ETA
ENERGIA TRASPORTI AGRICOLTURA

PROJECT N° : NNE5-CT-2001-00604

ACRONYM : COMBIO

TITLE: A New Competitive Liquid Biofuel for Heating

PROJECT CO-ORDINATOR : VTT Processes

PROJECT START DATE : 1.01.03

DURATION : 42 months

TECHNO-ECONOMIC ASSESSMENT, THE ITALIAN CASE STUDY

SUMMARY

PREPARED BY: ETA Renewable Energies

Energy, Environment, Sustainable development

Project supported by the European Commission, DG Research within the Fifth Framework Programme, EESD (1998-2002)

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The Italian case study is a techno-economic assessment of the whole bioenergy chain from biomass sources to pyrolysis oil production, pyrolysis oil emulsion production, transportation and utilisation in small scale boilers in Tuscany.

Pyrolysis oil utilisation in substitution of light fuel oil (LFO) in small boilers is a promising application However some problems, such as instability, high viscosity, high ignition point and especially corrosion, should be taken into account.

An interesting method for PO upgrading is given by emulsification with conventional diesel oil.

As PO and diesel are not miscibile, a third component, called emulsifier or surfactant, has to be added to obtain a stable emulsion.

The potential end-users are 20-30 kWth heating systems usually running on light fuel oil, namely diesel oil.

The techno-economic assessment is part of Work Package 5.1 of the COMBIO project and aims at providing concrete information about the techno-economic feasibility of the bioenergy chain and the possible exploitation and market application of the proposed technology in order to promote pyrolysis oil use for potential customers in Europe.

In this document a summary is provided.

Tuscany is one of the twenty administrative regions of Italy and has an high percentage of its territory covered by forests (about 47%).

A GIS (Geographic Information System) based model has been used to select a potential location to set up a biomass to pyrolysis oil and emulsion production plant in Tuscany and to make an estimate of the costs of the biomass as provided to the plant.

In running the simulations the location with the minor marginal cost for the delivered biomass resulted as the best location.

The runs differed mainly on the set of biomass typologies analyzed, on the amounts and on the increasing resolution of the results. Each run was following the analysis of the results of the previous run.

After having tried different running periods, plant sizes and biomass typologies, two plant sizes were chosen as the most interesting for a real application, 2 t/h and 5 t/h (biomass to the pyrolysis unit, having 8% moisture content), and these parameters were fixed:

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- a running period of 6400 hours/year, corresponding to 4 weeks of continuous operation, 24 hours a day, then one week stop for maintenance, having an additional one month stop per year for heavy maintenance;
- the following biomass typologies: forestry residues (only for the 5 t/h pyrolysis plant), wood industry residues and agricultural woody residues.

Strada in Chianti (Figure 1) has been chosen as the best location.

The resulting biomass costs are:

- for a 2 t/h plant, running 6400 h/y, the marginal cost is 29.61 €/t and the average cost is 22.74 €/t as received;
- for a 5 t/h plant, running 6400 h/y, the marginal cost is 33.74 €/t and the average cost is 27.89 €/t as received.

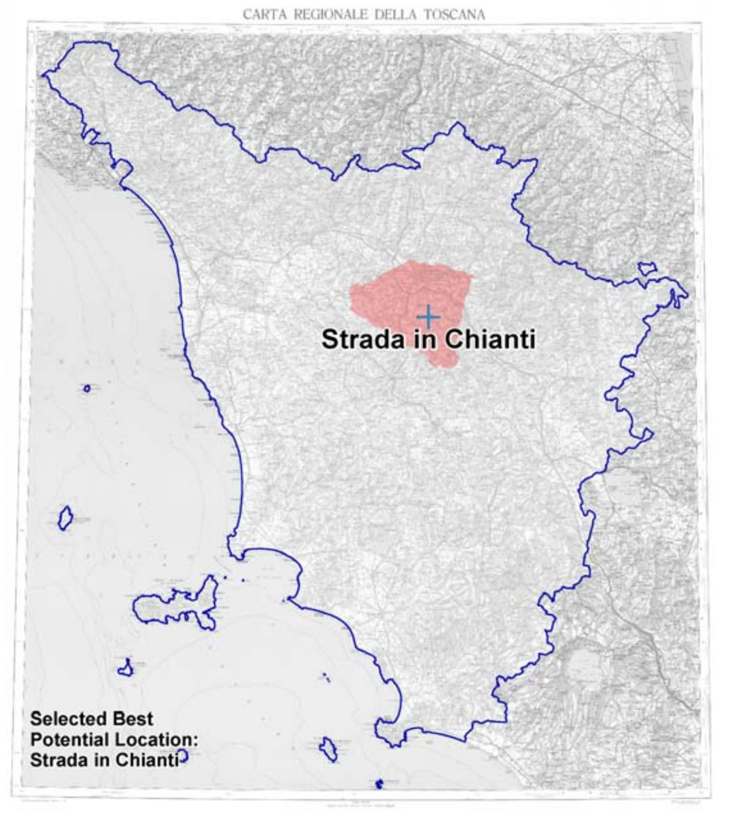

Figure 1 - Selected Best Location and related district

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The bioenergy chain has been subdivided in sub-systems (Figure 2) and for each one mass and energy balances and an estimate of the investment and operating costs have been carried out.

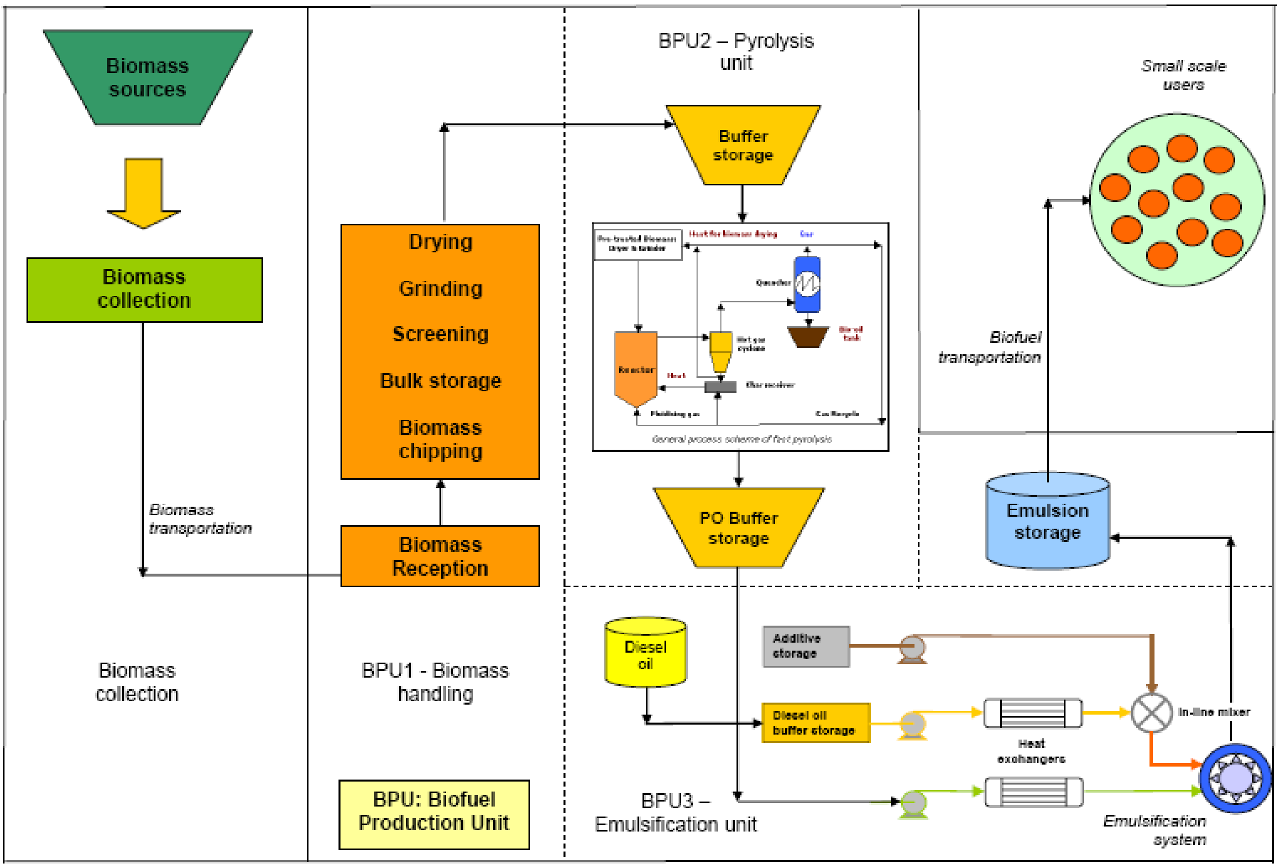

Figure 2- Bioenergy chain scheme

The main results from the mass and energy balances are provided in Table 1 and the main results from the economic analysis are given in Table 2 and in Figures 3-8.

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		Pyrolysis plant size (inlet capacity-8%MC)	
		5 t/h	**2 t/h**
Biomass fed to the plant	t/h	6.7	2.99
Annual biomass demand (as received)	t/yr	42886	19129
PO production	t/h	3.4	1.36
PO annual production	t/yr	21763	8705
PO emulsion production	t/h	10.8	4.32
PO emulsion annual production	t/yr	69122	27649
Energy content in PO emulsion	GJ/yr	2344656	937862
Diesel oil annual demand	t/yr	50780	20312
Surfactant annual demand	t/yr	218	87
Annual electricity consumption	MWh_{el}/yr	3477.2	1400.8
PO emulsion utilization in small scale boilers (30 kWth)			
Diesel oil annual consumption	litres/yr	4500	
Equivalent PO emulsion consumption	litres/yr	4962	
	Kg/yr	4714	

Table 1: Main results from mass and energy balances

		Pyrolysis plant size (inlet 8%MC)	
		5 t/h	**2 t/h**
Total investment costs	Euro	9744637	5605832
Capital amortization (annual investment cost)	Euro/yr	1261975	725981
Total operating costs	Euro/yr	61172865	24615636
Diesel oil cost (included in operating cost)	Euro/yr	57882790	23153116
Annual production cost of PO emulsion	Euro/yr	62434840	25341617
PO production cost	Euro/t	147.5	183.75
	Euro/GJ	10.03	12.49
PO emulsion production cost	Euro/t	903.26	916.55
	Euro/GJ	26.63	27.02
PO emulsion total cost (incl. transport and VAT)	Euro/t	1089.9	1105.88
	Euro/GJ	32.13	32.60
	Euro/l	1035	1051
Diesel oil cost	Euro/GJ	32.34	
Cost difference in using PO emulsion		-0.63% (reduction)	+0.81% (increase)
Additional cost for modifications to heating system	Euro	450	
Pay Back Period of the investment			
PBP with white certificates	years	5.51	70.33
PBP with regional support	years	9.60	n.a.
PBP with certificates and regional support	years	3.86	49.23
PBP without any incentive	years	13.71	n.a.

Table 2: Main results from the economic analysis

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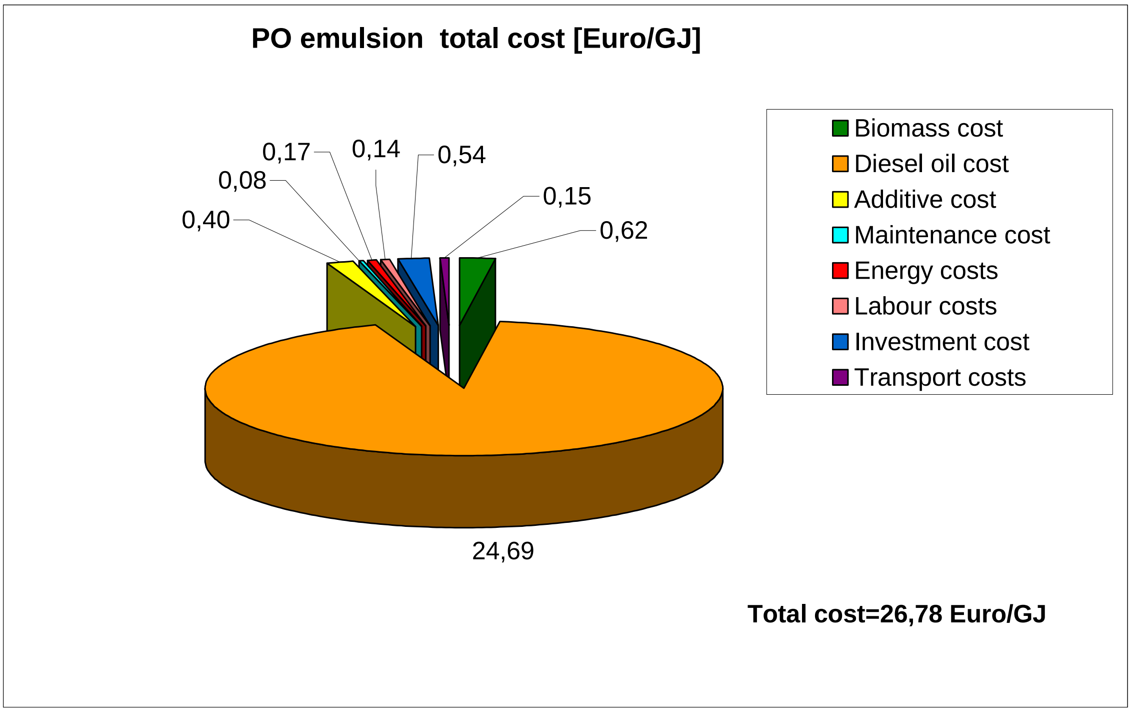

Figure 3: Contributions to PO emulsion total cost (case 5 t/h)

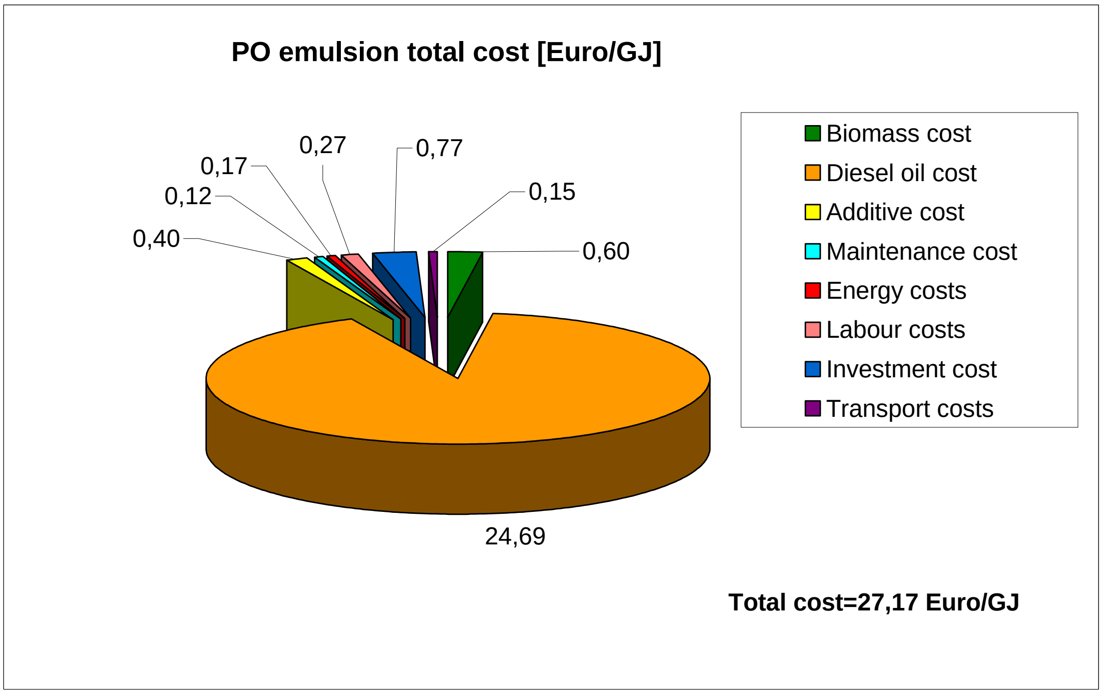

Figure 4: Contributions to PO emulsion total cost (case 2 t/h)

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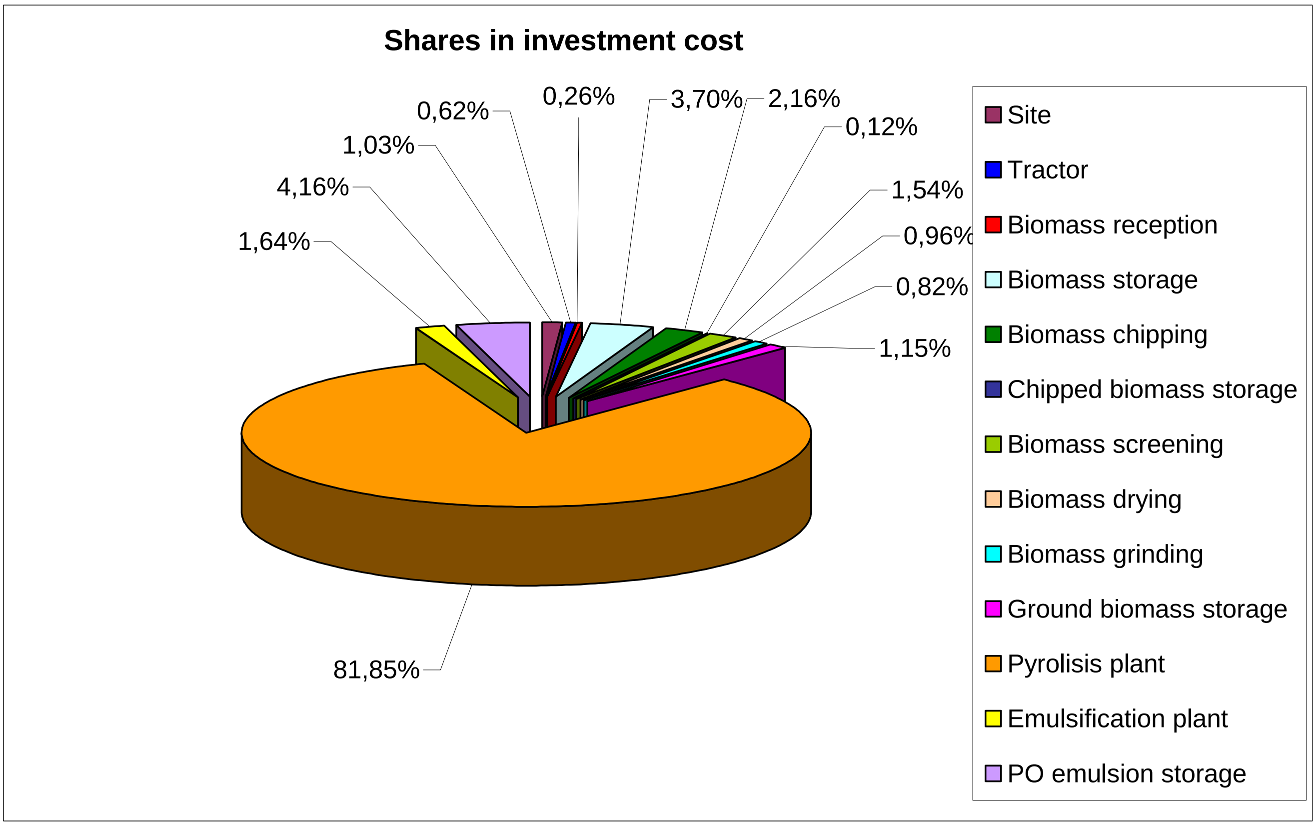

Figure 5: Shares in the investment cost (case 5 t/h)

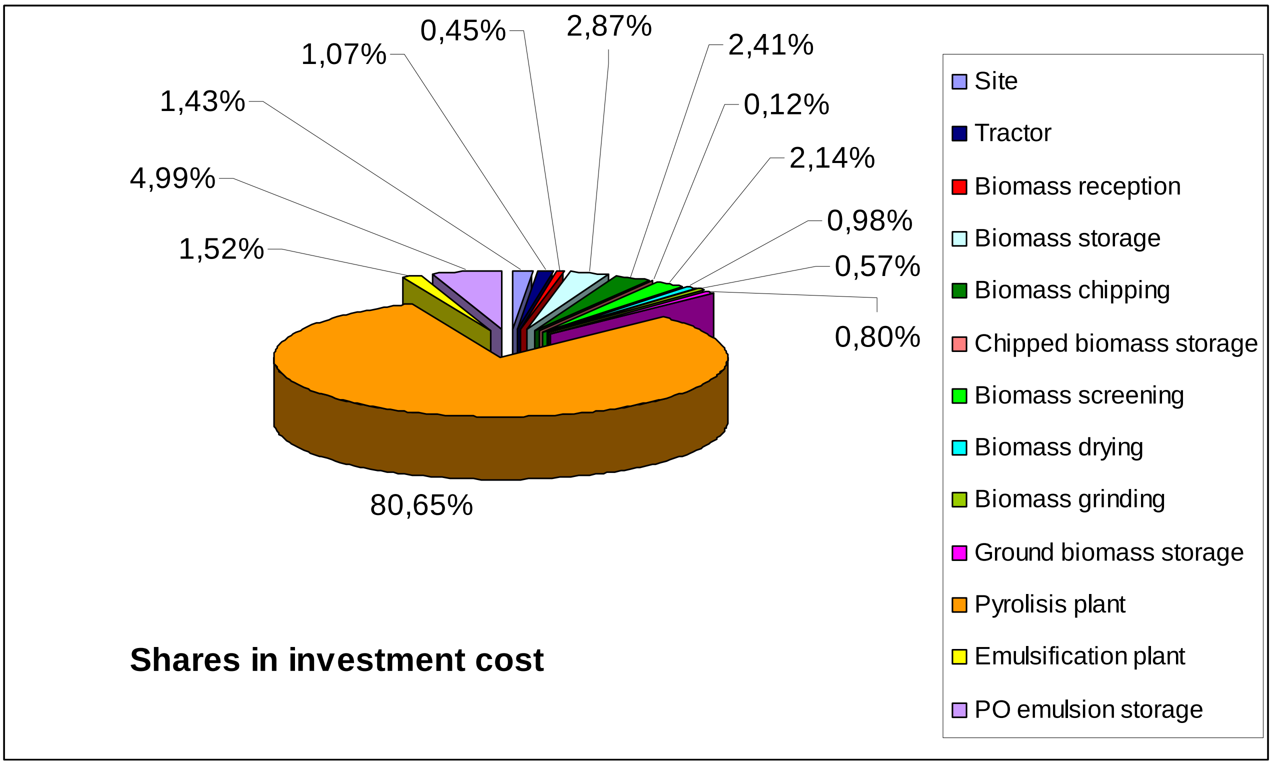

Figure 6: Shares in the investment cost (case 2 t/h)

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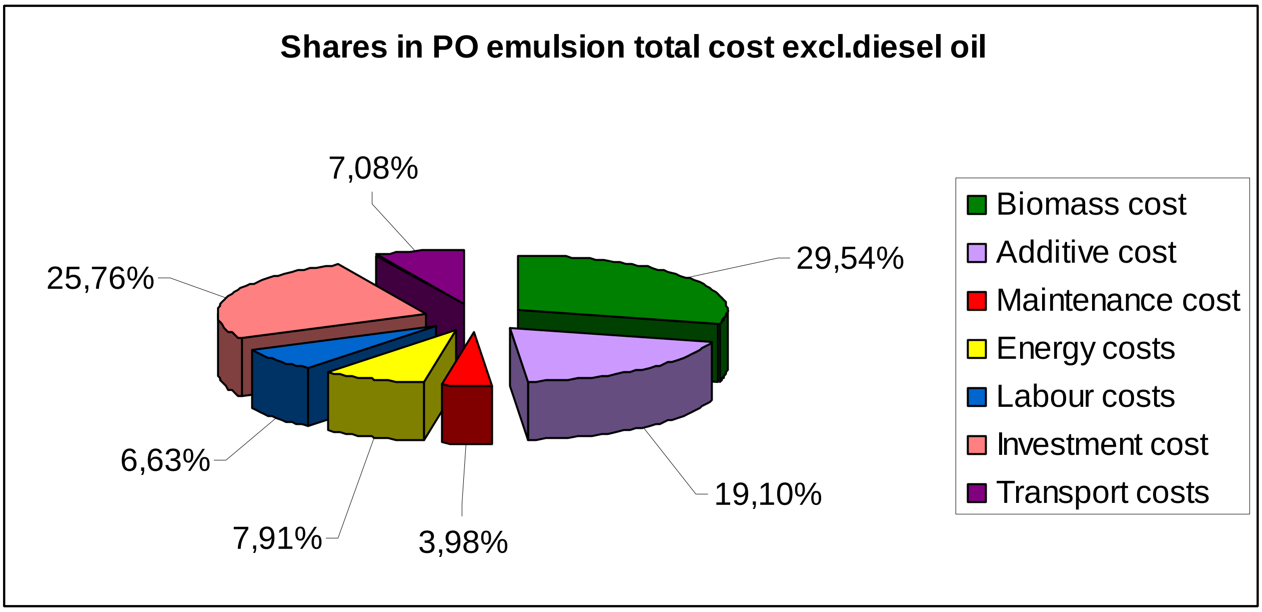

Figure 7: Shares in PO emulsion total cost not taking into account diesel oil cost (case 5 t/h)

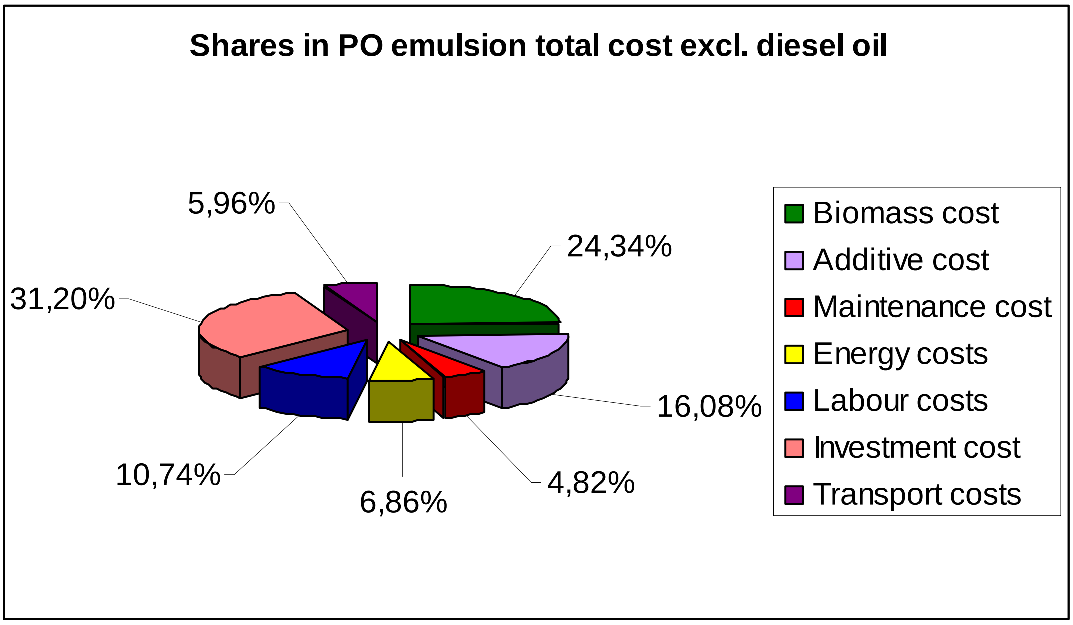

Figure 8: Shares in PO emulsion total cost not taking into account diesel oil cost (case 2 t/h)

A sensitivity analysis pointing out the influence of the most important factors on the economics of the whole system has then been carried out.

Graphs related to the 5 t/h pyrolysis plant size follow (Figures 9-12).

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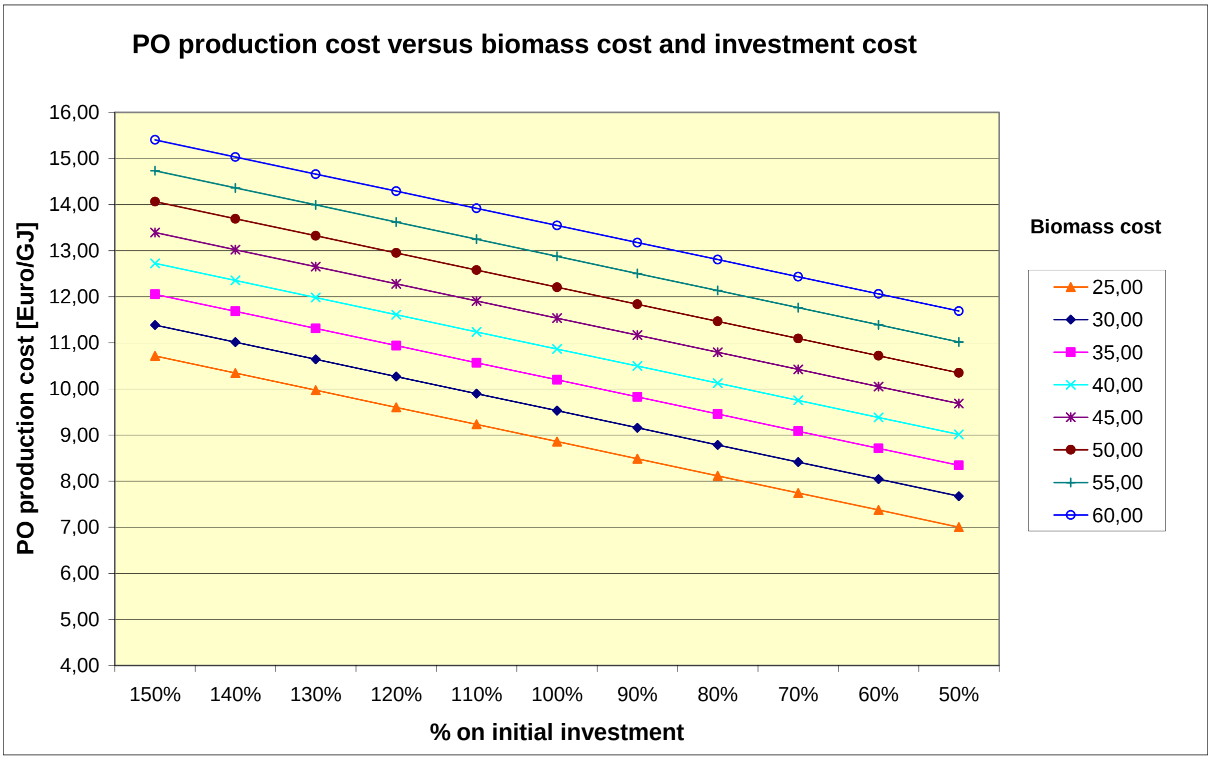

Figure 9: PO production cost versus biomass cost and investment cost (case 5 t/h)

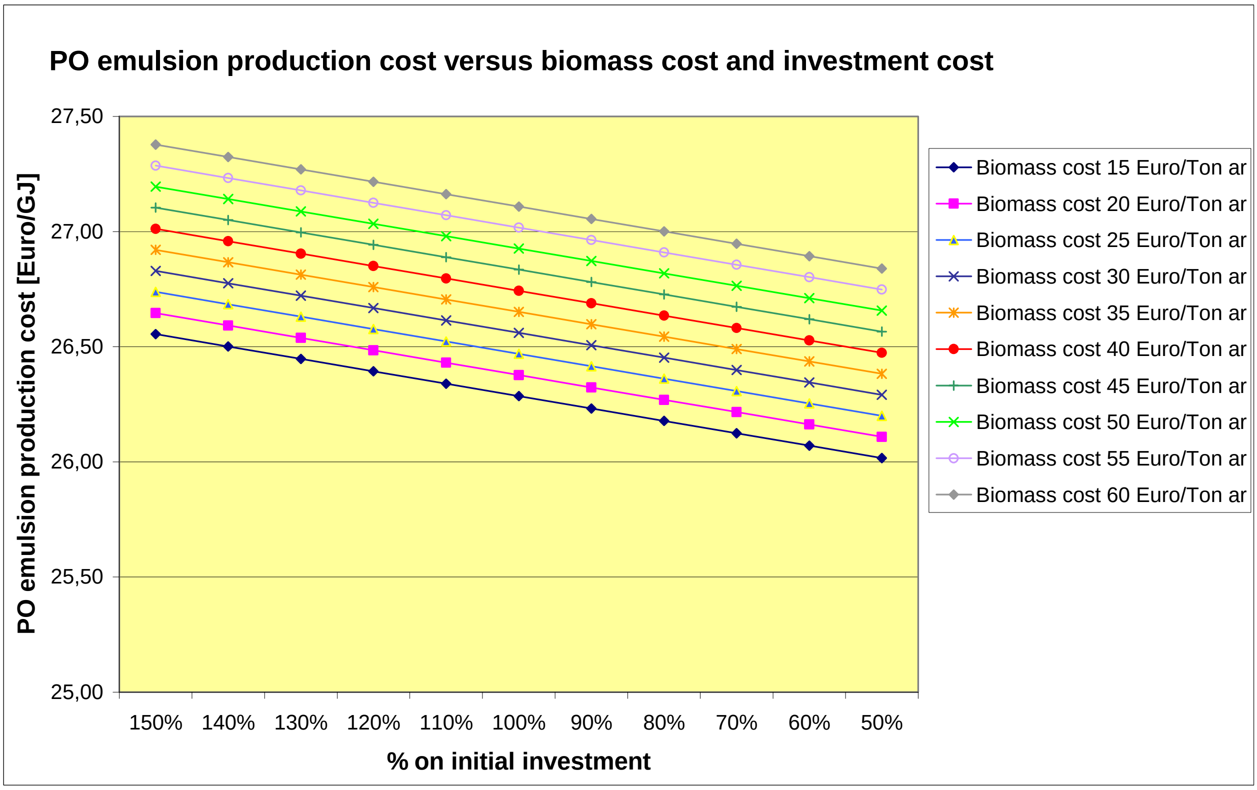

Figure 10: PO emulsion production cost versus biomass cost and investment cost (case 5 t/h)

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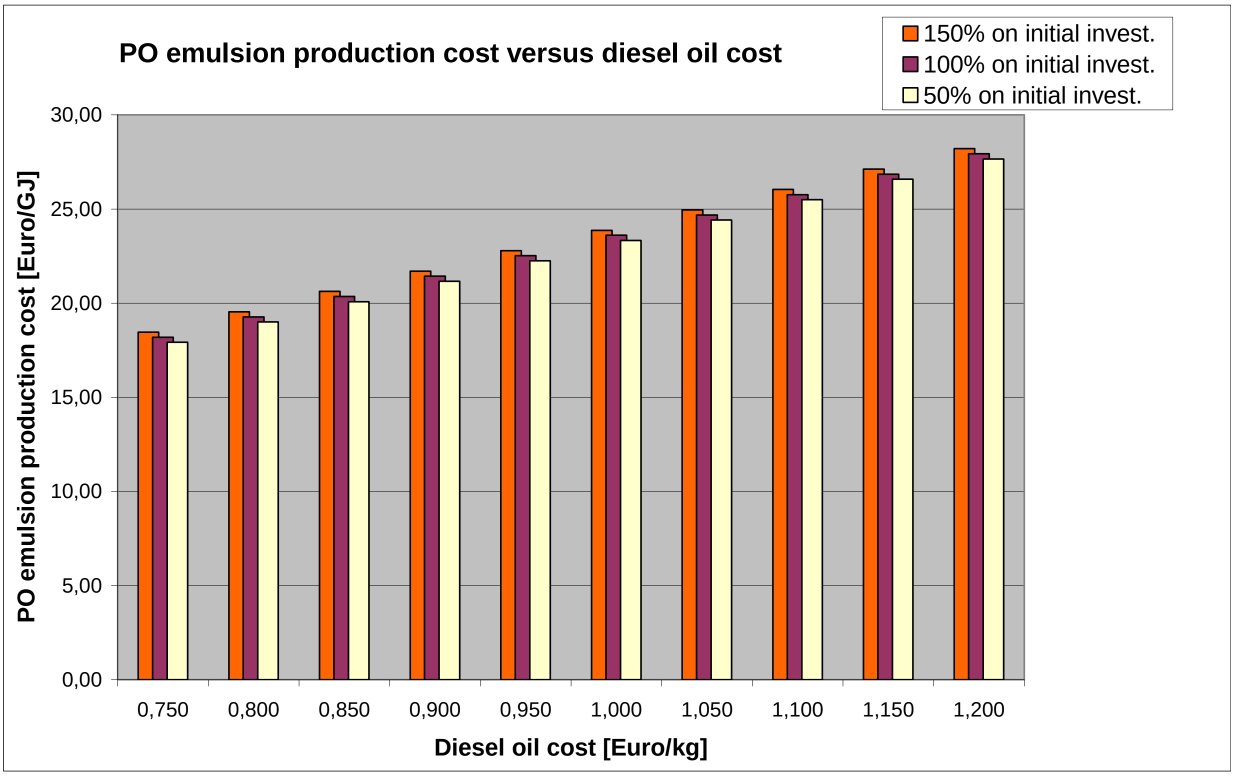

Figure 11: PO emulsion production cost versus diesel oil cost (case 5 t/h)

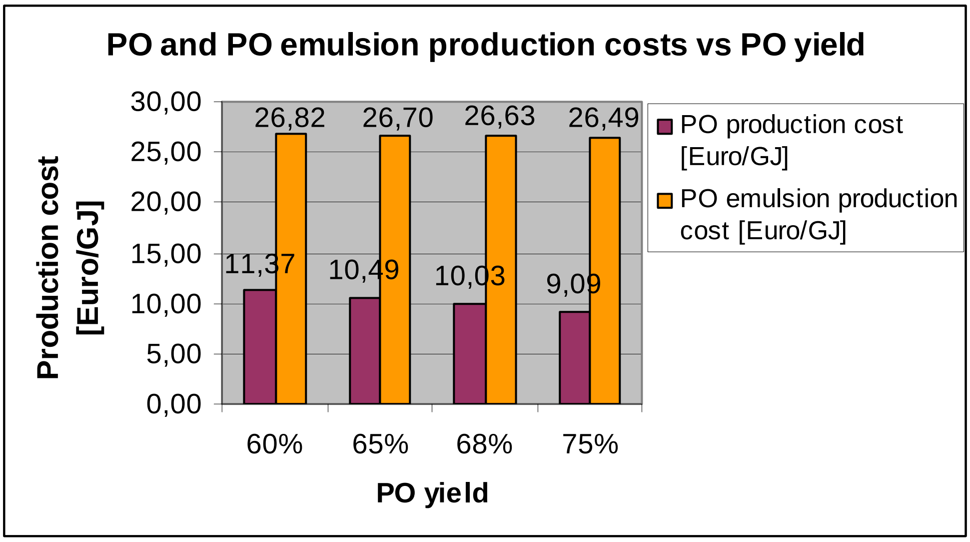

Figure 12: PO and PO emulsion production costs versus pyrolysis reaction yield (case 5 t/h)

From the analysis of the results and from the sensitivity analysis the main observations are:

- The final cost of PO emulsion is strongly dependent on the diesel oil cost. The diesel oil cost is more than 91% of the total cost of the pyrolysis oil emulsion and accounts for more than 94% of all the running costs;

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- PO and PO emulsion production costs increase with the feedstock cost and the investment cost. The sensitivity of bioenergy systems to feedstock costs is well known. When diesel oil cost is not considered biomass cost and investment cost account for more than 55% of the PO emulsion cost: for the 5 t/h pyrolysis plant size the share is 25.76% for the investment cost and 29.54% for the biomass cost, while for the 2 t/h pyrolysis plant size the share is 31.20% for the investment cost and 24.34% for the biomass cost;
- The influence of the total investment cost on the PO emulsion cost is limited; in fact 97.98% of the PO emulsion production cost is given by the running costs and 2.02 % by the capital amortization (annual investment cost) in the 5t/h case. A little higher share for the capital amortization is in the 2 t/h case, corresponding to 97.14% for the running costs and 2.86 for the capital amortization;
- Among the investment costs the pyrolysis plant has the highest share, about 81%;
- PO production cost decreases of about the same percentage as the yield of the pyrolysis process rise, while the PO emulsion production cost shows a less significant dependence on the pyrolysis yield, being much more influenced by the diesel oil cost;
- Feedstock cost becomes much more important at a larger scale, while investment cost and labour cost, being less dependent on the plant size, have a stronger influence on the smaller scale;
- The viability of PO emulsion production and utilization in small scale boilers replacing light fuel oil is strongly dependent on the plant size. Production costs are lower for the 5 t/h pyrolysis plant by virtue of the scale economies and only for this size the PO emulsion cost is lower than diesel oil. However an additional cost for the burner feeding system has to be considered to allow for the necessary modifications. A reasonable pay back period is given only for the 5 t/h pyrolysis plant size when a support can be foreseen or in terms of white certificates or with white certificates plus a regional support. No acceptable pay back period can be obtained for the 2 t/h pyrolysis plant size, even considering the incentive of white certificates plus a regional support, due to the higher cost of PO emulsion.

Therefore PO emulsion utilization in small scale boilers is not feasible without incentives, even if a support from the government cannot be a along term solution. Moreover plants below 2-3 t/h feed rate are unlikely to be viable.

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However the profitability could be greatly enhanced by fully recovering the heat associated to the char and flue gas produced in the pyrolysis reaction, or by selling waste heat and by-product char. Actually the by-product char and flue gas are partially used in the biomass drying process, but a significant amount is wasted.

Another way of reducing PO cost could be the co-production of speciality chemicals in the pyrolysis process.

An additional consideration is that comparing innovative systems with established systems is difficult, as these last have the benefit of learning effects.

Novel technologies are hampered by high capital costs, high labour costs and low reliability.

Future systems should also benefit from reduction in feed costs through improvement in silvicultural practices and in agricultural residues recovering, better reliability and reduced running costs through optimized processes.

In summary pyrolysis oil utilization has great potential to generate a profit in the long term, but a process development and optimization is needed and it has to be proven over long term operation.

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