POLYGENERATION FROM VINEYARDS PRUNING RESIDUES IN AN UMBRIAN WINE COMPANY

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ABSTRACT: The research project ERAASPV has been completed installing a pilot plant for energy production starting from vineyard pruning residues near an Umbrian wine and viticulture company. The biomass energy conversion pilot plant consists of harvesting and chipping machines, chips storage, chips transportation system, thermal oil biomass boiler, exhaust gas treatment, hydraulic distribution system, heat exchangers and absorption chiller. The present work analyses the energy process requirements, the designing and the building stage of the pilot plant and the choices and methods followed during the project are described. The financial evaluation, trough the calculation of investments costs, biofuel supplying cost and biomass plant yearly cash flow, shows a 8-9 years payback period without financing, but the energy chain could be further improved. A future optimisation of the pilot plant is the recovery of heat from exhaust gas in order to feed thermoelectric elements for 10 to 20 kW electricity production.
Keywords: agricultural residues, pilot plant, recovery of residues

1 INTRODUCTION

Current prescriptive figure for National and European energy sector provides binding objectives in the production of renewable energy (target of 20% of energy consumption in the EU by 2020); table I shows some national targets from renewable sources in final consumption of energy in 2020 [1].

In the biomass energy production, the National goals are the improving from the present 4% of energy consumption to more than 8% by 2010, while, in the biofuels sector, 5,75% of total fuel consumption by 2010 and 10% minimum target by 2020 [2-4].

In order to reach these objectives in Italy, it will be necessary use more than 3 million hectares of agricultural lands to produce biomass for the several energy chains; figure 1 shows an evaluation of the necessary area for biomass cultivations in order to reach the 8% target of energy produced by biomass in 2010. Considering that in Italy land availability, without being in competition with food cultivations, is, in the best scenario, about 1,5 million hectares (adding 800.000 hectares of set-aside, energy reconversion of sugar beet and the use of marginal lands), it's in evidence the necessity of integrating energy crops with residual biomass, which don't occupy land[5].

Table I: National overall targets from renewable sources in 2020 [1]

Country	2005 renewable source	2020 renewable source
Belgium	2.2%	13%
Denmark	17.0%	30%
Germany	5.8%	18%
Spain	8.7%	20%
France	10.3%	23%
Italy	5.2%	17%
Austria	23.3%	34%
Portugal	20.5%	31%
Slovenia	16.0%	25%
Finland	28.5%	38%
Sweden	39.8%	49%

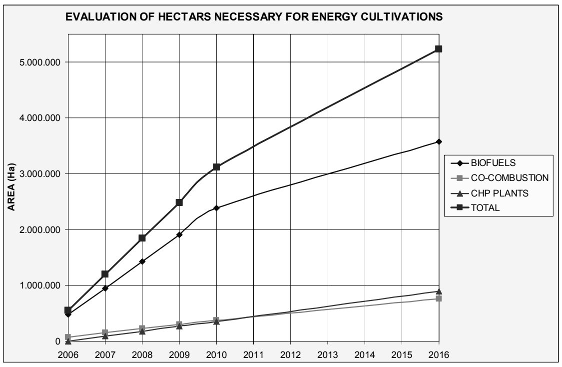

Figure 1: Evaluation of necessary area for biomass crops in Italy [5]

Table II shows main crops where obtain biomass pruning residues in Italy, total cultivated areas (ha), average residues production (tons/ha) and total theoretical quantity obtainable from biomass harvesting (Mtons). Total hypothetical biomass quantity from pruning residues is more than 5,5 Mtons, equivalent approximately to 500.000 hectares of energy crops.

The agroenergy chain project ERAASPV (renewable energy for farms deriving from vineyards pruning residues) is financed by the Italian Ministry of Agriculture and Forestry. The project target is design and

Table II: Available biomass pruning residues in Italy [6-7]

Crop	Cultivated area (ha) [6]	Residue (ton/ha) [7]	Total biomass obtainable (Mt)
Vineyard	871.597	2,9	2,53
Olive trees	1.170.362	1,7	2,00
Apple trees	64.447	2,4	0,15
Pear trees	45.826	2,0	0,09
Peach trees	67.458	2,9	0,20
Citrus trees	179.470	1,8	0,32
Almond trees	86.406	1,7	0,15
Hazel trees	69.561	2,8	0,19
TOTAL	**2.555.127**	**-**	**5,63**

build a pilot plant for biomass pruning residues energy recovering, and has reached the finishing of the energy conversion power plant. The project will be concluded at the end of 2008 with plant start-up and four weeks monitoring.

In the energy chain both economic and environmental analysis are carried out; a description of plant designing is also reported.

2 ANALYSIS OF ENERGY REQUIREMENTS

The wine and viticulture company chosen has more than 250 hectares vineyards and a structure approximately 8.000 m^2. The company has several oil and LPG boilers for steam and heat production, and compression refrigerating machines for air cooling and barrels conditioning in vinification processes.

Total company consumptions are the following:

- 30.000 litres diesel for offices heating, for barrels heating and for steam production necessary to bottles sterilization processes;
- 11.000 litres of liquefied petroleum gas (LPG) for red wine barrels heating and laboratory and tasting room heating;
- 709.000 kWh/year electricity consumed from the company and approximately 336.000 kWh/year of them are used to feed compression refrigerating machines.

In particular the company has seven boilers and five compression refrigerating machines. Table III and IV describe boiler and conditioning machines utilization characteristics. The choice of the biomass thermal plant positioning has depended on the space availabilities of the farm and on the position and frequency utilization of the energy conversion plants; these elements evidenced the necessity of reject some boilers and the refrigerators for offices conditioning, too far from biomass plant and with low utilization. For the other equipment we evaluated energy requirements based on electricity or gas bills, gas meters reading and fossil machines and biomass boiler efficiencies. Table V reports the consumption of the single boiler and refrigerator to connect to the new biomass plant. The monthly consumption of boilers and refrigerators, on the basis of the period of utilization are shown in table VI.

Table III: Fossil fuels boilers utilization characteristics

Boiler use	Power	Fuel	Utilization
C1 - Bottles sterilisation	581 kW	diesel	2-4 h/week all the year
C2 - offices heating	235 kW	diesel	8 h/day Nov-Mar
C3 - red wine heating	34,5 kW	LPG	all the year (16-18°C)
C4 - laboratory heating	29,7 kW	LPG	8 h/day Nov-Mar
C5 - white wine heating	34,8 kW	LPG	12 h/day Ott-Gen
C6 - isolated zone heating	100 kW	diesel	occasionally Nov-Mar
C7 - guardian home heating	24 kW	LPG	8h/day Nov-Mar

Table IV: Compression refrigerating machines utilization characteristics

Refrigerator use	Cooling power	period utilization	fluid temperature
GF1 - barrels conditioning	210 kW	6 h/day all the year	0°C
GF2 - barrels conditioning	89 kW	2 h/day all the year	0°C
GF3 - barrels conditioning	157 kW	2 h/day all the year	0°C
GF4 - barrels conditioning	65 kW	6 h/day all the year	-10°C
GF5 - rooms conditioning	32 kW	8 h/day Giu/Ago	7°C

Table V: Annual consumptions of single boilers (C) and refrigerators (GF)

Thermal machine	Power (kW)	Fuel	energy requirement MWh/year
C1	581	diesel	73
C2	235	diesel	208
C3	34,5	LPG	36
GF1	210	electricity	1.248
GF2	89	electricity	175,2
GF3	157	electricity	312
GF4	32	electricity	64,8
TOTAL			**2.117**

Table VI: Monthly consumptions of boilers and refrigerators

Month	Boiler Consump. (MWh)	Refrigerators consump. (MWh)	Total (MWh)
January	50,68	144,60	195,28
February	50,68	144,60	195,28
March	50,68	144,60	195,28
April	9,08	144,60	153,68
May	9,08	144,60	153,68
June	9,08	166,20	175,28
July	9,08	166,20	175,28
August	9,08	166,20	175,28
September	9,08	144,60	153,68
October	9,08	144,60	153,68
November	50,68	144,60	195,28
December	50,68	144,60	195,28
TOTAL	**317**	**1.800**	**2.117**

3 BIOMASS BOILER TECHNOLOGICAL AND POWER SELECTION

The analysis of energy company requirements is fundamental to define type of technology and power plant.

The wine company needs several shapes of energy, in particular:

- hot water (80°C) for rooms winter heating;
- cold water up to -10°C for barrels conditioning in the vinification process;
- cold water up to 7°C for summer conditioning of company rooms;
- superheated water (95°C) for bottles sterilization process.

Table VII: Biomass boiler characteristics

Characteristics	Performance
Biofuel	wood chips
Burner power	600 kW
Useful power	400 kW
Thermal efficiency	66%
Type of burner	moving grate
Thermal recovering	gas/diathermic oil exchanger
Thermodynamics fluid	diathermic oil up to 300°C

The types of energy requirements addressed the choice to a boiler able to heat diathermic oil up to 300°C in order to produce hot water, superheated water and steam by means of heat exchangers, and cool water up to -10°C by means of absorption chiller machines.

Biomass boiler power depends on requirements and on the evaluation of biomass residues potentiality and total renewable energy obtainable. Experimentation and optimization done on vineyards pruning residues harvesting stage furnished results between 0,70 and 0,75 tons per hectare (dry basis), and a low heating value (LHV) analyzed in laboratory approximately 4,8 kWh/Kg. Company vineyards area is more than 200 hectares so every year biomass availability is approximately 150 tons, corresponding to 720 MWh thermic energy [7-8].

Biomass diathermic oil boiler size is 400 kW useful power, which represents a correct compromise between yearly biomass residues availability, average monthly consumptions and machines peak load. Main biomass boiler characteristics are shown in table VII.

4 BIOMASS HANDLING AND STORAGE DESIGNING AND BUILDING

Vineyard prunings have been harvested by means of a round baler that produces cylindrical bales stored in a open area 1 kilometre far from biomass plant. Chipping stage takes place, by means of a modified mixer wagon for animal feeding, in a large square in front of chips storage. Storage silo has been measured in order to assure an autonomy of 7-8 days in the heaviest conditions. For the measurement of the silo input data are:

- boiler consumption: 120 Kg/h dry biomass;
- chips density: 250 Kg/m^3;
- daily working hours peak load: 16.

With these data, a 60 mc volume storage can assure a minimum working of 7-8 days. Chips produced by mixer wagon are transferred inside the storage silo by means of a conveyer belt; another conveyer belt provides to distribute biomass in the whole volume. The storage room has been designed and built by a suspended floor, because it was impossible to make excavations, but it was necessary to create a difference of level (approximately 1,5 meters) between the storage and the thermal room.

Silos filling and chips moving until a third conveyer belt in the thermal room is assured by moving racks anchored to the suspended floor and moved by hydraulic rams. Figure 2 shows the plan and the section of biomass movement system from the mixer wagon to the thermal room and the chips storage; figure 3 shows a detail of the suspended floor where are anchored the moving racks.

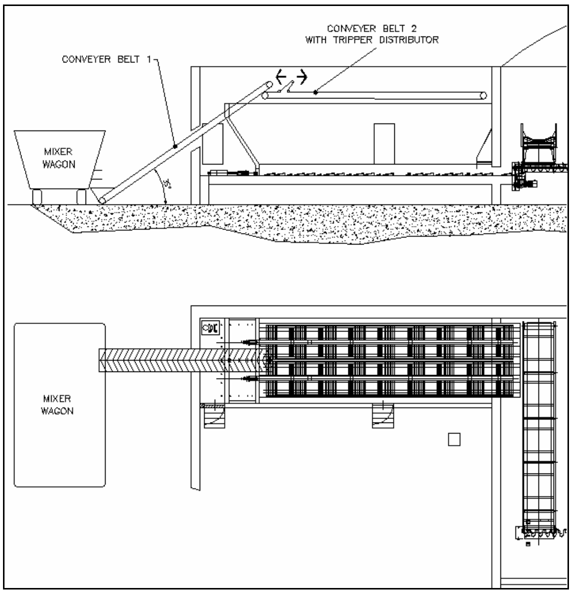

Figure 2: Plan and section of biomass movement system and storage


Figure 3: Moving racks anchored on the suspended floor

5 BIOMASS THERMAL PLANT DESIGNING AND BUILDING

Biomass thermal plant consists of the following sections:

- biomass loading and moving system realized by conveyer belts from the storage and a cochlea to load chips to the burner;
- burner with moving grate furnace water cold, with primary and secondary air ventilation system, combustion regulation panel and switch-board;
- automatic ash dumping with two screws that move ashes from burning chamber to a wagon tank;
- thermal recovering section made up of a gas-diathermic oil exchanger up to 300°C, with 400 kW useful power;
- exhaust gas cleaning and ejection made up of a cyclone dust collector, gas extractor fan and a chimney 9 meters tall;
- diathermic oil pipeline system for fluid distribution to the thermal and refrigerating users, with safety equipment established from Law (safety heat exchanger, manostat and

thermostat).

The thermodynamics fluids distribution net consists of:

- diathermic oil pipeline which feeds a diathermic oil-superheated water exchanger, a diathermic oil-hot water exchanger and an absorption chiller;
- superheated pipeline which starts from diathermic oil-superheated water to feed a heating boiler and steam production boiler;
- hot water pipeline from diathermic oil/hot water exchanger, which feeds red wine barrels room heating boiler;
- refrigerated fluid (-10°C) pipeline that starts from the absorption chiller and feeds an accumulation tank (10 cubic meters) for barrels room conditioning.

The distribution net has been built trough more then 1.000 meters pipe laying, because user machines are distributed in all the 8.000 m^2 structure while biomass plant is placed in a peripherical position.

Both diathermic oil and superheated pipe required the installation of expansion joints to compensate thermic expansions.

Figure 4 shows plan and section of the thermic plant room; Figure 5 shows a picture of the diathermic oil boiler and Figure 6 the detail of the exhaust gas cleaning and ejection system.

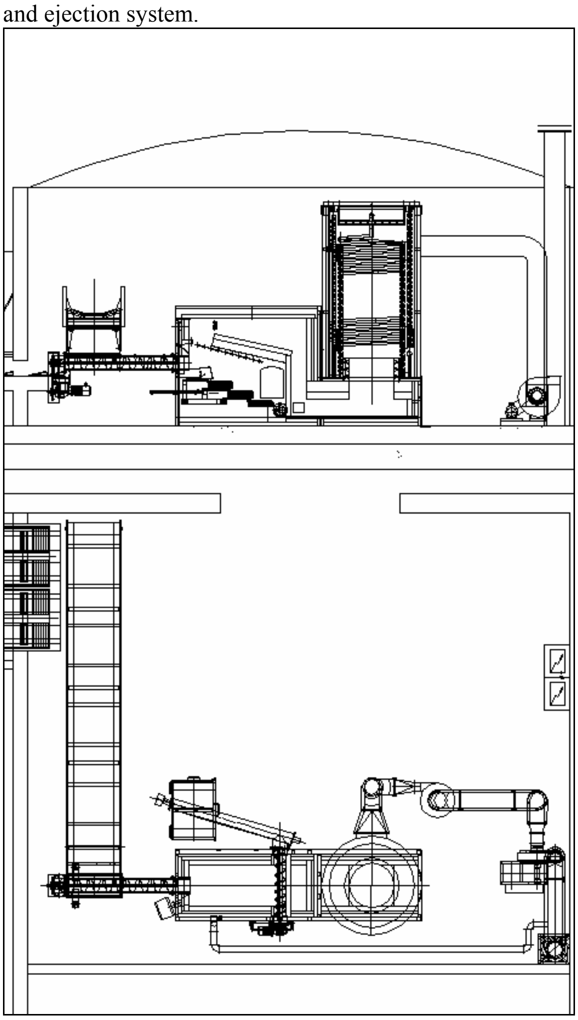

Figure 4: Plan and section of the biomass thermic plan room

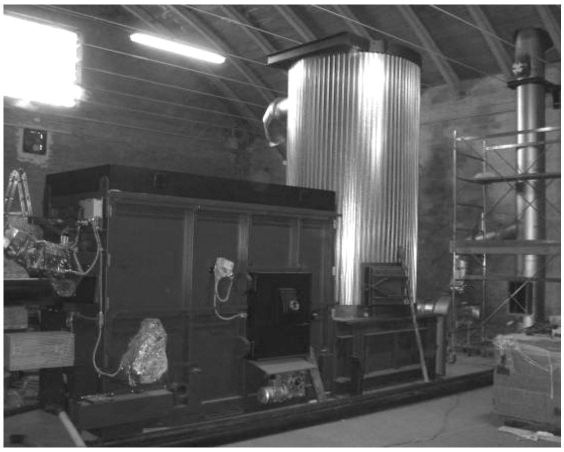

Figure 5: Picture of the diathermic oil boiler

Figure 6: Picture of the exhausted gas cleaning and ejection system

The energy used during all the chain stages are shown in table VIII in function of the dry biomass obtained. The first three items show the diesel consumption of the tractors and the lorries used in the project. The last three items show power machines used in the thermal plant (moving racks, conveyer belts, pumps, cochlea).

Electricity consumptions are then transformed in fossil energy considering the average efficiency of thermoelectric plants (approximately 40%).

Table VIII: Energy wasted during the stages Vs. biomass obtained

Operation	Fuel	Consumption	Fossil energy
Harvesting	diesel	5,74 l/t	57,4 kWh/t
Transport	diesel	22 l /t	220 kWh/t
Chipping	diesel	5,25 l/t	52,5 kWh/t
Silos charging	electricity	5,5 kWh/t	14 kWh/t
Chips moving	electricity	65 kWh/t	163 kWh/t
Oil pumps	electricity	30 kWh/t	75 kWh/t
TOTAL			**581,9 kWh/t**

Total Energy used (581,9 kWh/t) has been compared to the low heating value of the dry biomass (4.850 kWh/t). The result shows that 12% of the energy produced in the boiler is used during the biomass energy chain; therefore 88% of energy produced represents the renewable and effective energy.

6 ECONOMIC ANALYSIS

The economic analysis of the investment requires the evaluation of the whole energy chain cost, the management costs, the biomass supplying costs in order to feed the power plant and proceeds deriving from fossil fuels and electricity saving.

6.1 Evaluation of biomass energy chain costs

The recovery of vineyards pruning residues energy chains consist of the following stages:

- biomass pruning harvesting (by means of a round baler machine);
- round bales transport from vineyards to the storage and open air drying;
- bales transport from storage to the large square near biomass plant;
- biomass chipping by means of a mixer wagon;
- chips storage.

Table IX shows the different items and the relative costs; total energy chain investment cost is approximately 280.000 €.

Table IX: Items and relative costs

Item	Cost (€)
Round baler + modifies	16.000,00
Mixer wagon for chipping	13.000,00
Loading conveyer belt	3.000,00
Absorption chillers (4)	28.000,00
Storage and movement system	30.000,00
Biomass thermal room	134.000,00
Pipeline distribution and connections	58.000,00
TOTAL	**282.000,00**

6.2 Management and biomass supplying costs

Management costs consist of ordinary management of the boiler, of the movement system of the chips, of the automatic ash dumping and of absorptions chillers; altogether the cost is about 2.500,00 €/year.

Biomass supplying costs have been estimated in 100 €/tons, so biomass total cost is 15.000,00 €/y [7].

Therefore total yearly expenses are 17.500,00 €/y.

6.3 Proceeds

Proceeds deriving from vineyard pruning energy chain consists of fossil fuels (diesel oil and LPG) consumption savings, electricity consumption savings, white certificates trading, assigned to energy savings plants; sale price for the 2008 is 100 € each ton of oil equivalent (TOE) saved.[9]

Biomass plant is structured so that it gives priority to the heating side for hot water and superheated water production; cool water production is indeed bound to energy availability.

Starting from these hypothesis and on the basis of monthly consumption evaluated in the previous paragraph, we have evaluated yearly proceeds obtainable, as illustrated in table X.

The evaluation of electricity savings has been accomplished considering three additional absorption chillers to the installed one; the other machines will be installed when the monitoring stage will give positive results.

Table X: Yearly proceeds

Item	Quantity	Price	Proceed (€/y)
Oil saving	28.000 l/y	1,24 €/l (*)	34.700,00
LPG saving	5.000 l/y	0,90 €/l (**)	4.500,00
Electricity Saving	80 MWh/y	120 €/MWh (***)	9.600,00
White Certificates	27 Toe/y	100 €/toe	2.700,00
TOTAL			**51.500,00**

(*) Italian Ministry for Economic development, 25/02/08 survey
(**) Processing by Statistics and Economic information Division
(***) Processing by 2006 electricity company bills

6.4 Investment economic analysis

The difference between yearly costs and proceeds generates the cash flow, equal to 34.000,00 €/year.

Once evaluated cash flow and investment cost, it's possible to define investment payback period, approximately between eight and nine years, without public financing.

Figure 7 shows the biomass plant net present value (NPV) in function of the interest rate. The investment is favourable for interest rate values lower than 6%.

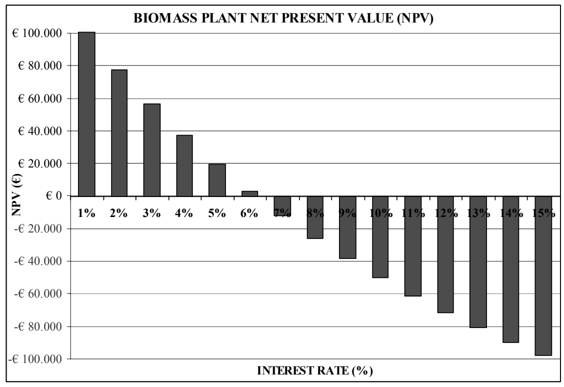

Figure 7: Biomass plant net present value (NPV)

Investment profitability must consider the following elements that contributes to improve the energy chain convenience:

- biomass boiler power isn't completely used because of the low vineyard pruning availability, so yearly proceeds could improve if the company would obtain more biomass (for example making agreements with near vineyards owners);
- the experimentation on the energy chain has improved chips supplying costs, but there are yet good improvement margins;
- the possibility to obtain public financing to reduce considerably the initial investment; in the present project Ministry financing has been more than 80%;

- the constant increase of energy products prices, that causes a larger and larger economic gap.

7 CONCLUSIONS

The biomass energy production pilot plant from vineyards pruning required a detailed designing of all the sections, in function of biomass availability and farm energy requirements. The system chosen and built is a diathermic oil boiler fed with chips that allow to produce hot water for heating, steam for bottles sterilization and cool water up to -10°C for barrels and room conditioning.

Energy used in all the chain (582 kWh/t) is approximately 12% of total energy obtained by biomass residues, while the remaining 88% (4268 kWh/t) represents the renewable energy quote.

The economic investment evaluation shows the convenience of the energy chain; payback period is 8-9 years without financing, but the result is improvable optimizing the energy chain and increasing biomass residues availability.

Future development preview the installation of a thermoelectric system in the chimney flue that can recover the high exhaust gas temperature (350-400°C) to produce approximately 10 kW electricity, sufficient to supply the energy plant equipment.

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