SECTOR - Production of Solid Sustainable Energy Carriers from Biomass by Means of Torrefaction

Euroheat & Power 2012 Annual Conference, Copenhagen

26th of April 2012

The research leading to these results has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 282826.

Agenda

- Background & Drivers
- Introduction to Torrefaction & History
- Fuel Properties & Characterisation
- Handling & Logistics
- Torrefaction Roadmap
- SECTOR- Project
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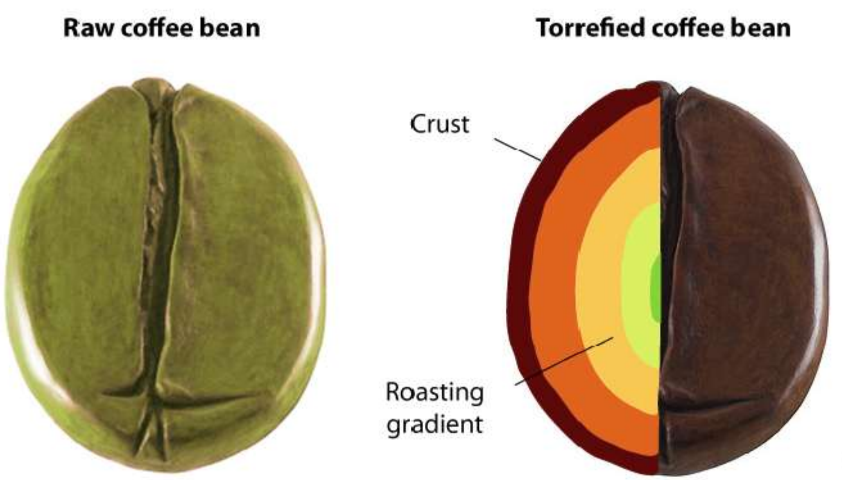
  - Objectives
  - Structure
  - Torrefaction Concepts
- Summary

Background & Drivers

- Market development of torrefaction is driven by renewable energy targets
- EU targets till 2020:
  - 20% renewables of the total primary energy consumption
  - 10% biofuels in transport sector
- Torrefied products can be applied in different market segments from medium scale to large scale applications
- Cofiring in coal power plants especially attractive due to:
  - already existing market volume
  - comparable fuel properties
  - expected cost savings (price, subsidies, CO_2-certificate savings)
- 5-10% biomass cofiring is possible without major technical adaptations but to reach the political targets up to 50% biomass cofiring is needed
- According to IEA coal contributes with more than 40% to the world electricity production →10% cofiring in 10% of all coal power plants worldwide requires 33 Mio. t (torrefied) biomass!

What is Torrefaction?

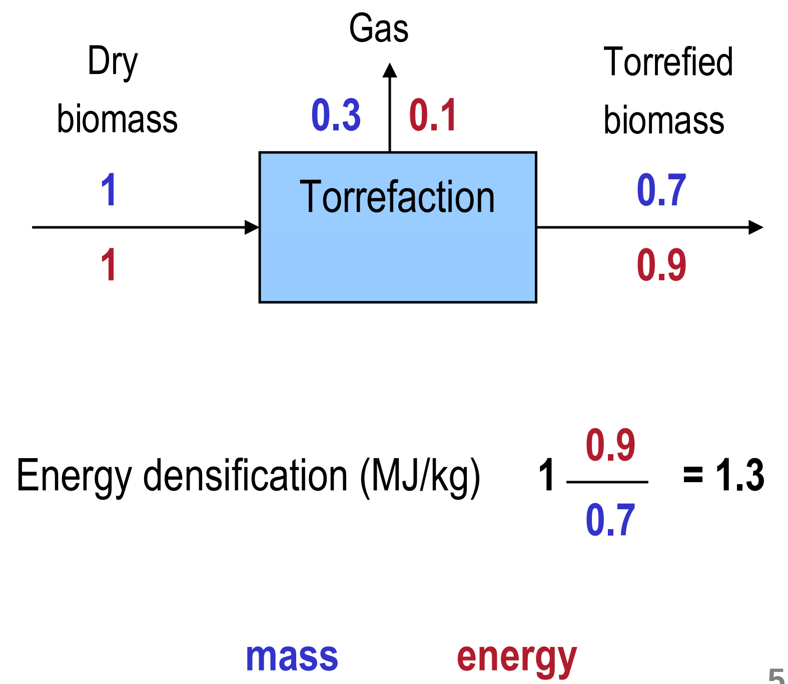
- The **classical torrefaction process** was developed for coffee beans in the 18th century and was described with the following process conditions, e.g.:
  - It's a hot air soft thermal treatment / toasting at temperatures around 250 °C
  - Short residence time (10 to 20 minutes) to produce a heating / roasting gradient:



source: Thermya

What means Biomass Torrefaction ?

- The technical process is still in development and more than one definition tries to describe it, for example:
  - ...a dry, fat-free heating of plants (foodstuff) up to 300°C - extension for biofuels: in the absence of oxygen
  - ... a mild form of pyrolysis at temperatures typically ranging between 200-320°C
  - ... thermal upgrading process of solid biofuels
  - ... controlled carbonisation of biomass
  - ... destruction of hemicellulose, depolymerisation of cellulose and lignin (but it should keep its binding capacity (for pelletisation)) ....



source: ofi, ECN

Indicative fuel properties of woody biomass products

	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





Abbreviations:
db = dry basis
LVH =Lower Heating Value

sources: ECN (table, fig.1, 3), Pixelio (fig. 2, 5), ofi (fig. 4)

Ranking of fuel characterisation by first estimations

	Coal	Wood chips	Wood pellets	Torrefied fuels	
Moisture content					slower biodegradation potential, higher energy density
Energy content					high bulk density supports effective fuel transport
Handling and logistics					reduced water retention force (hydrophobicity); better grindability due to embrittlement; decreased handling, storage and transport costs
CO_2-emissions					renewable feedstock
Extra Investments					investments in torrefaction plant reduce fuel supply costs and investments at the conversion site
Cofiring ratio		10 to 15 %	8 to 15 %	50%	good fuel properties allow higher cofiring ratio

source: ofi (adapted)

Handling and logistics of torrefied material

Advantages

- Increased feedstock basis as option to reduce transport distances
- High energy density of torrefied products ➲ effective transport
- Reduced water retention force (hydrophobicity)
- Slower biodegradation potential
- Better grindability due to embrittlement
- Decreased costs for handling, storage and transport
- Biomass torrefaction can create new markets and trade flows as a commodity fuel (➲ product standards are needed).

Disadvantages / Challenges

- Dust and dirtyness at handling and transport
  - Safety issues must be assessed
  - Self ignition and spontaneous combustion occurs at 150-170°C
- Explosion hazards increase compared to conventional biomass but probably not in comparison with coal
- Compacting (pellets / briquettes) is more difficult
- Additional fuel properties (e.g. degree of torrefaction, grindability, hydrophobic nature, resistance against biodegradation) and sustainability criteria must be defined ➲ ISO work

sources: ECN, ofi, Kleinschmidt, Wild & Partner, Vattenfall

Roadmap Torrefaction and Densification Technology Development

Capacity: 5-10 kg/h · 30-200 kg/h · 20-50 kton/a · 60-200 kton/a

Woody biomass: Proof-of-principle · Proof-of-concept · Prototype (pilot-scale) · Technical demonstration · Commercial role out

Time: 2002 · 2004 · 2006 · 2008 · 2010 · 2012 · 2014 · 2016 · 2018

Non-woody biomass residues: Proof-of-principle · Proof-of-concept · Prototype (pilot-scale) · Technical demonstration · Commercial role out

source: ECN

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Proof-of-concept
- Experimentally based process designs
- Technology identification
- Knowledge base
- Experimental infrastructures torrefaction
- Economic evaluations full-scale (study about 30%)
- Set-up pilot phase of development

Prototype development (pilot-scale evaluation)
- Pilot plants / prototype technology
- Demo technical feasibility
- Process & product characterization (design)
- Economic evaluations full-scale (preliminary ca. 20%)
- Business plan(s) (technical demo, semi-commercial)

Technical demonstration
- Demonstration plants (semi-commercial)
- Technical optimization (refined design)
- Product applications (logistics & end-use)
- Economic evaluations full-scale (definite ca. <10%)
- Business plan(s) (commercial operation)

Commercial role out
- Commercial plants (full-operation)
- Quality control and assurance (product)
- Best practice for sustainability
- Product standardisation
- Purchase agreements (from energy & chemical sector)

Production of Solid Sustainable Energy Carriers from Biomass by means of Torrefaction

- Collaborative project: SECTOR
- Project start: 01.01.2012
- Duration: 42 months
- Total budget: 10 Mio. Euro
- Participants: 21 from 9 EU-countries
- Coordinator: DBFZ

University of Stuttgart Germany
ECN
Danish Technological Institute
Deutsches Biomasseforschungszentrum gemeinnützige GmbH
DBFZ
e.on
SLU Swedish University of Agricultural Sciences
RWE The energy to lead
Vattenfall
ofi
VTT
IEN
Topell Energy
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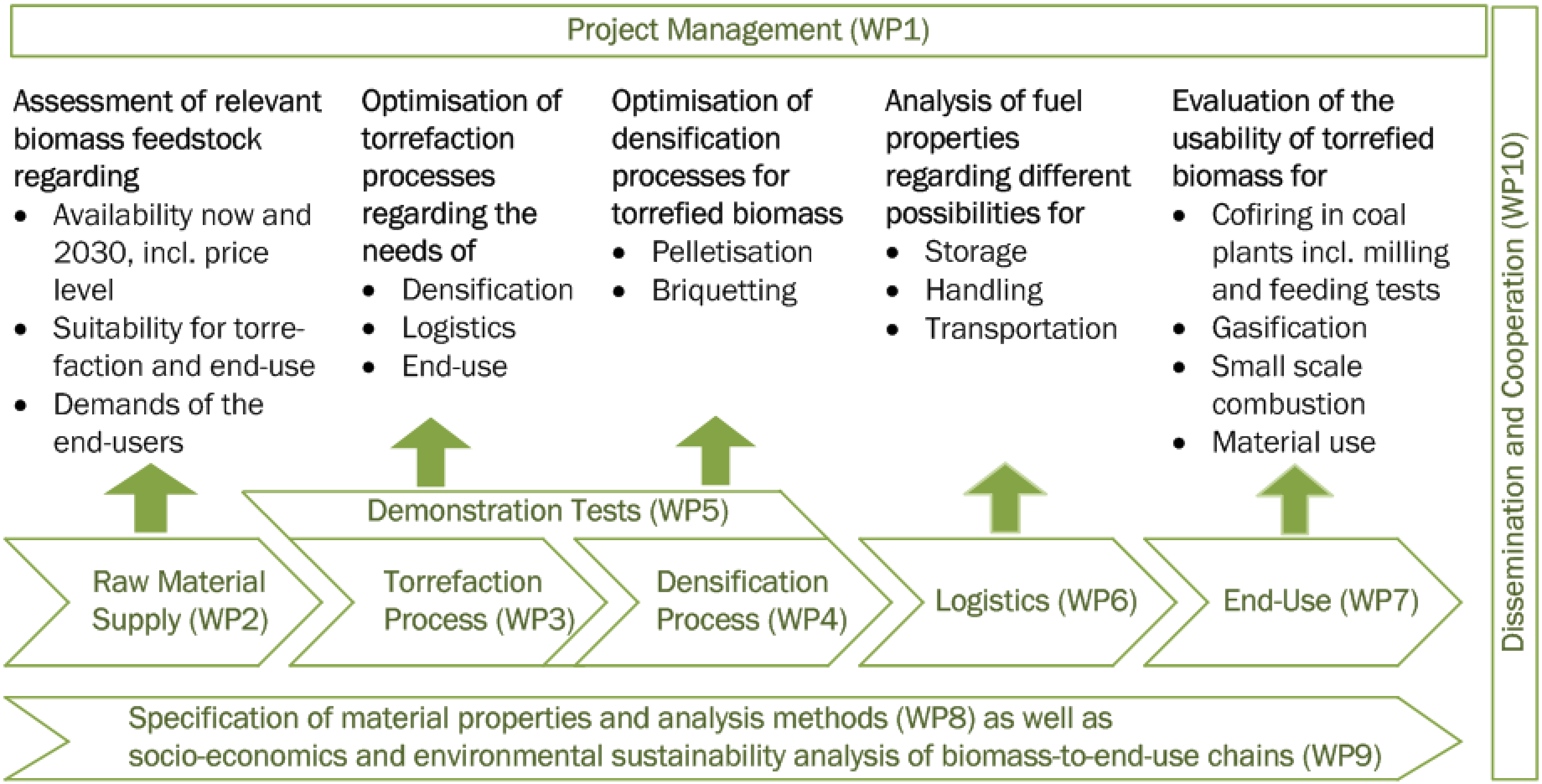
PROCEDE
Doosan Doosan Power Systems
Helmholtz Centre for Environmental Research – UFZ
TU Wien
bioenergy2020+
BIOS Bioenergiesysteme GmbH
Technologie- und Förderzentrum im Kompetenzzentrum für Nachwachsende Rohstoffe

SECTOR Objectives

- **Support the market introduction** of torrefaction-based bioenergy carriers as a commodity renewable solid fuel
- **Further development of torrefaction**-based technologies (up to pilot-plant scale and beyond)
- **Development of specific production recipes**, validated through extensive lab-to-industrial-scale logistics and end-use performance testing
- Development and standardisation of dedicated **analysis and testing methods** for assessment of transport, storage, handling logistics and end-use performance
- Assessment of the role of torrefaction-based solid bioenergy carriers in the bioenergy **value chains** and their contribution to the development of the **bioenergy market in Europe**
- Full **sustainability assessment** of the major torrefaction-based biomass-to-end-use value chains
- **Dissemination** of project results to industry and into international forums (e.g. EIBI, EERA, CEN/ISO, IEA and sustainability round tables)

SECTOR - Project Structure



Torrefaction reactor concepts

- Existing conversion techniques require different fuel properties
- Different reactor types with different process conditions (pressure, temperature, etc.) are on the start or in development
- Future development will show their market potential and technical feasibility
- Project SECTOR is centred around four torrefaction technology options (3 pilot scale plants & 1 demo plant involved)

Reactor technology	European Technology developers & suppliers
Rotary drum	CDS (UK), Torr-Coal (NL), BioEndev (SE), ACB (AT), BIO3D (FR), Atmosclear (CH), CENER (ES)
Multiple hearth furnace	CMI-NESA (BE)
Screw reactor	Biolake (NL), FoxCoal (NL)
Torbed reactor	Topell (NL)
Moving bed reactor	ECN (NL), Thermya (FR), Bühler (CH)
Belt reactor	Stramproy Green (NL)
Fluidised bed reactor	VTT (FI)

source: ECN, Kleinschmidt

Torrefaction Technologies within SECTOR

ECN: Moving bed reactor

Source: ECN

Characteristics:

- Moving bed torrefaction
- Direct heating using recycled torrefaction gas
- Recycle boosting of torgas to compensate for pressure drop
- Torgas utilization for internal energy demand

CENER, Umea University: Rotary drum reactor

Source: ECN

Characteristics:

- Proven technology
- indirectly heated with flue gas
- Accepts larger particles

Topell: Torbed reactor

Source: Topell

Characteristics:

- Cylindrical reactor
- Hot rotating process gas keeps raw material in motion (creates „bed“ that is formed by biomass itself)
- Quick heat-to-mass transfer
- No moving parts

Summary

- Torrefaction process:
  - accepts **many types of ligno-cellulosic biomass**
  - offers optimised balance between energy and mass yield
  - ensures more homogeneous production and constant product quality
  - **does not** significantly reduce sulphur, chlorine and alkali concentrations
- Torrefied products:
  - can be directly milled and cofired with coal
  - are dry and have a high calorific value
  - are brittle and easily break down into small particles
  - have a high volumetric energy density → **significant cost savings**
- Worldwide there are over **50 torrefaction developers / initiatives** (planning capacities between 300 - > 500 kt); no commercial plant exists today, but first demonstration projects are on the way (e. g. Topell from NL 60 kt/a)
- European development in parallel to R&D in North America (USA/CA) → this will speed up the process
- **Technical and commercial challenges** have to be solved, e.g.:
  - optimisation of torrefaction and densification process
  - determination of standardised fuel properties/qualities
  - minimisation of logistical and end-use risks

Thank you for your attention!

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