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"Gasification plants for agriculture: test results"

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GASIFICATION PLANTS FOR AGRICULTURE: TEST RESULTS

Summary

Work was carried out to evaluate the technical and operative performances of five gasification plants for farms use (heat and electricity generation).

Each gasifier was tested under variable conditions recording several operating parameters.

Results confirm that the updraft solution performs satisfactorily only when fuelled with charcoal. Downdraft gasifiers, suitable for biomass, had, in electricity generation, an interesting specific consumption near the maximum electrical output; in heat generation, gasifier efficiency was 65-75%. All plants tested posed some problems concerning gas purification.

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FOREWORD

Rational application of renewable energy sources on the farm requires careful evaluation of the quality and quantity pattern of the farm's energy demand. In fact, since the cost of all renewable energy sources is significantly higher than that of conventional energy of fossil origin, the energy supply should closely match the demand pattern so as to maximize utilization without expensive storage systems.

With specific reference to electricity generation, the technologies at present having a more favourable cost/benefit ratio are biogas production from animal waste, micro-hidraulic and vegetal byproduct gasification.

The former specifically finds its optimum utilization when the electricity demand is constant with time and therefore matches biogas supply. The second solution, directly connected with water availability, is suitable for mountainous or hilly regions and for relatively constant and small loads. When, as is often the case on a farm, energy demand swings widely during the day or during the year, a gasifier fuelling an electric generating set undoubtedly makes better sense. In this case, in fact, energy is stored as biomass, which is much easier and cheaper to store than other forms of renewable energy, and the plant can be run only when energy is actually needed.

Based on the above, exhaustive experiments were run on gasifiers of various types, having different technical and operational characteristics, to evaluate their performances and assess their actual usefulness to agriculture.

1. PLANTS DESCRIPTION

The plants tested break down into three main groups: downdraft gasifiers, updraft gasifiers and fluidized bed gasifiers. Specifically, main characteristics of five gasification plants are:

PLANT (A) (electricity generation)

* Manufacturer : S.E.S. (Italy)
* Gasifier : downdraft type
* Feeding : manual
* Gas purification system : dry and wet scrubbing
* Engine : Otto, 4,800 cm^3
* Electric generator : asynchronous, three-phase, 25 kVA, 220-380 V, 50 Hz, 1500 rpm

* Utilized fuel	: chopped wood, hazelnut shells, corn cobs
* Gas output	: up to 50 Nm^3/h (55,000 Kcal/h)

PLANT (B) (electricity generation)

* Manufacturer	: Fritz-Werner (FRG)
* Gasifier	: downdraft type
* Feeding	: automatic by conveyor belt
* Gas purification system	: dry and wet scrubbing
* Engine	: Otto, 5,650 cm^3
* Electric generator	: asynchronous, three-phase, 33 kVA, 220-380 V, 50 Hz, 1500 rpm
* Utilized fuel	: woodworking residues, corn cobs, grape seeds, sawdust briquetts, choppedwood
* Gas output	: up to 100 Nm^3/h (110,000 Kcal/h)

PLANT (C) (gasification only)

* Manufacturer	: Institute of Agricultural Engineering, Milan (Italy)
* Gasifiers	: updraft type
* Feeding	: manual
* Gas purification system	: dry
* Utilized fuel	: charcoal, as is and in ovules
* Gas output	: up to 30 Nm^3/h (35,000 Kcal/h)

PLANT (D) (heat generation)

* Manufacturer	: Del Monego (Italy)
* Gasifier	: downdraft type
* Feeding	: automatic by conveyor belt
* Gas purification system	: dry
* Utilized fuel	: chopped wood, maize cobs, sawdust briquetts
* Gas output	: up to 180 Nm^3/h (200,000 Kcal/h)

PLANT (E) (heat generation)

* Manufacturer	: Fuel Research Station, S. Donato Milanese (Italy)
* Gasifier	: inert fluidized bed
* Feeding	: automatic by screw conveyor
* Gas purification system	: dry and wet scrubbing
* Utilized fuel	: sawdust, grape cake, olive husks, grape seeds, chaff
* Gas output	: up to 30 Nm^3/h (35,000 Kcal/h)

The above plants represent different approaches, since types (A) (fig.1) and (B) (fig.2) are of medium to high technological level, plant (A) is more sophisticated, being equipped with a pneumatic filter-cleaning system, forced draft gas cooling and automatic feeding system with a load cell which controls fuel supply; (C) (fig.3) is a very simplified and cheap plant, suitable to exploit the significant mass of currently non-utilized charcoal dust in the developing countries; (D) (fig.4) is suitable for large heat demand, and (E) (fig.5) can be bulk-fed with any small-sized byproducts (oil residues, rice chaff, wood working residues) which could not be used in a downdraft or updraft gasifier without expensive briquetting processes.

2. RESULTS

Protracted operation (some 200 h) of the five prototypes led to the following conclusions concerning utilization and typical problems.

Gas quality: with the downdraft gasifiers, gas composition and heat value scarcely vary with the type of fuel, provided the latter is of a lignocellulosic nature and its moisture content does not exceed 15-18% by weight; fluidized bed gas analysis are comparable with the ones of downdraft plants, while some differences exist for updraft gasifier fuelled with charcoal (table 1). Load variations and consequent air intake rate variations of the reactor are of limited influence. Heat value swings from 900 kcal/Nm^3 to 1,250-1,300 kcal/Nm^3.

Gasifier efficiency: in plants for electricity generation (A-B), specific fuel consumption (biomass with 12-15% moisture content), varies from 2.2 to 1.3 kg/kWh, depending on the load; when running at 20-30% of maximum rated load, consumption lies around 2 kg/kWh, while it drops to some 1.3 kg/kWh at 90-100% of maximum rating (fig.6); updraft gasifier gas production is 4.5-4.8 Nm^3/kg of charcoal. In all the plants tested gasifier efficiency varies from 68% to 75%.

Char build-up: it depends on biomass type and size; with wood of optimum size for the gasifier, char drops to a minimum (2-3%), and increases with nutshells and the like (4-5%).

Generator set efficiency: the efficiency of the gas-electricity conversion ranges from 13% minimum to 23% maximum when the load goes from 25-30% to 90-100% of rated load; when accounting for gasifier efficiency, the overall efficiency (electric power output/biomass energy input) lies between 9-10% minimum and 19-20% maximum, with low moisture, optimum size biomass.

Tar and oily matter build-up: with the downdraft technique, build up of heavy oily matter (mostly of a phenolic nature) is significantly reduced. In fact, the vapours and distilled matter flow through the oxidizing zone, where they are cracked and converted into permanent gases. With the updraft technique instead, useing biomass, a large amount of watery and oily vapours rich in acid, alcohol and phenolic compounds takes place, connected with operating problems. Therefore, the results confirm that the updraft solution is suitable for the gasification of charcoal having low volatile matter content

(6-8% against 70-75% of usual biomass). Because of the low pyrolysable matter content, the gas is relatively clean. When air is fed under the stoker, the ashes come in contact with highly oxidizing gas and the metals of the salts contained in the ashes (sulphates, silicates, carbonates, bicarbonates, etc.) remain in the oxidized (maximum valence) state and have high melting temperature. With the downdraft technique instead, the ashes are in permanent contact with strongly reducing gas; the salt metals tend to go over to a lower valence (sulphates to sulphides, oxides to metals), and form low-melting eutectics, mostly consisting of alkaline salts, with consequent softening and caking of the gasification residues, which tend to clog the air path.

Efficiency of the purification and cooling system: all the gasifiers tested posed some operating problem concerning gas purification. None behaved regularly, without clogged filters, scrubber cyclons or bags and consequent, sometimes large increase of pressure drop of the gas flowing through these devices. Further, in plants equipped with washing and cooling water system and fuelled with nitrogen-rich biomass (such as briquetted grape seeds), corrosion sets on in the wet coolers due to the build-up of ammoniacal condensates that attack metals (table 2).

Remarks on fluidized bed gasifier operations: the temperature profile within an inert fluidized bed is very uniform (as compared with the fixed-bed gasifier) in consequence to the large heat exchange generated by the rapidly moving solid particles.

However, the mean bed temperature is at least 200 °C lower than that obtainable in the downdraft system, and the esothermal reactions developing CO and H_2 are not as strong.

For equal combustion air/fuel ratios, owing to the lower temperature, the biomass yields 10-20% less gas. The gas has slightly poorer quality, its heat value is lower (some 1,000 kcal/Nm^3) and density greater. The heat value can be raised to 1,200-1,300 kcal/Nm^3 by running at lower air/fuel ratios (enrichment with heavy hydrocarbons); in this case however, the combustion residues grow to some 15% of biomass, with a negative effect on the gasification efficiency.

3. CONCLUSION

Notwithstanding the problems encountered, which show further development work to be needed, the operating characteristics of the plants tested prove gasification to be of viable interest. During the tests the plants showed fair overall efficiency, and, when fed with the proper fuel, ran reliably and without interruption. In particular, electricity generating plants of 25-30 kW rated power appear to be sufficiently suitable for farm use.

Other aspects to be considered are the design of rational chains to feed the plants with biomass of suitable physical and dimensional characteristics and a study of the time required for plant operation and maintenance under continuous service conditions.

As regards this problem, plant B has been installed in a dairy farm (S.Cosimo Farm - PV) one year since, to supply breeding electrical demand (milking parlour, cowshed). Gasifier is fuelled with woodworking residues (42 US$/t and 15-18% moisture content) and produces 100-120 kWh/day running for 5.5-6.0 h/day.

The production cost of electricity - considering only the running costs - is, in this case, about 20-25% higher than national grid price. Considering the total costs of the plant, on the contrary, the production cost is very high (3.5 times than grid price) as shown in fig. 7.

The fluidized bed type instead is of greater manufacturing and operating complexity and is better suited for large power plants.

REFERENCES

(1) BODRIA L., FIALA M., (1985), Energia elettrica da residui vegetali: primi risultati di prova di un impianto di gassificazione - Rivista di Ingegneria Agraria, (in printing)

(2) BODRIA L., FIALA M., LAZZARI M., (1985), Principali parametri di funzionamento di un gassificatore semplificato per carbone di legna - Rivista di Ingegneria Agraria, (in printing)

(3) GARRETT D.E., (1979), Conversion of biomass materials into gaseous' products - 6th Biomass thermoconversion contractors' meeting, Tucson, Arizona, 1.

(4) REED T.B., (1979), Survey of biomass gasification (voll. I, II, III) - S.E.R.I., Golden, Colorado, 7.

Table 1 : Gas analysis

GASIFIER	GAS COMPOSITION (% in vol.)					
	H_2	CO	CH_4	CO_2	N_2	O_2
Downdraft	10-18	15-20	1-2	8-12	45-58	2-5
Updraft	4-5	25-30	.1-.3	4-10	59-64	.5-1.0
Fluidized bed	7-10	12-17	3-4	13-15	53-58	5-6

Table 2 : Some chemical characteristics of washing water in wet coolers after 10-15 hours of plant running

BIOMASS	CHARACTERISTICS			
	pH	TC (mg/l)	TOC (mg/l)	NH_4^+ (g/l)
Corn cobs	11	12,000	2,800	12.7
Wood	8.5	4,650	1,100	5.7
Sawdust briquetts	9	1,500	250	1.5
Chopped wood	8.5	4,125	2,380	3.1
Grape seeds briquetts + woodworking residues	11	13,000	10,600	11.4

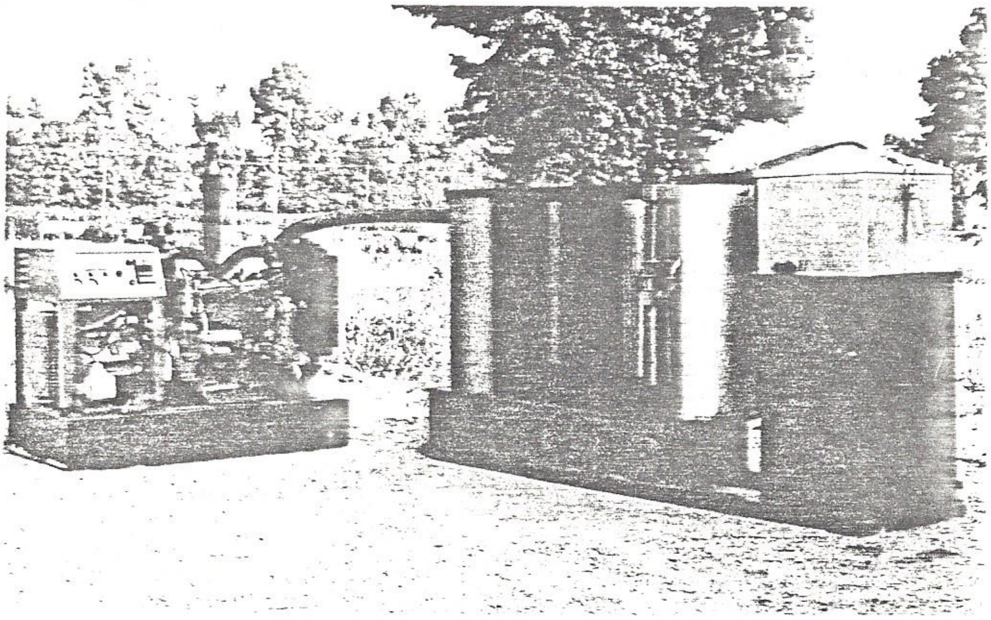

Fig. 1 - Downdraft gasifier (plant A) for electricity generation (S.E.S.)

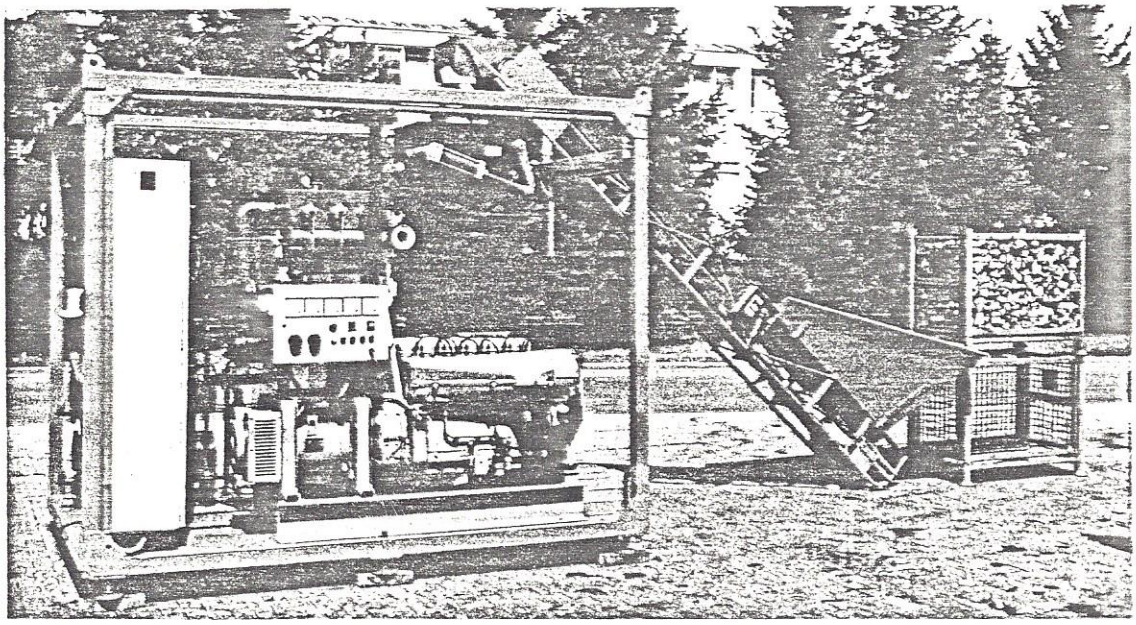

Fig. 2 - Downdraft gasifier (plant B) for electricity generation (Fritz-Werner)

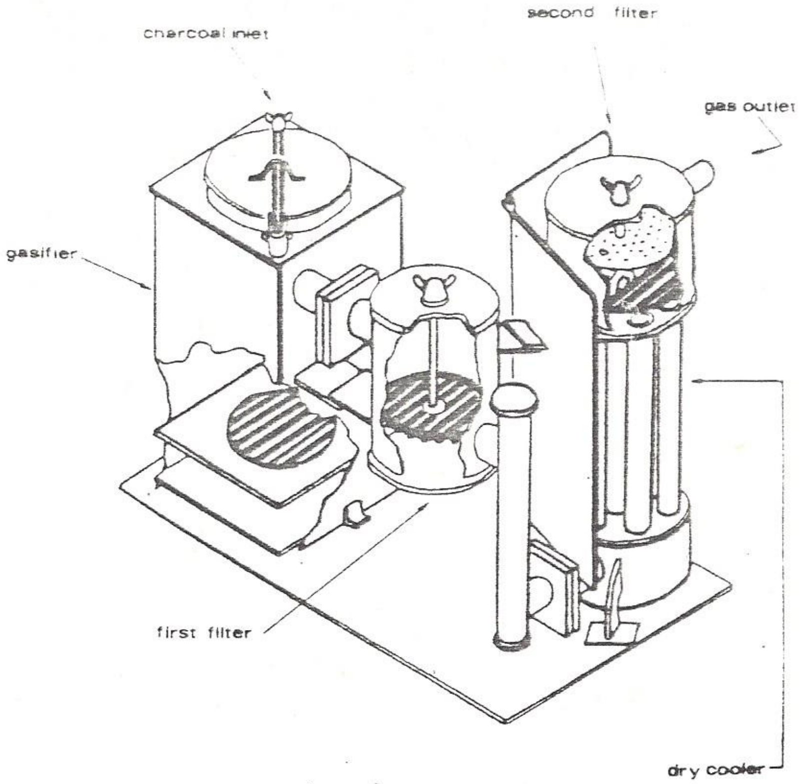

Fig. 3 - Scheme of updraft gasifier (plant C) (Ist. Agr. Eng.)

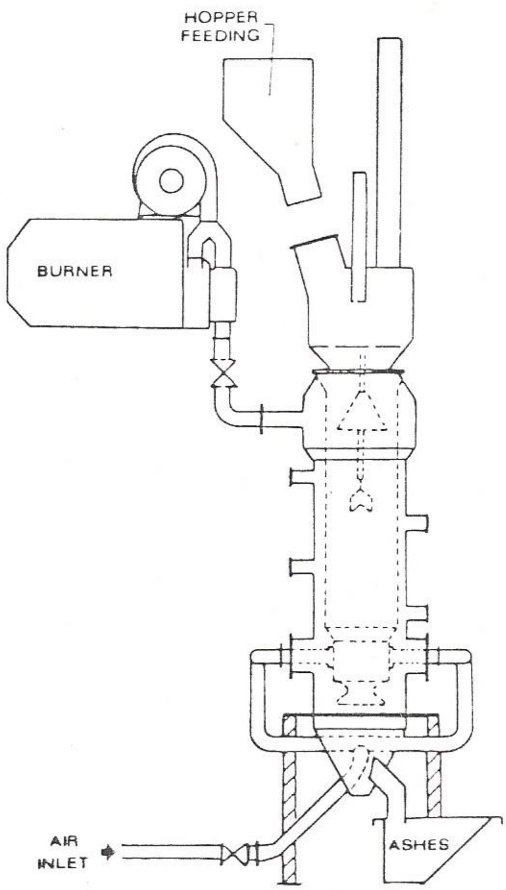

Fig. 4 - Scheme of downdraft gasifier (plant D) for heat generation (Del Monego)

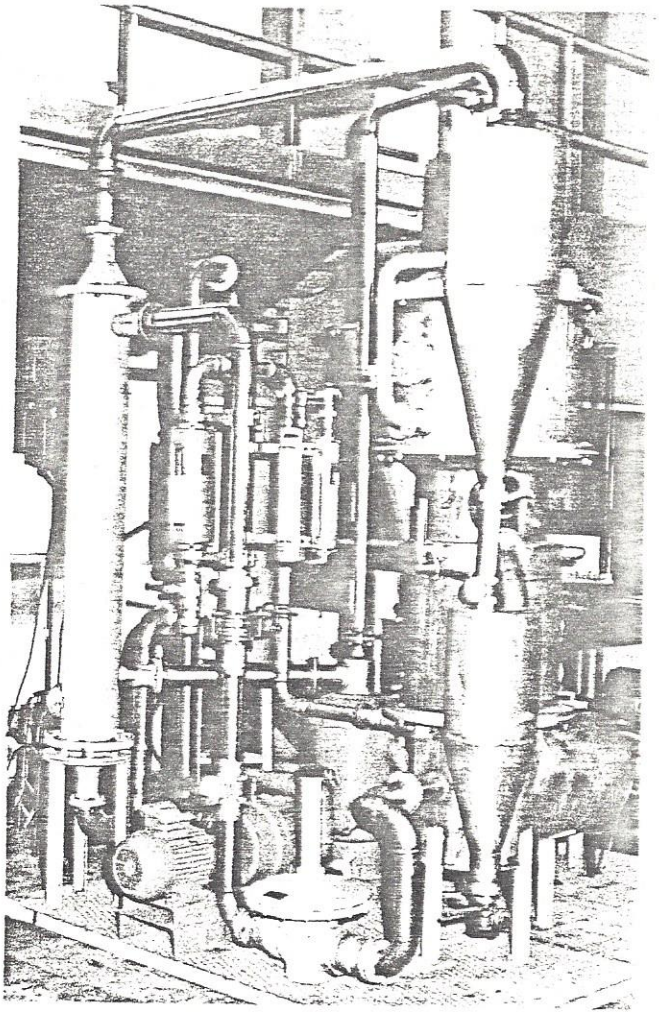

Fig. 5 - Fluidized bed gasifier (plant E) for heat generation (Fuel Stat. Res.)

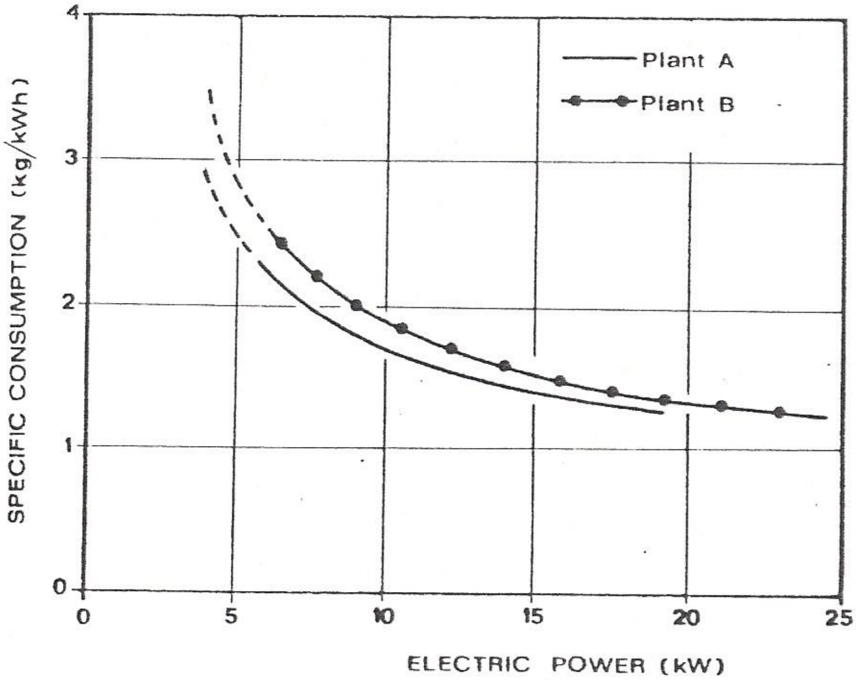

Fig. 6 - Specific biomass consumption related to the power output in plants A and B

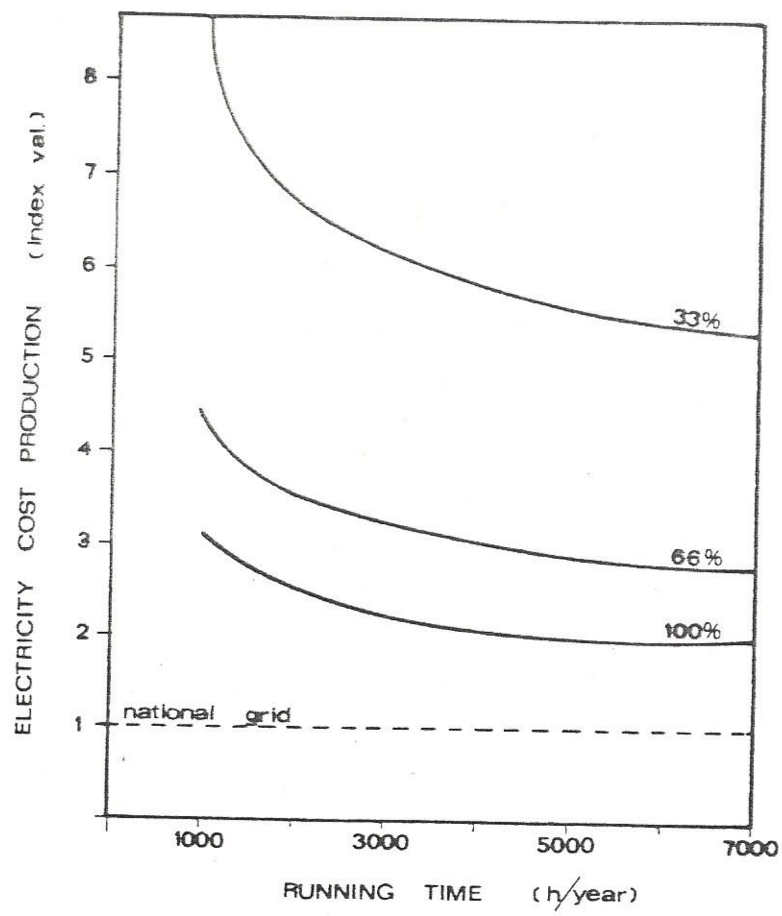

Fig. 7 - Electricity cost production using plant B in a dairy farm (S.Cosimo Farm - PV, Italy) related to the plant running time for different rated load (cost of the plant: 36,000 US$ or 1200 US$/kW; cost of biomass: 42 US$/t; cost of manpower: 5.5 US$/h)