Torrefaction Quality Control

Based on logistic & end-user requirements

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Abstract

Torrefaction is a promising key technology for boosting large-scale implementation of bioenergy. It involves the heating of biomass in the absence of oxygen to a temperature of 200 to 300 °C. As a result, the biomass becomes easy to grind and water resistant, which reduces risks of spontaneous biological degradation and heating and permits outdoor storage. By combining torrefaction with pelletisation or briquetting, biomass is converted into a high-energy-density commodity solid fuel with superior properties in view of (long-distance) transport, handling and storage, and also in many major end-use applications (e.g., co-firing in coal-fired power stations, gasification-based biofuels production and production of bio-based chemicals).

ECN is executing an extensive research and development program in which the most important aspects of torrefaction and pelletisation upstream as well as logistics and end-use downstream are investigated. ECN's torrefaction technology is now proven on bench-, lab- and pilot scale, with the 50-100 kg/hr pilot scale plant producing tonnes of torrefied material already used in specific semi-industrial milling and pelletisation trials. Furthermore, quality analysis are being performed in relation to logistics, on-site transport and handling, and end-use application of the torrefied wood pellets (i.e. co-firing in existing combustion and gasification plants).

In the presentation, the results of torrefaction tests with different types of biomass (deciduous, herbaceous and coniferous) are outlined, including the consequences for logistics and end-use application. Furthermore, an update is be provided on the scale-up and demonstration of the ECN torrefaction technology, for which ECN has teamed up with a leading European energy company as well as a worldwide operating technology supplier to continue to develop its torrefaction technology and bring it to the market.

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Torrefaction Quality Control

based on logistic & end-user requirements

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Content

- ECN and torrefaction
- Lab-scale torrefaction tests
  Different types of wood and waste streams with different shapes
- Production of BO_2 pellets
  The BO_2 technology and the Patrig pilot plant
- Performance and quality control
  Milling and densification behavior, yields, composition
- Conclusions and outlook
  Market acceptance, scale-up & demonstration of technology

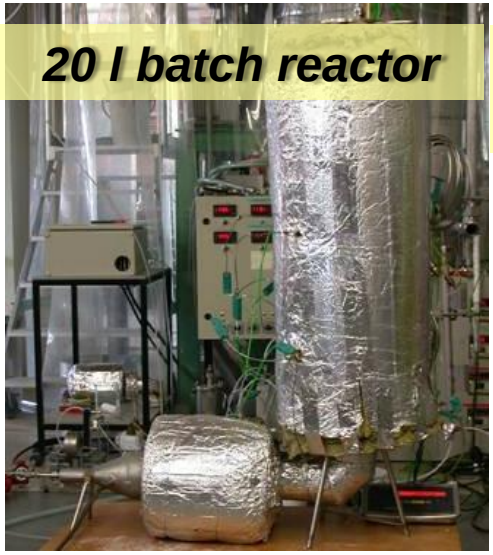
ECN and torrefaction

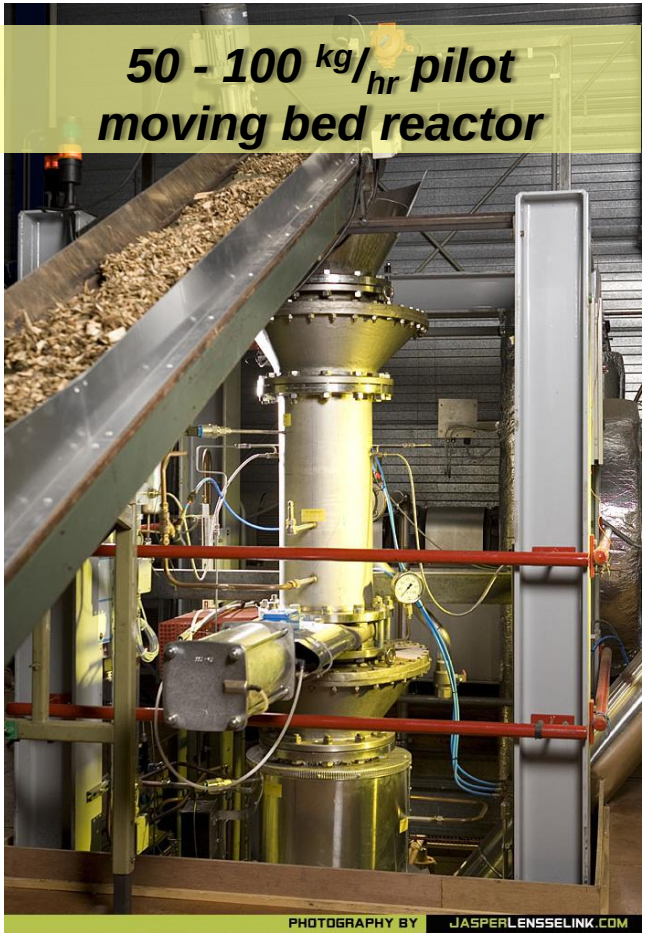
Frontrunner in torrefaction

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

ECN and torrefaction

Torrefaction reactors

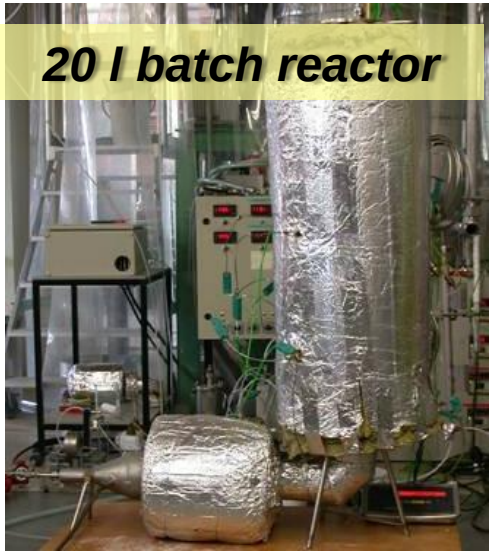




- Main product groups:
  solids, permanent gases, organics, lipids, water
- Permanent gases:
  CO, CO_2, CH_4, C_xH_y, …
- Organics:
  acetic acid, methanol, furaldehyde, hydroxyaceton, hydroxybutanon, phenol, formic acid, propionic acid, …

Lab-scale torrefaction tests

Torrefaction behavior of a variety of biomass streams



BAGASSE

Raw

~250°C/~30 min

~280°C/~30 min

GRASS SEED HAY

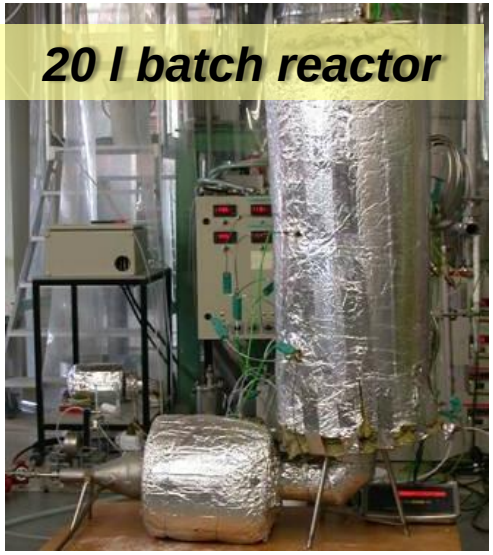
Raw

~250°C/~30 min

~280°C/~30 min

Lab-scale torrefaction tests

Torrefaction behavior of a variety of biomass streams



ROAD SIDE GRASS

Raw

~255°C/~30 min

~295°C/~30 min

STRAW

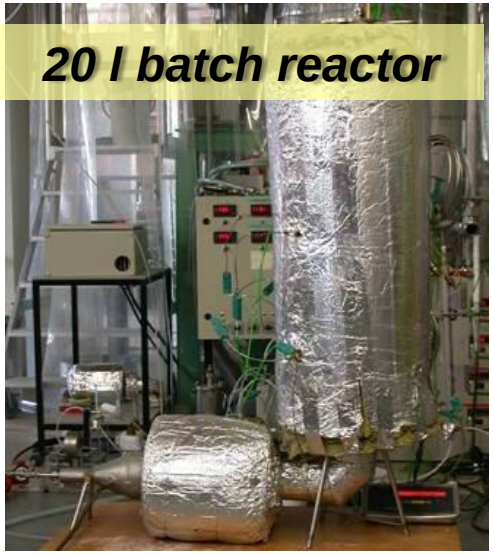
Raw

~260°C/~30 min

~270°C/~30 min

Lab-scale torrefaction tests

Torrefaction behavior of a variety of biomass streams



PINE

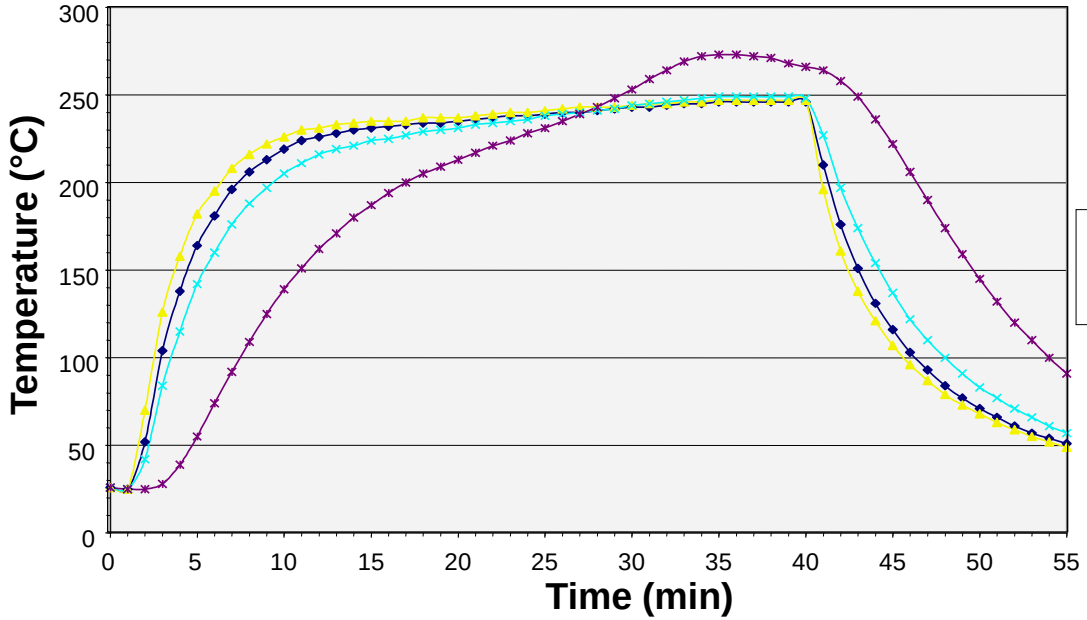
Raw	*~275°C/~30 min*	*Raw*	*~320°C/~30 min*

SPRUCE

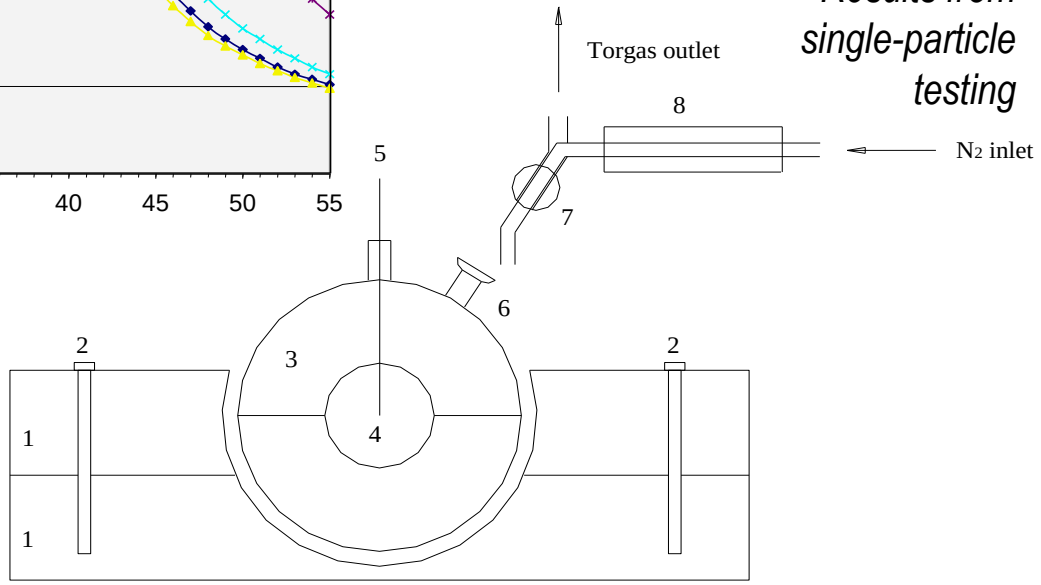
Raw	*~285°C/~30 min*	*Raw*	*~290°C/~30 min*

Lab-scale torrefaction tests

Torrefaction reactions overall exothermal



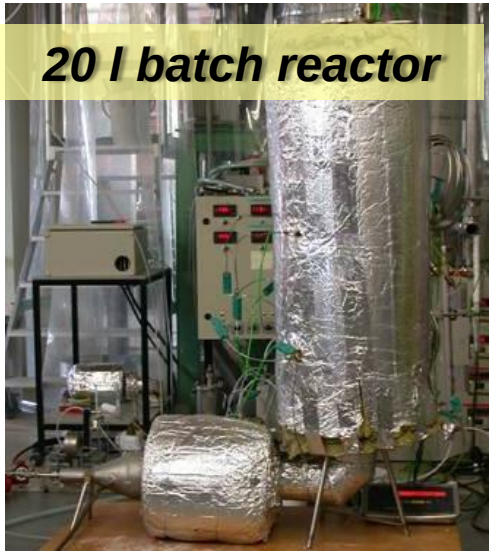
Results from single-particle testing



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

Lab-scale torrefaction tests

Torrefaction behavior of a variety of waste streams



REFUSE DERIVED FUEL (RDF)

Raw

~245°C/~30 min

~265°C/~30 min

DRY STABILATE

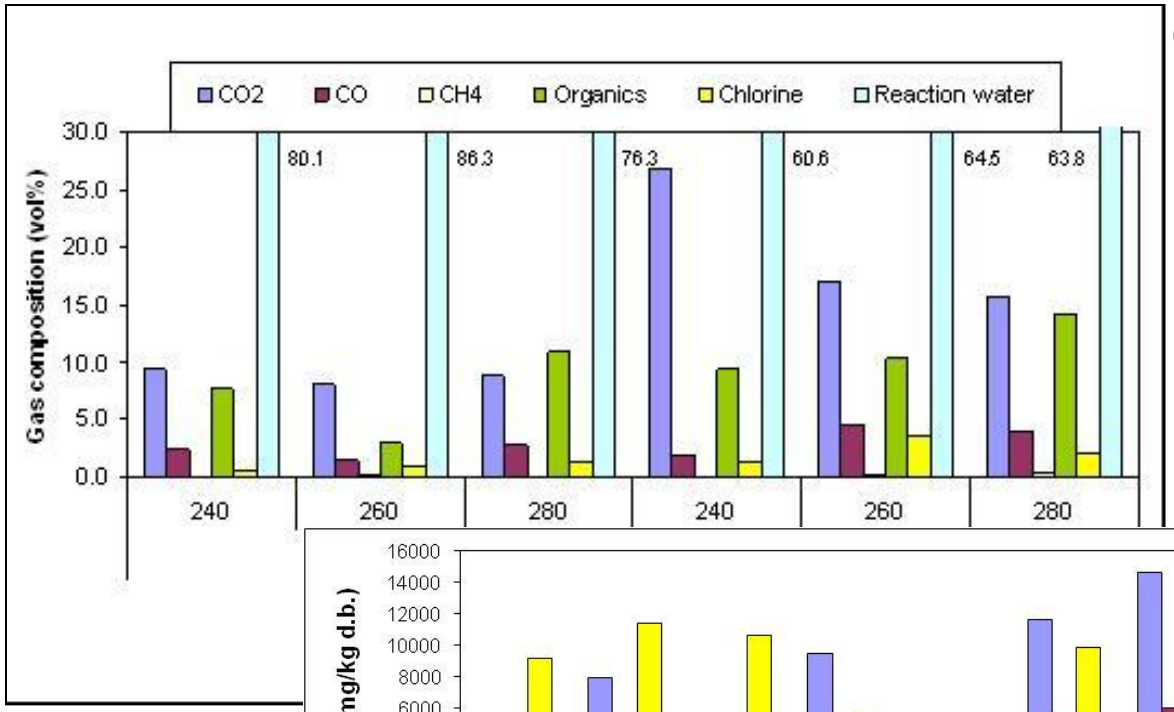
Raw

~250°C/~30 min

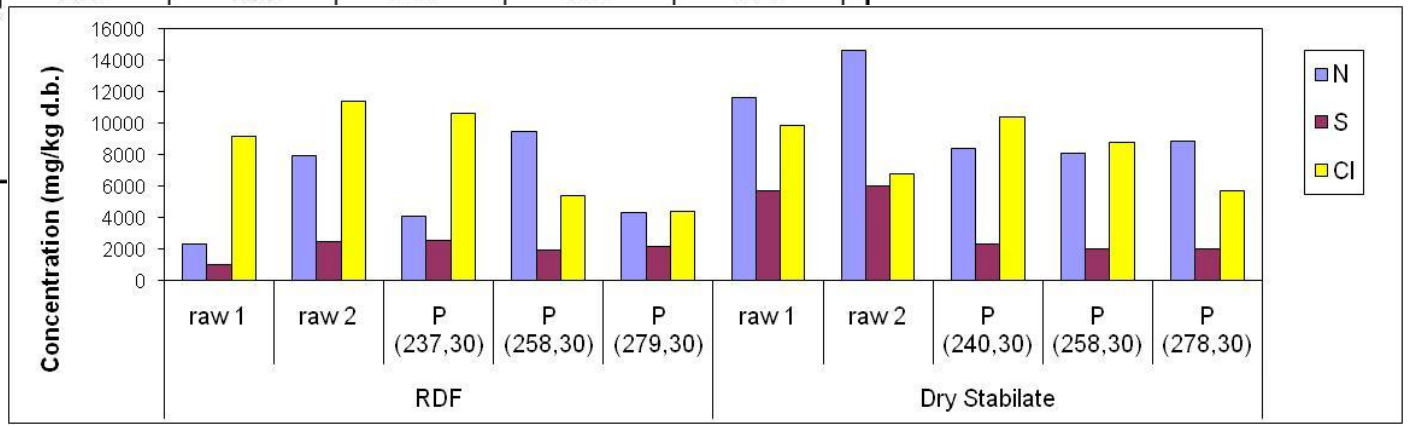
Lab-scale torrefaction tests

Devolatilization of chlorine compounts

GAS COMPOSITION

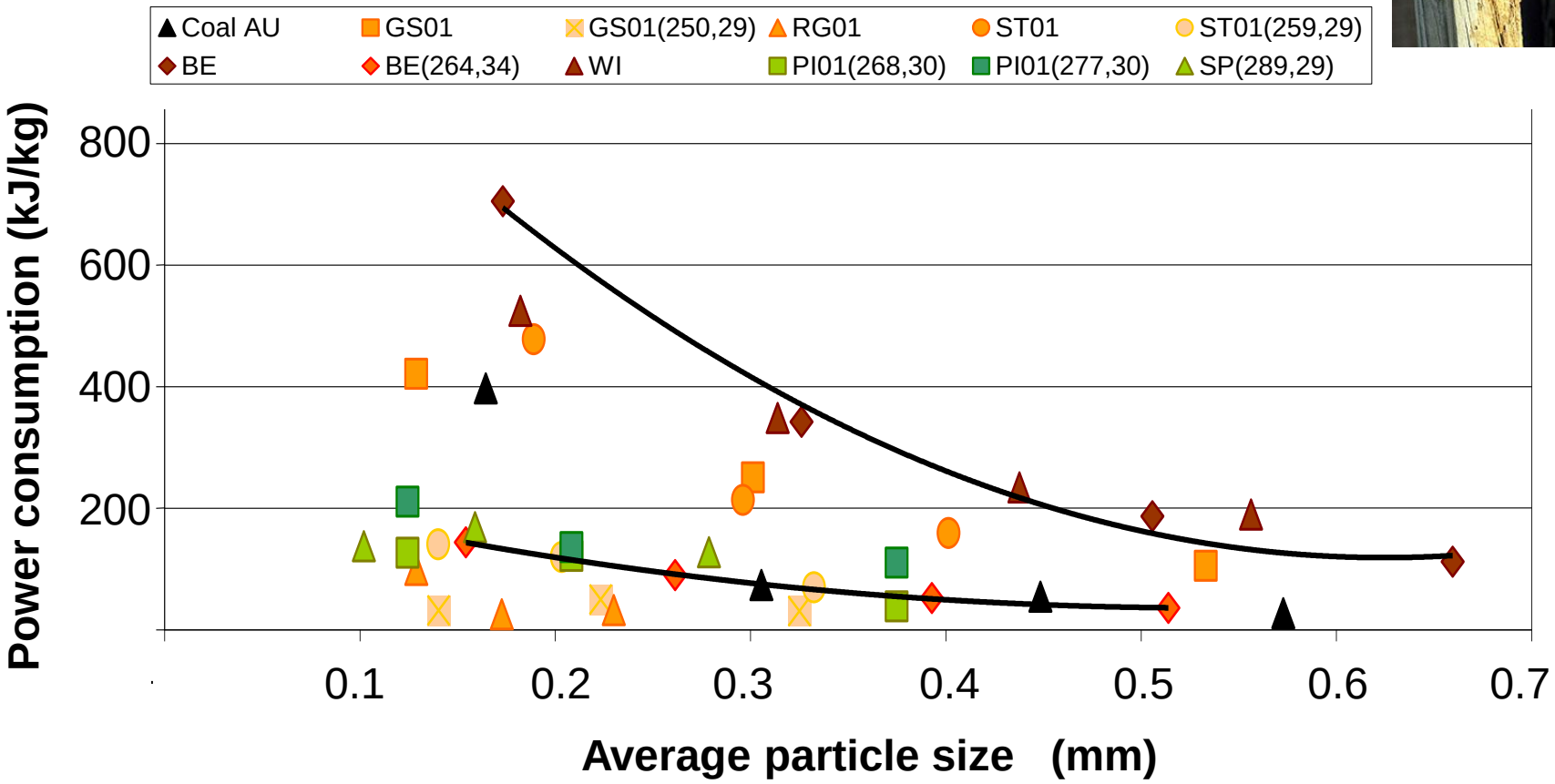


SOLID COMPOSITION



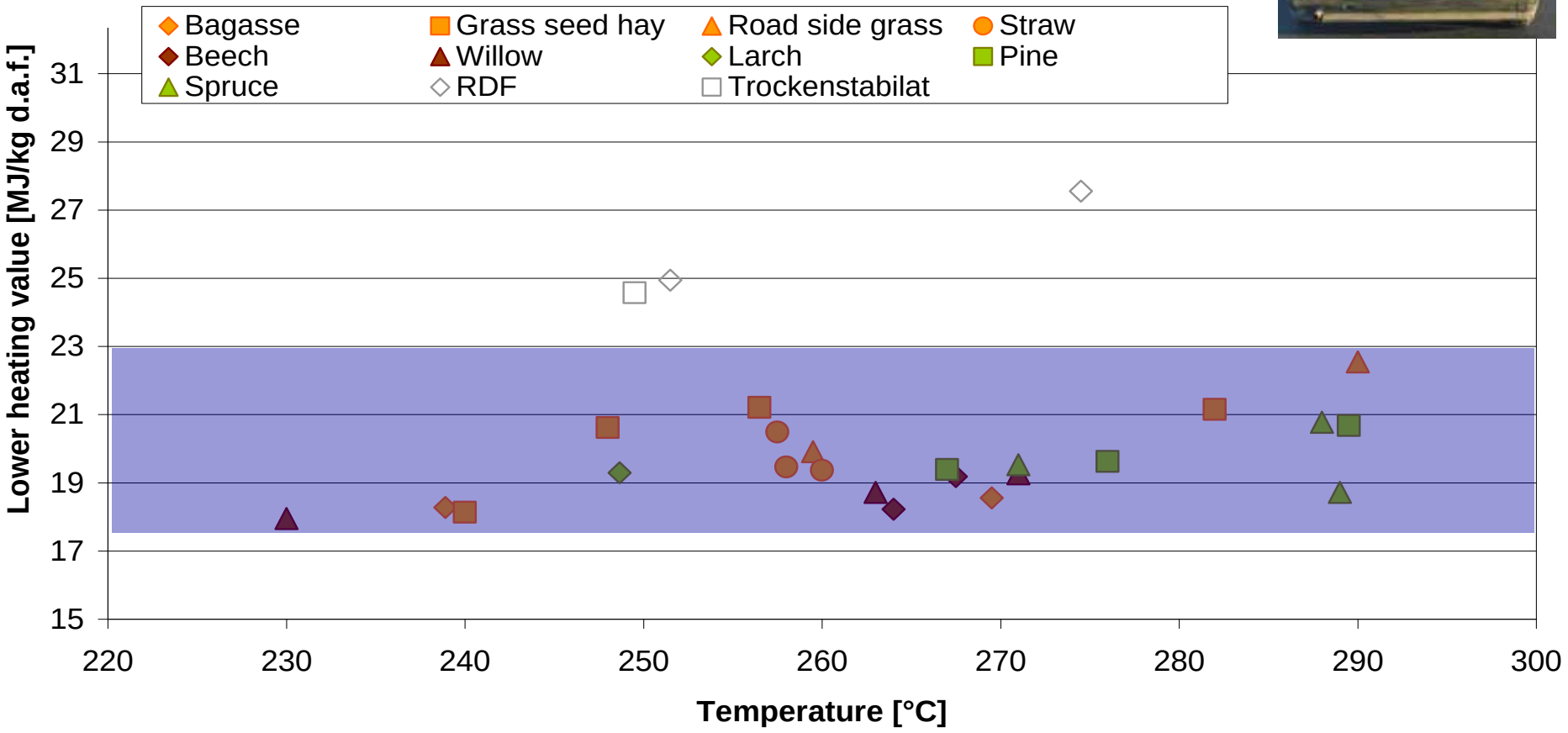
Lab-scale torrefaction tests

Grindability of a variety of torrefied biomass streams



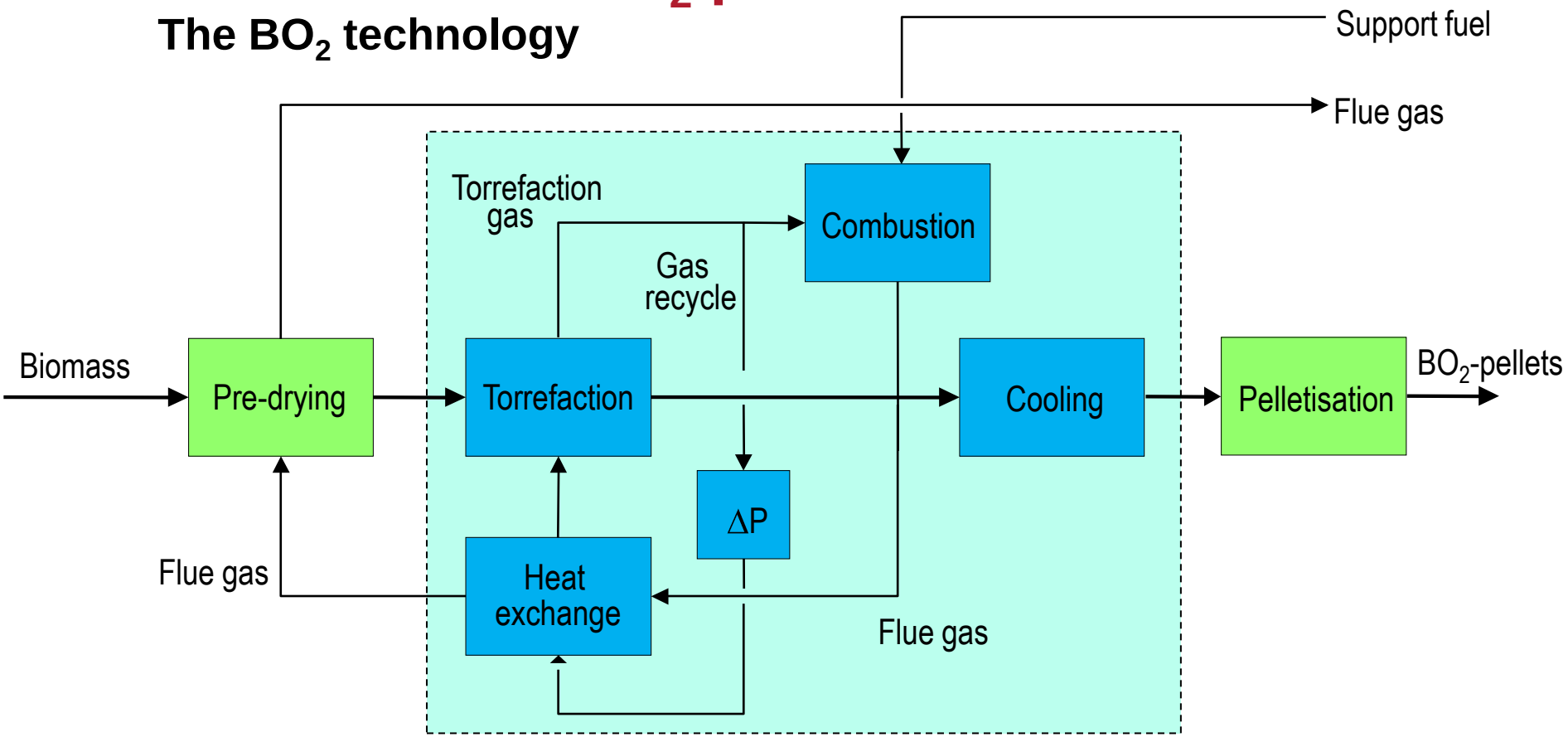
Lab-scale torrefaction tests

LHV of a variety of torrefied biomass streams



Production of BO_2 pellets

The BO_2 technology



Features conventional drying and pelletisation combined with dedicated moving bed technology with direct heating

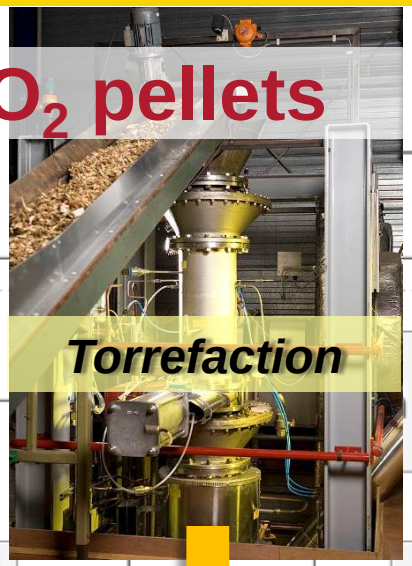
High energy efficiency (> 90%) / Cost effective / IP is patent protected

Production of BO_2 pellets

Patrig pilot plant

50 - 100 $^{kg}/_{hr}$ feeding

Pre-drying



Torrefaction

Conditions:

220 - 300°C
30 - 60 minutes

1 - 10 tonne test batches

Pelletisation

Cooling and storage

Torrefaction gas

Torrefaction

Heat exchange

Cooling

Fl gas

s

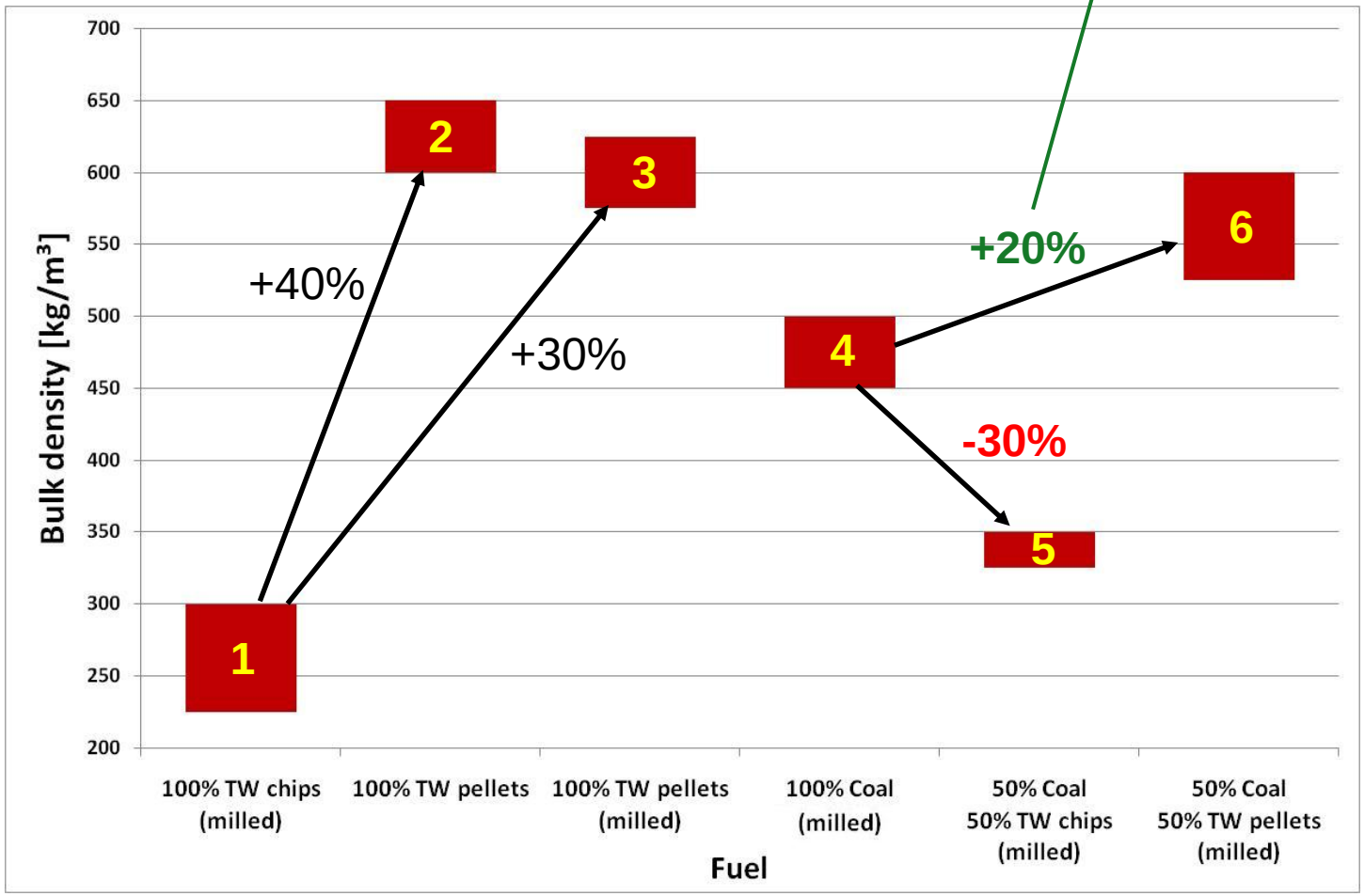
Performance and quality control

Torrefied biomass pellets in perspective

	Wood chips	Wood pellets	Torrefied wood pellets	Charcoal	Coal
Moisture content (wt%)	30 – 45	7 – 10	1 – 5	1 – 5	10 – 15
Calorific value (LHV, MJ/kg)	9 – 12	15 – 17	18 – 24	30 – 32	23 – 28
Volatile matter (wt% db)	70 – 75	70 – 75	55 – 65	10 – 12	15 – 30
Fixed carbon (wt% db)	20 – 25	20 – 25	22 – 35	85 – 87	50 – 55
Bulk density (kg/l)	0.20 – 0.25	0.55 – 0.65	0.65 – 0.80	0.18 – 0.24	0.80 – 0.85
Vol. energy density (GJ/m^3)	4.5 – 6.0	8 – 11	15 – 19	6.0 – 6.4	18 – 24
Hygroscopic properties	Hydrophilic	Hydrophilic	Moderately Hydrophobic	Hydrophobic	Hydrophobic
Biological degradation	Fast	Fast	Slow	None	None
Milling requirements	Special	Special	Standard	Standard	Standard
Product consistency	Limited	High	High	High	High
Transport cost	High	Medium	Low	Medium	Low

Performance and quality control

Bulk density versus heating value



1. Basic Plant Data CHP Reuter West

CHP Reuter West

Gross power output:
2 x 300 MWel (cond.);

Steam data: 540°C; 196 bar
Max 1.000 t/h

Fuel delivery: Barge/train

Mills: 4 mills/unit
Max. 28t/h hard coal

2 Large Scale Unloading Tests (2.400 t):
Unloading and transfer to conveyor

Unloading with water dispersion system in operation (top view)

Transfer point from ship unloader to conveyor belt with water dispersion system in operation

The dust suppression system resulted in minimal/irrelevant dust formation.

→ Conclusion:

Unloading of tested Black Pellets is possible with existing system, given minor adaptations in dust suppression systems and in the unloader grabs

2 Conveying

Airborne dust measurements within at a.) converyor belt and b) transfer point at tower

- No critical/explosive airborne dust concentrations
- Total dustfall was at some points higher than in coal operation
- Some pellets slipped through the rubber fittings at the transfer points

→ Conclusion:

Conveying is possible with coal conveyors, given minor adaptions in the dust absorbtion system, fittings and optionally mesh grids on the pathways

2 Storage at Reuter West hard coal yard

Stacker/Reclaimer in operation

Pellet pile from top of stacker/reclaimer

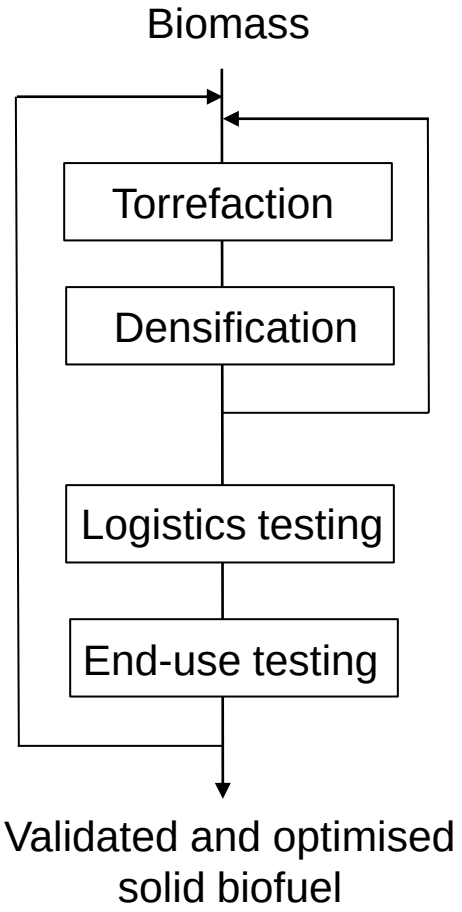
- Laboratory analysis resulted in high COD values of the leaching water, so that a ground insulation was installed

- From May – July, 4.318 t were stored and tested at Reuter West hard coal yard.

Conclusions and outlook

Product quality optimization

- Pilot, demo and 1st commercial plants produce kg to tonne scale batches allowing representative logistics & end-use performance testing by industry
- Many coal-fired power plants want to be early adaptors and perform successful co-firing trials (*e.g.* RWE, Vattenfall, CEATI consortium)
- Product quality optimisation requires a systematic iterative approach (2 iterative loops)
- For this purpose, European torrefaction developers, combustion and gasification technology providers and end-users have joined forces in the EU-FP7 project SECTOR



SECTOR

Conclusions and outlook

Scale-up & demonstration torrefaction technology

- **Vattenfall supports ECN in upscaling torrefaction technology**

  The Energy research Centre of the Netherlands (ECN) and Vattenfall in June 2010 agreed on a partnership for upscaling ECN's BO_2 technology. This marked an important step towards the commercial application of ECN's BO_2 technology for upgrading biomass into high-quality solid fuel.

- **ECN closes deal with Andritz OY**

  The Energy research Centre of the Netherlands (ECN) and Andritz OY in June 2011 agreed on a partnership for developing and commercialising torrefaction technology. Andritz has acquired the exclusive right to use the patents and knowledge of the ECN torrefaction technology. ECN will also provide Andritz with technical support, starting with the joint development of a demonstration plant.

More information

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