Status of ECN torrefaction technology

J.H.A. Kiel

R.W.R. Zwart

F. Verhoeff

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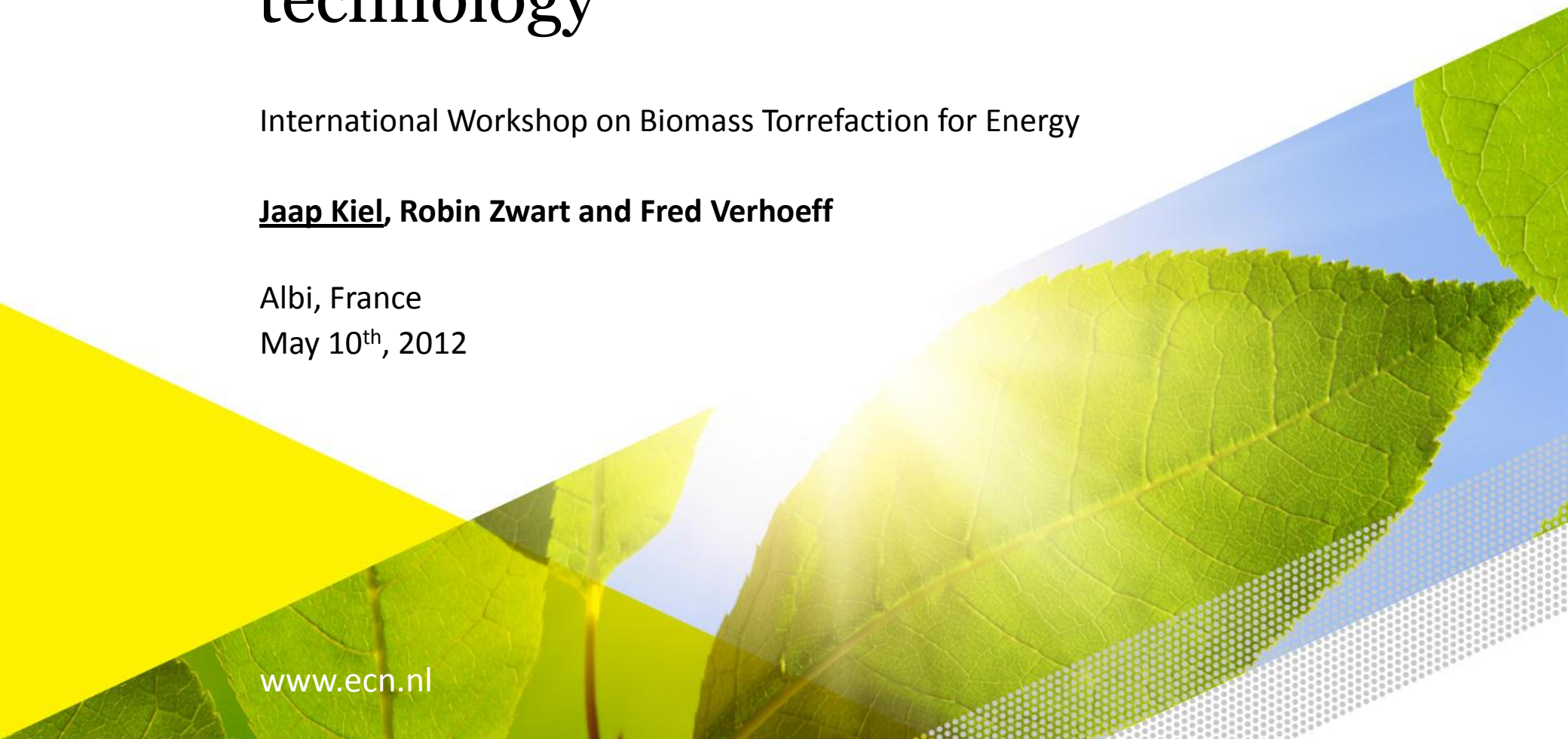
International Workshop on Biomass Torrefaction for Energy

Jaap Kiel, Robin Zwart and Fred Verhoeff

Albi, France
May 10th, 2012



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Presentation overview

- Introduction to the Energy research Centre of the Netherlands (ECN)
  - General mission
  - Core activities in biomass
- ECN and torrefaction
  - Challenges
  - Small-scale research
  - ECN's torrefaction technology
  - Pilot-scale testing
- Torrefaction technology demonstration and commercialisation
  - Co-operation between ECN and Andritz
  - Demo plant features
  - Status

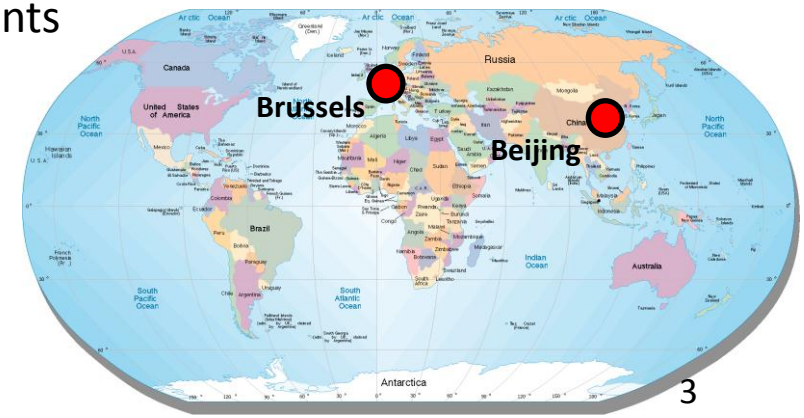
Energy research Centre of the Netherlands (ECN)

- 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 to industry
  Feasibility studies, system & technology assessments




Biomass


Solar


Wind


Energy efficiency


Policy studies

ECN and torrefaction

- 20 years experience in biomass co-firing R&D, identified the potential of torrefaction and played a pioneering role in adapting torrefaction to bioenergy applications since 2002
- ECN's torrefaction technology proven on pilot-scale and together with industrial partners now taken to demonstration and commercial market introduction
- Contract R&D for industry to assess the torrefaction potential of specific feedstocks, produce test batches and optimise product quality

Bioenergy – major challenge

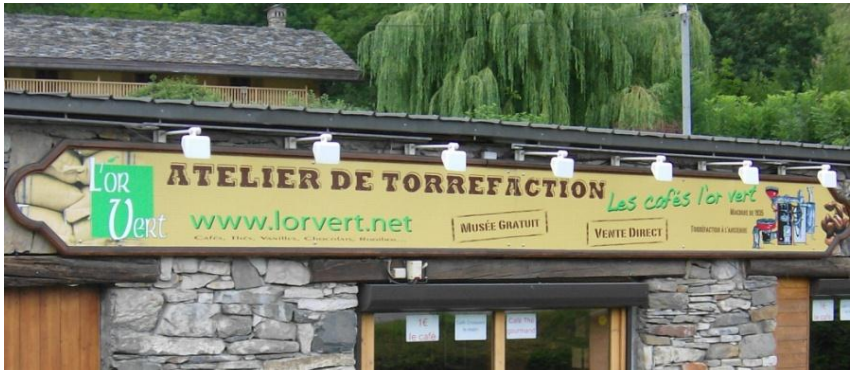
- Enable decoupling of biomass production and use
  - Place
  - Time
  - Scale

- By converting biomass in high-quality bioenergy carriers (solid, liquid or gas), that:
  - Better fit in (existing) logistic infrastructures
  - Allow efficient, reliable and cost effective conversion into electricity and heat, transport fuels and chemicals

Solve biomass related problems at the source

Torrefaction for upgrading biomass

- Process parameters
  - Temperature: 200-300 °C
  - Absence of oxygen



Tenacious and fibrous
LHV = 9 - 12 MJ/kg
Hydrophilic
Biodegradable
Heterogeneous

Torrefaction

Friable and less fibrous
LHV = 18 - 24 MJ/kg
Hydrophobic
Preserved
Homogeneous

Pelletisation

Bulk density = 650-800 kg/m^3
Bulk energy density = 12 - 19 GJ/m^3

Biomass torrefaction for energy applications

- Not straightforward !
- Absence of oxygen requires air-tight system
- Torrefaction should be considered as a separate thermal regime, distinctly different from drying, slow pyrolysis or charcoal production
- Characteristic features:
  - Overall exothermal reaction (due to secondary cracking reactions)
  - Condensables composition and behaviour
  - Nature and behaviour of the solid product (e.g., self-heating)
- High energy efficiency is crucial in view of overall cost and sustainability
- Reactor and process should allow large-scale production with minimal environmental impact

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
- To achieve high energy efficiency, heat integration using the energy content of the torrefaction gas is crucial

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

20 l batch reactor

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%

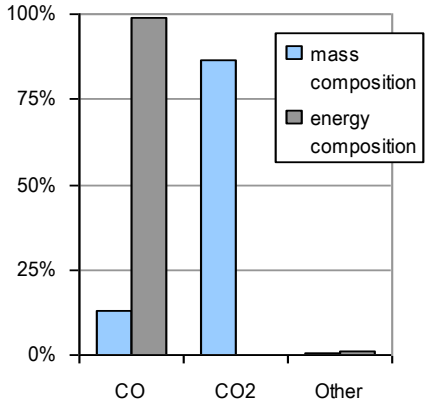
Torrefied Willow
Size: 10 - 30 mm
LHV: 18.5 MJ/kg
Moisture: 1.9%
Fixed carbon: 22.1%

Bench-scale testing

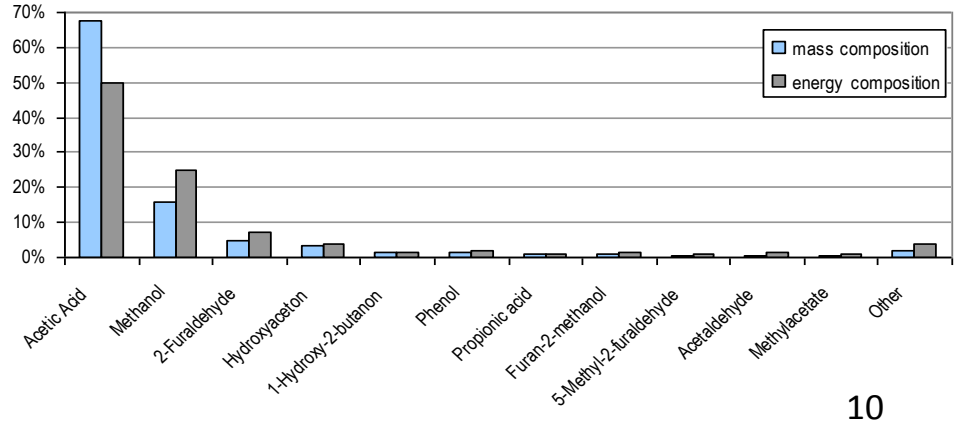
Continuous test – Torrefaction of willow (280 °C, 17.5 min)

5 kg/h Auger reactor (screw reactor)

Permanent gases

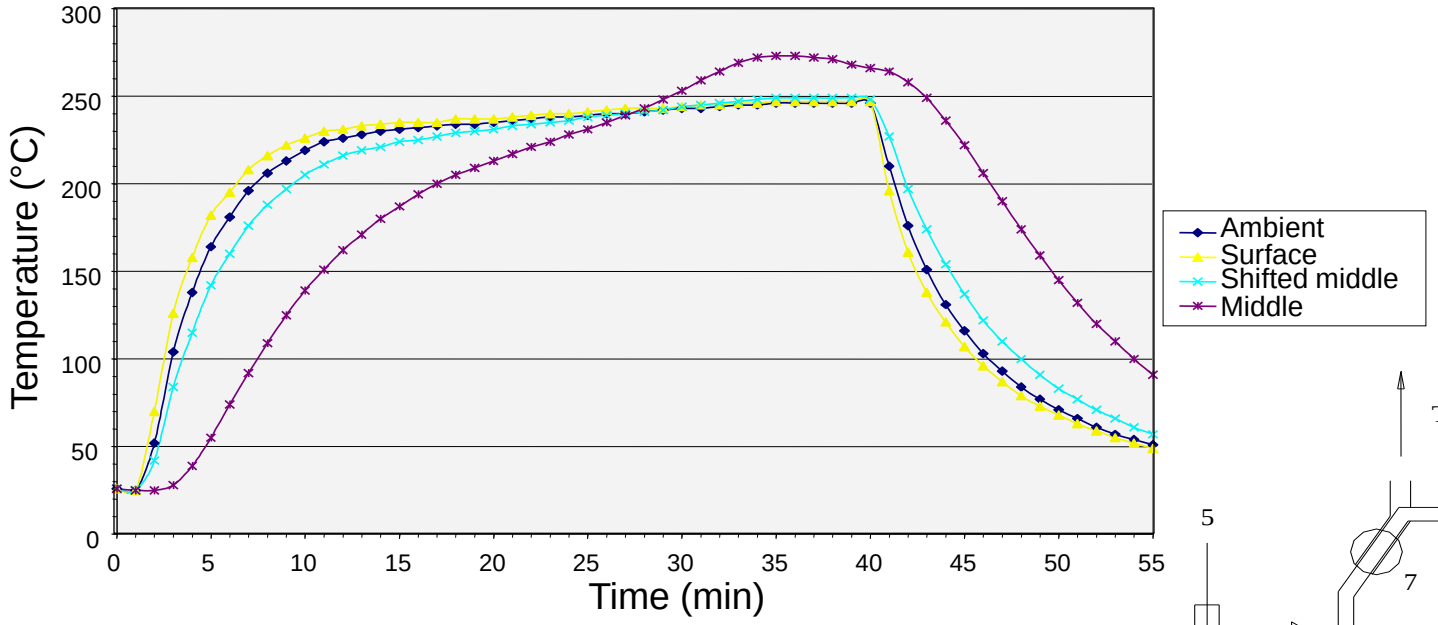


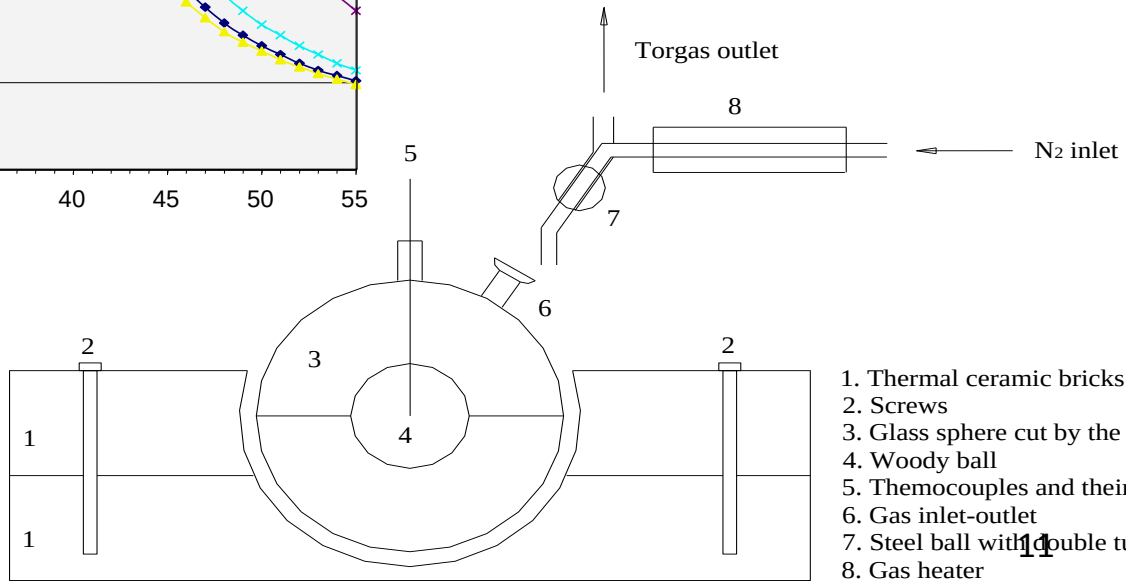
Organics



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

Bowes-Cameron cage test

- Self-heating properties determined using *Bowes-Cameron cage test* as described in the UN Recommendations on the Transport of Dangerous Goods:
  - Filled wire mesh cube placed in oven
  - Oven temperatures 100, 120 or 140 °C
  - If sample exceeds oven temp by 60 °C, than: self heating
- 3 Samples tested: pellets from torrefied wood chips, EFB and OPF
  - Crushed pellets from torrefied wood chips and torrefied OPF pellets not classified as a self-heating substance
  - Torrefied EFB pellets have self-heating properties; the material needs to be classified as a self-heating substance

Wood chips

Empty Fruit Bunches

Oil Palm Fronds

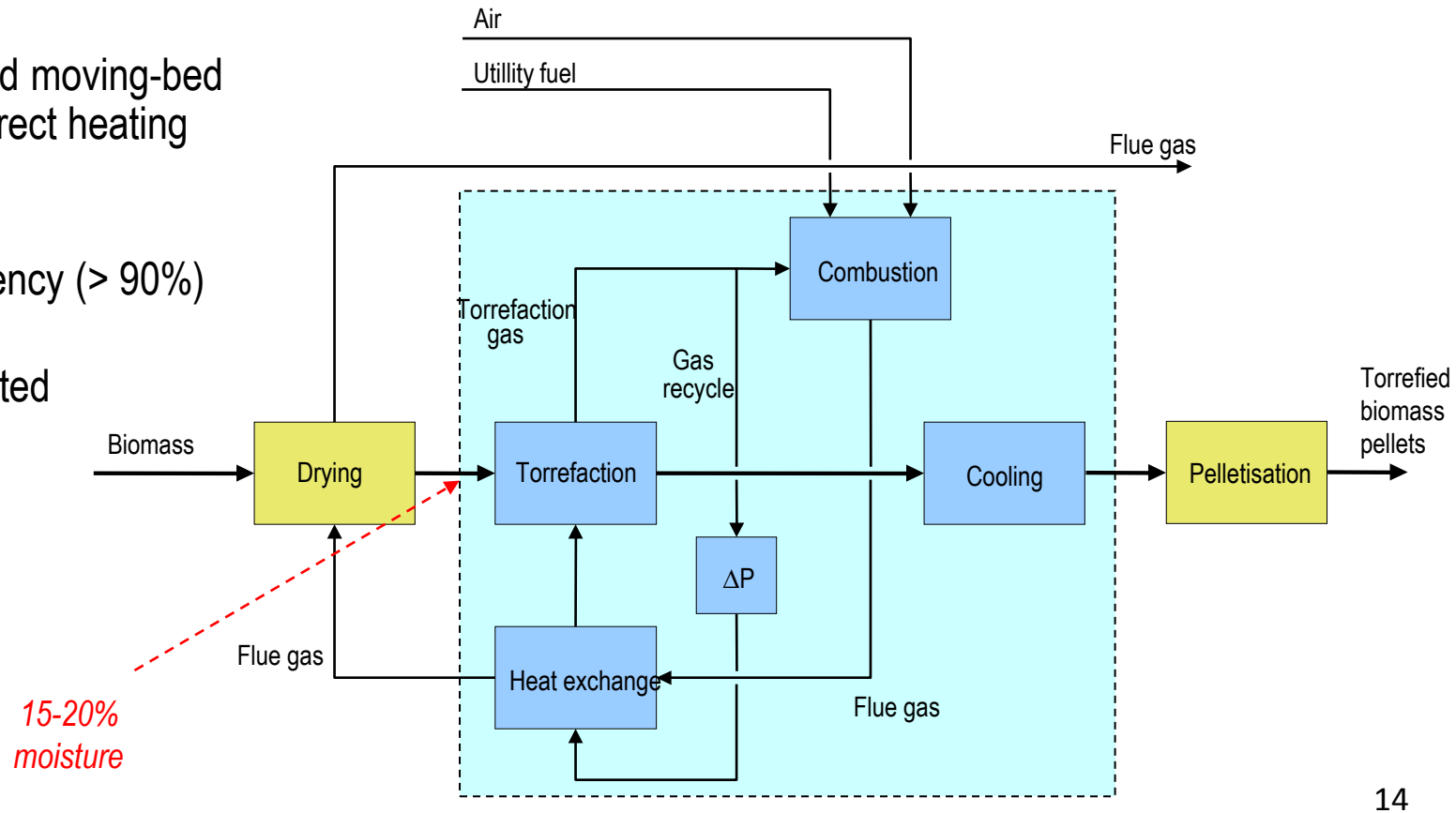
Densification

- 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 (e.g., die type) 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:

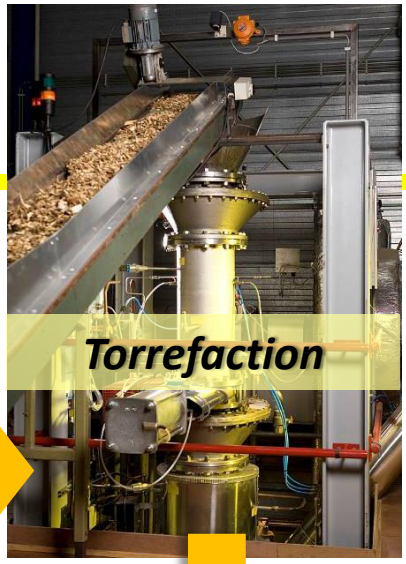
- Conventional drying and pelletisation
- Compact dedicated moving-bed technology with direct heating (no moving parts)
- Heat integration
- High energy efficiency (> 90%)
- Cost effective
- IP is patent protected

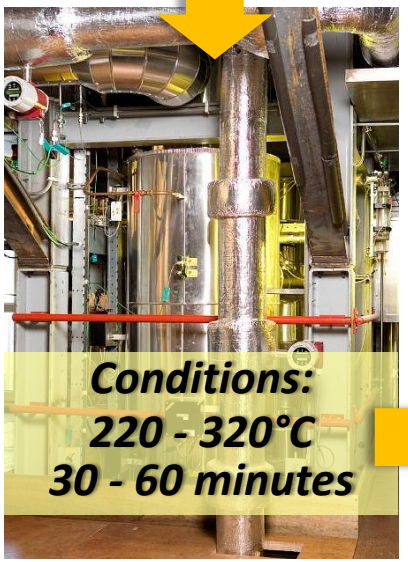


ECN 50 kg/h torrefaction pilot plant
(Since February 2008)

Torrefaction

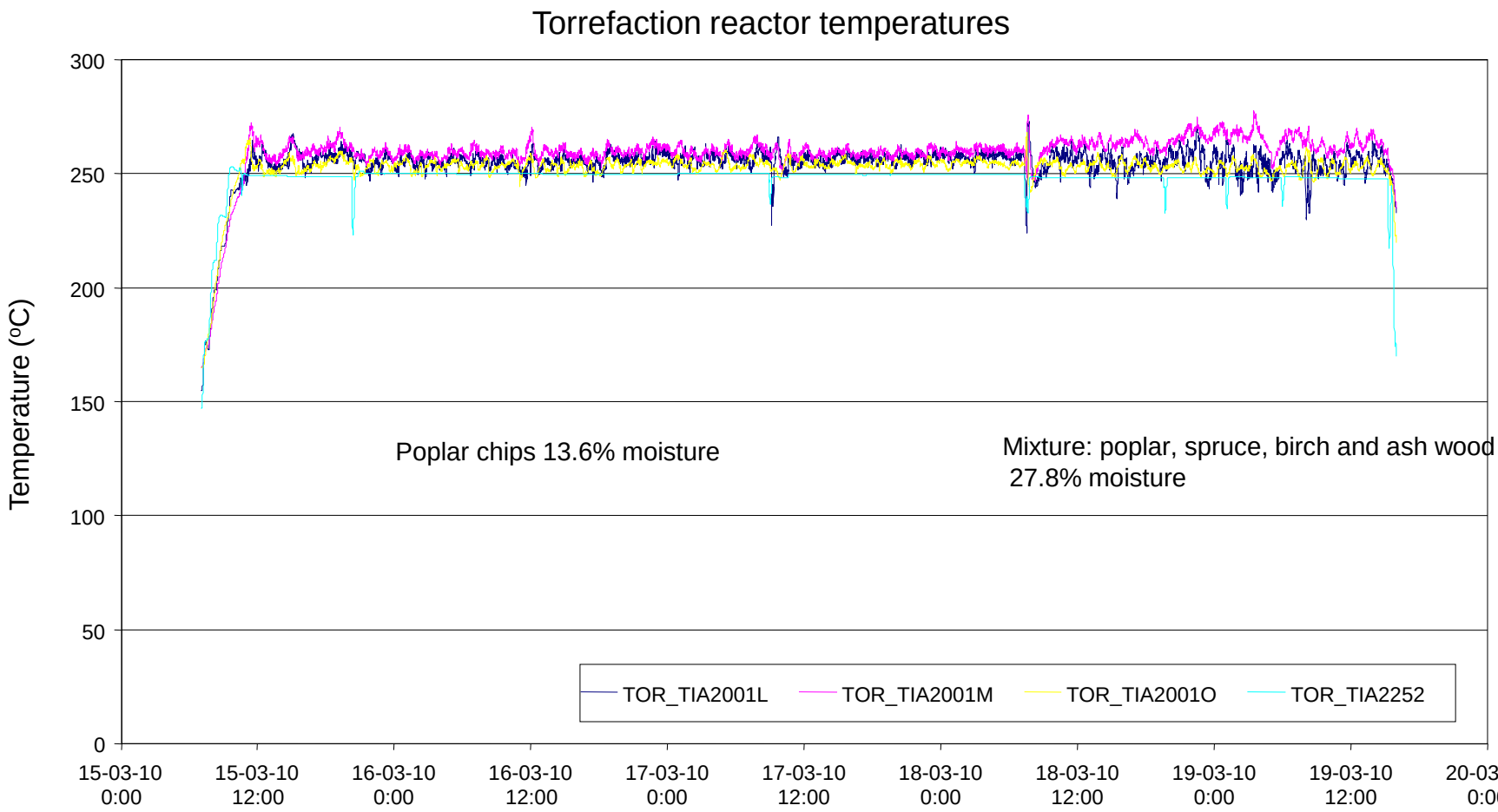
ECN pilot-scale testing





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

Andritz-ECN Demo Plant
(March 2012)

ECN and Andritz

- ECN and Andritz signed a cooperation agreement relative to the development of torrefaction technology in mid-2011
- As part of the agreement, 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

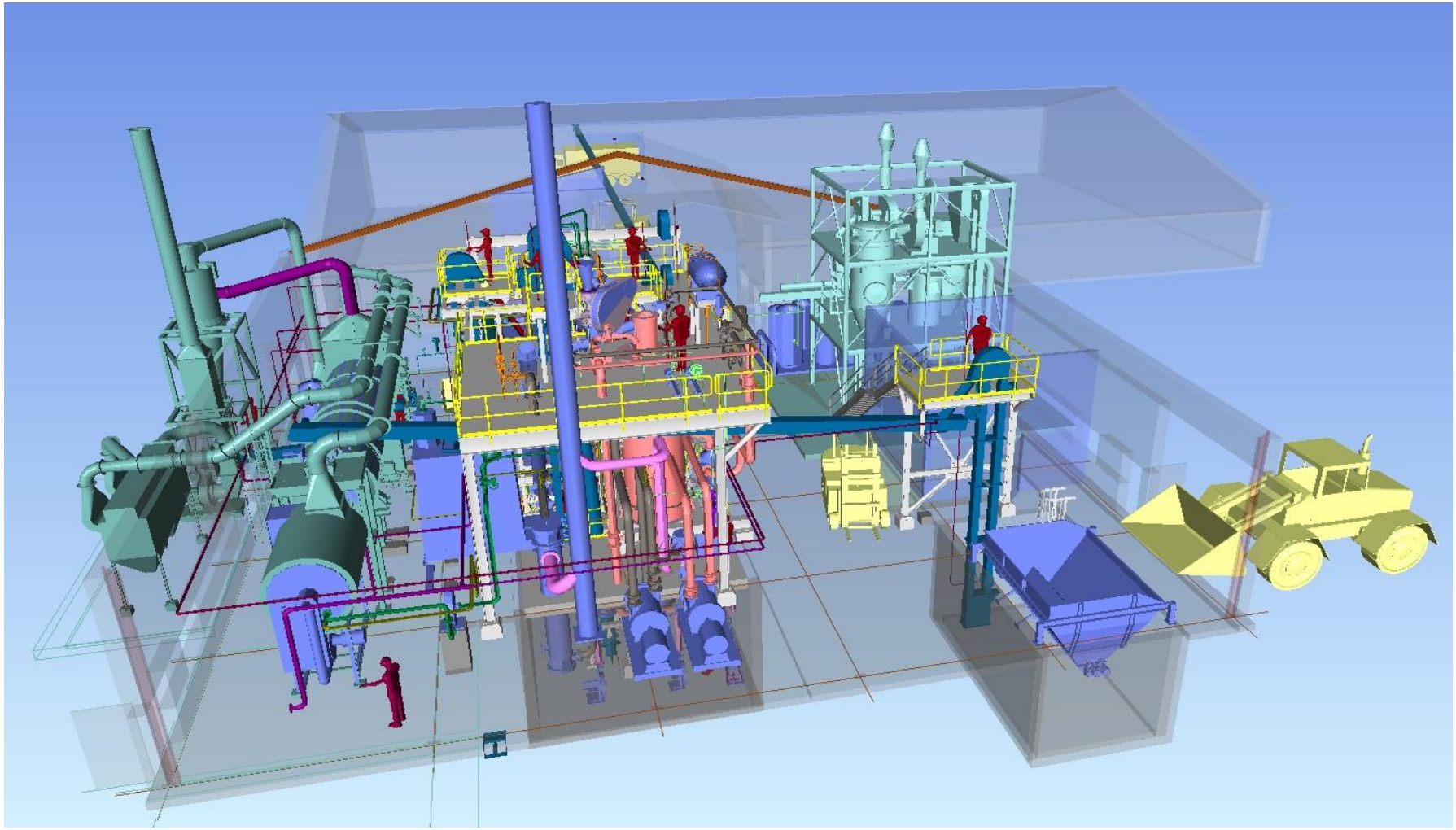
Torrefaction demo plant

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 will begin during May 2012
- 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:

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For more information, please contact:

Jaap Kiel
Programme Development Manager
Biomass & Energy Efficiency

T +31 88 515 45 90
F +31 88 515 84 88
kiel@ecn.nl

P.O. Box 1, 1755 ZG PETTEN
The Netherlands
www.ecn.nl

Production at ECN of tonne-scale test batches for industrial trials