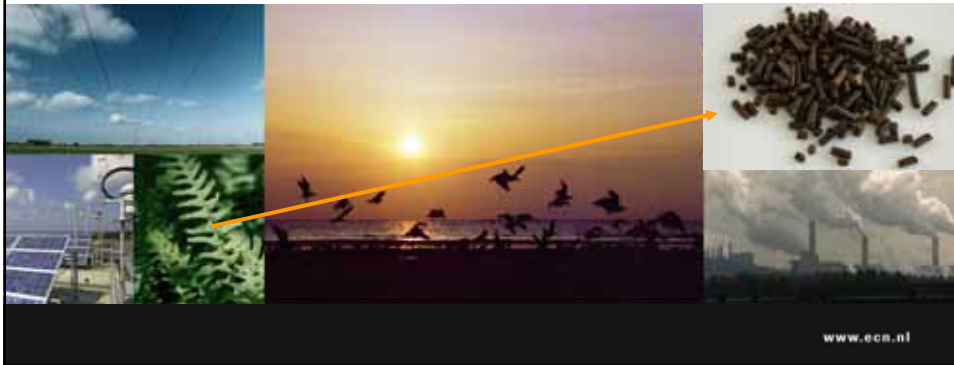


**ECN BO<sub>2</sub>-technology for biomass upgrading**

Jaap Kiel

BUS final meeting, Wageningen, 20 November 2007

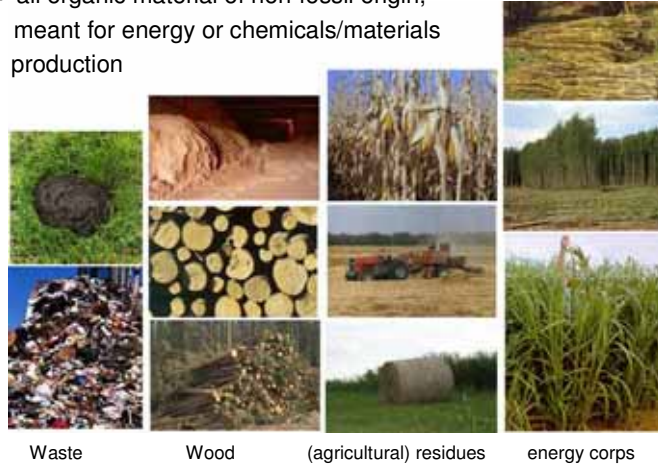
**Presentation overview**

- Torrefaction principles
- ECN BO<sub>2</sub>-technology
- Economics
- Development status and market implementation



## Biomass – a diverse energy source

- Biomass = all organic material of non-fossil origin, meant for energy or chemicals/materials production



Waste

Wood

(agricultural) residues

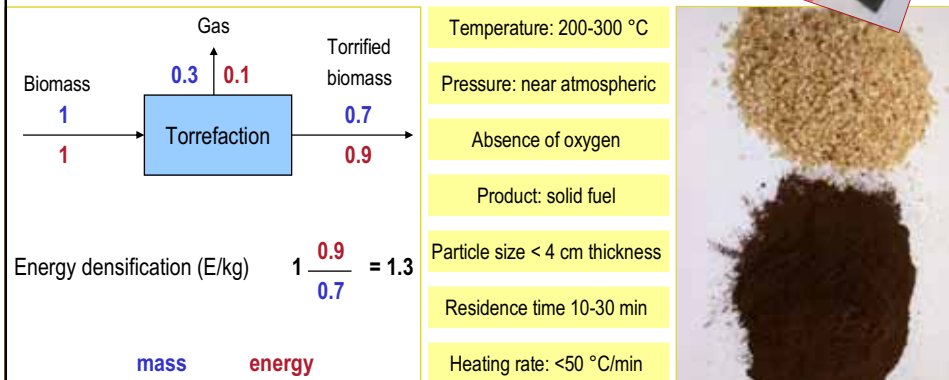
energy crops

## Biomass is a difficult energy source

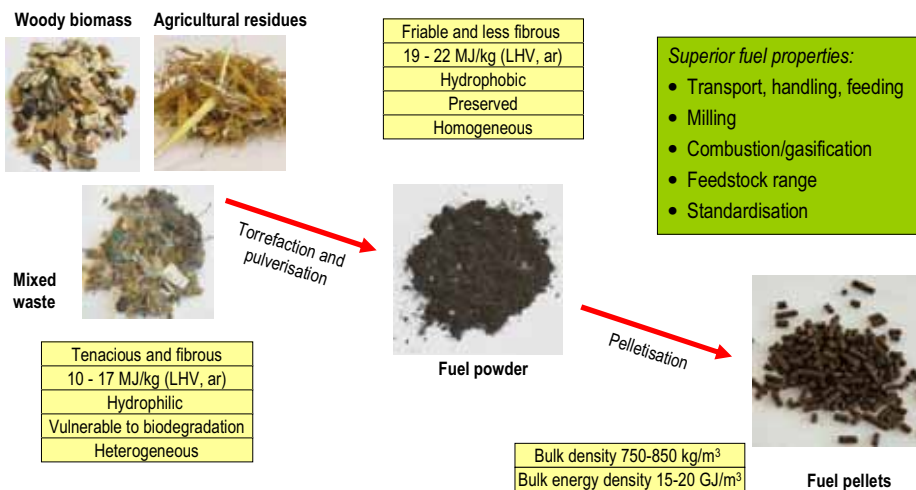
- Production
- Harvesting, collection
- Handling
- Transport
- Storage
- Pre-treatment (e.g., milling)
- Feeding
- Conversion



## Torrefaction for biomass upgrading general process description



## From biomass/waste to commodity fuels



## Starting points ECN BO<sub>2</sub>-technology development (1)

- Torrefaction (combined with pelletisation) has the potential of becoming a *key unit operation* in biomass upgrading schemes for a wide range of applications, including:
  - Biomass storage and (long-distance) transport – biomass import
  - Co-firing in pf boilers
  - (Co-)firing in entrained-flow gasifiers for producing power (IGCC) or transportation fuels (e.g., Fischer-Tropsch diesel)
  - Small-scale pellet boilers and stoves

⇒ Torrefied biomass pellets may become a biomass commodity fuel

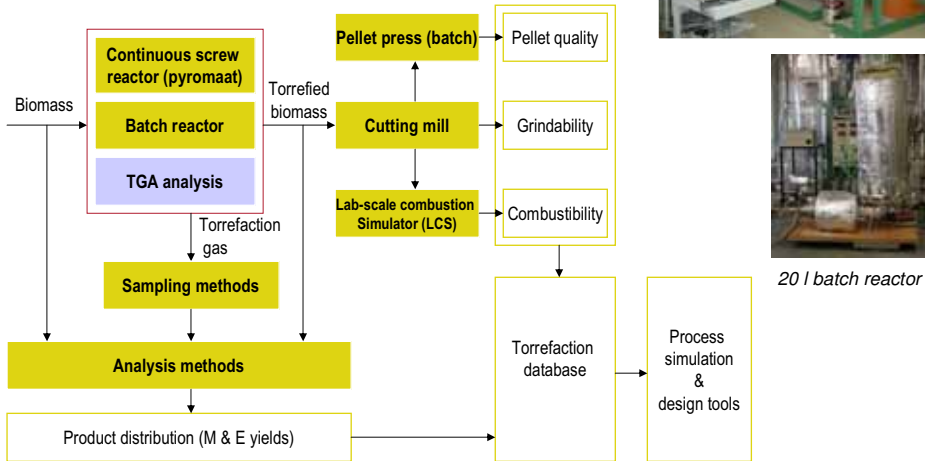
## Starting points ECN BO<sub>2</sub>-technology development (2)

- Torrefaction principle not new, but many aspects relevant to application for upgrading biomass into biomass fuel for thermal conversion processes were not addressed, including:
  - Scale of operation in relation to reactor technology and process layout
  - Characterisation and quantification of product quality and how this relates to process conditions
  - Nature and quantity of emissions
  - Prospects of heat integration including utilisation of the energy containing torrefaction gases
  - The economic viability of torrefaction as a biomass upgrading technique for bulk applications

⇒ 2002 start ECN BO<sub>2</sub>-technology development

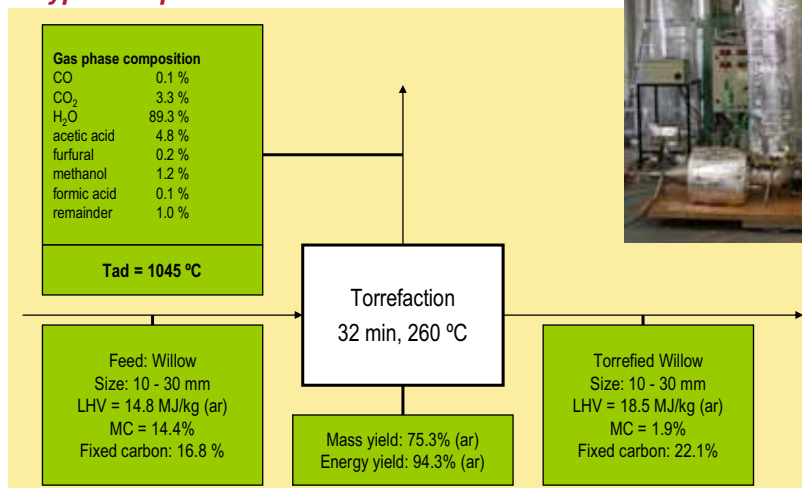
## Proof-of-concept approach

5 kg/h screw reactor

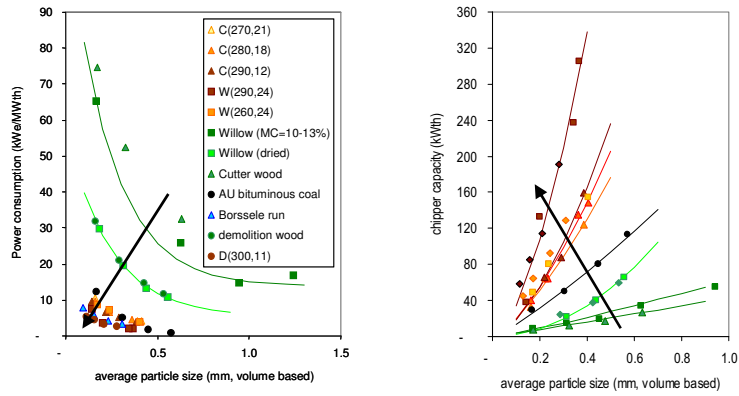


20 l batch reactor

## Torrefaction Typical experimental results

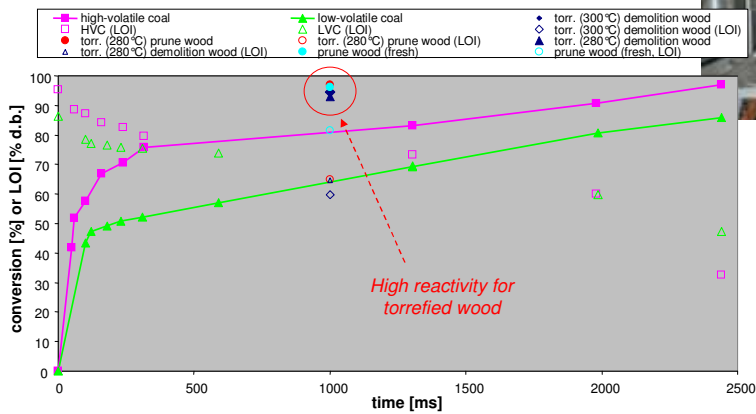
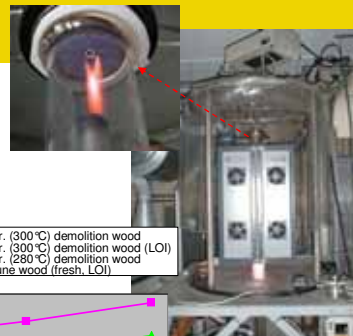


## Grindability of (torrefied) biomass



*Torrefaction leads to a dramatic decrease in required milling power and increase in milling capacity*

## Combustion reactivity of torrefied wood Lab-scale Combustion Simulator experiments



## Semi-industrial pelletisation tests



Features:

- 10 kg/h
- No automatic moisture supply



- Preliminary findings:
  - Easy pelletisation
  - Low energy input required
  - Pellet quality strongly dependent on pelletisation conditions

## BO<sub>2</sub>pellets – features

- High energy density (15-20 GJ/m<sup>3</sup>, >3x biomass, 1.5-2x wood pellets)
- Water resistant (no swelling or disintegration)
- No/less biological degradation and heating
- Excellent grindability (similar to coal)
- Good combustion and gasification properties

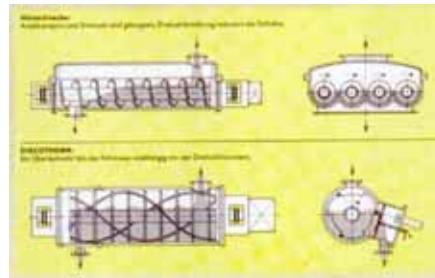
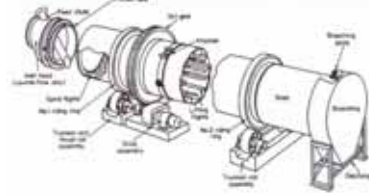
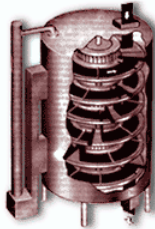
*But how to produce them with a high energy efficiency and at low cost ?*



## Pre-existing “torrefaction technology”

**Features:**

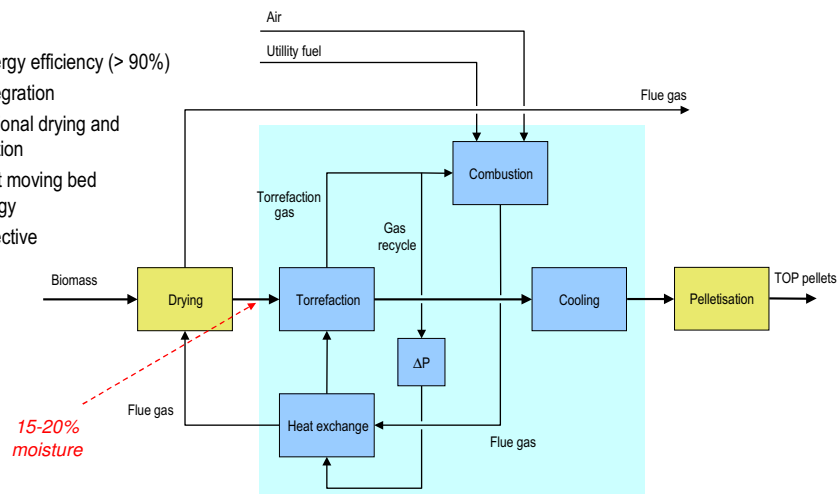
- Derived from cooling or pyrolysis technology
- Not fuel flexible / robust
- Limited scale-up
- High investment cost
- Difficult control of process parameters



## ECN directly heated torrefaction technology

**Features:**

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

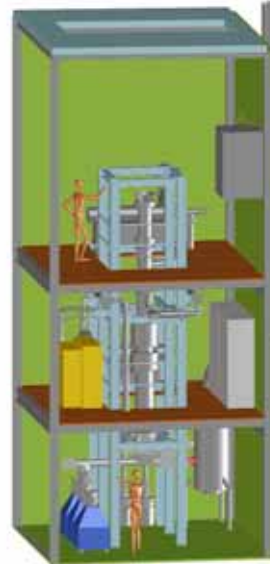




## ECN torrefaction technology

*Innovative moving bed reactor*

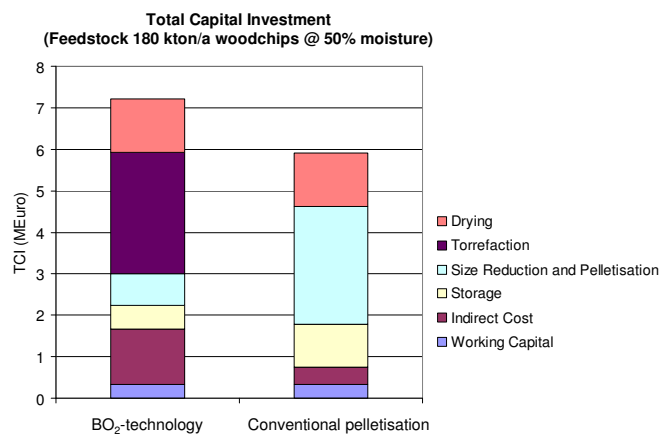
- Compact reactor
- Small footprint
- High heat transfer rates
- Accurate T-control
- Uniform product quality
- Feedstock flexibility
- Low capital investment



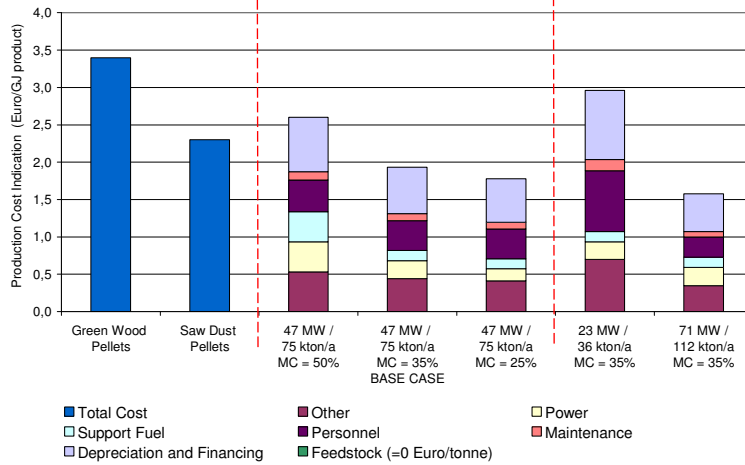
*Pilot-scale torrefaction reactor at ECN*

## Total capital investment – study estimate

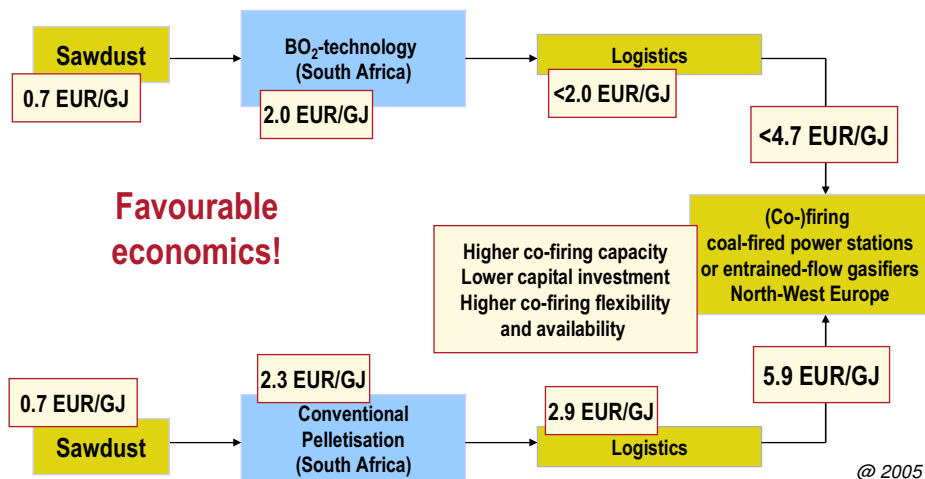
*(BO<sub>2</sub>pellets vs. wood pellets)*



## Total production cost – study estimate ( $BO_2$ pellets vs. wood pellets)



## Chain study ( $BO_2$ pellets vs. wood pellets)



## ECN BO<sub>2</sub>-technology – market potential

..... some figures

- EU-27: coal-fired plants with 10% co-firing requires 70 Mton/a dry biomass  
≅ 700 BO<sub>2</sub>-plants with plant-size 100 kton/a
- EU-15: 43 Mton/a dry biomass (agro-residues) available for energy purposes;  
substantial possible role of BO<sub>2</sub>-technology to increase efficiency and reduce  
cost of overall biomass-to-energy chain
- Current world-wide wood pellet production approx. 7.5 Mton/a, expected to  
increase rapidly in coming 5-10 years to tens of millions of tons, mostly coarse  
shavings and green wood. Thus good prospects for BO<sub>2</sub>-technology.
- EU-27: 10% biofuels in 2010, ≅ 1300 PJ/a, corresponding to approx. 110 Mton/a  
dry biomass (@ 60% conversion efficiency). BO<sub>2</sub>-technology is an enabling  
technology for HT gasification-based BTL.

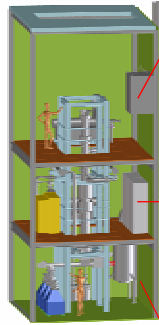
## ECN BO<sub>2</sub>-technology – status

- Pilot-scale testing (PATRIG) ongoing
  - Validation of reactor and process concept
  - Optimisation of process conditions for a broad feedstock range (woody biomass, agro-residues)
  - Industrial pelletisation tests
  - Extensive quality evaluation BO<sub>2</sub>pellets  
(e.g., hygroscopic nature, biodegradation, strength, milling characteristics, combustion/gasification reactivity)
- IP in BO<sub>2</sub> Energy concepts bv
- Industrial partnership established aimed at demonstration and market introduction
- Continued basic R&D (in co-operation with institutes/universities)
  - E.g., contaminated biomass (residues) and waste

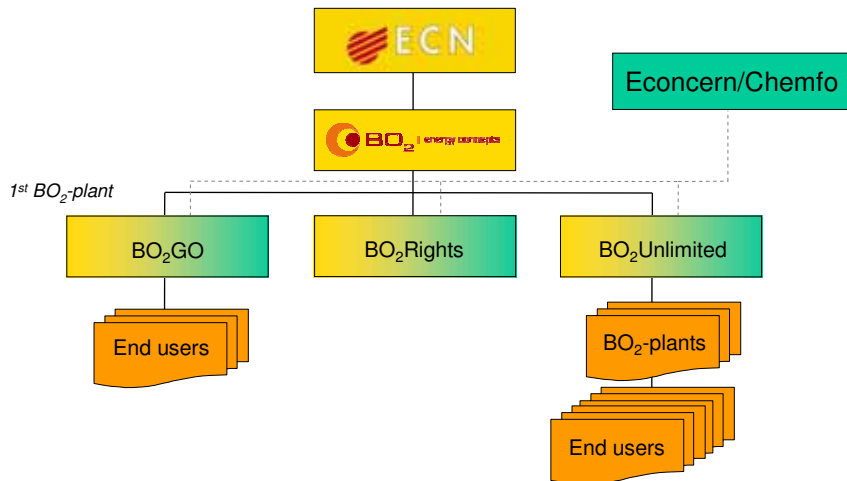


### PATRIG torrefaction pilot-plant Status November 2007

- Construction and commissioning (nearly) completed
- Biomass supply and pre-treatment arranged



### ECN BO<sub>2</sub>-technology market introduction



## ECN BO<sub>2</sub>-technology market introduction

- Partnership ECN – Econcert – Chemfo
- Design and construction 1<sup>st</sup> production plant BO<sub>2</sub>GO, scheduled for operation in 2009
- Start-up of BO<sub>2</sub>Unlimited for supply of commercial BO<sub>2</sub>-plants
  - add-on to wood pellet plants
  - residues food & feed sector
  - agricultural residues



## In conclusion

- ECN BO<sub>2</sub>-technology allows cost-effective production of commodity fuels from a wide range of biomass/waste feedstock with a high energy efficiency (>90%)
- 2<sup>nd</sup> generation BO<sub>2</sub>pellets show:
  - High energy density
  - High water resistance
  - No/Limited biological degradation
  - Excellent grindability
  - Good combustion and gasification properties
- Fields of application:
  - Long distance biomass transport
  - Co-firing in pf boilers
  - (Co-)firing in entrained-flow gasifiers
  - Small-scale pellet boilers/stoves
- Pilot-plant testing started, industrial partnership for 1<sup>st</sup> plant and commercialisation, strong market pull for BO<sub>2</sub>-plants and BO<sub>2</sub>pellets



**Thank you for your attention.....**

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**and I will be happy to answer your questions!**