Self-Construction Manual of an agricultural Compact Biogas Plant for 30 - 225 Units

(Type: 400m^3 digester, 55 kW$_{el}$, Canadian standard)

"Solar- and biogas technology, `cause the future demands it"

Issued by:

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Note: This document has been prepared following Swiss standards. Additional requirements may be necessary to meet Ontario Regulations.

Introduction:

Within the scope of an R&D project of the Swiss Federal Office of Energy, the first compact biogas plant of Switzerland was built and this self-construction manual was then compiled and issued. The manual helps farmers and farm cooperatives to build their own biogas plants and provides the basics for economic calculations.

Caution:
This manual does not claim completeness. The author and publisher reject all claims in connection with the construction of a biogas plant according to this manual. Prior to constructing a biogas plant, all construction permits must be obtained and a professional engineer familiar with biogas technology should be consulted.

Objectives of this manual:

- Standardization of the biogas technology (simplified construction and functionality)
- Eased proceedings for construction permits and commissioning due to standardization
- Big reduction of capital investment compared to existing plants

Brief description of chapters A – B

Chapter A:

In this chapter the construction of a compact biogas plant is described in detail with the help of pictures. The construction parts mentioned are proven components of the biogas technology. Similar products of other brands might be used as well. Following the pictures, a detailed description of them is provided.

Chapter B:

This chapter contains a detailed parts list and an up-to-date cost overview (August 2002). The costs may vary according to local conditions and supply conditions. Possible ways of personal contributions are also pointed out. With the parts list the individual construction project can be evaluated and possible deviations from it can be spotted out.

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Short picture overview (digester, machine room, gas storage)

These three pictures show a compact biogas plant in operation

Plant owner:
G. und J. Schmid,
Paradiesweg 7,
9403 Goldach
Switzerland

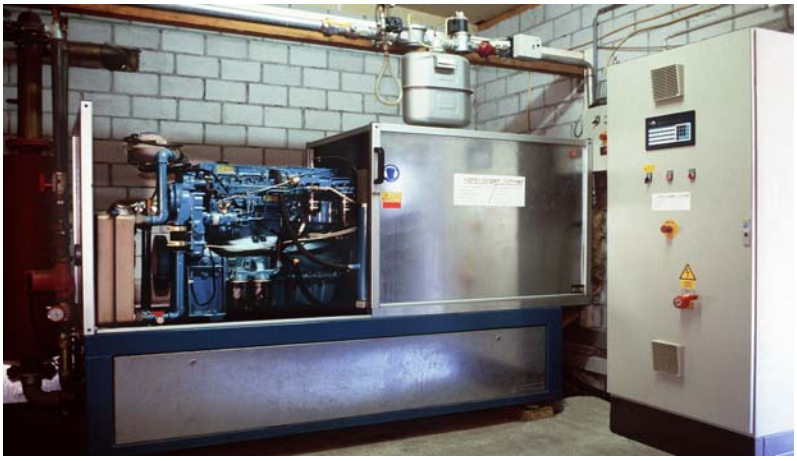
Plant size:
Units: 60
Co-substrate:
- vegetable waste
- grass waste
- dough waste
- mill dust

Investment:
Total capital amount:
225,000.- Cdn$
(2002)

Technical Data:

Digester:	400 m^3
Dimensions:	d=9m; h=5m
Gas storage:	100 m^3
Cogeneration unit:	55 kW_{el}
	65 kW_{th}

Space requirement:
Space: 10 m x 13 m



100 days full load operation: (25.10.98 - 1.2.99)

Gas production:	43'737 m^3
Electricity product.:	95'725 kWh
Operating hours:	1'987 hrs
Gas consumption:	22 m^3/h
Efficiency:	33 % el.
Methane content:	59.5 %
Fuel oil ratio:	10%
Biogas:	437 m^3/day
Electricity:	957 kWh/day
Operating time:	20 hrs./day
Power output:	48 kW_{el}
Temp. digester:	40° C

Connection to the farm:
- Main electricity line
- Heat line
- Liquid manure line

Installation suppl. by owner:
- Collecting dump
- Heat line, domestic heating
- Effluent Storage Effluent application

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Operating scheme of the compact biogas plant

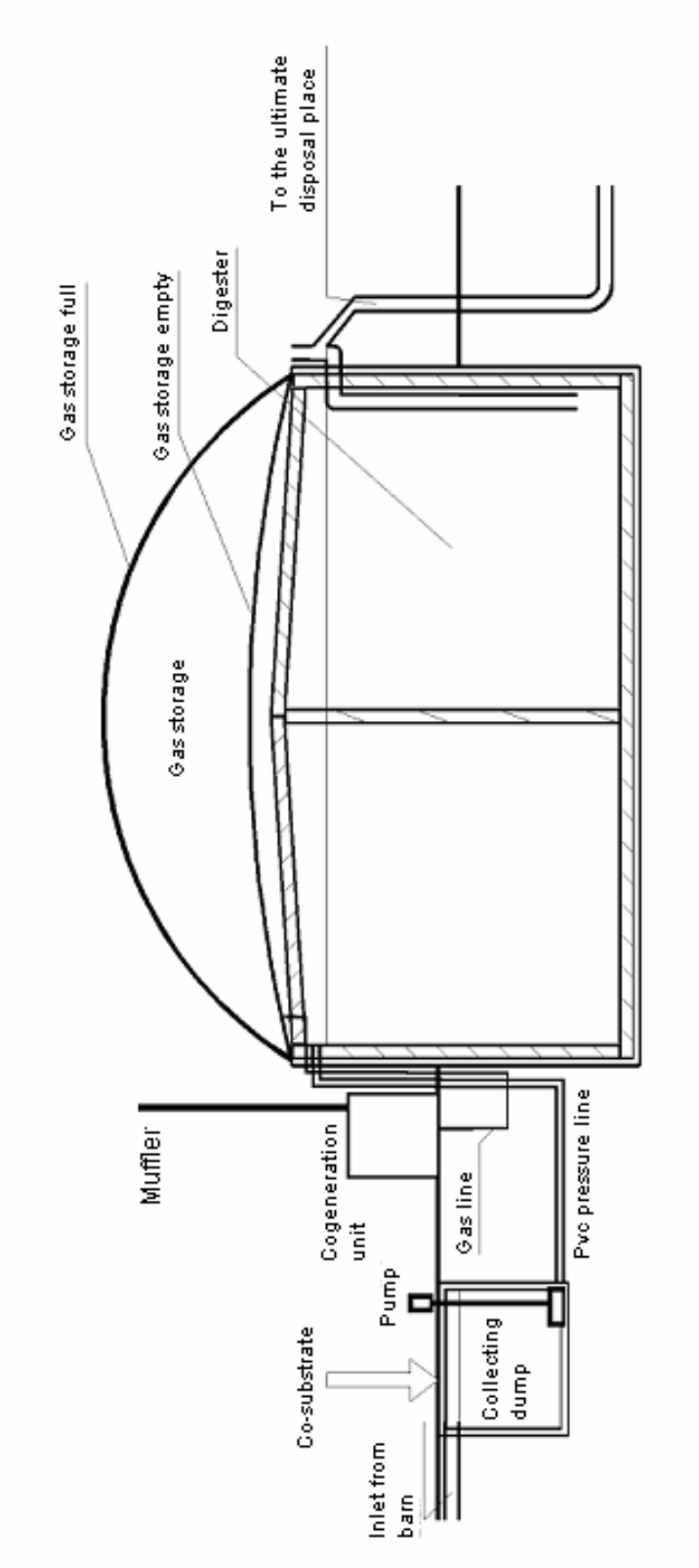

Figure I: Operating scheme of the compact biogas plant

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Chapter A: Complete plant construction (picture documentation)

Cross-reference:

Chapter A:
Detailed description
Pos.: 1

Chapter B:
Parts list
Pos.: 1.3/1.4/2

Figure 1: Ground leveling and begin of floor insulation
Short description: Excavation with slab of lean concrete and begin with the laying out of the bottom insulation. The insulation plates are laid out starting from the center. The diameter of the bottom insulation must be at least 9.8 meters. The insulation plates have to lie tight on the slab.

Cross-reference:

Chapter A:
Detailed description
Pos.: 1

Chapter B:
Parts list
Pos.: 1.3/1.4/2

Figure 2: Bottom insulation
Short description: Completed bottom insulation with marked perimeter on it for the concrete formwork of the bottom slab. Begin with reinforcement of the bottom slab. If water should accumulate at the bottom, or if there's a possibility this could happen in the future, a seepage water drainpipe has to be installed. Due to heat losses the digester must not stand in water.

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Chapter A: Complete plant construction (picture documentation)

Cross-reference:

Chapter A:
Detailed description
Pos.: 1

Chapter B:
Parts list
Pos.: 1

Figure 3: Digester wall formwork and marking of clearances
Short description: On the digester wall formwork the positions of the clearances are marked (red marks in the picture above, indicating position and dimensions). It is important to mount the pvc pipes (for concrete clearances) perpendicularly to the wall, as well as the frame for the clearance of the agitator.

Short description:
Corbel of bottom slab (max. 10 cm exceeding the digester wall).
The insulation of the digester wall is put on the 10 cm wide corbel of the . bottom slab. The rim of the 25 cm thick bottom slab is insulated with surplus insulation pieces.

Also, the finished bottom insulation can be seen in the picture.

Cross-reference:

Chapter A:
Detailed description
Pos.: 1

Chapter B:
Parts list
Pos.: 4./5.

Figure 4: Bottom insulation with bottom slab and digester wall formwork
Note: This document has been prepared following Swiss standards. Additional requirements may be necessary to meet Ontario Regulations.

Chapter A: Complete plant construction (picture documentation)

Cross-reference:

Chapter A:
Detailed
description
Pos.: 1

Chapter B:
Parts list
Pos.:
6./7./8./9./10./
11./12.

Figure 5: Outside Walls of digester with necessary clearances
Short description: Clearances from left to right (rectangular: agitator clearance; liquid manure spillway, big gauge-glass, small gauge-glass, heating, excess pressure, gas outlet, liquid manure inlet and spare opening not visible). Control duct of seepage water drainpipe at bottom left.

Short description:
Two-part insulation of Digester wall.
Each insulation layer is fixed by 3 to 4 plastic tapes (without using dowels or glue!).
2 to 3 people are necessary for an easy installation.

Cross-reference:
Chapter A:
Detailed
description
Pos.: 1

Chapter B:
Parts list
Pos.: 2./5

The insulation of the lower part of the digester wall can be seen in figure 6. After the insulation of the wall is done, the rim of the bottom slab is insulated with surplus pieces that are held in position by compacted earth.

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Figure 6: Wall insulation with insulation of bottom slab (surplus insulation pieces)

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Chapter A: Complete plant construction (picture documentation)

Cross-reference:

Chapter A:
Detailed description
Pos.: 1/2

Chapter B:
Parts list
Pos.: 4/5, as well as some additional material

Figure 7: Finished Wall insulation with supply lines
Short description: From left to right: liquid manure spillway (300 mm pvc pipe), heat line to the house (black pipe bend, supplied by owner), digester heating, main current line (orange pipe on the ground, 2 pcs.), gas lines (black pipe, 2 pcs.), ground wire (visible left of the gas lines) and liquid manure supply line.

Short description:
The digester wall heating comprises of three heating loops (each 200 m or 6 turns long).
The support rails are fixed by stainless steel bolts approximately 60 cm above ground. After installation of the heating loops, additional support rails are mounted contrariwisely on every other rail (not visible in the picture).

The bottom bearing-stand of the agitator is visible on the bottom right.

Cross-reference:

Chapter A:
Detailed description
Pos.: none

Chapter B:
Parts list
Pos.: 13. / 13.1

Figure 8: Wall heating of digester and bottom bearing-stand of agitator

Note: This document has been prepared following Swiss standards. Additional requirements may be necessary to meet Ontario Regulations.

Chapter A: Complete plant construction (picture documentation)

Cross-reference:

Chapter A:
Detailed description
Pos.: 3

Chapter B:
Parts list
Pos.: 19

Figure 9: Digester wooden top
Short description: The digester wooden top is made of wooden boards (5 cm thick). Plastic bolts fix them. The part where the agitator is located can easily be removed in order to enter the digester when necessary.

Short description:
Wooden top with middle post (interior view).
The middle post must have a diameter of at least 60 cm. Thus, all the 18 beams lie properly on the post and no screw connection is necessary (Corrosion).
In the concrete wall clearances according to the beam dimensions have to be taken into account. The clearances start 10 cm below the upper rim and are about 12 cm deep

Cross-reference:
Chapter A:
Detailed description
Pos.: 3

Chapter B:
Parts list
Pos.: 17-19.2

Figure 10: Digester wooden top (interior view)

Note: This document has been prepared following Swiss standards. Additional requirements may be necessary to meet Ontario Regulations.

Chapter A: Complete plant construction (picture documentation)

Cross-reference:

Chapter A:
Detailed description
Pos.: 1

Chapter B:
Parts list
Pos.: 33-44
particularly
Pos.: 42

Figure 11: Positioning cogeneration unit
Short description: The cogeneration unit is put at the right spot in the machine room, directly in front of the air supply duct. No fixing necessary. Professionals carry out the final connection of the gas line, heat line and power line.

Cross-reference:
Chapter A:
Detailed description
Pos.: none

Chapter B:
Parts list
Pos.: 39, 42

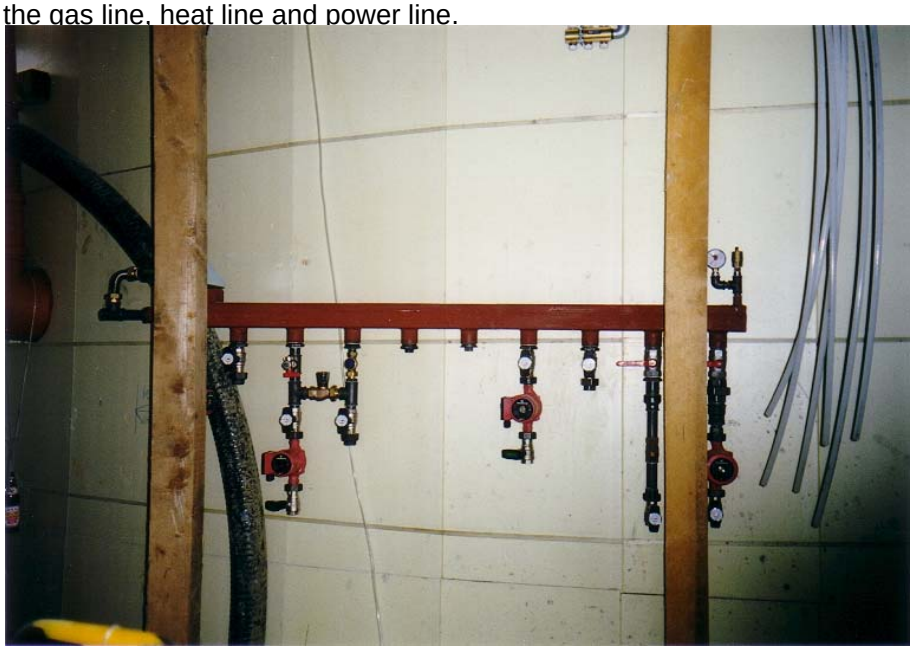

Figure 12: Premounted heating distributor
Short description: The heating distributor, premounted by the supplier, is mounted to the wooden posts. In the picture above, the heating pipe (black tube) can be seen. To the right there are the three heating loops (thin white tubes) of the digester heating. All together there are 10 heating loops installed and combined in a separate heating distributor. From left to right the following connections are visible: house connection (one connection is hidden), digester inlet, spare outlet, emergency cooler outlet, and lines from the cogeneration unit, front run and back run.

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Chapter A: Complete plant construction (picture documentation)

Cross-reference:

Chapter A:
Detailed description
Pos.: 4, 5

Chapter B:
Parts list
Pos.:21, 22, 23, 26, 26.1, 28

Figure 13: Agitator control cabinet, sulfur and methane gauge
Short description: The following components can be seen from left to right: Agitator control unit with display of digester temperature, air pump and flow gauge for desulfurization, and the gas analysis gauge. They're mounted next to the control unit of the cogeneration unit (not visible) in order to have an easy overview of all important components.

Cross-reference:

Chapter A:
Detailed description
Pos.: none

Chapter B:
Parts list
Pos.: 33

Figure 14: Display of the cogeneration control unit
Short description: The display of the cogeneration control unit shows the actual operating status of the plant. Malfunctions are indicated by LEDs and by text messages. Every electric component has its own fuse. Thus, a clear operating structure is achieved.

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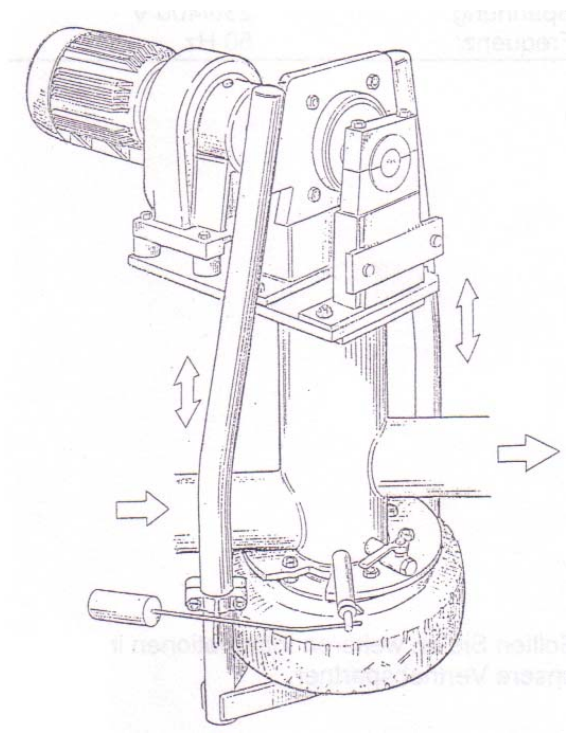
Chapter A: Complete plant construction (picture documentation)

Cross-reference:

Chapter A:
Detailed description
Pos.: 2

Chapter B:
Parts list
Pos.:33, 43, 44,

Figure 15: Machine room after installation of all components
Short description: In the picture there can be seen all control units (gas gauge, cogeneration unit control cabinet, agitator control cabinet with display of digester temperature, disulfurization unit and the gas analysis unit). They're all neatly arranged and allow for an easy overview of the system.



Short description:
The charging pump is mounted in or next to the collecting tank. It pumps 14 m^3/h and up to fist-sized solids. Also, it does not incure damage when running dry. The low powered motor enables an energy efficient charging of the digester. When mounted in the tank, frost won't damage it, but maintenance is more elaborate.
The pump charges at a constant flow.

Cross-reference:

Chapter A:
Detailed description
Pos.: (Prospect available)

Chapter B:
Parts list
Pos.: 30, 31, 32

Figure 16: Charging pump
Note: This document has been prepared following Swiss standards. Additional requirements may be necessary to meet Ontario Regulations.

Chapter A: Complete plant construction (picture documentation)

Cross-reference:

Chapter A:
Detailed description
Pos.:

Chapter B:
Parts list
Pos.:33

Figure 17: Cogeneration unit
Short description: The cogeneration unit has a sound insulation hood that can be pushed aside for maintenance. Thus, the engine is easily accessible. In the picture above, the engine can be seen with its integrated cooling water heat exchanger. On the very left, there's the exhaust gas heat exchanger.

Cross-reference:

Chapter A:
Detailed description
Pos.: none

Chapter B:
Parts list
Pos.: 33, 41

Figure 18: Electric generator of cogeneration unit
Short description: In the picture above, the electric generator of the cogeneration unit can be seen. The air cooler of the turbo charger, which is supplied by fresh air directly from the air supply duct, is at the front side. This arrangement is important to keep the thermal stress on the engine low and to increase its mechanical efficiency. If possible, the air intake should be on a north or east wall of the room.

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Chapter A: Complete plant construction (picture documentation)

Cross-reference:

Chapter A:
Detailed description
Pos.: 1, 6

Chapter B:
Parts list
Pos.: 4, 19, 47

Figure 19: Wall composition of digester
Short description: The digester wall comprises of the following layers: 2 x 50 mm of insulation, fixed with a plastic tape running all around, 25 cm of concrete with inserted Seeger circlip on top rim, and 5 cm thick wooden top supported by wooden beams.

Cross-reference:

Chapter A:
Detailed description
Pos.: 2

Chapter B:
Parts list
Pos.: 49, 57, 58, 58.1

Figure 20: Control duct with condensate trap
Short description: Condensate trap with fore and back run of the gas line. The trap itself is not visible in the picture. The two gas lines from the digester and the machine room are installed with as much decline as possible. This ensures that all humidity in the gas condensates. The line between the control duct and the machine room should be at least 30 meters long.

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Chapter A: Complete plant construction (picture documentation)

Cross-reference:

Chapter A:
Detailed description
Pos.: 1, 6

Chapter B:
Parts list
Pos.:4, 27, 46

Figure 21: Digester without wooden casing
Short description: In this condition the digester is ready to operate. On the right side the machine room is visible. There, all front and back run lines come together, safe from frost and sunlight, except the liquid manure supply, which is outside.

Cross-reference:

Chapter A:
Detailed description
Pos.: none

Chapter B:
Parts list
Pos.: 7.2, 41

Figure 22: View at machine room without wooden casing
Short description: On the right side of the wall of the machine room the fan, which supplies the turbo charger with fresh air, is visible. It also ventilates the room. To keep the fan noise low, a hood is mounted to the wall (Pos. 68 in chapter B). On the opposite side of the machine room an identical outlet is made to ensure cross-ventilation of the room. At left the spillway of the digester can be seen.

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Chapter A: Complete plant construction (picture documentation)

Cross reference:

No further details are provided in this book since these are only additional options and have to be examined case by case.

Figure 23: Optional (Inlet for solid waste)
Short description: If solid organic waste is available on the farm that can't be charged by the pump, a separate inlet provides a way to add small amounts of them to the digester. Only the opening of the inlet can be seen in the picture above.

Short description: The immersion agitator can be used when there's only liquid manure operation.

This agitator is less expensive than the one mentioned in chapter B, pos. 27-29

Cross-reference:

Chapter A: Detailed description Pos.: 5

No further details are provided in this book since these are only additional options and have to be examined case by case.

Foto 24: Optional (Immersion agitator)
Note: This document has been prepared following Swiss standards. Additional requirements may be necessary to meet Ontario Regulations.

Chapter A: Complete plant construction (picture documentation)

Cross-reference:

No further details are provided in this book since these are only additional options and have to be examined case by case.

Figure 25: Optional (Chaff cutter for organic waste)
Short description: This chaff cutter is directly situated above the collecting dump. It can be charged with a front loader or a conveyer (see picture below). The cutter is very robust and low-cost in maintenance. (Purchase price 16,000.- Cdn$, source of supply: Böhni Energy & Environment Ltd)

Cross-reference:

No further details are provided in this book since these are only additional options and have to be examined case by case.

Figure 26: Optional (Complete process unit for organic waste)
Short description: If the biogas plant is charged with bigger amounts of organic waste, it is an advantage to cut them into little pieces first. The picture above shows a complete process unit with integrated sort-out system. Via a dosing unit the organic waste goes onto a conveyer, where non-organic matter is sorted out. From there it goes directly into the chaff cutter.

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Chapter A: detailed construction description (addendum to the figures)

1. Instruction to digester construction

The excavation:
The diameter of the excavation has to be at least 2 meters bigger than the outer diameter of the digester to be built.

Leveling:
Leveling gravel 18 - 32 should be used for leveling the excavation. A layer of leveling material 8 x 8 comes on top of the leveling layer. This material is easy to smooth out and will provide a good sub grade for the bottom insulation. Contact the concrete contractor if the ground is boggy.

Bottom insulation:
On top of the leveling layer insulation plates (100 mm x 600 mm x 2500 mm) are laid out (Figures # 1, 2). The diameter of the insulation has to be about 1 meter bigger than the outer diameter of the digester. When casing the bottom slab care has to be taken that there is enough space left (10 cm) for putting up the wall formwork. If the slab gets too big in diameter, problems will arise later on when insulating the corbel.

Concrete works:
When casing the digester walls pvc pipes for clearances (see parts list) have to be included.

There's an agitator in the collecting dump. A charging pump delivers the liquid manure into the digester through a pressure pipe (nominal width 125 mm).
A pvc pipe for clearance (nominal width 125 mm) serves as an inlet approximately 30 - 40 cm below the upper digester rim to prevent backflow of the manure.

A pvc pipe for clearance (nominal width 125 mm, see parts list) serves as a manure outlet and is put into the formwork approximately 350 cm above the bottom slab. To connect the ultimate disposal place, a piece of pipe is put into the pvc pipe for clearance. On top comes a bow 87°. Connect a vertical piece of pipe up to the 45° turn off (Y-piece). The lower level of the turn off is equal to the level of the digester. This should be at least 40 - 50 cm below the wooden top. The maximum digester level must not be above the lower edge of the gauge-glass! (See figure # 5)

The owner determines the positions of the pvc pipes for clearances of all connections. They depend on the conditions on site. Die pvc pipes for clearances have to be mounted vertically to the formwork! See figure # 5 "digester overview" for help. Finally, to finish the concrete works, the spare woods (pos. 15 chp. B) for the wooden top as well as the Seeger circlip (pos. 47 chp. B) have to be put in place (see figures # 10 and 19).

Control duct:
To drain off ground water or to detect quickly digester leaks, a ring line has to be set around the bottom slab (drainpipe nominal width 100 mm). This line, as well as the gas line (figure # 20), leads into the control duct next to the bottom slab. The duct has to be easily accessible (diameter of the duct rings at least 800 mm).

Insulation:
- Styrodurformat: 100 x 600 x 2500 mm for bottom and top insulation
- Styrodurformat: 50 x 600 x 2500 mm for wall insulation

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Digester wall:
Two layers of insulation plates (50 mm x 600 mm x 2500 mm) are mounted to the digester wall. The plates are mounted up right and get tied to the wall with polyester tape. It is important to set the first plate absolutely perpendicularly. A polyester tape with an inserted elastic tape (bicycle tire) makes the mounting of the rest of the plates easy. Once the first row is done, polyester tapes tighten the plates to the wall. The second layer has to be mounted in the same way. Next, the second row is mounted as described above. Clearances to the digester have to be cut out within the insulation. Where the insulation is not going to be buried with earth later on, a wooden casing has to be mounted as a protection to it. The casing is tight together with wire and wire spanner.

Wooden top:
- The wooden top has to be built like described on page # 22.
- On top of the finished wooden top insulation plates (100 mm x 600 mm x 2500 mm, with tongue and groove) are laid out and cut to fit the inner wall radius.
- To fix the plates Styrodur nails (LT nails 140 mm x 9 mm, pos. 3.1. chp. B) are used.
- Drill 9 mm holes into insulation plates and wooden boards, then use Styrodur nails.
  See Figures # 9 and 10

Test for leaks / filling in:
After the control duct has been set and all the underground connections (gas line) are made, the excavation is filled up again. Before that, several points have to be kept in mind:
- A loose or badly packed filling yields hollow spaces. Rain, surface, snow and drain water can get below the bottom slab through these pockets. The resulting water pressure can destroy the slab!
- The gas line can locally drop where the ground is badly packed. This can cause condensate pockets.

Hints:
- Before filling in, fill the digester with water up to a level of 1 meter. This is also a test for leaks and prevents the digester from floating. Later on the water can be used to heat up the digester.
- Use no construction debris as filling material.
- Set up filling material layer by layer around the digester and pack well.
- The two bottom layers have to be packed most.
- If possible use clay or similar material.
- Take out water in the control duct (submersion pump).

Cogeneration unit location:
The cogeneration unit is put up in the machine room, just next to the digester (see Figure # 15). The following points are important:
- Ensure a good road access exists.
- Concrete slab (app. 4 x 6 m) has to be dimensioned generously in size to have enough space for the fuel oil tanks.
- To keep the unit safe of frost, the digester wall insulation near the unit can be omitted.

Ground wire:
The ground wire (included in pos. 45 chp. B) serves as an electric potential. The agitator (pos 27 chp. B) has to be connected to it. The wire has to be connected to the reinforcement of the bottom slab.

2. Mounting of the gas line:
Biogas has a high content of humidity. It cools down in the gas line and condensates. Consequently, all the gas line has to be mounted with a decline and lead to a condensate trap, which is the lowest point in the gas system. With the help of a T-pipe, immersed half-ways in water, condensate can drain off, but no gas will escape (see figure # 20).

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Putting in the control duct:
The line of the biogas to the control duct should be as long as possible. It is best to lead the line around the digester with a constant decline and take it into the control duct. From there to the machine room, the line has to incline steadily. The duct has to be on the same level as the bottom slab in order to include the drainpipe for leak control and ground water (see Figure # 20).

The duct has to be accessible for control and maintenance and its diameter should be at least 80 cm.

Mounting jobs in the digester:
Plastic pipes (nominal width 100 mm, pos. 12.1-12.6 chp. B) are installed in the digester to take the gas out. To get an optimized desulfurized biogas, the take out is situated between the wooden top and the plastic gas foil of the gas storage. The pvc pipe for clearance should be app. 25 cm below the upper digester rim. The distance to the next beam should be app. 50 cm.

The gas line in the digester can be installed after the wooden top is finished. The plastic pipe is fixed to the top by polyester tape and led to the middle of the digester. Connect pipe bow 87° to end of pipe and lead through wooden top and insulation. Always check the decline during the line work.

The fixing of the gas line is made with polyester tape (due to corrosion) to the top, which gets drilled through therefore.

Mounting jobs outside of the digester:
The following jobs have to be finished before installing the gas line:
- Inlet for solid waste is installed (if planned).
- Digester wall insulation is mounted.
- Control duct set to level of bottom slab and have drainpipe inserted.

Gas line connections outside of the digester:

A: to the connection
- turned 2 1/2 " nipple (pos. 44 chp. B), bushing from outside with pvc pipe for clearance of gas line.
- Connect to the 2 " T-piece (pos. 44 chp. B) with double nipple.
- going upwards, reduce to 1 " ball valve to discharge gas to ambient (pos. 44 chp. B).
- going downwards connect to a 2 " double nipple and 2 " gas stop valve (pos. 44 chp. B).
- below that connect to a 2 " double nipple and a 2 " T-piece with a reduced 1/2 " 90° (pos. 44 chp. B).
- connect premounted gas high/low pressure gauge of cogeneration unit to ½“ piece.
- Connect 2” piece to T-piece.

This part of the gas line has to be premounted properly before putting in the pvc pipe for clearance!

B: up to the control duct
B: up to the control duct
- fasten the counterpart of the 2" fitting at a 90^{o} angle (Pos. 44 chp. B).
- mount the double nipple horizontally and continue at a 90^{o} angle vertically downwards (Pos. 44 chp. B)
- manufacture a 2" tubing double nipple as needed and, using a 90^{o} union fitting, couple the PE line to the nipple (Pos. 44 chp. B).

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- install the gas line around the digester to the condensation trap. Ensure that the line has a constant decline of at least 5%!
- Starting at the condensation trap and working outwards, mark the height levels for the decline (5 cm/m). To avoid settling, tightly seal the underground prior to installation of the line.
- In the trap, connect the gas line ends with a 90^o fitting. Install a plastic T-fitting between the gas hose and the 90^o fitting. Point the free end of the T-fitting vertically downwards and extend it using a 40 cm long piece of pipe. This pipe must be immersed in 25 cm of water. In the planning stages, ensure there is room for a corrosion-resistant container. (Figure #20)

3. Mounting of wooden floor:

Hints and preparation
- Check figures # 9 and 10.
- Check list of wood to be complete (see parts list pos. 18 -19.2 chp. B).
- Middle post has to be centered and fixed to the ground.
- Middle post is at least 20 cm higher than the clearances of the beams in the digester wall.
- All 18 wood pieces for clearance (pos. 15 chp. B) have to be removed.
- Cut support beams (pos. 18 chp. B) to length and taper the other end (support middle post).
- Attach support beams, one after the other, to front loader and lift them above the digester. An assistant puts the beam in the wall clearance on one end and atop the middle post on the other, the tapered end. (Caution: dangerous work).
- Measure, cut to length and mount wooden boards (pos. 19 chp. B).
- Watch out for big enough joint gaps (0,5-1 cm). Humid gas will make wood swell. Also, keep an eye on the joint gap at the digester wall!
- Don't fix yet those boards where digester has to be accessible (agitator).
- Lay out insulation plates and fix them (pos. 3.1. chp. B).

4. Mounting of the desulfurization unit:

How does it work:

Biogas has a high content of sulfur. Sulfur causes corrosion in the combustion chambers of the engine and has to be taken out. If a certain amount of oxygen is added to the gas, it chemically reacts with sulfur and the sulfur falls out. It's important to keep the biogas/oxygen ratio the same. A too high content of oxygen may result in an explosive gas-mixture in the digester!

Instructions:
- Check components according to parts list pos. 21 - 26 chp. B for completeness
- Drill 20 mm holes through wooden top beams (app. 5 cm away from digester wall)
- Install clear pvc tube (pos. 24 chp. B) as a ring-line through the beams.
- Make app. 6 holes (as injection nozzles) evenly distributed over the ring line. Close the tube end.
- Put supply hose from dosing pump through the clearance of the little viewing glass (pos. 24.3 chp. B) and connect it to the ring-line.
- Put in a check valve (pos. 22 chp. B) in front of the dosing pump (pos. 21 chp. B). Biogas could otherwise escape and build up an explosive mixture if the pump failed!
- The amount of air from the dosing pump has to be adjusted according to the daily biogas amount (see desulfurization table below).

Desulfurization table:

Gas amount per day, air injection per minute

100 m^3 / day needs app. 3.5 ltr./min (= app. 5 %)

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200 m^3 / day needs app. 7.0 ltr./min (= app. 5 %)
300 m^3 / day needs app. 10.5 ltr./min (= app. 5 %)
400 m^3 / day needs app. 14.0 ltr./min (= app. 5 %)
500 m^3 / day needs app. 17.5 ltr./min (= app. 5 %)

5. Mounting of the agitator
The tangential agitator is delivered completely mounted by the supplier and needs therefore no closer description (pos. 27 chp. B; Figures # 5 and 21)

Optional: Mounting of an immersion pump:
Instructions:
- Check pump and support for completeness.
- For positioning the pump, check this:

A: If the digester has an inlet for solid waste, the agitator has to be set next to the inlet (flow direction away from inlet).

B: If the digester has not an inlet for solid waste, the agitator has to be set 2-3 m away from the gauge-glass to control it visually and to prevent soiling the glass. For mounting and maintenance the agitator should be easily accessible from the top. The agitator gets connected through the lighting opening. Watch out for sufficient cable length to the cabinet.

- Fix support with dowels to the digester wall. Watch out for sufficient cable length to the cabinet. The level in the digester should be 15 cm above the pump propeller (upper edge of propeller). The maximum digester level is given by the height of the 45° turn off (Y-piece), which leads to the ultimate disposal place.

-Adjusting angle
Turn the agitator as much away from the wall as is needed for the extended agitator axle to create a current covering 1/3 of the total area. Using a spacing frame, fasten the agitator to the wall in this position.

- Connecting cable
Pull cable through the beams to the lighting glass (nominal width 200 mm). Drill hole into beams with corresponding drill bit. Pull cable through screwed cable gland and screw it tight.
- Connect agitator according to electric scheme. Watch out for a correct sense of direction. Agitator blade will push, i.e. flow goes away from agitator!

6. EPDM gas foil:

Instructions
I. Preparation
- Finish wooden top.
- Finish top insulation and fix it to wooden top.
- Break outer edge of top insulation all around the perimeter (chamfer with a knife).
- Clean and dry Seeger circlip, break sharp edges on the transition to the concrete.

II. Mounting the gas foil
- Check out figure # 19.
- Roll out gas foil from the middle of the wooden top (pos. 46 chp. B).
- Roll out gas foil the way that it exceeds evenly the top perimeter.
- Pull out foldings; gas foil has to lie on the Seeger circlip without any folding.
- Keep sealing hose (pos. 47 chp. B) clean of dirt and lay it out along the circlip.
- Watch out that the overlapping ends of the sealing hose are at the inlet of the digester and that there is no gas foil seam there!
- Let escape air of the sealing hose, turn out valve.
- Starting from the closed end of the sealing hose, first push the gas foil into the Seeger circlip with your fingers. Then put in the sealing hose until it's completely laid into the circlip.

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- Overlap the two ends of the sealing hose at least 20 cm and tie them together with tape. Then put this part into the circlip, too.
- Pump the sealing hose up to at least 1 bar.
- Fasten excessive gas foil with wire or tape.

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Chapter B:
Parts list, material description, costs, source of supply

Note: This document has been prepared following Swiss standards. Additional requirements may be necessary to meet Ontario Regulations.

Parts and price list of a compact biogas plant, 400 m3 digester and 55 kWel cogeneration unit

Updated Aug. 02

Pos.	Quan-tity	Unit	Description	Material	Price per unit Cdn$	Total price Cdn$	Supplier	Own calculations	Remarks
			Digester						
1.0	400	m3	Concrete works 10 x 5 m without top Cdn$/m3 assumption concrete price 190.- Cdn$/m3	Concrete	56	22'400	Local contractor		Formworks, rein-forcement,concr.
1.1	160	hrs	4 men for help for 3 days		22	3'520	Internal labour		
1.2	100	m3	Earth works Cdn$/m3		8	800	Estimation	Costs depend on project	
1.3			Leveling (sand or lean concrete)			500	Estimation	Costs depend on project	
1.4	4		Leveling (gear and labour) Cdn$/hr		60	240	Estimation	Costs depend on project	
1.5	50	m	Drainpipe NW 100, only when necessary		2.25	113	Estimation	Costs depend on project	
			Insulation digester						
2.0	7.8	m3	Bottom insulation 100x600x2500mm (Cdn$/m3) 4 pcs/package	Jakodur 35-300 NF	159	1'240	Specialized dealer		
3.0	5.76	m3	Top insulation 1200x600x80mm (5 pcs/package)	Floormate 200	190	1'094	Specialized dealer		
3.1	600	pcs	Styrodur nails LT-nail 140x100 (more tape)	Plastic	0.608	365	Specialized dealer		
4.0	15.6	m3	Wall insulation 50x600x2500mm 8 pcs/package (Cdn$/m3)	Jakodur 35-300 NF	159	2'480	Specialized dealer		
5.0	28	hrs	Mounting Insulation 4 men 1 day		22	616	Internal labour		
			Pvc pipes for clearances						
6.0	2	pcs	Inlet liquid manure supply NW 125	Plastic	23.66	47	Local contractor		
6.1	70	m	Liquid manure supply line NW 125	PE PN 10	9.1	637	Estimation	Costs depend on project	
6.2		pcs	Liquid manure supply line pipe bend NW 125	PE PN 10		0	Estimation	Costs depend on project	
6.3	8	hrs	Mounting labour		22	176	Internal labour		
7.0	1	pcs	Outlet liquid manure NW 300	Plastic	70	70	Local contractor		
7.1						0			
7.2	18	m	Outlet pipe NW 300	PE		657	Specialized dealer		
7.3	div.	pcs	Pipe bends for outlet line NW 300	PVC		284	Specialized dealer		
7.4	div.	pcs	Pipe bends for outlet line NW 300	PE		361	Specialized dealer		
7.5									

be necessary to meet Ontario Regulations.

may

7.6	1	pcs	Y-piece for outlet pipe NW300	PE	524	524	Specialized dealer		
7.7	1.5	hrs	Mounting labour		22	33	Internal labour		
8.0	1	pcs	Clearance for gauge glass NW 300	Plastic	70	70	Energy&Environment		
8.2	1	pcs	Lighting glass with pipe	Pipe +plexi glass	247.80	248	Energy&Environment		
8.3									
8.4	0.1	hrs	Mounting labour		22	2	Internal labour		
9.0	1	pcs	Inlet lighting NW 200	Plastic	45.50	46	Energy&Environment		
9.1									
9.2	1	pcs	Lighting glass with pipe 250 mm	Pipe +plexi glass	209	209	Energy&Environment		
9.3									
9.4									
10.0	2	pcs	Inlet heating line NW 300	Plastic	70	140	Energy&Environment		
10.1	2	pcs	Inlet with 10 holes 28 mm	PE	147	294	Energy&Environment		
10.2									
10.3	1	pcs	Inlet heating lines cable gland PG 21	Plastic	0	0	Price included in pos. 13		
10.4	0.25	hrs	Mounting labour		22	6	Eigenleistung		
11.0	1	pcs	Clearance for excessive pressure valve NW150	Plastic	23.66	24	Energy&Environment		
11.1	1	pcs	High- and low pressure gauge NW 150	Plastic/glass	486	486	Energy&Environment		
11.2	0.5	hrs	Mounting labour		22	11	Internal labour		
12.0	3	pcs	Inlet gas line NW 100 (2 spare pieces) pipe	Plastic	10.50	32	Local supplier		
12.1	0.5	m	Pipe with bushing on one end NW100 9.20 Cdn$	HP	12	6	Local supplier		
12.2	1	pcs	Reduction piece NW 100 / 70	HP	7	7	Local supplier		
12.3	5	m	Pipe NW 100 (2 x 2m;1 x1m) 14.90 / Cdn$ 28.50 Cdn$	HP	9	45	Local supplier		
12.4	1	pcs	Pipe bends (1 x 90°) NW 100	HP	5	5	Local supplier		
12.5	2	pcs	Pipe bends (2 x 45°) NW 100	HP	5	10	Local supplier		
12.6	0.5	hrs	Mounting labour		22	11	Internal labour		
			Digester heating						
13.0	1	pcs	Digester wall heating incl. mounting set and distributor (8 loops, 1000m line)		2440	2'440	Local supplier		
13.1	20	hrs	Mounting digester wall heating		22	440	Internal labour		

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			Additional clearances digester						
14.0	1	pcs	Clearance agitator			0	Local contractor	Price included in pos. 1	
15.0	18	pcs	Clearances for support beams pos. 18	Styrodur	10.50	189	Local supplier		
16.0	1	pcs	Mounting Seeger circlip on wall top			0	Local contractor	Price included in pos. 1	
			Wooden parts in and around the digester						
17.0	1	pcs	Middle post (fir) D = 600 mm app. 5.2 meters		50	50	Own cut wood		
18.0	18	pcs	Support beams (100mm x 180 mm)		24	432	Own cut wood		
19.0	65	m2	Wooden top 5cm fir or pine		20.30	1'320	Own cut wood		
19.1	16	hrs	Mounting pos. 17,18, and 19		22	352	Own cut wood		
20.0	78	m2	Boards for casing 2 cm tamarack		17.50	1'365	Own cut wood		
20.1	90	m	Wire D= 5 mm with spanner 3 rings		1.40	126	Local supplier		
20.2	8		Mounting boards Cdn$/hr		22	176	Internal labour		
			Accessories desulfurization						
21.0	1	pcs	Dosing pump 0 -20 l / min		495	495	Energy&Environment		
22.0	1	pcs	Check valve (price incl. in pos.21)				Energy&Environment		
23.0	1	pcs	Flow meter 0-20 l (price incl. in pos.21)				Energy&Environment		
24.0	25	m	Desulfurization line, clear, 6x2 mm		1.50	38	Energy&Environment		
24.1	15	m	Desulfurization line rest from pos.13				Energy&Environment		
24.2	1	pcs	Reduction from pos.24 to pos.24.1		3	3	Energy&Environment		
24.3	1	pcs	Clearance glass gauge NW 200 screwed cable gland PG 13.5	Plastic	2	2	Energy&Environment		
25.0	1.25	hrs	Mounting desulfurization unit		22	28	Internal labour		
26.0									
			Agitator/Charging pump						
27.0	2	pcs	Agitator 7.5 kW (propeller agitator)		4000	8'000	Energy&Environment		
28.0									
29.0	12	hrs	Electric connection agitator 5.5 kW Cdn$/hr		40	480	Estimation		
30.0	1	pcs	Charging pump 2.2 kW DN 150		4740.00	4'740	Energy&Environment		
31.0	1	pcs	Control unit with timer incl. labour		700	700	Costs depend on project		
32.0	4	hrs	Mounting pump		22	88	Internal labour		

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			Cogeneration unit						
33.0	1	pcs	Cogeneration unit 55 kWel.		66948	66'948	Energy&Environment		
33.1	1	pcs	Shipping cogen unit 55 kWel. and accessories		1550	1'550	Energy&Environment		
34.0	0	pcs	Sound insulation hood		1670	0	Energy&Environment		
35.0	1	pcs	By-pass oil filter		376	376	Energy&Environment		
36.0	1	pcs	Oil filling device		565	565	Energy&Environment		
37.0	1	pcs	Gas control device		3465	3'465	Energy&Environment		
37.1	1	pcs	Spare gas valve		445	445	Energy&Environment		
38.0									
39.0	1	pcs	Heating distributor		4565	4'565	Energy&Environment		
40.0	1	pcs	Pressure expansion tank 200 l		577	577	Energy&Environment		
41.0	1	pcs	Fan incl. Duct for cogen unit		990	990	Energy&Environment		
41.1	1.50	hrs	Mounting fan and duct		22	33	Internal labour		
41.2	1	pcs	Digital Temperature display with 5 m cable premounted in control unit		270	270	Energy&Environment		
42.0	2.50	hrs	Premounting distributor and gas control device, setting cogen unit		22	55	Internal labour		
43.0	40.00	hrs	Connecting cogen unit: gas, heat, exhaust gas, power, fuel oil		40	1'600	Local supplier	Costs depend on project	
44.0	1	pcs	Accessories for connection cogen unit		825	825	Local supplier	Costs depend on project	
45.0			Connection cogen unit, electricien			6'500	Estimation	Costs depend on project	
			Storage gas foil/gas line						
46.0	1	pcs	Gas foil EPDM; 1.2 mm; D= 11.60 m		2795	2'795	Energy&Environment		
47.0	1	pcs	Seeger circlip for gas foil D =10.25 m		855	855	Energy&Environment		
47.1	1	pcs	Gas outlet connector		154	154	Energy&Environment		
47.2	1	pcs	Fire extinguisher and sulfure gauge		424	424	Energy&Environment		
48.0	2.00	hrs	Mounting gas foil (mounting Seeger circlip incl. in pos.1)		22	44	Internal labour		
49.0	50	m	Gas line 75 mm ND 8mm Cdn$/m		6	300	Energy&Environment		
50.0	4	pcs	90° G bend 75 mm HDPE		18	72	Energy&Environment		
51.0	14	pcs	Electronic bushing 175 mm HDPE		14	196	Energy&Environment		
52.0	1	pcs	T-piece; 75 mm HDPE		51	51	Energy&Environment		

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53.0	2	pcs	Reduction 75 mm / 63mm	HDPE	13	26	Energy&Environment		
54.0	1	pcs	Methylene chloride		15	15	Energy&Environment		
55.0	2	pcs	Isoflo coupling 63 mmx 2"		36	72	Energy&Environment		
56.0	2	pcs	63x 5.8mm		5	10	Energy&Environment		
57.0	1	pcs	Condensate pie and clamps		32	32	Energy&Environment		
58.0	1	pcs	Control duct D =800 incl. lid		472	472	Energy&Environment		
58.1	1.50	hrs	Setting duct		22	33	Internal labour		
59.0	8.00	hrs	Mounting gas line		22	176	Internal labour		
			Machine room 4x6 m (app., depends on project)						
60.0	24	m2	Concrete slab for machine room Cdn$/m3		25	600	Local contractor		
61.0	1	pcs	Cogeneration unit container		15342	15'342	Energy&Environment		
62.0	1	pcs	Shipping to Canada		4500	4'500	Energy&Environment		
63.0								Costs depend on project	
64.0								Costs depend on project	
65.0								Costs depend on project	
66.0									
67.0								Costs depend on project	
68.0									
69.0	35.00	hrs	Mounting		22	770	Internal labour		
			General things						
70.0	20.00	hrs	Transport/gathering of accessories von		22	440	Internal labour		
			Permits and engineering						
71.0			Construction guide/Engineering			14'000	Energy&Environment		
72.0			Construction permits			750	Estimation		
73.0			High voltage inspection permit			650	Estimation		
74.0			Commissioning			2'000	Energy&Environment		
			Total without PST			**192'813**			
			8.0 % PST			15'425			
			Total incl. PST			**208'238**			

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Chapter C:

Project outline (what should be there already)

It is assumed that there is an existing collecting dump (collecting all the manure from the farm and from outside) and that a charging pump can be mounted there. Further on it is assumed that for the construction of the biogas plant a space of app. 13 x 10 m is available. The spillway of the digester should lead to the ultimate disposal place at a steady decline.

The above-mentioned conditions have to be met if the capital investment of a compact biogas plant shall stay within the frame of discussion. The plant is designed the way that a co-digestion of additional organic substrate is possible without enlarging the plant (cogeneration unit and digester). A further discussion of the capacity of the ultimate disposal place and the heating system of the farmhouse is not provided in this manual.

Chapter D:

Instruction of commissioning of the digester:

1. Requirements

Digester is completely insulated and gas tight. High-pressure protection is filled with water. All pipes have to be connected and to be fixed tight in the digester. The agitator is mounted and connected. Heating system is filled with water and tested for leaks, including fore and back runs (connections have to be retightened after they warm up). The cogeneration unit is ready to start, fuel oil tanks are full.

2. Filling digester with water

Fill digester with water up to a level of app. 2.5 meters (150 m^3 at a digester diameter of 9 m). Heat water up to 40° C to provide a good climate for mesophile methane bacteria. This can take between 4 – 6 weeks, depending on the ambient temperature and the operating hours of the cogeneration unit.

3. Supplying liquid manure

20 – 25 m^3 of liquid manure can be added to the digester once the water temperature is high enough. The water temperature will drop by app. 10° C. Heat on and check gas production. The cogeneration unit can be started as soon as the content of methane has reached 30%. Bad gas quality can be dumped by the ball valve.

4. Daily supply of liquid manure

As soon as the gas production in the digester is at a steady rate the daily amount of manure can be added evenly distributed over the day (timer). Now the gas foil has to be gas tight in the Seeger circlip and no gas should escape to the atmosphere.

5. Commissioning agitator

The agitator has to start as soon as it is covered with liquid manure. The timer has to be set the way that liquid surface is in a circular movement and homogenous. There must be no flocks of solid materials. It has to be switched on at least twice a day.

Chapter E:

Full-time operation:

The digester has to be checked daily. This includes:

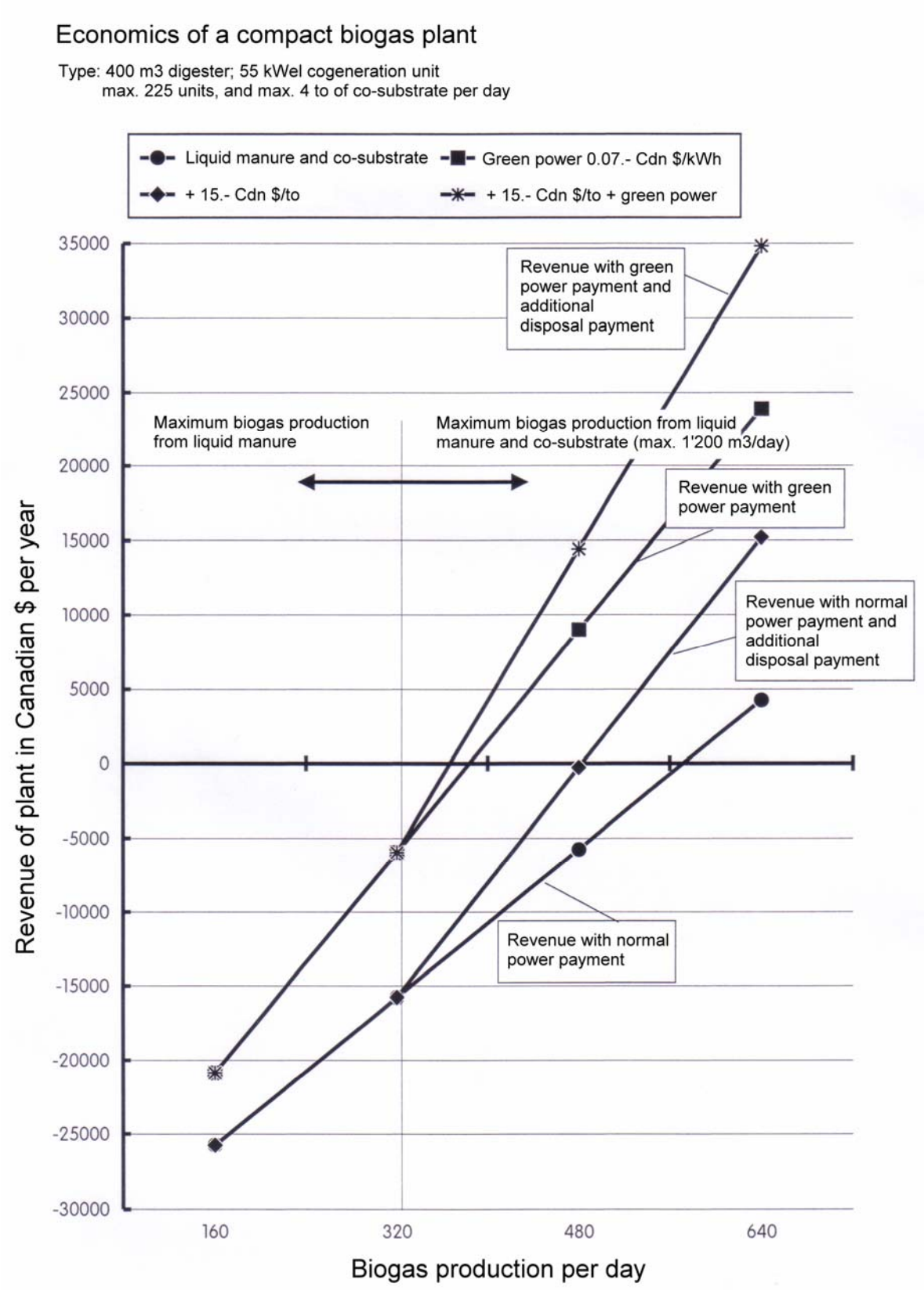
- Visual control of digester level / flocks of material (gauge glass)
- Checking the right amount of air injection of desulfurization (dosing pump)
- Checking the daily gas amount and cogeneration unit operation hours
- Checking front and back runs and digester temperature
- For operation and maintenance of cogeneration unit see separate manual of cogeneration unit (not included in this manual).

Note: This document has been prepared following Swiss standards. Additional requirements may be necessary to meet Ontario Regulations.

Appendix

Economic chart

Note: This document has been prepared following Swiss standards. Additional requirements may be necessary to meet Ontario Regulations.



Note: This document has been prepared following Swiss standards. Additional requirements may be necessary to meet Ontario Regulations.

Appendix

Additional pictures

Note: This document has been prepared following Swiss standards. Additional requirements may be necessary to meet Ontario Regulations.

Figure A1: Compact biogas plant “Flach”: Inside machine room

Figure A2: Compact biogas plant “Flach”: Outside View

Note: This document has been prepared following Swiss standards. Additional requirements may be necessary to meet Ontario Regulations.

Figure A4: Compact biogas plant “Grass”: Middle post

Figure A4: Compact biogas plant “Grass”: Inside digester view

Note: This document has been prepared following Swiss standards. Additional requirements may be necessary to meet Ontario Regulations.

Figure A5: Compact biogas plant “Flach”: Digester heating

Figure A6: Compact biogas plant “Flach”: Machine room from on top

Note: This document has been prepared following Swiss standards. Additional requirements may be necessary to meet Ontario Regulations.

Figure A7: Compact biogas plant “Flach”: Digester heating

Figure A8: Compact biogas plant “Flach”: Digester heating

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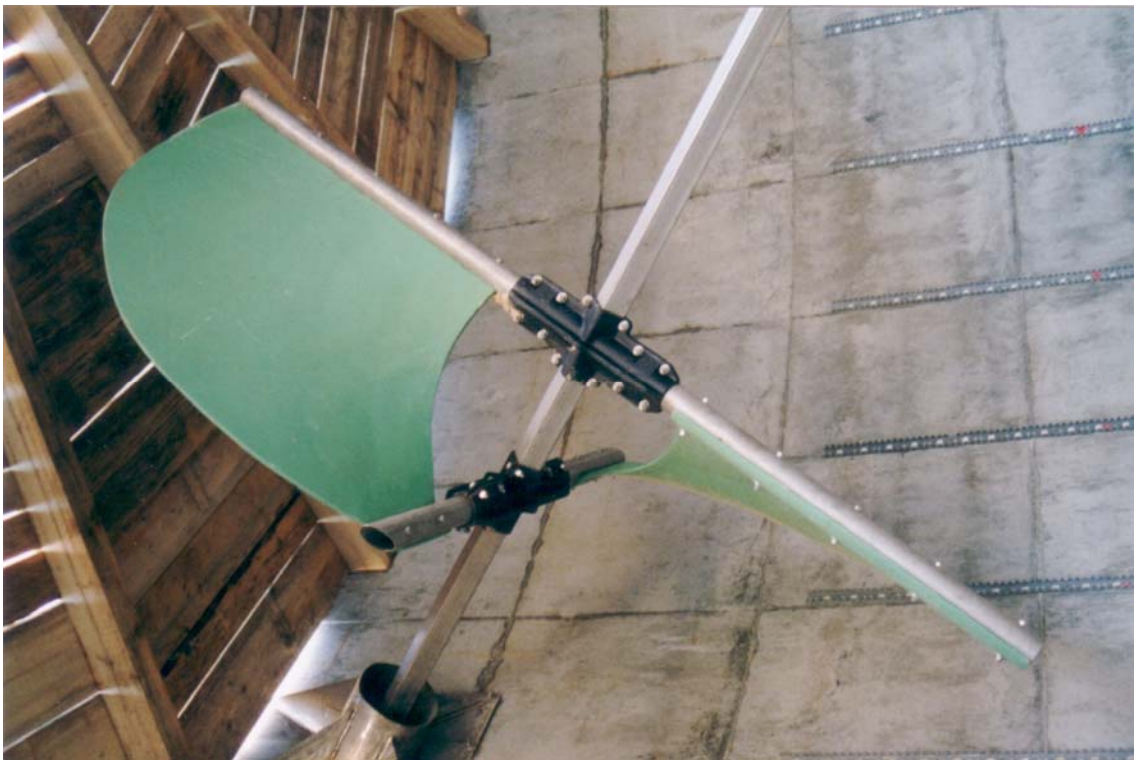

Figure A9: Compact biogas plant “Flach”: Agitator

Figure A10: Compact biogas plant “Flach”: Wooden top support beams

Note: This document has been prepared following Swiss standards. Additional requirements may be necessary to meet Ontario Regulations.

Figure A11: Compact biogas plant “Flach”: Spillway digester

Figure A12: Compact biogas plant “Flach”: Spare pipe machine room

Note: This document has been prepared following Swiss standards. Additional requirements may be necessary to meet Ontario Regulations.

Figure A13: Compact biogas plant “Flach”: Connections on wall

Figure A14: Compact biogas plant “Flach”: Heating distributor

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