Biokenaf Seminar

Thermochemical Conversion of Kenaf

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Douwe van den Berg
BTG biomass technology group bv
vandenBerg@btgworld.com

BTG biomass technology group bv

> Dutch private company with staff of 35 persons

> Conversion of biomass into fuels and energy
  – Mission: contribute to the accomplishment of a significant share of bio-energy in the total of primary energy carriers in a socio-economic and environmentally sound way

> Two divisions:
  – Research & Development
  – Consultancy & Project Development

> Projects in > 80 countries; > 50 systems installed

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Overview of presentation

> Introduction thermal conversion processes
>
> Feeding of core and whole plant material
>
> Ash behaviour
>
> Gasification experiments
>
> Combustion experiments
>
> Pyrolysis experiments

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Introduction

Bio-energy conversion chain

biomass

- woody
- sugar c.
- oil cont.
- herbacious

pre - treatment

- sizing
- compacting
- drying
- sieving
- transport
- storage
- etc.

conversion

- thermal
- fysical
- biochemical

product

- heat
- electricity
- fuel

← ← ← Specification

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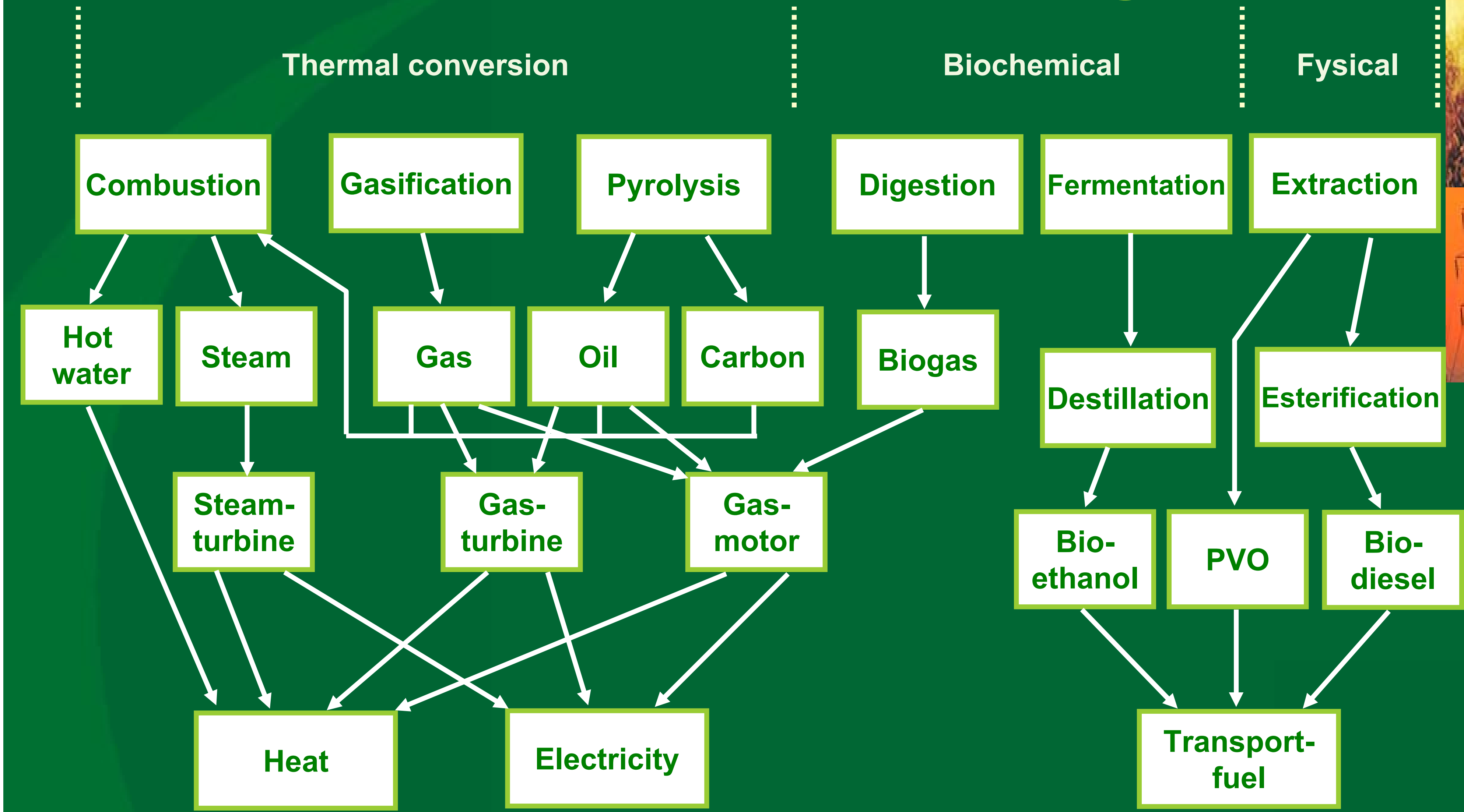
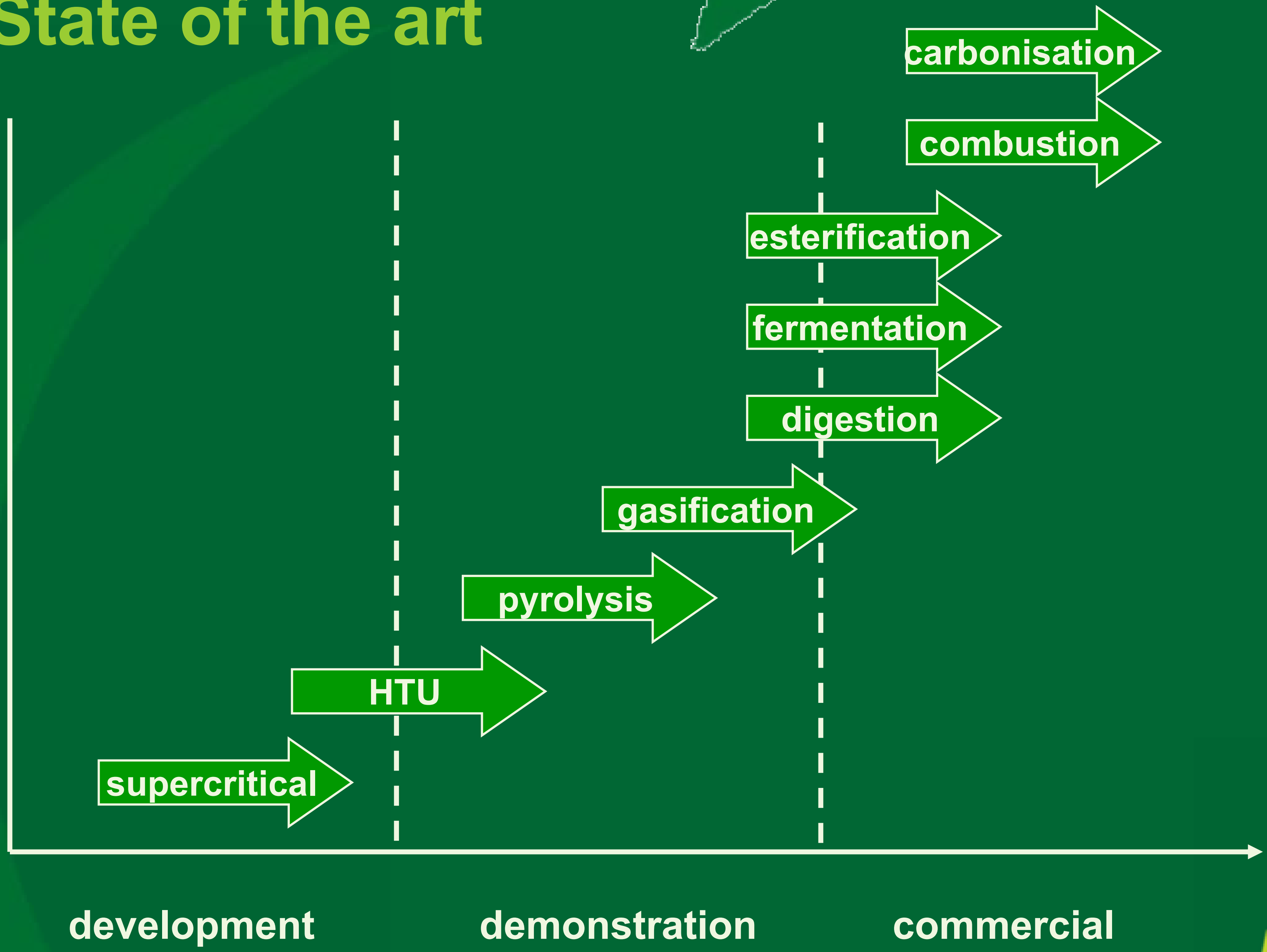
Introduction

Overview conversion-technologies



Introduction

State of the art



Introduction

Biomass technology combinations

- “dry” biomass
  - combustion, gasification, pyrolysis
- “wet” biomass
  - (co-)digestion
  - new technologies (HTU, SCW)
- oil and fat
  - combustion, gasification, (co-)digestion
- oil containing crops
  - extraction and esterification
- sugar and starch containing crops
  - fermentation

Biomass technology combinations

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Introduction

Thermochemical conversion

biomass ($CH_{1.4}O_{0.6}$)

combustion
(excess O_2)

$CO_2 + H_2O$

gasification
(sub stochiometric O_2)

$CO + H_2 + CO_2$

pyrolysis
(without O_2)

char (solid)
pyrolysis oil (liquid)
non condensibles (gas)

Introduction

Combustion - example

biomass-plant Lelystad The Netherlands (NUON)

- capacity: 1,7 MW electric + 6,5 MW thermal
- fresh wood residues, 25.000 ton_{45}/a
- fixed bed combustion with steamcycle
- $\eta_{el} \approx 16\%$, $\eta_{th} \approx 66\%$, $\eta_{tot} \approx 82\%$
- investment about 6.900 €/kW_e

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Introduction

Gasification - example

biomass-gasifier Güssing (Austria) - 2001

- capacity: 2 MW electric, 4,5 MW thermal
- wood chips
- fluidised bed gasifier with gas engine
- $\eta_{el} \approx 25\%$, $\eta_{tot} \approx 80\%$
- total total investment around 4.500 €/kW$_e$

Introduction

Pyrolysis - example

- 12 000 t/yr commercial plant recently implemented by BTG in Malaysia
- Bio-oil for (co-)combustion in power plants
- Research is being carried out to upgrade bio-oil to transport fuel by water removal and hydrotreating.

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Feeding

Kenaf samples

- > Samples received April 2005
- > “whole plant”
  - – 2004 harvest from CETA
  - – chipped and dried under roof
- > “core material”
  - – 2005 harvest from CETA
  - – seperated by KEFI

Feeding

Kenaf properties and preparation

Milling

Feeding

Kenaf properties and preparation

- Bulk density
- Particle size and size distribution
- Flow properties

	Bulk density [kg/m3]	Particle S & D	Flow properties	Moisture $[wt\%]_{wb}$
Core	120	+	+	16.4
Whole plant	60	- -	- -	15.7
Whole plant milling	80	-	-	15.7

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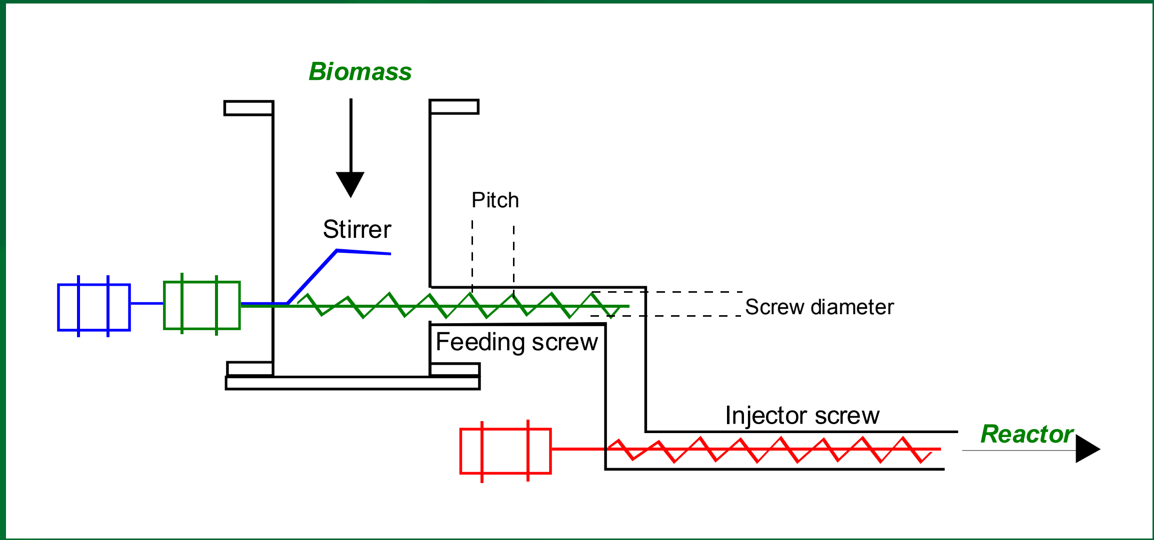
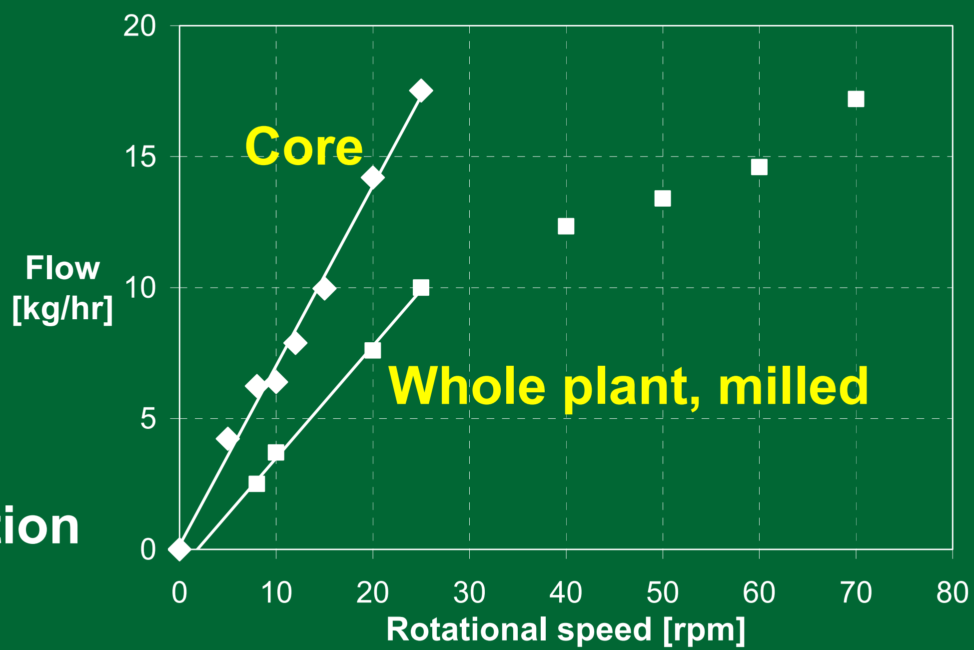
Feeding section reactor and calibration



Feeding system



Calibration

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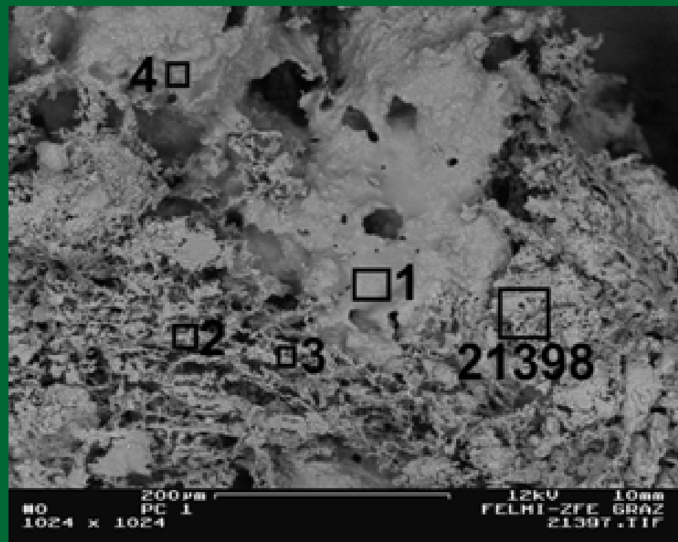
Ash behaviour

Ash content and ash melting

> Both ash content and ash quality important

> Ash melting can cause damage to bio-energy system

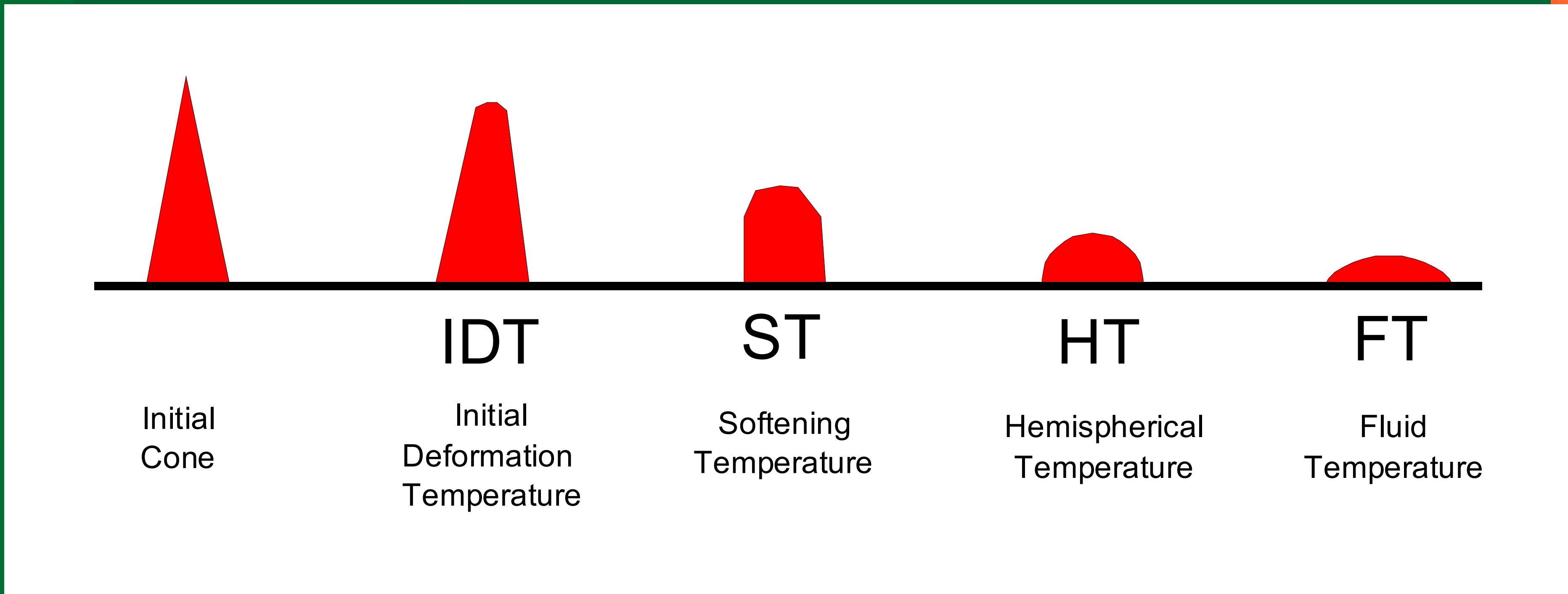
> Ash melting can cause sintering of bed material



Ash behaviour

Ash fusibility test

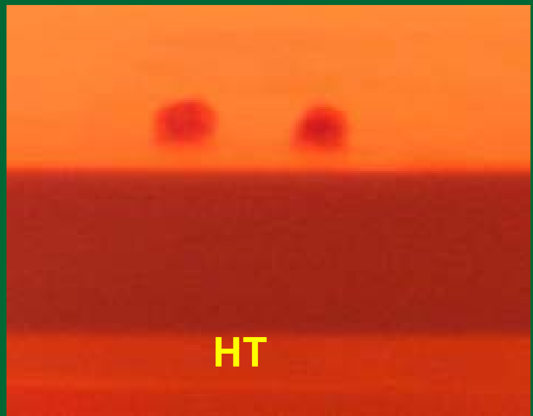
- Seger cone method
- ASTM D2013 - D3174 (for ash from coal and cokes)
- Oxidising (air) and inert environment (N2)



Ash behaviour

Ash fusibility test - example

ash cones



Ash behaviour

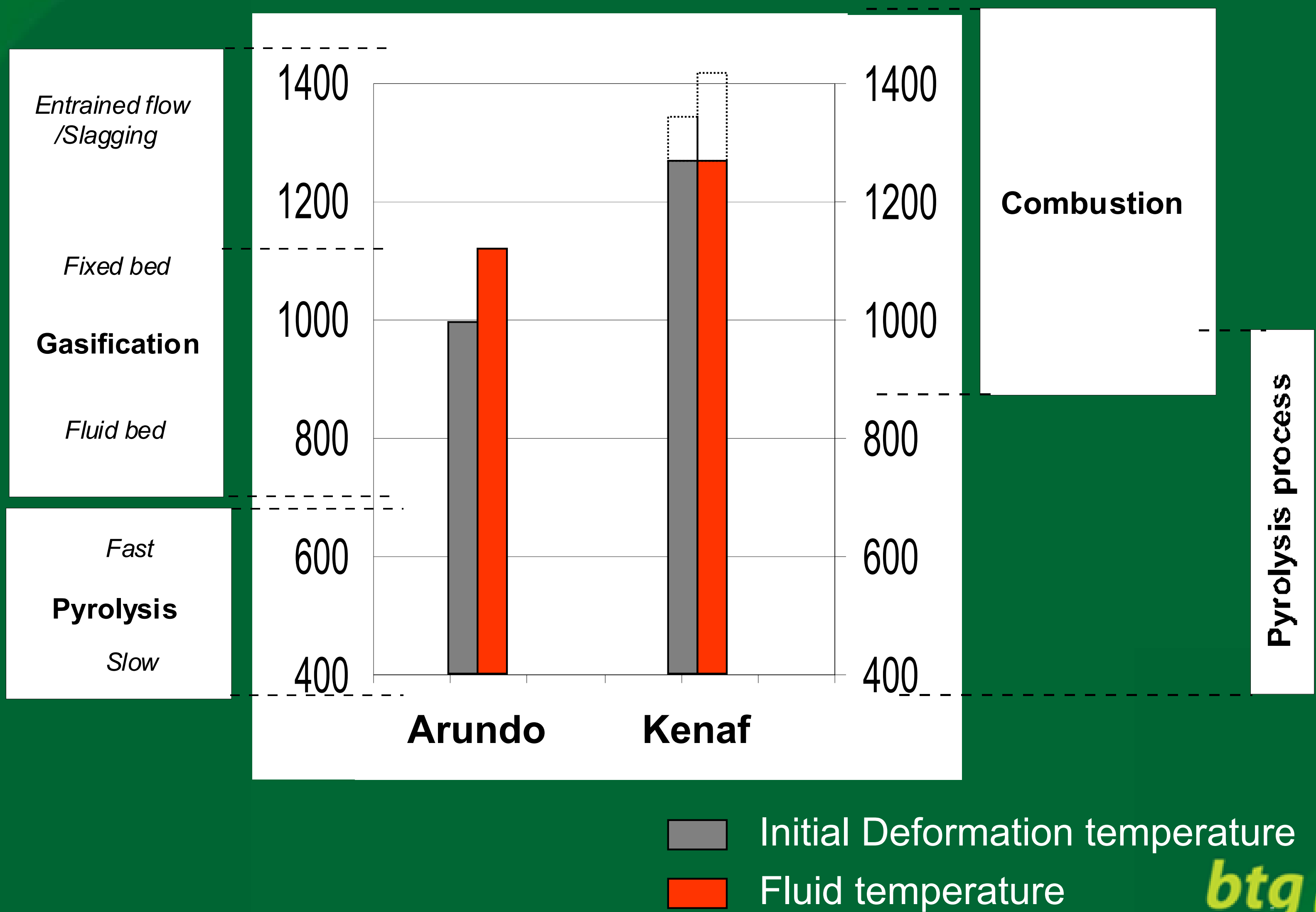
Ash fusibility tests - results

	Ash content [wt%]	Initial Deformation Temperature	Fluid Temperature
Kenaf Core	2.0	> 1270	>> 1270
Kenaf Whole plant	2.4	> 1270	>> 1270
Beech (hardwood)	2.3	> 1270	>> 1270
Pyne (softwood)	0.3	> 1270	>> 1270
Miscanthus	2.0	1060	1210
Switch grass	4.8	1080	1230
Arundo	4.5	1000	1150

Ash behaviour

Ash fusibility tests - results

Non-oxidising environment *Oxidising environment*



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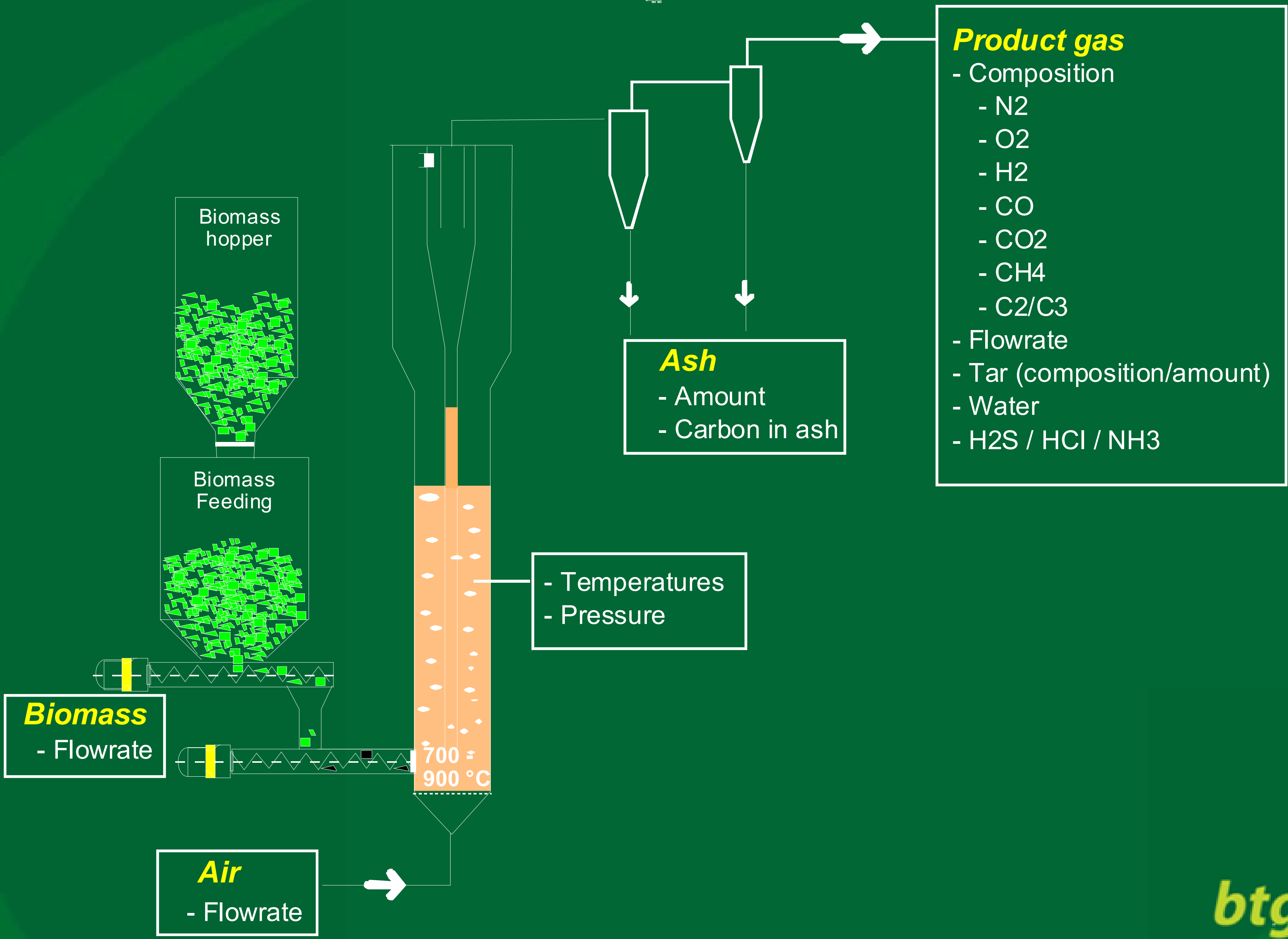
Gasification

Experimental set-up

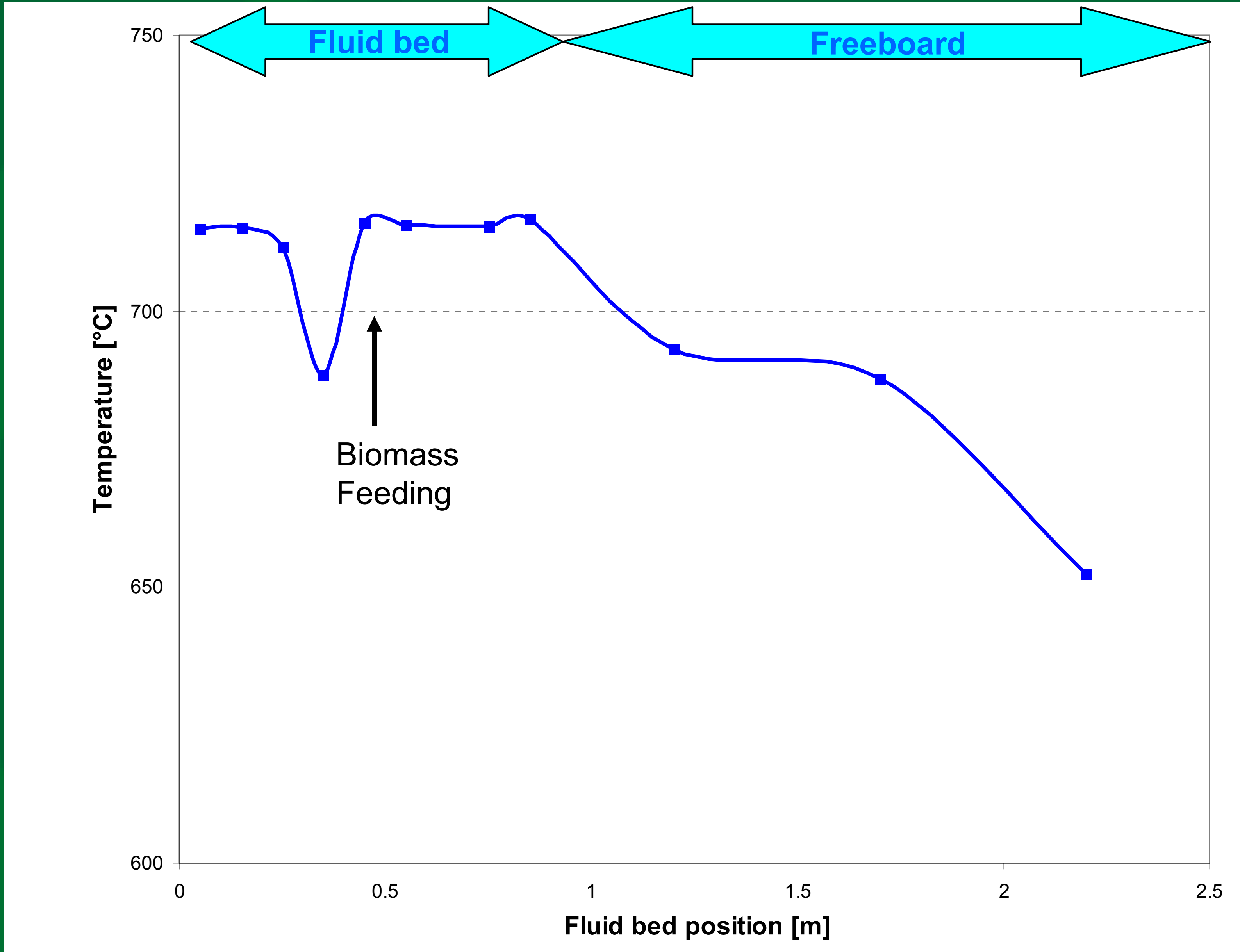
Gasification

Flow scheme



Gasification

Axial temperature profile



Gasification

Results

	Core	Whole plant	
Biomass feed			
Flow rate	7.1	6.7	kg/hr
Energy in	25	23.6	kW
Air supply			
Flow rate	8.4	5.8	kg/hr
Product gas			
Flow rate	15.7	12.3	kg/hr
Composition			
H_2	9.1	11.9	vol%
CO	8.1	8.2	vol%
CO_2	20.3	23	vol%
CH_4	2.6	3.3	vol%
C2+	1.5	1.9	vol%
N_2	58.3	51.7	vol%

Gasification
Results

	Core	Whole plant	
Product gas			
Traces			
NH_3	> 100	> 100	ppm
H_2S	40	40	ppm
HCl	< 1	< 1	ppm
Tar	0.5	0.3	g/m3
Energy balance			
Biomass, in	25.0	23.6	kW
Gas, out	13.6 (= 54.4 %)	11.4 (= 48 %)	kW
Tar, our	1.8 (= 7 %)	1.1 (= 5 %)	kW
Ash/Char, out	1.8 (= 7 %)	1.4 (= 6 %)	kW
Total, out	17.3 (= 68.8 %)	13.9 (= 58.7%)	kW

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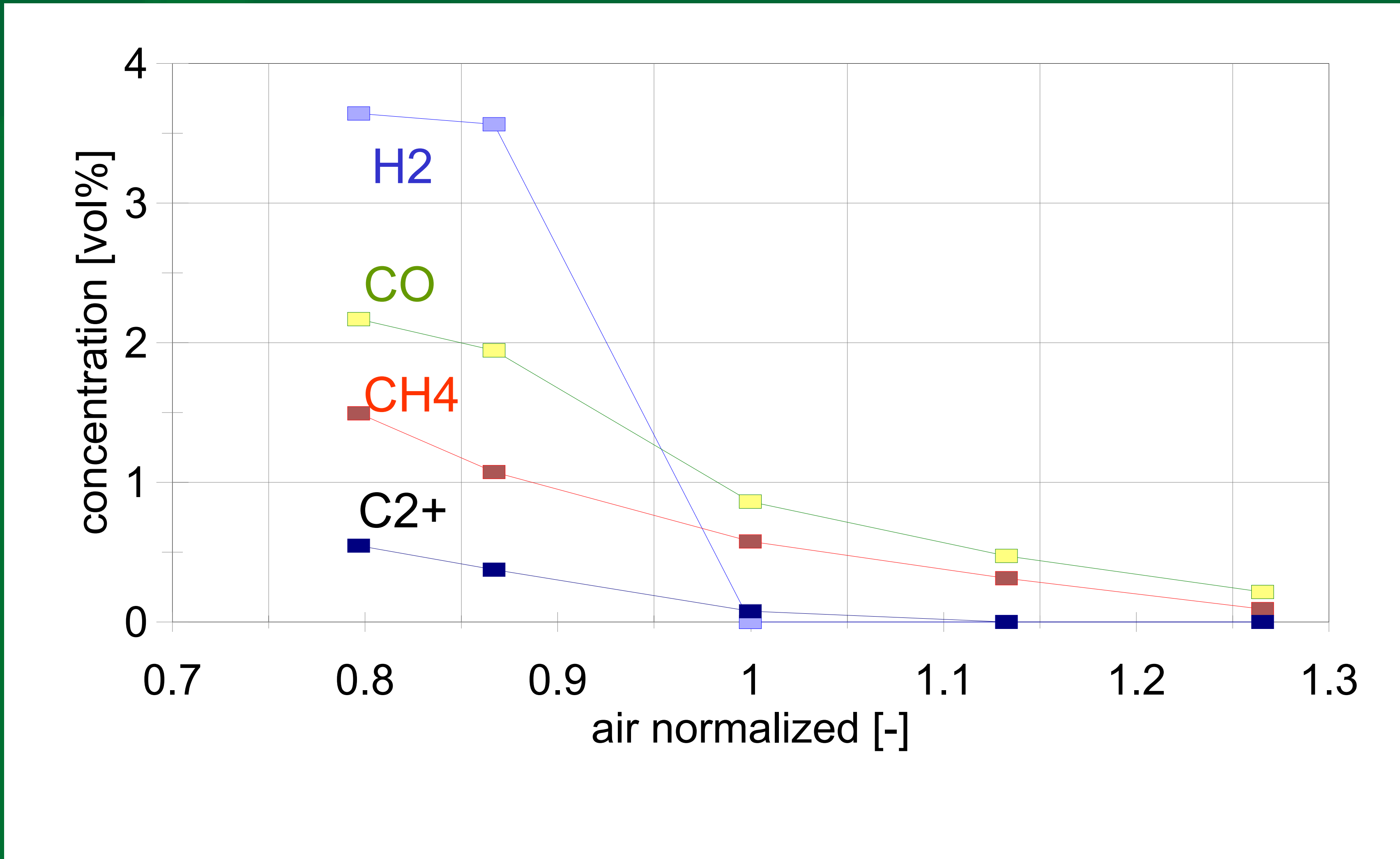
Combustion

Experimental set-up

- Fluidised bed combustion
- Experimental set-up and flow scheme corresponding to gasification tests

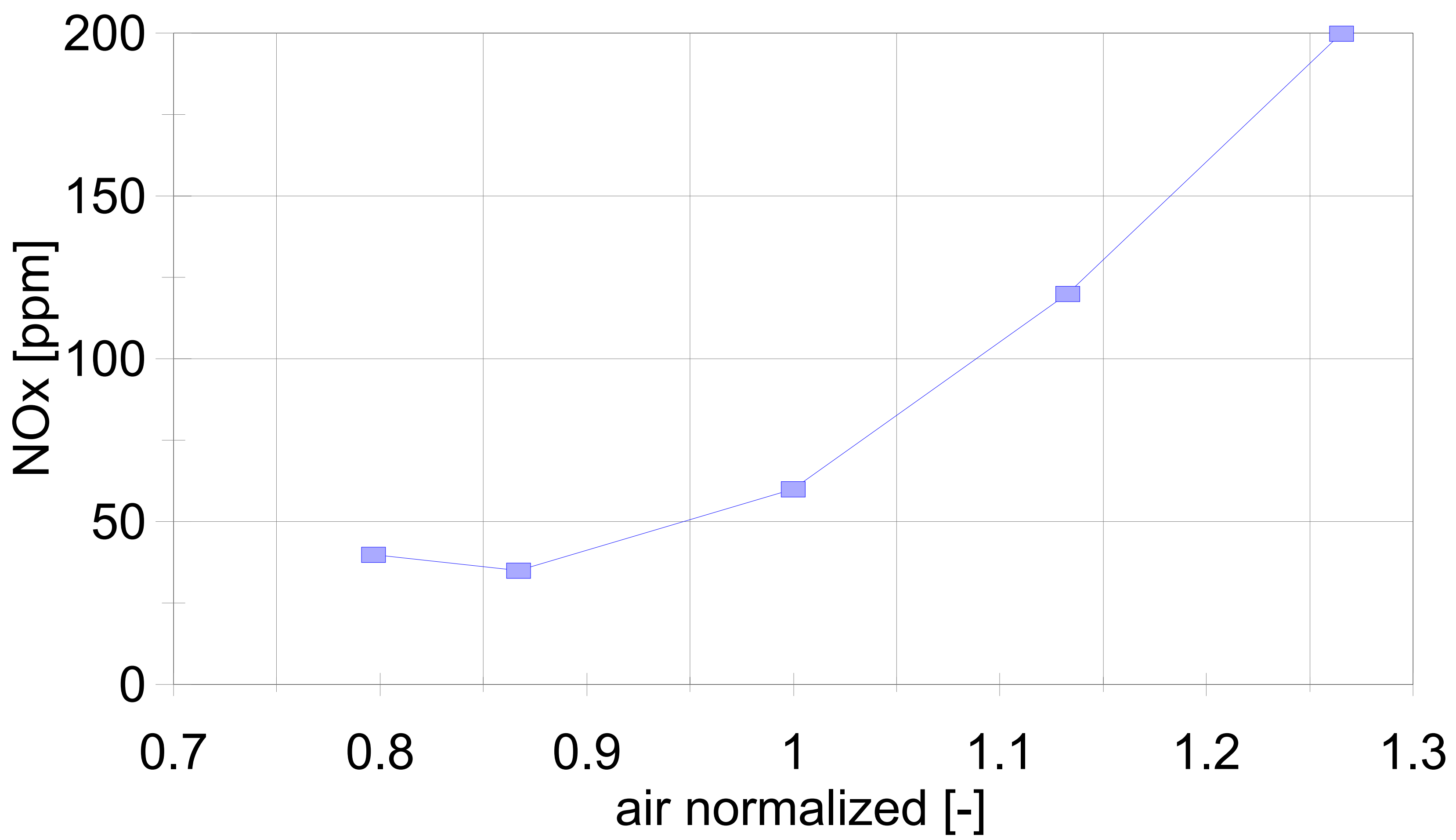
Combustion

Results - gas analysis Kenaf core



Combustion

Results - NOx emissions Kenaf core



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Pyrolysis

Experimental set-up

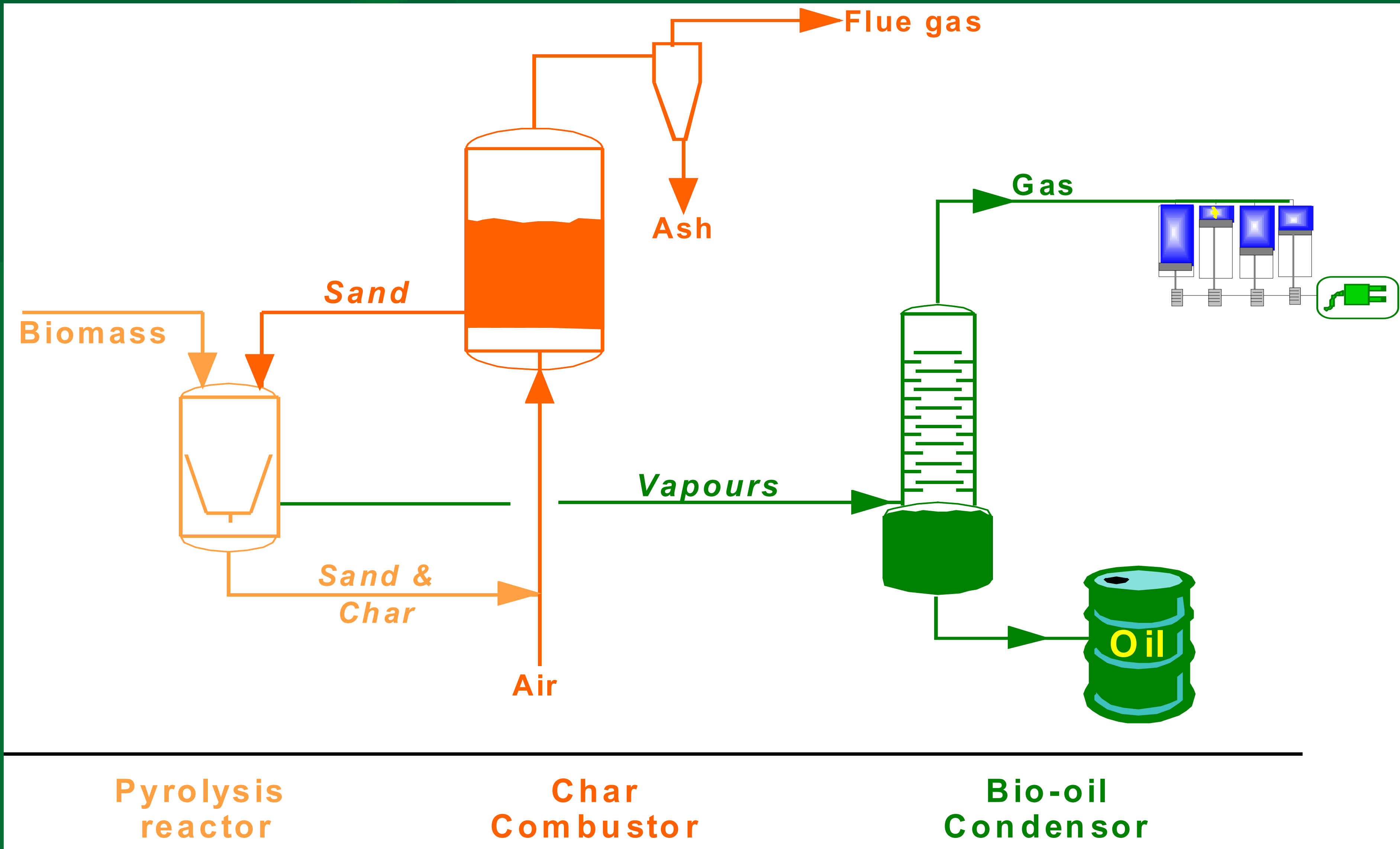
Feeding system

Pyrolysis reactor system (placed in hotbox)

Bio-oil condensing system

Pyrolysis

Flow scheme



Results: mass balance

	Overall	Biomass
IN (kg/hr)		
Biomass	2,96	2,96 (100%)
Air	10,47	
Nitrogen	0,14	
Total, in	13,57	2,96 (100%)
OUT (kg/hr)		
Bio-oil	1,44	1,44 (49%)
Heavies	0	0
Ash	0,08	0,08 (3%)
Pyrogas	1,20	
Combugas	10,92	
Charcoal		0,50 (17%)
NC gasses		0,87 (30%)
Total, out	13,63	2,89 (98%)

Pyrolysis

Results: bio-oil yield and quality

> Total bio-oil yield is 49%
  - comparable to other herbaceous crops (45 - 55 wt%)
  - lower than wood (about 70 wt%)

> High water content in bio-oil (38 wt%) and strong phase separation
  - water originating from water in feedstock and
  - water formed during reaction and catalyzed by minerals

Concluding

Is kenaf a suitable energy crop?

- Feeding
  - Whole plant needs additional pre-treatment to allow stable and trouble free feeding
  - For core material design of feeding system needs modifications compared to wood (larger volumes)
- Ash melting
  - High initial deformation temperature compared to other crops prevents ashmelting problems at thermal conversion
- Thermal conversion
  - Low water content if harvested after winter (fibre quality?)
  - Combustion of whole plant gives high NOx emissions
  - Further optimisation gasification to obtain higher efficiency
  - Additional drying and/or post-treatment needed to obtain a one-phase oil (pyrolysis as such is no problem)
- General
  - Better results for core compared to whole plant material (better morphology and lower N-content)
  - Economy determines (costs kenaf vs. other biomass residues/crops)!

Thank you for your attention!