

## **MAS EL CROS BIOGAS PLANT. EVALUATION OF 18 YEARS IN OPERATION.**

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### **Abstract**

The biogas plant in Mas El Cros pig farm, Santa Pau, Catalonia - Spain-, was designed in 1981 together with the farm project. This fact made possible the plant, its management and maintenance, as an integrated element to the farm facilities.

The plant started up by the end of 1983. Supply to the farm heating system began in March 1984. During 1994 it was stopped in order to replace equipment affected with corrosion. Since 1984 to December 2001, the biogas consumption has been 710,397 m<sup>3</sup>. Average energy consumption for the maintenance of the digestion process has been 38.4% of the total energy output. The rest has covered an average of 45.9 % of the farm's thermal energy demand. The total saving in primary energy is estimated in 252 toe.

The scenario that explains that the biogas plant is still operative, and serving the farm after 18 years, is configured by the following facts: The construction of the biogas plant together with the farm (minimising investment costs); the conceptual simplicity of its design; the integration of all its elements as integral part of the farm; the maintenance and supervision tasks done by local technicians; and the global integrated vision of swine manure in the whole of the farm, as an energy and nutrients resource.

### **Background**

In summer 1981, the company Mas El Cros SA commissioned the engineers team “Tecnologies d’Aprofitament Solar” – TApS -, to develop the concept, the executive project, the building and assembly direction and the start up of a biogas plant for a breeding and fattening pigs farm, which was also in the stage of project in Santa Pau, Catalonia, Spain.

The aim of the plant was originally to cover the heating energy demand of the warehouse destined to births. The fact that the farm was under project was limiting in the sense that there were no data available about the quality and quantity of manure or about heating demand. Although, such conditions allowed certain advantages: deciding the right placement of facilities in order to minimise manure transportation costs; aesthetic integration within the building structure - important issue, as the farm is placed in a natural protected area; distribution of equipment to facilitate the integration of the biogas plant maintenance within the usual farm management practices.

These and other circumstances, such as possible increase in the number of pigs, future increase of energy demand, and maintenance methodology configuration, lead to choose the design criteria discussed further on.

### **Description of the farm**

In the first stage of building, breeding warehouses were assembled. They house the pigs in their different stages: pregnancy (I); births and lactation period (II) and first age (III). The average number of animals per warehouse has increased from 220 to 550 sows and from 500 to 1500 first age animals, since 1984 until 2001.

Warehouses consuming heating energy are births (II) and first age (III) - radiant floor plaques kept at 30° C-. Between both warehouses there is the control room, from which two boilers -gas and gas-oil -, feed the two heating circuits. Energy demand per warehouse is determined by air renewals, weight of housed animals and the outside temperature, showing a high dependence on minimum temperatures average. Gas boiler and gas-oil boiler worked in parallel until 1999. During 1999 boilers were connected in serial that has produced a decrease in thermal energy consumption

In a second stage of building, and as an enlargement of the first project, warehouses for fattening were built in similar features as the previous ones, with same sludge cleaning method but without heating energy demand.

Manure is evacuated automatically every 12 hours to pre-digester ditch, from breeder naves, and to 1000 m<sup>3</sup> general reservoir from fattening naves, by channels under slats. Feed production and composition, according to every physiological stage, and its transport to warehouses, is microcomputer controlled.

Two to four people (depending on the number of animals) take over the farm management, so the basic mechanical systems operating in the farm -energy and feeding- need to be self-controlled so as to keep the optimal conditions to manage the pigs on a continuous basis.

### **Design criteria**

Basic criteria used to design the biogas plant responded to the need to completely integrate the plant into the farm. So the common issues of a biogas plant had to be dealt within the framework of the whole farm.

1. A minimum possible effort is sought to transport sludge and gas, so digesters have to be near the pig warehouses and near the control room/boilers, observing also the current regulations regarding minimum distances between combustible gas production and storage facilities and lived in buildings.
2. In order to have a simple maintenance, the minimum use of mechanical elements to transport sludge is desired. Thus, gravity motion by means of 0.5 m wide pipes and a minimum slope of 6% was chosen.
3. The pigs are distributed in three types of warehouse, according to different needs for feeding, sanitary treatments, slurry characterisation and cleaning and disinfecting procedures.

Antibiotics are inhibitors of the methanogenic bacteria, and disinfectants can be toxic, so slurry don't have to be treated when their quality is influenced by the presence of disinfectants, antibiotics or an excessive cleaning water flow. This is achieved with a set of hatches at the pre-digester ditch entrance that allow derive the flow to the farm's general reservoir.

Nevertheless, it makes sense to distribute the manure coming from the three warehouses into three digesters, in order to decrease the incidence of any unbalancing element over the total gas production. This provides the advantage of keeping a different control in function of the number of existing animals in each warehouse, at every time -variation of the retention time by variable height overflows-. This distribution also presents the advantage of allowing cleaning of one digester during the summer, while the other two in service cover the low demand at this time of the year.

4. The farm is in an area with reported winter minimum temperatures of -10° C, so it is important to achieve a thermal stable design.

The solution was to build three integrated digesters –ditch with three compartments, separate external control, able to be linked when necessary- buried in a coating of volcanic sand, limited at the sides with clay and isolated with projected polyurethane.

5. It was desirable that the local technicians in charge of the rest of the farm's equipment could do the maintenance and eventual repairing. Thus, themselves carried out the plant building and assembly. Such decision envisaged –and achieved indeed- to make local technicians assume the project as theirs, and to simply and efficiently solve little problems. Otherwise, they would have not dared to intervene in a facility, which would have been globally strange to them.
6. Although it was expected to cover energy demand of warehouse II only, out of the manure produced in the three first naves, volume of digestion was not to be limited in order to allow:
  - a) To work with a retention time of up to 40 days, in case a need of depurating, stink removing and environment quality control demanded it.
  - b) To absorb manure from other warehouses in a later enlargement and cover other energy demands.

Since the end of 1984, the plant is fed also from warehouse III, and by the end of 1985, digesters feeding started to be supplemented with manure from fattening warehouses with the aim of increasing the gas production.

The different criteria, prompted by the surrounding conditions, lead to design a continuous system of mesophilic anaerobic fermentation and plug flow regime, with horizontal displacement and transversal pneumatic stirring.

### **Characteristics of the biogas plant**

Fig. 1 shows a scheme of the biogas plant, and Fig. 2 shows a general view. Building characteristics follow:

1. Raw material: swine manure from gestating pigs, mothers and first ages pigs until 1985 (average organic loading rate -OLR-:  $0.7 \text{ kg VS/m}^3 \cdot \text{day}$ ). Complemented with manure from the fattening stage until 1993 (average OLR:  $2.7 \text{ kg VS/m}^3 \cdot \text{day}$ ). Homogeneous mixture from all the integrated cycles till the present (average OLR:  $3.9 \text{ kg VS/m}^3 \cdot \text{day}$ ). Current flow rate:  $10\text{-}12 \text{ m}^3/\text{day}$ .
2. Separation of disinfectants and cleaning water: by hutches placed at the digestion pre-ditches.
3. Fermentation pre-ditches (3)
  - 3.1. Material: Reinforced concrete.
  - 3.2. Maximum capacity:  $12 \text{ m}^3$  each.
  - 3.3. Placement: Adjacent to the digesters and in serial.
4. Digesters (3)
  - 4.1. Material: reinforced concrete.
  - 4.2. Non-permeability: Inside lap with resins.
  - 4.3. Geometry: Parallelepiped.
  - 4.4. Inside dimensions:  $8 \times 3 \times 2 \text{ m}^3$  each.
  - 4.5. Available digestion volume:  $42 \text{ m}^3$  each.
  - 4.6. Insulation: 8 cm projected polyurethane coated with volcanic sand.
  - 4.7. Manure inflow: gravity fall from the pre-ditches, through  $0.25 \text{ m}^2$  ports on the structure base
  - 4.8. Heating: inside water/manure heat exchanger -  $24 \text{ m}^2$  EPD elastomer per digester,  $65^\circ\text{C}$  water fed.
  - 4.9. Average thermal energy consumption:  $0.25 \text{ MW} \cdot \text{h/day}$  (winter) and  $0.17 \text{ MW} \cdot \text{h/day}$  (summer).

4.10. Stirring: Intermittent timed gas re-circulation at  $0.4 \text{ kg/cm}^2$ , by gas blower with 7 kW flameproof engine. Average energy consumption for mixing:  $2.5 \text{ kW}\cdot\text{h/day}$ .

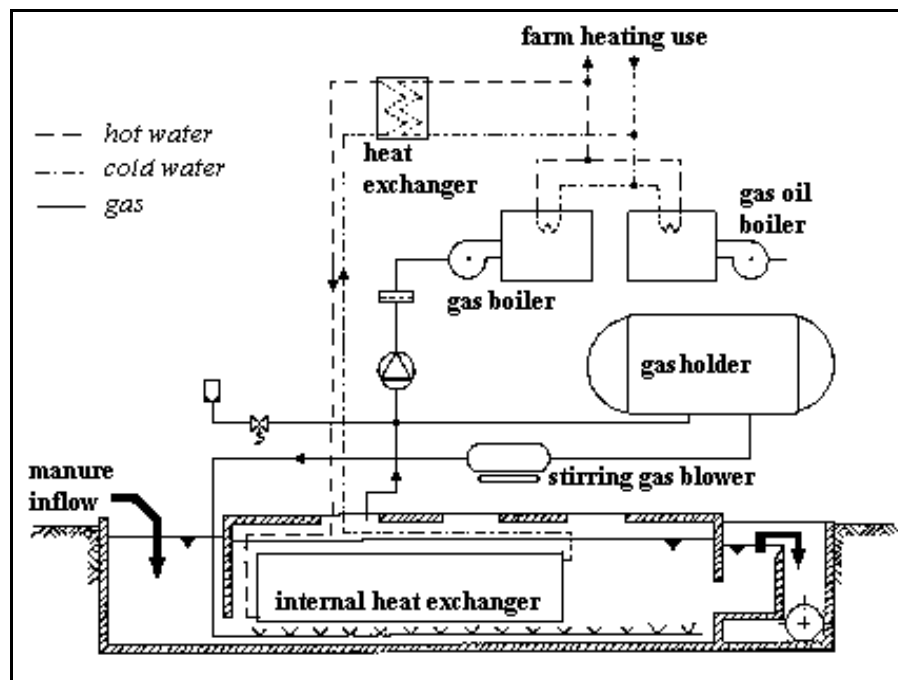


Fig. 1.- Biogas plant flow chart



Fig. 2.- A view of Mas El Cros biogas plant

## 5. Gas circuit

- 5.1. Storage: Flexible gas-holder with a capacity of  $35 \text{ m}^3$ . Maximum work pressure: 45 mbar.
- 5.2. Maximum working pressure control: 3 safety valves –independent control per digester-, with variable water column height. Working pressure: 30 mbar. Protection against frost.
- 5.3. Gas drive to the boiler: by 0.2 kW gas blower, flameproof.
- 5.4.  $\text{SH}_2$  removal: With iron oxide, with an average reduction of 60 %.
- 5.5. Gas quality: variable between 62.5% and 70%  $\text{CH}_4$ .

## 6. Heating circuit

### 6.1. Gas boiler:

Thermal fluid: Water

Service water temperature: 65° C

Nominal gas consumption: 10 m<sup>3</sup>/h

Burner inlet gas pressure: 10 mbar.

6.2. Digesters heating: Heat exchanger water/water between warehouse heating circuit – 3 bars – and digesters heating circuit – 1 bar.

6.3. Fermentation temperature: 35°C. During winter, temperature is fixed at 28°C, since 1994, to minimise the relation thermal self-consumption / production.

### **Evaluation of 18 years in operation**

On November 28th 1983 digesters were started up, and it began to produce low quality combustible gas in the last week of December. At the end of January 1984 they reached stable operation. Once the adjustment and modification works done and the gas burner adjusted, on March 10th 1984 heating energy supply to the farm started. During 1984 the available digestion volume was variable, and it was operated at retention times between 15 and 40 days. An average of 29 m<sup>3</sup>/day manure proceeding from the birth and first age warehouses was treated (1). During that year, gas consumption was 8,212 m<sup>3</sup>, and average year energy savings were 28.7%.

At the end of 1985 retention time was around 15 days, with complementary manure from the fattening warehouses, with an appreciable increase in the production (2). Since 1995 feeding has been done with a homogeneous mixture of farm manure with a higher content of organic matter.

During 1994 the system was completely stopped in order to examine the state of the facilities, the detailed historical analysis and the comparative of the farm energy system without the biogas input. In 1995 the system was restarted, and the parts damaged by use and corrosion were replaced.

During 1984 a methodology was established for the daily follow-up of the facility, having complete daily operation data since summer 1984. A summary of the period January 1985 – December 2001 (204 months) is presented below.

#### *Gas production*

Biogas consumption has been 710,397 m<sup>3</sup>. This coincides with the digesters production, except for the summer months in some years, when there's a surplus gas output. When this happens, gas is expelled to the atmosphere through the safety valves. The expelled gas is not measured in order to prevent obstruction in the safety line.

Output or consumption present daily and monthly variations (see Fig. 3). Monthly variations depend on digestion temperature, which depends on the environment temperature. Some days minimum temperatures less than –5°C have been reported, then thermal energy self-consumption is higher than energy output.

The increasing tendency in production, that can be appreciated in Fig. 3, is due to the increase of manure coming from the fattening stage and the increase on organic loading rate.

#### *Self-consumption energy*

Energy contribution for the plant maintenance has been 1,250.4 MW·h, of which 44.8 MW·h have been electrical energy. In terms of final energy, the output percentage has been between 26,2% (1994) and 67,2% (1985), with an average of 38.4%.

The heating energy consumption presents peaks in winter (see Fig. 4), so during the coldest months digesters are kept at 28°C since 1994. Since then, self-consumption energy average is 30.7%.

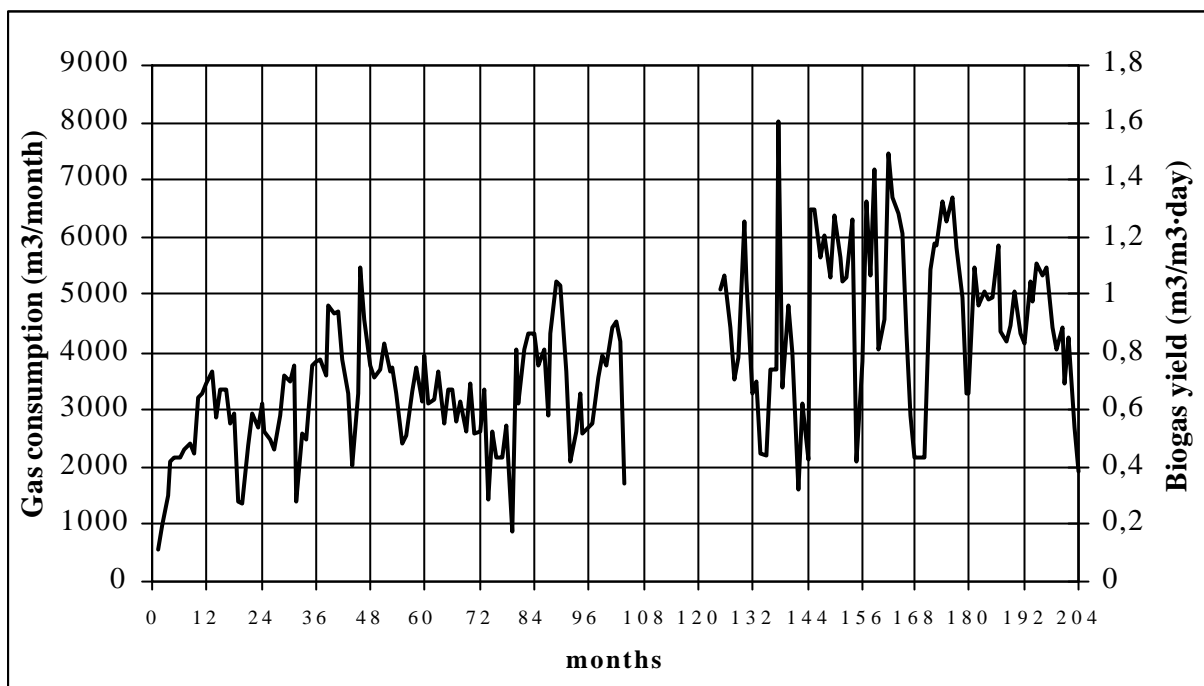


Fig. 3.- Approximate biogas yield and biogas consumption (1985-2001). Output coincides with consumption, except for the summer months.

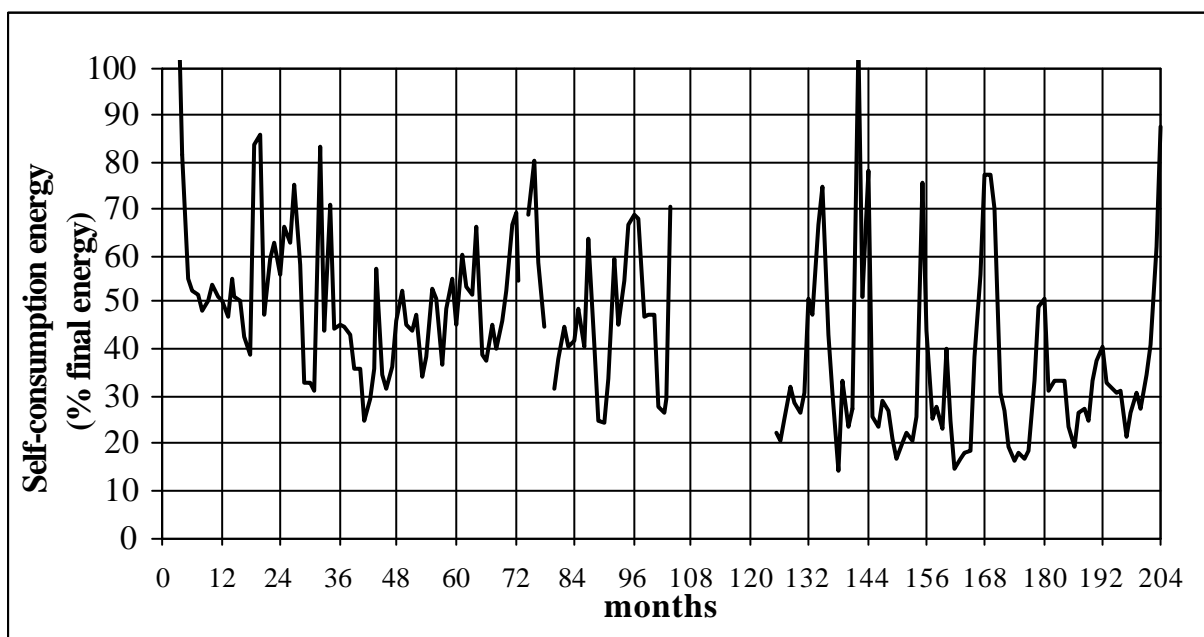


Fig. 4.- Evolution of thermal and electrical energy consumption rates for the digester maintenance, relative to the final energy output (1985-2001)

#### *Energy contribution and saving*

The warehouses heating energy consumption during the period 1985-2001 has been 4,659.4 MW·h, in final energy units. Biogas net contribution, taking off thermal and electric self-consumption, as well as boiler losses, has been 2,008.5 MW·h. The average net contribution of

biogas has been 43.1% during this period, moving between 30.5% (1993) and 63,1% (1989). Taking off year 1994, when the biogas plant was stopped, net contribution has been 45.9%.

Fig. 5 indicates the monthly consumption of the period. Consumption peaks coincide with low temperature months, and first age warehouse top occupation. The big increase in 1998 and 1999 coincides with an increase in capacity of this warehouse. Another building was added in December 1998, which meant an increase from 1000 to 1500 pigs in these two years.

The primary energy saving is assessed in about 252 toe (tonne oil equivalent).

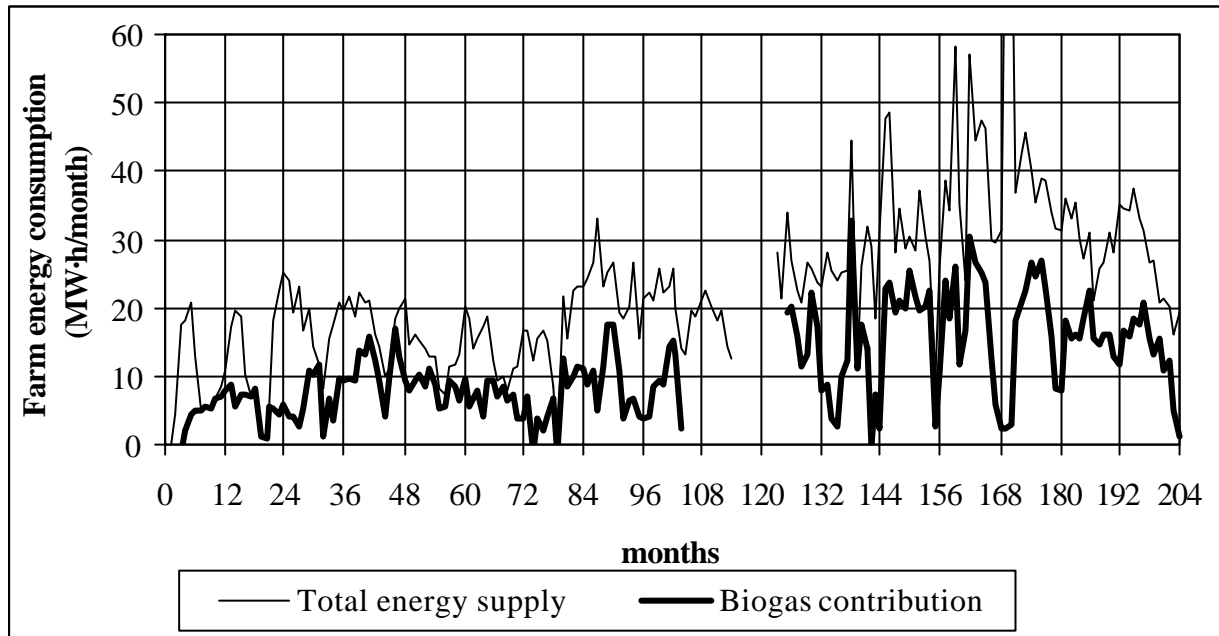


Fig. 5.- Evolution of the warehouses thermal energy supply and net contribution of biogas, in final energy units –MW·h/month - (1985-2001)

#### *Maintenance*

Maintenance is in charge of local technicians (electricians and handymen) who took part in the building and who are in charge of the farm's facilities maintenance. Thus, they are familiar enough with the system in order to solve any problem without having to turn to specialised engineers.

The fact of integrating the control systems to the farm heating system, allows an easy management from the farmers, with few minutes of daily dedication.

No serious problem has happened throughout the plant's life so far. At the end of 1993, the system was stopped, at first because of a gas leak in the flexible gas-holder, which had simple solution. Then the opportunity was taken to replace the parts that presented corrosion and jeopardised the facility operating capacity: 40% of gas and heating circuit valves, 30% of the copper pipes and the gas boiler.

Usually, during August, digesters are stopped sequentially for their cleaning. Starting up of digesters is done later with digested manure proceeding from the operating digesters, which allows a starting up time of 15 days.

#### *Other considerations*

In 1989 a comparative economic analysis between different biogas plants in Catalunya was carried out. Plant at Mas El Cros presented an internal income rate of 4% (3). Since then, no further detailed economic analysis has been done, but the investment costs, together with the maintenance costs, is less than the economic equivalent of the accumulated energy savings.

In a classical economic analysis, other benefits appreciated by the property are not taken into account: decrease of stink, manure mineralising, partial manure cleansing, and, in general, contribution to diminish the farm's environmental impact. The owner considers these aspects in a qualitative way as biogas plant benefits of concern.

On March 2002, the farm has been awarded by the Energy Council of the Autonomous Government of Catalonia –Spain-, for its contribution to energy saving and for the longest biogas plant operation in the country.

### **Manure integral management**

During 1992 and 1993 a farm manure management plan was done (4), which included a planning of application to crops, with adequate dosage and time, in order to minimise the impact on soil and water, and maximise manure use as fertiliser.

The farm's agricultural surface is mainly used as pastures for a cattle ranch. No sanitary or production problem has ever arisen due to manure use. Manure is injected. Pasture is *Bromus catharticus*, with a fast growth and high nitrogen fixation. Exceeding manure is used in neighbour farms upon request.

The integral management carried out during years has motivated the visit of many advanced courses students from different European Universities. The farm receives visit applications from different public and private companies. It can be considered that the farm has developed an important illustrative and pedagogical task about environmental management and use of residues, as source of energy and nutrients.

### **Global evaluation**

In the farm Mas El Cros, manure is considered as an economically valuable sub-product, as source of energy for the warehouse heating, and as nutrient source for pastures and to feed a cattle breeding ranch. The success of the biogas plant, with more than 18 year's operation, is mainly due to farm owner's global view of the productive cycles.

Building the biogas plant together with the farm (minimising the investment costs), the conceptual simplicity of the design, the integration of all elements as substantial part of the farm, not as a different facility, maintenance and supervision by local technicians, together with the global and integrated view of manure within the farm, make up for the right scenario to explain that, after 18 years operation, the plant still goes on serving the farm, and providing an example of sustainable waste management.

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