Biokenaf project

thermochemical conversion tests

Progress meeting in Catania, July 2005

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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

Introduction

Bio-energy conversion chain

biomass

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

pre - treatment

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

conversion

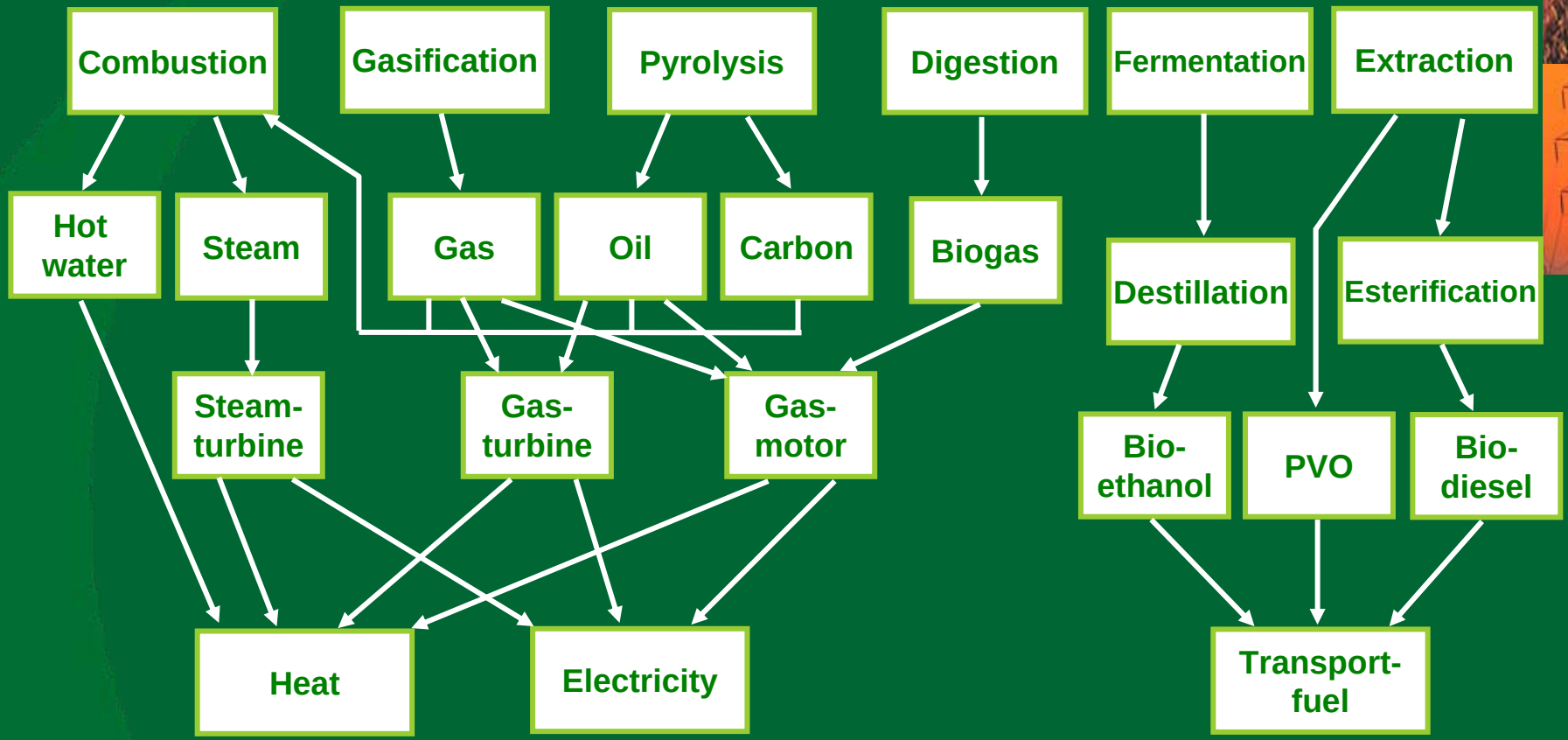
- thermal
- fysical
- biochemical

product

- heat
- electricity
- fuel

← ← ← Specification

Overview conversion-technologies

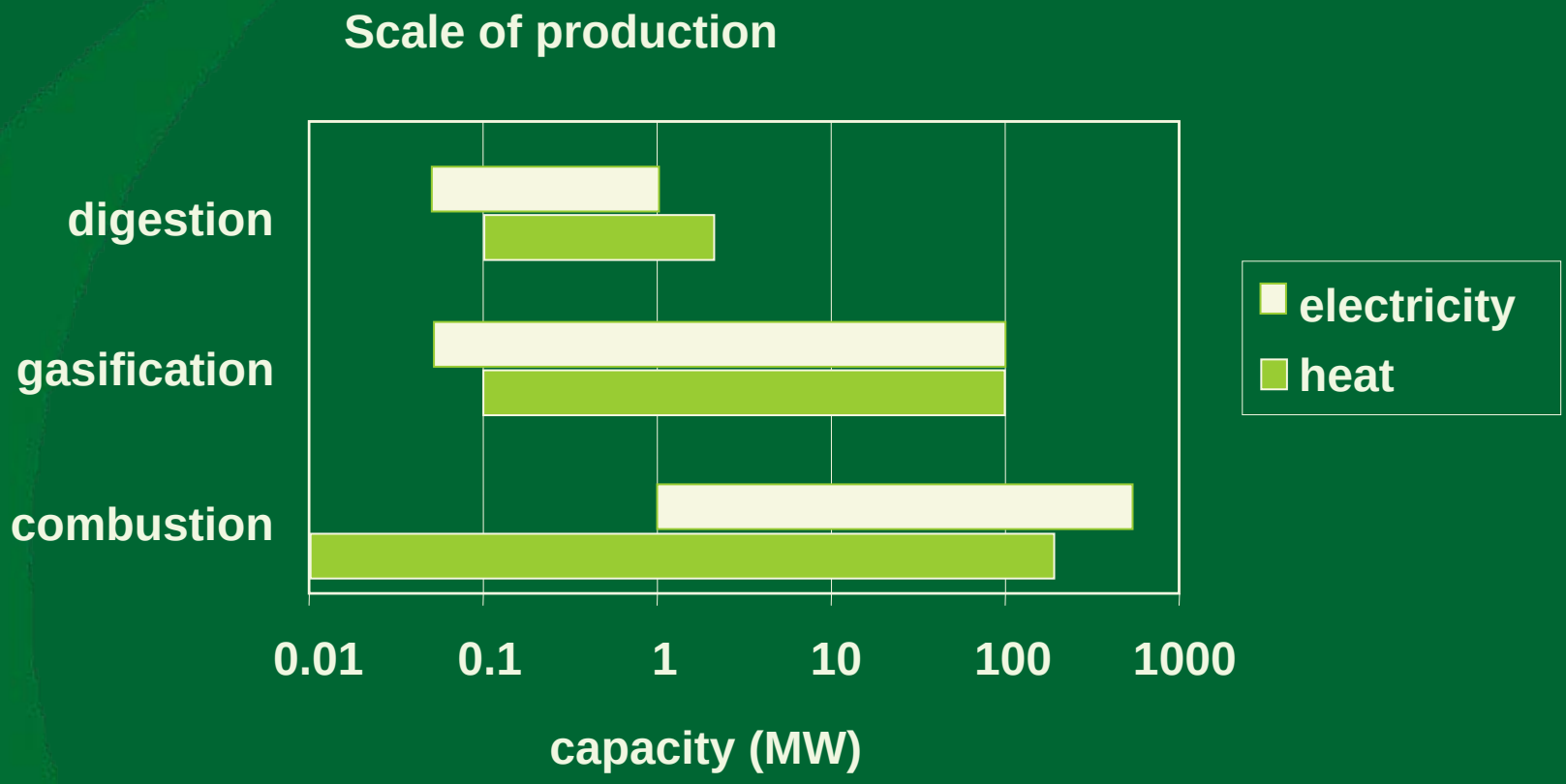


Biomass technology combinations

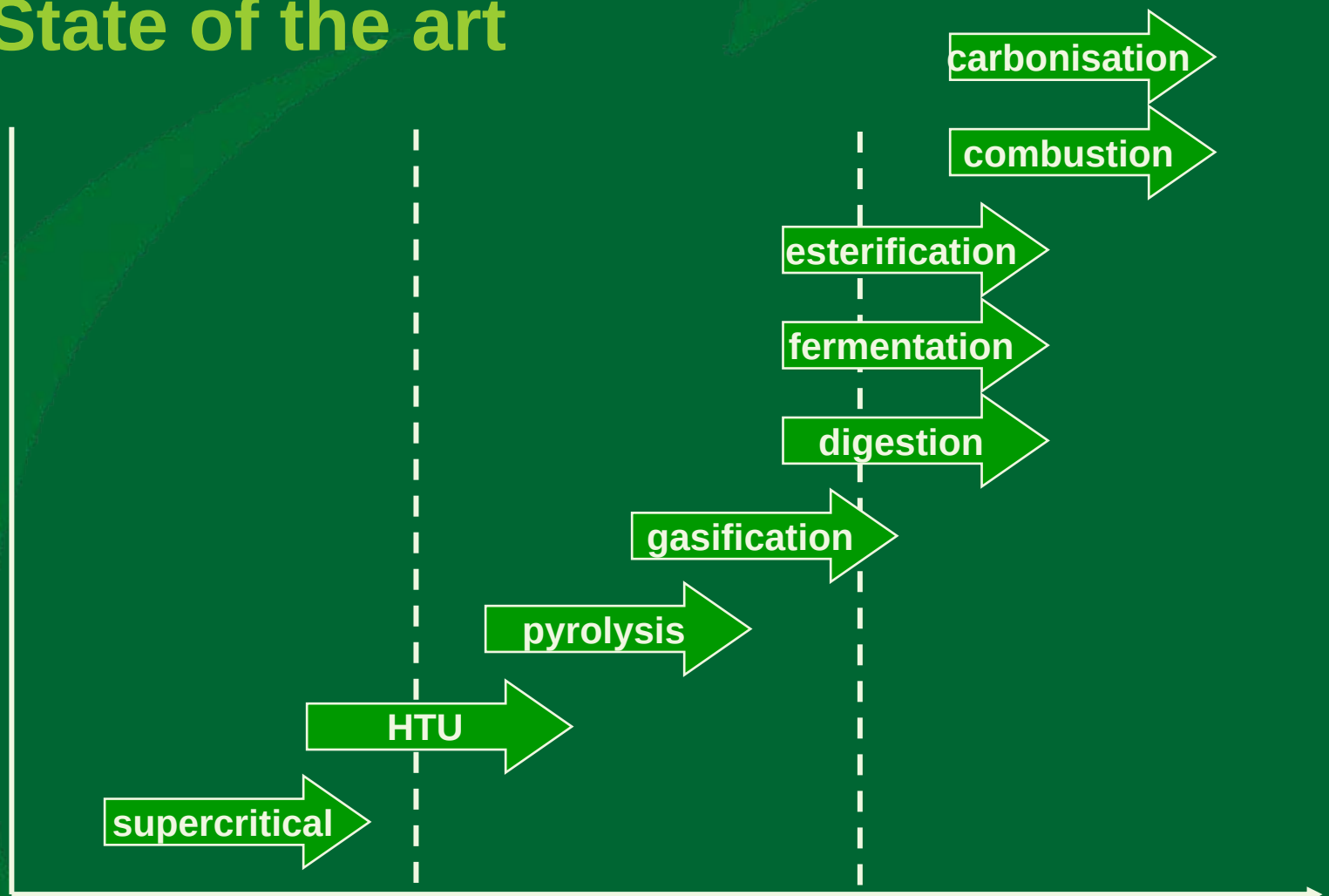
- “dry” biomass
  - combustion, gasification, pyrolysis
- “wet” biomass
  - (co-)digestion
  - new technologies (HTU, SCW)
- oil and fat
  - combustion, gasification, (co-)digestion
- oil containing crops
  - extraction and esterification
- sugar and starch containing crops
  - fermentation

Introduction

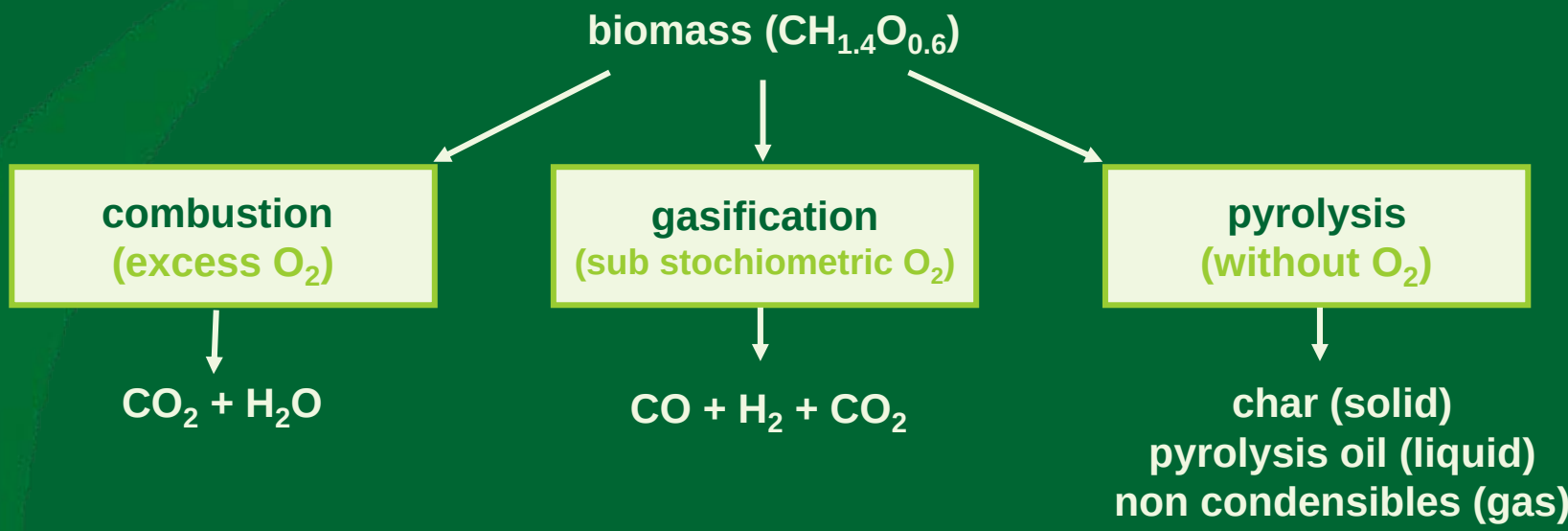
Capacities



State of the art



Thermochemical conversion



Combustion - example

biomass-plant Lelystad The Netherlands (NUON)

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

Gasification - example

biomass-gasifier Güssing (Oostenrijk) - 2001

- capacity: 2 MW electric, 4,5 MW thermal
- wood chips
- fluidised bed gasifier with gas motor
- $\eta_{el} \approx 25\%$, $\eta_{tot} \approx 80\%$
- total costs ca 9 M€

Pyrolysis - example

- BTG 2 t/hr commercial plant under construction 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.

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

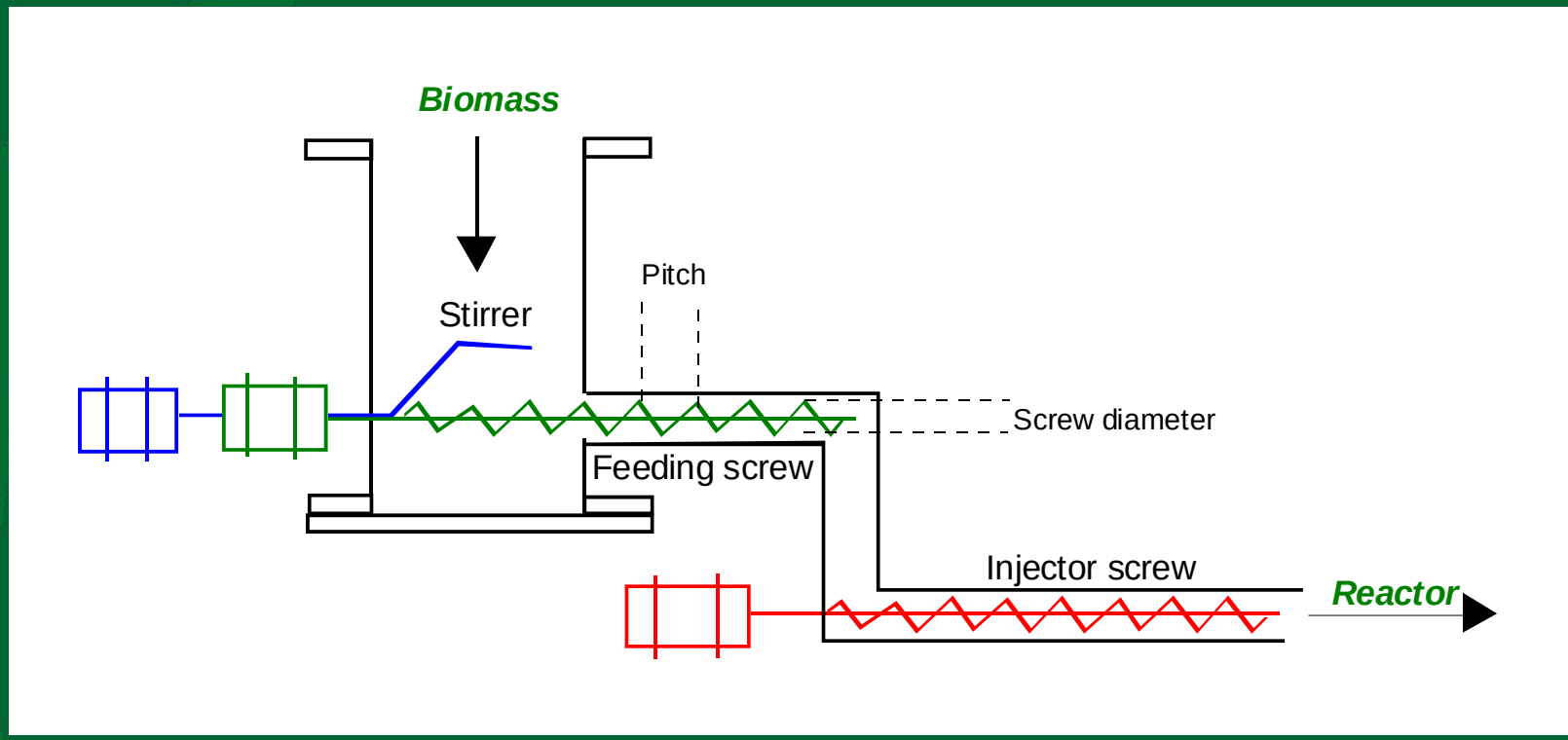
Milling

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**

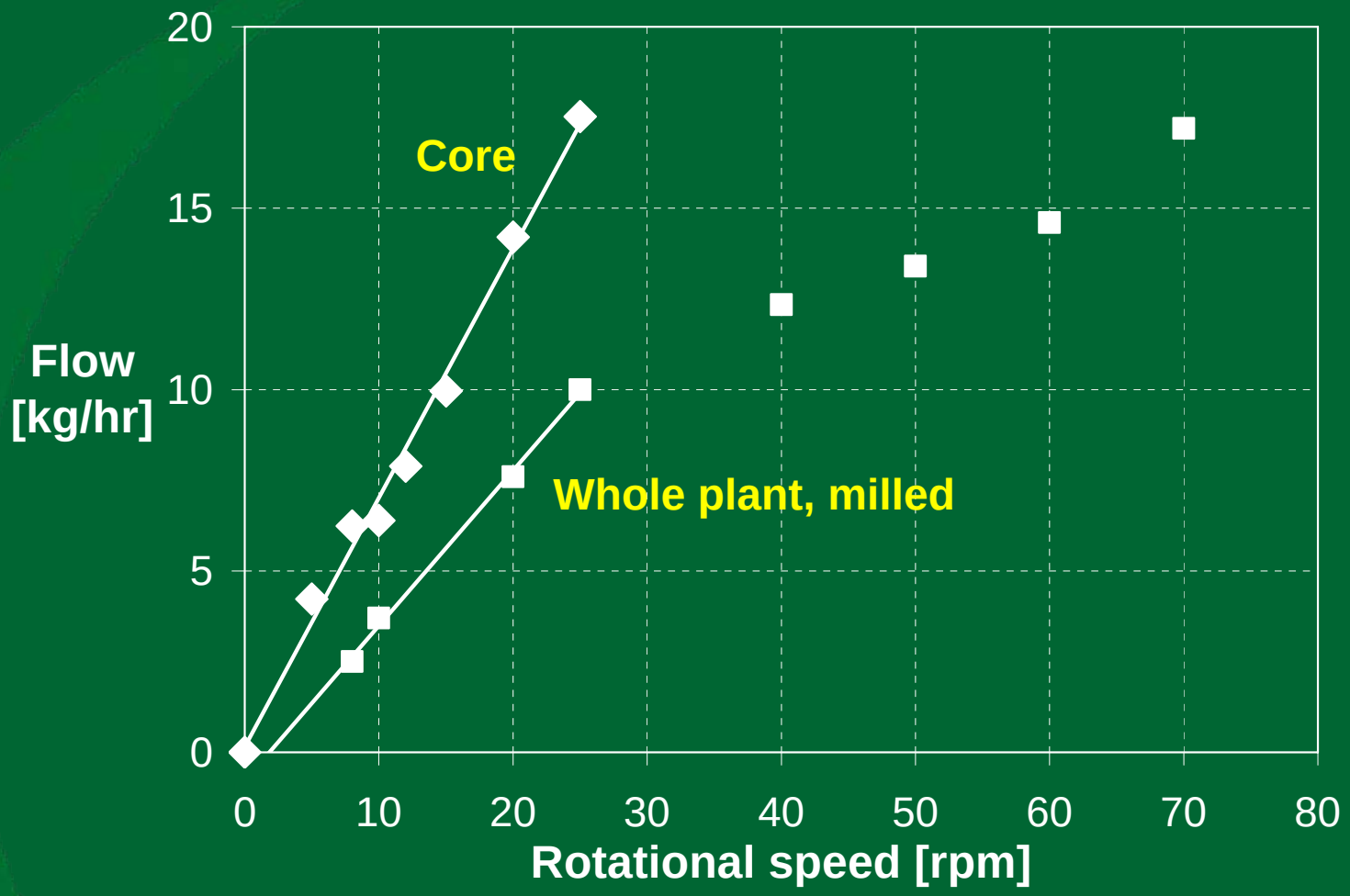
Feeding section reactor



Feeding system

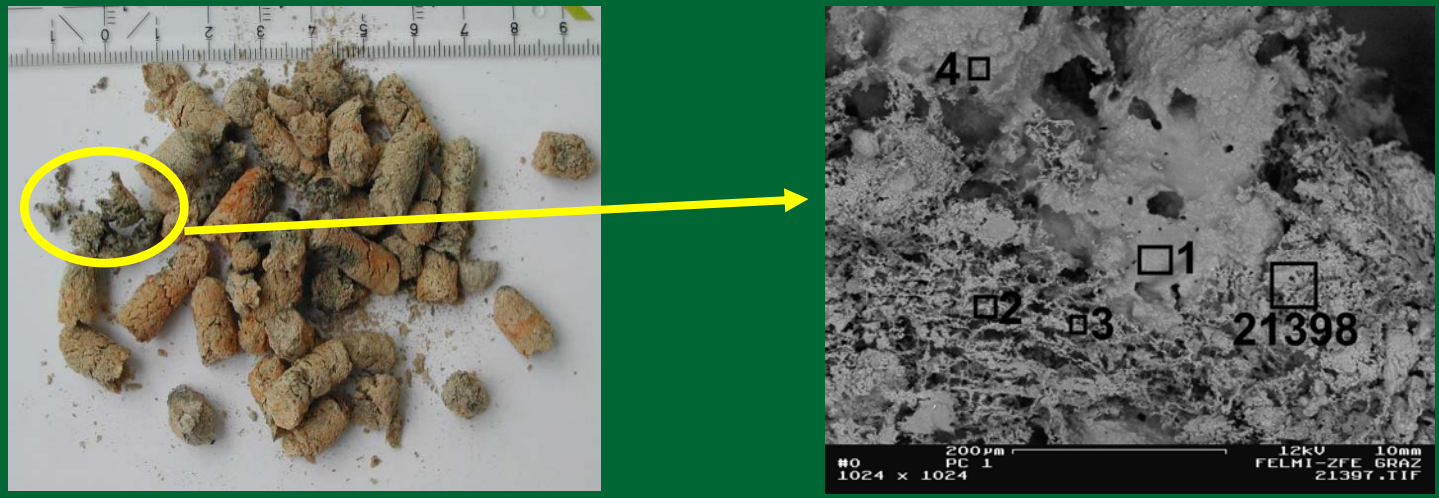
Feeding

Calibration



Ash content and ash melting

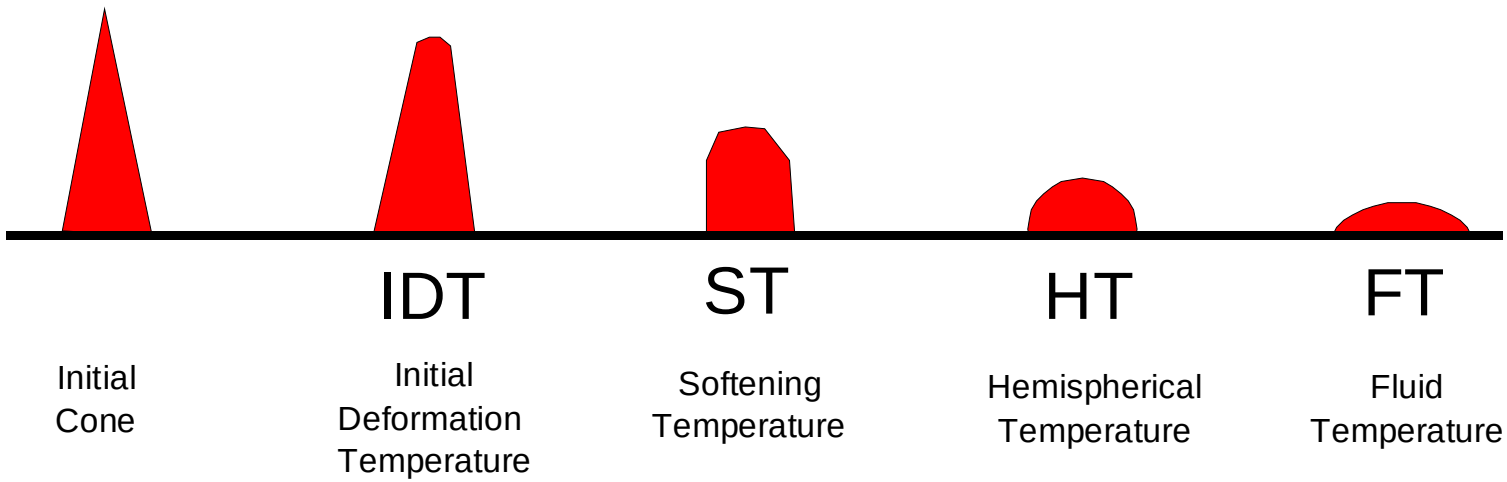
- Both ash content and ash quality important
- Ash melting can cause damage to bio-energy system
- Ash melting can cause sintering of bed material



Ash behaviour

Ash fusibility test

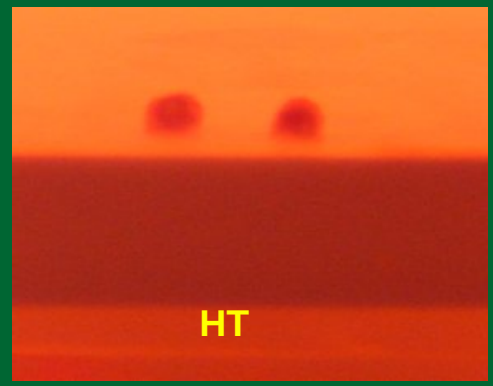
- Seger cone method
- ASTM D2013 - D3174 (for ash from coal and cokes)
- Oxidising (air) and inert environment (N2)



Ash behaviour

Ash fusibility test - example

ash cones



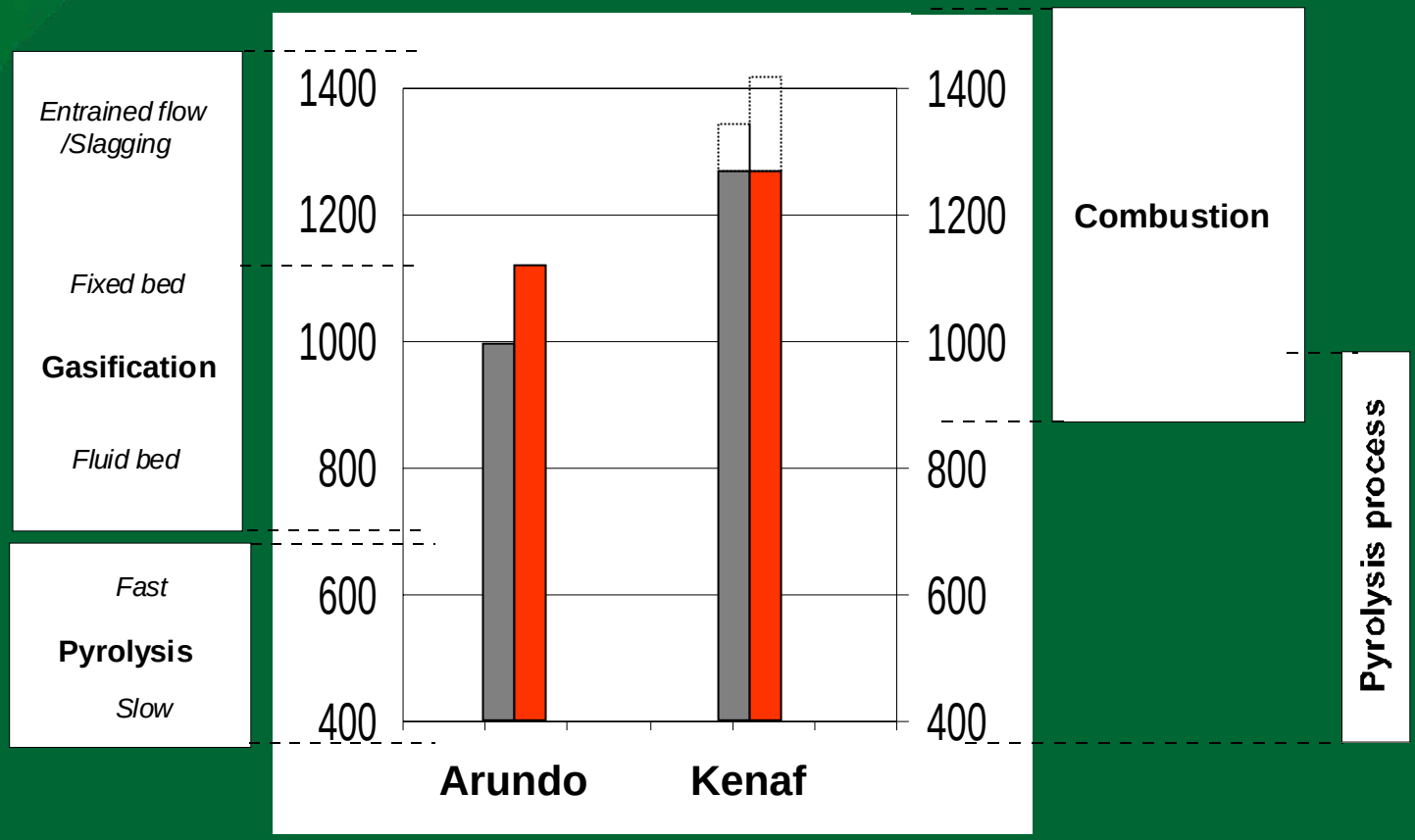
Ash fusibility tests - results

	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 fusibility tests - results

Non-oxidising environment

Oxidising environment

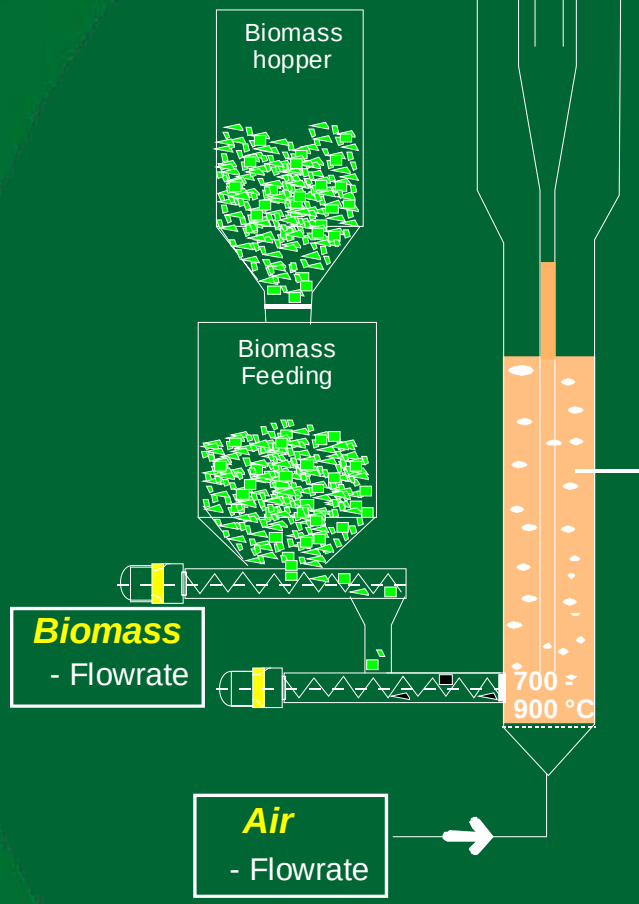


Gasification

Experimental set-up

Gasification

Flow scheme



Product gas
- Composition
  - N2
  - O2
  - H2
  - CO
  - CO2
  - CH4
  - C2/C3
- Flowrate
- Tar (composition/amount)
- Water
- H2S / HCl / NH3

Ash
- Amount
- Carbon in ash

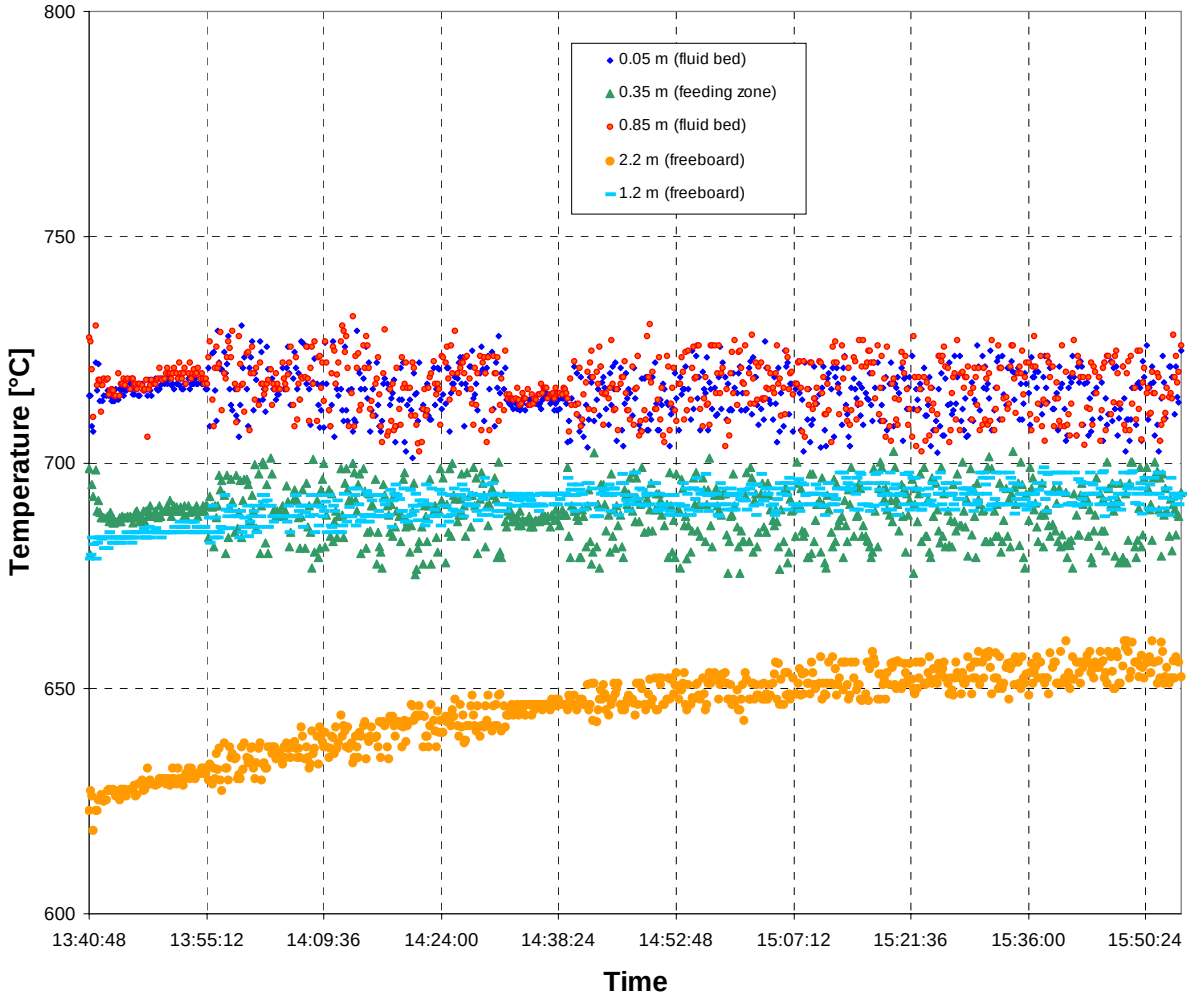
- Temperatures
- Pressure

Biomass
- Flowrate

Air
- Flowrate

Gasification

Temperature profiles



Bottom fluid bed

Top fluid bed

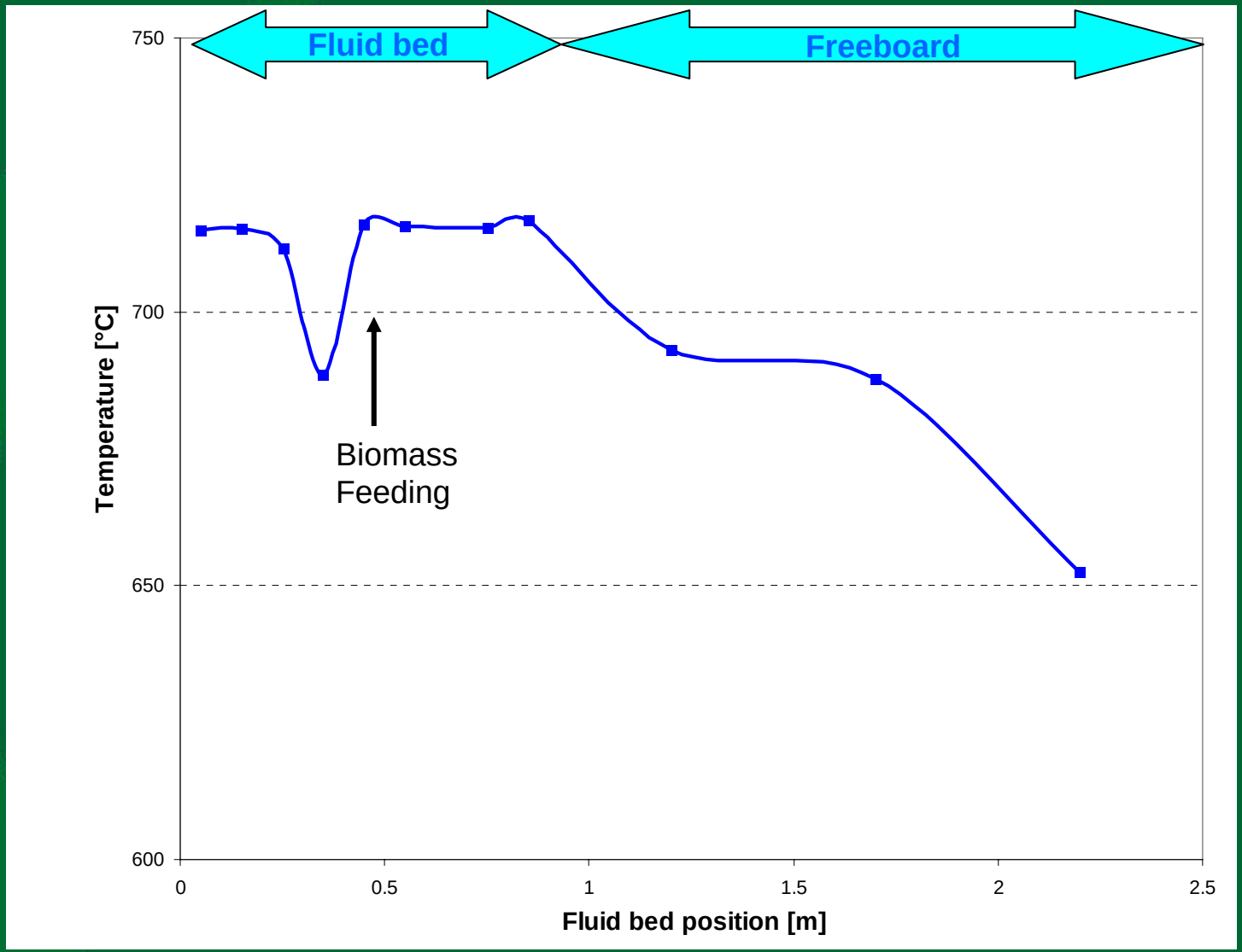
fluid bed - feeding point

Freeboard

Top Freeboard

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

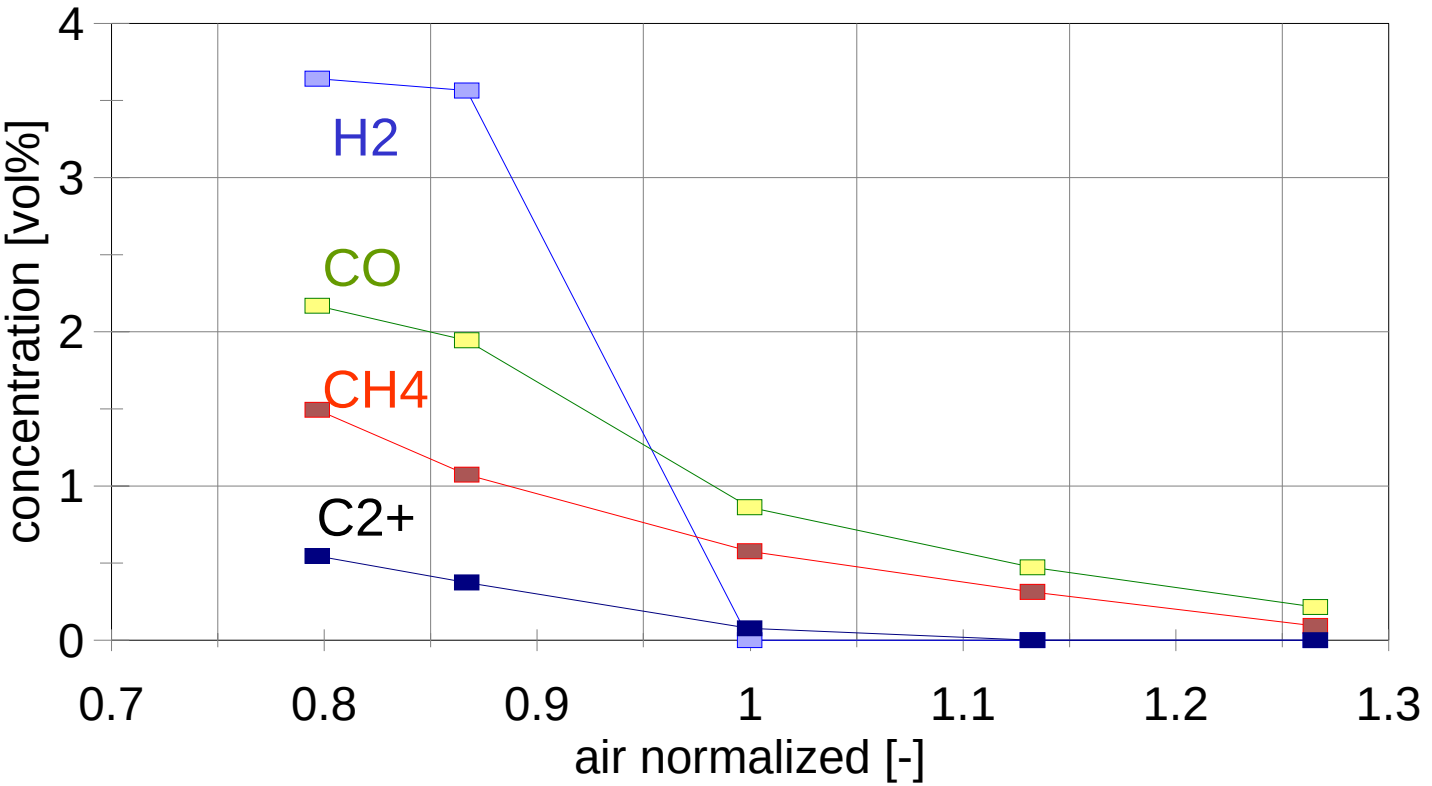
Results

	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**

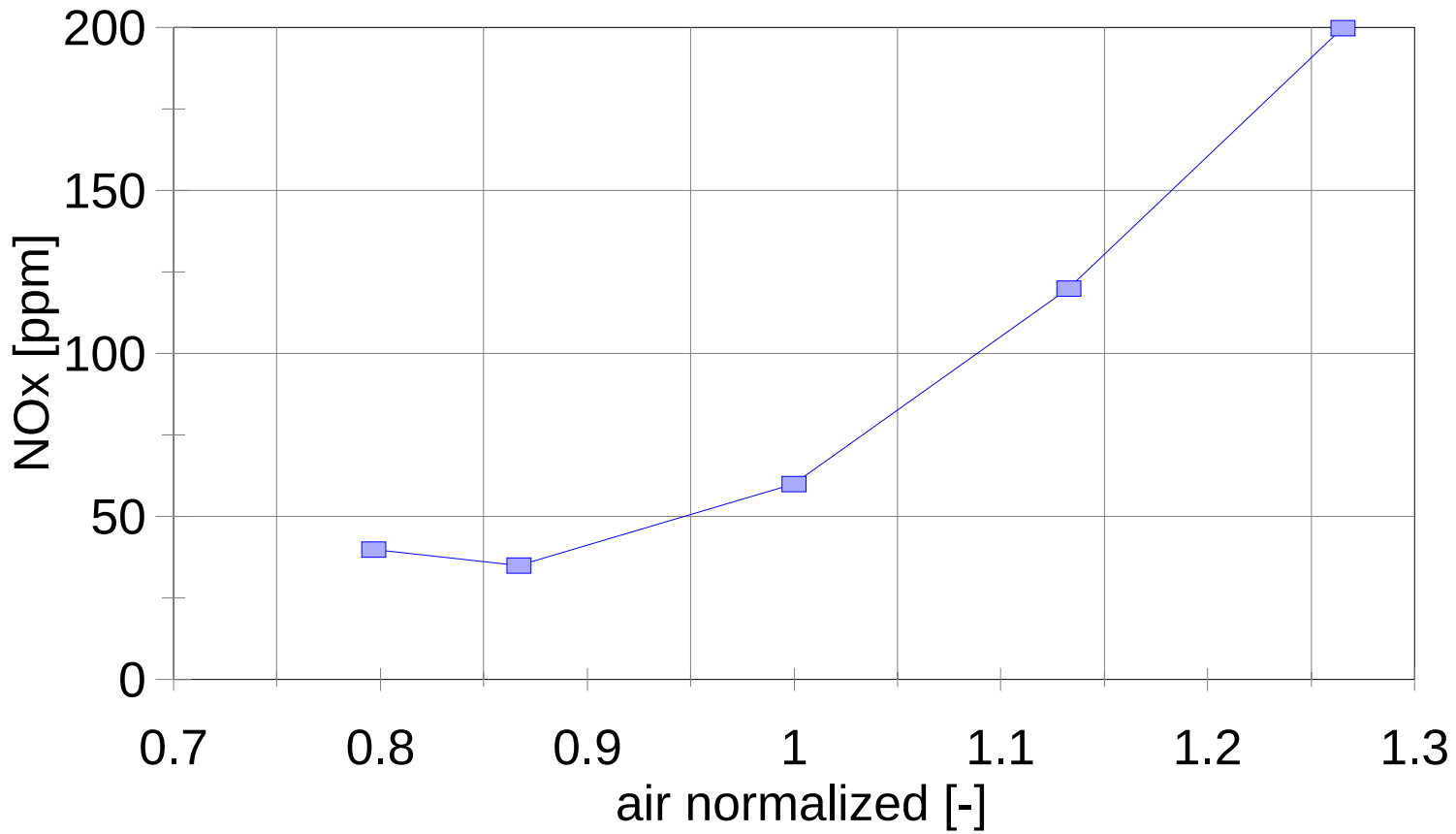
Experimental set-up

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

Results - gas analysis Kenaf core



Results - NOx emissions Kenaf core



Pyrolysis

Experimental set-up (new for Kenaf)

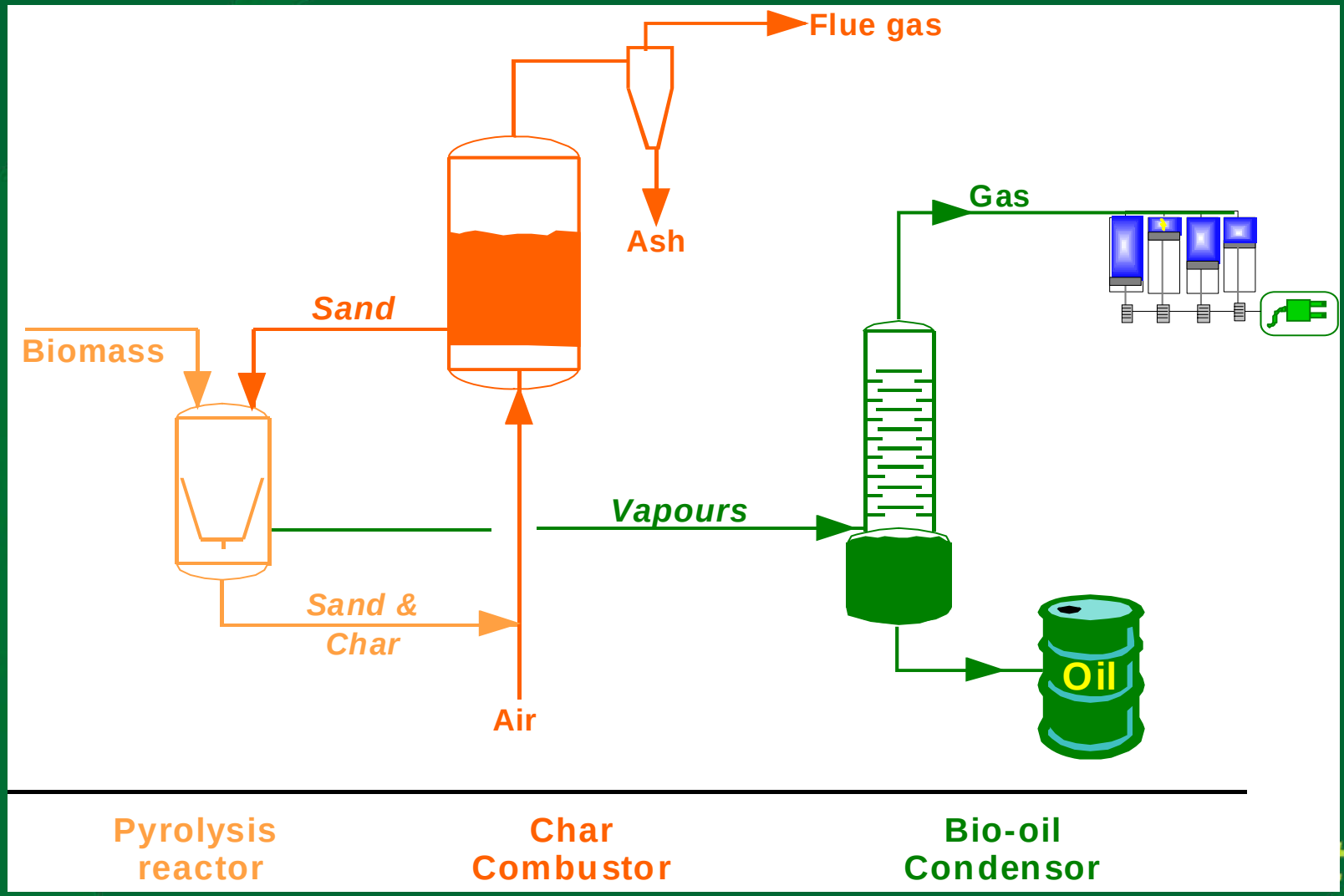
Feeding system

Pyrolysis reactor system (placed in hotbox)

Bio-oil condensing system

Pyrolysis

Flow scheme



Planning of experiments

- Measurements:
  - Bio-oil yield
  - Bio-oil quality
  - Mass and energy balance

- Time frame
  - Testing of new set-up : week 26
  - Drying of Kenaf samples (< 8 wt% moisture): week 27
  - Calibration of samples in feeding section: week 27
  - Pyrolysis experiments planned for week 28