THE AGRICULTURAL SECTOR AND BIOENERGY PRODUCTION

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INTRODUCTION

Today, the agricultural sector is facing a major evolution: the society expects from the agricultural sector not only to provide high quality food products, but also to undertake other activities such as landscape management, rural development, environment protection while keeping its competitiveness. Within this economic framework, it is essential for farmers to diversify their activities in order to answer society and economic development expectations.

One possible diversification is the production of bioenerg: agriculture is an important source of biofuels: energy crops – such as willow, miscanthus, bamboo, manure, agricultural residues are essential renewable sources of energy.

In this paper, we introduce three cases showing the potential of bioenergy in the agricultural sector:

- a small wood district heating system;
- gasification of short rotation coppice wood chips for electricity production;
- biomethanation of cattle and pig sludge.

For each case, we give a look on the biomass resource, on the technology, on the energy use as well as on the benefit for the farmer.

WOOD HEATING NETWORK – ENSCHERANGE

INTRODUCTION

Since October 1996, Mr. Roland Fischbach, part time farmer in Enscherange, northern Luxemburg, moved from his traditional fuel heating system to a wood district heating. Fed by crushed residues from a local sawmill, a 135 kW boiler supplies hot water to a buried pipe network. Nine nearby domestic houses take advantage of the plant. The whole functioning is managed by computer and does not necessitate many handling.

BIOMASS RESOURCES

In the frame of an agreement, Mr Fischbach buys all wood by-products from a local sawmill, about 1200 m³ per year at a price of € 2.5/m³.

The residues consist of sawdust and various wood pieces with a 50 cm maximum length and a 30 cm maximum diameter and a moisture content of approximately 50-60%. All the residues are crushed with a chipper. The sawdust and the crushed bark are sold separately for specific uses. Chips are stocked in a rain safe shed. After a few months, the moisture content goes down to 35-40%.

Only 600 m³ are used for feeding the heating system during one year, the remaining chips being sold for 14-15 €/m³.

TECHNOLOGY

A 200 kW boiler is installed in the exploitation warehouse. The combustion room is automatically supplied from an 85 m³ silo by feeder screws, biofuel feeding being regulated by the control panel. He combustion system is a step grate furnace. A pulsed air system causes a complete combustion of the fuel. The water primary network (short distance, 90/60°C) is heated by radiation and thanks to the hot gases. A filter cyclone separates the possible remaining particles from the exhaust gases before releasing. The good setting of the fans leads to a constant depression allowing an optimal combustion. The ashes are automatically collected from the combustion room to a container.

Through an interchange system, a 225 meter secondary water network (80/60°C) connected to a 5000 litres buffer tank supply nine nearby buildings with heat. 6000 litres of water are heated. The whole process is automatic and secure.

ENERGY PRODUCED

The plant runs on average 1 900 hours a year with a power of 135 kW. The feasibility study has expected a consumption of 199 500 kWh but now 260 000 kWh are used each year through the wood district heating. The boiler yield is about 85-90%.

At present, nine nearby domestic houses take advantage of the district heat. They are connected to the boiler by a buried pipe network. The network heat loss is about 1°C per 120 metres. Only two houses have kept a security traditional heating system, the others only use the wood district heat.

Each user is equipped with a meter measuring the heat consumption. Mr. Fischbach sold the heat supplied with prices fixed on agreement and depending on the Luxemburg fuel national prices. Today, he sells his heat for 0.04 €/kWh, corresponding to a fuel oil price of roughly 0.35 €/l (namely

€ 0.035/kWh), the heat is sold at a price of 0.05 €/kWh when the litre of fuel oil costs 0.44-0.47 € (namely € 0.044-0.047/kWh).

FINANCIAL SETTING

The financial data of the Enscherange heating network are given in Table 1.

Table 1. Bioenergy production in the agricultural sector: financial data of three cases (€)

	Enscherange (heating network)	Ophain (gasification)	Redange (biomethanation)
Investment			
Storage	16 133	–	186 000
Land and building	5 000	100 000	537 600
Boiler-Gasifier-Digester	99 563	100 000	1 069 200
Generator	–	125 454	891 600
Heating network	21 566	–	177 600
Heat exchangers and meters	14 873	–	–
Waste treatment	–	–	684 000
Final storage tanks	–	–	627 600
Vehicles	–	–	386 400
Total	**157 225**	**325 454**	**4 560 000**
Operational costs (per year)			
Chipper	1 144	–	–
SRC cropping and harvesting	–	18 176	–
SRC transport	–	724	–
Depreciation	11 344	24 212	159 600
Loan (5.5%, 15 years)	3 891	8 950	118 560
Biofuel	3 000	–	0
Operation and maintenance	1 572	3 255	114 000
Insurance (0.4% investment cost)	629	1 302	34 200
Employees	–	–	150 000
Operating energy (electricity)	–	–	69 000
Total	**21 581**	**107 983**	**645 360**
Total (without depreciation)	**10 236**	**83 771**	**485 760**
Income	10 400	95 167	870 000
Benefit	164	11 395	384 240
IRR	–	1%	20%
NPV	< 0	– 45 825	1 926 863
Payback time	–	32 years	< 5 years

The loan is calculated on the investment cost minus the grant.
The benefit is calculated on the operational costs without depreciation.
The Net Present Value is based on a rate of 5.5% and 15 years.

The Enscherange heating network has received a grant of 50% from the Government of Luxemburg and from the European Commission (Objective 5b). Even if the Enscherange wood district heating does not generate important financial benefits, the system is profitable. It takes advantage of unused residues from a local industry. The environmental advantages of the wood district heating are numerous. By substituting fuel for wood burning, Mr. Fischbach's plant allows a decrease of sulphur, nitrous oxide and carbon dioxide emissions. The exhaust gases have been controlled, these are below environmental norms.

Seeing that the whole feeding, heating and supplying systems are automatically managed, it does not need a lot of handling. Mr. Fischbach only crushes wood residues two weeks per year and fills the feeding silo every two weeks in the winter and every three months in the summer. The farmer, Mr. Fischbach is very satisfied with its fitting, which offers him a diversification of income.

SRC GASIFICATION – OPHAIN

INTRODUCTION

In 1995, the Walloon Region and Electrabel (the main electricity producer of Belgium) started a four year pilot project of decentralized biomass gasification power plant. The electricity is generated by gasification of wood chips obtained by cropping of an energy cultivated plant, the short rotation coppice (SRC) of willow. The electricity produced supplies the low-voltage grid.

The whole process has completely been studied from the crop husbandry to the conversion of the fuel into electricity by putting together the knowledge of four research centres:

- ECOP Unit from the Catholic University of Louvain-la-Neuve;
- Agricultural Engineering Department of the Agricultural research Centre of Gembloux;
- TERM Unit, also from the Catholic University of Louvain-la Neuve;
- Walloon Economy Research Centre of the FUNDP of Namur.

The gasification plant has been installed in a farm located in Ophain, a small town south of Brussels.

RESOURCES

Within a short rotation coppice, the willow is grown like an agricultural crop and no longer like a forest development. 10 000 to 20 000 cuttings of selected varieties are planted per hectare. At the end of the first year, the crop is cut back in the winter, stimulating the sprout of many stems the following spring.

Competition from weeds is the main danger for the SRC. Weeds must be eliminated the two first years. The willow is not very demanding. Soils with good water reserve and pH value exceeding 5.5, thus most soils of the Walloon Region, are suitable for growing short rotation coppice. There is no need for insecticide or fungicide. Rust, the main fungal disease, can be fought by using tolerant varieties. The coppice is cultivated using normal agricultural methods and simple conventional equipments.

Ideally, the shoots are harvested every three years. The winter is the best period for harvesting because the leaves – containing most of the mineral elements and with a very low energy content – have fallen and because the soil provides a better support. Harvesting may be done in one or two phases. Either the entire shoots are cut and crushed before being used with specific equipments, or they are cut and chipped directly in the field using a lightly modified maize silo filler. The crop has a 25 years life span.

To feed the gasifier on an operational basis of 4000 hours, 96 ha of willow coppice must been grown with an annual yield of 8 tons of dry material per hectare. On average, the chips have a moisture content ranging from 50 to 60% at harvesting and from 15 to 30% after storage according to the harvesting and chipping methods and the storage length.

TECHNOLOGY

A simple mobile bottom agricultural trailer (manure spreader) connected to a closed conveyer feeds the conversion unit. The dried willow chips are burned in vacuum within a fixed bed co-current gasifier producing a combustible gas. This one contains hydrogen (H_2), carbon monoxide (CO) and methane (CH_4) diluted in an inert fraction of nitrogen (N_2), carbon dioxide (CO_2) and water vapour (H_2O). This type of gasifier produces a gas that is low in tar. The fuel gas produced has a NCV (Net Calorific Value) of roughly 5000 MJ/m^3_N; carried out correctly, the gasifier can convert around 80% of the energy initially contained in the wood. At the exit of the conversion unit, the gas temperature is about 400°C. Then it is cooled and purified in a cleaning unit. The gas is cooled by spraying water directly into it. The hot water, now loaded with impurities, is collected, filtered, cooled a new time and re-injected into the circuit. The cooled and purified gas passes through a filter that removes any water droplets. The filtrate containing the tar is dried and loaded, along with the wood into the gasifier, thus eliminating any harmful effluent.

The fuel gas feeds an internal combustion engine which drives a generator producing electricity. The air-gas mixture is ignited in the engine by injecting a small quantity of fuel oil which self-combusts when compressed. The exhaust gases from the engine are saved for drying the wood. They are injected inside the closed conveyer feeding the gasifier.

THE WHOLE PLANT IS AUTOMATICALLY MANAGED

ENERGY PRODUCED

With a capacity of 200 kWh, the plant runs on average 4000 hours a year and generates 800 MWh per year. The unit size has been planned for providing the low-voltage power grid. The electricity can be sold at a price of € 0.06 per kWh. However, the new green certificate system set up in Wallonia to support the development of renewable electricity production offers better financial perspectives (see here below). Also, the part of the heat not used to dry the wood chips, is sent to the farm; this represents about 420 000 kWh.

This kind of plant is advantageous (limiting transport costs) for decentralized power production, being close to the SRC production site.

The advantages of this process are as numerous as various. Considering the neutral carbon cycle, the reduction of CO_2 emissions can be estimated around 20 tons per SRC hectare per year. The short rotation coppice, environmentally friendly crop, leads to many environmental benefits (erosion decrease, nitrogen retention, etc.). The coppice cropping allows a diversification of the farmer's income and by using the crop as a source of power, he can obtain a high added value product using a relatively simple technology. This process also allows jobs development in rural zones.

FINANCIAL SETTINGS

The financial data of this gasification project are given in table 1. The farmer has received a grant of 50% of the investment. Electricity sales represent more than 50% of the income. In addition, the green certificates systems increases significantly the revenue of the farm. In Wallonia, the green certificates system is based on the reduction of fossil CO_2 emissions that the plant allows. A green certificate is estimated at a price of € 100 here, and the gasification plant should receive 304 green certificates. The heat used in the farm is valorised at a price of 0.04 €/kWh). But, even with these attractive revenues, the benefit of the farmer is not important. The internal rate of return is equal to 1%, and the payback time is a little bit lower than 32 years. The only solution is to increase the number of operational hours of the gasifier, up to 6000 or 7000 hours.

AGRICULTURAL COOPERATIVE "BIOGAS UN DER ATERT"

INTRODUCTION

In 1998, the EU initiated a project called LSDN (Local Sustainable Development Network) with partners of Austria, German, Spain and Luxemburg. The project mainly aims at initiating different techniques to produce renewable energies from biomass. In Redange, GD of Luxemburg, the idea of the project was to co-finance an agricultural biogas plant. After some general information conferences about biogas, the interest of the local farmers on a biogas plant increased. 28 farmers (cooperative "Biogas un der Atert") agreed to participate in a collective biogas project. The idea was to put all the agricultural biomasses into a central biogas plant together with organic waste. In Redange the local waste syndicate planed to install a composting unit to treat organic waste out of the region. So it was interesting for the project to propose to the responsible syndicate to treat all this organic waste in the projected biogas plant.

RESOURCES

All agricultural biomasses will be treated in the central biogas plant:
Liquid manure: 18 500 m^3
Solid Manure: 10 000 m^3

In addition to the manure, the farmers will grow about 70 ha of energy crops (maize, sugar beat) and add 4000 tons of organic waste out of the private households collected separately in the region of Redange.

TECHNOLOGY

Agricultural biomasses are treated in 6 separated digesters (6 × 1000 m^3). The organic waste is pre-treated in a separate digester (260 m^3) before being put together with the agricultural biomasses. The biogas produced in the 7 digesters is collected in 6 storage tanks before being transformed thanks to the cogeneration modules.

A total electrical power of 600 kWe corresponding to 900 kWth will be installed in Redange. About 40% of the produced heat is necessary to hygienise the whole final product (agricultural biomasses together with the bio-waste) during 1 hour at 70°C.

Part of the rest of the heat (about 3 000 000 kWh per year) is used thanks to an interchange system. A 1 000 meter district heating supplies the local swimming pool, the sportscenter and the building of the technical staff of the administration of Redange. The whole process is automatic and secure.

After the valorisation in the digesters and the hygienisation process, the final product is stored in tanks. Tanks adapted to the surrounding land are built on 10 different places. These decentralised storage tanks allow to reduce the transporting costs to a strict minimum. The transporting vehicle collects fresh manure in the farms and drives it to the central plant. On his way back to the farms, the truck drives the digested manure in the decentralised storage tanks. So farmers only need to take out the corresponding quantities needed to put on the surrounded land.

ENERGY PRODUCED

The plant produces about 5200 m^3 of biogas per day with an average concentration of 60% CH_4. Out of this gas, the cogeneration modules produce about 4 600 000 kWh electricity and 6 300 000 kWh of heat. Thanks to the district heating, about 3 000 000 kWh of heat are actually used.

The electricity is sold 0.1 €/kWh to the local electricity company. The heat is sold to the swimming pool, the sports center and the building of the technical staff. The heat supplied is sold with prices fixed through an agreement based on the Luxemburg fuel national prices. The minimum selling price of the heat will be about 0.03 €/kWh.

FINANCIAL SETTING

The financial data are reported in Table 1. In addition to the electricity and heat sales, the plant receives an income for the treatment of 4000 tons of green waste at a price of 80 € per ton. This collective biogas plant shows very interesting financial results. Thanks to a very attractive buyback rate for the electricity, the revenues of the plant are high, leading to an internal rate of return equal to 20%. Consequently, the payback time is lower than 5 years.

CONCLUSIONS

Three different projects implemented in Belgium and Luxemburg show the potential of bioenergy production (heat and/or electricity) by farmers, leading to significant reductions of greenhouse gases emissions. However, this potential can only be achieved if several conditions are met:

– bioenergy equipment are more expensive than fossil fuel energy equipment (2 to 3 times more); consequently, there is a need for a financial support of the farmer investing in such equipment: a grant of 50% of the investment is necessary;

– the buyback rate of heat or electricity must be attractive enough, typically between 0.03 and 0.05 €/kWh for heat and between 0.08 and 0.1 €/kWh for electricity;

– to ensure the viability of his bioenergy project, the farmer must produce an important amount of energy, corresponding to at least 6000 hours of operation.

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SUMMARY

The present article introduce three cases showing the potential of bioenergy in the agricultural sector: a small wood district heating system; gasification of short rotation coppice wood chips for electricity production; biomethanation of cattle and pig sludge. Also was give a look on the biomass resource, on the technology, on the energy use as well as on the benefit for the farmer.