emissions, liquid effluents, and waste water treatment plants. **COM Decision 1** (dated 28/6/2006) : approval of MoE and CDR MSW plan for Lebanon which consists of(1) dividing Lebanon into 4 service areas(2)construction of solid waste complexes (sorting,composting and land filling). **COM Decision 55** (dated 1 September 2010) to amend and complement the SWM plan of 2006. It advocates waste-to-energy technologies in large cities (Generation of electricity from waste conversion technologies). It also invites private sector participation in waste management systems. **Decree 8006** (June 2002) amended through Decree 13389 (September 2004) classifying the different healthcare waste categories and addressing their relative disposal conditions. **Law No. 462/2002** sets up the rules and principles governing the Electricity sector. It defines the role of the Government as well as the rules and principles organizing the sector as well as the basis of transferring it or its management, totally or partially to the Private Sector.

3.2.Institutional framework

Ministry of Environment
Review all studies related to SWM (EIAs, TORs, Tender documents, ...)
Participation in committees for reception of works linked to SWT facilities
Preparation of Strategies, Master plans and programs related to SWM
Define standards and environmental limit values for disposal of SW
Ministry of Interior and Municipalities
Municipalities are responsible for waste collection, building facilities
The Ministry control the Independent Municipal Fund IMF
Council for Development and Reconstruction CDR
Implementation of SWM plans in Lebanon.
Develop proposals, TORs and Tender Documents for SWM
Office of Minister of State for Administrative Reform OMSAR
Develop a program to improve the provision of SW services in rural areas
Develop proposals, TORs and Tender documents for projects under the

same program.
EDL It was founded by Decree No. 16878 dated July 10, 1964, and is responsible for the generation, transmission, and distribution of electrical energy in Lebanon.

3.3. ICS 75.060 and UNI norms

The norm called UNI 10458 2011 mentions standards which describes the classification, the guidelines and requisites for construction, the trade offer, final order and acceptance tests of the plants for the production and the use of biogas based on anaerobic digestion processes. The norm has been copied from different international norms within the Code ICS 75.060. This standards identifies also the technical requisites for the acceptance tests. This standard applies to all the plants based on the anaerobic digestion processes for the transformation of the organic materials of biomass, sludges and wastes with biogas production. Biogas production units in landfill sites are not covered by this standard.
The full UNI norm is in ANNEX 7. The ICS 75.060 norms are available on line.

4.Applicable Biogas Technologies

Anaerobic digestion is a naturally occurring biological process that uses microbes to break down organic material in the absence of oxygen. In engineered anaerobic digesters, the digestion of organic waste takes place in a special reactor, or enclosed chamber, where critical environmental conditions such as moisture content, temperature and pH levels can be controlled to maximize gas generation and waste decomposition rates.
One of the by-products generated during the digestion process is biogas, which consists of mostly methane (ranging from 55% to 70%) and CO_2 . The benefit of an AD process is that it is a net generator of energy. From the energy produced by the AD facility, depending on the technologies, only maximum of 15 % is required for the AD facility itself. The rest can be sold or distributed to other facilities like it is going to happen in the Baalbek WC in form of heat, steam or electricity.
The level of biogas produced depends on several key factors including the process design, the volatile solids in the feedstock (composition of the feedstock) and the carbon/nitrogen (C:N) ratio.
During the past 20 years many different AD technologies have been developed and adapted to perform with different sources of biomass and with different systems.
Anaerobic digestion technologies fit for many different biomass production; in table 3 are broadly defined the mostly used.
Moreover each technology has been described in the following paragraphs starting with the Biological Phases and Operational Mode criteria.

Table 3 - AD technologies

criteria	types of plant	features
Thermal Process	Psicrophilia	(20° C)
	Mesophilia	(35-37° C)
	Themophilia	(55° C)
Percentage of Solids in the Process	Wet digestion	(5-8% total solid matter)
	Semi dry digestion	(8-20% total solid matter)
	Dry digestion	(> 20% total solid matter)
Biological Phases	Single phase process	the all chemical processes occur in the same reactor
	Separate phase process.	The hydrolytic phase and the fermentative (acidogenic) phase occurs separate from the methanogenic phase
Operational Mode	Reactor in continuous	material is mixed o with a plug-flow system
	Reactor in batch (non continuos)	material is not mixed inside the cells

4.1.Single phase processes - Continuous

Single phase process can be divided following the Percentage of Solids.

4.1.1.Wet Anaerobic Digestion

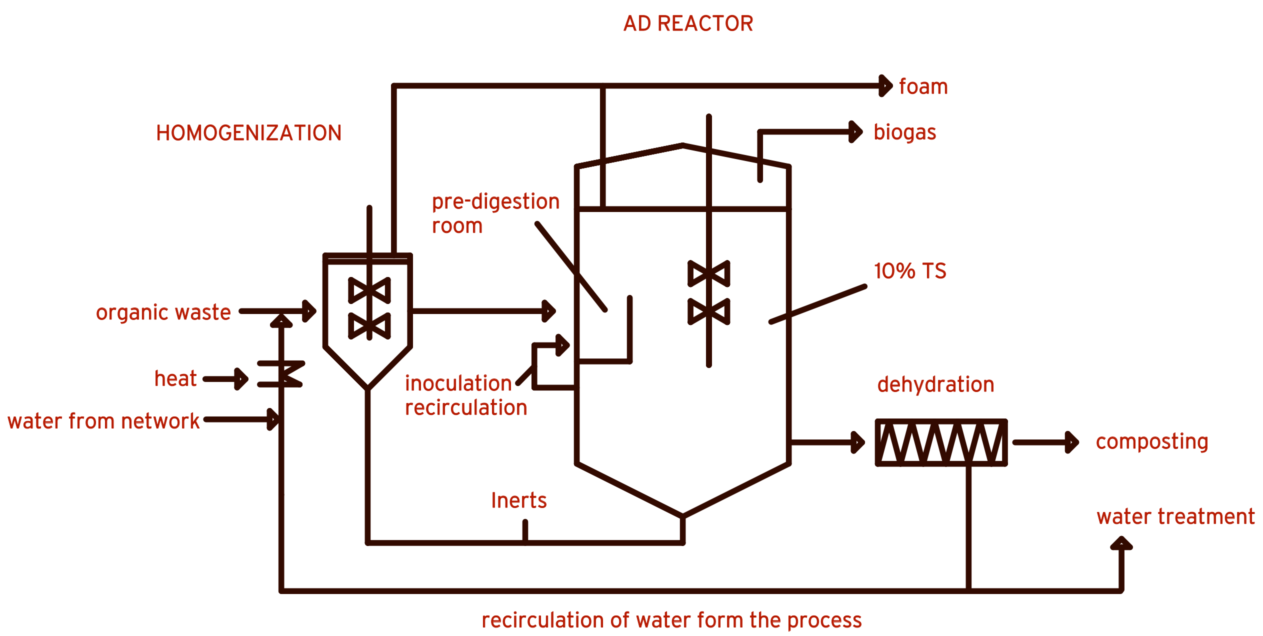
The process has been the first treating Biowaste coming from the MSW. The technology has been used for decades with sludges coming from Waste Water Treatment Facilities.
In the Wet Digestion the biomass from MSW need to be treated and diluted in order to reach the 8-10 % of solid matter and than processed inside the classical stirring reactor CSTR fully mixed. The main pre treatment consist on removing the inserts material (plastics, metals, rocks) followed by a process of mixing to obtain an homogeneous mixture. Once inside the reactor, the material is stirred.
One of the main problem using this technology is that inside the digester the biomass keep stay separated into 3 different phases following the gravity and the different density. The heavy material get stuck on the bottom making problems on the stirring system, the light material and the foam stay on the top and mainly in the mieddle the biogas production occur.

The dilution can be done using the water from the network or from the reactor effluent. The main advantages and disadvantages are showed in the table 4.

Table 4 - Advantages and disadvantages of Wet AD

Criteria	Advantages	Disadvantages
Technologic	• Good knowledge of the process (due to previous use for sludges). • It can work mixing also waste water from different process (cow farms, chicken farms).	• Short circulation hydraulic. • Non homogeneous. material, heavier stay on the bottom and the lighter is floating. • Abrasion of the mechanical parts due to sands and inert material. • Complicate pre treatment.
Biologic	• Dilution of the pics of concentration and dilution of the hazardous waste	• Loss of organic matter during the pre treatment
Economical and environmental	• Pumping and mixing system available easily on the market	• High investment costs • High waste water production form the process

Figure 1 - Wet AD facility scheme



4.1.2.Semi Dry Anaerobic Digestion

The process has been studied to treat a biomass from MSW with a content in Solid Waste of 15-20 %. The technology used is again the stirred reactor (CSTR) but with a smaller dilution. The facility scheme is the same showed in figure 1. Treating a kind of material more viscous gives the advantage to have a smaller reactor with a reduction in the investment costs.
In table 5 the advantages and disadvantages of the Semi Dry AD Technologies.

Table 5 - Advantages and Disadvantages of the Semi Dry AD Technologies

Criteria	Advantages	Disadvantages
Technologic	‣ Waste pumping system easy to be found on the market. ‣ Less pre-treatment (especially using material collected from source sorting collection)	‣ Non homogeneous material, heavier on the bottom and lighter on the top ‣ Abrasion of mechanical parts. ‣ Same pre-treatments of the Wet system for coomingled MSW
Biologic	‣ Less concentration of hazardous waste	‣ Loss of organic matter during the pre treatment
Economical and environmental	‣ Pumping and mixing system less expensive	‣ High investment costs ‣ High waste water production from the process

4.1.3.Dry Anaerobic Digestion

The system processes biomass with solid material in percentage between 25 and 40% (>50%). The method from a biochemical point of view does not change but the equipment and the reactors need to be different. from the previous plants.
The system need to work with very viscous material and the equipment is more expensive than Wet AD; on the other hand dry AD does not need many pre-treatments and the waste are not diluted. The only pre treatment is a screening to take out the items over 40 mm. Because of that the loss of material is very low. Again the system works better with biomass coming from source sorting collection.
Due to the viscosity of the material the reactor is not CSTR but use pistons plug-flow which have a simplified but stronger mechanic. Using dry AD the problem on having 3 different phases inside the reactor has been solved.
Three main system have been patented so far, Draco, Kompogas and Valorga

Draco: the system take the digested effluent resulting from the process to be pumped from the bottom of the reactor to the top with the new biomass:

- **1 part of fresh waste**
- **6 parts of effluent digested.**

The technology can treat biowaste with a percentage of solid between 25-50 %.

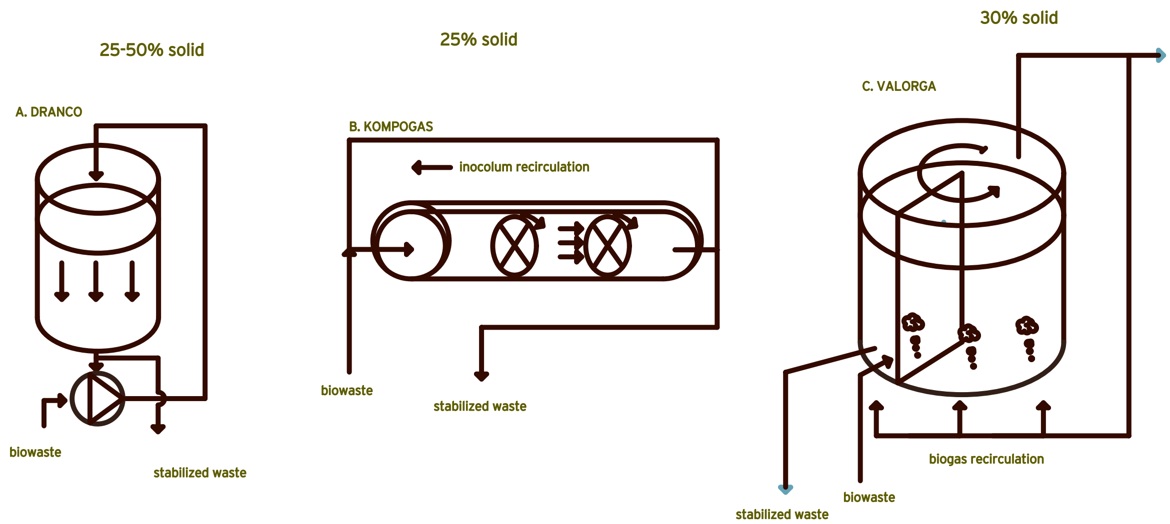
Kompogas: the technology use a cylindric reactor with an horizontal flow with internal mixers with a slow turning cycle. The reactor works better using biomass with 25% of solid matter.

Valorga: This technology use a reactor with a cylindric shape but the flow of material is circular and the mixing occur using biogas coming from the bottom of the digester. The optimum of solid matter for this system is 30%.

Table 6 - Advantages and Disadvantages of Dry AD technologies

Criteria	Advantages	Disadvantages
Technologic	‣ No need of mixer or stirring systems ‣ Resistance to heavy inert	‣ Biowaste with a reduce rate of organic matter can not be treated alone ‣ High tech equipment and maintenance is needed ‣ Small size waste only
Biologic	‣ No loss of organic matter in the pre-treatment ‣ High OLR	‣ Small dilution to reduce the negative effect of hazardous waste
Economical and environmental	‣ Small pre-treatment ‣ Smaller dimension of the reactor ‣ Small use of water ‣ Less costs for heating the reactor	‣ High investment costs

Figure 2 - Different type of Dry AD



4.2.Double Phase Process - Continuous

The two main phases of the AD process, the acidogenic phase and the methanogenic phase in this system are separated, so that each phase is more effective. Despite the efficiency of the two phases the production of biogas does not exceed the single phase systems. Up to now the double phase process is used more for the scientific purposes to better understand the biogas production in general.

4.3.Single Phase Process - In Batch

In this case the reactor is filled with high organic rate material and left inside to ferment, without any pumping system. The leachate produced is warmed up and recirculated to keep the temperature inside. The process need around 30 days. The digester is filled with the 40-50 % of new biomass and mixed with the old to which works as inoculus.

Table 7 - Advantages and Disadvantages of the Dry AD in Batch

Criteria	Advantages	Disadvantages
Technologic	‣ Easy management ‣ No size restriction for the incoming material (but less production)	‣ More manpower needed
Biologic	‣ Reliable process	‣ Minor biogas production
Economical and environmental	‣ No need of high technology systems, suitable for developing countries ‣ Less construction costs ‣ No need of source of liquid waste to mix with	‣ Large space needed (compared with composting)

5.Technology selection

Due to the high need of water and the lack of a WWTF able to process the effluents, the first 2 Technologies in continuous has been discarded immediately.
Between the continuous technologies only the Dry AD has been at the beginning considered but in the SCMF the biomass available will be screened at 80 mm while the dry AD need material screened at 40 mm, moreover the technology needed high tech skills and the maintenance skills that in Lebanon is not available.

The only suitable technology has been found is Dry Anaerobic Digestion in Batch. See ANNEX 1 and ANNEX 8. In table 8 are summarized the reasons for the technology selection.

Table 8 - Summary for the reasons for the selection of the Dry AD in Batch

Advantages	Comments	Disadvantages	Comments
▸ Easy management ▸ No size restriction for the incoming material (but less production)	▸ Due to Lebanese WM is better to choose for a Technology easy to manage ▸ From the SCMF project data the size of the biomass to treat is between 0 and 80 mm.	▸ More manpower needed	▸ Man power has low cost in Lebanon
▸ Reliable process	▸ AD is the first time applied in Lebanon better a to taste a	▸ Minor biogas production	▸ The project is a pilot and is more important to have a facility with a reliable technology than higher the production, the In Batch system is modular
▸ No need of high technology systems, suitable for developing countries ▸ Less construction costs ▸ No need of source of liquid waste to mix with	▸ In the county better to have less high tech. ▸ The project has a limited budget ▸ Source of liquid is not available	▸ Large space needed (compared with composting)	▸ The space for a 2 cells pilot facility is available and has been selected already a place for a future extension.

5.1.Biogas via Dry Fermentation

Until now,biogas technology mainly concentrated on "wet fermentation"of agricultural and municipal organic waste. Processability of renewables with a high dry matter content (e.g., corn silage) or solid waste were limited. The recently dry fermentation process, on the other hand, allows methane yields from stackable organic matter with a high dry matter content, requiring no
conversion into pumpable, liquid substratum. This method renders fermentation of biowaste possible with up to 50% dry matter content which from the available data from OMSAR is the

only technology which can guarantee a biogas production with the output organic material coming from the SCMF (See Facility schemes in ANNEX 6).

5.1.1.The Process

Organic matter, or biowaste, is inoculated with substratum that has already been fermented. It is then filled into the digester and fermented under air tight conditions. Continuous inoculation with bacterial matter occurs per recirculation of percolation liquid, which is sprayed over the organic matter in the digester.

During the fermentation process, no further mixing, pumping or stirring is necessary inside the digester, nor further material should be added. Excessive percolation liquid is collected in a drainage system, temporarily stored in the percolation tank, and then re-sprayed over the biomass in the digester.

The best fermentation temperature occurs at mesophile (i.e., fermentation friendly) temperatures of 35–37° C,which are regulated through heated floors and walls. The produced biogas is then pumped into a combined heat and power unit.

A biogas engine in the co-generation unit generates electricity. Continuous biogas production is guaranteed by several digesters running simultaneously with progressive biogas production stages. Once the fermentation process is completed, the digesters are emptied and the digested matter either undergoes further composting or is used as high-quality organic compost.

5.1.2.Modular Expansion

The digesters (i.e.,fermenters) are gas-tight, concrete, oblong, garage-like chambers and can be filled and emptied with wheel or front-end loaders. Several digesters may be built next to one another and run simultaneously in progressive biogas production stages, to guarantee continuous biogas production. Since Dry Fermentation plants treat biowaste with very high dry matter content, the digesters and hence, overall plants are built in a very compact manner. Given the modularity of construction, the plant's capacity may easily be increased at a later point in time, if desired.

The system ideally complements and it is easily integrated into composting plants. Wheel loaders and front-end loaders at hand may be used to fill and empty the digesters.

5.1.3.Heated Floors, Walls and Gates

Temperatures of around 35 - 37 ° C within the isolated digesters are maintained and regulated using a floor and walls heating system, Heating tubes are integrated into the cement floor and walls during construction. Accordingly, no intrusive parts bar the digester's interior. In addition, a heat exchanger warms the self-fed percolation liquid. By this means, temperatures are optimally controlled in the digester.

Dry fermentation digesters have hydraulically operated, gas-tight, steel gate-like doors. They have a seal which, when inflated towards the cement entry wall, make the entrance gas-tight. Before the gates are opened, the air in the seal is released. These are then opened top-down, thus preventing the wheel-loader from colliding into and damaging them. The inflatable seal lies within the gate's edge and is therefore also protected from damage. The system will run under light over pressure at 20 hPA, thus categorically preventing any potential form of gas-air explosion, even in the case of leakage.

5.1.4.Interaction with the SCMF

The biogas facility will have 2 main entrance for the biowaste:

1- from the sorting process of the SCMF.
2- from clean source like market waste, spent oil, slaughterhouse etc...

The biowaste from the SCMF should come in through a conveyor belt which has been foreseen to be movable in order to send the material to the mixing area of the biogas facility upon request. When the biogas facility will receive the sufficient amount of biowaste, the conveyor will be redirected towards the composting area of the SCMF.

The biowaste will be dropped by the belt to the mixing floor in front of the fermentation cells. The waste transportation will be in a cover area liked to the SCMF to reduce the odor spreading.

Depending from the size and quality (mainly man made impurity content) of the biowaste coming from the conveyor belt could be necessary to install a shredder machine before the mixing floor, to reduce the size and to increase the gas production.
The mixing area will be designed to have an additional opening and storage area where clean material collected form outside will enter the facility. The clean material will be dropped in the storage area and mixed with the biowaste coming from the belt when needed.
After the biogas production the digestate will be given back to the SCMF to be composted using the wheel loader or through a conveyor belt system or a truck.

5.1.5.Operation Efficiency

One main advantage of the dry fermentation technology is that constant mixing of the biomass is unnecessary. Pumping and stirring units are not needed like for the wet process. The fermentation substratum usually does not requires pre-treatment. The technology is therefore much simpler and robuster than wet fermentation plants. However if the SCMF is going to have a screening with opening of 8 cm diameter as the only biowaste separation system, it could be necessary to have a pre-treatment which consist, as mentioned before, on shredding the organic matter coming from the Sorting Facility.
The shredder will be installed before the mixing area and after the conveyor belt. The dry digesters have no moving parts. Therefore, wear and tear costs are low,as well as maintenance costs and staff costs. Process energy consumption is also minimal, making it easy to treat biomass with high dry matter content and interfering substances. Wood,plastic,sand,shrubs and glass does not influence the process unless they don't pass the 15% in weigh.

5.1.6.Computer Monitoring

The process will be monitored and controlled with a computerized system. The various percolation cycle, heating and cogeneration unit parameters are regulated individually per digester. Constant monitoring of the control parameters entails continuous process optimization and hence, maximum fermentation performance within the digesters.

5.1.7.Safety

The fermentation plant will be subject to a sophisticated, high-security concept. Explosions during the methane-to-air transition phase, when the digester is emptied, will be impossible. Methane-air mixtures are excluded. During filling and emptying a vacuum system ensures that the digester is constantly furnished with fresh air. A facility control room should be design to ensure a direct view of the digester entrance at all times. In case of extra production the gas will be stored into reservoir. In case of extra production and reservoir at full capacity a torch will be installed to burn the exceeding biogas quantity. The flame will be used also to burn the biogas production at the beginning of the process, The production will be burned into the torch until the computerized sensors will find a biogas production with at least the 60% of methane.

5.2.Sample of some facility working with the same technology - MUNICH WM company

For a better understanding of the process below has been inserted the description of a biogas production facility already existing. As sample experience on biogas production has been chosen the plant belonging to the Waste Management Company in Munich (Germany). See pictures in ANNEX 5

Munich, the capital of the German State of Bavaria. Munich biowaste, with its low percentage of interfering substances, is well-suited for this method.
With the production of environmentally friendly energy from kitchen and garden waste, the Munich Waste Management Company Abfallwirtschaftsbetrieb München (AWM) is breaking new ground in recycling Munich biowaste. The dry fermentation plant in the north of Munich uses the energy potential of Munich biowaste by processing it with the environmentally friendly method of dry fermentation.
AWM uses this new technology while accounting for the principles of sustain- able management and practicing regional recycling management with a high value-adding chain. This is an essential contribution to protecting our climate and conserving resources.

5.2.1.The Dry Fermentation Plant

The AWM plant works with a dry technology in cells which can be assimilated to the one chosen for Baalbek project. The plant in Munich annually processes up to 25,000 tons of kitchen and garden waste from their brown bio waste containers, while supplying enough high-energy biogas to produce approximately 3,780,000 kilowatt hours of electricity
a year which means around 470 kilowatt/h . This is roughly enough electricity to satisfy the annual consumption demands of around 1,600 Munich households; this replaces about 375,000 liters of heating oil. Moreover the plant produce also heat from the motor. The heat is used in the plant to heat various substance flows. The fermentation residues are processed into finished compost which is then sand back to the biomass cycle as
valuable fertilizer.
The pilot system with four digesters (biowaste reaction chambers) was completed July 2003. Initially, the plant processed 6,500 tons of biowaste per year. By May 2006, this amount had in creased to approx. 9,500. The annual output of the test system most recently generated 930,000 kilowatt hours electricity, i. e, enough to supply energy to around 400 Munich households. Later on in 2007 the number of digester was increased from 4 to 10 enabling the plant to process up to 25,000 tons per year of biowaste from households.

5.2.2.Fermentation of Waste in the Digester

Various decomposition reactions take place within the digester. The most important processes are: hydrolysis, acid formation, and methane formation. Cell water (percolate) is released during hydrolysis. The percolate contains an easily degradable organic substance and bacteria, and represents a valuable natural catalyst in the procedure. The percolate is caught on the bottom of the digester and temporarily stored in a tank. Here it is kept warm and then reused to spray the biomass. During the biomass's entire retention time in the digester, the percolate is kept in circulation, allowing the fermentation process to continue. The fermentation process takes place at a mesophile temperature ranging from 34 to 37° C. Integrated bottom and wall heating in the digester maintains this temperature.
An heat exchanger can also be used to thermally adjust the added percolate. This allows optimal, economic control, since the heating energy is self-supplied by the waste heat from the incineration process in the combined heat and power plants.
The biowaste spends 4 to 5 weeks in the digester, depending on the quality and condition of the substrate and the time of year. At the end of the detention time, the fermentation chamber is completely emptied and then refilled. The digesters are run in so-called batch operation. This means: once biomass is filled into the digesters, it remains there until the end of the retention time, without further material being added or removed. The plant is remote controlled by a computer supported operational control system.

5.2.3.Filling the Digester

The biowaste that is delivered it's mixed with material that has already been fermented and then filled into the digester with a wheel loader. Each chamber holds 370 to 450 tons of biowaste. To ensure that there is always enough biogas for the combined heat and power plant, a number of digesters are operated simultaneously in progressive stages. Two of the plant's digesters are filled each week.
The digester gates open upwards, which prevents a wheel loader from accidentally colliding into a gate and damaging it during filling and clearance. Once filled, the digesters are sealed with hydraulically operating gas-tight gates. An inflatable sealing lip attached to the gate provides the gas-tight seal for the digester. Before the gate is opened, the air is again let out of the seal.
The biogas accumulates in the digester above the fermenting substrate, where it is temporarily stored during fermentation. Costly external gas storage is not necessary, since the combined heat and power plants are regulated according to the gas that is available. The biogas produced from the biowaste is dried, and then the gas quality and quantity are measured. A gas control path and a gas compressor are used to feed the biogas to the combined heat and power plants. Experience to date has it that no desulphuration is needed. The low sulphur content may be attributed, above all, to the fact that, in Munich, primarily raw plant waste and not food and animal waste (protein carriers) are disposed of in the biowaste container.
The biogas is completely converted into electricity in three combined heat and power plants, each with 190 kilowatts (electric). In case of malfunction emergency, the biogas is burned by the excess gas burner (torch). The biogas burns completely in the combined heat and power plants, where an electricity supplying generator is driven producing alternating current. The generated

electricity is fed into the public network. The waste heat produced during combustion is optimally used by the combined heat and power plant. It serves as process heat and dries the various substances in
drying boxes set up especially for this purpose.

5.2.4.Composting Fermentation Residues

At the end of the fermentation process, fermented biomass is removed with the wheel loader. The biomass then enters a downstream composting process, without further processing or additives. The fermented biomass leaves the digesters at decomposition stage 3 to 4. Further decomposition then takes place near the plant, on a covered area with a sealed bottom. There, the material reaches decomposition stage 5 and it's hygienized through the substrate's self-heating process. Thus, after 6 to 8 weeks, fermentation residues have turned into a valuable product that only need to be sieved. The finished com- post is subject to strict quality assurance by the Bundesgütegemeinschaft Kompost e.V. and bears the RAL quality mark. There are various possibilities for using the
finished compost, thanks to its high quality. Private use and use in gardening are both possible, as is agricultural use.
Electricity & Power Production from Biogas. The ten digesters at the plant continually produce biogas throughout the year. Approximately 13 % of the biomass used is converted in the process, with the methane content of the biogas amounting to roughly 50 to 60 % by volume.

5.2.5.End products

Electricity

Three combined heat and power plants, each with 190 kilowatts electric output, generate the electricity. The dry fermentation plant's ten digesters together supply enough biogas to generate approximately 3,780,000 kilowatt hours of electricity per year. This is roughly enough electricity to satisfy the annual consumption demand of about 1,600 Munich households. Biogas from biowaste, as a renewable energy source, is funded in accordance with the Erneuerbare-Energien-Gesetz (EEG –German Renewable Energy Sources Act). For the electricity produced in the expanded plant, AWM receives a basic payment, a CHP bonus (see "Heat Output") and a technology bonus of 2 cents per kilowatt hour, pursuant to the 2004 version of the EEG law. This funding is far better than that of the existing plant's compliance with EEG 2000. The increased payment for feeding the electricity is guaranteed by the EEG act for a period of 20 years.

Heat Output

The heat is used as process heat to warm the plant and the adjacent commercial building. A further portion of the heat is used to dry the sieve residue and further substance flows. This combined heat and power generation is particularly encouraged by the EEG (CHP bonus). Valuable Products with Definite Return on Investment

Biogas

The Munich pilot plant has been supplying biogas since 2003. Up to 50 to 60 % of the gas mix volume is made up of high energy methane. Further components are carbon dioxide (40 to 45 % by volume) and traces of hydrogen sulphate, nitrogen, hydrogen and ammonia. Biogas serves as the energy source for producing renewable energy.
It is turned into electricity and heat in the combined heat and power (CHP) plant.

Table 9 - Summarized data for the Munich AD In Batch plant

Technical Plant Data

- Capacity: 25,000 tons p.a.
- Substrate throughput at 90 % availability: 22,500 tons p.a.
- Volume of the 10 digesters: 7,500 m^3
- Biogas yield: approx. 1,800,000 m^3 p.a.
- Combined heat & power plant (CHP) electric output: 3 x 190 kilowatt (electric)
- Electricity yield: 3,780,000 kilowatt hours p.a. (with 5.5 kWh/m^3 biogas
- Energy content and a 38 % degree of efficiency (electric) for the CHP plant)
- Fermentation residues for further processing: around 17,000 tons p.a.
- Finished compost produced: 9,000 tons p.a.

6.Biogas Economics

The calculation has been made using the material coming only from the sorting line in the SCMF. The evaluation of the biogas production has been calculated based on the average calculation of methane production of each biochemical type of material estimated in the biowaste selected by the MSW treatment plant.

Table 10 - Methane percentage in the Biogas produced using different organic molecules

Type of material	biogas production	methane content
Carbohydrates	0.8 m^3/kg om* digested	50%
Proteins	0.8 m^3/kg om* digested	70%
Fat	12 m^3/kg om* digested	67%

* om: organic matter

Following the parameters in the table above and the available data in the EIA about the organic component in the MSW and the sorting facility capacity can be expected a production of biogas of about 100 Nmc for each ton of biowaste with the 60% of methane inside.
Following the project results the minimum production should be 200 kW/h for 1,600,000 kWh/y. In the table is showed the difference on quantities to reach the electricity amount desired. Using different biowaste source.

Table 11 -Quantity needed to produce 200 kW/h of electricity in to 2 main biowaste composition with different yield.

Waste needed using only the organic fraction of MSW (100 m3/ton) to produce 200 kW/h
8500 ton/year*
Biogas production with organic fraction of MSW plus additional clean organic material to increase the yield (150m3/ton)
5600 ton/year*

*The calculation has been made taking into consideration 8000 hours par year of electricity production and an average of 1,9 k<w per Nm3 of biogas

The facility producing with technology chosen on average should consume the 10% of the electricity produced by itself, which means that with a production of 200 kW/h around 180 kW/h can be used by the rest of the facilities in the WC.
An economical analysis about the costs will be supplied as soon as it will be possible to know the electricity consumption of the remaining of the facilities.

Detailed data about the characteristics of the biowaste coming from the SCMF would allow to a better estimation of the biogas production. In case the input material would have more impurities than what is expected it can be that to produce 200 kW the costs exceed the budget. In that case the solution is to reduce the expected production below 200 kW.

6.1.Biogas composition

As anticipated before the fermentation process led to the biogas production. The gas is indeed a mixture of different types of gas where their quantity is determined by the technology used, by the type of biomass and by the quality of the fermentation process. The table below shows the average composition of the biogas produced:

Table 12 - Average Biogas composition

Components	Average value
Methane	45-75 %
Carbon Dioxine	25-55 %
Steam	3,1 %
Nitrogen	1 %
Oxigen	0,3 %
Hydrogen	< 1 %
Ammonia	trace

The biogas (heat of combustion between 5 and 7.5 kWh/m^3) after passing through a system of desulfuration, after being cooled down, and dried will be used as fuel in a generator to produce electricity

6.2.Operational costs

The draft financial plan in annex 4 represent an estimation of the running costs to understand the economical advantages for the all waste compound. The calculation has been done considering the electricity costs for the SCMF around 200 kW/h for 8000 hours a year (see ANNEX 4)

7.Biogas facility output

7.1.Electricity generation

The electricity is going to be produced by using a generator of around 25 kW/h of power. A special room or place should be assigned to it. A pipeline from the biogas reservoir will divert the gas into the motor. The pipe for the exhausted emissions will be directed to one of the cells where at the end of the process such emissions are needed to neutralize the biogas and avoid risks of explosion while opening the cell doors. If no cells need to be open the emission will be going to the atmosphere.
The electricity will be used for the biogas facility and according with the other plants will be directed with a dedicated network.
The motor will be cooled down using the leachate recirculation.

7.2.Heat
The electricity production give also the possibility to distribute heat. Within the framework of this project is not possible to design a heating pipeline but in the future could be interesting to get funds to provide the heating system for a nearby school or hospital.

7.3.Compostable Degestate
The digested material is the remaining solid fraction at the end of the AD process. The quantities of digestate can vary according to the formalities of management, the duration of the process and the quality of wastes incoming but on average it can be assumed that they constitute the 65-70% in weight of the biomass in entrance. The digestate after the process is completely stabilised, and therefore unscented.
This material right after will be sent to the composting plant, where it is going to be mixed with wood or other organic wastes and inoculated with the compost of the previous cycle.

For an amount of 7000 t/y of MSW became around 5000 t/y of digestate

8.Environmental Impact

8.1.Air Emissions and biofilter
Using the proposed biogas technology the gas production does not have processing air, but simply the air of organic fraction inside the storage room in entrance and the air coming from the shredding process area. AD itself occurs in vessels and no air is exit from the process. At the beginning the air will be consumed by the bacteria in the biomass and at the end the air still inside the biocells, mixed with gas, will be sent to the torch.
Moreover the biomass after the biogas process are stable and produce odours only during the first days after the cells opening.

Considering a room for the storage and shredding will have a volume of around 5m X 7m X 6m height =210 m3 and that 4 exchanges of air per hours are needed, the airflow will be on average 210X4 = 840 m3/h.

Considering that small quantity and the type of air it should be considered vain to built a biofilter just for the biogas facility. It is reasonable to send this air to the biofilter of the composting plant without modify its dimensioning.
Regarding the emissions from the electricity generator it should be mentioned that the biogas facility will have a system of hydrogen sulfurate, particulate matter and fine particles abatement than the pollutant released by the biogas combustion will be mainly:

- nitrogen oxides NO_x
- carbon oxide CO

8.2.Noise
The motor will be installed inside a soundproof container. The level of acoustic pressure at a distance of 10 meters can be considered inferior to 65 db. Noise value can be considered minimal.

8.3.Odours
It as has been reported that using the technology on cells and having the possibility from the SCMF to build the biogas facility inside the structure of the plant there are not air processing emissions and therefore there will not be any odours coming from the biocells. The only odours can be produced in the receiving and storage room of the biomass and during the emptying of the biocells. The air coming from those two phases has to go to the biofilter. The air produced

during the emptying of the biocells will be directed to the torch and burned without producing any odours.

8.4.Water and leachate Quality

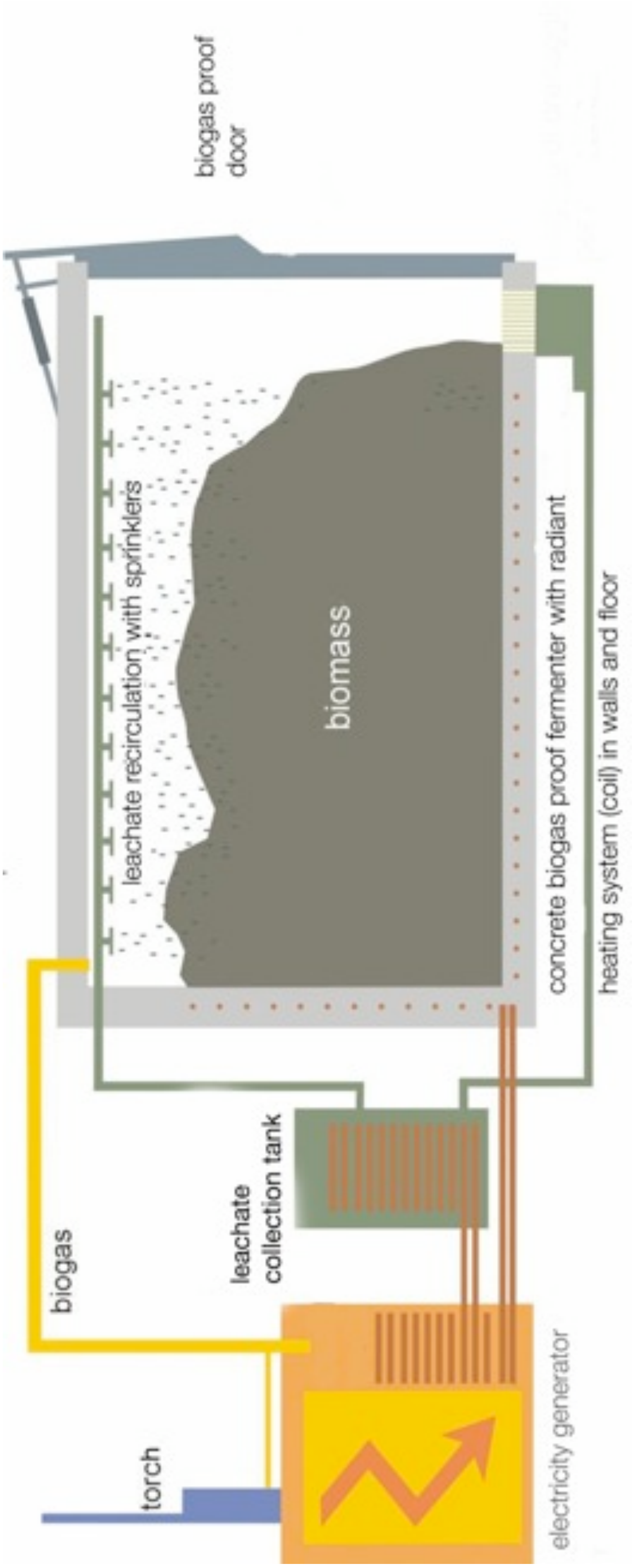
During the process of digestion a quantity of leachate will be produced and collected in a tank. During the process will be used for maintaining the moisture in the biomass cells during the process, nevertheless at the end quantity of peculate (about 20% in weight of the material in entrance) will remain. This quantity should be stored in a common tank with the sewage produced by the 3 plants, waiting to be sent to the Baalbek WWTF.

Calculating an average of 7000 ton/year the leachate production can be estimated in around 1400 ton/year

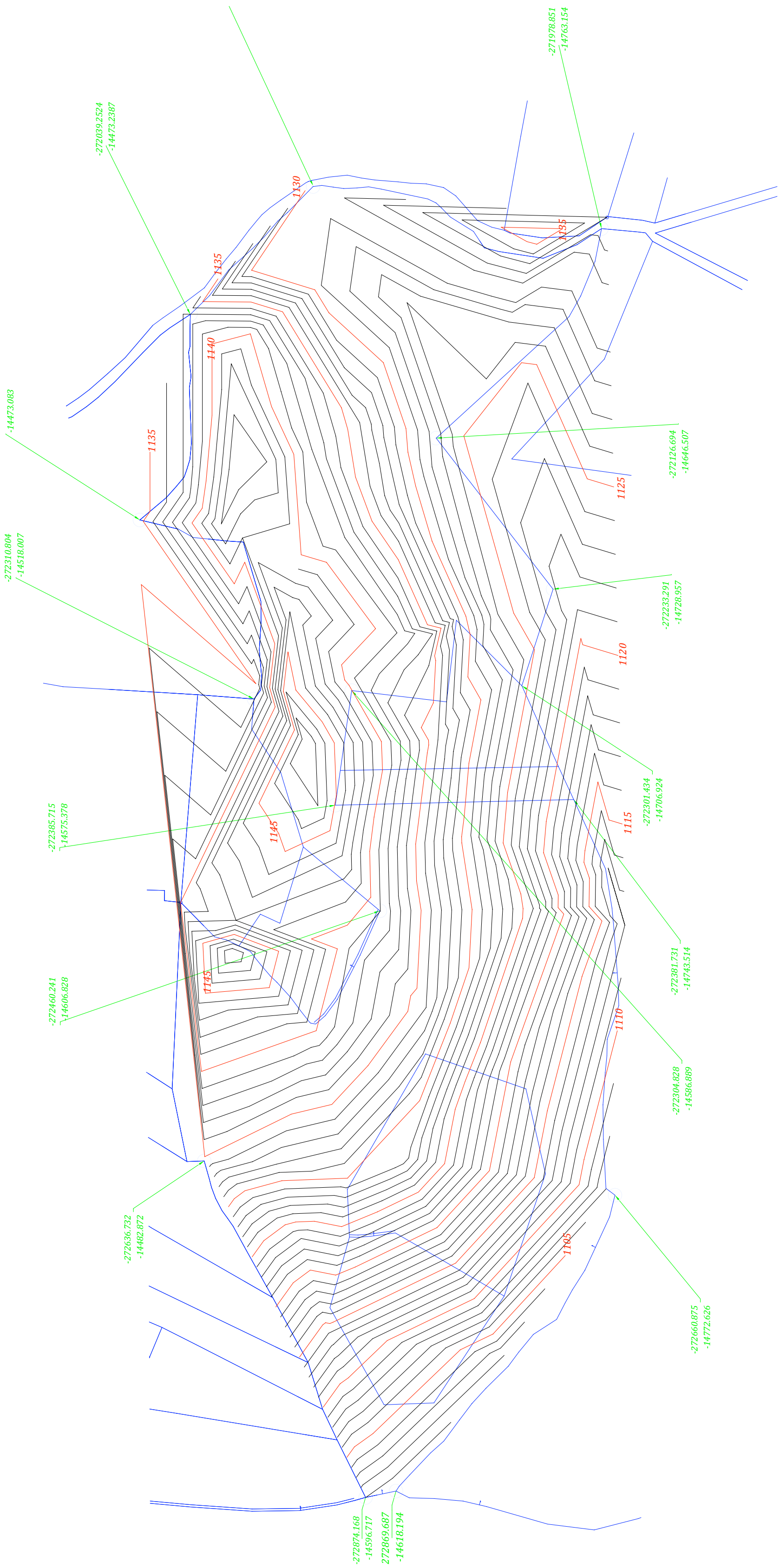
9.Mechanical and control building

The position and design of The mechanical and control building shall be specified need the Master Plan drafted by the experts of the Italian Cooperation Office to decide where to place the buildings and how to design them. In any case the biogas facility should have a receiving and mixing area directly connected to the SCMF to avoid odours.
Moreover the facility will be designed to produce the minimum landscape impact.

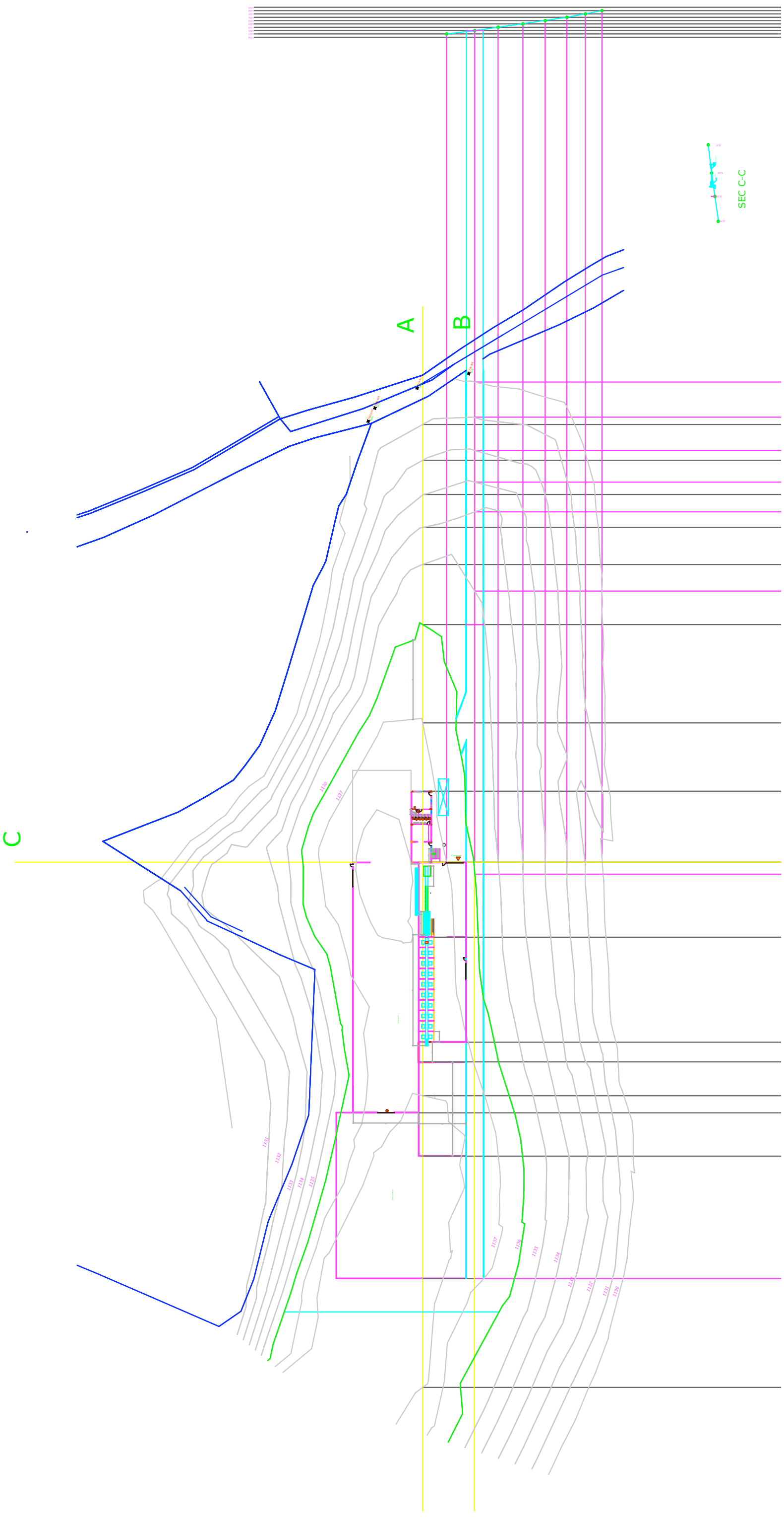
ANNEX 1 - DRY AD SYSTEM IN BATCH



ANNEX 2 - ASSIGNED AREA FOR THE WC - CONTOUR LINES



ANNEX 3 - FIRST DRAFT FOR FACILITY POSITIONING - OLD DRAFT DRAWINGS



ANNEX 4 - ESTIMATED OPERATIONAL COSTS - ESTIMATED FINANCIAL PLAN

ANNEX 4 - FINANCIAL PLAN - PAGE 1

BIOGAS PRODUCTION FACILITY (undersize material treatment from Baalbek and Hermel MSW)

INPUT	Quantity	Density	Days	GAS production	
	t/year	t/m3		m3/t	m3/year
MTB undersize material from MSW (size 80 mm)	8000	0,65		100	800.000
Loss from the process (15%)	1.200				
Available waste for the process	6.800				
Approximate period inside the fermenter			35		

Power generator (co-generation)	kW/h 200	
Thermal yield	43%	
Electrical yield (cogeneration)	37%	
Motor working hours h/y	8000	
Power produced from biogas kWh/m³	5,5	
Thermal energy from the process (%)	15	
Thermal energy useful	1.892.000	kWh/y
Electrical energy useful	1.628.000	kWh/y
Useful power/h	203,50	kWh/h

ANNEX 4 - FINANCIAL PLAN - PAGE 2

BIOGAS PRODUCTION FACILITY (undersize material treatment from Baalbek and Hermel MSW)

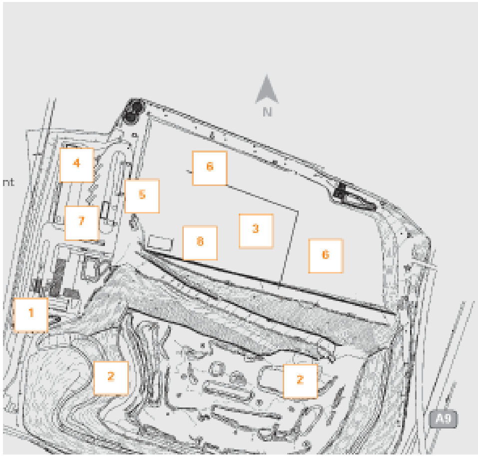
Investment costs						€
Total investment costs (€)					€	1.000.000

Operational costs						
	quantity	unit	quantity	unit	unit	costs
Leachate treatment fee		€/t			€/y	not available yet
Annual installment for the investment					€/y	free grant
Facility insurance			0,5%		€/y	5.000
Structure and tools			1%		€/y	10.000
Co-generator kW/h	200	kW/h	10	kW	€/y	16.280
Employees	400	€/month	2	person	€/y	9.600
Facility director	1000	€/month	1	person	€/y	12.000
Wheel loader	20	€/h	2000	h/year	€/y	40.000
Electricity consumption 7%	113960	€/kWh	14	0,12	€/y	13.675
Overhead				5%	€/y	5.328
Total costs					€/y	**111.883**
Unit cost					€/kWh	**0,069**

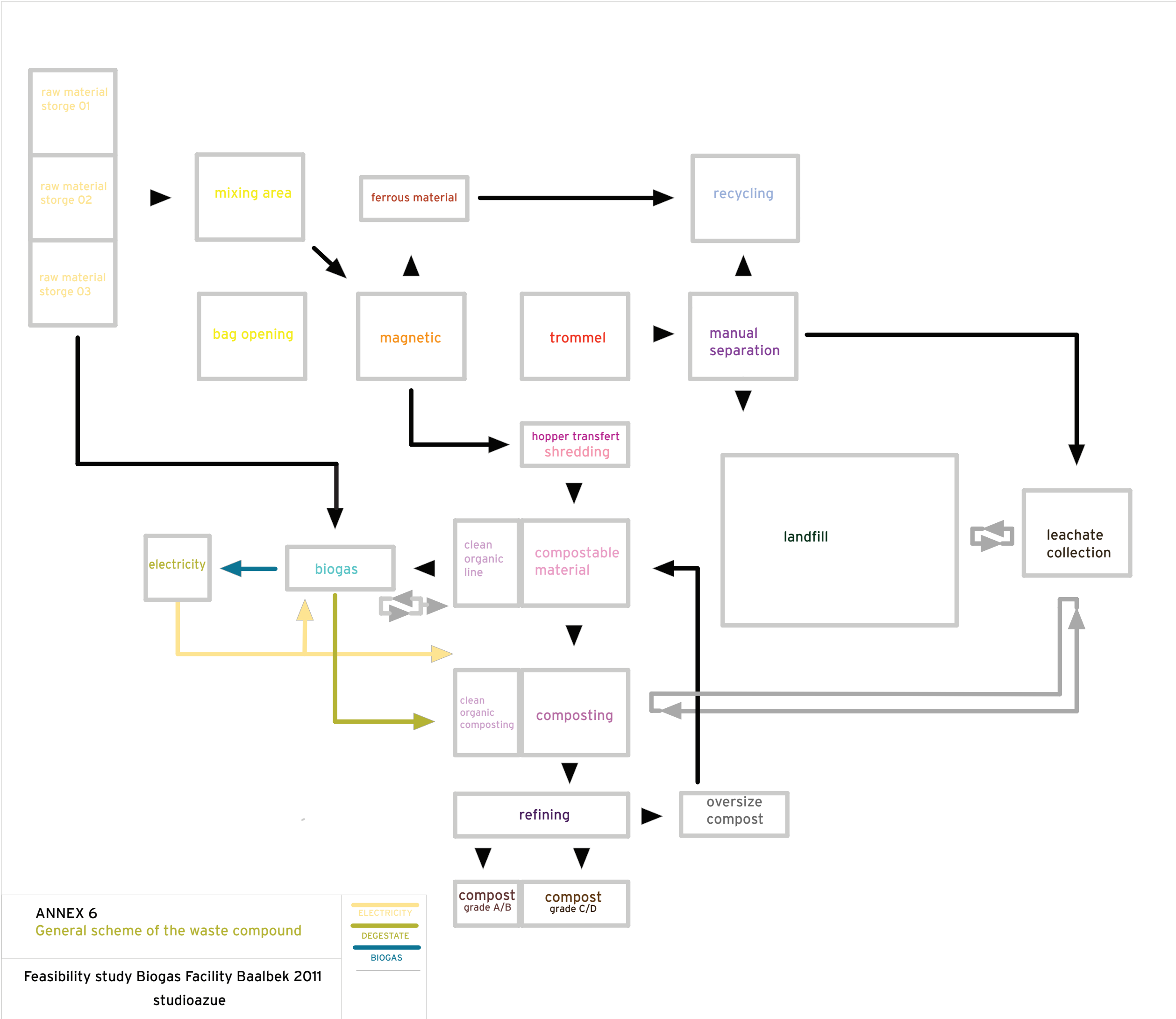
Value of the electricity production						
Thermal useful energy produced	kWh/year	1.892.000	not in use yet			1.702.800
Electrical useful energy produced	kWh/year	1.628.000	to be used by the waste compu			1.628.000
Cost for 200 kW/h using fuel generato	€/kWh	0,12			€/y	195.360
Cost 200 kW/h with EDL	€/kWh	0,03			€/y	48.840
Total electricity costs considering 4000 hrs with EDL and 4000 hrs with fuel motors						122.100
Unit cost					€/kWh	0,075
Profit					€/y	10.217

Annex 6 Munich SWM company (AWM) - Dry AD In Batch first pilot

ANNEX 5 - MUNICH WASTE MANAGEMENT COMPANY (AWM) - FERMENTATION PLANT

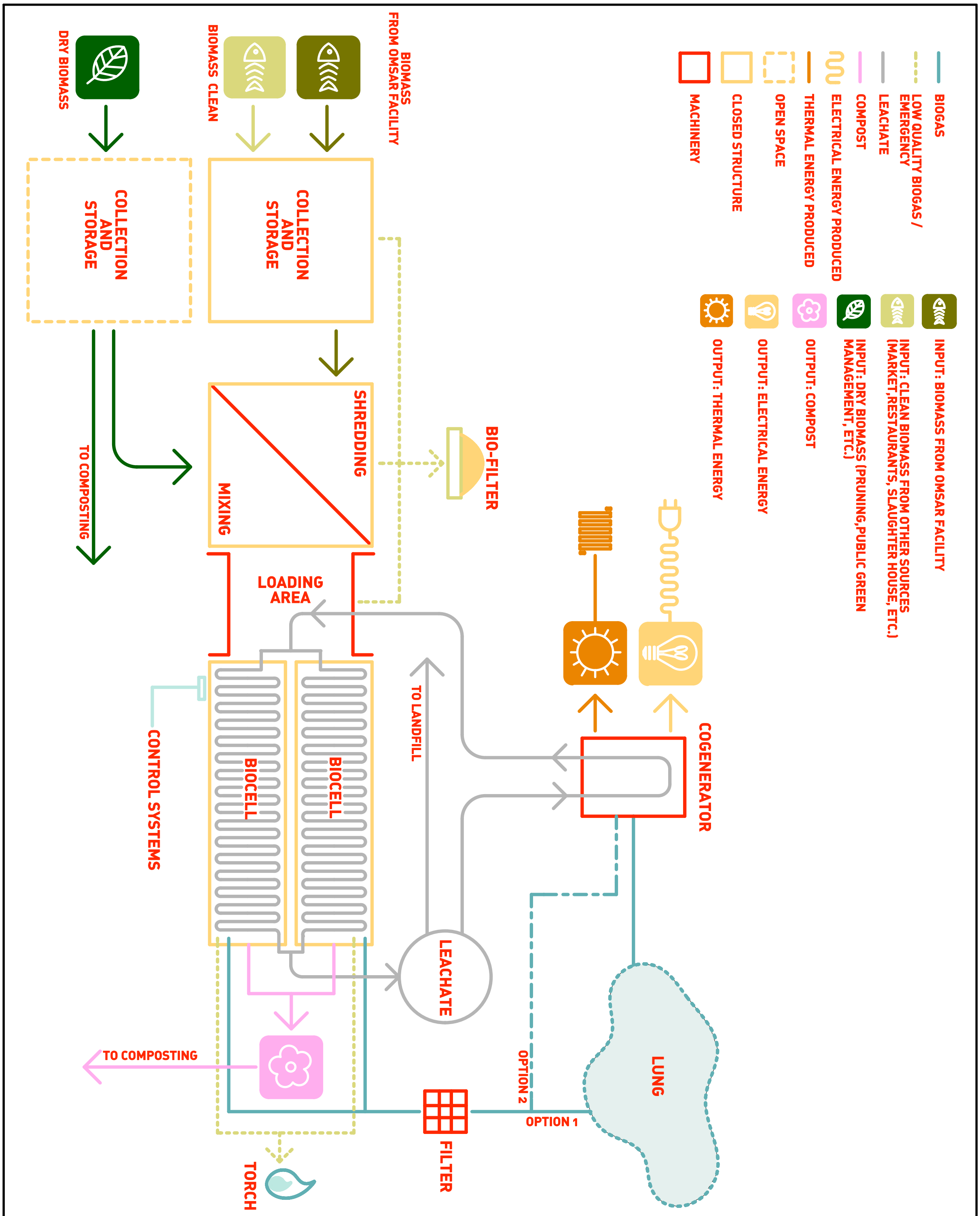


ANNEX 6 - BIOGAS FACILITY SCHEMES - General scheme of the waste compound



ANNEX 7 - UNI norm for biogas production facilities (available only in Italian language, see pdf file attached)

ANNEX 8 - Biogas Facility Scheme



studioazue	project: Toward clean energy and innovative environmental solutions in Lebanon DCI-ENV/210/256-762	scale: -	B-002
client: COSV ngo	drawing: biogas plant scheme	date: 14/10/2011	A-11