



Entrained Flow gasification of coal/torrefied woody biomass blends

**Michiel Carbo
Jana Kalivodova
Mariusz Cieplik
Bram van der Drift
Robin Zwart
Jaap Kiel**

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21 May 2012, Leipzig, Germany*

Entrained Flow gasification of coal/torrefied woody biomass blends

Efficient carbon footprint reduction

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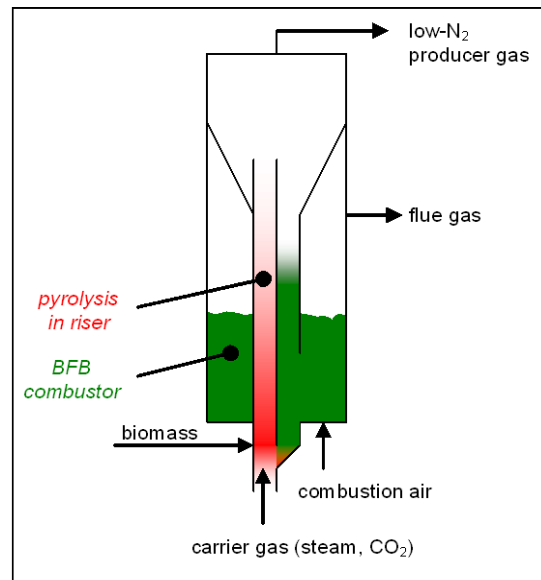
Leipzig, Germany
21 May 2012

ECN's Bio Energy Group

- Biomass pre-treatment
 - Torrefaction
 - Torwash
 - Densification
- Biomass (co-)firing
 - Fluidized bed: Agglomeration
 - Pulverised fuel: Slagging/fouling
- Biomass (co-)gasification
 - Fluidized bed:
 - Indirect gasification (MILENA)
 - Tar removal (OLGA)
 - SNG/BtL synthesis
 - Entrained flow:
 - Conversion/slagging/fouling

MILENA Indirect Gasifier

- Two integrated reactors for gasification and combustion
- Essentially N_2 -free producer gas
- Complete conversion
- High methane yield, very suitable for SNG-production



MILENA principle



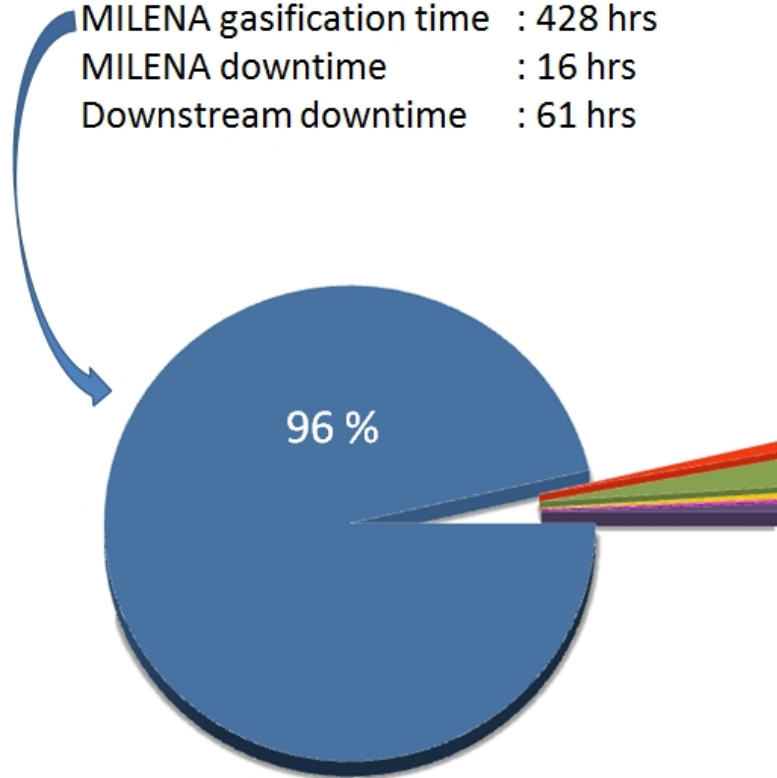
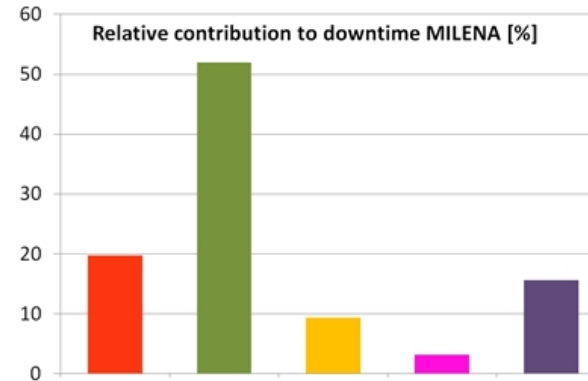
MILENA, 5 kg/h,
30 kW_{th}, 2004



MILENA, 160 kg/h,
800 kW_{th}, 2008

Availability MILENA (800 kW_{th})

Duration experiment : 505 hrs
 MILENA gasification time : 428 hrs
 MILENA downtime : 16 hrs
 Downstream downtime : 61 hrs



■ In operation
 ■ Forced stop
 ■ Screw conveyor blockage
 ■ Rotary airlock valve blockage
 ■ Repair dosing system
 ■ HSE

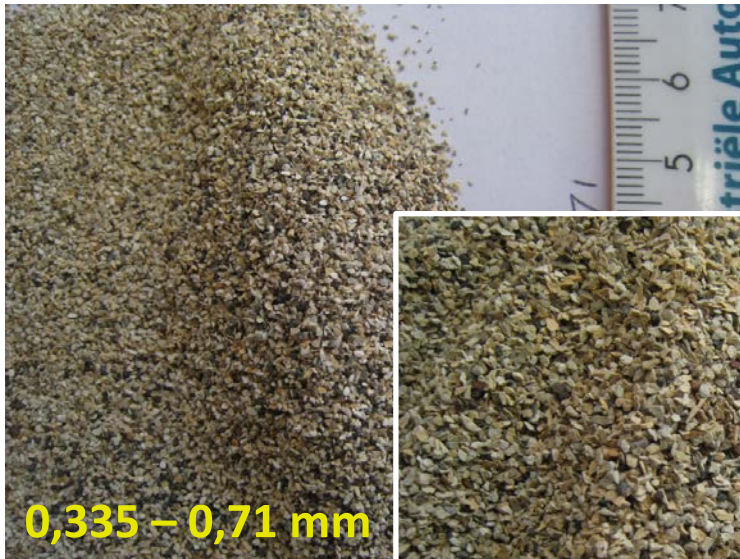
March/April 2012

Fuel Flexibility MILENA (30 kW_{th})

- Also very suitable for high-ash Asian coals (> 50 wt%)

Gas composition

CO (vol%)	14.9
H ₂ (vol%)	48.3
CO ₂ (vol%)	28.5
CH ₄ (vol%)	6.0
N ₂ (vol%)	2.6



Torrefaction

Woody biomass



Agricultural residues



Friable and less fibrous

19 - 22 MJ/kg (LHV, ar)

Hydrophobic

Preserved

Homogeneous

Superior fuel properties:

- Transport, handling, storage
- **Milling, feeding**
- **Gasification, combustion**
- Broad feedstock range
- Commodity fuel

Mixed waste



Torrefaction and pulverisation



Fuel powder

Pelletisation



Fuel pellets

Tenacious and fibrous

10 - 17 MJ/kg (LHV, ar)

Hydrophilic

Vulnerable to biodegradation

Heterogeneous

Bulk density 650-750 kg/m³

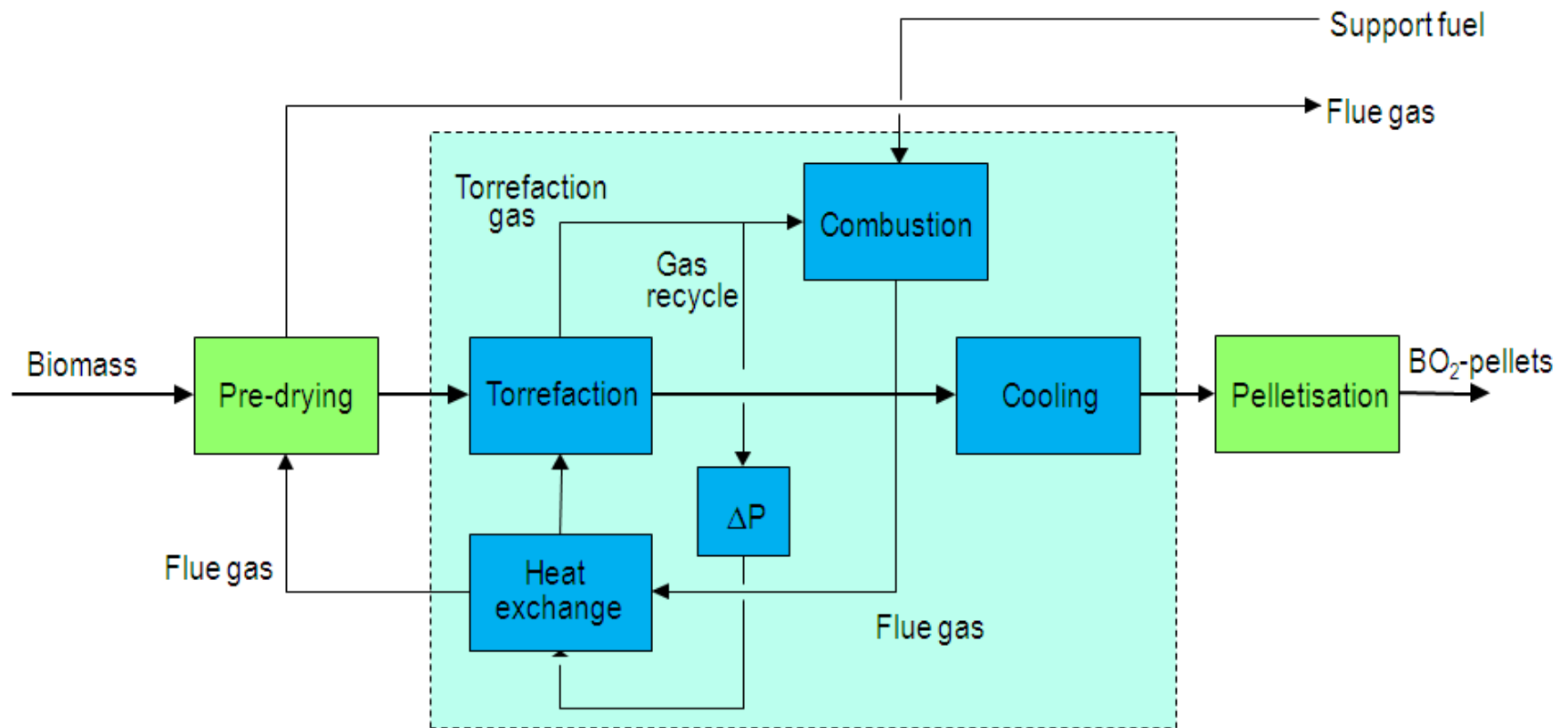
Bulk energy density 13-17 GJ/m³

Product Quality

	Wood chips	Wood pellets	Torrefied wood pellets	Charcoal	Coal
Moisture content (wt%)	30 - 55	7 - 10	1 - 5	1 - 5	10 - 15
Calorific value (LHV, MJ/kg)	7 - 12	15 - 17	18 - 24	30 - 32	23 - 28
Volatile matter (wt% db)	75 - 84	75 - 84	55 - 70	10 - 12	15 - 30
Fixed carbon (wt% db)	16 - 25	16 - 25	22 - 35	85 - 87	50 - 55
Bulk density (kg/l)	0.2 - 0.3	0.55 - 0.65	0.65 - 0.80	0.18 - 0.24	0.80 - 0.85
Vol. energy density (GJ/m ³)	1.4 - 3.6	8 - 11	12 - 19	5.4 - 7.7	18 - 24
Hygroscopic properties	Hydrophilic	Hydrophilic	Moderately Hydrophobic	Hydrophobic	Hydrophobic
Biological degradation	Fast	Medium	Slow	None	None
Milling requirements	Special	Special	Standard	Standard	Standard
Product consistency	Limited	High	High	High	High
Transport cost	High	Medium	Low	Medium	Low



Torrefaction Process Layout



Biomass Suitability For EF Gasification

- Determine optimum conditions torrefaction and densification
- Biomass typically leads to more slagging and fouling related issues → develop flux strategy
- FACTSage simulations to select appropriate flux material (theoretical slag/fly ash distribution, alkali trapping)
- Ash fusion experiments to assess slag behaviour
- LCS gasification simulator experiments to validate flux strategy

- Example: Torrefied Colombian Bamboo

Characteristics Bamboo (1)



Fuel	Russian Coal	Wood	Guadua angustifolia
Moisture	10.4	7.1	16.4
Proximate analysis (% mass, dry fuel basis)			
Ash @ 815°C	8.0	1.4	6.3
Volatile matter	32	80	70
HHV (KJ/kg)	27800	20093	18750
Ultimate analysis (% mass, dry fuel basis)			
C	68.0	50.3	47.1
H	4.0	6.1	6.1
N	0.9	0.4	1.0
S	0.35	0.03	0.13
O by diff.	11.6	44.2	44.0

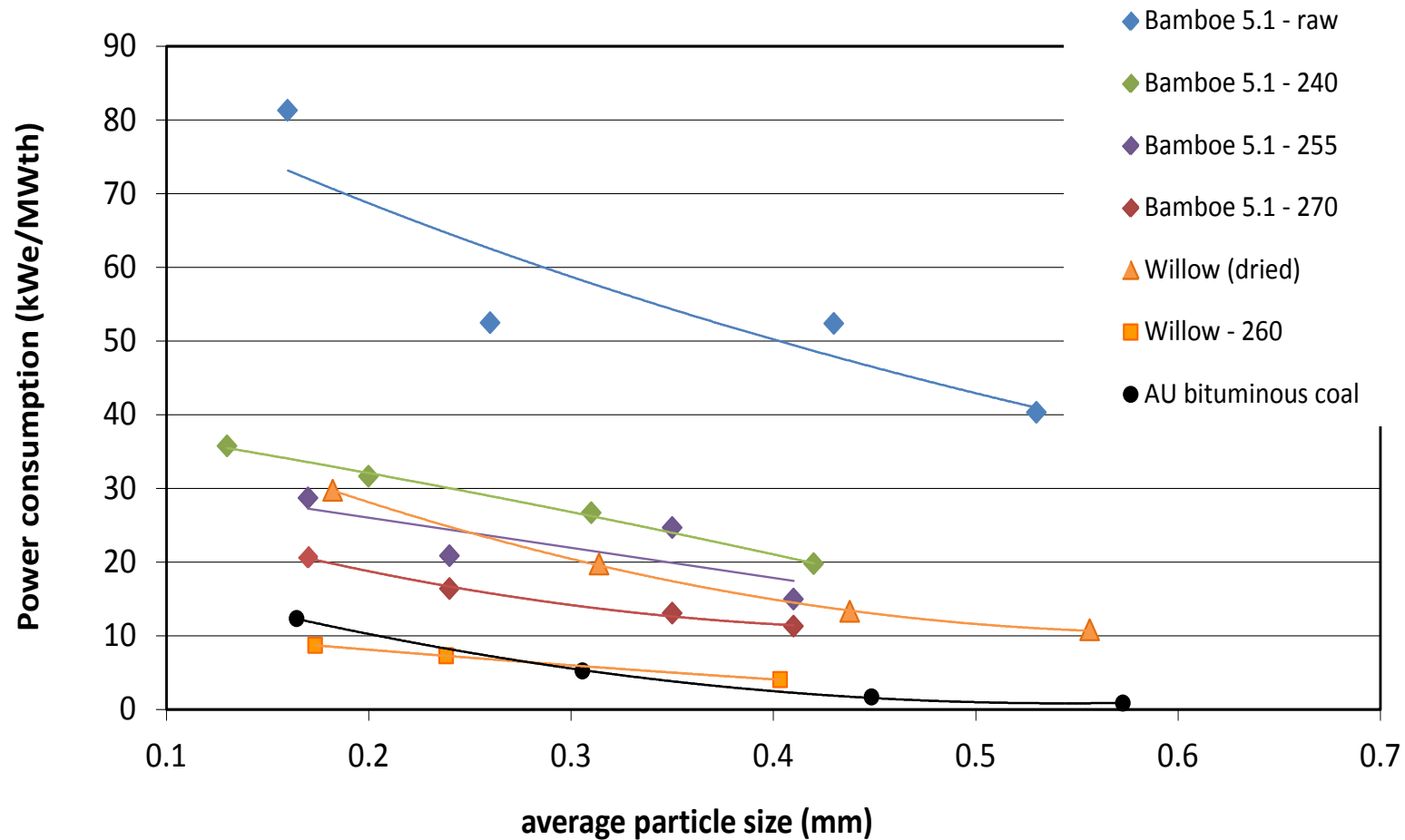
Characteristics Bamboo (2)

Fuel	Russian Coal	Wood	Guadua angustifolia
Moisture	10.4	7.1	16.4
Ash composition (mg/kg fuel, dry basis)			
Na (± 7)	405	191	111
Al (± 4)	16583	474	339
Si (± 90)	34841	1331	12143
→ K (± 20)	2390	984	23029
Ca (± 20)	2750	1919	344
Fe (± 4)	6077	301	140
S	3500	260	1284
→ Cl (± 20)	100	253	568

Results Torrefaction Experiments



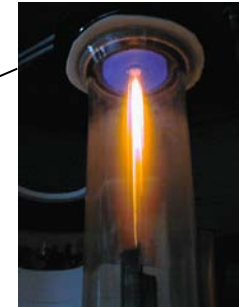
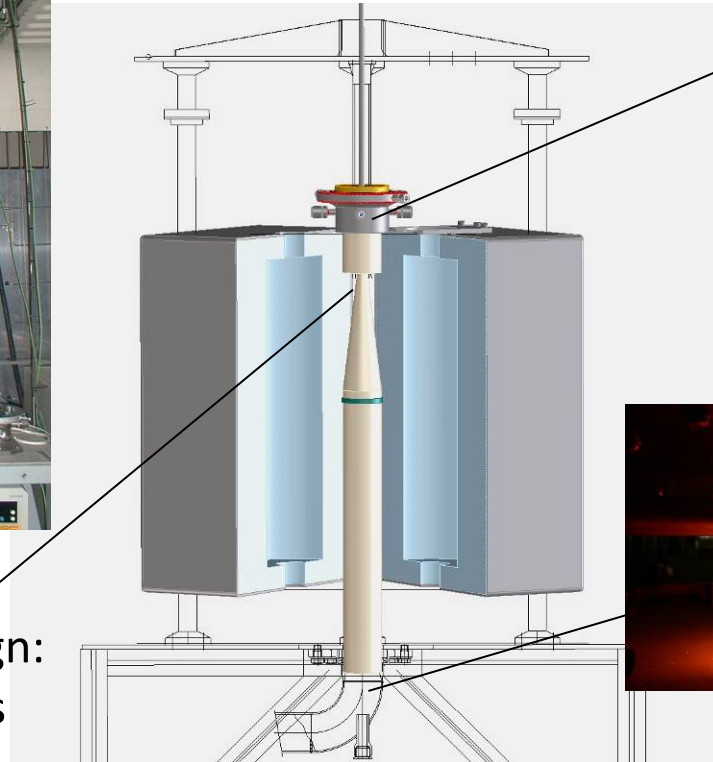
Grindability



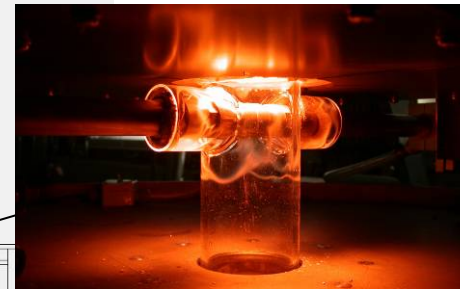
LCS Gasification Simulator (1)



Unique reactor design:
1-2s residence times



Staged gas burner:
high heating rate &
realistic gas atmosphere

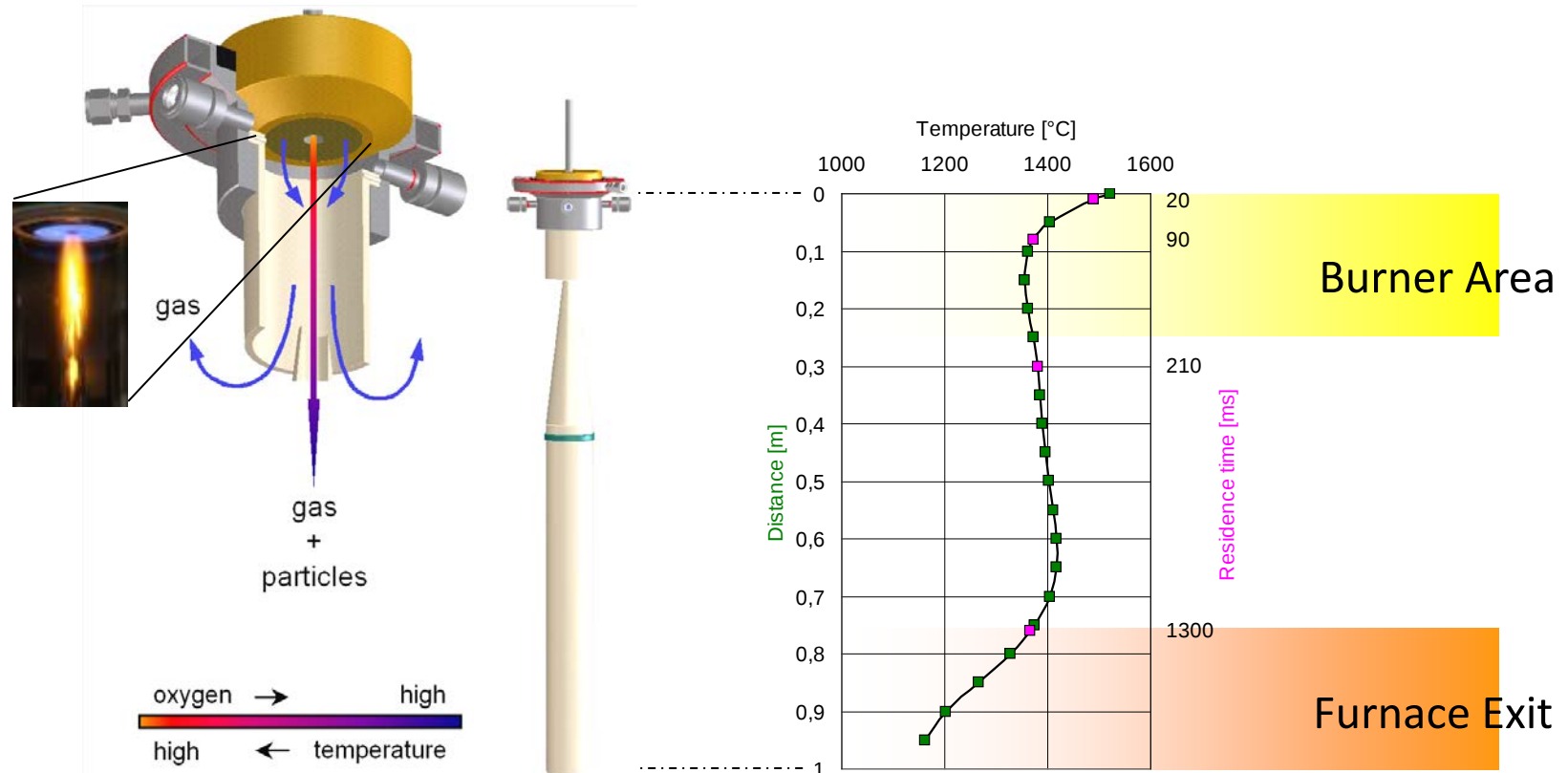


Fouling probe



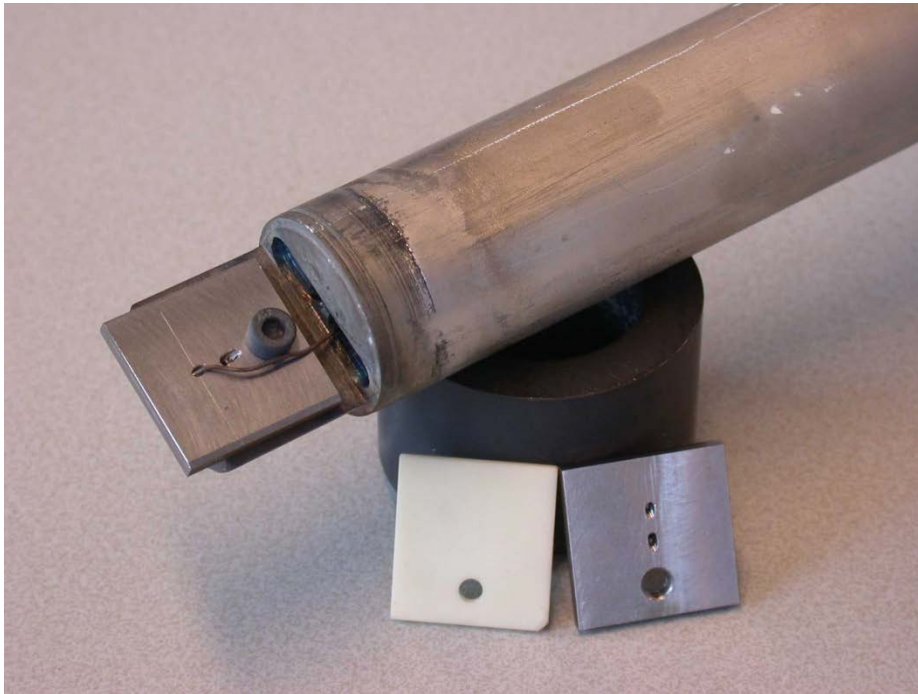
Particle sampling/
deposition probe

LCS Gasification Simulator (2)



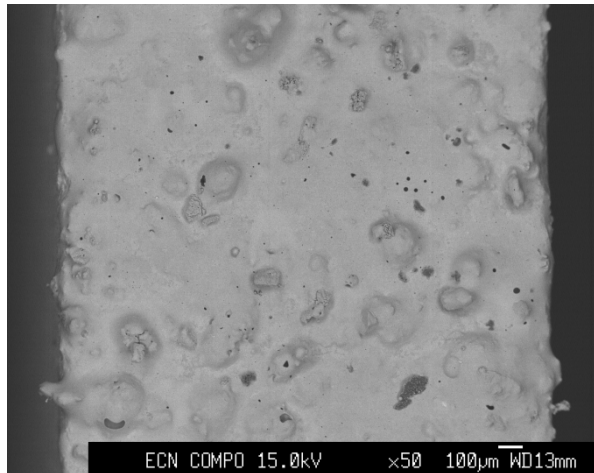
LCS (controlled conditions, 5 ms up to 2500ms, 600-1550°C, gas composition)

Slag formation

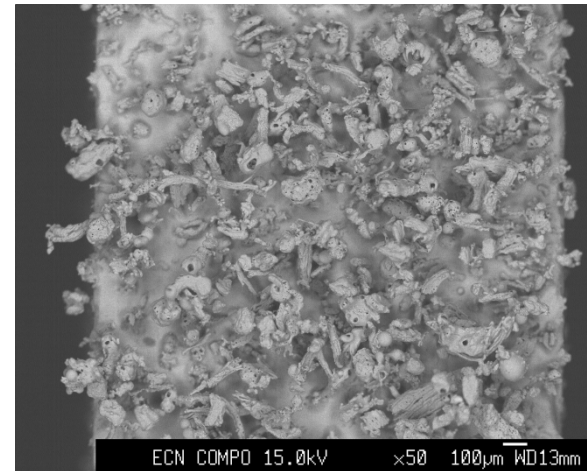


Vertical deposition probe

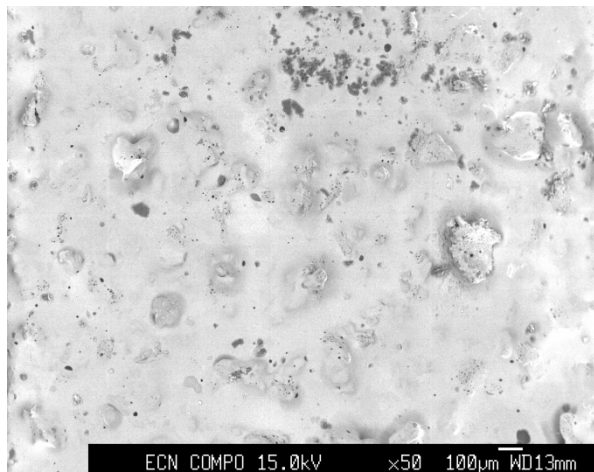
Slag formation at 1550 °C



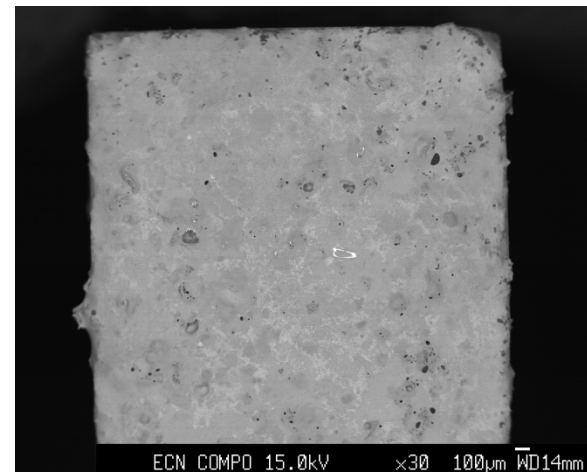
100%
coal



100%
torrefied
bamboo

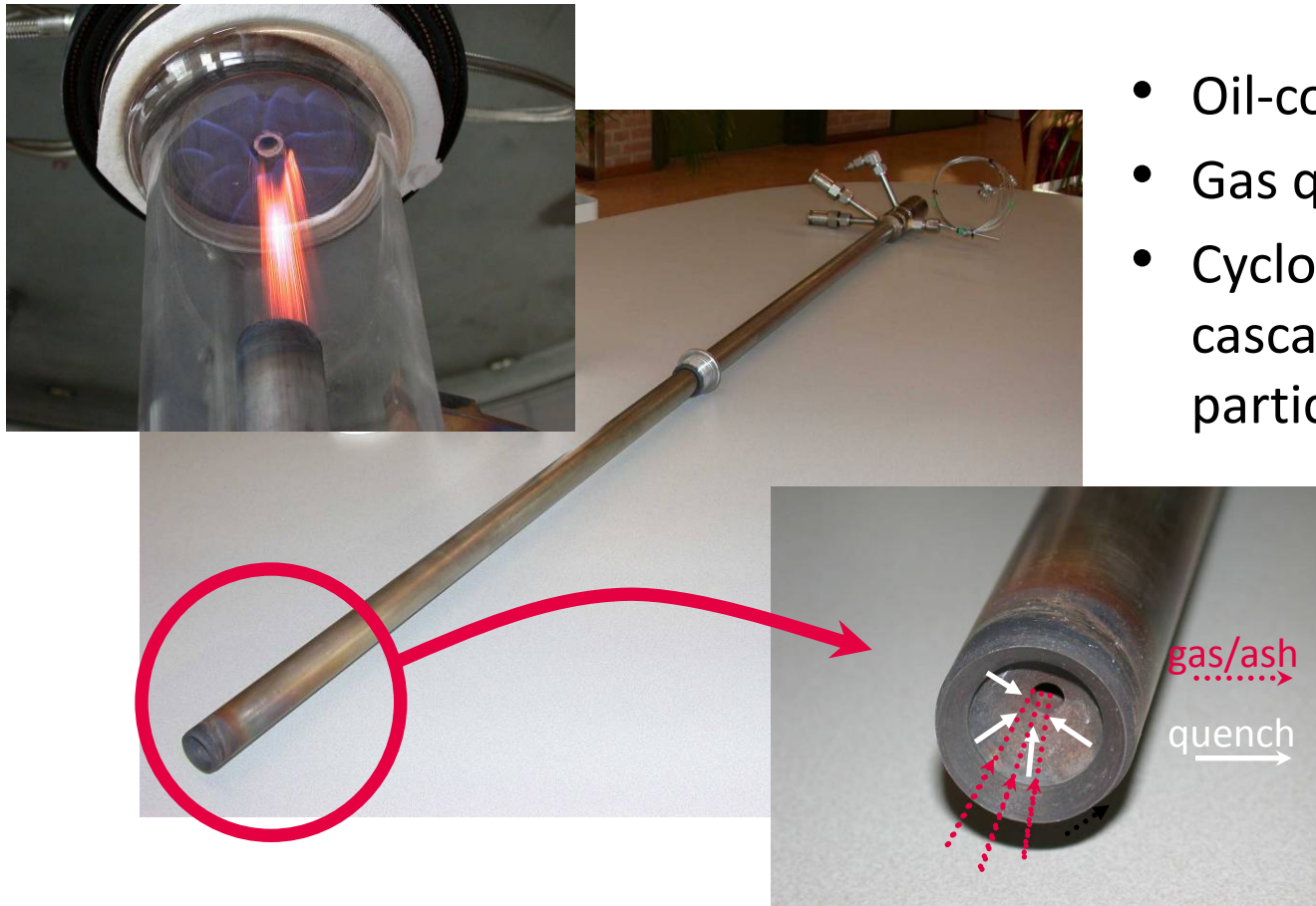


80% coal/
20% torrefied
bamboo



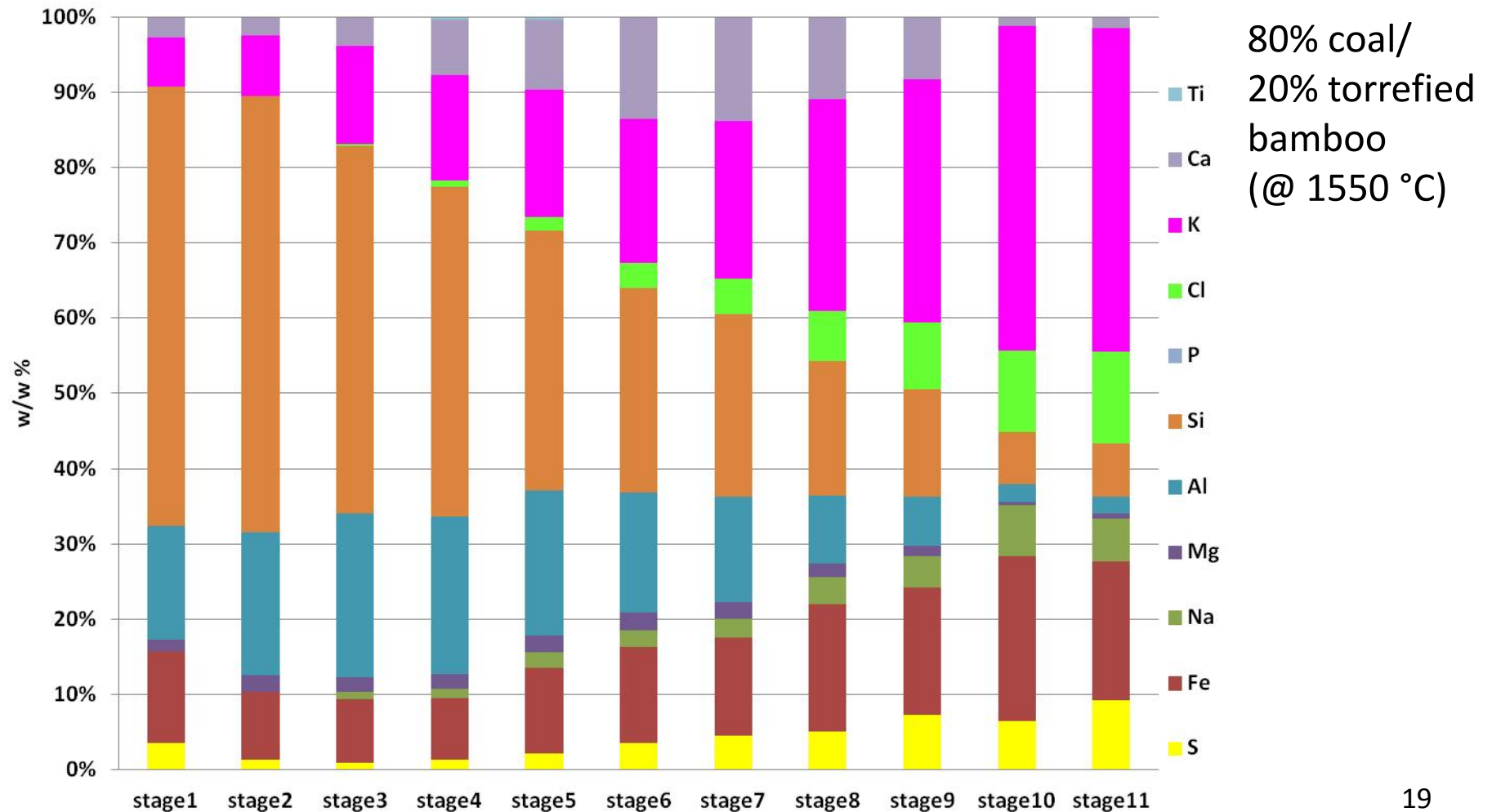
80% coal/
20% torrefied
bamboo
+ 4% flux

Particle Sampling (1)

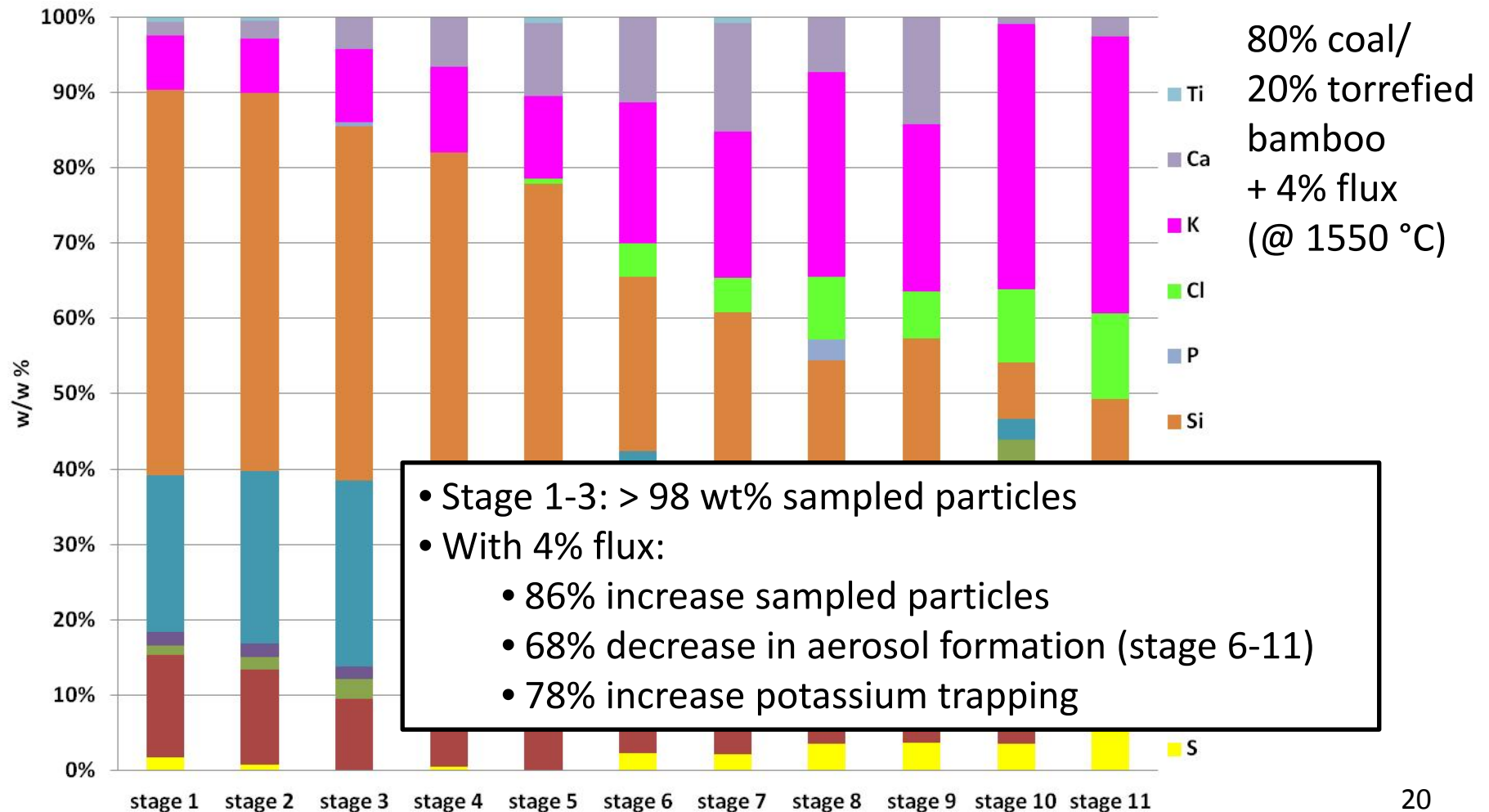


- Oil-cooled
- Gas quench (N_2 or He)
- Cyclone/filter/cascade impactor for particle sampling

Particle Sampling (2)



Particle Sampling (3)



Conclusions

- Biomass torrefaction and densification:
 - Significant increase volumetric energy density (up to 5x)
 - Straightforward handling, logistics, grinding and feeding
- Entrained flow gasification of torrefied biomass:
 - Slagging and downstream fouling issues
- Flux materials potentially mitigate these issues:
 - Proper slag formation
 - Alkali trapping

Thank you for your attention

This work forms part of the project “Torrefied bamboo pellets for sustainable biomass import from Colombia” which is partly financed by NL Agency under the subsidy scheme Sustainable Biomass Import. The project aims to assess the techno-economic potential and the sustainability of bamboo as a biomass supply chain for bioenergy production. Partners in the project are: Technological University of Pereira (CO), Colombian Bamboo Society (CO) and Imperial College of London –Imperial Consultants (UK).

Michiel Carbo

Project Manager

Biomass & Energy Efficiency

T +31 88 515 47 92

F +31 88 515 84 88

carbo@ecn.nl

Westerduinweg 3, 1755 LE PETTEN

P.O. Box 1, 1755 ZG PETTEN

The Netherlands

www.ecn.nl