through the combustion process and friction in the gas motor, heats the water to around 85˚C.

The produced heat makes up ±50% of the total energy. The heated water circulates through the main water line manifold to the TGL's inside the digester and towards two boilers situated inside the cheese factory.

The water line is an enclosed system, and the cooled water circulates through the engine heat exchanger to be heated yet again.

Electricity produced from the CHP is for own consumption only at this stage, and is not allowed to be fed into the Eskom power grid.

- Current gas production is 41 m^3/hr
- CHP's installed capacity is 75 kW
- Currently the project produces 834 435 kWh electric and 1 074 570 kWh thermal energy and is engine is running 8 760 hrs a year
- There is a plan to install additional 50 kW that will increase the capacity to 125 kW.
- After upgrading:
  - 75 kW engine will run 24 hrs a day
  - 50 kW will run only 8 hrs a day for peak shaving
- this will increase the total energy output to 2'300MWh per year

Cheese farm demand

The farm is supplied directly by Eskom under the Ruraflex Tariff which contains three components:

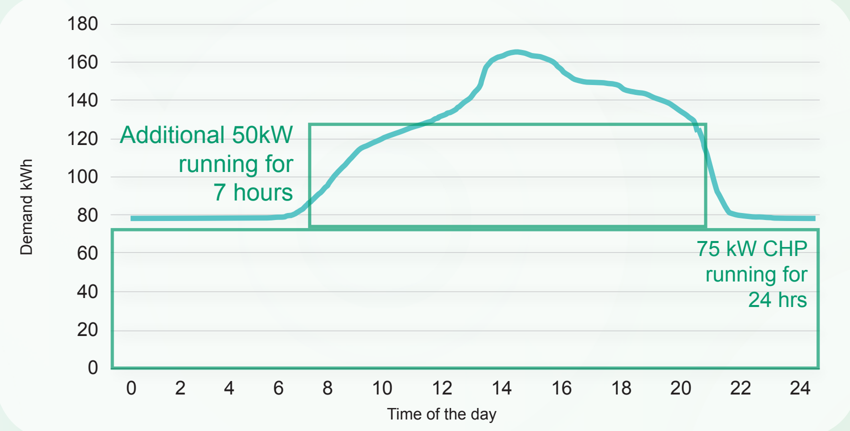
- Peak
- Standard
- Off-peak

The farm has a total electricity usage of +-120 000 kWh per month or 1 430MWh per year.

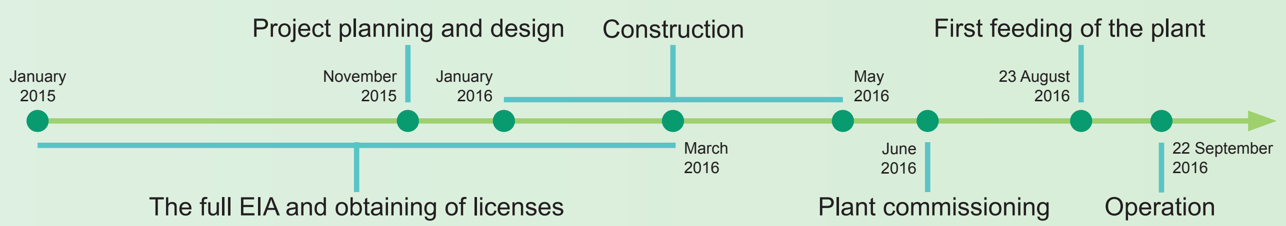
Electricity and diesel are used to preheat the water to generate steam which is used in the cheese manufacturing process. The hot water produced by the CHP will reduce the demand for the diesel boiler and electrical heating. Based on current indications and calculations it will be possible to generate around 58% of all the electricity and 70% of all the heat required.

Providing optimal quantity of organic feed to the digester is very important for achieving maximum biogas production. Providing the digester with less organic material which could be decomposed by microbes, results in a lower biogas production and therefore in insufficient biogas quantity for the CHP engine to operate optimally. Providing the digester with too much organic material which the micro-organisms can decompose, will cause the microbes to become unstable. This may cause process instability and acidification within the digester.

Electricity and heat consumption



Project timeframe



Employment factors

Number of persons employed during construction

12 persons for civil engineering *(of which 2 were specialists from iBert and 4 for water works)*

Number of permanent staff on site

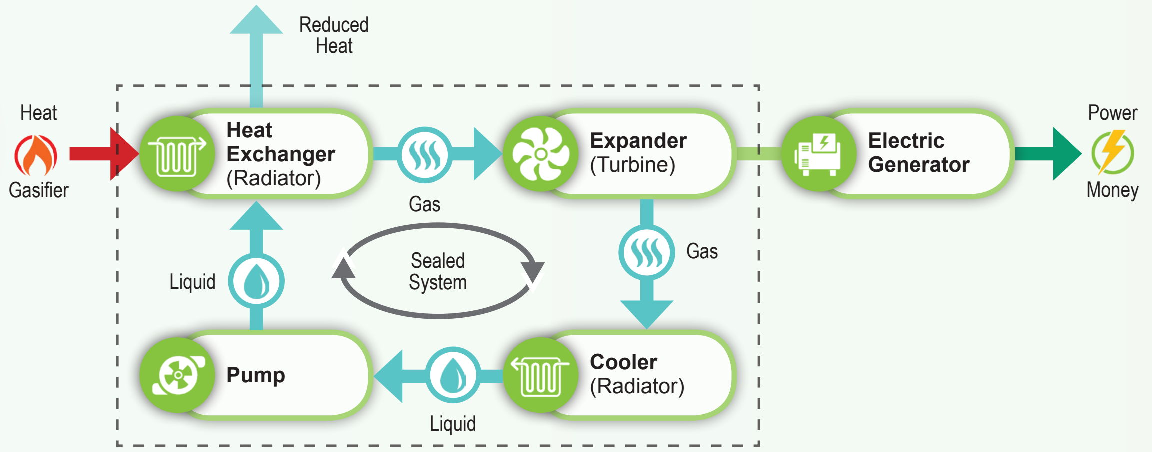
2

Way forward

In the future, if Eskom allows connection to the grid, there are plans to introduce the organic rankine cycle (ORC) as the plant produces too much heat which the client currently cannot make use of. The opportunity of adding abattoir waste from the neighbouring farm and building another digester is also being examined.

The Organic Rankine Cycle: ORC

The ORC converts heat to electricity using a temperature differential. The cycle uses an organic fluid that is high in molecular mass with a lower boiling point (point where liquid changes to vapour) than the water-steam phase change. The fluid allows for Rankine cycle heat recovery from the lower temperature source. The low-temperature heat is converted into useful work that can itself be converted into electricity. An advantage of implementing the cycle is that one can overcome the problem of high investment costs for machinery such as steam boilers, due to the low working pressures. Additionally, the working fluid unlike steam, is non-corrosive and non-eroding thereby ensuring longer machinery life span.



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Case Study

Zandam Farm Biogas CHP Plant

Figure 1: CHP container at Zandam Farm, Western Cape *Source: iBert*

Anaerobic digestion (AD) is a wide spread concept for the processing of organic waste and production of biogas. AD brings along advantages such as efficient waste management, own electricity and heat production, on-site use of the digestate produced via this process, and lowers your carbon footprint.

For several years now, South Africa is becoming increasingly aware of the advantages of AD technology. One of the pioneers in this area in South Africa is biogas technology supplier and turnkey solution provider iBert. The company started through the cooperation between the Austrian based Bio4gas Express Rector Technology Company (bert), the commercial leg of Innsbruck University, and South African energy specialist Mr Otto Hager.

iBert recently commissioned their 5th biogas pant in Zandam Farm, which is situated 18 kilometres east of Durbanville in Western Cape. The farm consists of a cheese factory (Zandam Cheese) and a piggery (Zandam Pork). A total of 6650 pigs produce around 22 tonnes of manure per day with 12% dry matter content. This manure forms the feedstock, and the substrate is fed into the biogas digester through underground pipes.

Figure 2: From left to right; storage tank, digester tank & CHP container *Source: iBert*

Biogas plant technology overview

The bio-digester system can be separated into four different divisions:

- the raw slurry storage pit of 30m³ (mixing pit),
- the digester,
- the storage tank, and
- the CHP engine container

The schematic overview of the process can be seen below:

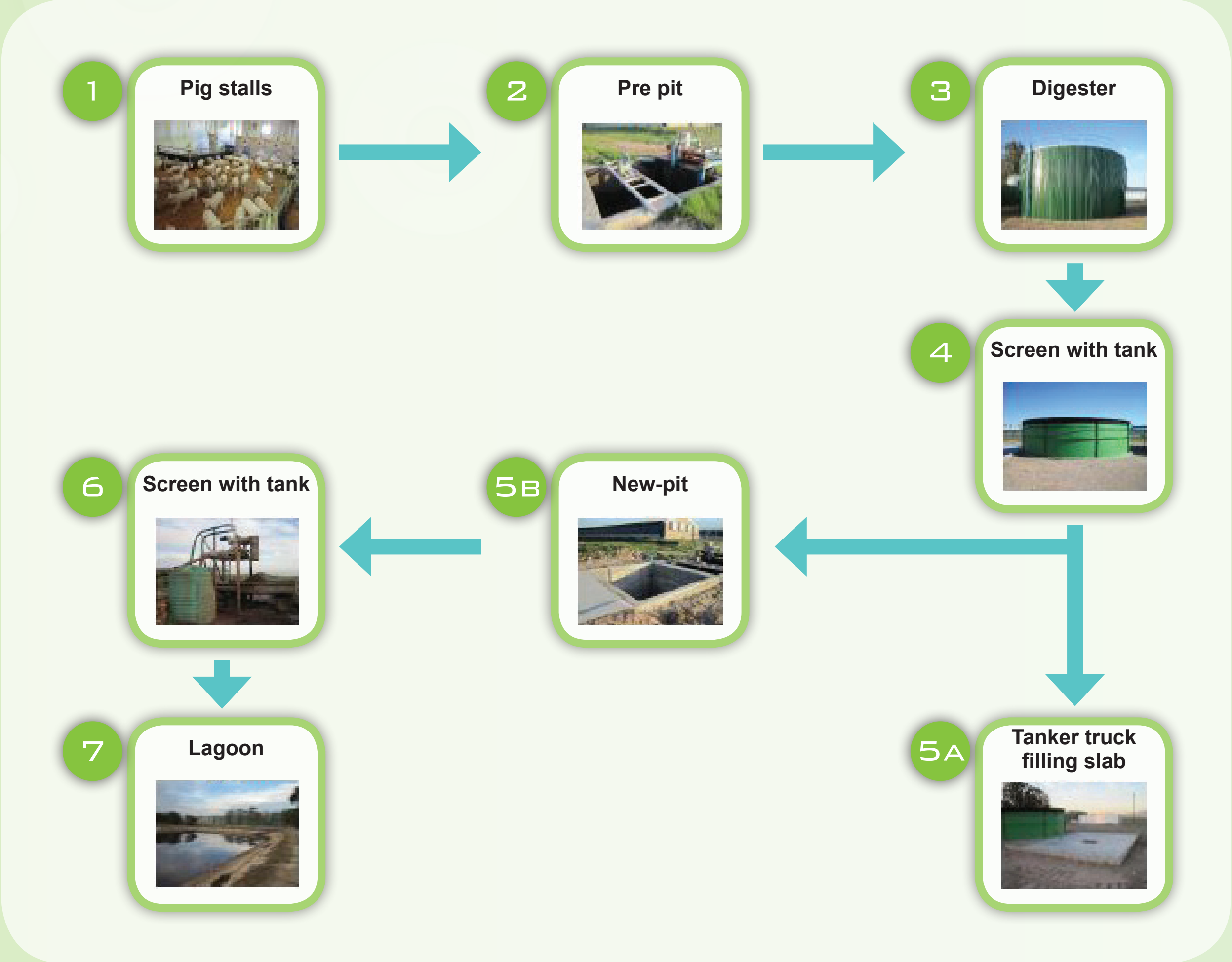


Figure 3: Bio-digester Slurry Cycle *Source: Zandam Operation Manual*

The digester is a Bert500; it has a total volume of 500m³ with a total slurry volume of ± 490.5m³. The digester is cylindrical in shape and consists of two chambers i.e. the outer chamber (chamber 1) and the inner chamber (chamber 2). The digester is equipped with three mechanical agitators (mixers with the capacity of 7.5kW), one on either side of chamber 1 rotating the material clockwise, and one mixer positioned close to the centre of chamber 2. The mixers are connected to a 6m vertical beam which is anchored to the roof and floor of the digester. The thermal gas lift (TGL), iBert's patent, is fitted in each chamber and serves the following purposes:

- **Provides heating:** the heated water circulates through the TGL to heat the slurry content to the desired temperature between 37-38°C (mesophilic conditions).
- **Provides effective mixing:** The warmest area at the top of the thermal gas lift, causes the colder slurry at the bottom of the digester to move upwards, through the centre of the TGL. This cause continuous movement which ensures proper mixing. Air blown in from the bottom also contributes to the (slurry movement) desulphurisation of the biogas.

The retention time of the slurry in the digester is 26 days.

The general principle is that the rate of chemical reactions within the digester increases with temperature. In the case of anaerobic digestion, it must be considered that the micro-organisms involved in the process have different optimum temperatures. If the temperature is above or below their optimum range, the relevant micro-organisms may be inhibited or, in extreme cases, suffer irrevocable damage. The micro-organisms involved in decomposition can be divided into three groups on the basis of their temperature optima. A distinction is drawn between psychrophilic <20°C, mesophilic 20°C - 40°C and thermophilic >40°C. The majority of familiar biogas-forming bacteria have their growth optimum in the mesophilic temperature. Biogas plants operating in the mesophilic range are the most widespread in practice because relatively high gas yields and good process stability are obtained in this temperature range.

The storage tank is a 200m³ steel tank, supplied with three mild steel pieces fitted together to produce the cylindrical shape. A gas level control sensor is fastened on top of the gas-dome, which is connected to the Hagl distribution board inside the CHP container, indicating the amount of biogas present within the storage tank. The effluent material (digestate/organic fertilizer) inside the storage tank is pumped to a tanker truck (10-20m²), or to the new pit from where it is screened. This organic fertilizer after being screened will have a total solids content of no more than 1-3%.

An important parameter for dimensioning the biogas digester is the hydraulic retention time (HRT). The HRT is the average time interval when the substrate is kept inside the digester tank. HRT is correlated to the digester volume and the volume of substrate fed per time unit.

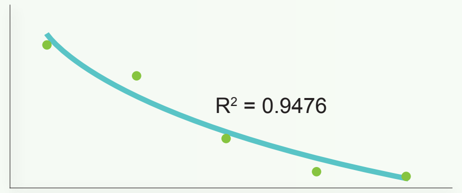


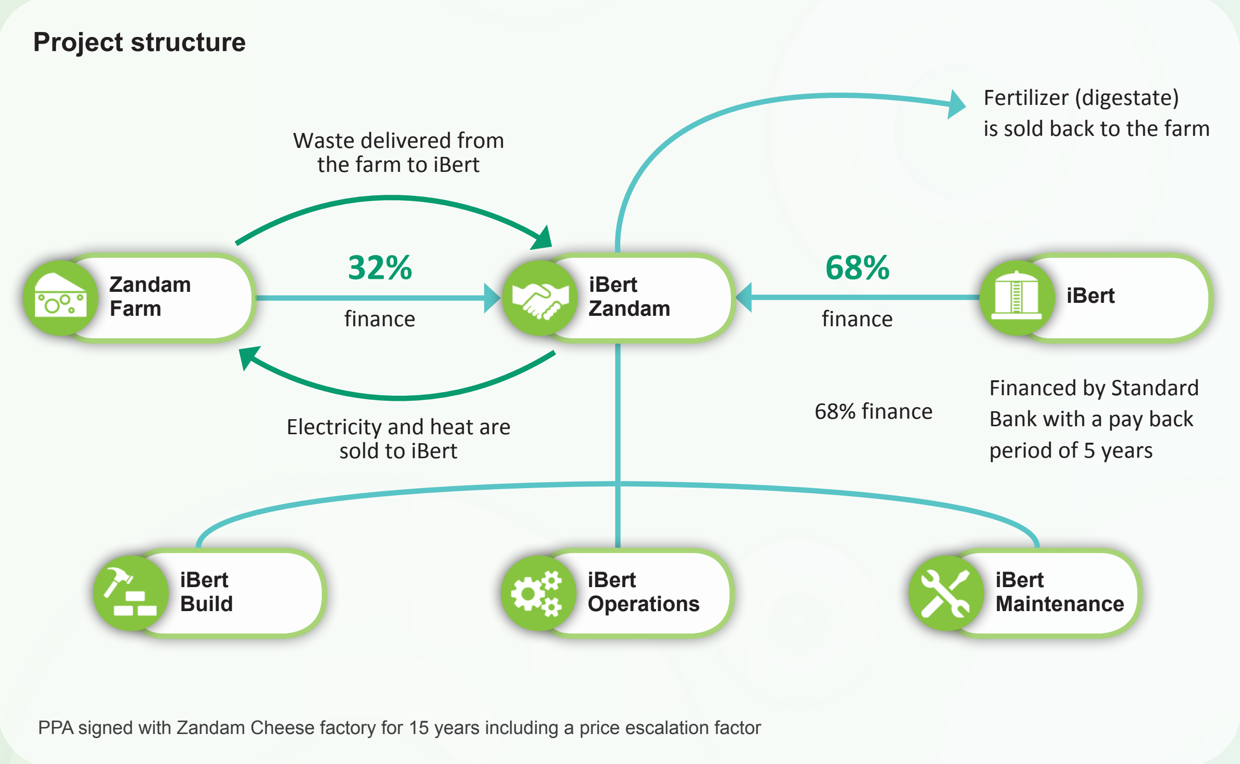
Figure 4: Storage tank
Source: Zandam Operation Manual

Project structure and finance

iBert is the turnkey supplier of the project and was in charge of the construction. iBert also does the operation and maintenance. Zandam supplies their waste to iBert, and iBert sells the heat and electricity produced from the combined heat and power (CHP) engine for in-house use. At this stage, feed-in of electricity to the Eskom grid is not allowed. Extra costs of 150000 ZAR was budgeted for the installation of protection devices for the Eskom grid, connected to the buzz bar of the farm. The protection device helps to regulate the electricity produced by CHP linked to the load of the farm.

The total cost of the project was 9.2 million ZAR. 32% of the investment came from Zandam and 68% was invested by iBert.

The digestate is sold to a nearby tomato farm.



Environmental Assessments and Licensing

A full Environmental Impact Assessment (EIA) was done therefore the waste license was included in the piggery license. No extra water is needed for the digestion.

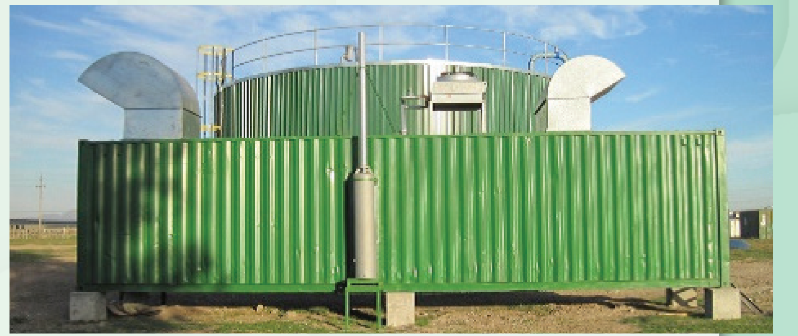


Figure 5: CHP container *Source: Zandam Operation Manual*

Electricity and heat production overview

CHP is the abbreviation for "Combined Heat & Power". It is a standard MAN diesel engine which is modified to run specifically on biogas. The biogas consists of around 60% methane and this is used by the motor as a fuel. Around 36m³/hr of the biogas is consumed by the engine.

The CH_4 gets burned inside the engine and produces mechanical energy through rotating a mechanical shaft. This rotating mechanism empowers a generator which produces electrical energy. The generator is a 75kW producing 75kWh when fully operated. The heat that is produced by the engine,