Torrefaction by ECN

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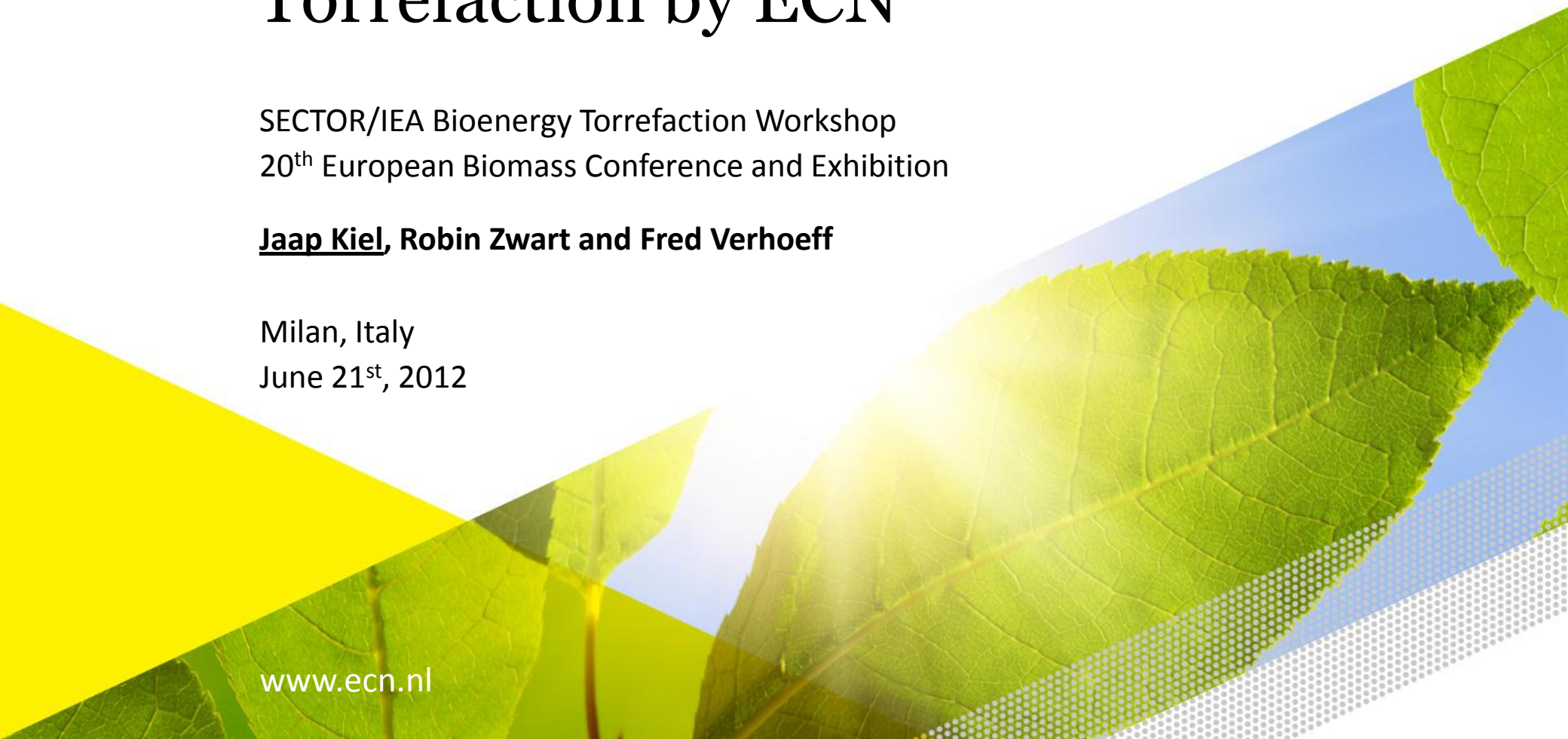
ECN
Your energy. Our passion.

Torrefaction by ECN

SECTOR/IEA Bioenergy Torrefaction Workshop
20th European Biomass Conference and Exhibition

Jaap Kiel, Robin Zwart and Fred Verhoeff

Milan, Italy
June 21st, 2012



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Presentation overview

- Introduction to ECN
  - Mission
  - Core activities in biomass
- ECN and torrefaction
  - Small-scale research
  - ECN's torrefaction technology
  - Pilot-scale testing
  - Logistics and end-use testing of torrefied material
- Torrefaction technology demonstration and commercialisation
  - Co-operation between ECN and Andritz
  - Demo plant features
  - Status

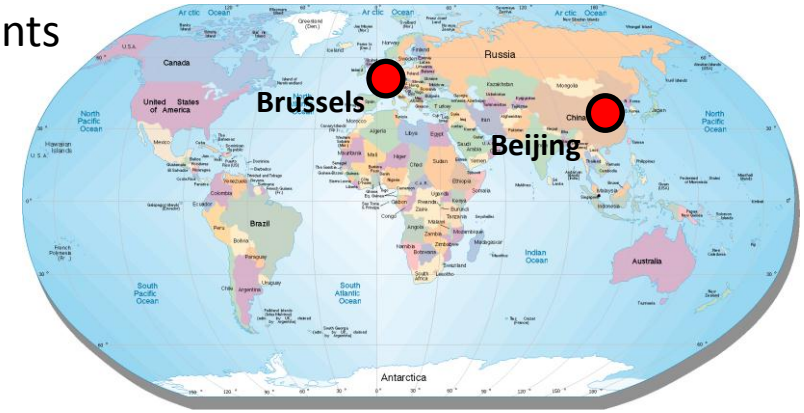
Energy research Centre of the Netherlands (ECN)

- Dedicated to Sustainable Energy Innovation

  With and for the market, ECN develops knowledge and technology that enable a transition to a sustainable energy system

- Core activities in biomass

  Sustainable energy technology development
  R&D services and consultancy to industry
  Feasibility studies, system & technology assessments




Biomass


Solar


Wind


Energy efficiency


Policy studies

ECN and torrefaction

- 20 years experience in biomass co-firing, played a pioneering role in adapting torrefaction to bioenergy applications
- ECN's torrefaction technology proven on pilot-scale and with industrial partners now taken to demonstration and commercial market introduction
- Contract R&D for industry to assess the torrefaction potential of specific feedstock, produce test batches, and assess and optimise product quality
- Continued basic R&D to increase the knowledge base

Initial torrefaction R&D at ECN

- ECN was one of the first to recognise the potential of torrefaction for biomass-to-energy purposes
- Initial small-scale research started in 2002-2003, revealing:
  - Quantitative relation between torrefaction conditions (residence time, temperature) and product properties (solid + gas) for a broad range of biomass feedstocks
  - Underlying mechanisms (structural changes in the biomass)
  - Pelletisation behaviour of torrefied biomass
- Based on the small-scale research, dedicated reactor and process concepts were developed, aiming at: good process control, low investment cost, high capacity, high feedstock flexibility, high energy efficiency and minimum environmental impact
- Heat integration, using the energy content of the torrefaction gas, is crucial to achieve high energy efficiency (minimize cost and GHG footprint)

Bench-scale testing

Batch test example

Gas phase composition	
CO	0.1 %
CO_2	3.3 %
H_2O	89.3 %
acetic acid	4.8 %
furfural	0.2 %
methanol	1.2 %
formic acid	0.1 %
remainder	1.0 %

Tad = 1045 °C

Feed: Willow
Size: 10 - 30 mm
LHV: 14.8 MJ/kg
Moisture: 14.4%
Fixed carbon: 16.8 %

Torrefaction
32 min, 260 °C

Mass yield: 75.3%
Energy yield: 94.3%

20 l batch reactor

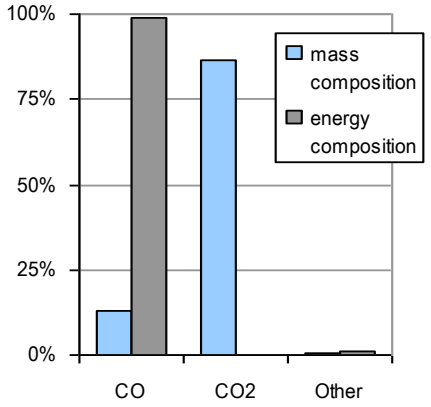
Torrefied Willow
Size: 10 - 30 mm
LHV: 18.5 MJ/kg
Moisture: 1.9%
Fixed carbon: 22.1%

Bench-scale testing

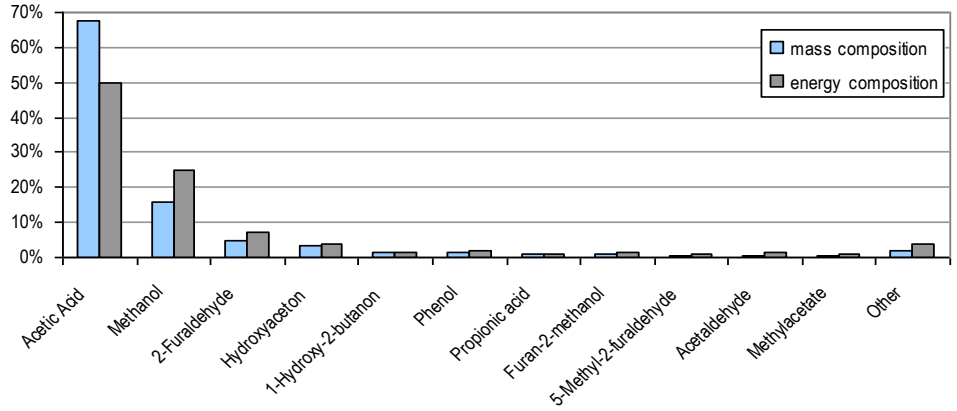
Continuous test – Torrefaction of willow (280 °C, 17.5 min)

5 kg/h Auger reactor (screw reactor)

Permanent gases

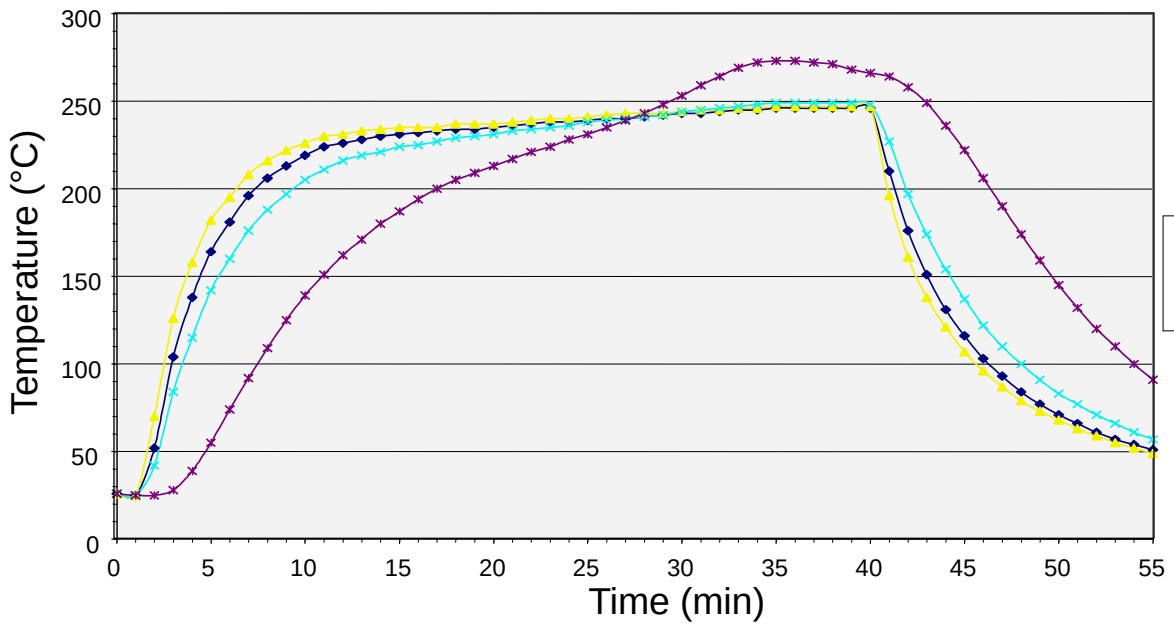


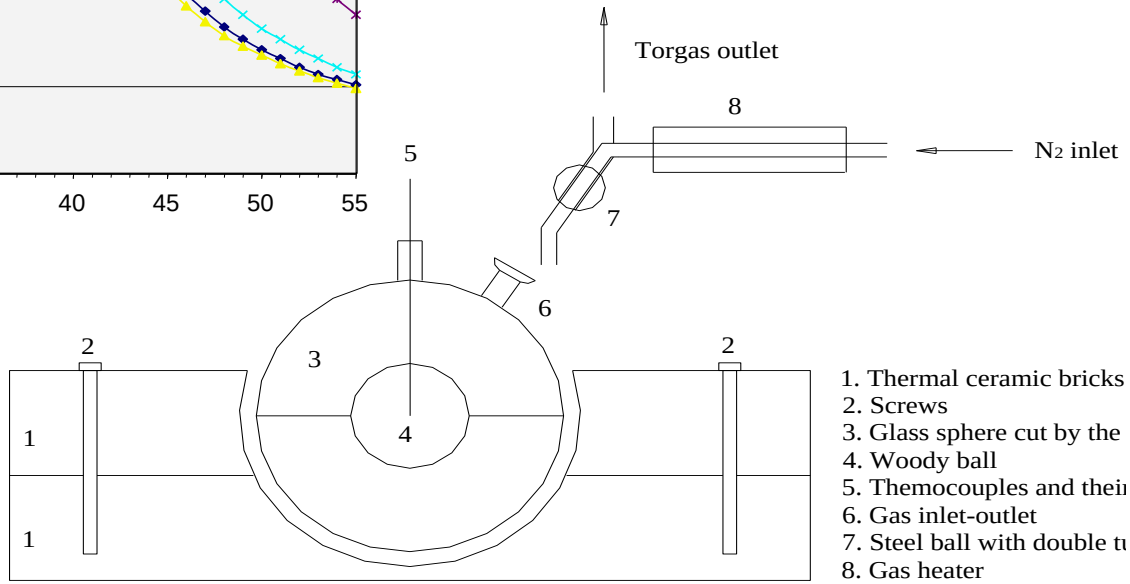
Organics



Exothermicity

Single particle tests





1. Thermal ceramic bricks
2. Screws
3. Glass sphere cut by the middle
4. Woody ball
5. Themocouples and their inlet
6. Gas inlet-outlet
7. Steel ball with double tube to act as inlet and outlet
8. Gas heater

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Self-heating

Chemical oxidation of torrefied material

- Accidents detrimental to the entire torrefaction industry
- ECN conducted extensive bench-scale testing to better understand and quantify self-heating propensity
- Self-heating propensity dependent on type of biomass, torrefaction degree and type of product (e.g., torrefied chips or pellets)

End of production run on Wednesday → **Fire on Saturday**

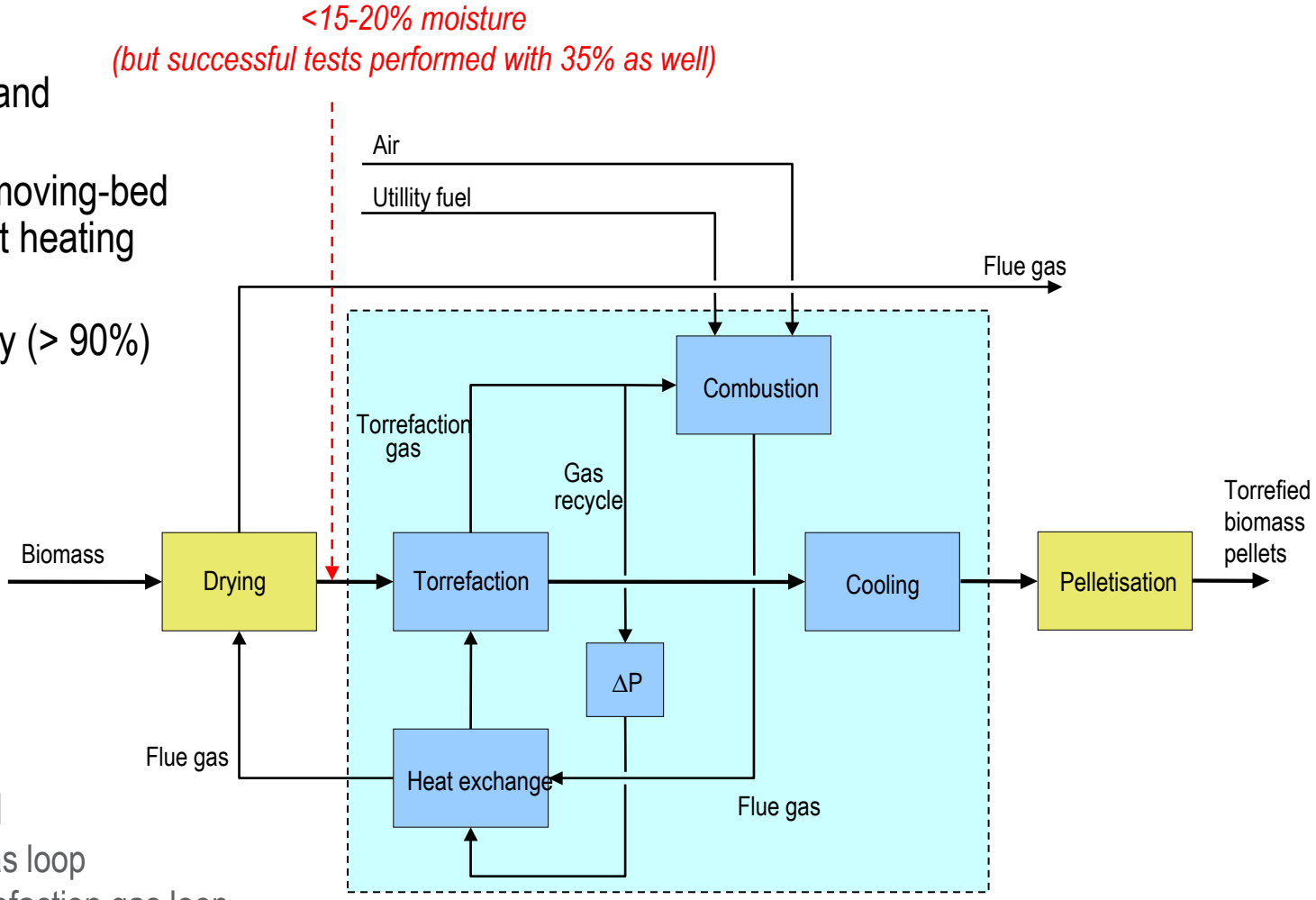
Densification

- Focus on pelletisation, but briquetting considered as well
- Good quality pellets can be produced without additional binder
- But:
  - Pelletisation performance strongly dependent on biomass feedstock
  - Case-by-case tuning of the pelletisation conditions required
  - Good control of torrefaction conditions is essential
  - Without binder, window for tuning product quality to logistics and end-use requirements may be small
  - Special attention to safety issues (e.g., self heating, dust explosions)

ECN's torrefaction technology

Features:

- Conventional drying and pelletisation
- Compact dedicated moving-bed technology with direct heating
- Heat integration
- High energy efficiency (> 90%)
- Cost effective



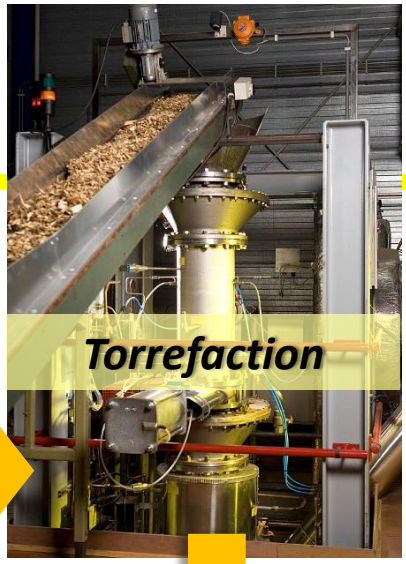
Intellectual Property:

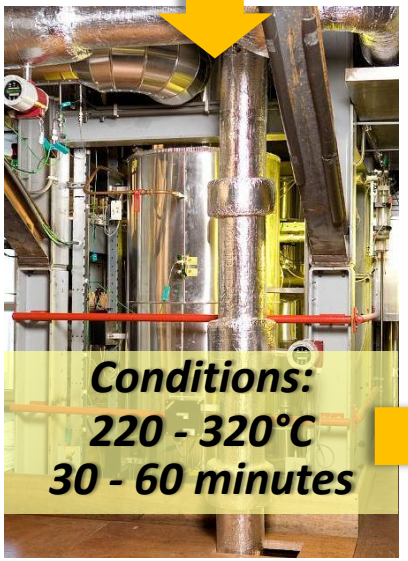
- IP is patent protected
  - Co-current drying gas loop
  - Counter-current torrefaction gas loop

ECN 50 kg/h torrefaction pilot plant
(Since February 2008)

Torrefaction

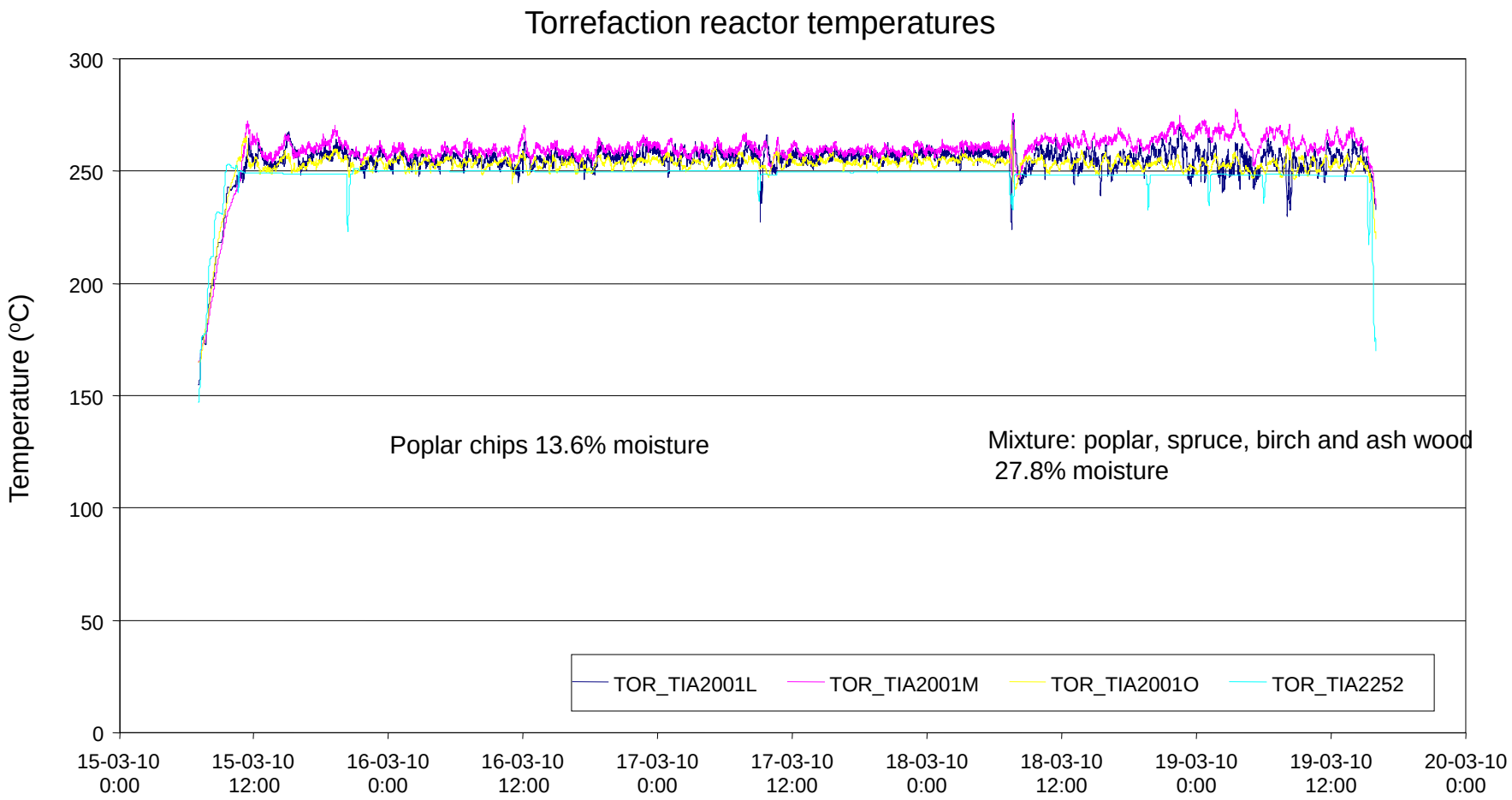
ECN pilot-scale testing





ECN pilot-scale torrefaction

Results of typical 100 hour test run



ECN pilot-scale torrefaction

Biomass feedstock and test conditions

- Biomass feedstock
  - Aspen
  - Bamboo
  - Birch
  - Empty Fruit Bunches (EFB)
  - Forest residues
  - Oil Palm Fronds (OPF)
  - Pine
  - Poplar
  - Whole tree chips
- Temperatures & residence times
  - 220°C – 320°C
  - 30 – 60 min

ECN pilot-scale torrefaction

Recent test run – bamboo

ECN biomass (co-)firing R&D

Focal points and methodology

Focal points
- Grindability
- Pneumatic feeding
- Conversion kinetics
- Slagging / Fouling / Corrosion
- SCR catalyst performance
- Ash quality
- Emissions

Full-scale diagnostics
- PM / Gas emissions
- Slagging / Fouling / Corrosion

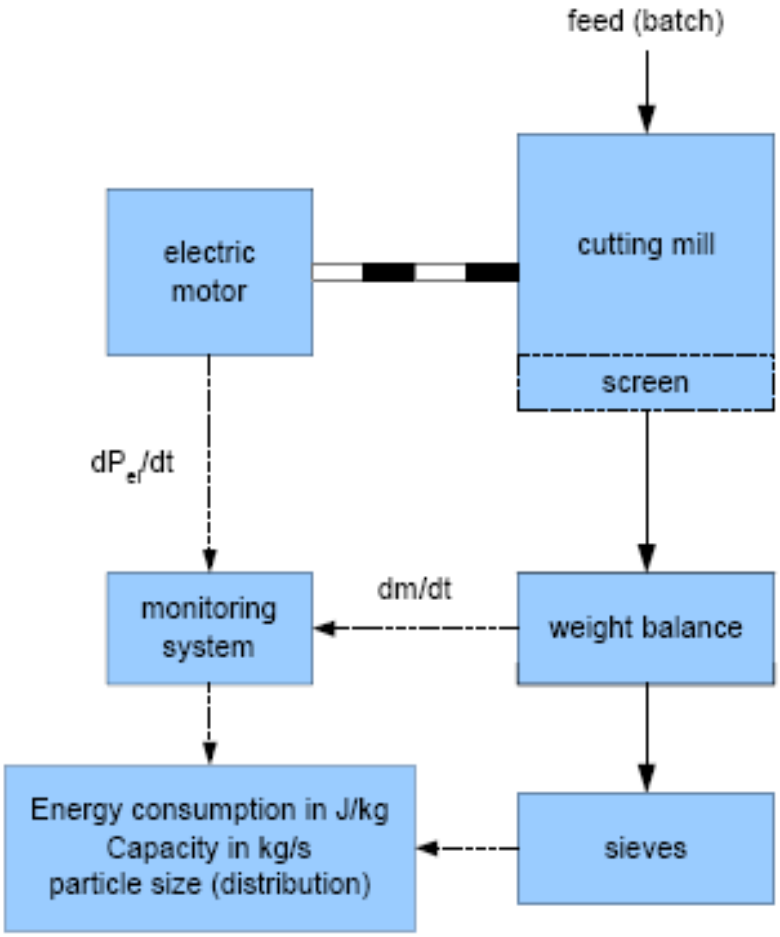
Advanced analytical tools
- Wet chemical
- (CC)SEM/EDX
- TGA/DSC, GC/LC/MS

Experimental tools
- Grinding test
- Fluidisation and bridging tests
- Lab-scale Combustion Simulator (LCS)
- Fluidised-bed combustion test rigs
- Deposition probes + cascade impactor
- SCR catalyst test facility
- pH-static extraction

Numerical tools and databases
- BIOMax ash model
- ORCHESTRA / LeachXS
- Co-firing Advisory Tool
- CFD
- Thermodynamics
- Phyllis/BIODAT biomass property database

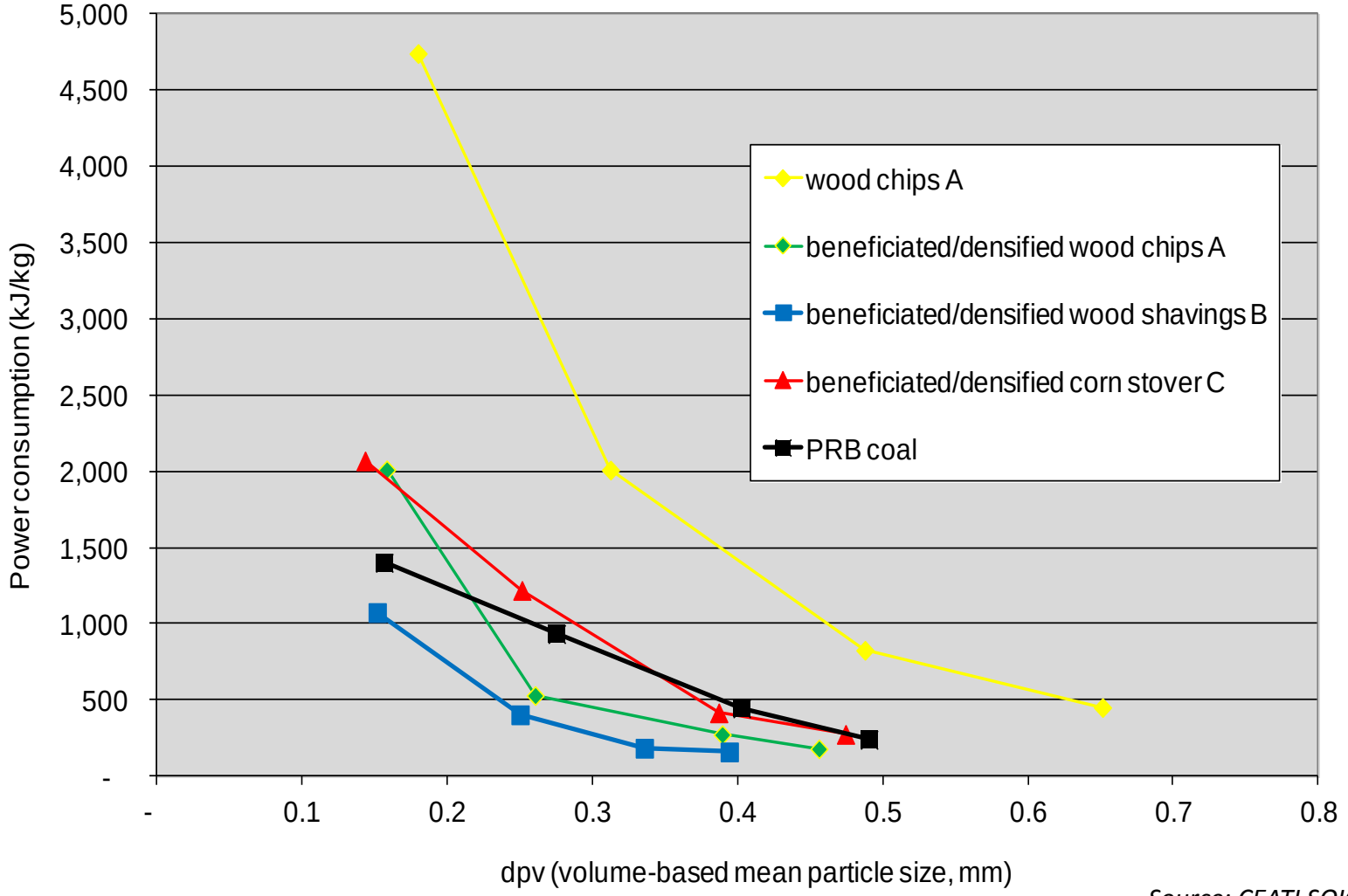
Grindability
Equipment and method

- ECN method
  - based on a cutting mill (RETSCH SM 2000)
  - motor rpm kept constant and power consumption registered
  - milled product is then dry sieved
  - result: curves relating power consumption to particle size distribution
  - integral particle size distribution verified by Malvern Mastersizer laser light scatter analyses



Grindability

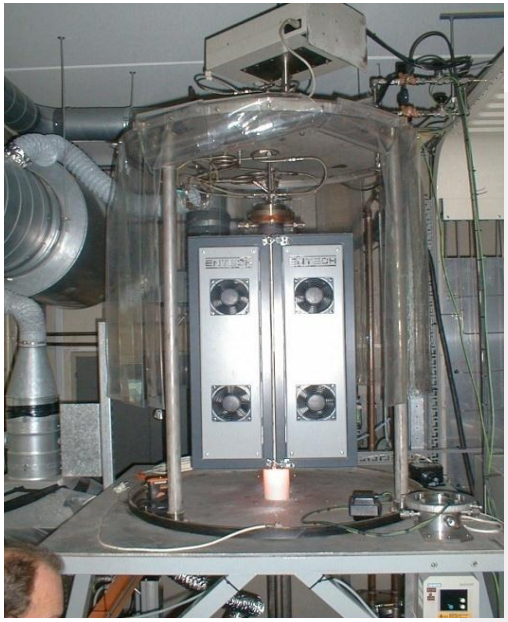
Results, power requirement

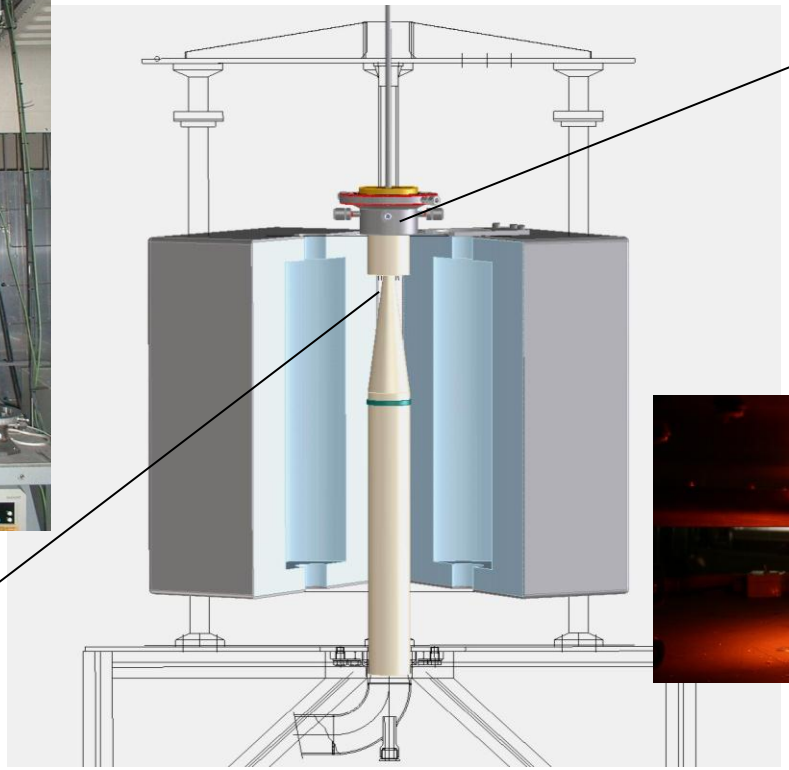


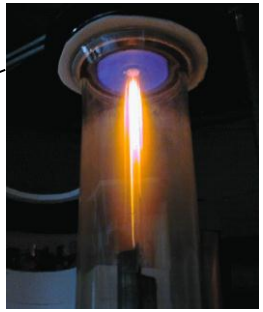
Source: CEATI SOIG 0530 B/C project

Lab-scale Combustion Simulator (LCS)

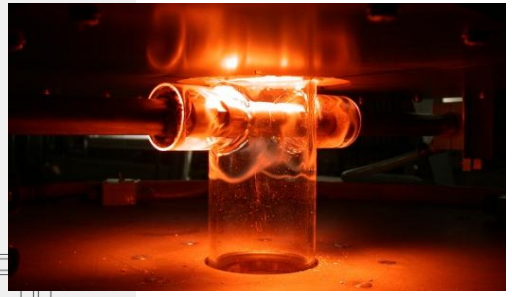
Mimic pulverised-fuel combustion and high-temperature gasification conditions







Staged gas burner: high heating rate + proper gas atmosphere



Fouling probe

Particle sampling probe

Special reactor design:
1-2s residence times with only limited total reactor length

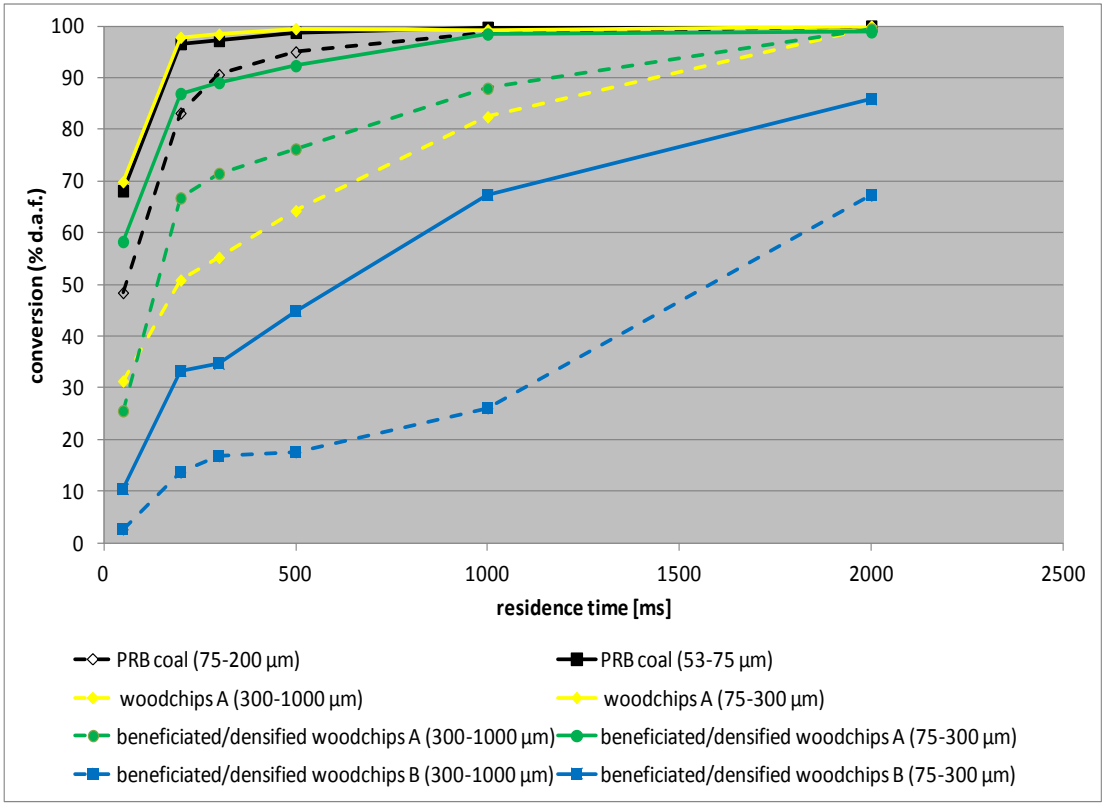
Fuel reactivity

Results, fresh/beneficiated fuels kinetics

$T_{flame/furnace}$ = 1450/1300 °C

$[O_2]_{final}$= 3.8 % vol dry

(shallow) burner staging (~200 ms)



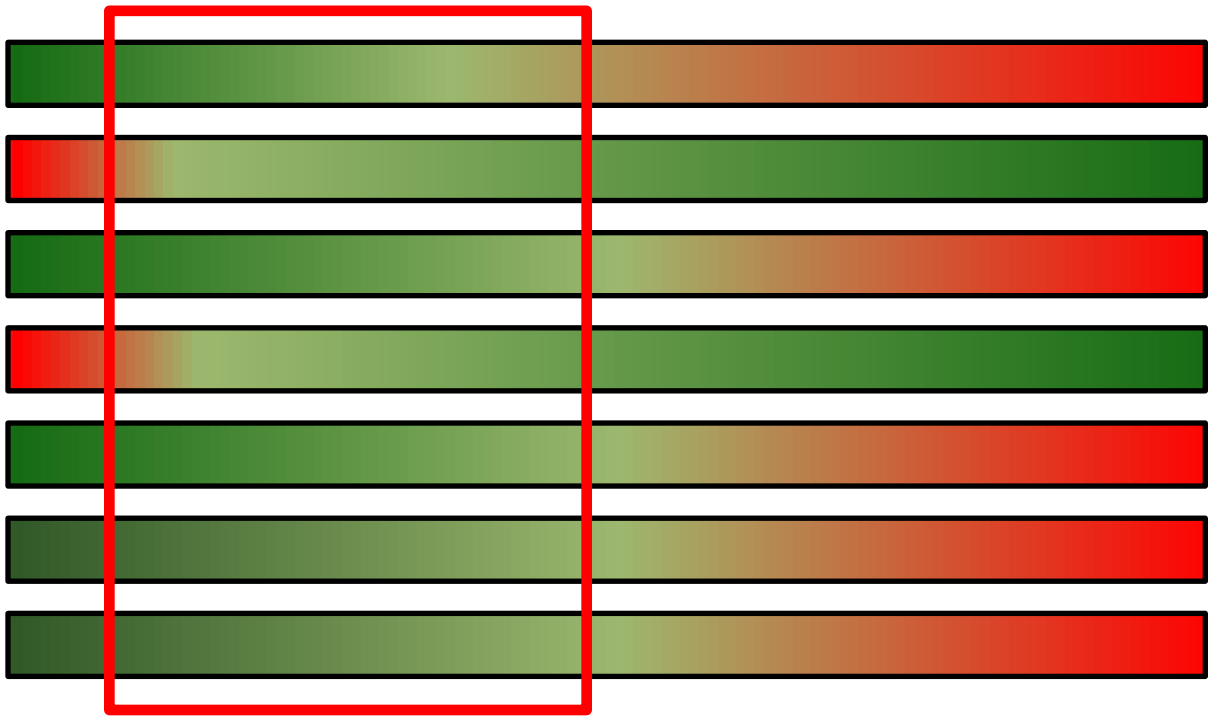
- Reactivity:

  - High impact of milling
  - (300-75 µm) fresh wood > PRB coal (53-75 µm)
  - (300-75 µm) beneficiated wood ~ PRB coal (75-200 µm)
  - (300-1000 µm) biomass significantly slower (fresh and upgraded)
  - Very low for deeply-torrefied B material

Source: CEATI SOIG 0530 B/C project

Impact of torrefaction degree

- Densification
- Grindability
- Self-heating
- Heating value
- Reactivity
- Cost
- Sustainability
- …..



Mild torrefaction preferable
for most applications

Andritz-ECN Demo Plant
(March 2012)

ECN and Andritz

- ECN and Andritz signed a cooperation agreement on the development of torrefaction technology in mid-2011
- Andritz has licensed key technology from ECN
- ECN is providing technical and research services to Andritz
- The combination of ECN and Andritz technology is being tested in a Demo Plant in Denmark

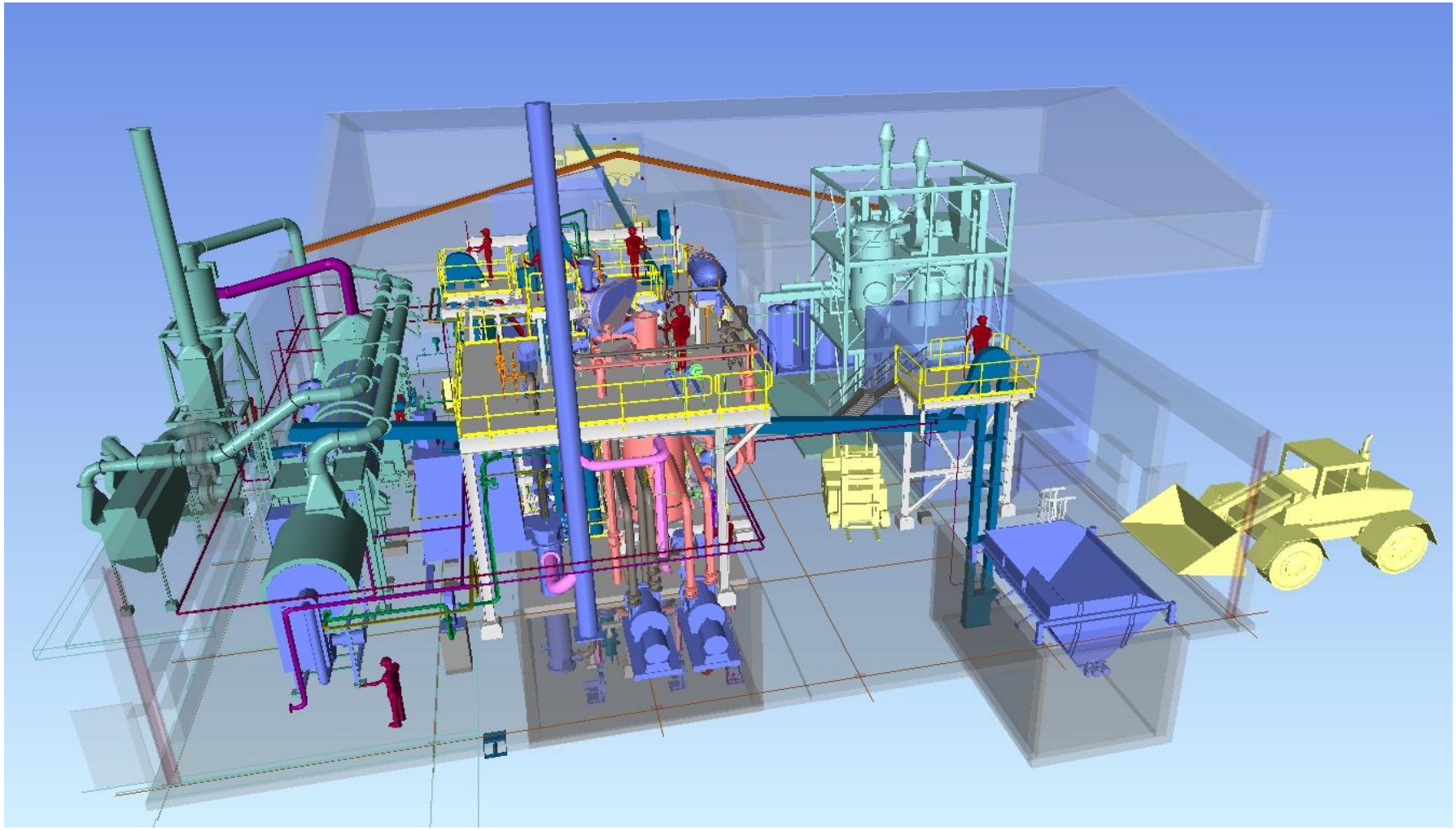
Torrefaction demo plant

Key features torrefaction reactor

- Blends ECN and Andritz technologies
- Pressurized for more effective heat transfer
- Provides a separation between the final drying zone and the beginning of torrefaction
- Includes a co-current torrefaction zone followed by a counter-current torrefaction zone
- Lends itself to scale up to large single unit capacities

Torrefaction demo plant

Overall view



Torrefaction demo plant

Status

- The demo plant is in the final stages of construction
- Commissioning is underway
- Initial operation on biomass will commence following commissioning

Pictures: March 2012

Thank you for your attention!

This presentation was prepared in close co-operation with:

ANDRITZ Pulp & Paper

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