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CHARCOAL PRODUCTION WITH REDUCED EMISSIONS

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This paper describes the old Twin Retort (or Tandem Retort) carbonisation technology. That same principle is used by Clean Fuels, however, augmented by the principles of the Condensing Retort and FFLIT technology for energy storage and bio-oil combustion.

ABSTRACT: Charcoal remains a popular fuel throughout the world. Demand is already large, and increasing rapidly. Worldwide consumption is estimated at 40.5 million tonnes, with Africa alone responsible for 19.8 million tonnes. The traditional charcoal production process is inefficient. Weight efficiencies of 10-15% are not uncommon, i.e. 7-10 kg of wood are needed for one kg of charcoal. Depending on the sustainability of the wood, greenhouse gas emissions could be substantial on the global level. In The Netherlands, a 'Twin-retort' carbonisation process has been developed to address charcoal production efficiency and emission problems, and different sized factories have successfully been set up in China, Estonia, Ghana, and The Netherlands. The retort-type system produces charcoal at a rate of 900 tonnes per year, and several batches of these retorts can be made to function in tandem. The efficiency is more than double that of the traditional charcoaling process, thereby reducing emissions with at least a factor two. In addition, all gases generated during the carbonisation phase – which escape into the atmosphere with the traditional production process - are reintroduced into the retort and burnt, resulting in very low overall emissions.

Keywords: charcoal, timber residues, operating experience

1 BACKGROUND

Charcoal, mainly produced from wood, is a fuel used extensively in the world, for various purposes. In the developing world, charcoal is primarily used as cooking fuel in urban areas, and in the western world charcoal is used in the metallurgical industries and as barbecue fuel.

The demand for it is already fairly large, and is increasing rapidly. Worldwide consumption is estimated at 40.5 million tonnes annually, with 19.8 million tonnes just for Africa [1].

Charcoal production involves thermal decomposition of wood, and can be carried out in open pits, kilns or retorts. Charcoal production in open pits and kilns takes place with a more or less controlled air supply, allowing for heat supply by burning part of the wood. In retorts, charcoal is produced in the absence of air, implying that heat supply must come from another source.

The traditional production process in open pits or kilns, as carried out in rural areas, is inefficient. Weight efficiencies of 10-15% are not uncommon, i.e. 7-10 kg of wood to produce one kg of charcoal. Depending on the sustainability of the wood used to make charcoal, greenhouse gas emissions released into the atmosphere could be substantial on the global level.

2 THE 'TWIN-RETORT' SYSTEM

2.1 Retort carbonisation technologies

Retort carbonisation technologies can be categorised into continuous and semi-continuous systems. Continuous systems consist of a vertical, horizontal, or inclined retort with an automatic charge and discharge system. The retort is heated by an external heat source and the wood is gradually carbonised while moving through the retort.

In the Netherlands, Norit B.V. is the only known manufacturer of continuous carbonisers (horizontal retorts). Another example of continuous carbonisers (vertical retorts) is the system of Lambiotte & Cie, from Belgium. Continuous systems are capital intensive and are therefore mainly interesting for large-scale applications.

2.2 Technology description

In the nineties, the development of the 'Twin-retort' systems started in The Netherlands. The Twin-retort system is a semi-continuous production module, with a capacity of 900 tonnes of charcoal per year. One module consists of two retorts, placed in an insulated oven, which is mounted on an armed concrete floor and placed in a hall. The hall should be provided with a monorail and overhead crane that enables lifting the retort vessels into and out of the carbonisation unit. A modified fork-lift and often also a woodcutter are necessary. In figures 1 and 2 pictures of the Twin-retort system are shown.

Figure 1 Side view of a Twin-retort carbonisation unit. To the right two carbonisation vessels are shown

In each of the two retorts a vessel with fresh wood is to be placed alternately. Carbonisation of one vessel usually takes about twelve hours. With two carbonisation modules, this implies that on average every three hours a vessel of charcoal has to be replaced by a vessel of fresh wood

When one vessel has reached the carbonisation temperature (ca. 500°C), thermal decomposition takes place, and pyrolysis gases are emitted from the vessel. These gases are combusted in-situ to provide the heat supply for heating up the other vessel. This way, no external energy source is needed after start-up. An oil burner is used to provide heat for the initial process start-up.

Figure 2 Front view of a Twin-retort carbonisation unit. Two carbonisation vessels are placed in the unit to function in tandem.

After carbonisation, the hot vessels, filled with charcoal, are placed in a sand lock and left for a 20-24 hours (natural) cooling period before emptying. This means that spare vessels are needed to keep the carbonisation system running. The production steps are graphically depicted in figure 3.

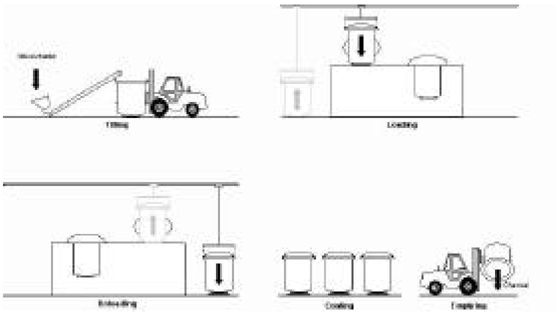

Figure 3 Operation of the Twin-retort system.

Wood input can be both hardwood and softwood. Residues from sawmills or similar wood processing industries are excellent. Size reduction into pieces of ca. 10-30 cm is required.

Freshly cut wood, which has often a too high moisture content of up to 50% (wet basis) cannot be used directly, since this would increase carbonisation time and requires too much heat. However, with the off-gases from the exhaust of the carbonisation units, the wood can be dried prior to carbonisation. Vessels with fresh wood are placed on a pre-drying platform, and dried to acceptable moisture content levels (20% or less, on a wet basis). This system is currently in use in the production facilities in The Netherlands and in Estonia.

2.3 Benefits

Besides low emissions, the Twin-retort charcoal production process possesses several other strong points:

- Because of the extensive refractory lining of the modules, high carbonisation efficiencies and a superior product quality can be attained. Yields are typically 33% on weight basis, implying that for every 3 tonnes of wood one tonne of charcoal is produced. This is more than double the efficiency of a traditional charcoaling process, implying a reduction in CO_2 emissions of a factor two.
- Charcoal quality is excellent, with a carbon content of 92%, which is well above the European requirement of 83% as set out in the prEN 1860-2 standard for barbecue charcoal [2]. Also all other requirements set out in the prEN 1860-2 standards, namely ash content, moisture content, and granulation, are easily met.
- Operation is straight-forward. Since the modules are equipped with simple and understandable controls, relatively low-skilled personnel can operate the system.
- Scale-up is readily performed. Since the system is modular, with units of a 900 tonne per year capacity each, scale-up is accomplished by implementing more modules, leading to economy-of-scale benefits due to the better utilisation of auxiliary equipment (such as the monorail, fork-lifts, etc.)

3 EMISSIONS

Compared to traditional charcoal production processes, the Twin-retort system is very low on emissions. CO_2 emissions for example, are far lower because of the higher efficiency of the system. Weight efficiencies of 33%, as opposed to 10-15% for traditional charcoal making, imply that for traditional charcoal production roughly twice the amount of wood is needed. This means that the amount of CO_2 emissions released from the Twin-retort system is about half that of traditional charcoal making. Net CO_2 emissions are however dependent on the sustainability of the wood input.

When comparing non-CO_2 emissions, effects are more pronounced. This is to be expected, because non-CO_2 emissions are for a large part linked to process layout and control. Because of the in-situ combustion of the pyrolysis gases released from the wood, emissions from the Twin-retort system comply to the Dutch NeR standard, which is among the strictest in the world [3]. In Table 2 these emissions are compared with the IPCC default values for traditional charcoal production [4].

Table 1: Comparison of non-CO_2 emissions from the Twin-retort system with traditional charcoal production.

Compound	**Traditional production (kg/TJ charcoal)**	**Twin-retort system (kg/TJ charcoal)**	**Twin-retort system (mg/Nm^3) at 3% oxygen**
CH_4	1000		
NO_x	10	< 6.7	<70
CO	7000	< 4.8	<50
NMVOC	1700		
CH_4 + NMVOC		< 1.0	<10
N_2O	NAV	NAV	NAV
SO_2	NAV	< 3.9	<40
Particles		< 0.5	<5

Non-CO_2 emissions from the Twin-retort system have been derived using the NeR-values, as given in the middle column of Table 1, and IPCC assumptions (e.g. an energy content of 30 MJ/kg charcoal). Especially methane (CH_4) and non-methane volatile organic compounds (NMVOC) are far lower in the Twin-retort system.

4 ECONOMICS

4.1 Application case study Estonia

Process economics are dependent on local circumstances, such as wood price, charcoal price, plant size, labour costs, etc. For each specific application, a different calculation must be made. In the next tables, one such calculation is included based on the existing plant in Estonia, when it started more than one year ago.

This plant is located in Pärnu, and uses green alder, birch and aspen as raw material. Charcoal is produced both for the consumer market and for industrial clients, and is sold domestically and in Scandinavia. Currently, production is twice the initial capacity because of the addition of one additional carbonisation unit.

Sample production parameters are listed in Table 2. In this application case, fresh wood is used, pre-dried as described earlier. It is assumed that the plant is operated continuously (24 hours per day, seven days per week) during 90% of the time (capacity factor 90%).

Table 2: Production parameters for the Estonian Twin-retort carbonisation plant

Number of ovens		1
Capacity of one vessel	[m^3s wood/vessel]	3
Specific weight wood (dry)	[tonne/m^3s]	0.5
Moisture content wood	[%, wet basis]	50%
Efficiency	[tonne wood (dry)/tonne of charcoal]	2.4
Actual efficiency (wt)	[tonne wood (wet)/tonne of charcoal]	4.8
Average production time for one vessel	[hours]	12
Capacity	[tonne/year]	900
Capacity factor	[prod. hrs/total hrs.]	0.9
Annual input	[tonne wood (wet)/year	3,888
Annual output	[tonne charcoal /year]	810

Financial data are listed in Table 3.

Table 3: Financial data for the Estonian Twin-retort carbonisation plant

Wood (moisture content 50%, wet basis) costs	[EUR/m^3s]	8
Charcoal sales price	[EUR/tonne]	250
Project time	[years]	10
Investment	[EUR]	480,000
O&M costs	[percentage of investment]	10%
Discount rate	[%]	15%

Wood costs are modest compared to usual prices in Estonia, also because of the high moisture content. Labour costs for normal operation are included in the Operation and Maintenance (O&M) costs. Investment costs comprise costs for the carbonisation unit including installation, civil works, working capital and project preparation and technical assistance. A discount rate of 15% is normally applied in Estonia.

Table 4: Financial results for the Estonian 'Twin-retort carbonisation plant

Annual costs	[EUR/year]	79,104
Annual revenues	[EUR/year]	202,500
Annual cashflow	[EUR/year]	123,396
Simple payback	[year]	3.9
Net Present Value (NPV)	[EUR]	121,127
Internal Rate of Return (IRR)	[%]	22%

Annual costs and revenues follow directly from the data of Table 4. The positive NPV implies an IRR above the discount rate.

4.2 Sensitivity analysis

In figure 3 the sensitivity of the IRR with respect to several parameters is shown. The Figure shows that costs for Operation and Maintenance (O&M) and fuel (wood) have relatively little influence on the economic viability of the project. An increase of 50% of either one will not result in the IRR decreasing below the Discount rate.

Of larger influence are the other three parameters, capacity factor, charcoal market price and to a lesser extent the investment costs. If either capacity factor or charcoal market prices are only 75% of the assumed values (90% and 250 EUR/tonne respectively), the project IRR will end up significantly lower. On the other hand, increases in these parameters result in large increases in the IRR. Investment costs may increase with 50%, without the IRR going below 10%; When investment costs are reduced by 50%, the IRR would increase up to 50%.

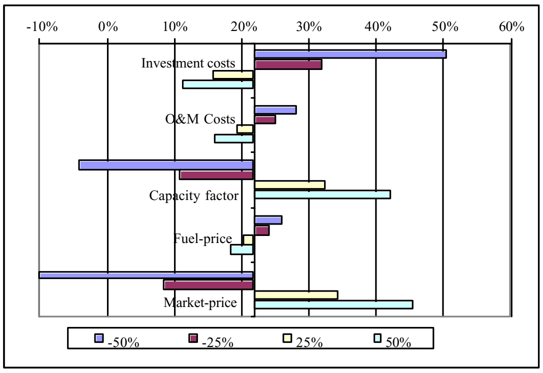

Figure 4 Sensitivity of the IRR for changes in key parameters for the Estonian 'Twin-retort' carbonisation plant

From this economic analysis, and from this sensitivity analysis, it follows that the implementation of one Twin-retort module is under the assumptions made in this sample case study economically feasible in Estonia, a result which is underlined by the plant in Pärnu, which is operational since 2001.

5 IMPLEMENTATION TRACK RECORD

Since the start of the development in the early nineties, Twin-retort carbonisation systems have been implemented in various countries in the world. In Table 5 locations, current capacities and year of production start-up are listed.

Table 5: Implementation locations of the Twin-retort system

Location	**Current capacity (tonne charcoal/year)**	**Operational since (year)**
Almelo, The Netherlands	11,000	1998
Pärnu, Estonia	1,800	2001
Manso Amenfi, Ghana	1,800	2001
Hailin, China	900	2000

On these locations, charcoal is produced for local markets, with some charcoal destined for export. Raw materials range from sawmill waste wood to forestry thinnings. Currently, implementation of new systems is planned in Cuba, and in South Africa.

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