

**CLEAN FUELS b.v.**  
for a sustainable energy economy

POSSIBLE TRENDS IN THE CHARCOAL MAKING INDUSTRY  
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FAO

POSSIBLE TRENDS IN THE CHARCOAL MAKING INDUSTRY

Market pull ?

Technical options for improvements ?

## END-USER MARKETS

Traditional markets for charcoal are not likely to trigger innovative technologies:

<ul style="list-style-type: none"><li>• Metallurgical industries</li><li>• Purification (active coal)</li><li>• Barbecue in industrialized countries</li></ul>	Based on unique Charcoal properties Markets are gradually growing
<ul style="list-style-type: none"><li>• Household cooking in DCs, mainly urban</li></ul>	Relatively clean (moderate local emissions) Low costs (incl. low-costs of appliances) Likely to be phased out

NEW MARKET FOR INDUSTRIAL FUELS (INCL. FOR THE ELECTRICITY SECTOR)

As alternative to fossil fuels

Based on two properties:

- Potentially sustainable (GHG-neutral) (if properly management!)
- Supply diversification

Alternative products for the same energy market are:

- Pyrolysis oil (PhD Siemons 2002)
- Wood pellets (2006: Danish power plants ~ 570,000 t wood pellets and chips, and 910,000 t straw pellets).

Compare BBQ Europe: ~ 600,000 t/a (right Yves?)

## TRADING PROPERTIES BIOMASS FUELS

Suitability for trading:

- Ease of application (storage, handling, combustion)
- Cost-effective calorific value and density.

### Bio-fuels and mineral coal

Fuel type	NCV (MJ/kg)	Density ( kg/m <sup>3</sup> b)	Energy density (MJ/m <sup>3</sup> b)	Ash (d)
Straw pellets	15	600	9000	5%
Wood pellets	17.5	650	11400	0.50%
Charcoal (lump)	29	200	5800	1.5%
Pyrolysis oil	17.2	1300	22400	0.10%
Coal	25	1000	25000	13%

Some ideas:

Charcoal/water (60/40) slurries -----> increased energy density by 3 (18,000 MJ/m<sup>3</sup>b)

Charcoal/pyrolysis-oil (60/40) -----> increased energy density by 6 (32,000 MJ/m<sup>3</sup>b)

Could this stimulate a particular development of carbonization technologies?

## TECHNICAL OPTIONS FOR IMPROVEMENTS ?

Consider:

- Scale-up (realizing economies of scale)
- Processing yield (reducing operational costs)
- Simplification (reducing capital costs)

## SCALE-ECONOMY

Lambiotte (Belgium): 2000 and 6000 t charcoal/a (~ wood input = 8000-24000 t/a)

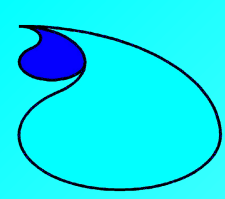
Carbo Group (The Netherlands): 1000 t/a (~ wood input = 3000 t/a)

Interest in scaling up:

- Lambiotte unknown
- Carbo not easily upscalable (Carbo prefers parallel operation)

Counter indications:

- Wood acquisition risk
- Perhaps: Increased costs of raw material (wood)



## PROCESSING YIELD

- Traditional kilning: 5%-20%, occasionally higher (Schenkel, 1998)
- Industrial retorting: 20%-30%

## Technical limitations to results of R&D?

Antal, M. J. jr. (Hawaii Natural Energy Institute), M. Grønli (SINTEF Energy Research):  
maximum theoretical yield appr. 30%.

## Their approach:

- 1 Define the raw material (cellulose) and the product (simplified by postulating only CO<sub>2</sub>, C (graphite), H<sub>2</sub>O, CH<sub>4</sub> and CO,
- 2 Define the thermal production conditions by pressure and temperature,
- 3 Analyse thermodynamic equilibrium (not chemical reactions)

## Critical questions:

- 1 Charcoal = graphite?
- 2 Carbonization = disintegration of wood into charcoal and vapours that are gone?  
Relevance of secondary carbonization reactions of vapours (precipitation of fixed carbon)?

'HIGH PRESSURE, HENCE HIGH YIELD' ?

No, not according to equilibrium model Antal et al.

Yes, according to experiments carried out by Antal et al.

Our Hypothesis: high yields result from increased vapour residence time at high T.

If so, favourable reaction circumstances are:

- Slow vapour removal from charcoal matrix
- Vapour exposure to high-T charcoal

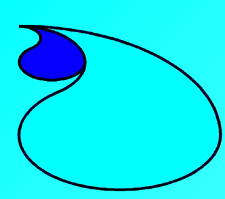
Options for optimised reactor configuration:

- Closed container
- Vapour flow control

The closed container is actually pursued by Antal (Flash Carbonisation):

- Average charcoal yield of 34%,
- Average energy efficiency of 60%

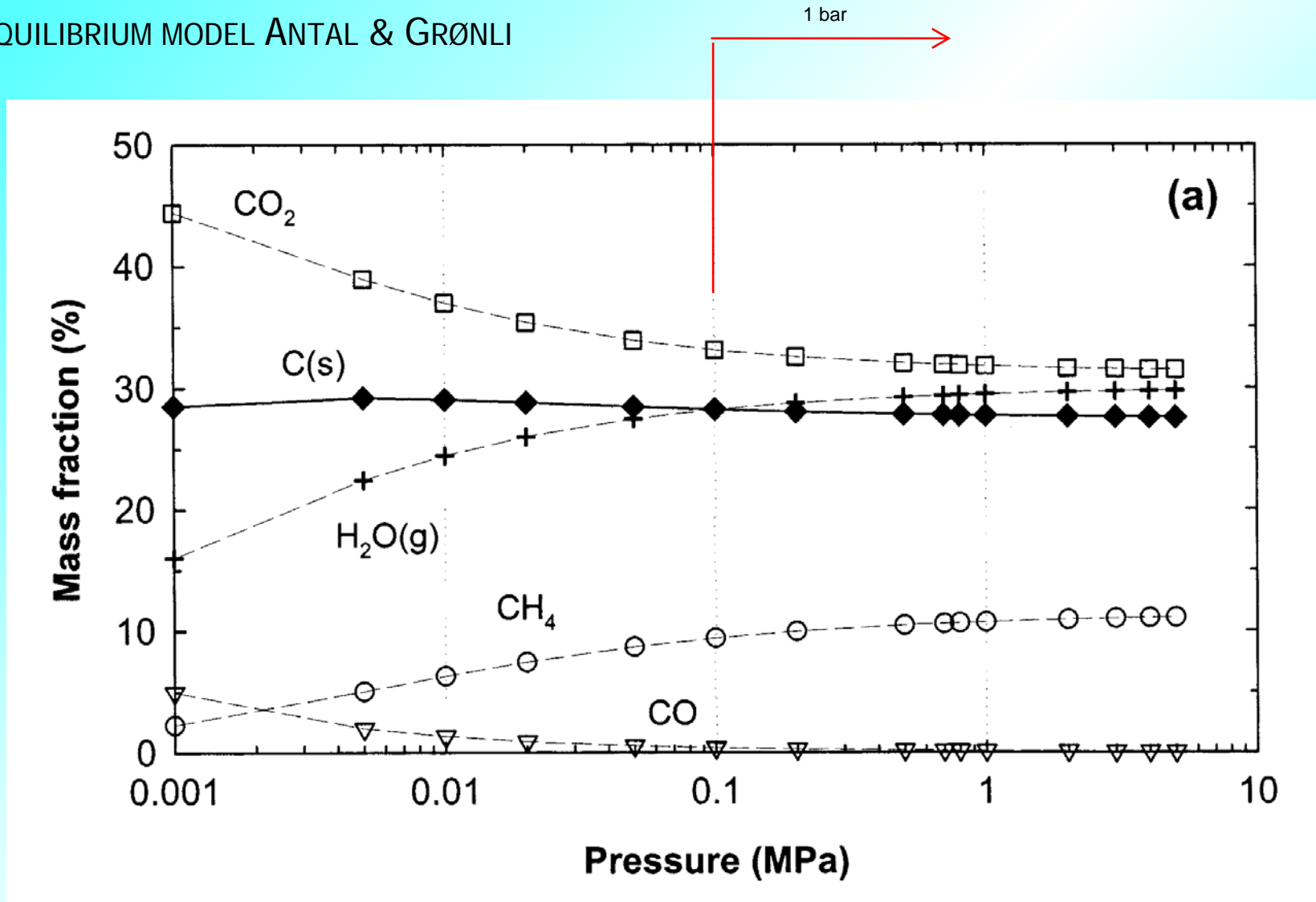
Not very dramatic in comparison with other technologies.



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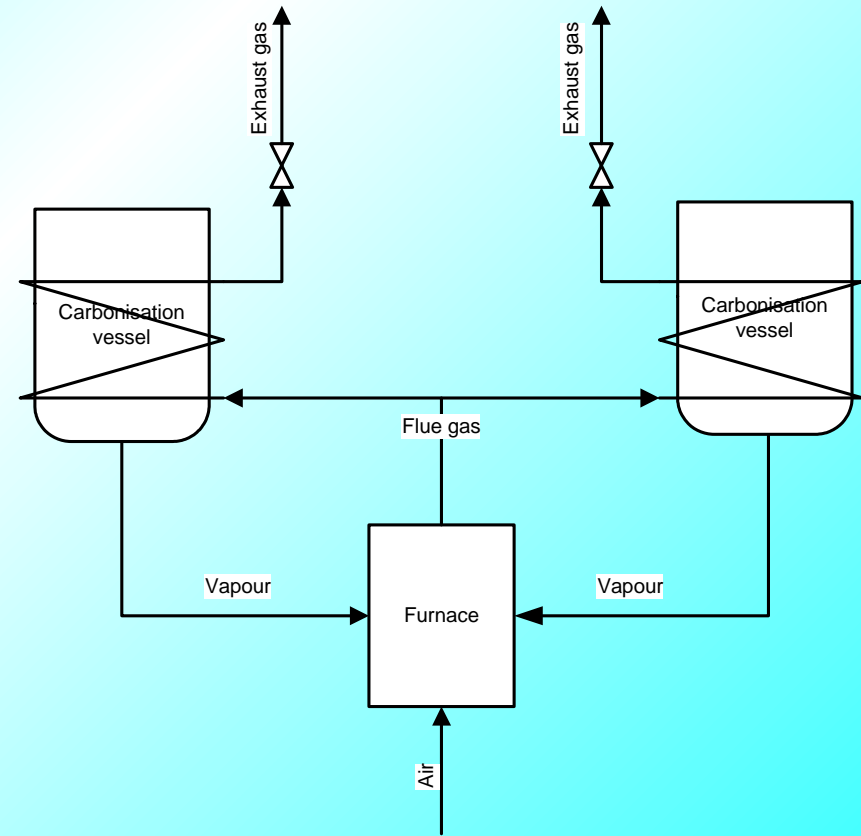
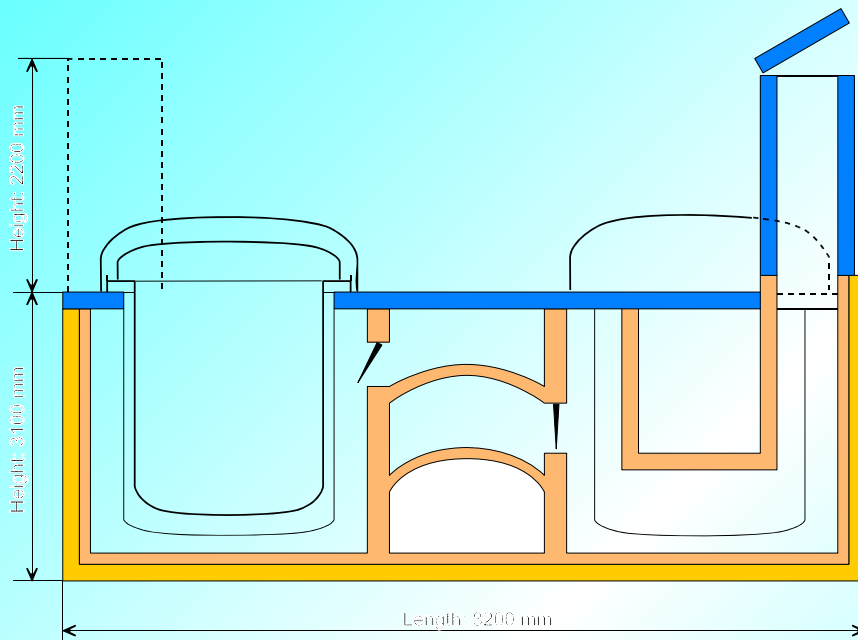
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RESULTS EQUILIBRIUM MODEL ANTAL & GRØNLI



## DEVELOPMENT AT CARBO GROUP

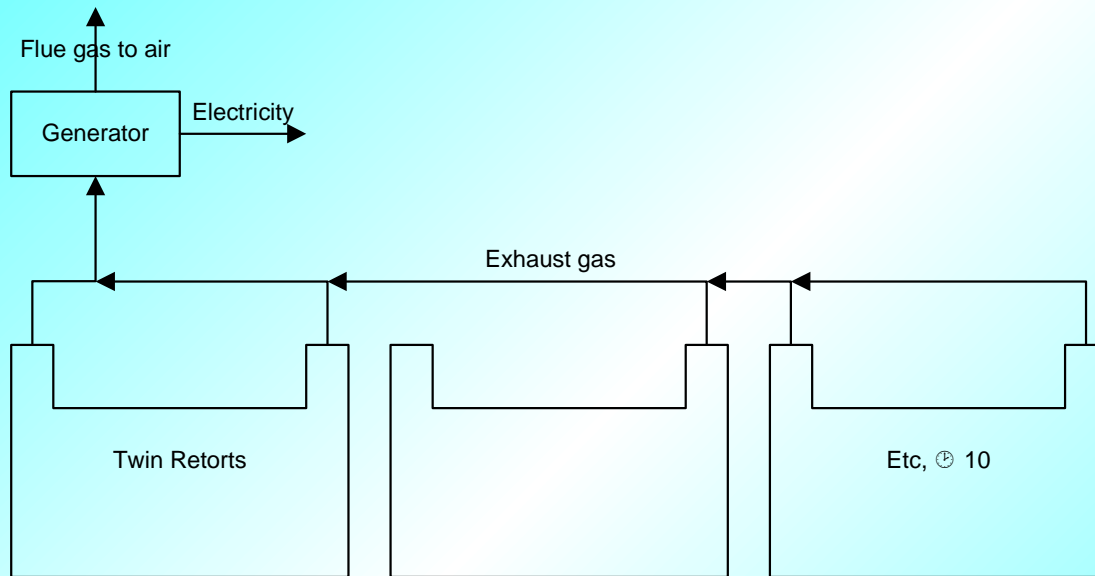
### Operating principle



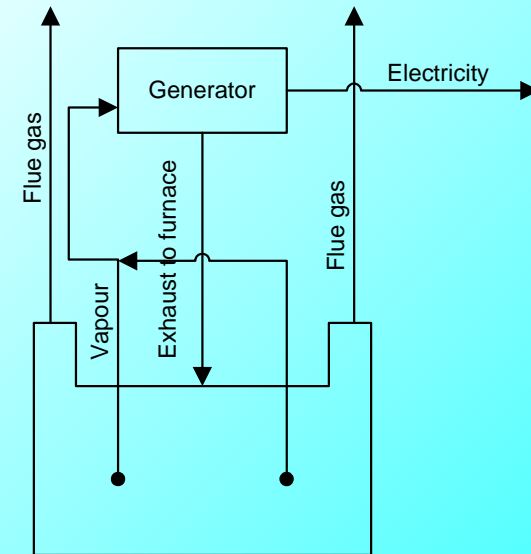
## FEASIBILITY STUDIES COGEN OF CHARCOAL AND ELECTRICITY

### Alternatives:

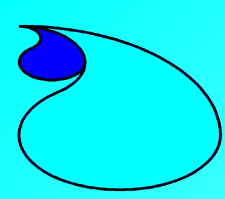
- 1 Exhaust: Steam or ORC cycle, at exhaust of carbonization process
- 2 Extraction: Direct utilization of surplus carbonization vapours
  - 2.1 Steam or ORC
  - 2.2 Vapour gasification (can be combined with 1)



Exhaust alternative  
(steam or ORC)



Extraction alternative  
(steam, ORC, or  
gasification)



## EXISTING TECHNOLOGIES (STEAM, ORC, STIRLING)

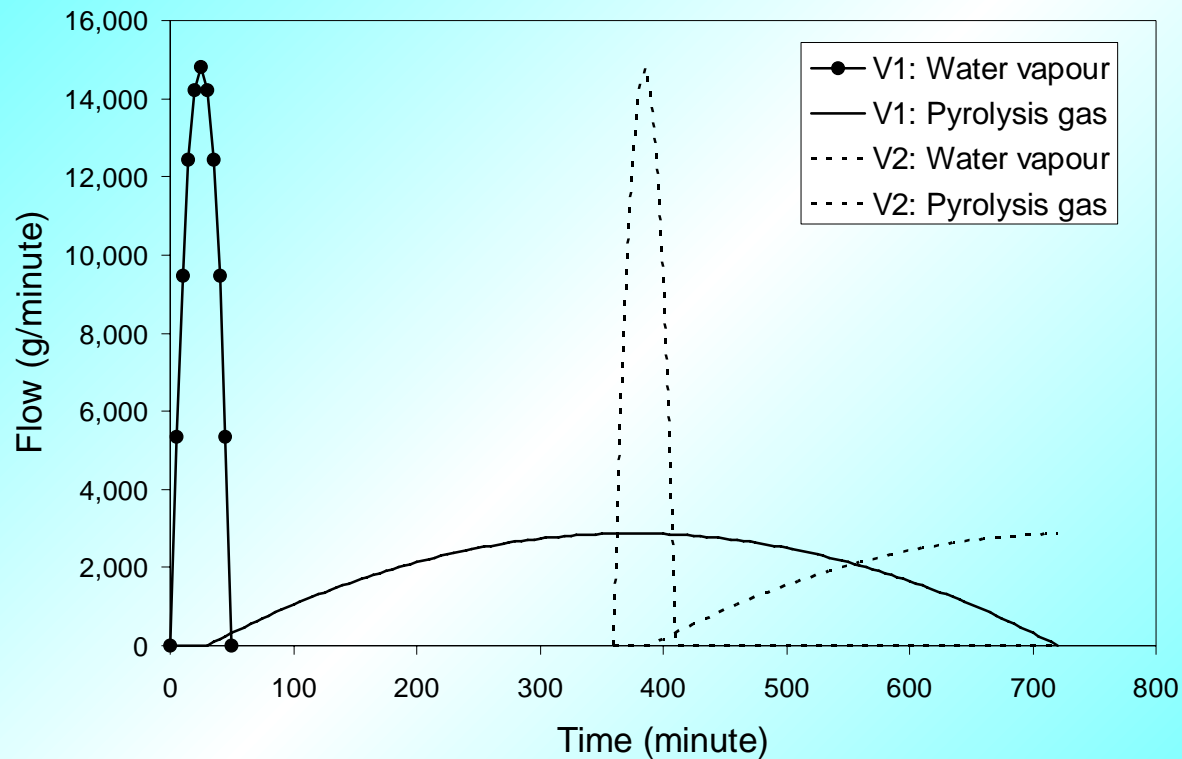
	Steam				ORC		
	625	390	475	300	Triogen	Turboden	GMK
Capacity (kW)	625	390	475	300	155	500	440
Investment (€/kW)	3487	4938	4559	6374	4880	2771	1993
Efficiency	19%	12%	19%	12%	17%	18%	20%
Variant	Extraction	Extraction	Exhaust	Exhaust	Exhaust	Exhaust	Exhaust
Twin Retorts #	10	10	10	10	4	10	10

ORC is less expensive, especially for smaller power capacities  
 Stirling: efficiency too low (hence very small power capacities)

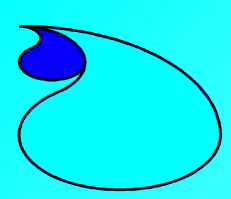
Smaller scale is preferred (single Twin Retort): need for vapour gasification technology

## R&D VAPOUR GASIFICATION

Technical potential: 50 kW per Twin Retort (on time average of vapour flow)



Technology: nickel-alumina catalysts (KATALCO), at 700 °C



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THANK YOU  
FOR YOUR KIND ATTENTION