250 kg/h biomass fast pyrolysis plant for power generation, Wellman Process Engineering Ltd., Oldbury, England (1998-2002)


250 kg/h fast pyrolysis plant for liquids   *250 kWe dual fuel diesel engine*

Project background

Within an EU funded JOR3-CT97-0197 contract, Biomass Technology Group (BTG) and Wellman Process Engineering Ltd. (WPEL) were tasked to operate a 200 kg/h and a 250 kg/h fast pyrolysis units respectively for the production of pyrolysis liquids. The product liquids were then to be combusted by Ormrod Diesels for power generation. The task of C.A.R.E. Ltd. was to determine the production costs of liquids production and subsequent electricity generation in a dual fuel diesel engine, using standard costing methods. The costs calculated were only the breakeven cost and no account of profitability or return on investment was made, due to the R&D nature of the processes. The costs were calculated for a range of input biomass to the pyrolysis reactor from 0.25 to 10 t/h.

Project summary

In order to assess the production costs of the liquids and the cost of electricity produced from the liquids, this contract offered a unique opportunity to assess and compare two different fast pyrolysis technologies, with similar wood throughputs, on a consistent basis and with the same starting and end points to minimise errors. The starting point was delivered wood chips (whole tree chipped material, wet), which were then subjected to biomass pre-treatment and preparation followed by fast pyrolysis to a stored liquid product. The liquid products would be subsequently combusted in a dual fuel diesel engine for the production of electricity, based on a 10% energy input from the diesel. A base plant size of 2 t/h dry feed input was used which can be scaled up or down to give credible capital cost estimates from 0.25 to 10 dry t/h feed rate. The overall system consisted of three modules:

- Biomass preparation/pre-treatment,
- Fast pyrolysis to a recovered liquid product
- Power generation in a dual fuel diesel engine.

Pyrolysis liquids production costs

The estimated production costs for the pyrolysis liquids versus wood capacity and feedstock cost are presented in
Table 1. A cost comparison of the liquids is also given in Table 2 on a mass, volume and energy basis for a 2 t/h plant, 7000 hours/y operation.

Table 1. Cost of pyrolysis liquids (€/t) v's wood feed rate and feedstock cost

Feedstock cost (€/t)	Plant capacity (dry t/h)						
	0.25	**0.5**	**1**	**2**	**5**	**7.5**	**10**
Wellman							
0	555	321	203	134	84	70	63
50	625	392	274	205	155	141	134
100	696	462	344	276	226	212	204
BTG							
0	514	294	184	120	73	60	53
50	592	372	262	198	151	138	132
100	670	450	340	276	229	217	210

Table 2. Pyrolysis liquids production costs on a mass, volume and energy basis (2t/h capacity)

Feedstock Cost (€/t delivered)	€/t		€/m^3		€/GJ	
	Wellman	BTG	Wellman	BTG	Wellman	BTG
0	134	120	111	99	9.5	8.0
50	205	198	170	164	14.6	13.2
100	276	276	228	228	19.6	18.4

The production cost of the pyrolysis liquids was very high, on an energy basis with a cost of 14.6 €/GJ and 13.2 €/GJ for Wellman and BTG respectively for a feedstock cost of 50€/t and a plant capacity of 10 t/h. The relative differences between Wellman and BTG were small, but the higher proposed yield for Wellman (79wt% relative to 72wt% for BTG) offset the higher installed capital cost. The cost for domestic heating oil at that time averaged 9.9 €/GJ across a range of EU member states (2000 basis). The opportunity for pyrolysis liquids, for use purely as a heating fuel oil would be in a select few countries where taxation levels are high (Denmark, Italy and the Netherlands for example).

Electricity production costs

The electricity production cost was based on the overall plant and took into account all of the wood preparation, pyrolysis and subsequent utilisation in a dual fuel diesel engine. The costs for both processes are presented in Table 3 and Table 4. From the data, it can be seen that the cost of "bio-electricity" was very high for both processes. Only those processes where the net electrical output was over 10 t/h appeared to be viable (€cents 12.6 /kWh and €cents 11.9 /kWh for Wellman and BTG respectively at 10 t/h wood input and a feedstock cost of €50/t). These prices could not compete with base electrical production costs for industry, but may offer some limited scope for domestic consumers in a few countries (Denmark, Italy and the Netherlands for example). If the end user is using the electricity for on-site use, in a domestic capacity, then there is an opportunity for pyrolysis liquids to meet the demand, as domestic prices are much higher than industrial prices. This will also depend on whether any incentives are offered for the "green" electricity and whether taxation on fossil fuels, i.e. environmental credits, can be applied to the technology.

Table 3. Electricity production cost for Wellman process + engine – different pyrolysis plant capacities (delivered feedstock cost €50/t).

Plant capacity (t/h feed)	**0.25**	**0.5**	**1**	**2**	**5**	**10**
Electrical output (MWe)	0.33	0.67	1.33	2.67	6.67	13.33
Electricity Production Cost (€cents/kWh)	49.2	32.6	23.8	18.5	14.4	12.6

Table 4. Electricity production cost for BTG process + engine – different pyrolysis plant capacities (delivered feedstock cost €50/t).

Plant capacity (t/h feed)	**0.25**	**0.5**	**1**	**2**	**5**	**10**
Electrical output (MWe)	0.339	0.678	1.357	2.714	6.785	13.56
Electricity Production Cost (€cents/kWh)	44.2	29.6	21.9	17.2	13.6	11.9

Project status

The BTG fast pyrolysis plant was already in existence and the Wellman plant was constructed within the framework of the contract, however, due to excessive authorisation costs under IPPC, the WPEL plant never operated beyond initial hot commissioning.