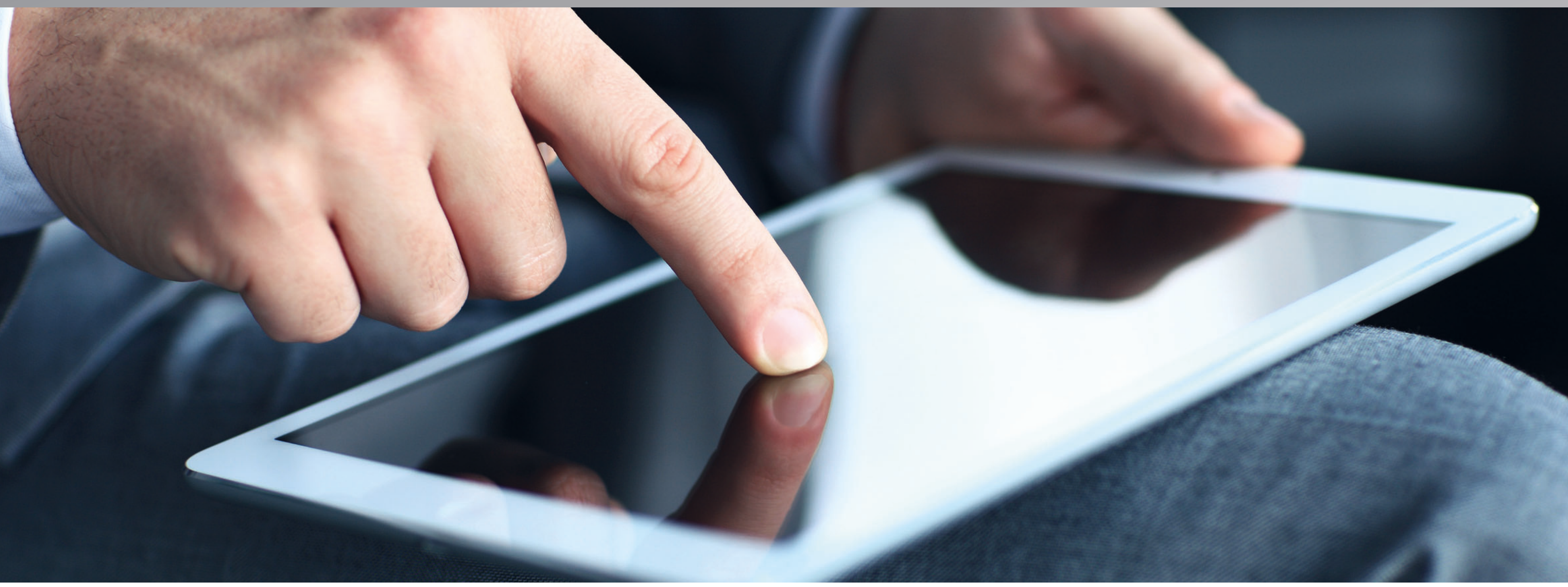
Deutsches Biomasseforschungszentrum
gemeinnützige GmbH

DBFZ

EUBC&E 2015
Side-Event „Thermally treated biofuels“



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Side-Event "Thermally treated biofuels" (EUBC 2015)

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Table of content

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EUBCE 2015
1 - 4 JUNE | VIENNA - AUSTRIA
Messe Wien Congress and Exhibition Center
23rd European Biomass Conference & Exhibition

Words of Welcome

Dear Reader,

the use of renewable energies has grown significantly in the last couple of years and is expected to experience a further increase based on the targets outlined in the European Renewable Energy Action Plans (NREAP). Currently biomass has a share of about 19% of the final energy consumption worldwide. The largest contribution of energy from biomass is in the renewable heating sector. There, wood is the predominantly used biofuel. However, wood is a limited and increasingly scarce resource with potential utilization conflicts. Thus, a more efficient use of wood or alternative biomass resources are required for energetic purposes.

Dr.-Ing. Janet Witt (DBFZ)

For solid fuels the homogenization of the fuel properties is one of the major research and development topics. It is the basis of increasing the efficiency of the entire supply and utilization systems. Various pre-treatment options (including washing processes) and different levels of thermal modification (e.g. HTC, torrefaction) were investigated to enlarge the range of raw materials as well as to improve the quality of the fuels.

The side event “Thermally treated biofuels”, held on the 3rd of June 2015 within the 23rd European Biomass Conference 2015, gave a detailed overview to the concepts currently being developed and introduced. First experiences with combustion experiments of selected batches were also shown. The different lectures presented the state of the art as well as R&D results of process technologies like pyrolysis, torrefaction, hydrothermal-carbonisation. Also information on modelling, simulation and optimisation of an european-wide biomass logistics network were given. The side event was closed by an insight into the Japanese wood market and research on torrefication as well as an open discussion with all the speakers.

We are pleased to present you the digital conference proceeding with all the abstracts, presentations and profiles of our guests from the Netherlands, Japan, Austria and Germany. We also would like to thank everyone who took part at the DBFZ Side-Event “Thermally treated biofuels” and contributed with presentations, questions and valuable insights.

Sincerely,

Dr. -Ing. Janet Witt
(DBFZ, Bioenergy Systems Department)

ABSTRACTS AND PRESENTATIONS

Dr. Annett Pollex, DBFZ

Overview about thermally treated solid biofuels

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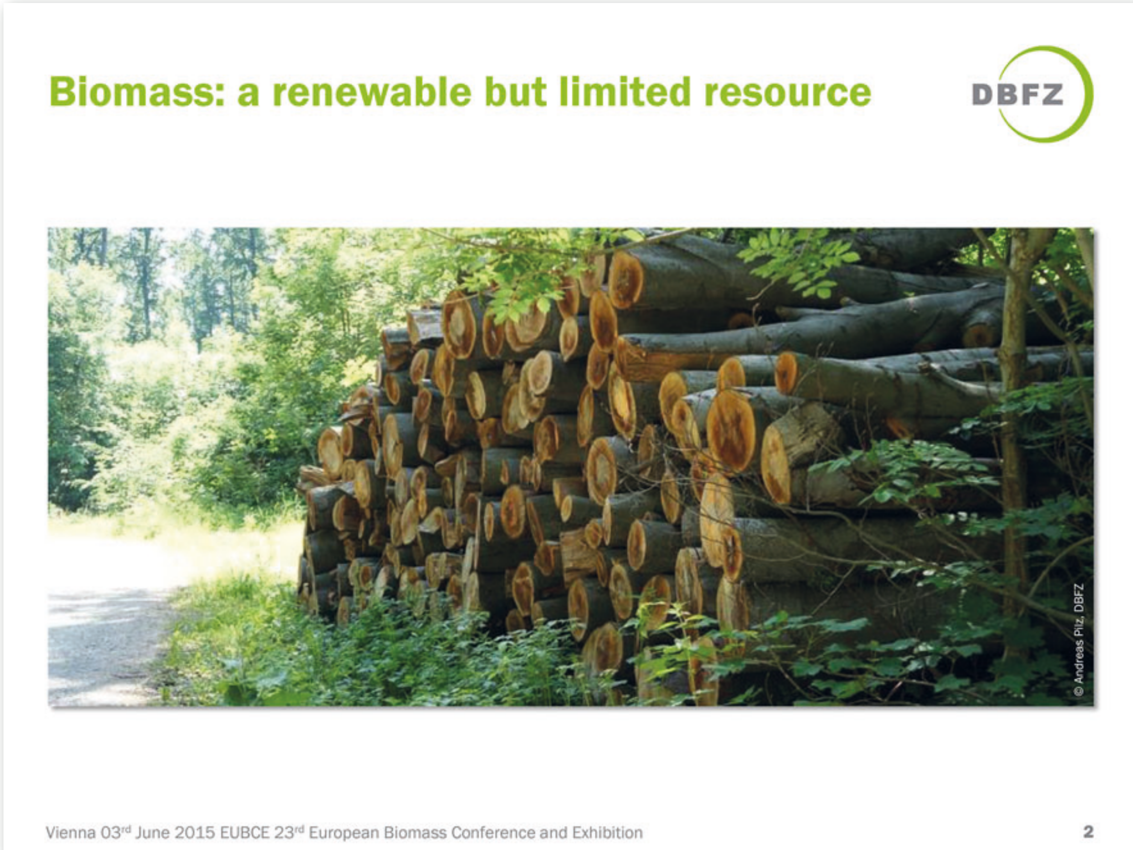
Renewable energy supply has been steadily growing in the last couple of years and is expected to experience a further significant increase based on the targets as outlined in the European Renewable Energy Action Plans (NREAP). Limitation of the global warming to two degree compared to pre-industrial average temperature levels would require an even more vigorous effort to limit greenhouse gas emissions and increase renewable energy utilization. Currently about 19% of the final energy consumption worldwide is provided by biomass.

The largest contribution of biomass is in the renewable heating sector. There, wood is the predominantly used biofuel. However, though it is renewable wood is still a limited and scarce resource with potential utilization conflicts. For example, it is a popular building material, widely used for paper production and one of the preferred raw materials for large scale biorefinery concepts.

Thus, alternative resources are required to enable further rising use of biomass. There is a large variety of currently unexplored biomasses as well as biogenic residues from the forestry and the agricultural sector. However, these resources are often characterized by varying properties and a higher content of critical elements that may lead to higher emissions, fouling and corrosion problems as well as slag formation in the bottom ash. Furthermore, various residues and side products with large unexploited potentials e.g. the biogenic share of municipal waste streams, digestate, sludge and similar materials are characterized by high water contents.

Overall, all those characteristics make a pretreatment of the different feedstocks a prerequisite to enable or facilitate their utilization as solid biofuels in different applications. The presentation will give an overview about selected, predominantly thermal pre-treatment options for the production of optimized solid biofuels. Applicability, pretreatment conditions, product characteristics and major attainable improvements are encompassed and chances and challenges are highlighted.



Biomass: alternative feedstocks with challenging properties

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Different applications – different fuel requirements

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Centralised power generation

Desired fuel properties

- Improved wood fuel characteristics with respect to: grindability, energy density, heating value, volatiles, outdoor storability, ignition temperature, burnout rate

Decentralised heat and CHP

Desired fuel properties

- Mitigated critical fuel composition in particular homogeneity and ash content
- Characteristics enabling for high load-cycle tolerance and low emissions

Optimisation of fuel properties

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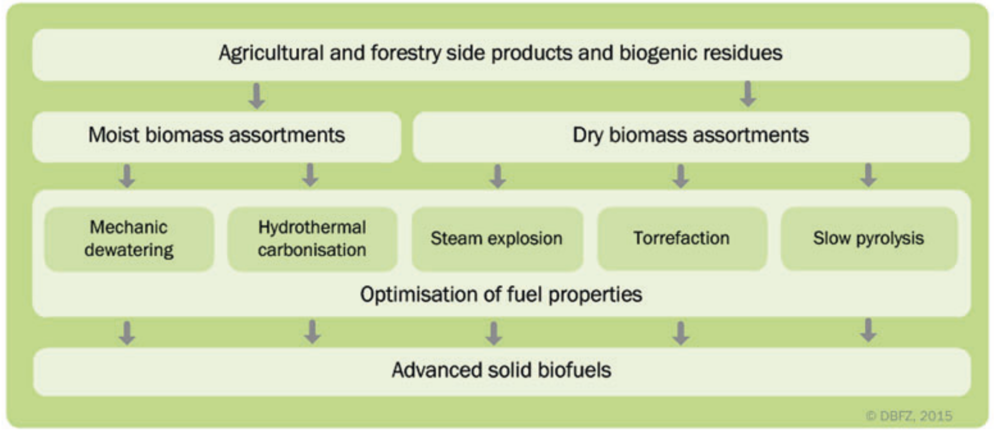

Mechanic dewatering

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Typical input material

- Fresh or ensiled biomass streams with water content >50%, e.g. foliage, grass clipping, landscape conservation material

Reaction conditions

- Amibient temperature or temperated slurry
- Dewatering with mechanic pressure

Product properties

- Solid light brown material (>90% of the original mass)
- Significant reduction of the mineral content

Mechanic dewatering – chances and challenges

Chances

- Significantly improved fuel properties with very good combustion results in particular with respect to reduced fine dust emissions.
- Complementation with fermentation of the nutrient rich process water for biogas production increases rentability and reduces waste streams.
- First demonstration plants have been constructed in Germany.

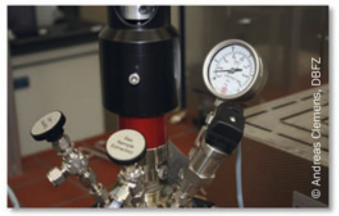
Challenges

- Based on input stream especially suitable on local level which reduces the return of investment.
- Logistics and biodegradation of moist biomass resources.

Hydrothermal carbonisation (HTC)

Typical input materials

- Wet biomass stream with water content of ~80% e.g. biogenic share of residential waste streams, grass clipping, digestate



Reaction conditions

- Pressurised aqueous solution, 180- 250 °C, 10-40 bar
- Residence time: 2-6 h

Product properties

- Solid dark brown to black material (40-70 % of the original mass, 5-20% soluble organic compounds)
- Slight reduction of mineral content

Hydrothermal carbonisation – chances and challenges

Chances

- Variable, cheap input streams with limited conflicting use.
- Successful homogenisation of the fuel properties.
- First industrial scale demonstration plant erected in Germany.
- Improved pelletizing characteristics compared to raw material.

Challenges

- Utilization of process water.
- Sufficient reduction of the ash content especially during continuous operation.
- HTC-coal requires drying and possibly also compacting depending on transportation distances.

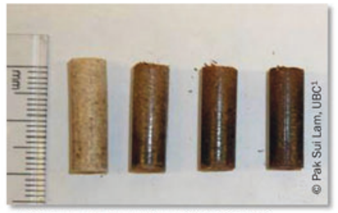
Steam explosion

Typical input material

- Wood or other dry biomass assortments with water content <20%

Reaction conditions

- Steam atmosphere, 180 -240 °C, pressure of ~30 bar abruptly reduced by at least 10 bar
- Residential time: typically 5-10 min



[1] P. S. Lam et al. *Energy Fuels* 2011, 25, 1521

Product properties

- Solid (dark) brown material (~60 % of the original mass)
- Increased carbonisation, no reduction of ash content

Steam explosion – chances and challenges

Chances

- Applicability of the method for other processes (bioraffinery concepts for better digestion, cellulose production from wood) enables rapid technological development. There are several studies on pilot scale.
- Results indicate higher pellet quality and higher pellet production throughput that can be realised with steam exploded material.
- Good results during co-firing tests at Vattenfall (coal-fired power station Reuter West 2011) with co-firing rates up to 20%.

Challenges

- Enrichment of ash.

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Torrefaction and densification

Typical input material

- Dry biomass with water content below 10 wt.-%
- Mostly wood chips

Reaction conditions

- Inert atmosphere, ambient pressure, 200-320 °C
- Residence time: typically 10-20 min

Product properties

- Solid dark brown to black material (~70% of the original mass and ~90% of the original energy content)

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Torrefaction – Idenitfication of the optimal torrefaction degree

Higher torrefaction degree results in better grindability, higher heating value and higher hydrophobicity .

HOWEVER

At the same time, higher torrefaction degree requires higher energy input and leads to inferior pelletising characteristics and higher self-heating risk.

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Torrefaction – chances and challenges

Chances

- Successful optimisation of wood pellet properties enabling high co-firing rates in coal fired power plants (up to 100%).
- Successful upscaling tests and near commercial realisation state.

Challenges

- Dependence on imported biomass.
- Economic feasibility requires resurgence of incentives and implementation of frameworks supporting the decreased use of fossil fuels (e.g. CO_2 certificates in appropriate amount and price).

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Fuel optimisation by thermal pretreatment

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Thermal pretreatment process	Main improvement
Mechanic dewatering	Lower mineral content
Hydrothermal carbonisation	Increased carbon content (waf), reduction of some minerals
Steam explosion	Increased carbon content (waf), improved pelletizing characteristics
Torrefaction	Grindebility, heating value, carbon content, hydrophobicity

Outlook – fusion of methods

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Thermal modification can improve **selected** difficult fuel characteristics of unexploited biomass resources.

Combination of difficult characteristic may require **combination of pre-treatment processes**, e.g.:

- Mechanic dewatering and torrefaction
- Co-pelletising of torrefied biomass and HTC coal

Feasibility and viability of the realisation requires appropriate incentives and frameworks.

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Researching the energy of the future – come and join us!

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Dr. Nicolaus Dahmen, KIT

Pyrolysis as a thermally treated process technology - State of the art and R&D results

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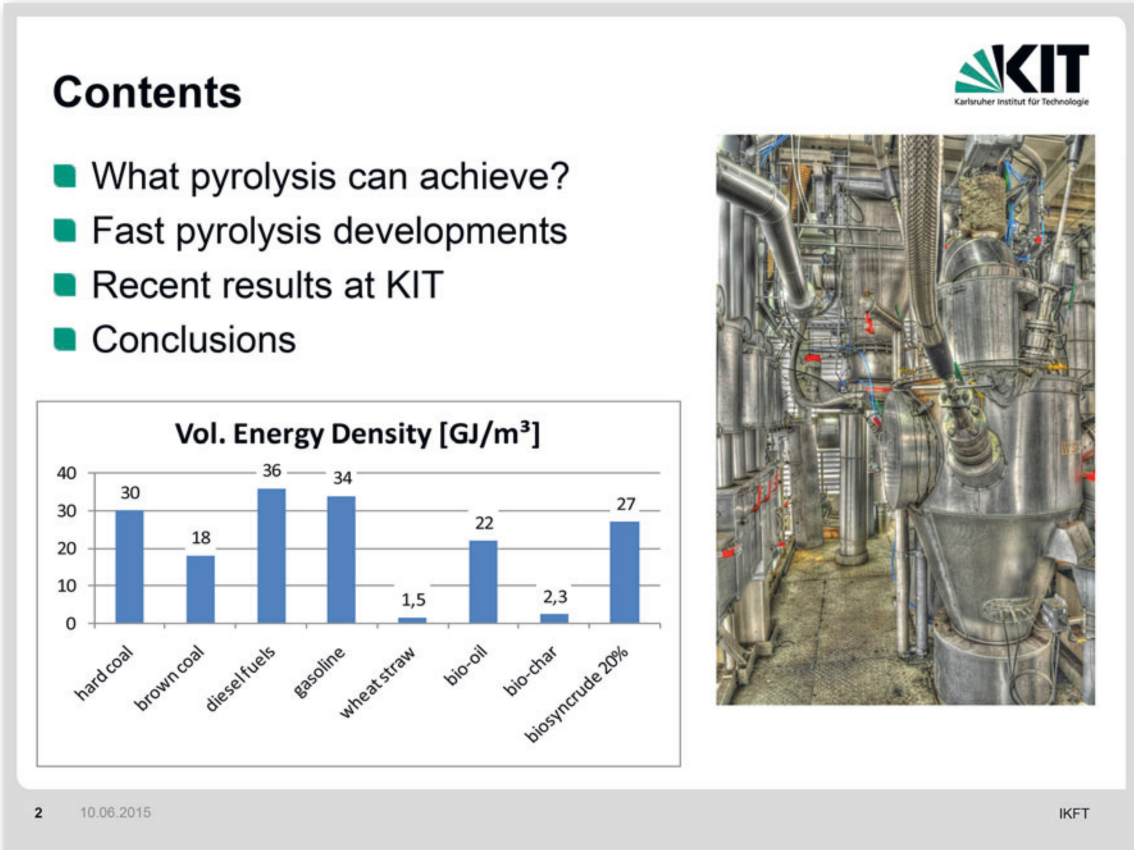
The European FP7 BioBoost project aims at boosting the biofuel production by making use of suitable biomass based energy intermediate. The project focuses on de-central conversion of biomass to optimised, high energy density carriers, which can be utilised either directly in small scale combined heat and power (CHP) plants or in large scale applications for the synthesis of transportation fuels and chemicals. Dry as well as wet residual biomass and organic waste are used as feedstock for conversion. Due to their secondary nature, these feedstocks have the potential for high environmental sustainability.

In the BioBoost project, these types of biomass are converted by means of fuel-flexible thermo-chemical processes such as fast pyrolysis, catalytic pyrolysis and hydrothermal carbonization (HTC) to produce stable energy carriers in the form of bio-oil, bio-coal or bio-slurries (biosyncrude). For straw, as an example, the energy density of the carrier can be increased by a factor of 10 to 15, enabling economic long range transportation from several regionally distributed conversion plants to few central large scale gasification plants for bio-fuel production.

Fast pyrolysis was developed and optimized towards the production of biosyncrude, a suspension of pyrolysis liquids and solids. By that, a maximum of biomass energy is conserved in a liquid-like product suitable high pressure gasification processes. From these high quality synthesis gas can be obtained to be converted into synthetic second generation fuels. As a second conversion technology, the catalytic pyrolysis was optimized with regard to the production of catalytic bio-oil that has a maximum product yield related to the biomass feed capacity with a minimum oxygen content.

This bioenergy carrier can be used for the co-production of transportation fuels in an existing refinery infrastructure. By hydrothermal carbonization feedstocks with high water contents can be converted into peat-like solid fuels. Validated by the use of municipal organic waste or spent breweries grain, the HTC-coal produced showed excellent combustion behavior when tested. Biomass consists of a broad variety of different feedstocks, altogether providing an enormous mass potential. If they are to be used in large scale, the implementation of feed flexible pre-treatment technologies, optimized towards the intended application, is mandatory. Thermochemical processes are promising due to their evident multi-feed ability and industrial scale applicability.

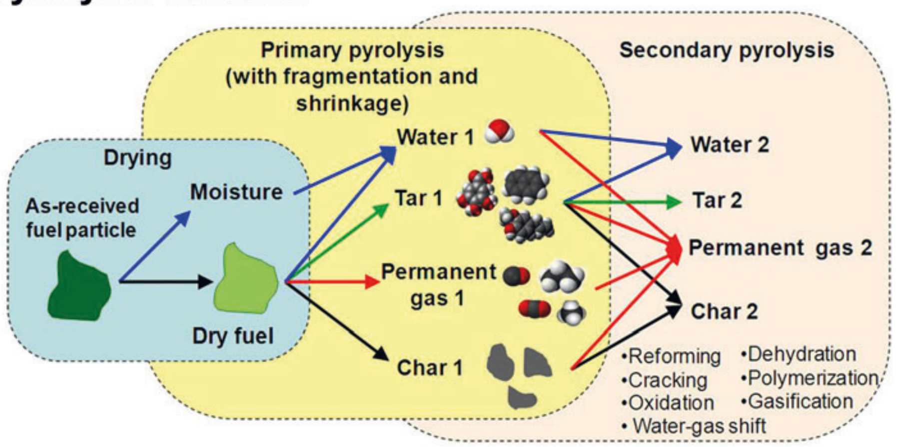


Thermochemical biomass pre-treatment

"Dry" processes (< 15 wt.% water)				Thermolysis
Fast pyrolysis	500 °C	atm.	sec	
Intermediate pyrolysis	500 °C	atm.	min	
Catalytic (fast) pyrolysis	500 °C	atm.	sec	
Torrefaction	200-300 °C	atm.	30 min	
Steam assisted processes				
Biomass steam processing	400 °C	atm.	30 min	
Flash carbonization	Flash fire	10 bar	30 min	
Hydrothermal processes (> 75 wt.% water)				Solvolysis
Carbonization, HTC	≈ 200 °C	10 bar	6 h	
(Catalytic) Liquefaction HTL	< 350 °C	150 bar	10 min	
(Catalytic) Gasification HTG	650 °C	300 bar	1 min	

3 IKFT

Pyrolysis kinetics



With rising reaction time gas formation increases (approach to chemical equilibrium in which only gas and char are produced)

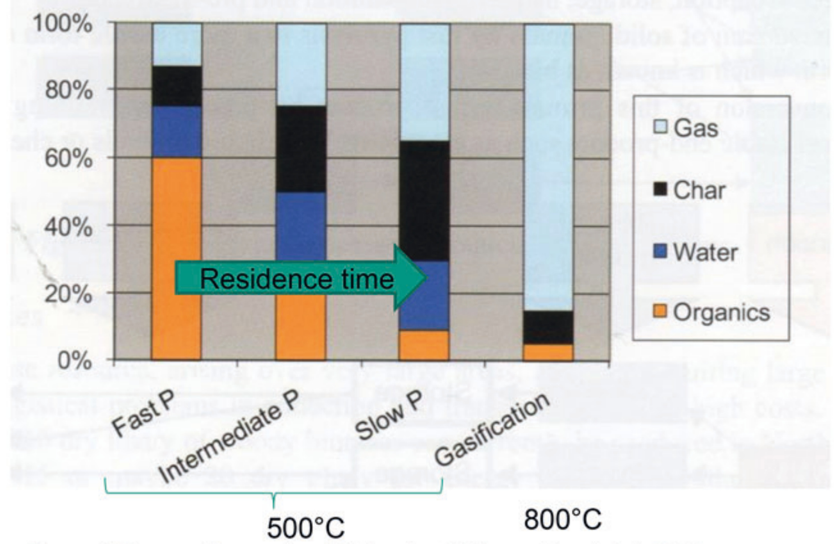
Process engineering task: Recover of as much of condensable substances (intermediates) as possible!

Quelle: Neves et al. (2011); http://dx.doi.org/10.1016/j.pecs.2011.01.001

4 IKFT

Products from pyrolytic reactions

At short reaction times chemical equilibrium can not be attained.
Many intermediates, forming liquids after condensation, are found as products

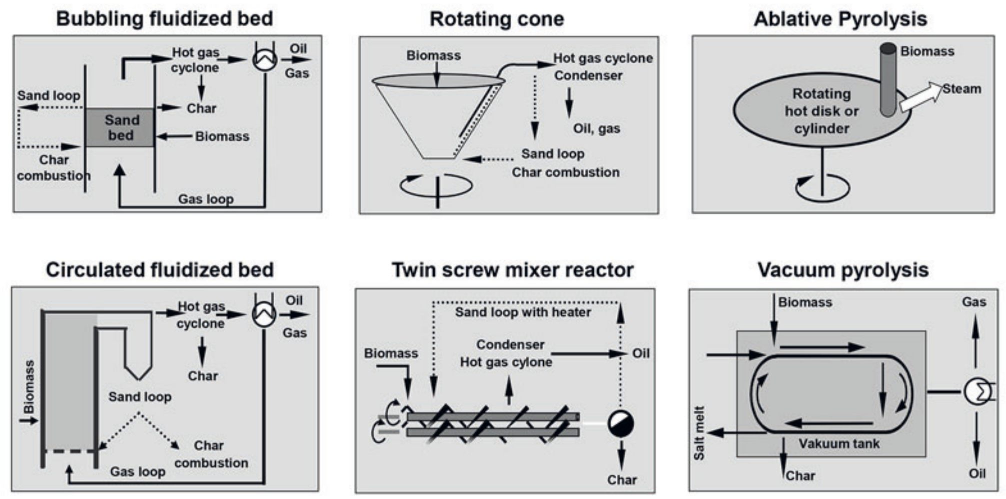


Source: Thermal Biomass Conversion, Bridgwater, Hofbauer, Loo (eds), 2009 .

5 IKFT

Fast pyrolysis reactor priciples

Rapid heating up – short residence time – instant quenching of pyrolysis vapors



Source: Thermal Biomass Conversion, Bridgwater, Hofbauer, Loo (eds), 2009 .

6 IKFT

Complete list in preparation by IEA bioenergy Task 34

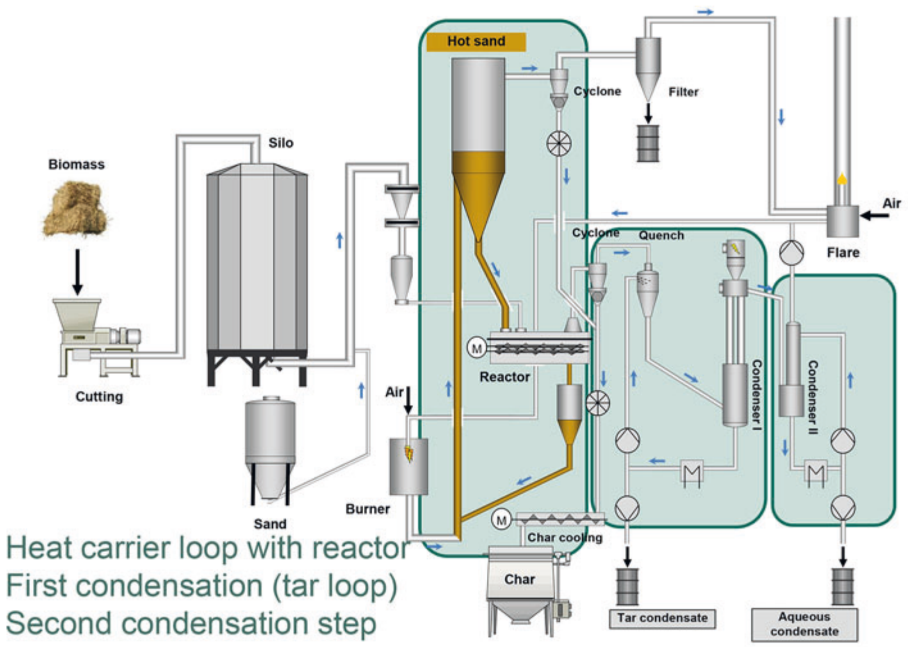
Selected examples

ENSYN RTP®	OntarioCAN	Screw reactor, ca. 10.000 t/a since 2014	Chemicals, heating fuels, in operation
FORTUM	Joensuu FIN	Integrated pyrolysis/CFB CHP plant 50 MW_{el}, 110 MW_{heat}, 50 kt/a	Biooil for heating, in operation
EMPYRO	Hengelo NL	Rotating cone reactor, 20 kt/a in 2 t/h plant in Malaysia for EFB, 200 kg/ PDU at BTG	Biooil for CHP, start of production
Pyroformer™	Aston UK	Intermediate pyrolysis, screw reactor with char recycle, mobile pilot plant	Biooil/diesel blend, char, in operation
bioliq FP	KIT, D	Fast pyrolysis twin screw reactor, 10 kg/h PDU, 500 kg/h pilot plant	Biosyncrude, In operation
IH2	GTI, USA	Catalytic Hydropyrolysis & Hydroconversion, 50 kg/d pilot plant	Hydrocarbon fuels

Images from IEA Task 34 newsletters

7 IKFT

Pyrolysis pilot plant scheme

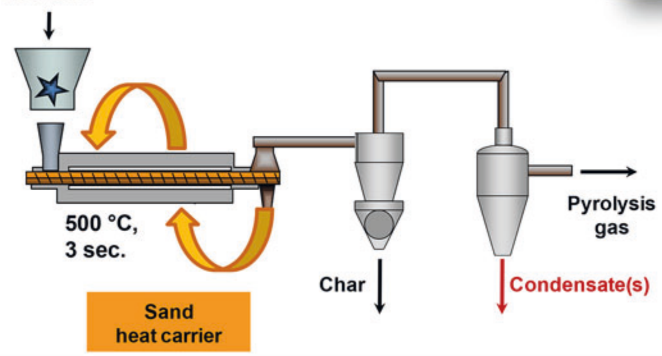


Heat carrier loop with reactor
First condensation (tar loop)
Second condensation step

9 IKFT

bioliq® fast pyrolysis process

- Biomass particles are rapidly heated up by sand as heat carrier
- By fast pyrolysis char, bio-oil, and pyrolysis gas are produced to
- Hot heat carrier is heated and circulated via natural/product gas combustion
- Pyrolysis vapours are rapidly condensed

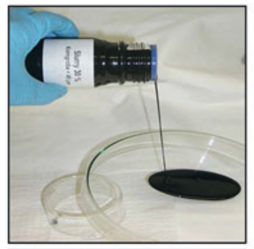


8 IKFT

Pyrolysis oils

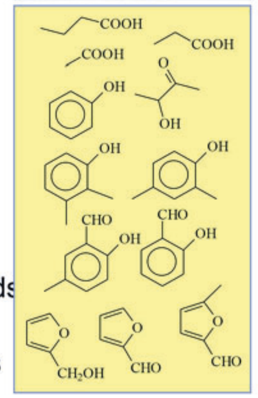
Advantages

- **Liquids** are better for transport, storage, feeding
- **Fuel utilization can be separated from biomass production** in time and location
- **Broad feedstock range**, any dry organic material
- Increase of **heating value**



Properties

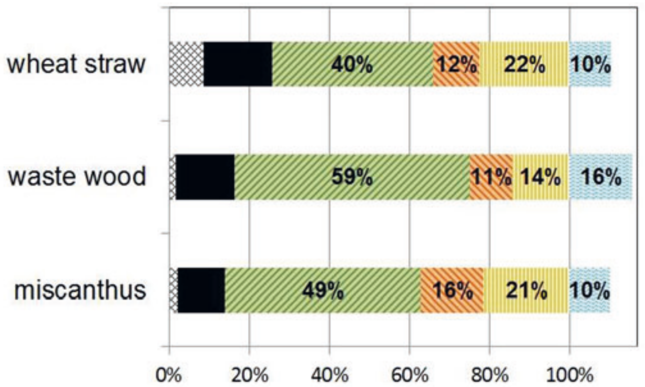
- Dark black-brownish, strongly smelling liquid
- **High viscosity** up to 1 Pas at room temperature
- **Water content** up to 30%, at higher water content or with ash rich biomass spontaneous phase separation
- **pH value** 2 – 3.5 (due to formic and acetic acid)
- **Complex mixture** of 300 – 400 organic species, e.g. acids, aldehydes, ketones, furfurals, phenols, pyrolytic lignin
- **Ageing** of oils by post-reactions of reactive intermediates

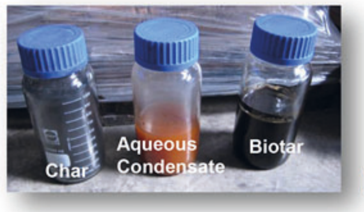


10 IKFT

Impact by different types of biomass

BioBoost





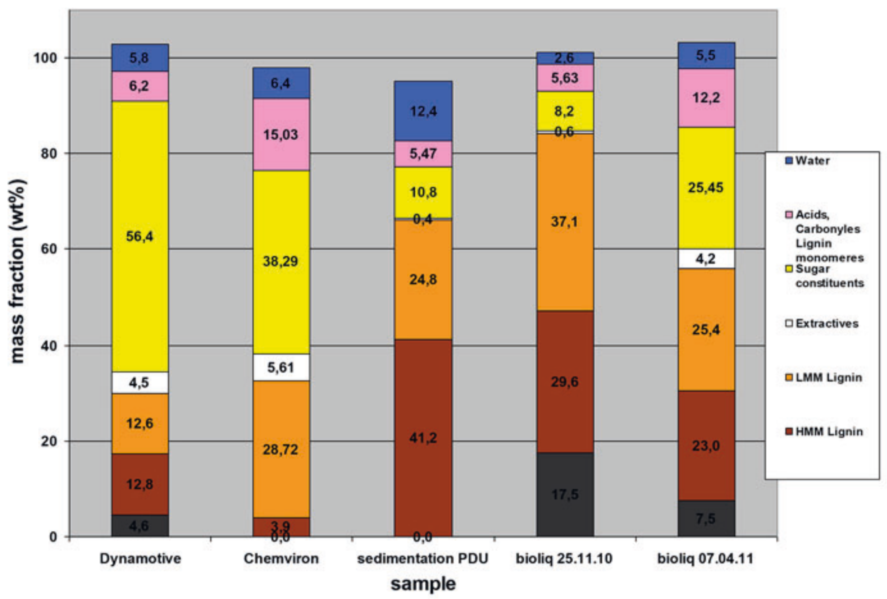
$CO_2 \geq 50$ %, $CO \approx 30-40$ %, $CH_4 \approx 2-5$ %, $C_6 \approx 3-6$ %

Not all condensates form a single phase!

11 IKFT

Product varieties

There is not the only one!



Extraction schemes according to VTT method

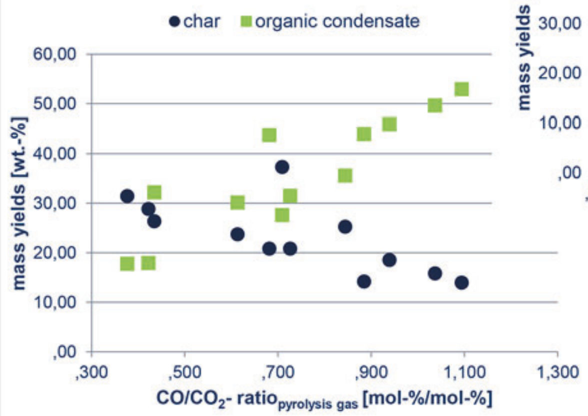
12 IKFT

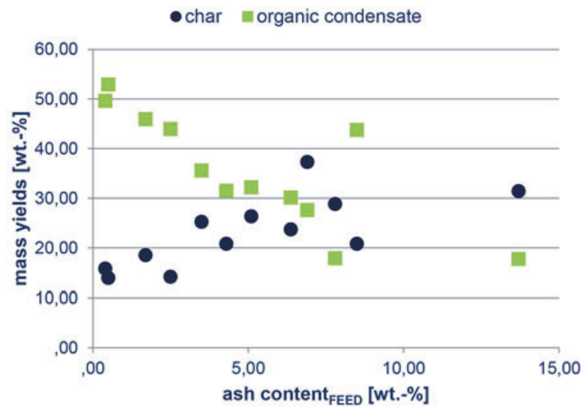
Correlations possible?

Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit

Energetische Biomassenutzung

Influence of ash content and CO/CO_2-ratio on the mass yields for fast pyrolysis of different types of biomass





Predictions and real-time correlations are possible!

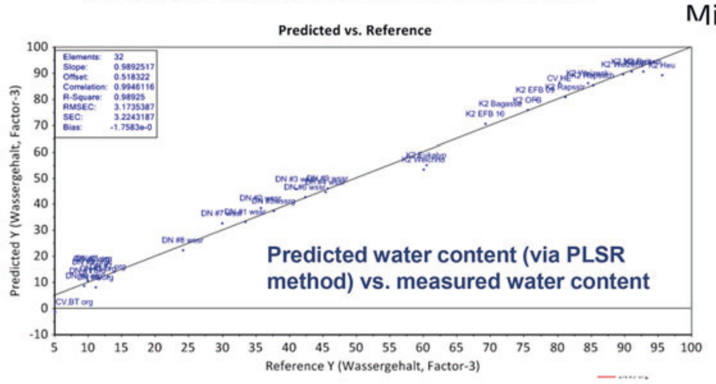
N. Tröger, D. Richter, R. Stahl, Journal of Analytical and Applied Pyrolysis 100 (2013)158–165

13 IKFT

On-line diagnostics

- ATR (IR)-spectroscopy
- High frequency measurements
- Low resolution NMR (NMR mouse) for determination of water and solids

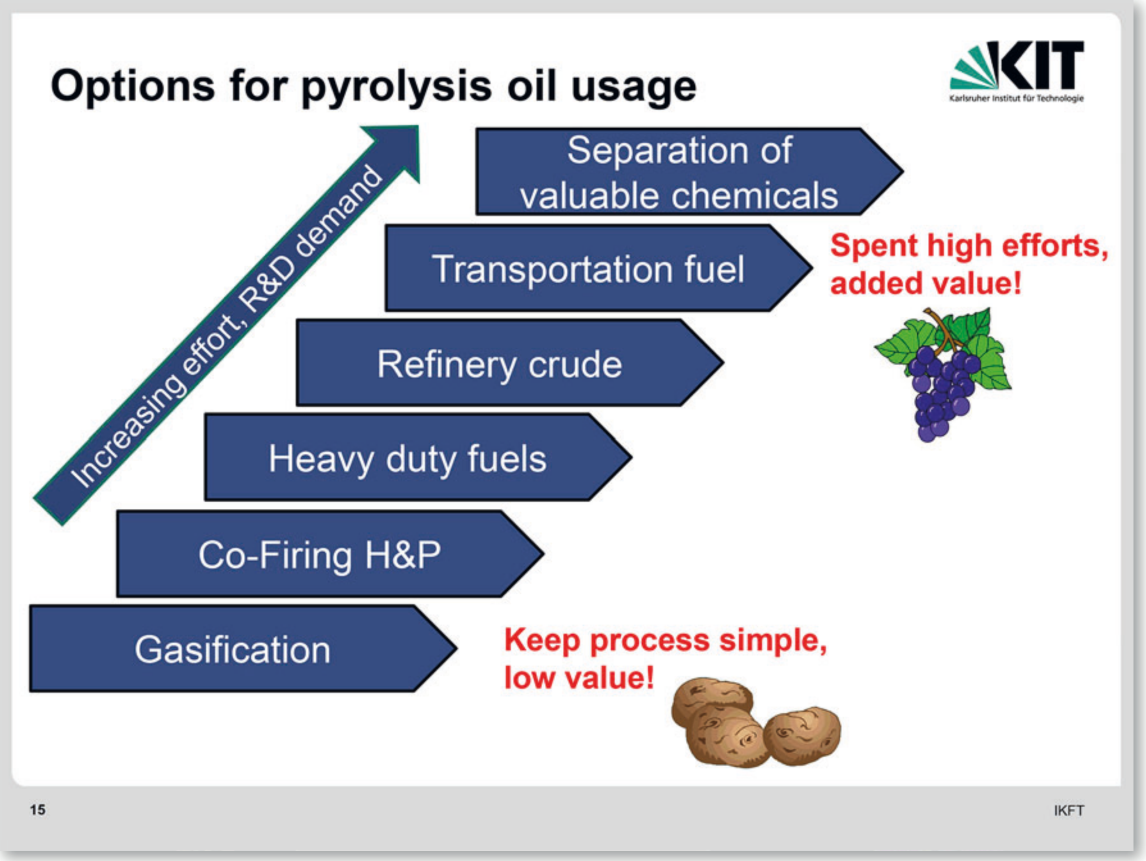
Microwave cell from *hf-Sensor*



Chemical and physical information available by high frequency reflection and transmission measurements!

F. Girke, IEA Bioenergy Task 34 Newsletter — PyNe 35, 30-32
F. Dalitz, A. Steiwand, K. Raffelt, H. Nirschl, G. Guthausen in Energy and Fuels, 2012, 26, 5274-5280

14 IKFT


Options for pyrolysis oil usage
KIT
Increasing effort, R&D demand
Separation of valuable chemicals
Transportation fuel
Spent high efforts, added value!
Refinery crude
Heavy duty fuels
Co-Firing H&P
Gasification
Keep process simple, low value!
15
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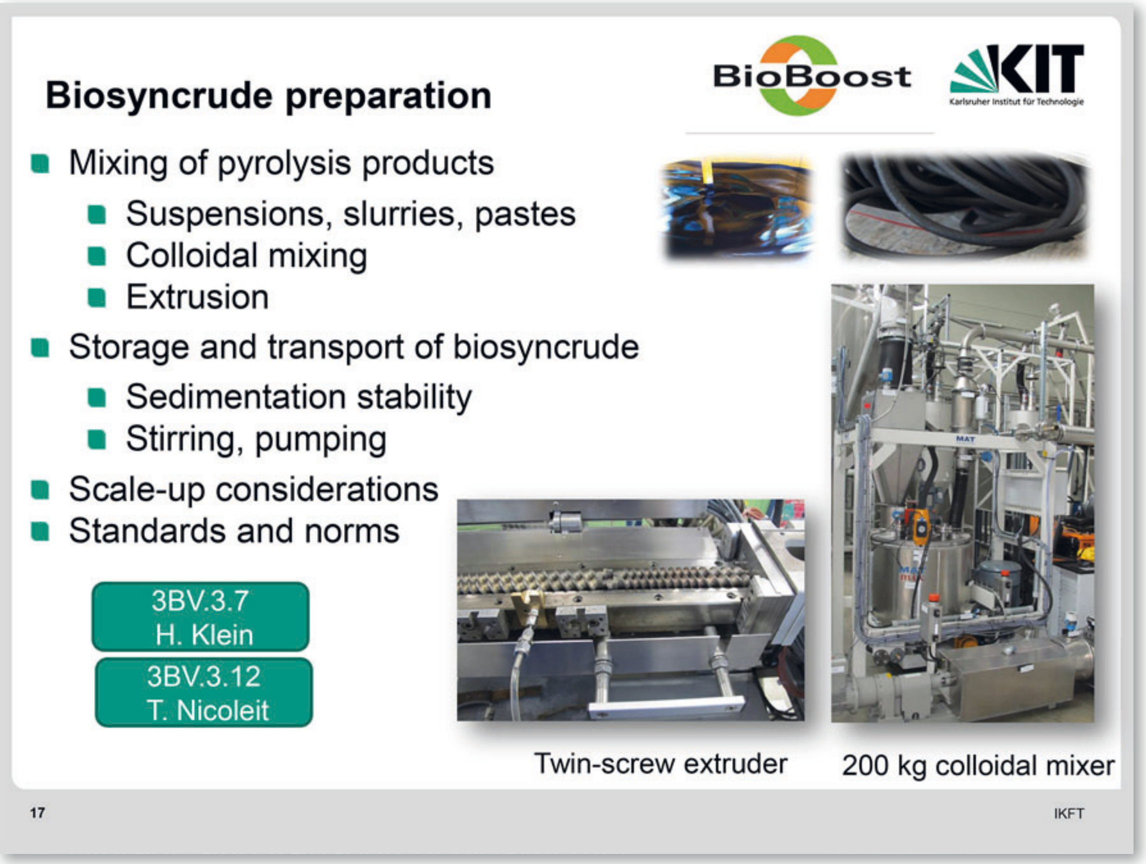
Biosyncrude preparation
BioBoost
KIT
Mixing of pyrolysis products
Suspensions, slurries, pastes
Colloidal mixing
Extrusion
Storage and transport of biosyncrude
Sedimentation stability
Stirring, pumping
Scale-up considerations
Standards and norms
3BV.3.7
H. Klein
3BV.3.12
T. Nicoleit
Twin-screw extruder
200 kg colloidal mixer
17
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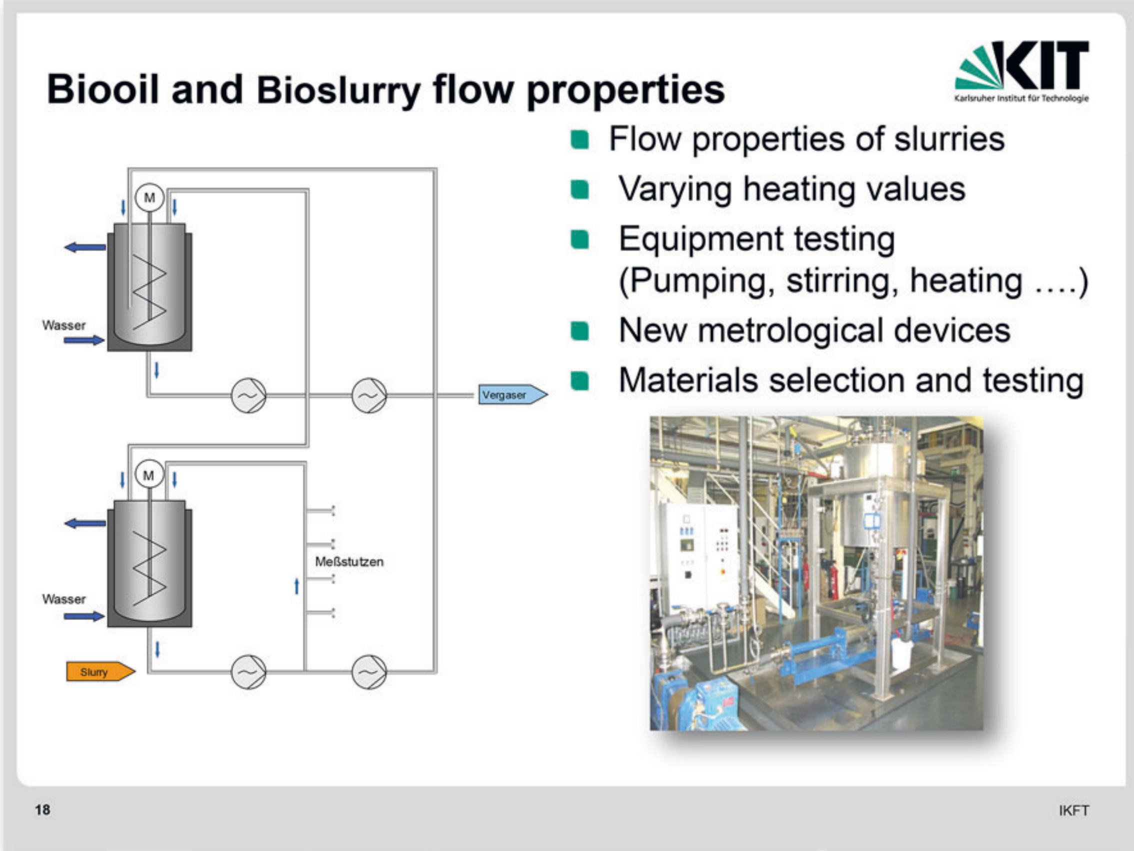
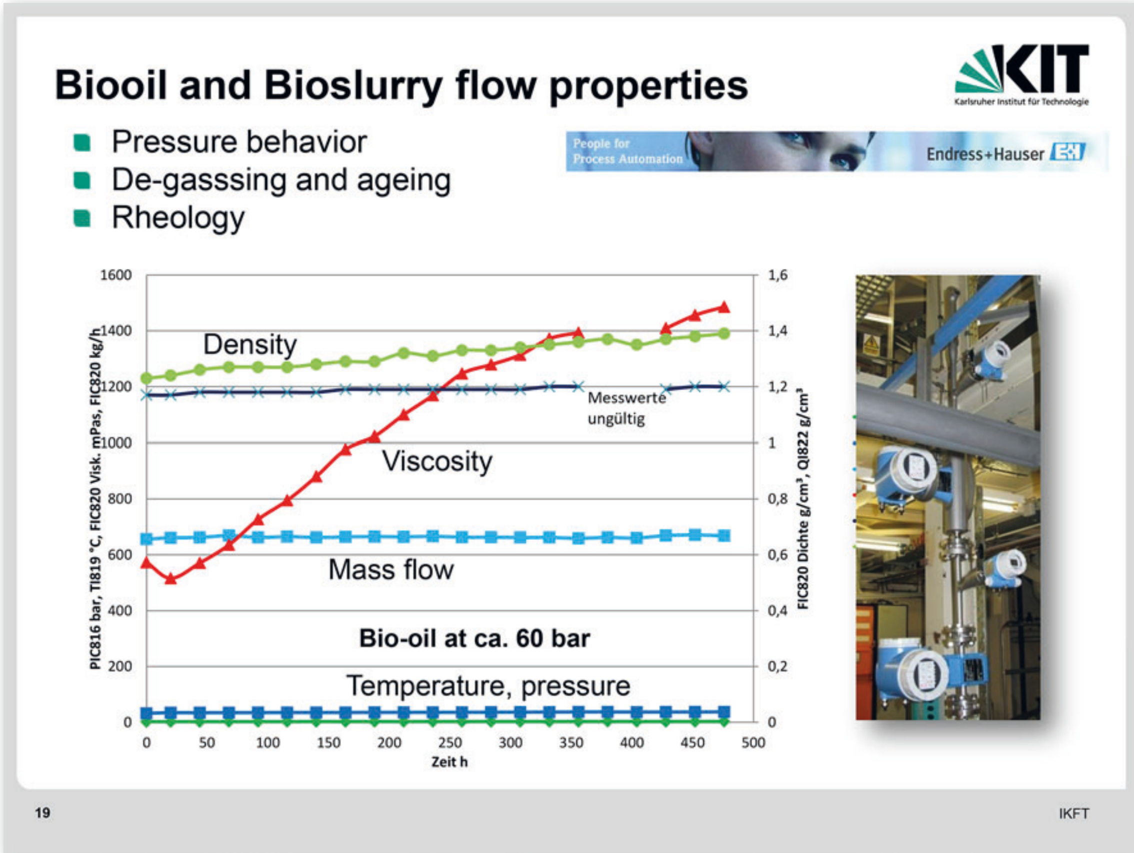

Biooil and Bioslurry flow properties
KIT
Flow properties of slurries
Varying heating values
Equipment testing
(Pumping, stirring, heating ….)
New metrological devices
Materials selection and testing
Wasser
Vergaser
Meßstutzen
Wasser
Slurry
18
IKFT


Biooil and Bioslurry flow properties
KIT
Pressure behavior
De-gasssing and ageing
Rheology
Endress+Hauser
Density
Messwerte ungültig
Viscosity
Mass flow
Bio-oil at ca. 60 bar
Temperature, pressure
Zeit h
19
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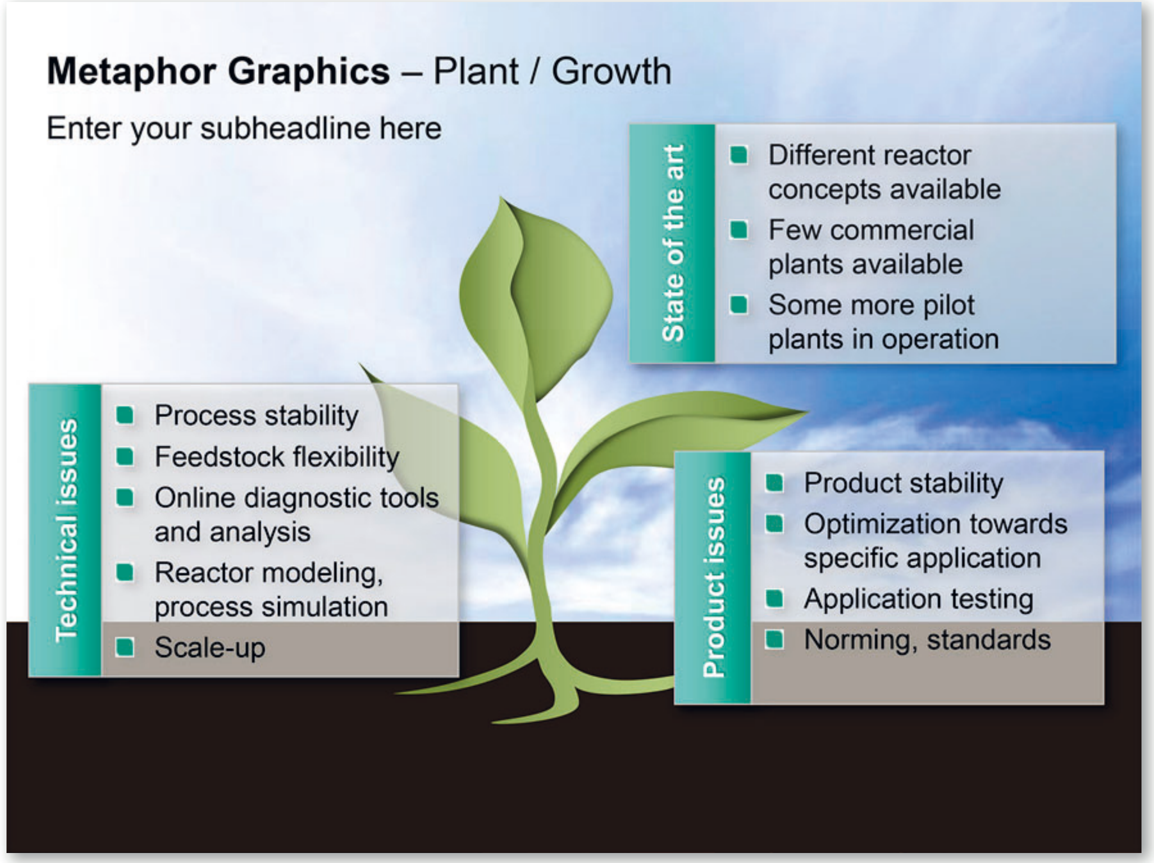

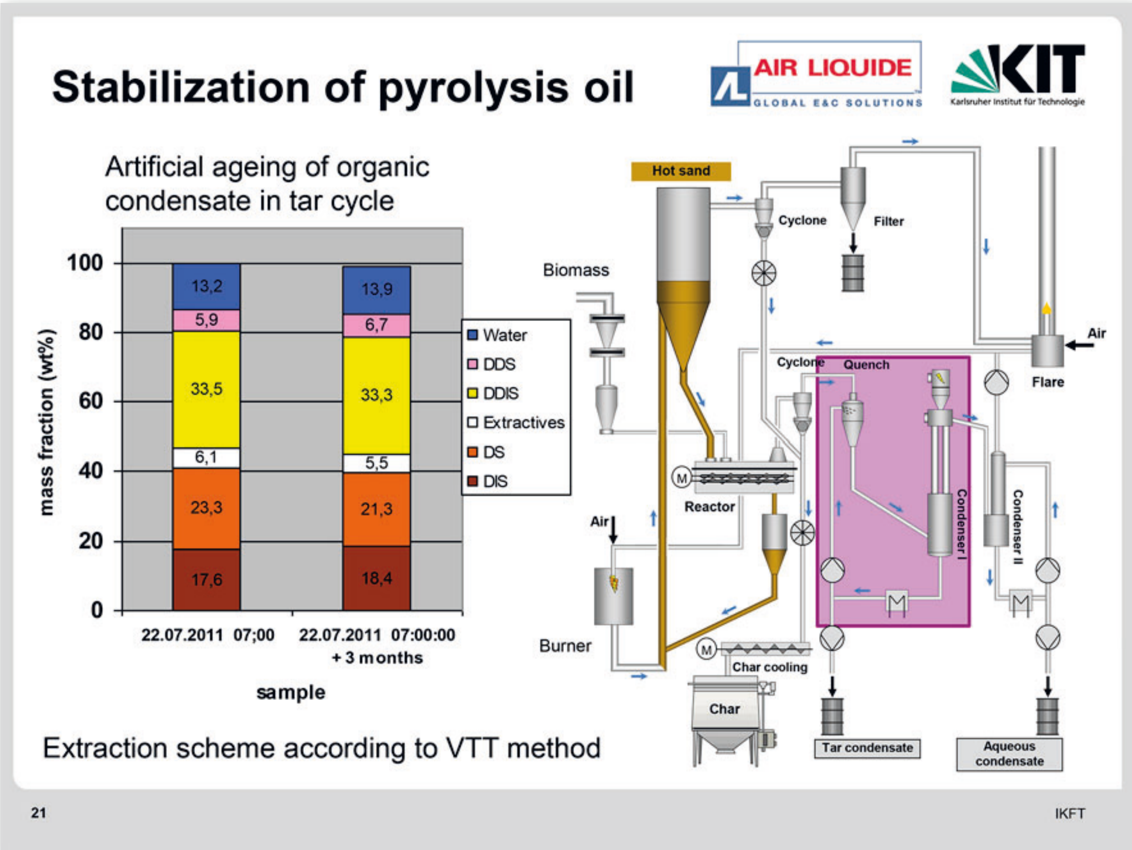

Dr. Janet Witt, DBFZ

Torrefaction as a thermally treated process technology - State of the art and R&D results

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In torrefaction, biomass is heated up in the absence of oxygen to a temperature of at least 250°C. By combining torrefaction with pelleting or briquetting, biomass materials can be converted into high-energy-density bioenergy carriers with improved behaviour in (long-distance) transport, handling and storage. Torrefaction also creates superior properties for biomass in many major end-use applications. The process has the potential to provide a significant contribution to an enlarged raw material portfolio for sustainable biomass fuel production inside Europe by including both agricultural and forestry biomass (residues).

The European (FP7) project SECTOR, aiming at the further development and market introduction of torrefaction-based technologies for the production of solid bioenergy carriers has reached its final period. The SECTOR project – with more than 20 partners from industry and science – is expected to shorten the time to market for torrefaction technology through extensive pilot and demo scale torrefaction as well as densification trials. The downstream value chain is elaborately assessed through logistics and end-use testing of the torrefied biomass, in combination with supporting small-scale experimentation and analysis. The technical work is accompanied by safety assessments, development of standards (both for dedicated analysis methods and torrefied products), techno-economic assessment of major biomass-to-end-use value chains and a complete sustainability assessment.

This contribution presents an elaborate overview of the most important project results that were obtained within the last 42 month. More than 200 tons of torrefied biomass were produced and densified (pelletised and briquetted) by the four producers from labscale up to demonstration stage. The production of these batches has led to the formulation of dedicated recipes for various feedstocks, through fundamental studies about changes in structure and composition during biomass torrefaction and densification. The torrefied pellets and briquettes have been tested by different SECTOR partners all over Europe to assess the material performance during handling and storage as well as in small- and large-scale end-use applications. Torrefied pellets and briquettes with different degrees of torrefaction were assessed and tried to characterise their behaviour according to durability, weathering, biodegradation, self-heating, self-ignition and dust explosivity. Larger samples of torrefied pellets have been subjected to outdoor stockpile tests, and to assess handling in existing feed lines of coal-fired power plants. Three principal end-use applications for torrefied biomass were under investigation in this project: co-firing in pulverised fuel boilers, (co-)gasification in entrained-flow gasifiers and combustion in commercial pellet boilers. Results that were obtained during lab-, pilot- and large-scale thermal conversion trials will be presented, in conjunction with results of grindability (milling tests) and feeding experiments. Parallel to the technical process development several standard test methods for the analysis of physical and chemical fuel properties of torrefied biomass were successfully validated in two extensive Round Robin tests, while new dedicated test methods and a specific product standards (ISO 17225-8) are under development. Lastly, a methodology has been developed for both the life-cycle-assessment and socio-economic assessment of the torrefaction-based value chains; for the environmental assessment these will be presented in the form of case studies for specific focus regions.

In summary, during SECTOR, project partners have been able to produce torrefied biomass of a better and more constant quality, and consistent data sets on logistics and end-use performance contribute to increasing confidence levels amongst relevant stakeholders. Finally strategic aspects for market implementation of this promising innovative fuel need to be discussed, considering markets perspectives manifold both in the energy sector but also in the bioeconomy or in the chemical industry (e.g. by torrefaction co-product conditioning as organic based pesticide).

EUBCE 2015

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23rd European Biomass Conference & Exhibition

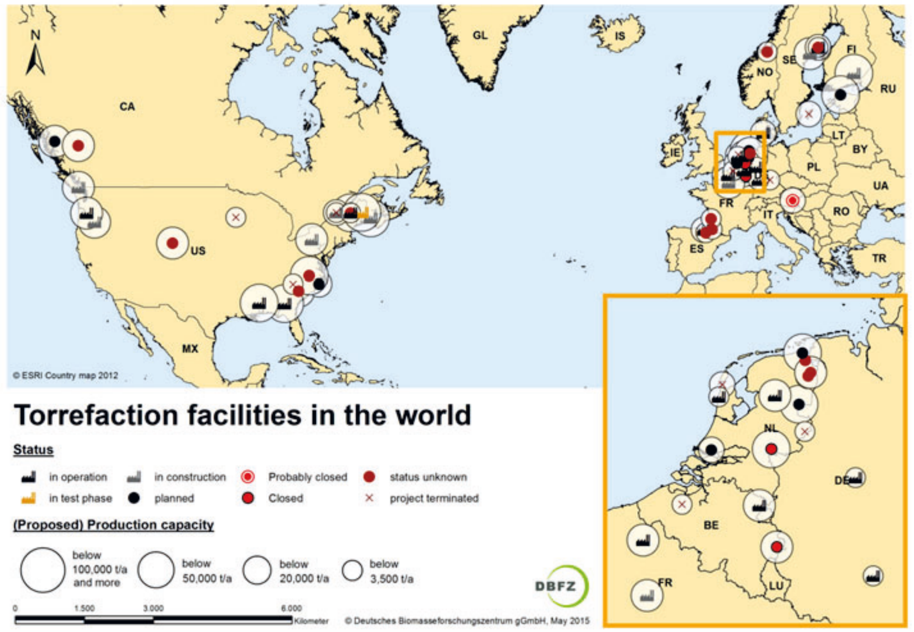
Torrefaction as a thermally treated process technology - State of the art and R&D results

J. Witt / K. Schaubach (DBFZ), D. Thraen (UFZ/DBFZ), M. Carbo/ J.Kiel (ECN)

3rd June 2015 – 23rd European Biomass Conference, Vienna
DBFZ Side Event „Thermally treated biofues"

Vienna, 1-4 June 2015

Distribution of (soon) operational torrefaction plants



3

Deutsches Biomasseforschungszentrum gemeinnützige GmbH

Vienna, 1-4 June 2015

Outline

- Background
- Highlights: torrefaction and densification
- Highlights: logistics and end use
- Highlights: value chains and standardisation
- Outlook: Market strategies and opportunities

2

Vienna, 1-4 June 2015

Latest large scale commercial role out plans

"...At this moment we are the only torrefied bio-coal plant project developers in Europe with a very clear vision. The ***capacity of our plant is definitely over 100 000 t/year****, because of economical reasoning perhaps even bigger and the amount of biomass available certainly would support it.*

We are ***supported by the NER300 program****, which means that the economical reasonability of the project is very well thought out and checked. "*

baltania

www.baltania.eu

Source: Jüri Roos,
Baltania, Mail
08.04.2015, baltania.eu

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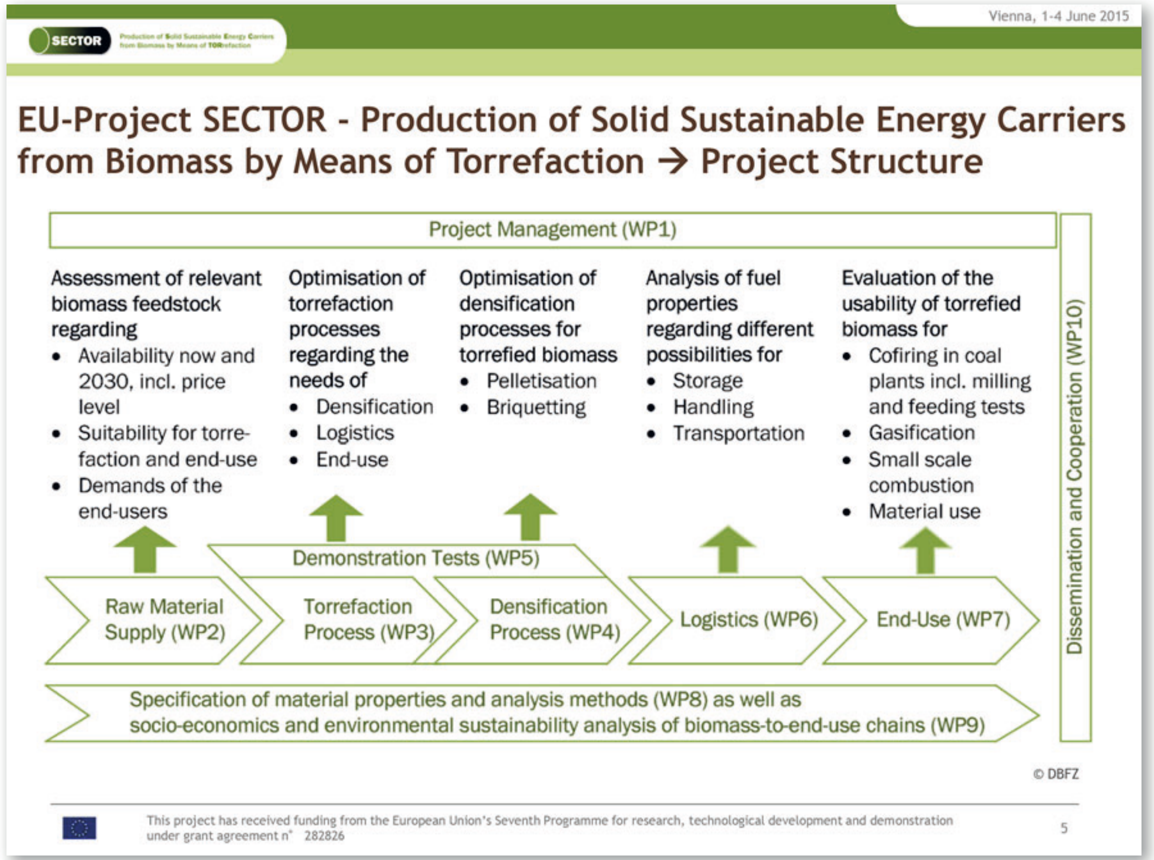
Vienna, 1-4 June 2015
SECTOR
EU-Project SECTOR - Production of Solid Sustainable Energy Carriers from Biomass by Means of Torrefaction → Project Structure
Project Management (WP1)
Assessment of relevant biomass feedstock regarding
• Availability now and 2030, incl. price level
• Suitability for torrefaction and end-use
• Demands of the end-users
Optimisation of torrefaction processes regarding the needs of
• Densification
• Logistics
• End-use
Optimisation of densification processes for torrefied biomass
• Pelletisation
• Briquetting
Analysis of fuel properties regarding different possibilities for
• Storage
• Handling
• Transportation
Evaluation of the usability of torrefied biomass for
• Cofiring in coal plants incl. milling and feeding tests
• Gasification
• Small scale combustion
• Material use
Demonstration Tests (WP5)
Raw Material Supply (WP2)
Torrefaction Process (WP3)
Densification Process (WP4)
Logistics (WP6)
End-Use (WP7)
Specification of material properties and analysis methods (WP8) as well as socio-economics and environmental sustainability analysis of biomass-to-end-use chains (WP9)
Dissemination and Cooperation (WP10)
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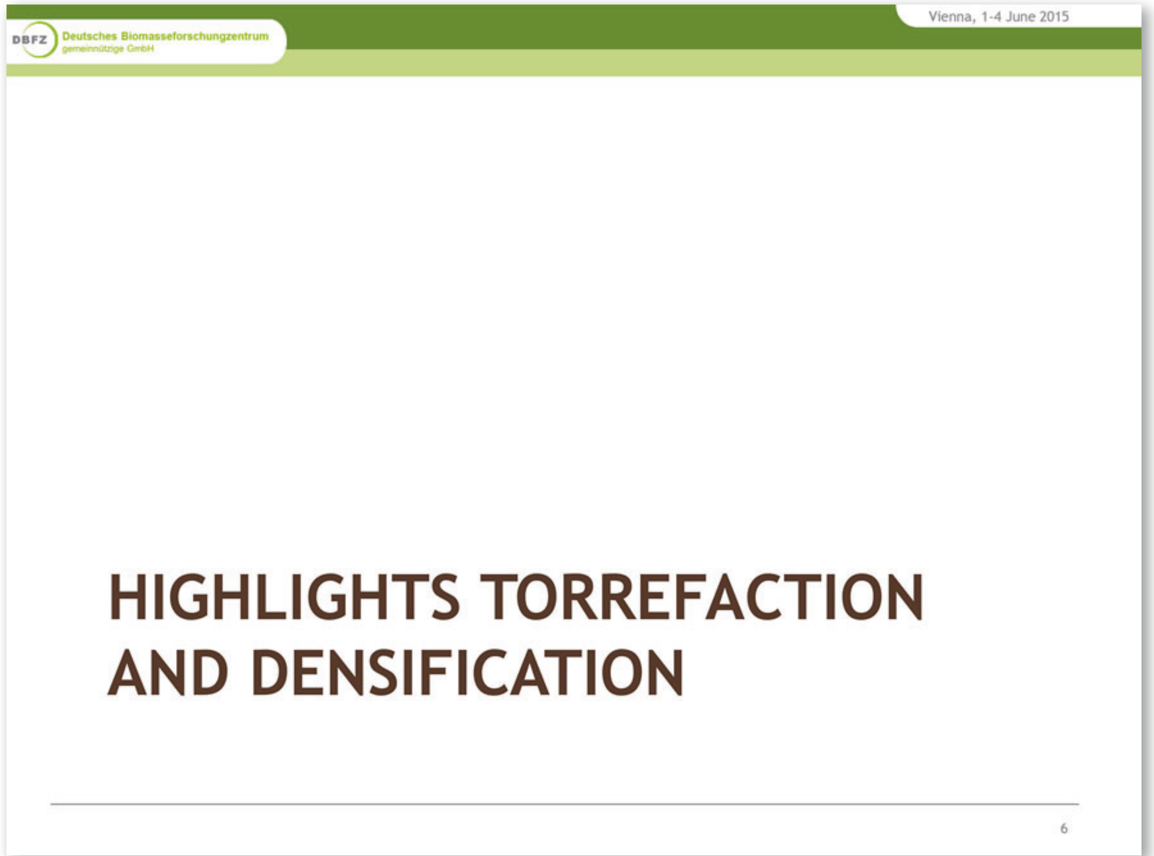
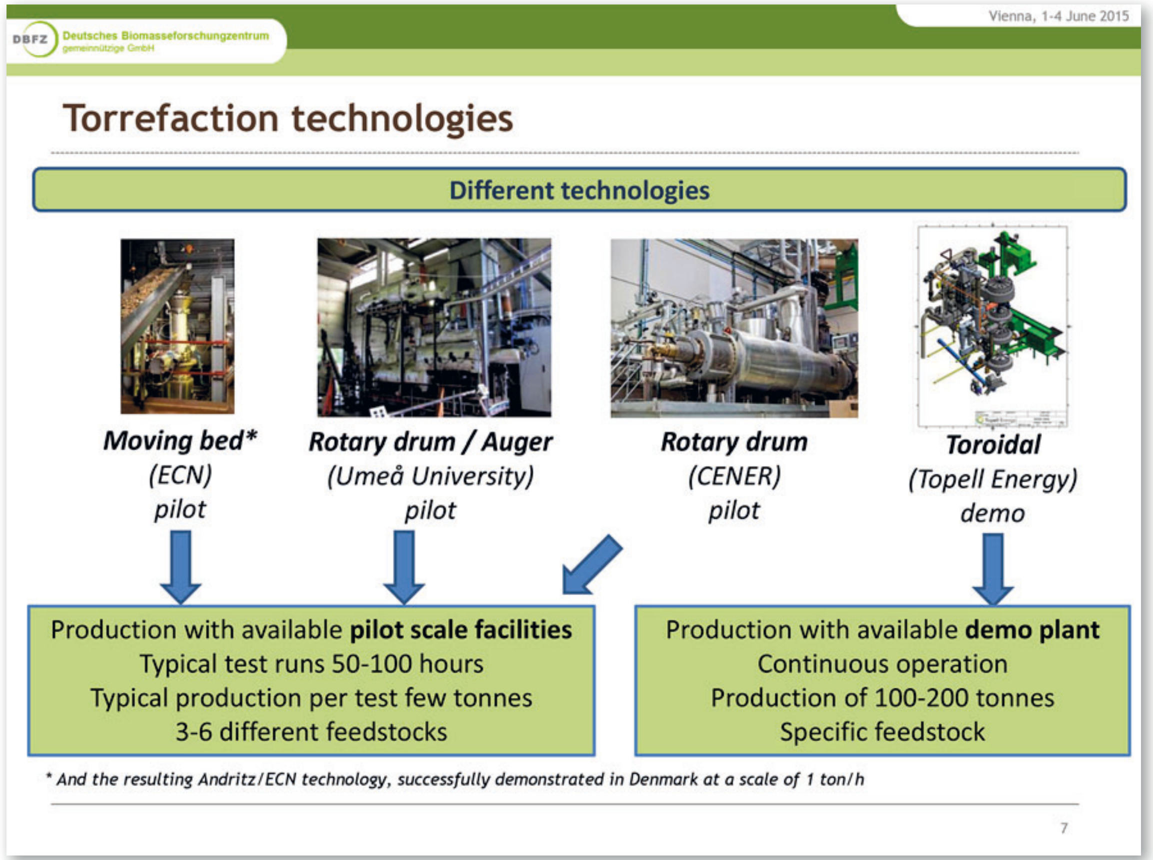
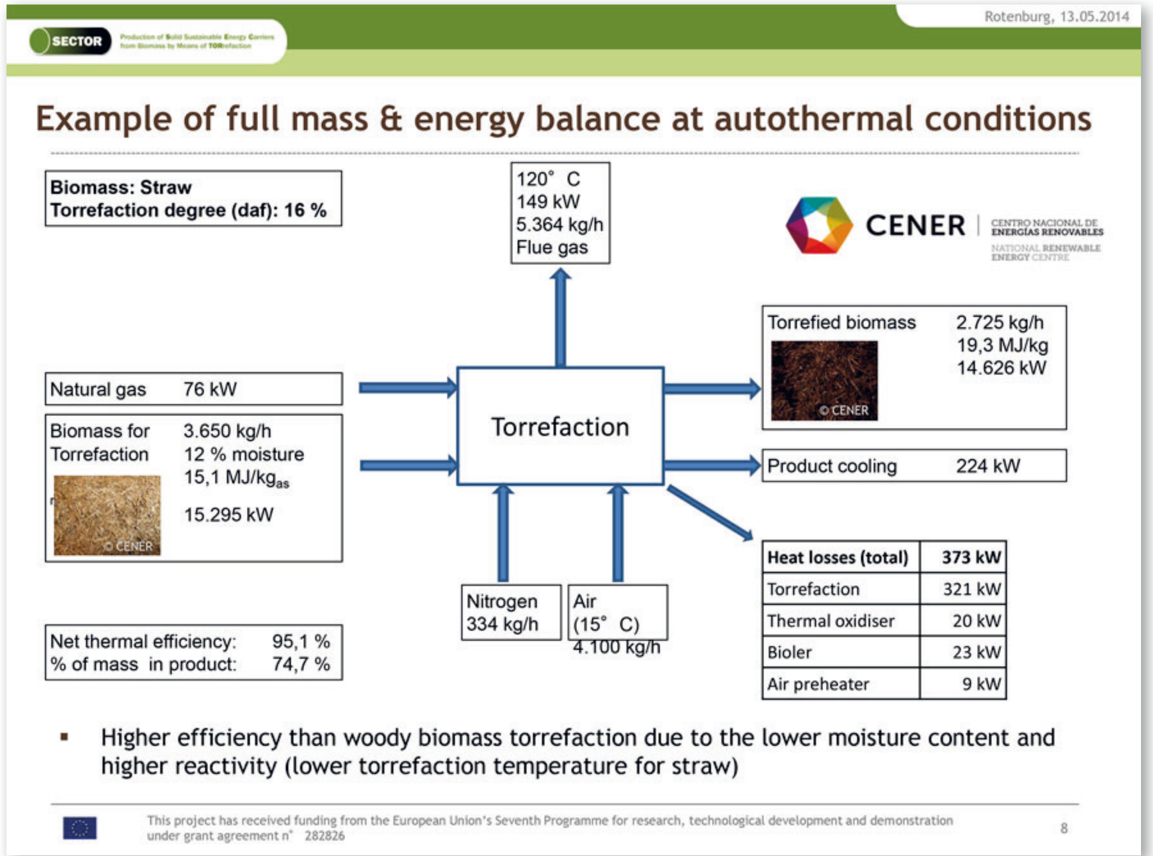
This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement n° 282826
5


Vienna, 1-4 June 2015
DBFZ Deutsches Biomasseforschungszentrum gemeinnützige GmbH
HIGHLIGHTS TORREFACTION AND DENSIFICATION
6


Vienna, 1-4 June 2015
DBFZ Deutsches Biomasseforschungszentrum gemeinnützige GmbH
Torrefaction technologies
Different technologies
Moving bed* (ECN) pilot
Rotary drum / Auger (Umeå University) pilot
Rotary drum (CENER) pilot
Toroidal (Topell Energy) demo
Production with available pilot scale facilities
Typical test runs 50-100 hours
Typical production per test few tonnes
3-6 different feedstocks
Production with available demo plant
Continuous operation
Production of 100-200 tonnes
Specific feedstock
* And the resulting Andritz/ECN technology, successfully demonstrated in Denmark at a scale of 1 ton/h
7


Rotenburg, 13.05.2014
SECTOR
Example of full mass & energy balance at autothermal conditions
Biomass: Straw
Torrefaction degree (daf): 16 %
120° C
149 kW
5.364 kg/h
Flue gas
CENER
Torrefied biomass 2.725 kg/h 19,3 MJ/kg 14.626 kW
Natural gas 76 kW
Biomass for Torrefaction 3.650 kg/h 12 % moisture 15,1 MJ/kg as 15.295 kW
Torrefaction
Product cooling 224 kW
Heat losses (total) 373 kW
Torrefaction 321 kW
Thermal oxidiser 20 kW
Bioler 23 kW
Air preheater 9 kW
Nitrogen 334 kg/h
Air (15° C) 4.100 kg/h
Net thermal efficiency: 95,1 %
% of mass in product: 74,7 %
Higher efficiency than woody biomass torrefaction due to the lower moisture content and higher reactivity (lower torrefaction temperature for straw)
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8

SECTOR

Vienna, 1-4 June 2015

Lab-scale and batch torrefaction tests

- Lab scale tests
  - TGA measurements on following feedstocks
    - ECN poplar, pine, spruce, bamboo
    - UmU pine, willow
    - CENER pine, straw
    - Bintuni mangrove
    - Viridis Energy PKS
    - Cradle Crops miscanthus
    - Anbenna sun flower husk
  - At following temperatures
    - 240, 260, 280, and 300°C
- Batch reactor tests
  - On following feedstocks
    - ECN poplar, pine, spruce, bamboo
    - UmU pine, willow
    - CENER straw
    - Bintuni mangrove
    - Viridis Energy PKS
    - Cradle Crops miscanthus
    - Anbenna sun flower husk
  - At following temperatures
    - 240, 255, 260, 270, 280, or 300°C

    (not all temperatures for all materials)

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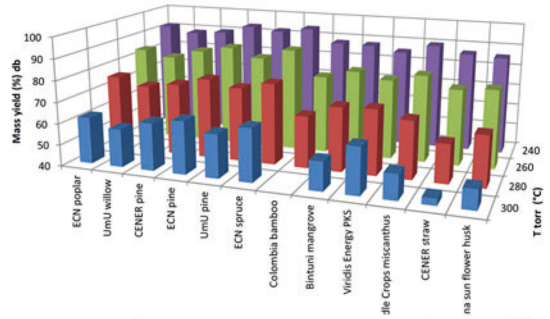
9

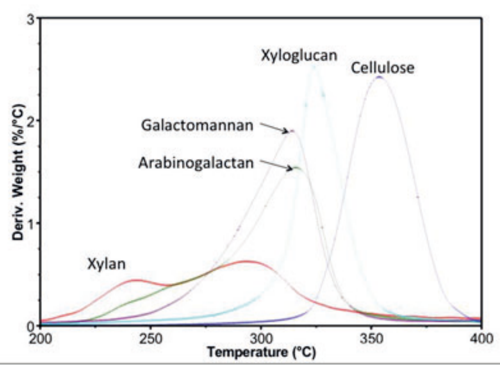
SECTOR

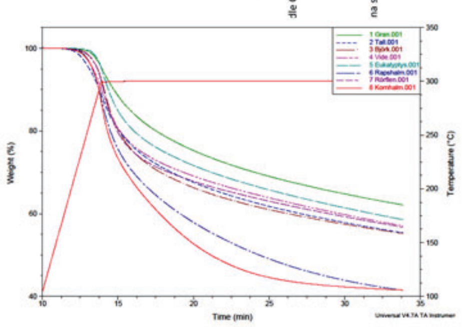
Vienna, 1-4 June 2015

Results of lab (TGA) and batch tests

- Mass yields
- Mass loss profiles
- Mass loss rate profiles (hemicelluloses)







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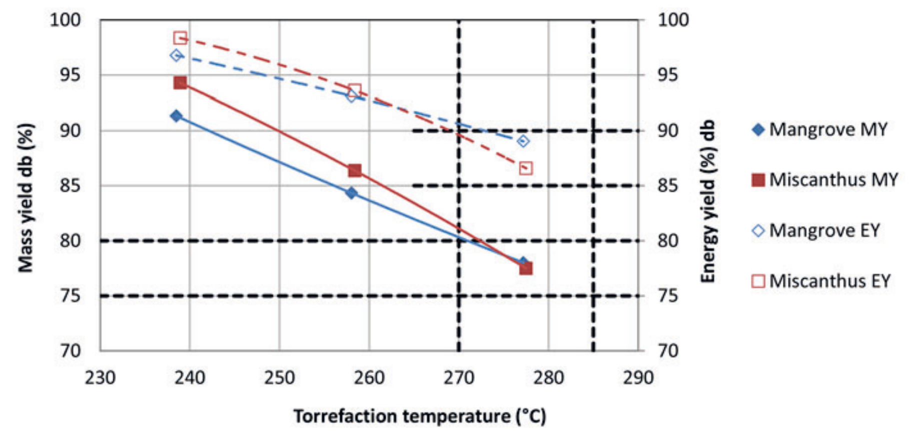
SECTOR

Vienna, 1-4 June 2015

Combined test results

- Mass yields and energy yields for determining working window

  e.g. mangrove and miscanthus (from batch reactor tests)



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11

SECTOR

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Pilot-scale torrefaction tests

- Net Thermal Efficiency (NTE) parameter is mainly influenced by biomass moisture content, mass yield of the torrefied product, energy integration and heat losses
- NTE values of cases including heat integration very similar

Partner	Torrefaction technology	Heat transfer type	Mass yield (% db)	Energy yield (% db)	Net thermal efficiency (%)	Thermal energy Consumption (kWh/kg[1])	Production capacity[2] (t/a)
CENER	Indirectly in- and externally heated rotating shaft	Indirect heating	79,0	90,5	92,1	0,46	31.041
UmU	Rotating drum	Indirect heating	75,7	87,9	83,6	0,30	114
ECN	Directly heated moving bed	Direct heating	81,3	87,6	92,4	0,34	112.682

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12

SECTOR Vienna, 1-4 June 2015

Demonstration tests: Topell

1. Goal: Improving the plant-process

2. Goal: Increasing product quality

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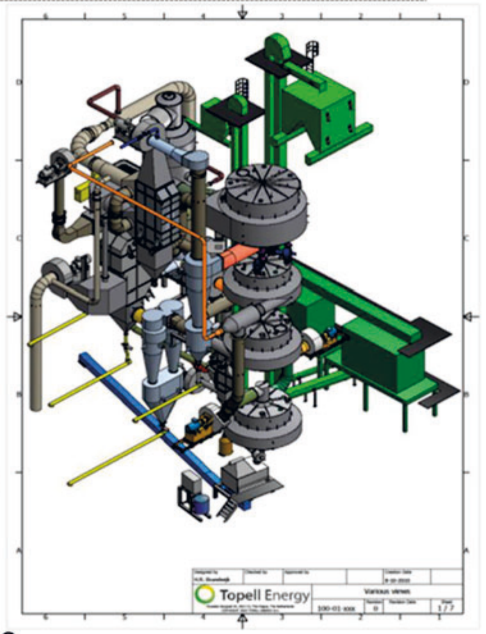
SECTOR Vienna, 1-4 June 2015

Demonstration tests at Topell: Achieved results

- **Plant**
  - Optimisation of torrefaction unit and densification island tested
  - All changes implemented commissioned and successfully tested
- **Process**
  - Successful production runs 4-6 tons/h
  - Developed production recipies for different feedstocks
  - Several thousands tons of pellets already produced
  - Pellets produced succesfully tested in power plant
  - Optimisation of biomass pre-conditioning and product quality accomplished ➲ leading position in the torrefaction market



14

SECTOR Vienna, 1-4 June 2015

Torrefaction process optimisation/integration

- Base Case: Stand-alone plant (50 MW_{th} torrefied wood pellets)
- Alternative 1:
  New sawmill and torrefaction integrated (158 MW_{th})
- Alternative 2:
  Existing sawmill and new torrefaction plant (72 MW_{th})
- Alternative 3:
  Existing CHP-plant (5 000 h/a) and new torrefaction plant (50 MW_{th})
- Alternative 4:
  Existing CHP-plant (3 500 h/a) and new torrefaction plant (50 MW_{th})
- Alternative 5:
  Existing pulp mill and new torrefaction plant (279 MW_{th})
- Alternative 6:
  Existing pulp and paper mill and new torrefaction plant (70 MW_{th})
- Alternative 7:
  Existing pulp and paper mill and new torrefaction plant (140 MW_{th})
- Alternative 8 & 9: Stand-alone plant in Nordic region and SE USA (343 MW_{th})

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SECTOR Vienna, 1-4 June 2015

Torrefaction process optimisation/integration

	Base Case	Alternative 1	Alternative 2	Alternative 5	Alternative 8	Alternative 9
Plant capacity, t torrefied pellets/a	72 800	231 600	101 100	407 200	500 000	500 000
Production costs of pellets, M€/a	19.3	48.8	24.3	82.5	104.2	87.6
Production costs of pellets, €/t	265	211	240	203	208	175
Production costs of pellets, €/MWh	43	34	38	33	34	29
Market price of wood pellets, €/MWh (PIX Pellet Nordic Index, 2012)	30	30	30	30	30	30
Price compared to base case, %	100	79	91	76	79	66
Price compared to market price, %	145	115	126	111	114	96

Legend: Stand- alone plants; Integrates

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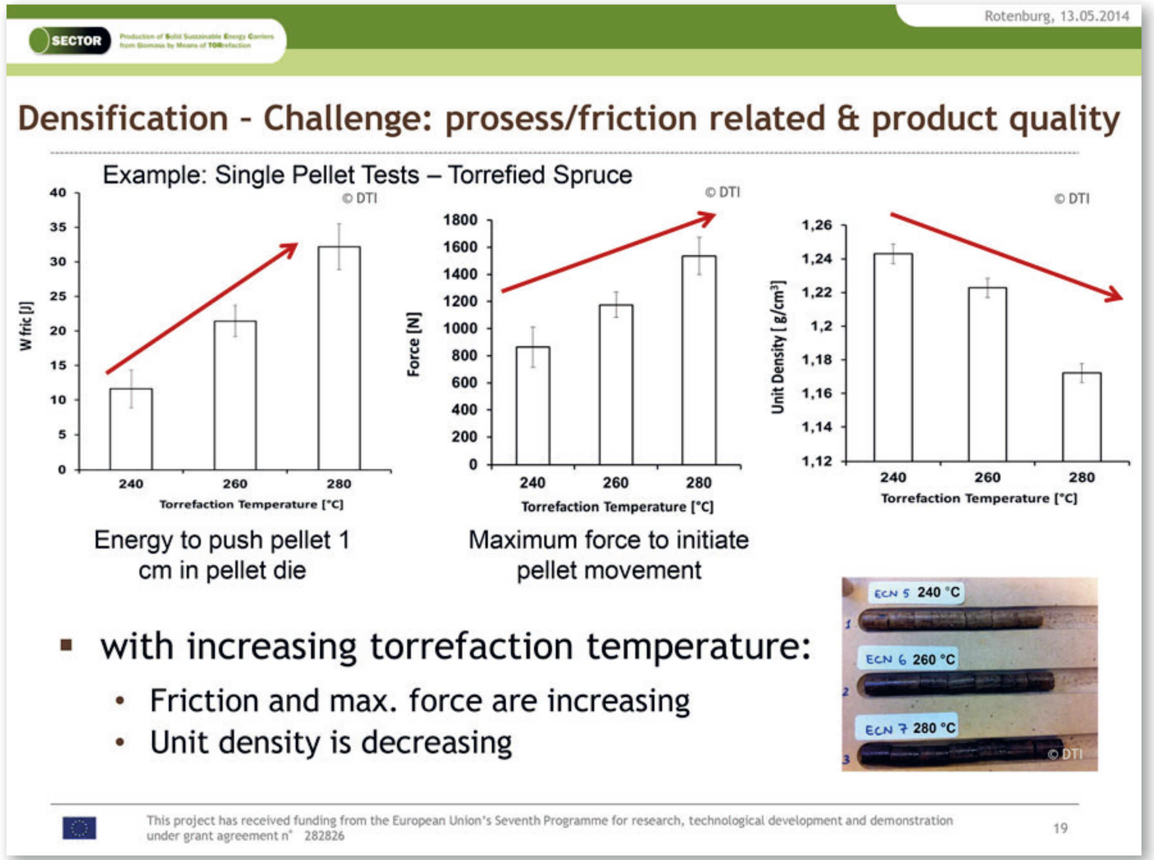
Rotenburg, 13.05.2014
SECTOR
Densification - Challenge: prosess/friction related & product quality
Example: Single Pellet Tests – Torrefied Spruce
© DTI
W fric [J]
Torrefaction Temperature [°C]
Energy to push pellet 1 cm in pellet die
Force [N]
Torrefaction Temperature [°C]
Maximum force to initiate pellet movement
Unit Density [g/cm³]
Torrefaction Temperature [°C]
ECN 5 240 °C
ECN 6 260 °C
ECN 7 280 °C
▪ with increasing torrefaction temperature:
• Friction and max. force are increasing
• Unit density is decreasing
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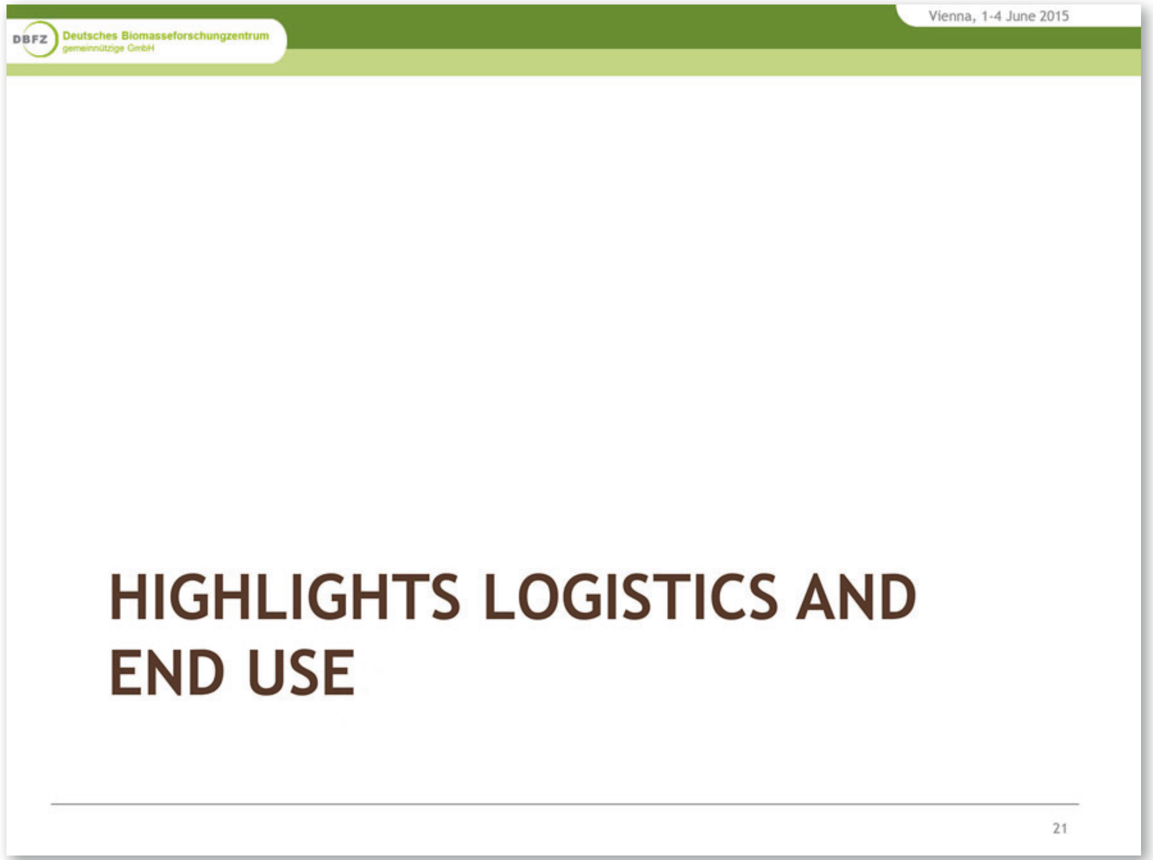
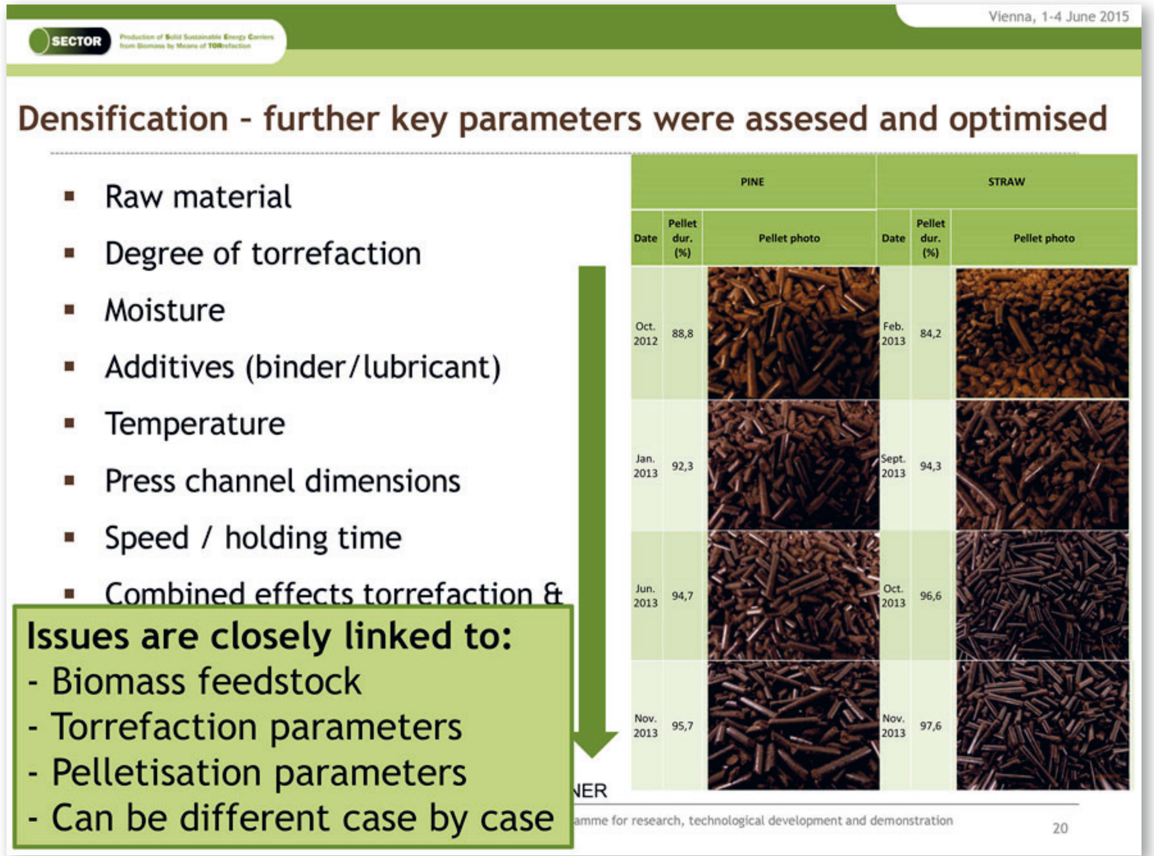
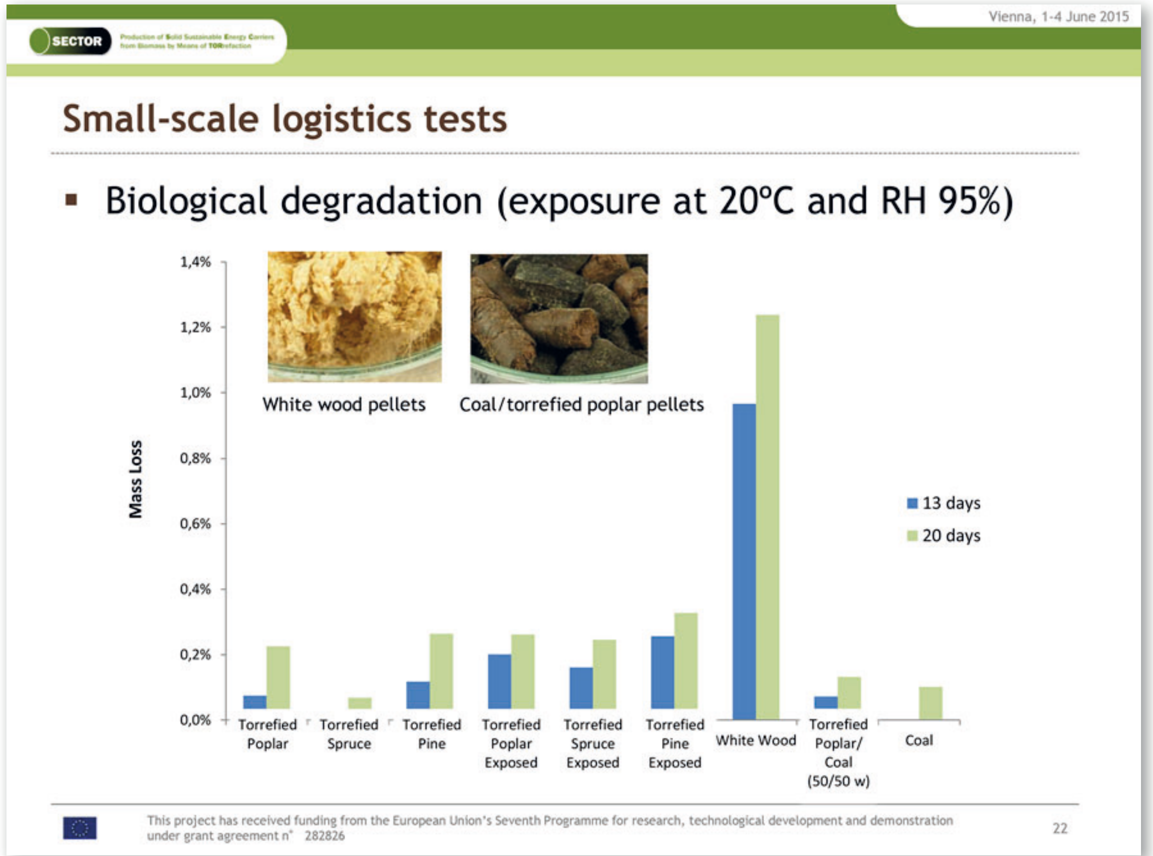

Vienna, 1-4 June 2015
DBFZ Deutsches Biomasseforschungszentrum gemeinnützige GmbH
HIGHLIGHTS LOGISTICS AND END USE
21


Vienna, 1-4 June 2015
SECTOR
Densification - further key parameters were assesed and optimised
▪ Raw material
▪ Degree of torrefaction
▪ Moisture
▪ Additives (binder/lubricant)
▪ Temperature
▪ Press channel dimensions
▪ Speed / holding time
▪ Combined effects torrefaction &
Issues are closely linked to:
- Biomass feedstock
- Torrefaction parameters
- Pelletisation parameters
- Can be different case by case
PINE
STRAW
Date
Pellet dur. (%)
Pellet photo
Oct. 2012 88,8
Jan. 2013 92,3
Jun. 2013 94,7
Nov. 2013 95,7
Feb. 2013 84,2
Sept. 2013 94,3
Oct. 2013 96,6
Nov. 2013 97,6
20


Vienna, 1-4 June 2015
SECTOR
Small-scale logistics tests
▪ Biological degradation (exposure at 20°C and RH 95%)
White wood pellets
Coal/torrefied poplar pellets
Mass Loss
13 days
20 days
Torrefied Poplar
Torrefied Spruce
Torrefied Pine
Torrefied Poplar Exposed
Torrefied Spruce Exposed
Torrefied Pine Exposed
White Wood
Torrefied Poplar/ Coal (50/50 w)
Coal
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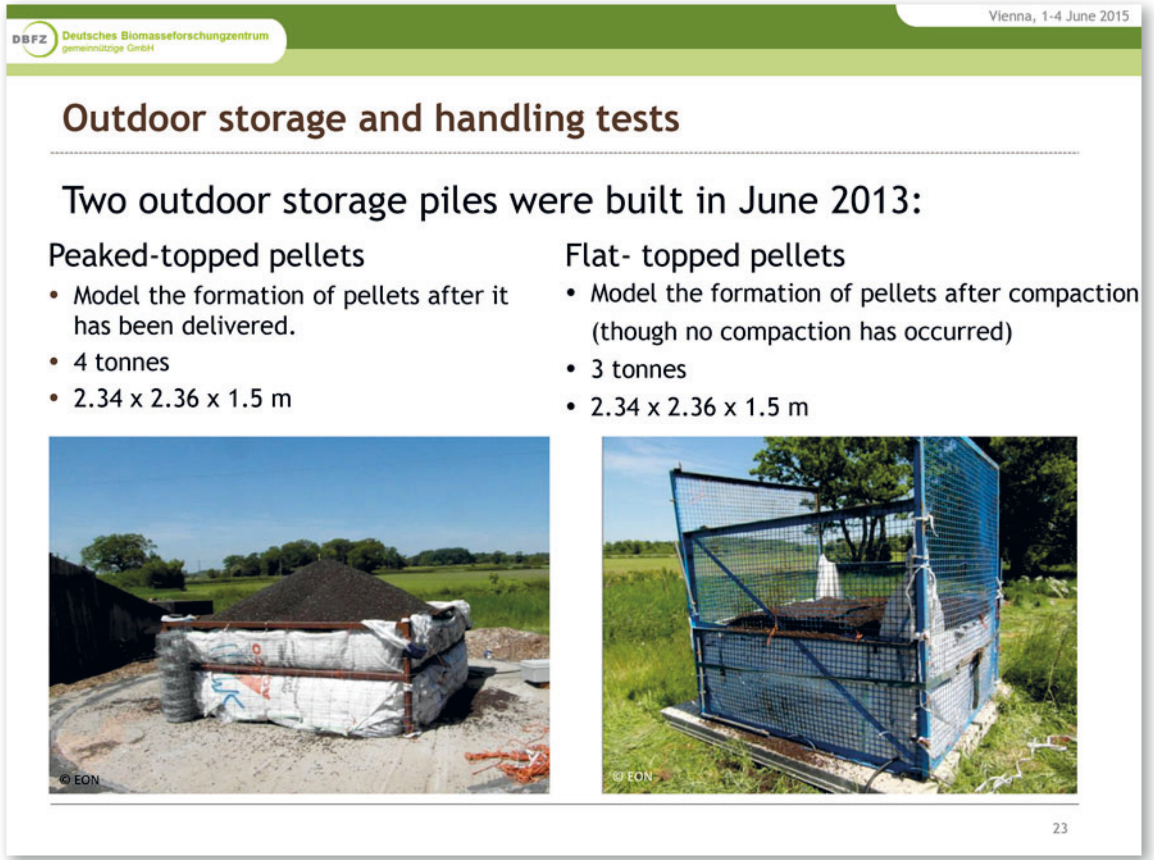
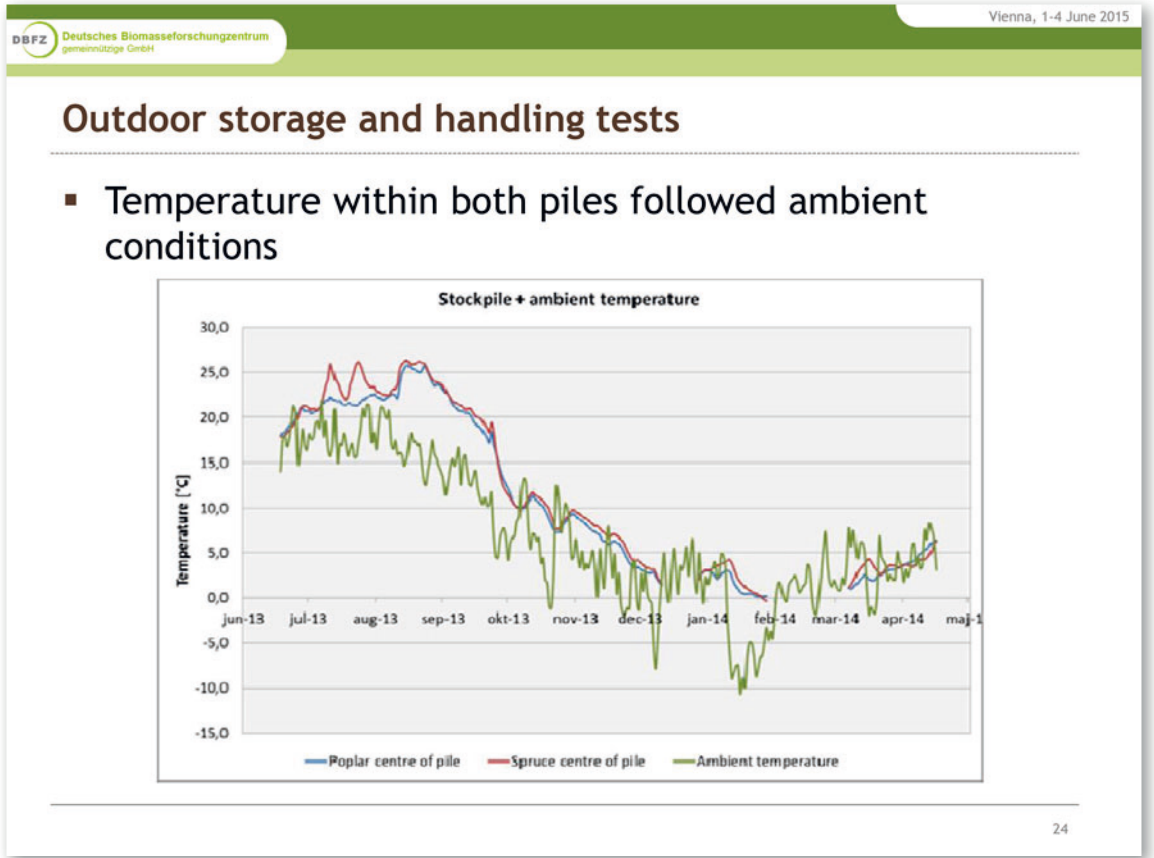
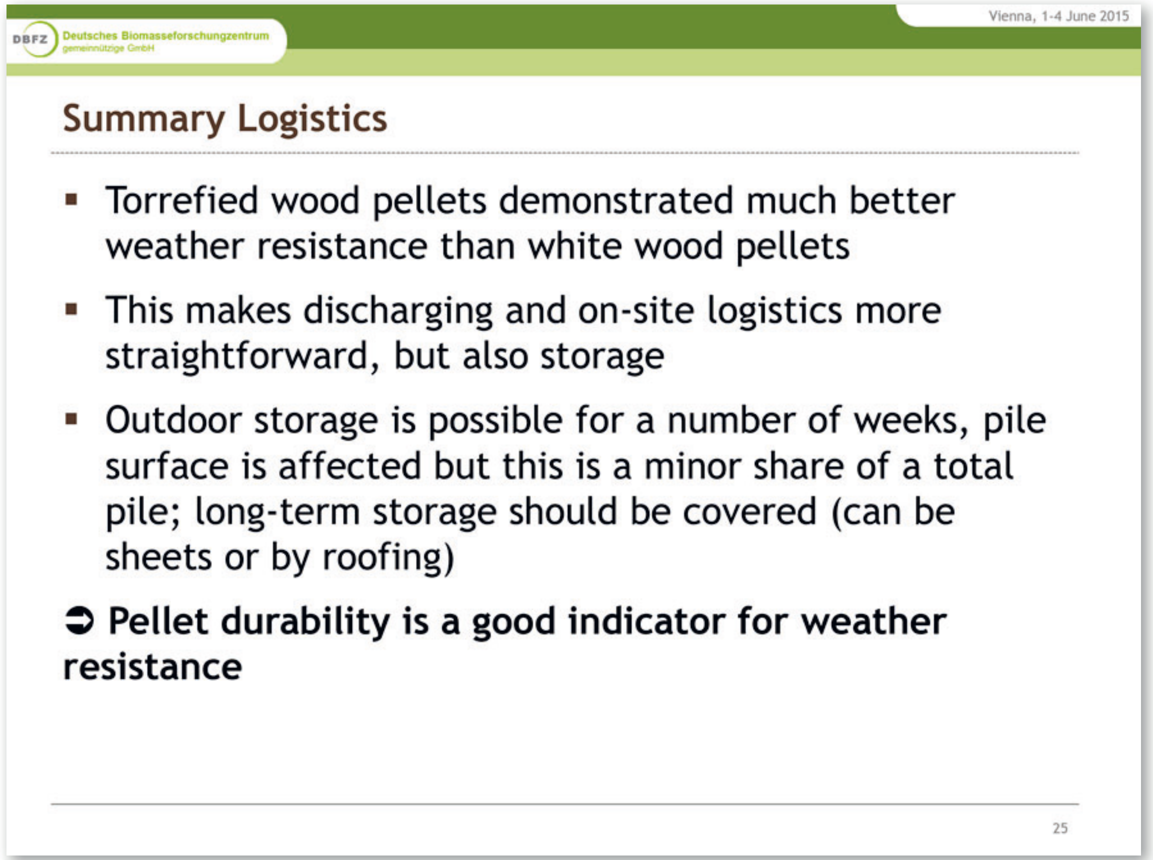
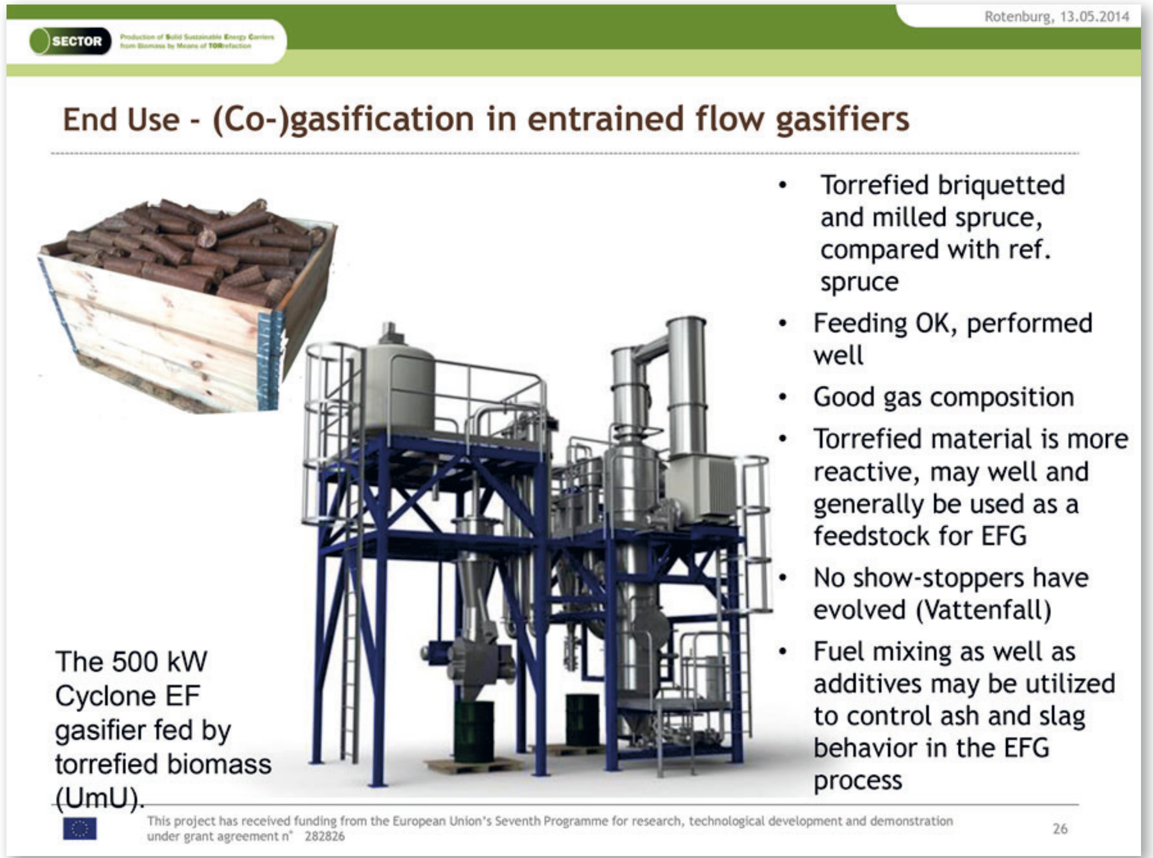

Deutsches Biomasseforschungszentrum gemeinnützige GmbH
Vienna, 1-4 June 2015
Outdoor storage and handling tests
Two outdoor storage piles were built in June 2013:
Peaked-topped pellets
• Model the formation of pellets after it has been delivered.
• 4 tonnes
• 2.34 x 2.36 x 1.5 m
Flat- topped pellets
• Model the formation of pellets after compaction (though no compaction has occurred)
• 3 tonnes
• 2.34 x 2.36 x 1.5 m
© EON
© EON
23


Deutsches Biomasseforschungszentrum gemeinnützige GmbH
Vienna, 1-4 June 2015
Outdoor storage and handling tests
▪ Temperature within both piles followed ambient conditions
Stockpile + ambient temperature
Temperature [°C]
30,0
25,0
20,0
15,0
10,0
5,0
0,0
-5,0
-10,0
-15,0
jun-13 jul-13 aug-13 sep-13 okt-13 nov-13 dec-13 jan-14 feb-14 mar-14 apr-14
Poplar centre of pile
Spruce centre of pile
Ambient temperature
24


Deutsches Biomasseforschungszentrum gemeinnützige GmbH
Vienna, 1-4 June 2015
Summary Logistics
▪ Torrefied wood pellets demonstrated much better weather resistance than white wood pellets
▪ This makes discharging and on-site logistics more straightforward, but also storage
▪ Outdoor storage is possible for a number of weeks, pile surface is affected but this is a minor share of a total pile; long-term storage should be covered (can be sheets or by roofing)
➲ Pellet durability is a good indicator for weather resistance
25


SECTOR
Rotenburg, 13.05.2014
End Use - (Co-)gasification in entrained flow gasifiers
• Torrefied briquetted and milled spruce, compared with ref. spruce
• Feeding OK, performed well
• Good gas composition
• Torrefied material is more reactive, may well and generally be used as a feedstock for EFG
• No show-stoppers have evolved (Vattenfall)
• Fuel mixing as well as additives may be utilized to control ash and slag behavior in the EFG process
The 500 kW Cyclone EF gasifier fed by torrefied biomass (UmU).
This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement n° 282826
26

SECTOR — Rotenburg, 13.05.2014

End Use - (Co-)gasification in entrained flow gasifiers

Vattenfall presents results from tests performed outside SECTOR in 2012 in the Plant "Willem Alexander Centrale" in Buggenum / The Netherlands

Plant:

- A 253 MW(el) power plant, entered service in 1993 as a coal gasification demonstration plant
- Hard coal as main fuel but continuous co- gasification of saw dust up to 15% (wt.)
- Co- gasification of thermally treated wood was tested at the plant:
  - Torrefaction product
  - Steam explosion product

Execution:

- Approximately 1200 tons of torrefied fuel was co- gasified together with hard coal in a ~24 hrs test campaign.
- The mixing rate was ~70% on energy basis.
  - Logistics
  - Milling
  - Off gas treatment of Coal Mill Dry installation
  - Sluicing
  - Nitrogen usage

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SECTOR — Karlsruhe, 21st May 2015

Highlights: End use - Co-gasification

- Unloading, storage, reclaiming, blending with coal and conveying of the torrefied pellets with the existing mechanical installation was basically possible.
- Necessary to install new dust suppression equipment
- The milling was not an important issue - sufficiently high grindability of the tested torrefied pellets.
- The sluicing and feeding system worked stable, no problems were reported.
- With a torrefied material with higher heating value (estimated on 22 MJ/kg) and good quality it will be possible to reach nearly the original power output → test plant ~230 MW_{el} at the 70 % co-gasification with small hardware modifications, adjustments and fine-tuning.
- Impact on the syngas was in the line with expectations, fouling was no issue
- The fly ash system worked stable

➲ **GENERALL FEEDBACK: Several smaller adaptions needed but no game-stoppers identified**

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SECTOR — Rotenburg, 13.05.2014

End Use - Co-firing in pulverised-fuel boilers (PC)

- Co-firing tests (10%, 25%, 50%, 75% as well as 100%) at USTUTT's 20 and 500 kW facilities with focus on emissions, burn-out, staging, deposition, fouling and corrosion.
  - Brown Coal (LaTBK) and Colombian hard coal (El Cerrejon) material were assessed. Torrefied pellets (wood mix, spruce, beech and pine) and reference white wood pellets.
  - Results show that **burnout improves during co-firing of torrefied fuels and no negative impacts on flame stability and process controllability were obeserved.**
- Lab-scale combustion experiments at ECN (100% thermal share, end-point kinetics) performed for 3 different torrefied materials
- Further large scale co-firing and logistic test are scheduled for summer 2014

KSVA(500 kW), USTUTT

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SECTOR — Vienna, 1-4 June 2015

Highlights: End use - Co-firing

- Combustion trials done at pilot scale in two setups, providing fundamental insight in combustion behavior, LOI, emissions, deposition aspects, etc.
- Validated CFD model used to extrapolate effects on full scale PC boilers
- Detailed insight made available into required modifications to enable torrefied biomass in two PC boilers

➲ **GENERALL FEEBACK: Results showed that all impacts can be dealt with, after minor plant modifications; transferability on other boilers can be quickly evaluated**

CHP coal plant in Helsinki, FIN; output 220 MWel, 420 MWth ➲ cofiring tests within SECTOR (79 t torrefied material)

Hanasaari power plant B,

Vienna, 1-4 June 2015

Highlights: End use - small scale boilers

In principle torrefied pellets can be applied in commercial small-scale wood pellet boilers

- Torrefied wood pellets have the potential to provide at least the same or even a higher combustion efficiency as achievable with wood pellets

Boiler technology	CO during start	Mass on grate	Temperature on grate	Power output	Air excess ratio
	+ 590 %	+ 40 %	+ 79°C	**+ 9 %**	+ 2 %
	+ 30 %	**+ 100 %**	**+ 94°C**	+ 6 %	- 3 %
	+ 20 %	n.d.	+ 47°C	+ 4 %	**- 6 %**
	+ 220 %	**+ 130 %**	**+ 158°C**	+ 3 %	- 4 %

Explanations: percentage shown are related to torrefied pellets in comparison to conventional softwood pellets (=100%)

Vienna, 1-4 June 2015

Highlights: End use - small scale boilers

In principle torrefied pellets can be applied in commercial small-scale wood pellet boilers

- Torrefied wood pellets have the potential to provide at least the same or even a higher combustion efficiency as achievable with wood pellets
- Modifications especially regarding process control are needed
- However: In principle, it is not permitted to operate the heating systems with fuels which are not certified by the boiler manufacturers
- Further test are needed: long term field tests over a full heating period with torrefied pellets before approval of these fuels

➲ **Close cooperation with boiler manufacturers is required to make torrefied fuels suitable for small-scale pellet boilers**

This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement n° 282826

32

Rotenburg, 13.05.2014

Highlights End Use - Production of chemicals or biomaterials

- Differences in the amounts and compositions of condensates between the feedstocks and the temperature phases were obtained.
- The high final temperature proved to be critical, because at 290 °C strong exothermic reactions occurred decreased the yield of torrefied material and produced tarry condensates.
- Condensates obtained at <240 °C are promising, for example, to be used as biodegradable pesticides to replace synthetic ones.
- The condensates obtained at higher temperatures may have potential in wood protection.

➲ **The quality and utilisation potential of the condensates can be affected by the temperature phases.**

This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement n° 282826

33

DBFZ Deutsches Biomasseforschungszentrum gemeinnützige GmbH

Vienna, 1-4 June 2015

HIGHLIGHTS STANDARDISATION AND VALUE CHAINS

34

Deutsches Biomasseforschungszentrum gemeinnützige GmbH — Vienna, 1-4 June 2015

Highlights: Standardisation

Fuel specification and analysis

- Standardisation work – proposal for a product standard including fuel specifications for torrefied material - ISO 17225-8
- Validation of existing methods for applicability for torrefied material
- Development of new methods for a better description of torrefied material
- Development of generall MSDS based on REACH
- Two international Round Robins oranised (43 and 31 participants,17 parameters)

Methods developed / tested, e.g.

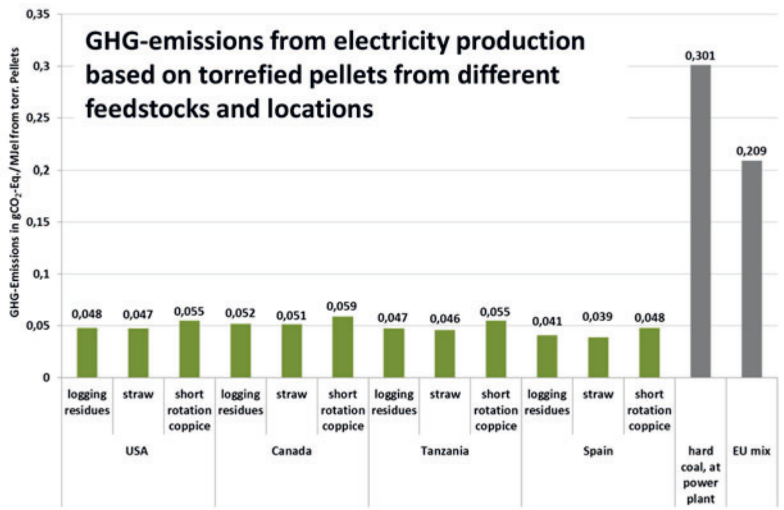
- Water absorption
- Grindability
- Degree of torrefaction
- Leaching behavior
- TGA
- NIR
- Flowability and size distribution

35

Deutsches Biomasseforschungszentrum gemeinnützige GmbH — Vienna, 1-4 June 2015

Highlights: Value chains and sustainability

- Economic and environmental characterisation of various (torrefied)-biomass-to-end-use-chains, e.g.



Results indicate that the emissions from the production of torrefied pellets are mainly driven by the demand and the origin of process energy for torrefaction and densification. Significant GHG emission savings compared to conventional CHP-production by using biomass for process heat supply.

36

Deutsches Biomasseforschungszentrum gemeinnützige GmbH — Vienna, 1-4 June 2015

Highlights: Value chains and sustainability

- Economic and environmental characterisation of various (torrefied)-biomass-to-end-use-chains
- Development and discussion of deployment scenarios for torrefied biomass
- Assessment of existing certification schemes for sustainable biomass production with regards to quality and comprehensiveness → proposal with improvement options
- Development of the BioChainS tool which allows to compare the economic performance of (torrefied)-biomass-to-end-use-chains

37

Deutsches Biomasseforschungszentrum gemeinnützige GmbH — Vienna, 1-4 June 2015

STRATEGY AND PERSPECTIVES FOR MARKET IMPLEMENTATION

38

Vienna, 1-4 June 2015

Torrefaction schedule to market implementation

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

BUT: Time has changed in the global biomass business, industrial market implementation might come later than expected and after SECTOR finalization

→ Original research **focus on large scale applications** (power market

→ NOW: **orientation towards alternative markets** (e.g. small and medium heating and CHP application

→ **Additionally intermediate product** for transport fuel market and / or bioeconomy sector

STILL REQUIRED: Investors are needed to build up commercial plants

39

Vienna, 1-4 June 2015

Perspectives for market implementation

- Torrefaction **technologies are manifold on the start but only few developers are able to provide a commercial offer for the realisation of a full scale plant.**
- **Barriers to market implementation:**
  - Low price for coal and CO_2-emission allowances vs high biomass price
  - When cofiring / co-gasification, then power plant operators see advantage in use of established / commodity biofuel ➲ white pellets
  - Existing investments of power plant operators in white pellet application (nearly same delivery costs per GJ, outside storage advantage of torrefied fuel covers not additional cost and disadvantage of dirty handling)
  - Project funding of commercial torrefaction plants to supply cofiring plants
- **Prospective markets currently:**
  - Countries in which supporting schemes exists for biomass cofiring or the use of 100% biomass fuels in large scale applications (e.g. UK, NL, BEL)
  - Countries in which the large scale biomass use starts now; thus appropriate infrastructure and plant modification to torrefied material can directly installed (e.g. Asia, South Africa) ➲ lower CAPEX

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40

Vienna, 1-4 June 2015

So, what to do...

- **Attractive markets perspectives:**
  - **Heating /CHP market**, due to the higher willingness to pay by end users → However, when introducing into small & medium scale market a separate delivery structure for torrefied fuel has to be established (no direct fuel supply from producer site and in parallel to the white pellets distribution network) ➲ no combined transport and storage facilities for black & white pellets
  - **High value applications**, e.g. bioeconomy sector, 2nd generation biofuels
- **Improving the market frame conditions for the application of torrefied biomass**
  - Attractive and stable EU and national policies ➲ SECTOR/BioBoost Policy WS 16./17.06.2015

This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement n° 282826

41

Vienna, 1-4 June 2015

SECTOR and BioBoost Policy Workshop in Brussels!

Date: 16. and 17. June 2015

Programme 16.6.15 – Policy session

14:00 **Welcome Address** *Maria Georgiadou, DG RTD*

14:15 **Bioenergy in the European Context** *Paul Verhoef, DG RTD (invited)*

14:45 **Perspectives for advanced Bioenergy Carriers** *Daniela Thrän,*

15:15 **Coffee Break**

15:45 **Panel Discussion**

Markets and regulatory framework for bioenergy and bioproducts

Paul Verhoef, European Commission (invited)
Daniela Thrän, DBFZ

Hubert Röder, Hochschule Weihenstephan-Triesdorf

Marijn Rijkers, DSM ChemTech BV

Ilmari Lastikka, Neste Oil

18:00 **Reception**

Programme 17.6.15 – Technology session

09:00 **Introduction and FP7 goals** *Jaap Kiel*

09:10 **SECTOR: Goals, Work Programme Achievements** *Daniela Thrän*

09:20 **BioBoost: Goals, Work Programme Achievements** *Nicolaus Dahmen*

09:30 **Technology Achievements SECTOR and BioBoost** *Anders Nordin, Angelos Lappas CPERI/CERTH*

10:30 **Coffee Break**

11:00 **BioBoost Specials: Tools, Value Chains, Economics and Sus tainability** *Erik Pitzer, FHOÖ*

11:30 **SECTOR Specials: Value Chains, Economics and Sustainability** *Michiel Carbo/ Stefan Majer*

12:00 **Panel Discussion: obstacles and solutions for market introduction**

Jaap Kiel, Kay Schaubach, Nicolaus Dahmen, Eija Alakangas, Michiel Carbo, Angelos Lappas

12:45 **Summary and Recommendation** *Jaap Kiel*

Register at www.sector-project.eu/policyworkshop

This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement n° 282826

42

SECTOR Production of Solid Sustainable Energy Carriers from Biomass by Means of TORrefaction — Vienna, 1-4 June 2015

So, what to do…

- **Attractive markets perspectives:**
  - **Heating /CHP market**, due to the higher willingness t… …users → However, when introducing into small S… …market a separate delivery structure for tor… …to be established (no direct fuel supply from produ… parallel to the white pellets distribution network) ➲ n… transport and storage facilities for black & white pellets
  - ➲ Delivery of limited high quality material to high end use applications
  - **High value applications**, e.g. bioeconomy sector, 2nd generation biofuels
- **Improving the market frame conditions for the application of torrefied biomass**
  - Attractive and stable EU and national policies ➲ SECTOR/BioBoost Policy WS 16./17.06.2015
  - Transparent and fixed sustainability requirements for solid biomass
  - Handling of REACH requirements ➲ SECTOR contribution, MSDS-development in cooperation with IBTC
  - Adaption of national regulations (e.g. German emission standards to integrate torrefied fuels; boiler type license to apply torrefied fuels)

➲ **SECTOR contributes to shorten the time to market implementation**

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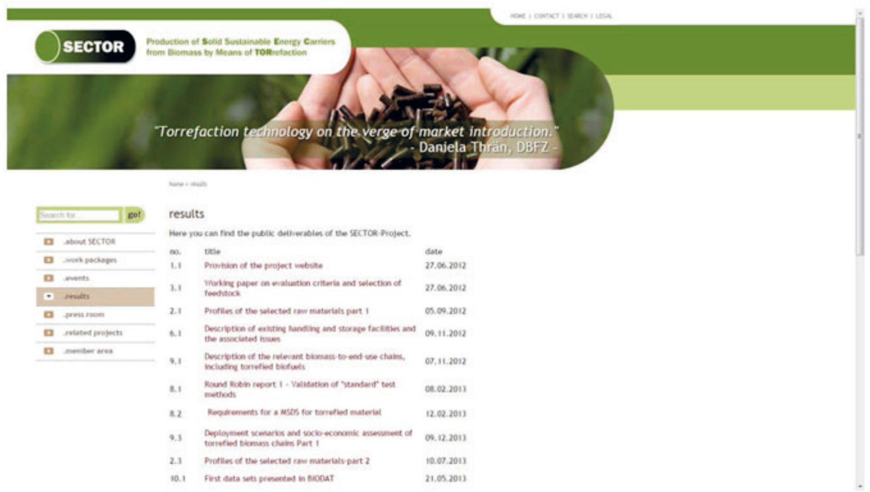
SECTOR Production of Solid Sustainable Energy Carriers from Biomass by Means of TORrefaction — Vienna, 1-4 June 2015

… more SECTOR results - report collection

www.sector-project.eu



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gemeinnützige GmbH

Thank you for your attention!

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More SECTOR results:
www.sector-project.eu

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Prof. Dr. Jaap Kiel, ECN

Torwash Technology

Prof. Dr. Jaap Kiel, Jan Pels, Michiel Carbo, Pavlina Nanou
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TORWASH is a new technology that is under development at ECN. TORWASH integrates torrefaction (roasting) with drying and washing. TORWASH technology converts bulky, wet and salty biomass feedstocks into an energy dense biomass fuel. Suitable feedstocks are grass and agro-residues, and possibly forest residues. Direct application of these materials as biomass fuels is difficult and leads to some practical problems:

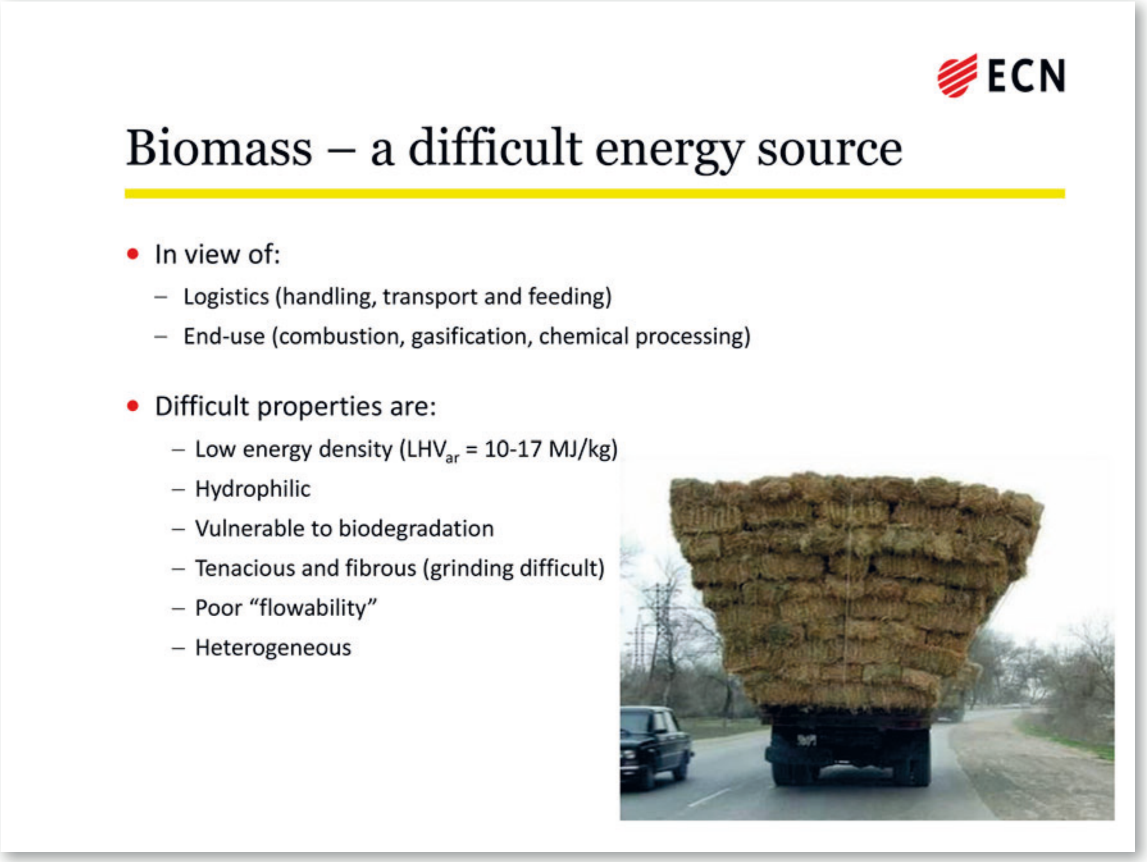
- high transportation costs
- corrosion, slagging and fouling due to high salt concentrations, in particular (K and Cl)
- low efficiency due to high moisture content
- seasonal harvesting and biological degradation during storage
- milling and feeding problems

The product of TORWASH is a solid fuel equivalent to clean torrefied wood pellets. TORWASH is complementary to dry torrefaction because it uses feedstocks that have high contents of water and salts. At the moment ECN has finished the first laboratory phase (proof of principle) and is designing a pilot installation (proof of concept).

In recent years, TORWASH has been successfully applied at laboratory scale for the following materials:

- wet agro-residues and wet waste streams from the food industry
- grass, reeds and clippings in general
- digestate and fermentation residue

Salt removal of over 98% has been accomplished. Pellets with 60-70% dry matter have been made by applying mechanical dewatering; no binder was needed. After further drying, the pellets showed good to excellent grinding behaviour. TORWASH is able to upgrade grass and reed to top-class (EN plus A1) energy pellets.



EUBC&E 2015 | Side-Event "Thermally treated biofuels"

(Dry) Torrefaction

ECN

An excellent proposition for many biomass feedstocks ....

	Wood chips	Wood pellets	Torrefied wood pellets	Charcoal	Coal
Moisture content (wt%)	30 – 55	7 – 10	1 – 5	1 – 5	10 – 15
Calorific value (LHV, MJ/kg)	7 – 12	15 – 17	18 – 24	30 – 32	23 – 28
Volatile matter (wt% db)	75 – 85	75 – 85	55 – 80	10 – 12	15 – 30
Fixed carbon (wt% db)	16 – 25	16 – 25	20 – 40	85 – 87	50 – 55
Bulk density (kg/l)	0.20 – 0.30	0.55 – 0.65	0.65 – 0.80	0.18 – 0.24	0.80 – 0.85
Vol. energy density (GJ/m^3)	1.4 – 3.6	8 – 11	12 – 19	5.4 – 7.7	18 – 24
Hygroscopic properties	Hydrophilic	Hydrophilic	(Moderately) Hydrophobic	Hydrophobic	Hydrophobic
Biological degradation	Fast	Moderate	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
LHV =Lower Heating Value

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

(Dry) Torrefaction

ECN

.... and on the verge of commercial market introduction ....

- >10 demo-units and first (semi-) commercial units in operation
- Successful co-firing trials help to build end-user confidence and allow product quality optimisation (e.g., at Vattenfall-Buggenum (NL), RWE-Amer 9 (NL), DONG-Studstrup 3 (DK), HELEN-Hanasaaren (FI))
- Example: Andritz-ECN torrefaction technology successfully demonstrated at 1 ton/h scale in Sdr. Stenderup, Denmark, and now ready for commercial market introduction

4

(Dry) Torrefaction

ECN

.... but limitations for wet and "salty" biomass!

- Problems with "salty" biomass
  - Difficulties in combustion and gasification
    - > chlorine = corrosion
    - > potassium = slagging, fouling and agglomeration
  - Difficulties in ash utilization, e.g., in building materials
    - > bad fuel quality = bad ash quality
    - > chlorine first element to cause problems
    - > alternative: land filling at high costs
- Solution: Wash chlorine and potassium from the fuel
  - *Washing biomass is done already!*
    - > not all is removed – bound in cells, poor access
    - > resulting 'fuel' is soaking wet – drying very energy-intensive

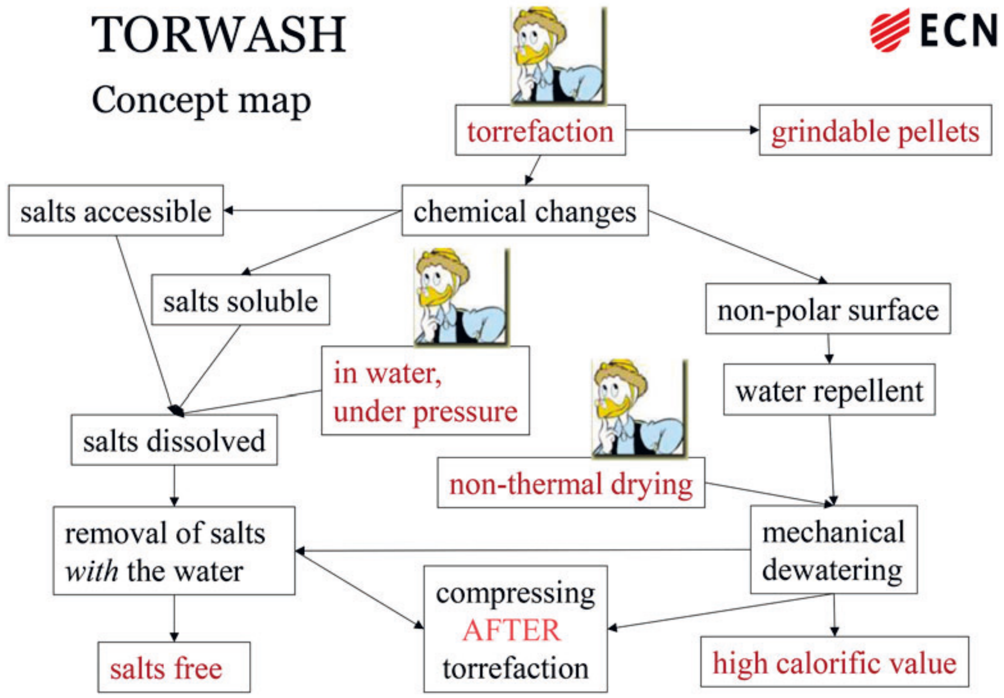
Key question: How can we combine washing (and drying) and torrefaction in an energy-efficient and economic way?

5

TORWASH

ECN

Concept map



But what about the effluent?

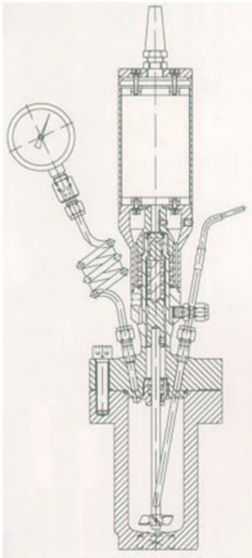
6

Wet torrefaction (TORWASH)

TORWASH unit operation

ECN

- Mild hydrothermal treatment (biomass in water at elevated temperature and pressure)
  - Temperature 150-250°C – depends on feedstock
  - Pressure = steam pressure + little bit CO_2
  - Residence time 10-30 minutes
  - L/S ratio about 7-10 litre per kg dry matter
  - No additives
  - **Max energy in the solid product and effluent digestable!**
- Chemical conversion consists of
  - Losing functional groups – decarboxylation
  - Degrading hemi-cellulose – hydrolysis
  - Weakening fibers
  - Completely dissolving alkali metals
  - Completely dissolving halogenides
  - Partially dissolving S, P, Ca, Mg, N
  - Hardly any Si, Al, Fe going into solution



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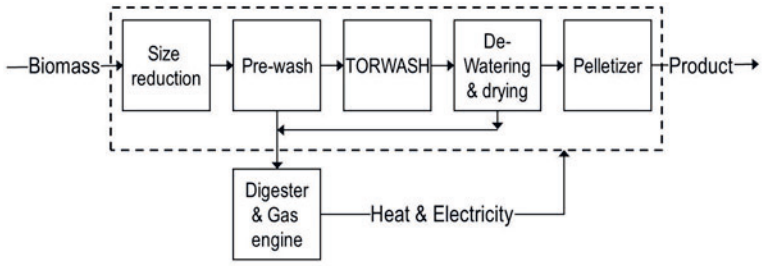
ECN-TORWASH process concept

ECN

- Features:
  - Heavy duty pre-wash + TORWASH; TORWASH allows deep "salt" removal and better mechanical dewatering + yields the benefits of torrefaction (energy density, grindability, hydrophobicity)
  - Mechanical dewatering (down to 25-35% moisture content) + limited thermal drying
  - Mild TORWASH conditions allow excellent pelletisation and effluent to be digested for biogas production (for process power and heat)
  - Efficient solid-liquid contacting to maximise washing efficiency and minimise fresh water requirement

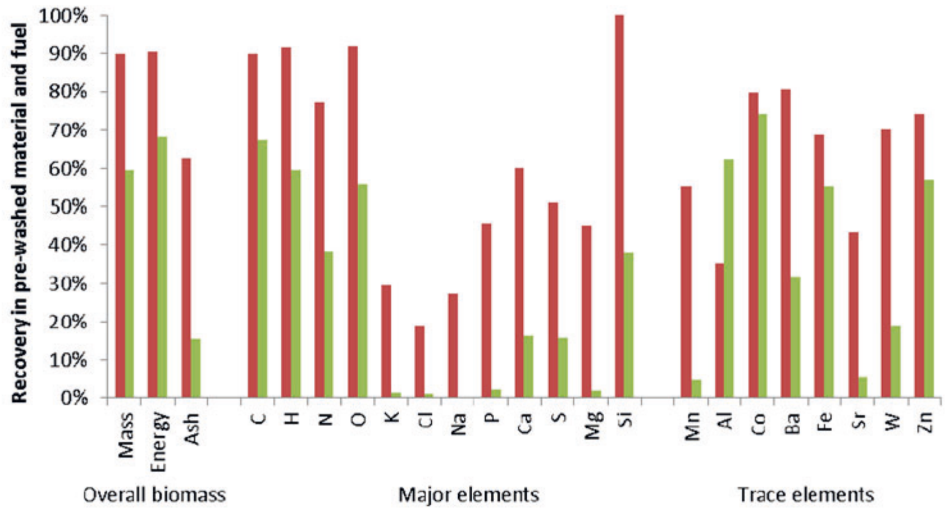


8

Impact of washing and TORWASH

Typical recovery percentages for *Arundo Donax* (Giant reed)

ECN



ECN-TORWASH process allows >99% removal of K and Cl

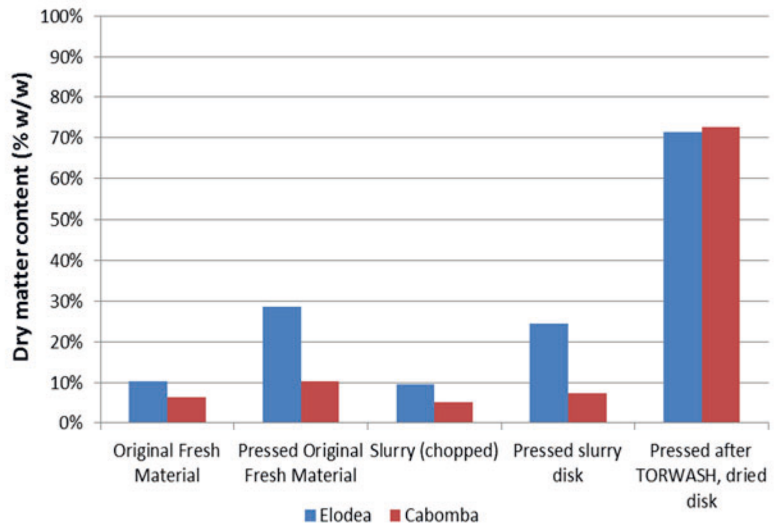
Red bars: washing only
Green bars: washing + TORWASH

9

Mechanical dewatering

Example: *Elodea nuttallii* (water weed) and *Cabomba caroliniana* (fanwort)

ECN



TORWASH largely improves the mechanical dewatering

10

Compliance to fuel standards
EN plus A1 and IWPB-I2

ECN

Parameter	Unit	EN Plus A1	IWPB-I2	Wood Pellets	Grass Raw	Grass Torwashed	Reed Raw	Reed Torwashed
Additives	wt%	0	< 3	none	none	none	none	none
Water	wt%	≤ 10	≤ 10	8.3	variable	4	variable	7
Bulk density	kg/m³	≥ 600	≥ 600	636	-	716	-	ND
NCV	GJ/ton DM	≥ 16.5	≥ 16.5	18.6	16.7	20.7	17.9	20.6
Ash	wt% DM	≤ 0.7	≤ 1.5	0.3	4.4	1.3	2.3	0.6
Cl	wt% DM	≤ 0.020	≤ 0.05	0.012	0.470	0.013	0.227	0.005
K	mg/kg DM			380	13 000	330	4924	116

ECN-TORWASH process is able to upgrade grass and reed to top-class energy pellets

Arundo donax, before and after Torwash, and after subsequent pelletization

11

ECN

TORWASH technology – current status

- TORWASH process concept proven on bench scale (batch, 10-20 kg)
  - Grass, reeds, straw, water plants, digestate, bamboo, brewer's grains
  - Typically 60-70% mass yield, 65-75% energy yield
  - Wet and "salty" biomass can be transferred into high-quality energy pellets compliant to standards for white wood pellets
  - Mechanical dewatering largely reduces energy consumption
  - Effluent allows anaerobic digestion (no expensive waste water treatment)
- Economically attractive feedstocks are wet and contain salts (K and Cl)
  - Best case for NW-Europe: road-side grass
  - Residues from plantations (Tropics) or food industry (Worldwide)

Empty fruit bunches

ECN

Effluent composition and processing

	Washing liquid	TORWASH effluent
Simple sugars	1%	2%
Other identified organic compounds	5%	37%
Dissolved ash-forming compounds; K, Cl, Si and others	10%	4%
Unknown	> 80%	> 55%

Compound	**Washing effluent**	**TORWASH effluent**	
Methanol	<250	311	mg/kg
Hydroxyacetone	<100	500	mg/kg
Acetic acid	951	6501	mg/kg
2-furaldehyde	<100	7153	mg/kg
Formic acid	<250	586	mg/kg
5-(Hydroxymethyl)-2-furaldehyde	<100	2258	mg/kg
Total		**17210**	**mg/kg**
		37%	of dissolved matter

Sugars	**Washing effluent**	**TORWASH effluent**	
Arabinose	37	<5	mg/kg
Fructose	110	89	mg/kg
Galactose	19	23	mg/kg
Glucose	13	913	mg/kg
Mannose	<10	38	mg/kg
Rhamnose	<5	<5	mg/kg
Xylose	31	90	mg/kg
Total	**210**	**1153**	**mg/kg simple sugars**
	1%	2%	of dissolved matter

- Example: Arundo Donax (Giant Reed)
- Anaerobic digestion tests have shown: Effluent suitable for anaerobic digestion (to produce power and heat); digester effluent may be used for fertilisation

12

ECN

TORWASH technology – the way forward

- Up-scaling for ***grasses*** (NW-Europe)
  - Pilot-installation 100 kg/hr input dry matter (0.8 kton/yr)
  - Demonstration at 10-30 kton/yr
- Up-scaling and demonstration for ***empty fruit bunches*** (oil palm plantations in Malaysia)
- More feedstocks under investigation
  - Second generation TORWASH = for ***digestate***
  - ***Sludges*** from food industry and bio-based product industry
    - without pre-wash
- Further R&D on co-production of energy carriers and higher-added-value products (e.g. nutrients)

Jakob Köchermann, DBFZ

Hydrothermal processes for thermally treated biofuels production

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The provision with bioenergy carriers such as wood is characterised by an increasing competition between different energetic and non-energetic applications. This is also the reason for rising wood prices and decreasing profitability. On the other hand there are large amounts of biogenic by-products or waste, which are neither ideal for combustion and gasification nor for biogas production. Especially for wet substances, the possibilities of thermo-chemical conversion are very limited. For that feedstock, hydrothermal processes can be an opportunity for the production of upgraded fuels. Because the reaction medium is water, wet biomass does not need to be dried before conversion. One important hydrothermal process is the Hydrothermal Carbonisation (HTC). In the HTC, the biomass or waste is converted in water at about 200°C and 20 bar into the upgraded solid fuel, called HTC-coal. In comparison with the input, major properties of the HTC-coal are improved, such as heating value, carbon content, volatile mater, homogeneity and defined structure.

The dewatering of coal is also easy and therefore energy demand for coal drying is low. That is why HTC can be the energy efficient alternative in many cases. The Hallesche Wasser und Stadtwirtschaft GmbH and the DBFZ do joint research for the Hydrothermal Carbonisation of municipal biogenic waste within a research project. Scientific fundamentals for the application of that fuel could be clarified. Based on this, a demonstration plant for 2500 t/a input was build and placed into operation.

The HTC-coal can be used as biogenous substitute for brown coal and other fossil fuels for example in power plants or industrial boilers and furnaces but also in non-energetic applications. In addition to solid fuels, also liquid and gaseous fuels can be produced in hydrothermal processes based on biomass.

Deutsches Biomasseforschungszentrum DBFZ
gemeinnützige GmbH

Hydrothermal processes for thermally treated biofuels production

Jakob Köchermann, Marco Klemm, Andreas Clemens; DBFZ
Regina Blümel, SWH; Falko Kietzmann, HWS

Structure

DBFZ

1 Short introduction
2 Experimental investigations
3 Energy balance
4 HTC Process water
5 Demonstration plant
6 Conclusion

2

Initial situation

DBFZ

- The provision with bioenergy carriers such as wood is characterised by an increasing competition between different energetic and non-energetic applications.
- This is also the reason for rising wood prices and decreasing profitability.
- There are large amounts of biogenic by-products or wastes, which are neither ideal for combustion and gasification nor for biogas production.
- Especially for wet substances, the possibilities of thermo-chemical conversion are very limited.
- For that feedstock, hydrothermal processes can be an opportunity for the production of upgraded fuels.

3

Hydrothermal process

DBFZ

- A Hydrothermal process is chemical conversion in hot compressed liquid or supercritical water.
- Water is reaction agent, catalyst, solvent, heat carrier, transport medium and keeps the air outside.
- Hydrothermal processes enables very different conversions of organic substances such as biomass.
- Because the reaction medium is water, wet biomass does not need to be dried before conversion.
- Solid, liquid and gaseous products can be generated by changing the process parameter.
- Various applications are exist.
- Focus here: Upgraded solid biofuels

4

The aims of biomass pre-treatment

DBFZ

fuel property upgrading

- homogeneity
- grindability
- handling
- behaviour against water
  - hydrophobic character
  - mechanical dewatering
- energy density
- reactivity
- combustion and gasification behaviour

5

Hydrothermal Carbonisation

DBFZ

Source: DBFZ

HTC →

Source: DBFZ

Feedstock:
- Biowaste
- Fermentation residue
- Sewage sludge
- ...

Thermo-chemical conversion process in hot pressured water at:
- 160 – 250 °C
- 6 – 40 bar
- up to several hours

Product:
- Solid: HTC coal
- Liquid: Water, ...
- Gas: CO_2, ...

6

Feedstock potential

DBFZ

Potential biomass resources (Germany):

Municipal biological waste	8.7 Mio tons/year [a]
Sewage sludge	8 - 10 Mio tons/year [a]
Residues from food industry	6 - 7 Mio tons/year [b]
Landscape management material	
Fermentation residues	
Residues from agriculture	

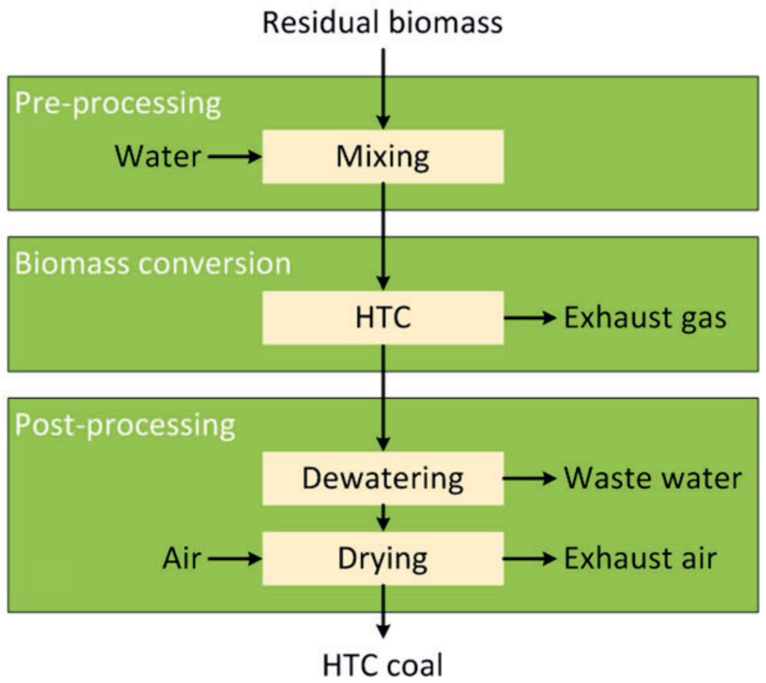
→ HTC of wet, biogenic residues has a great potential for energetic use.

[[a] Statistisches Bundesamt 2012, [b] Mahro, B.: Biogenic residues from the food industry – a valuable secondary feedstock. Müll und Abfall 42 (2010) 2 p.56- 62]

7

Overall process chain

DBFZ



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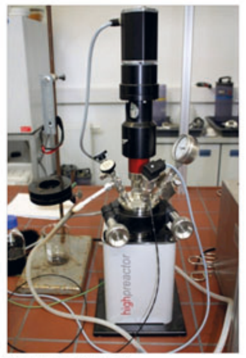
Experimental investigation at DBFZ

DBFZ

- Substrates: municipal biological waste (biowaste), landscape management material, fermentation residue, sewage sludge, algae, ...,
- 500 ml batch autoclave with heating jacket,
- Dry matter content 25 wt%; no catalysts,
- Heating rate: 2 K/min,
- 3 temperatures x 3 times.



Source: DBFZ

HTC	2 h	4 h	6 h
180 °C	x	x	x
200 °C	x	x	x
220 °C	x	x	x

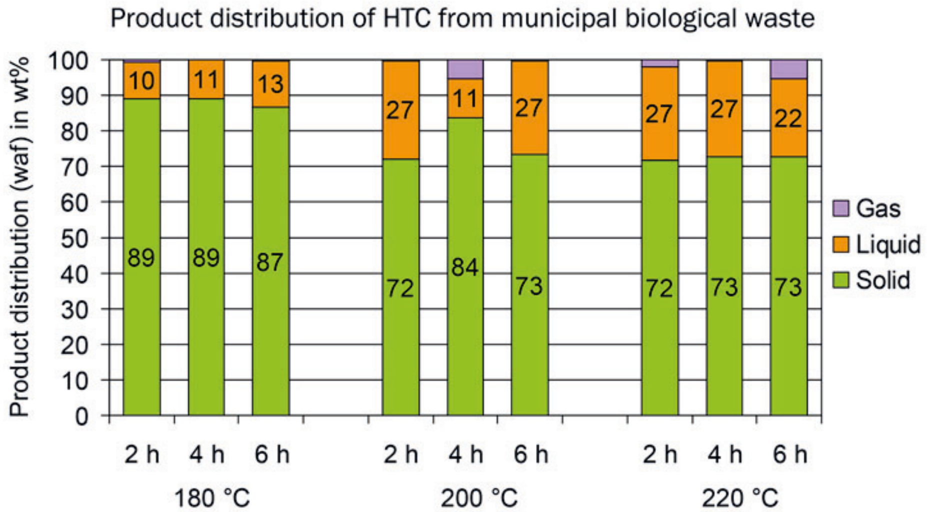
Analysis of the produced HTC coal:

- Elementary analysis (DIN EN 15104),
- Higher heating value (DIN 14918),
- Ash content (DIN EN 14775).

9

HTC coal | Product distribution

DBFZ



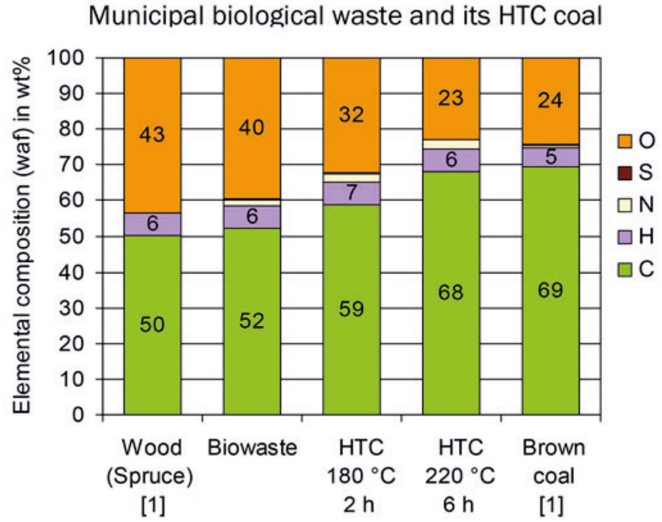
(waf = water and ash free)

Andreas Clemens, International VDI Conference – Biomass to Energy, Munich, 3 September 2013

10

HTC coal | Elemental analysis

DBFZ



[1] Kaltschmitt, M. et al.: Energie aus Biomasse (2009)

11

HTC coal | Higher heating value

DBFZ

- Carbon content and higher heating value (waf) of the HTC coal from municipal biological waste; (waf = water and ash free)

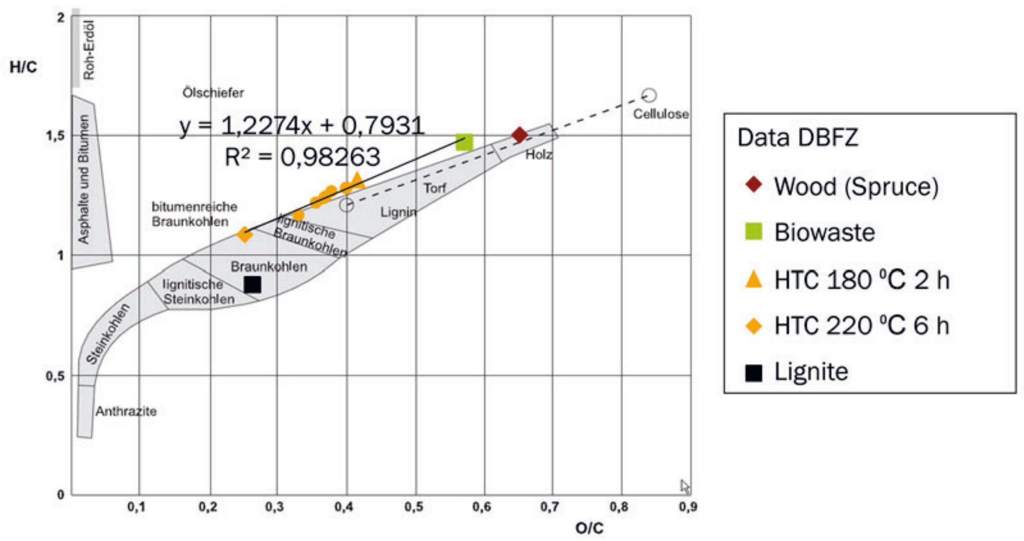
Carbon content (waf) in wt%			
HTC	2 h	4 h	6 h
180 °C	59	60	60
200 °C	61	61	62
220 °C	63	61	68

HHV (waf) in MJ/kg			
HTC	2 h	4 h	6 h
180 °C	23	24	24
200 °C	25	25	25
220 °C	25	26	27

12

HTC coal | van-Krevelen-Diagram

DBFZ



van-Krevelen-Diagram based on Belusa, T. et. al: Hydrothermale Karbonisierung und energetische Nutzung von Biomasse. In: Gülzower Fachgespräche: Hydrothermale Carbonisierung (2010)

13

HTC coal | Fuel specifications and quality

DBFZ

- Product specifications for HTC coal currently do not exist.
- Orientation gives DIN EN 14961-6: “Solid biofuels – Non-woody pellets for non-industrial use”.

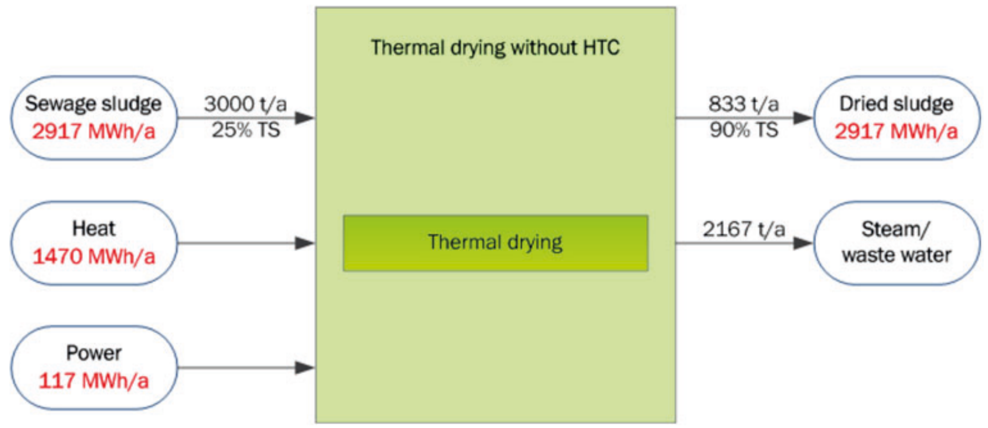
Parameters	Unit	References		HTC coal of DBFZ		
		DIN EN 14961-6	Lignite briquette	LMM	Biowaste	Fermentation residues
Water content	Ma-%	≤ 15	13	variable		
Ash content	Ma-% wf	≤ 10	4.2	27	17	22
LHV	MJ/kg	≥ 13.2	24.9	16.7	19.4	18.1
N	Ma-% wf	≤ 2.0	0.74	1.1	1.8	1.6
S	Ma-% wf	≤ 0.20	0.3	0.13	0.20	0.30
Cl	Ma-% wf	≤ 0.30	0.027	0.04	0.08	0.18

(wf = water free; LMM = landscape management material)

14

Energy balance – Thermal drying

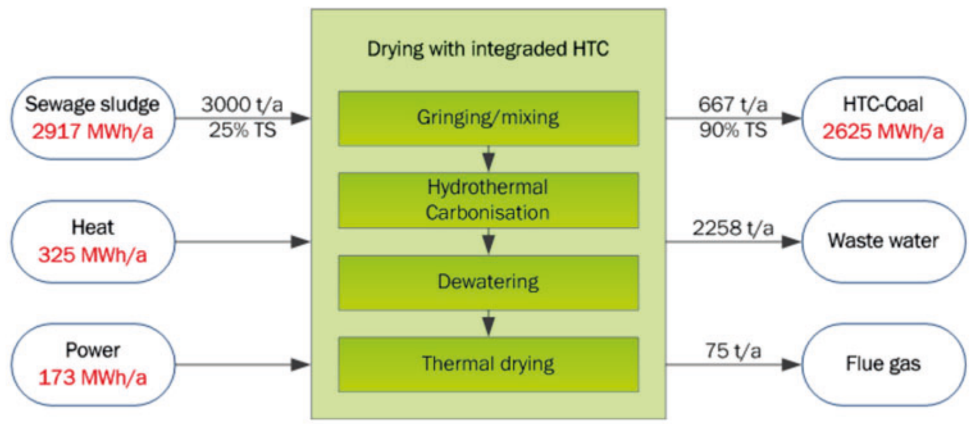
DBFZ



15

Energy balance – Drying after HTC

DBFZ



16

Possible applications

- Energy applications:
  - Combustion,
  - Co-combustion,
  - Gasification
- Soil conditioner,
- Industrial applications:
  - Metallurgy,
  - Activated carbon,
  - Technical carbon,
  - ...

17

HTC process water

- HTC process water → significant amount → disposal costs,
- High load of organic substances (CSB: 20,000 – 70,000 mg/l), but good biotic degradability (BSB_5: 10,000 – 25,000 mg/l),
- Several strategies of treatment:
  - Internal recycling,
  - Municipal waste water treatment,
  - Feed for anaerobic fermentation,
  - Potential of recovery of phosphor (PO_4-P : 200 mg/l).

18

HTC-Halle Demonstration project

"Integrated Utilisation Plant and Strategy for Community Biomass – HTC Halle Municipal Water Management and Waste Disposal Company"

Founded by	• German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
Funding period	• 01.12.2010 – 31.12.2014
Coordination	• DBFZ Deutsches Biomasseforschungszentrum gGmbH
Partner	• Hallesche Wasser und Stadtwirtschaft GmbH (Halle Municipal Water Management and Waste Disposal Company)
Goal	• Design, installation and optimization of an integrated HTC plant

19

HTC-Halle Demonstration plant

Source: DBFZ

Start 07/2013

HTC plant is manufactured by *Artec Biotechnologie GmbH*, Bad Königshofen

- Annual capacity of 2,500 tons wet input material
- Production of 1,000 t dry HTC coal / year
- Continuous plug flow reactor "Art coal 3000K"
- Waste heat of a CHP is used for the heat supply

20

Advantages of HTC

DBFZ

- Application of alternative feedstock,
- Limited technical effort,
- Small scale plants economically possible,
- Easy mechanical dewatering of solid product,
- Reduced effort for drying, high energetic efficiency for wet feedstock,
- Homogeneous and stabile product,
- Increased combustion and gasification behaviour,
- Coal application not only in large-scale power plants,
- Recycling of phosphor and removal of harmful substances.

21

Conclusion

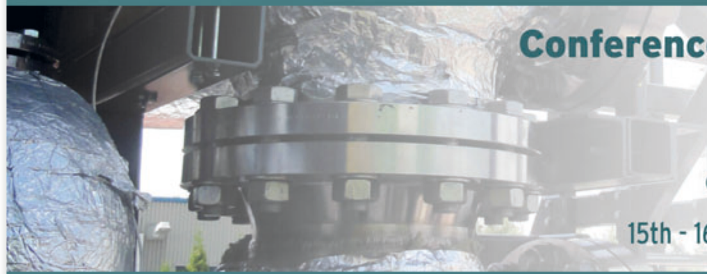
DBFZ

- HTC is a thermo-chemical conversion process in hot pressured water.
- HTC of (especially) wet, biogenic residues has a great potential for energetic use.
- HTC coal is a solid fuel with characteristics between wood and lignite.
- HTC coal is a “new” product. Product specifications currently do not exist.
- HTC process water has a high load of organic, but biodegradable substances. Potential of recovery of phosphor.
- HTC process is in the demonstration scale.

22

Event note

DBFZ



Conference HTP Hydrothermale Prozesse on Hydrothermal Processes

15th - 16th of June 2015 in Leipzig/Germany

Adress: Mediencampus Villa Ida, Poetenweg 28, Leipzig

Contact for fruther questions on the Innovation forum Hydrothermal Processes: htp-inno@dbfz.de

Registration for the conference: www.dbfz.de/htp

Funded by Federal Ministry of Education and Research | INNOVATIONSFOREN UNTERNEHMEN REGION | DBFZ

www.dbfz.de/htp

23

Deutsches Biomasseforschungszentrum
gemeinnützige GmbH

DBFZ

Researching the energy of the future – come and join us!

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Dr. Erik Pitzer, University of Applied Sciences Upper Austria

Modelling, simulation and optimizing of a european-wide logistics network

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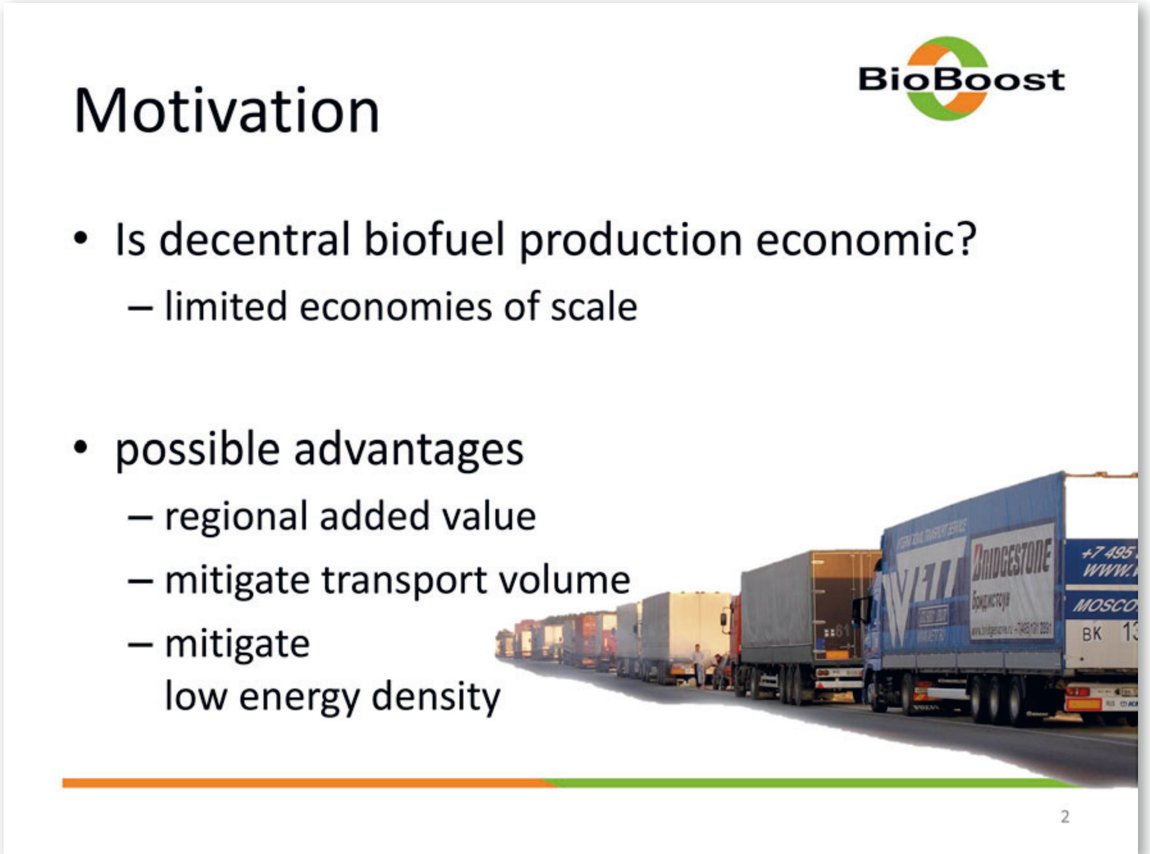
New conversion technologies for biofuels often deal with large volumes of low-energy feedstock. This requires the establishment of decentral conversion facilities for several reasons: On the one hand, the low energy density implies a relatively high transport cost with respect to transported energy content. On the other hand, the high transport volume could overload the transport infrastructure near conversion facilities to achieve economically reasonable scale. Therefore, not only the conversion itself but also the logistics are an important factor to consider. In the BioBoost project many partners have contributed information as a basis to build a comprehensive logistics model, ranging from high-resolution feedstock potentials throughout Europe, over feedstock market price distribution and modeling, to process parameters for conversion facilities and logistics concepts for different types of feedstock.

Additionally, regional influences such as different levels of labor cost or differences in transport infrastructure have been considered. This information has been fed into a novel sophisticated simulation model for large scale logistics that uses several techniques to provide fast scenario simulations with reasonable granularity.

This simulation model has many free parameters, such as the amount of feedstock to use in each region, the locations of plants to be build, the transport routes and transport modes, plant sizes, storage locations and so on. Together with the open-source optimization framework HeuristicLab the simulation model has been used to obtain good choices for these free parameters using evolutionary algorithms where several scenarios are iteratively improved in parallel. The resulting optimized scenarios can help to derive good estimates for potential initial plant locations where all these factors have been considered.It can also be used to find out possible ramp-up routes and give a first glimpse on the profitability or subsidy requirements for these types of decentrally converted biofuels.

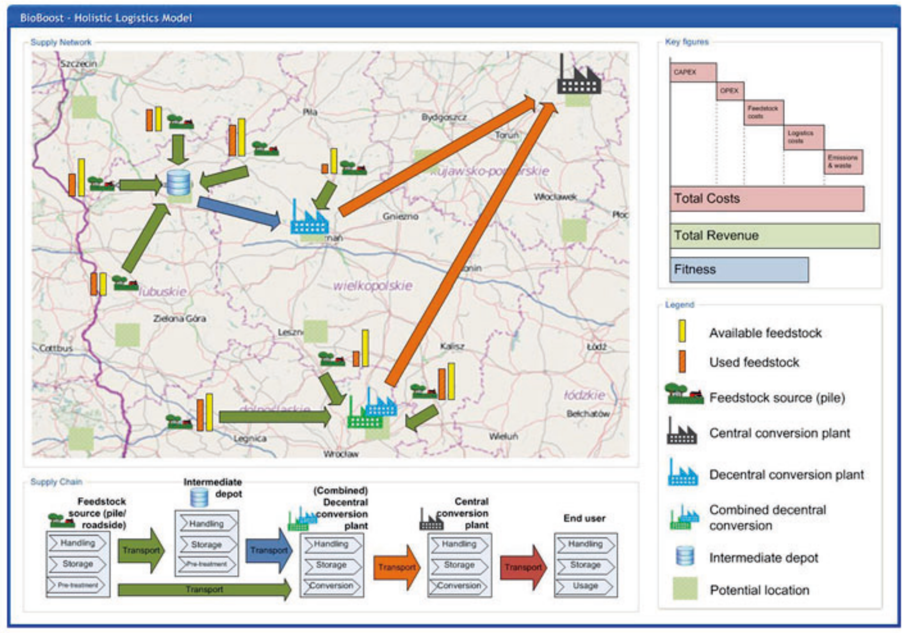


Vision

- optimal choice of
  - feedstock suppliers
  - logistic network
  - plant location
  - plant size
  - catchment area
- many factors to consider

3

Vision



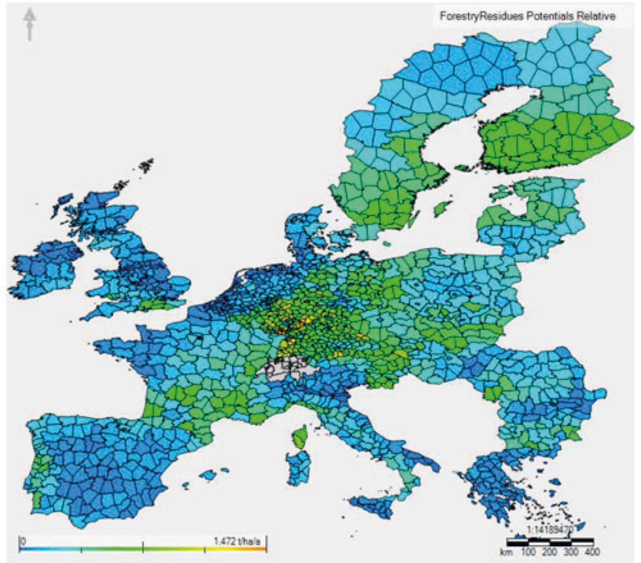
4

Required Data

- feedstock potentials (technical)
- market price (and development)
- transport modes & costs
- routes
- conversion possibilities (and scaling)
- product costs (feedstock, output, wastes)
- regional influences (labor, invest., infrastructure)

5

Feedstock Potentials



http://iung.neogis.pl/geoportal/

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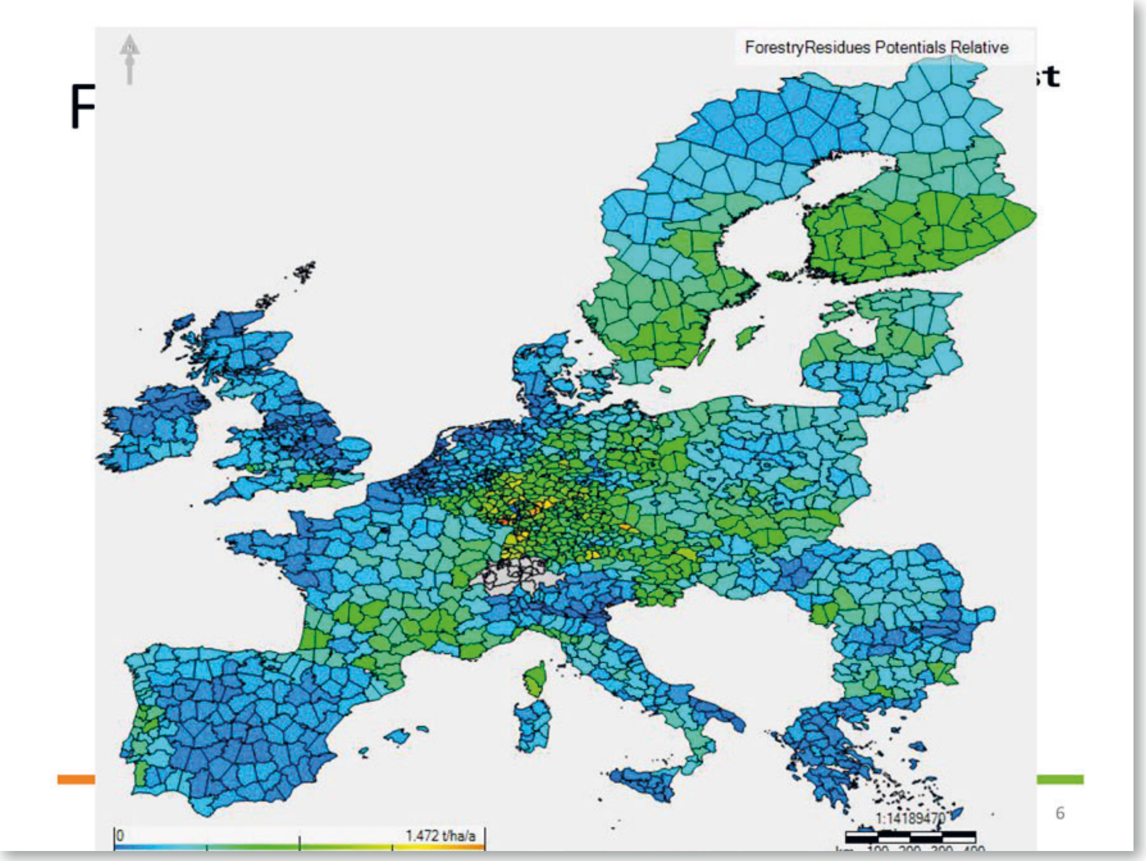
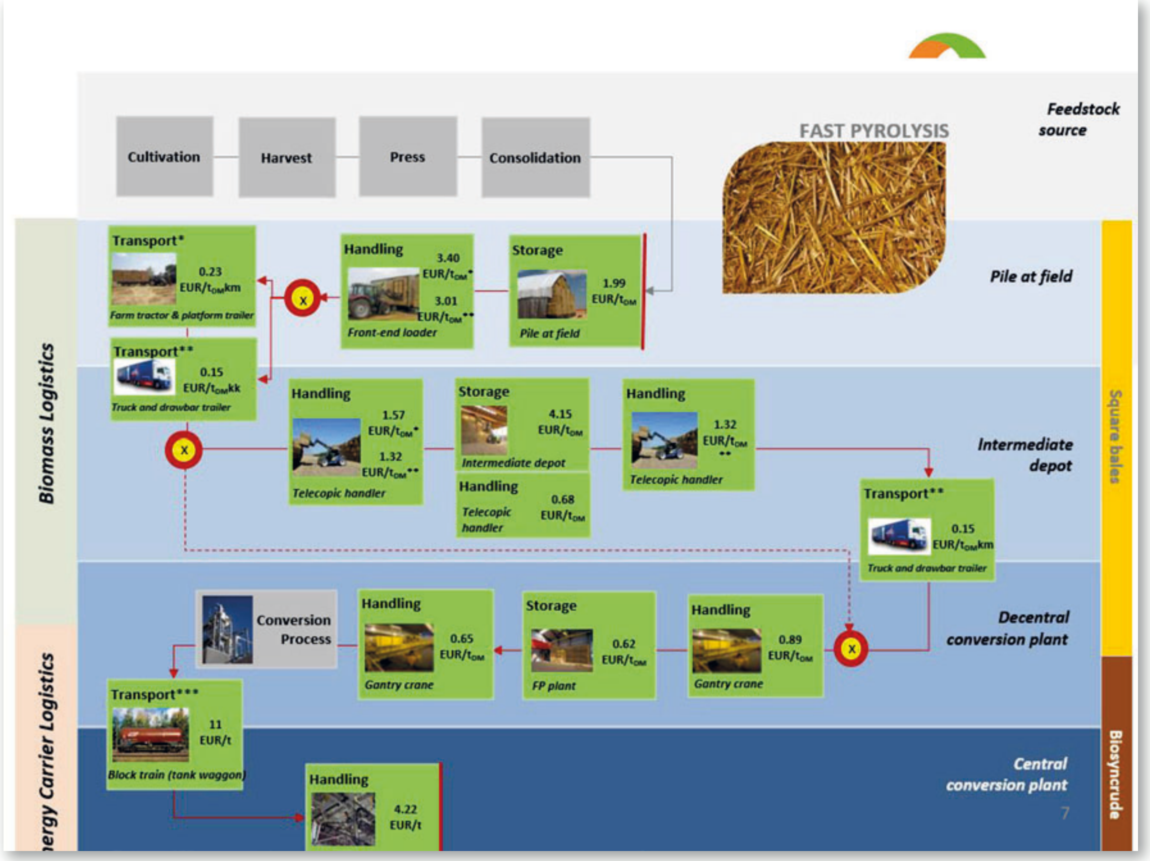
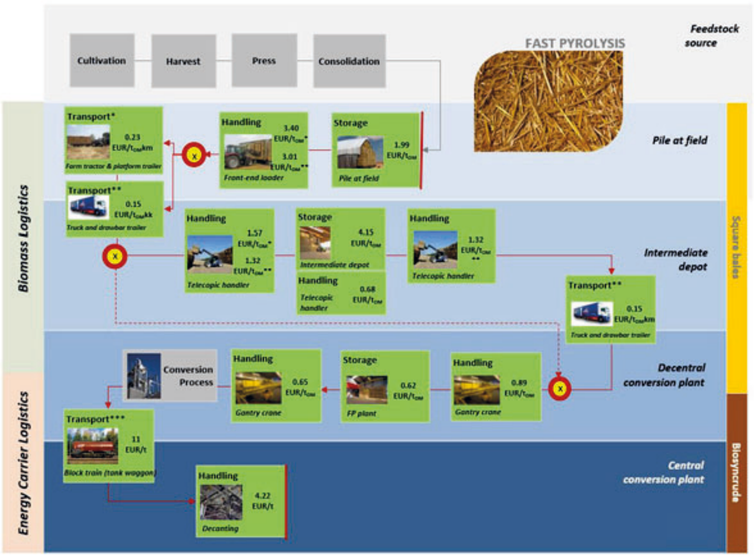




Logistics Concept



7

Conversion Parameters


```
conversions:
  - label: FastPyrolysis
    feedstock: Straw
    safety-stock: 365 # days
    dry-matter-loss: 0.08 # fraction
    storage:
      investment: 0.15
      labor: 0.35
      other: 2.1
    products: # [t/t]
      Biosyncrude: 0.675676
      CO2-green: 0.324324
      WaterVapor: 0.108108
      CoolingWater: -0.344595
      ElectricityIn: -0.087838
    main-product: Biosyncrude
    cost: 0 # [EUR/t]
    design-capacity: 219123.38028 # t/a
    construction: 11003716.52 # EUR/a
    maintenance: 7278442.59 # EUR/a
    construction-scaling-exponent: 0.7
    maintenance-scaling-exponent: 1 #factor
    utilization-factor: 0.913 # 8000 h/a
    available-maintenance-factor: 1
    max-capacities: { Default: 660000 } # 300%
    min-capacity: 125853 # 57%
```


8

Scenario Simulation

- target values
  - return on investment
  - total amounts (ramping up)
- many free variables
- many more variations

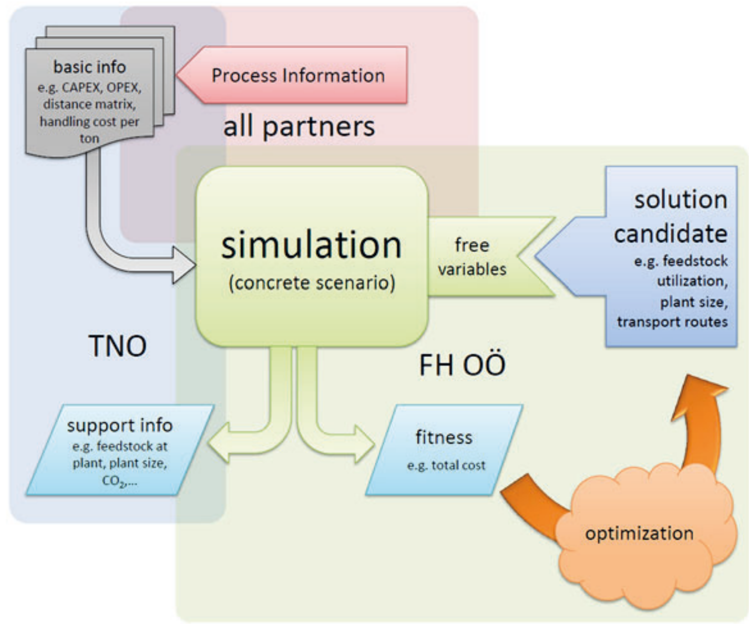
9

Simulation Efficiency

- aggregations
  - yearly averages
  - NUTS3 regions
- route pre-calculation (distance matrix)

10

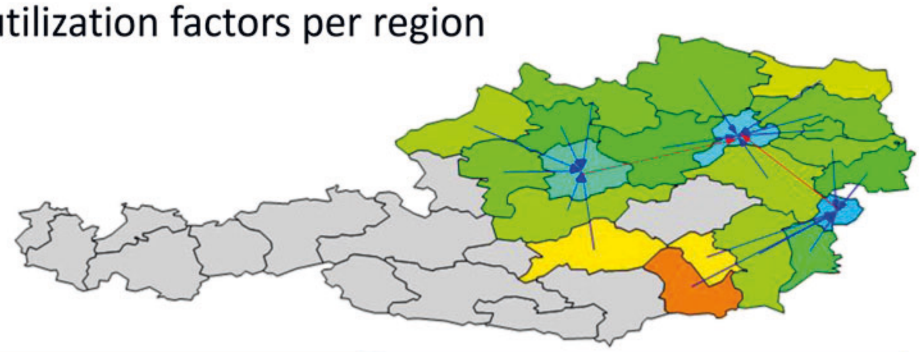
Simulation-based Optimization



11

Solution Space Reduction

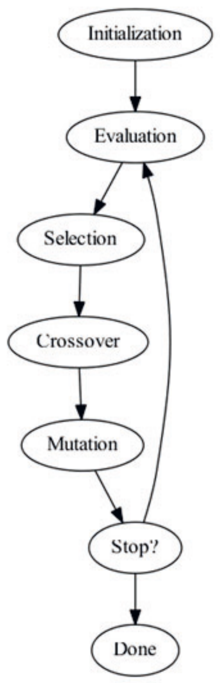
- implicit ("smart") choices for variables
- limits variables to
  - transport targets per product
  - utilization factors per region



12

Scenario Evolution

- evolution of scenarios
  - population based ("Evolution Strategy")
  - mutation i.e. moving/scaling plants
  - crossover



13

Results: Generic Model

- open-source software tool
  - plugin for HeuristicLab
  - http://dev.heuristiclab.com
- adaptable to other situations
  - e.g. raise transport tonnage allowance and reduce transport costs

14

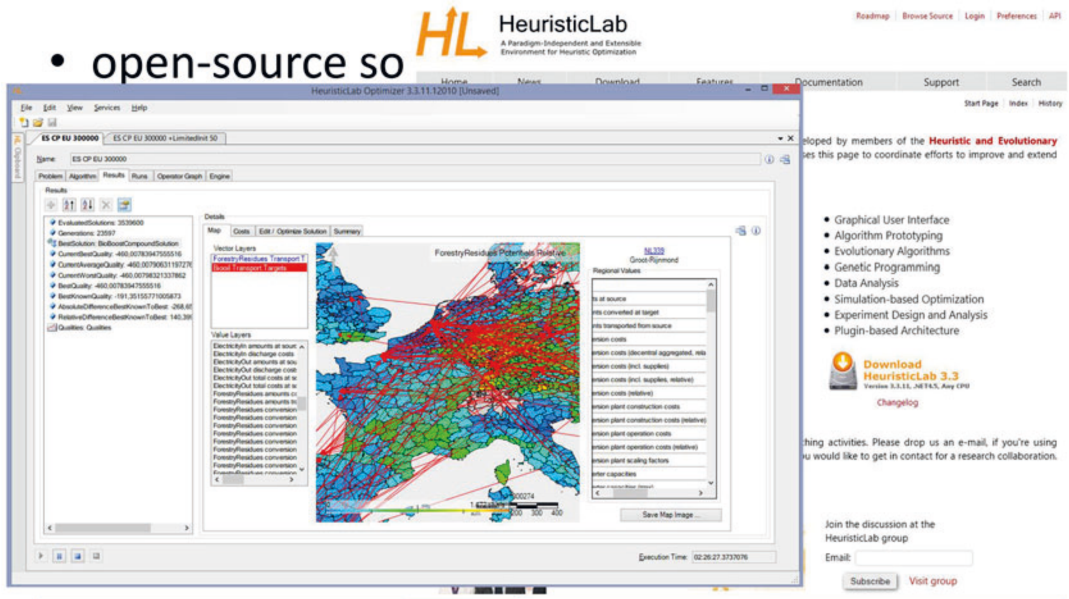
Results: Generic Model

- open-source so
  - plugin for Heur
  - http://dev.heu
- adaptable to ot
  - e.g. raise trans and reduce tra

14

Results: Generic Model

- open-source so



14

Results: Fast Evaluation

BioBoost

- several hundred scenarios per second
  - extended EU scenarios (1500 regions)
  - two echelons (decentral + central)
  - ROI and/or total amount
- 1-2 days per optimization (300-600 k generations)

15

Results: In Depth Analysis

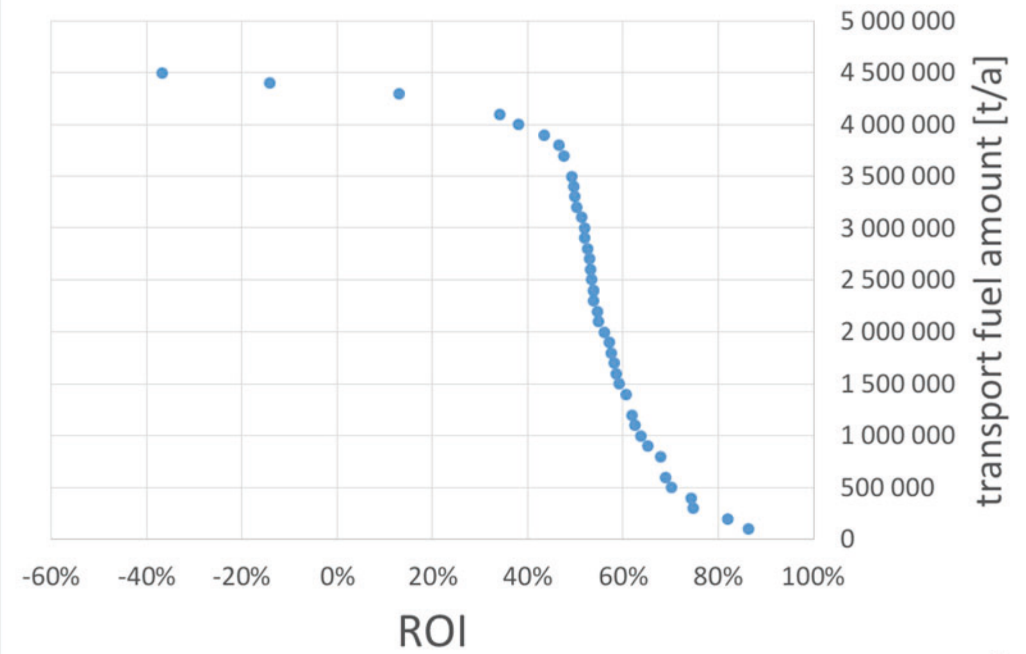
BioBoost

- more than 120 maps with different values e.g.
  - purchased amount in each region
  - conversion costs
  - logistic costs
- CSV export

16

Results: Ramp-Up Analysis

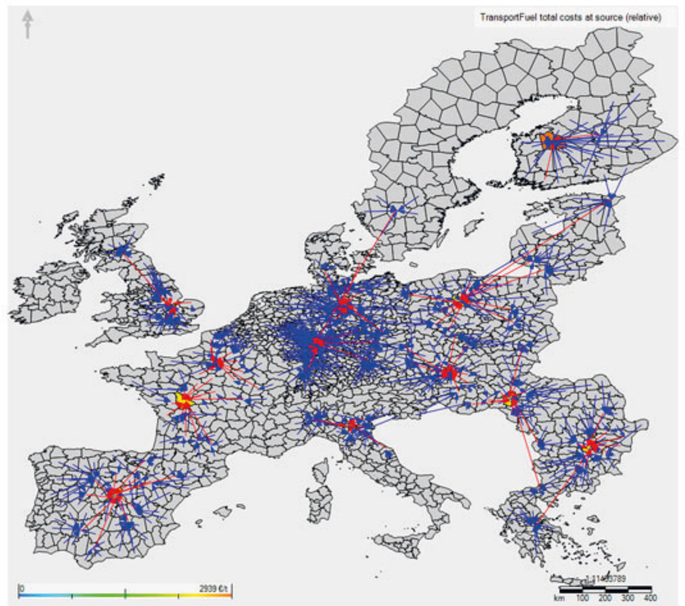
BioBoost



17

Results: EU FP

BioBoost



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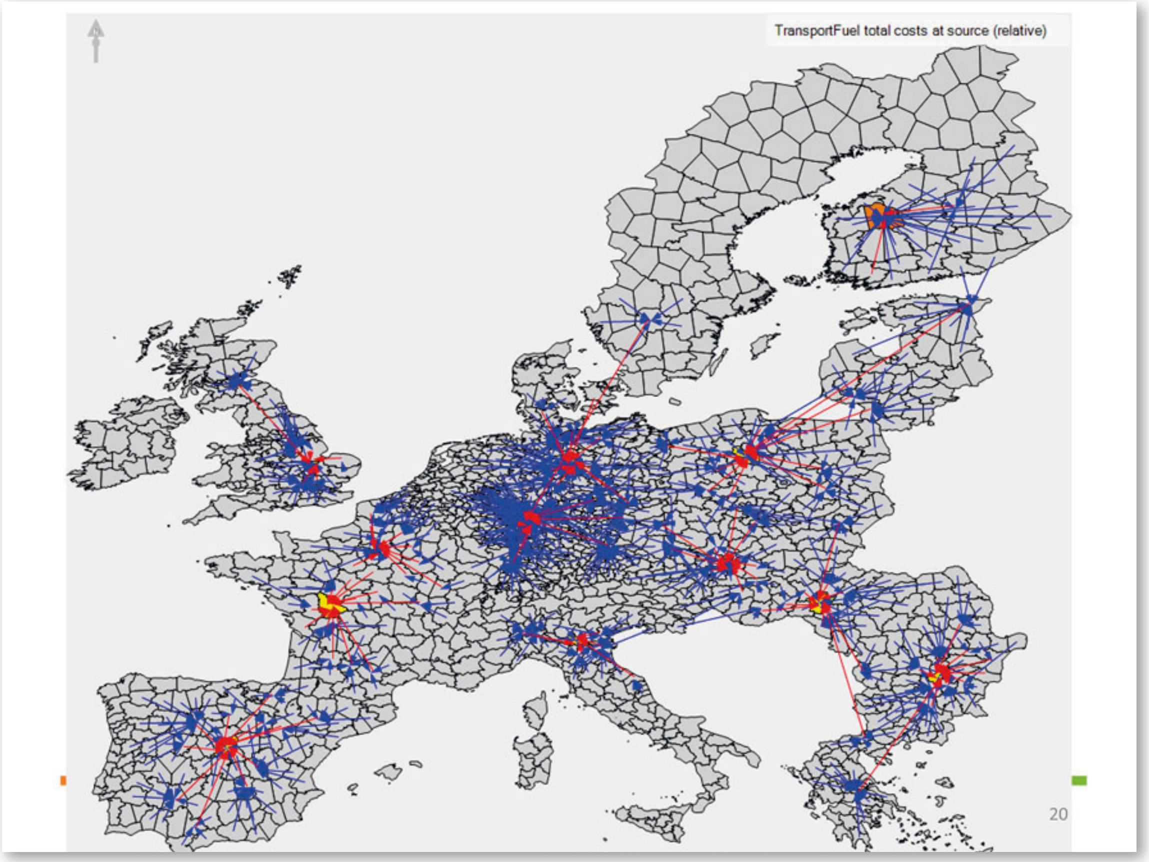

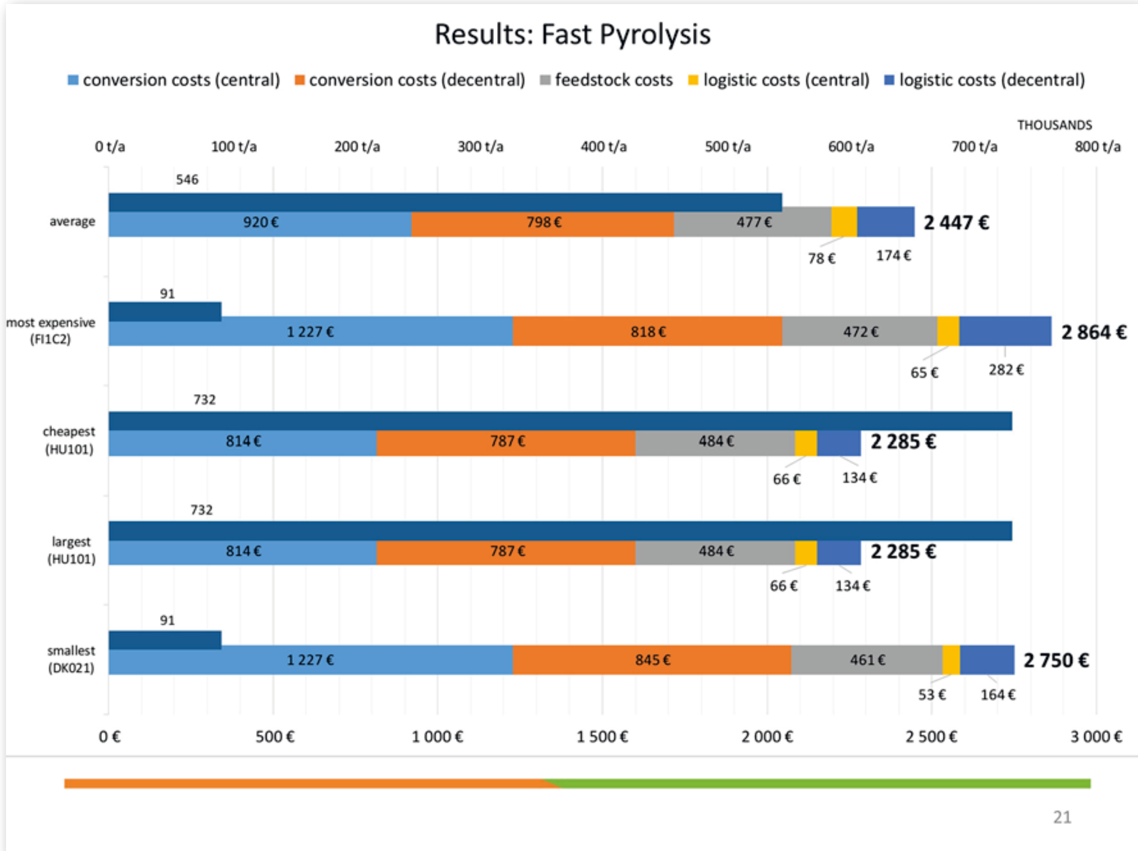

Dr. Takashi Yanagida, FFPRI

R&D results on torrefaction of woody biomass in Japan

Dr. Takashi Yanagida, Takahiro Yoshida, Makoto Kigucki
Forestry and Forest Products Research Institute (FFPRI)
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305-8687 JAPAN
Phone: +81-29-873-3211
Fax: +81-29-874-3720
E-Mail: tyoshid@ffpri.affrc.go.jp
Web: http://www.ffpri.affrc.go.jp/en/

In Japan about 8 million tons of forest residue including unused thinning wood are annually remained in the forests. To utilize such biomass, torrefaction is the one of the promising technology to upgrade fuel property. In FFPRI had started the fundamental study since 2009 and promoted the 2[nd] stage research since 2013. We built the demonstration plant with Actree Corp. and Sanyo Trading Corp. in the last December, and started to produce torrefied pellets. The main purpose to use the torrefied pellet in our project is for small scale usage such as pellet stove in domestic houses and pellet burner in agricultural greenhouses. We are studying the utilization model that collecting wood, torrefaction, pelletization and consumption are done in rural area as heating fuel.


Demonstration plant for torrefied wood fuel, Isehara, Japan

Takashi Yanagida, Ph.D
Takashi Yanagida studied bioengineering at University of Tsukuba, Japan, finishing his PhD in 2005. He started his professional work on biomass energy as a post-doctoral fellow at Advanced Industrial Science and Technology (AIST) until Aug. 2011, and at Hiroshima University as an assistant professor until Feb. 2014, then moved to FFPRI, Japan. In 2015, he become a senior researcher, specializing in system evaluation of biomass energy at FFPRI.

Takahiro Yoshida, Ph.D
Senior researcher

Co-authtor
Corresponding author

Makoto Kiguchi, Ph.D
Principal Research
Coordinator (Woody Biomass)

Co-author

European Biomass Conference and Exhibition (Jun 3rd, 2015)

R&D results on torrefaction of woody biomass in Japan

Takahiro Yoshida, Takashi Yanagida, Mariko Inoue, Daisuke Kamikawa, Yoshitaka Kubojima and Makoto Kiguchi

Forestry and Forest Products Research Institute, Tsukuba, Japan
Email: tyoshid@ffpri.affrc.go.jp

FFPRI

1

National Research and Development Agency
Forestry and Forest Products Research Institute

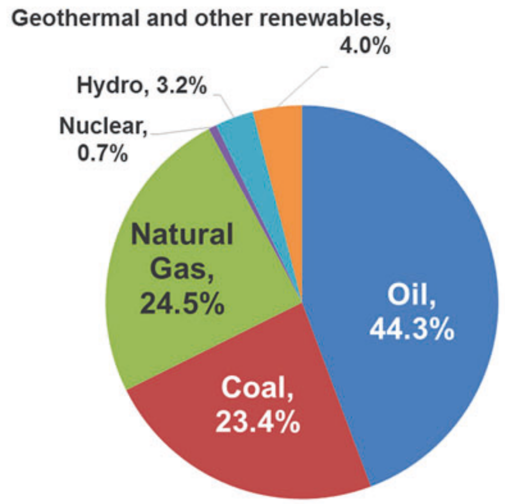
FFPRI

Established: 1905
Headquarter and 11 branches and field stations
Staff : 1,061
(Executives 8, Researchers 441, Officers 599, Experts 13)

2

Status of Energy Supply in Japan

- **Strongly dependent on fossil fuels**
- **The ratio increased from the Great Earthquake**
- **Reduction of using fossil fuels by utilizing renewable energy**



Primary energy supply in Japan (2012)

3

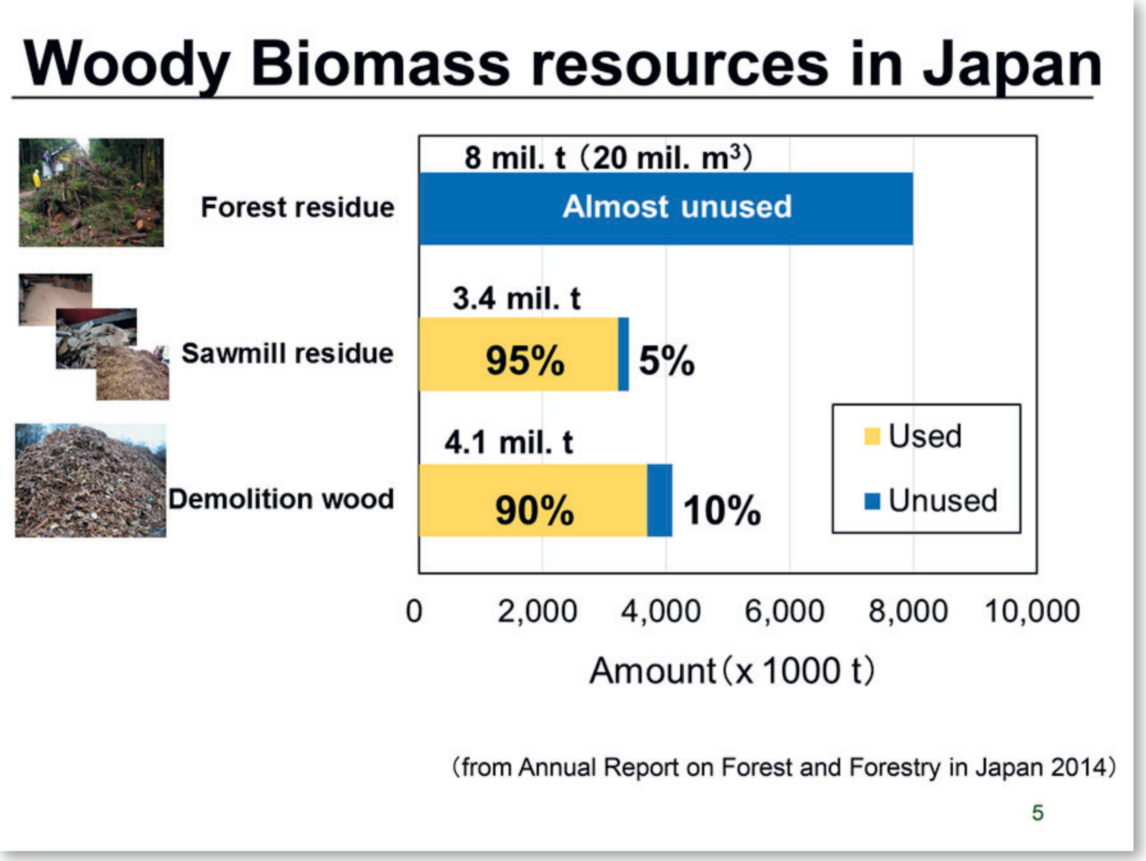
Wood resources and consumption in Japan

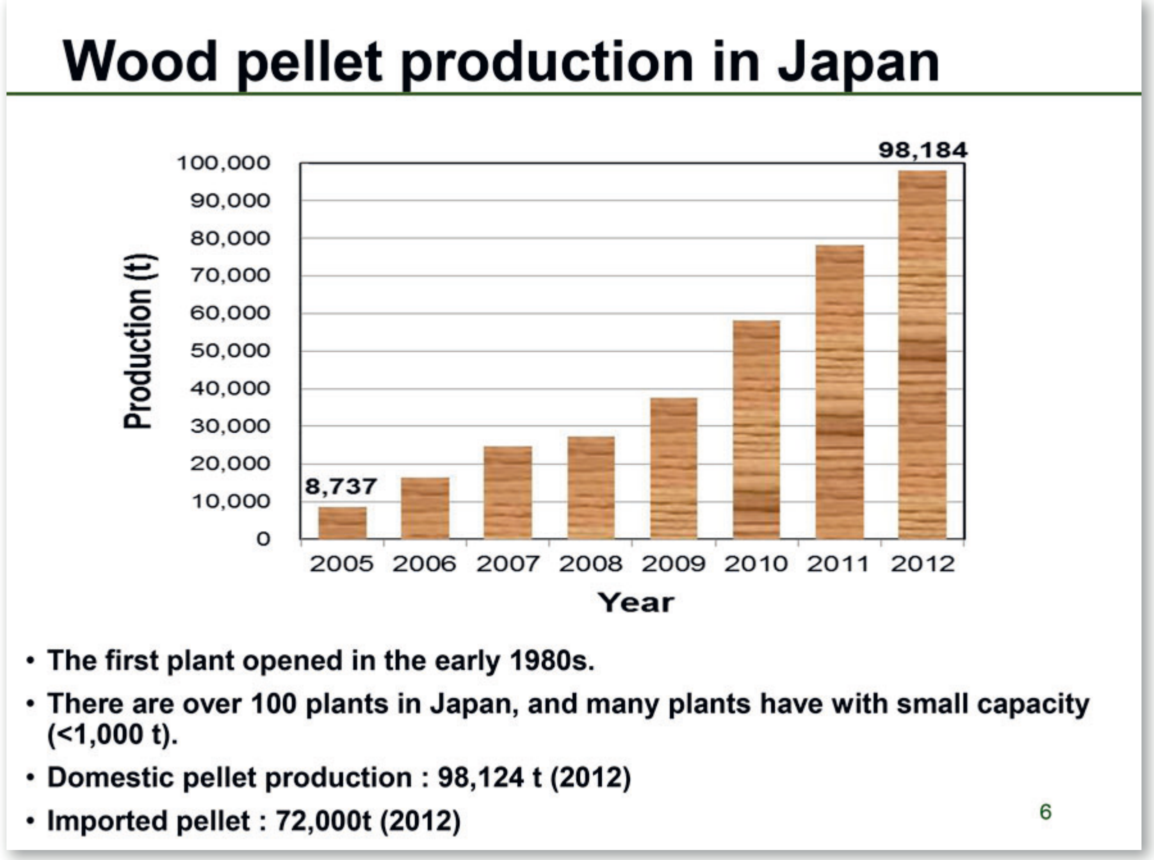
2/3 of land of Japan is covered with forest.

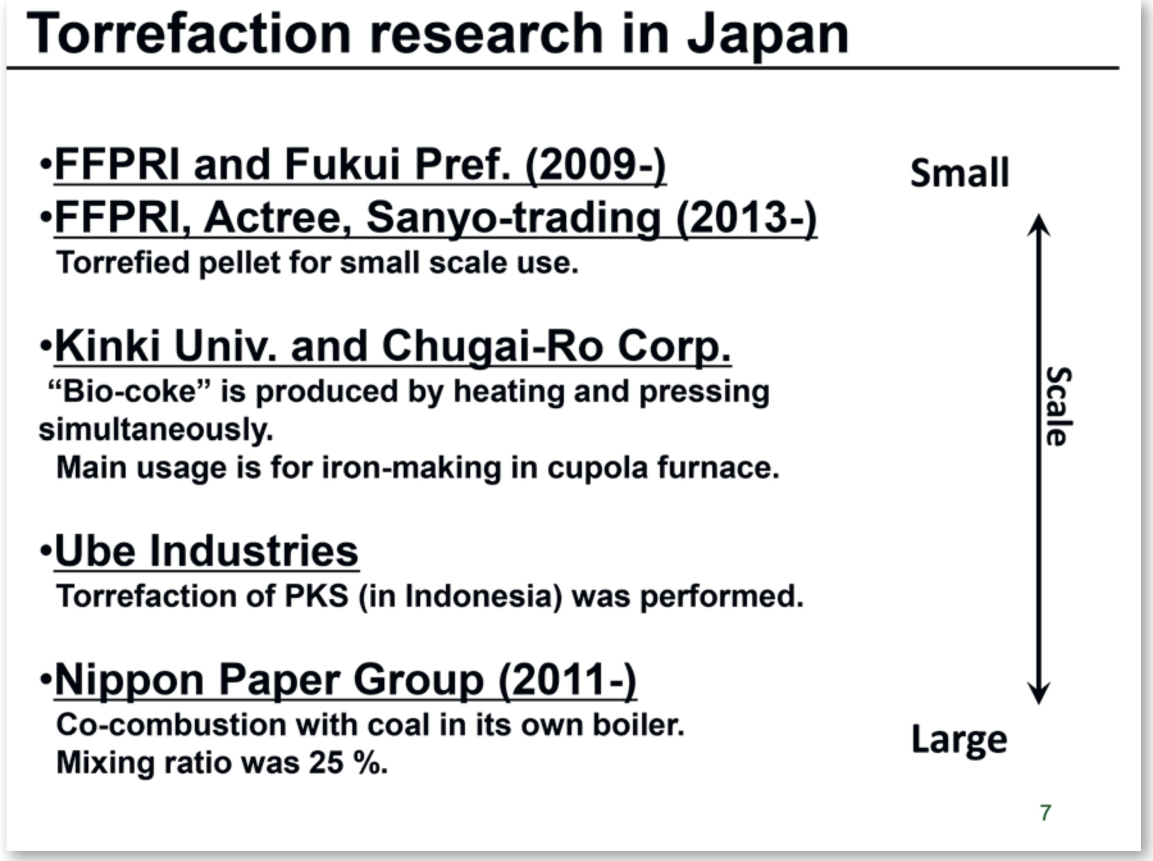
Forest area: 25 mil.ha
(Natural forest 15mil.ha
Manmade forest: 10mil.ha)
Volume: 4 bil.m^3

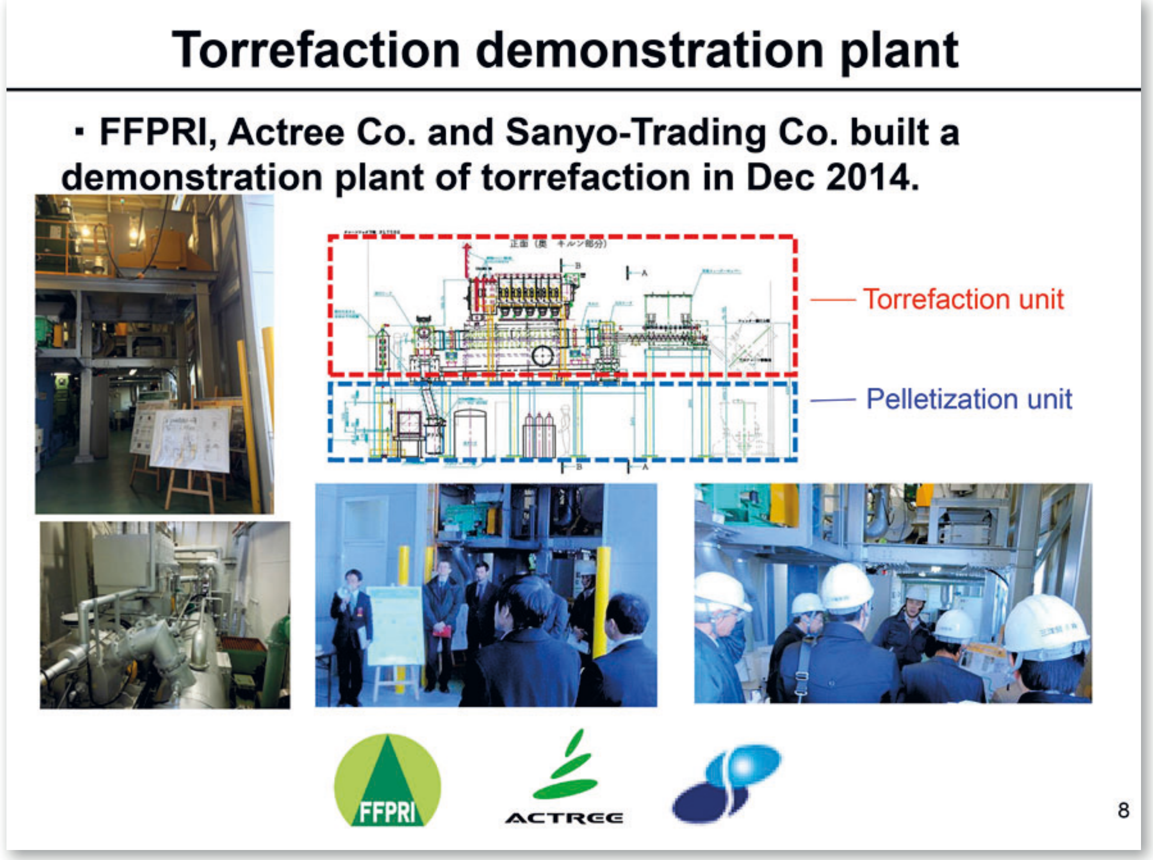
Consumption: 74 mil.m^3
(log-basis)
Wood from domestic 29%
from overseas 71%

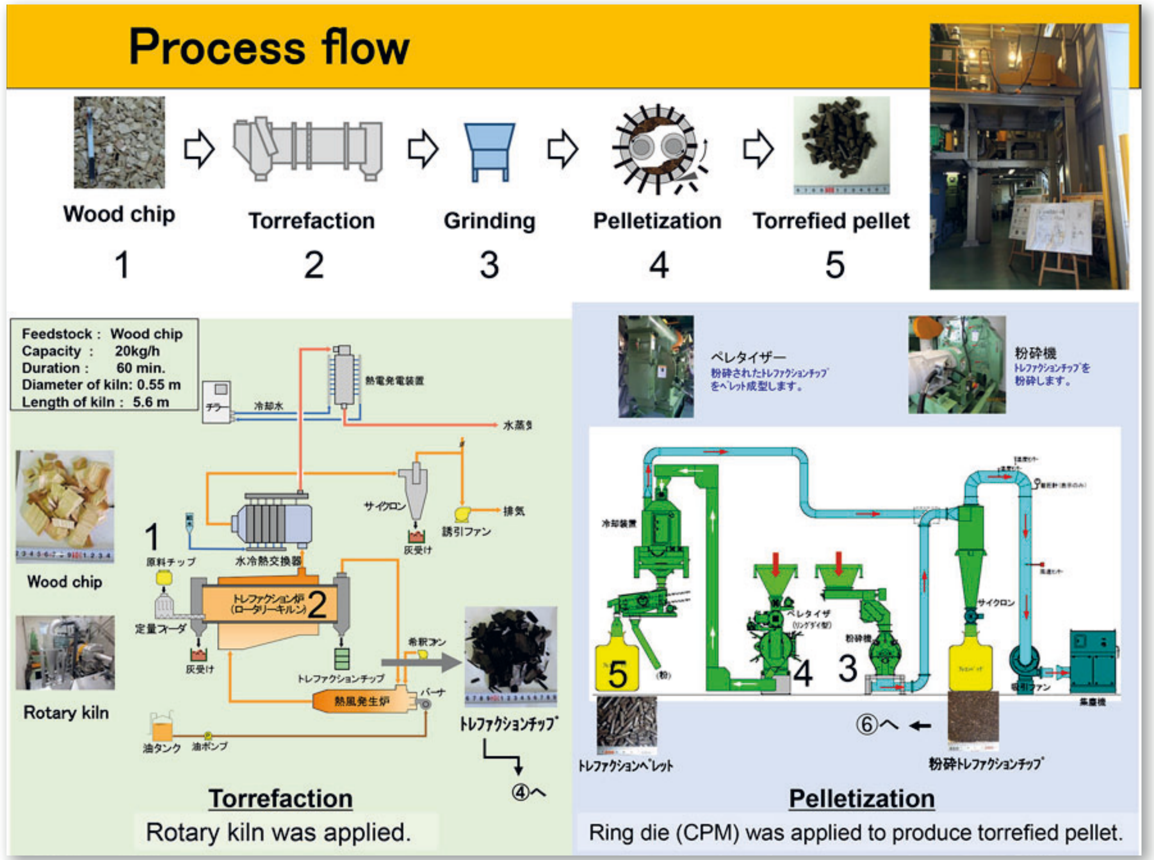
4

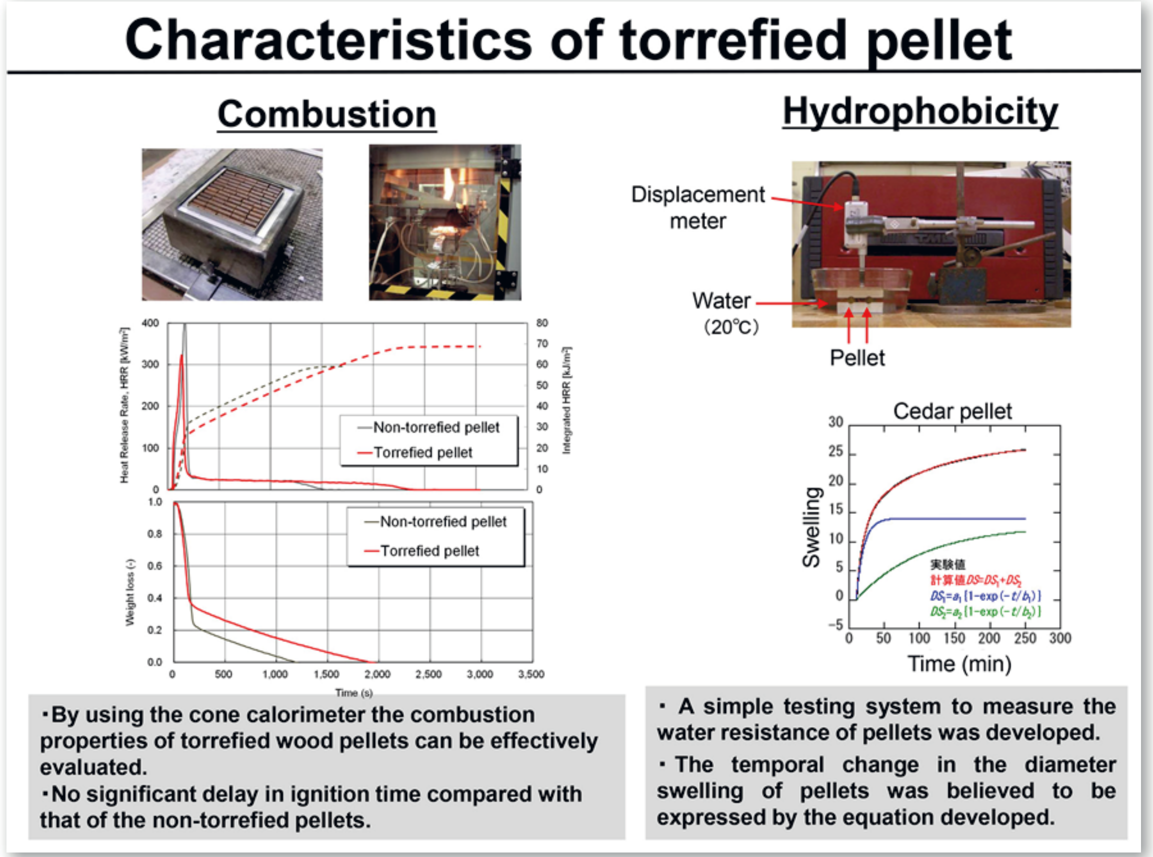

Woody Biomass resources in Japan
Forest residue
Sawmill residue
Demolition wood
8 mil. t (20 mil. m3)
Almost unused
3.4 mil. t
95%
5%
4.1 mil. t
90%
10%
Used
Unused
0
2,000
4,000
6,000
8,000
10,000
Amount (x 1000 t)
(from Annual Report on Forest and Forestry in Japan 2014)
5

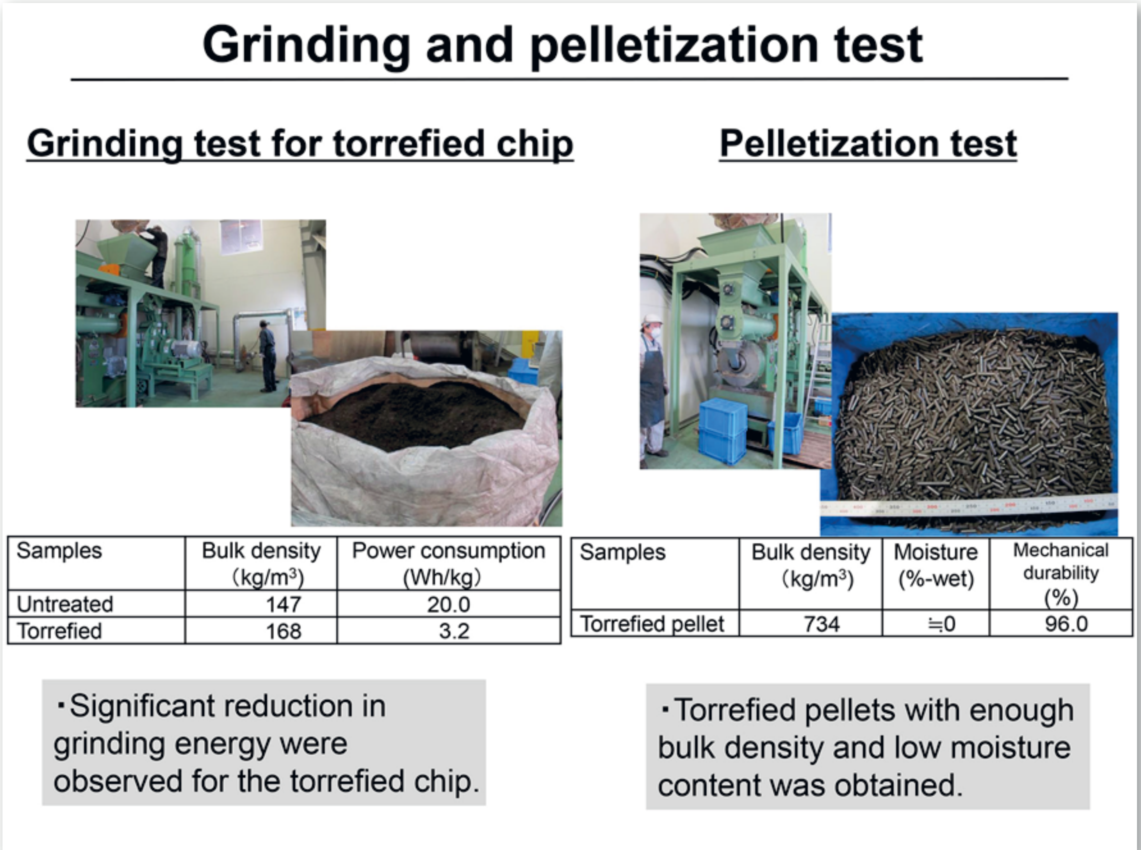

Wood pellet production in Japan
Production (t)
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
98,184
8,737
2005 2006 2007 2008 2009 2010 2011 2012
Year
• The first plant opened in the early 1980s.
• There are over 100 plants in Japan, and many plants have with small capacity (<1,000 t).
• Domestic pellet production : 98,124 t (2012)
• Imported pellet : 72,000t (2012)
6


Torrefaction research in Japan
•FFPRI and Fukui Pref. (2009-)
•FFPRI, Actree, Sanyo-trading (2013-)
Torrefied pellet for small scale use.
•Kinki Univ. and Chugai-Ro Corp.
"Bio-coke" is produced by heating and pressing simultaneously.
Main usage is for iron-making in cupola furnace.
•Ube Industries
Torrefaction of PKS (in Indonesia) was performed.
•Nippon Paper Group (2011-)
Co-combustion with coal in its own boiler.
Mixing ratio was 25 %.
Small
Scale
Large
7


Torrefaction demonstration plant
・FFPRI, Actree Co. and Sanyo-Trading Co. built a demonstration plant of torrefaction in Dec 2014.
Torrefaction unit
Pelletization unit
FFPRI
ACTREE
8

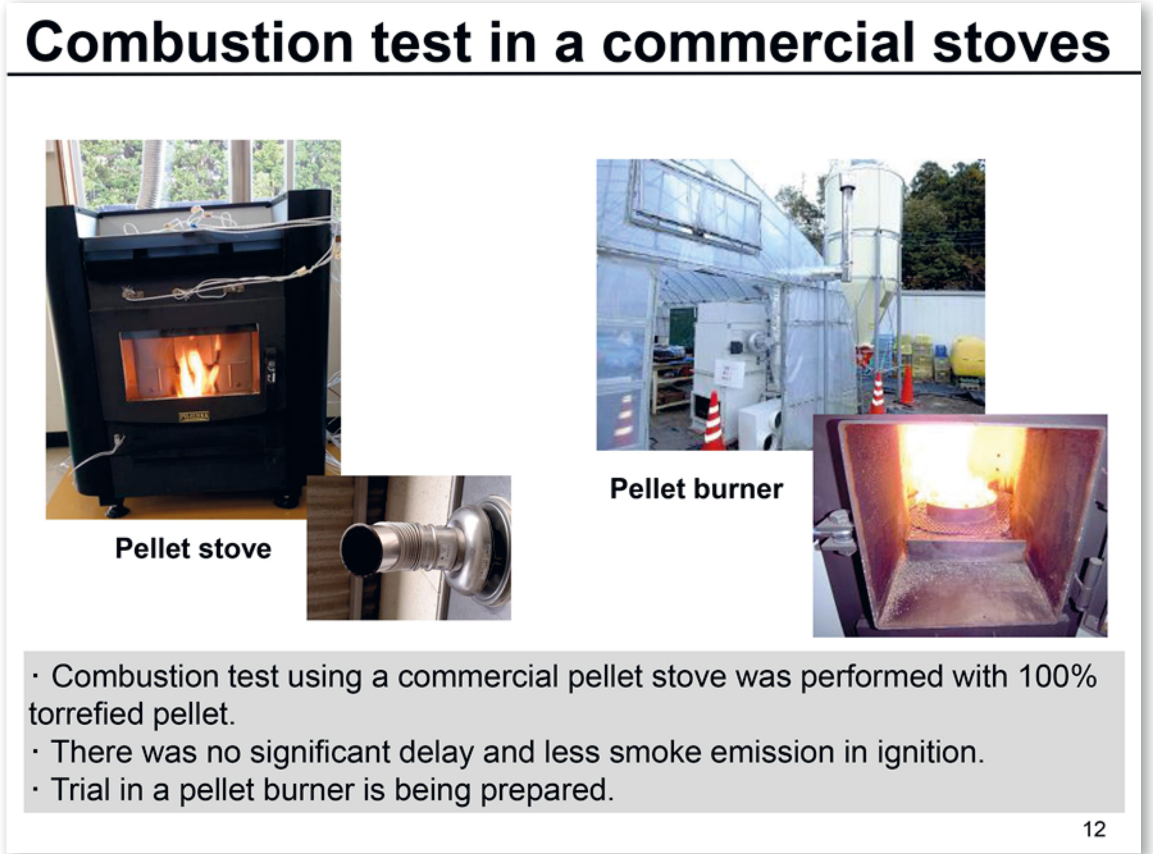


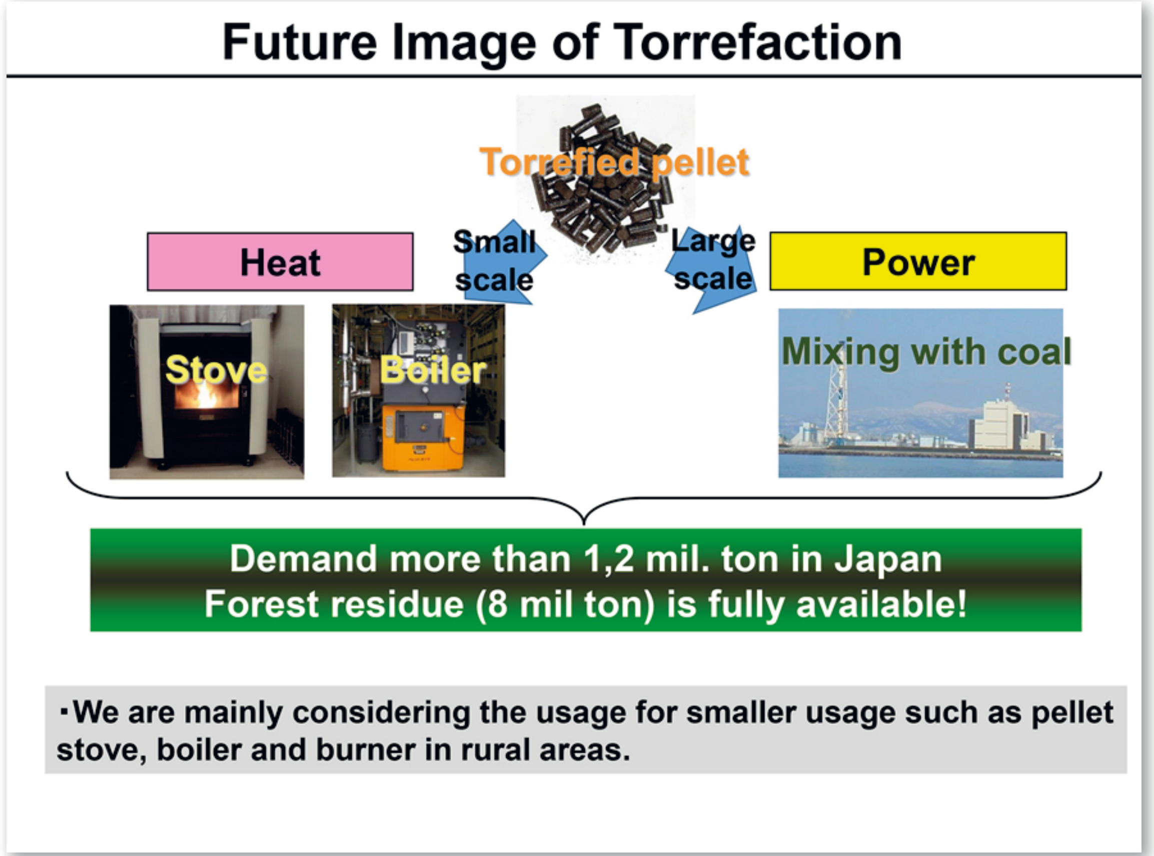




Samples	Bulk density (kg/m³)	Power consumption (Wh/kg)
Untreated	147	20.0
Torrefied	168	3.2

Samples	Bulk density (kg/m³)	Moisture (%-wet)	Mechanical durability (%)
Torrefied pellet	734	≒0	96.0





SPEAKER PROFILES

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Kaiserstraße 12
76131 Karlsruhe

Prof. Dr. Nicolaus Dahmen
Phone: +49 721 608-22596
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Most important career stations:
- 1992 PhD in chemistry at Ruhr-University Bochum
- 1998 Head of Division “High Pressure Processes” at Institute for Technical Chemistry, Research Center Karlsruhe
- 2005 bioliq process manager and Head of Division “Thermochemical biomass conversion”
- 2010 Habilitation at University Heidelberg
- 2014 Professor at Karlsruhe Institute of Technology

Position today:
Professor at Karlsruhe Institute of Technology

Statement

Biomass consists of a broad variety of different feedstocks, altogether providing an enormous mass potential. If they are to be used in large scale, the implementation of feed flexible pre-treatment technologies, optimized towards the intended application, is mandatory. Thermochemical processes are promising due to their evident multi-feed ability and industrial scale applicability.

Kiel, Jaap

Energy Research Center of the Netherlands
Westerduinweg 3
1755 LE Petten / The Netherlands

Prof. Dr. Jaap Kiel
Phone: +31 88 515 4590
E-Mail: kiel@ecn.nl

Most important career stations:
- In 1989, he joined ECN and became involved in the execution, and later organisation and management of a broad range of R&D projects in the field of thermal conversion of solid fuels
- He has played a pioneering role in the development of torrefaction technology and he has coordinated the torrefaction activities at ECN from early on

Position today:
Programme Development Manager Biomass,
Part-time professor Thermo-chemical Conversion of Biomass, TU Delft

Statement

TORWASH is a new technology that is under development at ECN and integrates torrefaction (roasting) with drying and washing. TORWASH technology converts bulky, wet and salty biomass feedstocks into an energy dense biomass fuel. Suitable feedstocks are grass and agro-residues, and possibly forest residues. The product of TORWASH is a solid fuel equivalent to clean torrefied wood pellets. TORWASH is able to upgrade grass and reed to top-class (EN plus A1) energy pellets.

Köchermann, Jakob

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Most important career stations:

- 2007-2014 Studies in chemical engineering at Karlsruhe Institute of Technology and Dresden University of Technology
- 2014 Diploma thesis at German Biomass Research Centre

Position today:
since 2015 Research assistant at German Biomass Research Centre

Statement

By means of hydrothermal carbonization biomass can be converted into a solid lignite similar energy carrier. Since water is used as reaction medium, wet biogenic waste such as sewage sludge, fermentation residues or organic waste are particularly suitable for this conversion process. The splitting of biogenic macromolecules by hydrolysis and the hydrophobization of the surface allow a very good mechanical dewatering of the HTC-coal. As a result, higher energy yields can be achieved in comparison to conventional thermal disposal of wet organic residues.

Lenz, Volker (Moderator)

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Most important career stations:

- postgraduate studies at the FH Darmstadt
- hessenENERGIE GmbH (wind, solar, bioenergy)
- Promotion for the reduction of particulate emissions from wood-burning stoves

Position today:
Head of the "Thermo-chemical Conversion Department"

Statement

In the beginnings we used wood and other biomass for open fires. Than we changed energy consumption towards coal and other fossil fuels due to higher energy density and better homogenisation potential. For the next transformation of the energy supply system we have to come back to renewables like biomass but keep the advantages of homogenious fuels with high calorific value. Thermal-treatment of biomass can be one of the necessary key technologies to achieve this goal.

Pitzer, Erik

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Most important career stations:

- 2004 - 2012 research associate at the University of Applied Sciences biomedical databases, de-novo peptide sequencing
- 2007 - 2009 research scholar at the Harvard Medical School, Decision Systems Group gene expression omnibus data mining, next generation sequencing

Position today:
since 2012 assistant professor at the University of Applied Sciences software and data engineering

Statement

Estimations for decentral biomass logistics require many pieces of information concerning competing factors and need powerful modeling and optimization techniques as well as an interdisciplinary expert dialog to arrive even at themost basic forecasts.

Pollex, Annett

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Most important career stations:

- Pollex studied Chemistry at the TU Dresden (Germany) where she completed her PhD thesis in Organic Chemistry under the guidance of Prof. Hiersemann (Uni Dortmund, Germany)
- postdoctoral research at the BIOS21 institute in Melbourne, Australia

Position today:
since 2010, she has been working at the German Biomass Research Center (DBFZ) in the field of innovative solid biofuel optimization and utilization. She also leads the analytic lab of the DBFZ.

Statement

There is a large variety of currently unexplored biomasses as well as biogenic residues from the forestry and the agricultural sector. However, these resources are often characterized by varying properties and a higher content of critical elements that may lead to higher emissions, fouling and corrosion problems as well as slag formation in the bottom ash. Furthermore, various residues and side products with large unexploited potentials e.g. the biogenic share of municipal waste streams, digestate, sludge and similar materials are characterized by high water contents. Overall, all those characteristics make a pretreatment of the different feedstocks a prerequisite to enable or facilitate their utilization as solid biofuels in different applications.

Witt, Janet

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Most important career stations:
- S&P Sahlmann Haustechnik GmbH, Leipzig, specialist planner for building service engineering (heating-, climate and sanitary installations)
- Institute for energy and environment gGmbH (IE) , Project leader energy economics Promotion at the technical University Hamburg-Harburg (TUHH) about Wood pellet deployment for small com bustion plants - analysis and evaluation of influence on the fuel resistance

Position today:
Since 2008 in DBFZ / department bioenergy systems, leader of working group markets and use and member of DIN/ISO standardisation committee of solid biomass

Statement

The process of torrefaction has the potential to provide a significant contribution to an enlarged raw material portfolio for sustainable biomass fuel production inside Europe by including both agricultural and forestry biomass (residues). The SECTOR project – with more than 20 european partners from industry and science – is expected to shorten the time to market for torrefaction technology through extensive pilot and demo scale torrefaction as well as densification trials. The downstream value chain is elaborately assessed through logistics and end-use testing of the torrefied biomass, in combination with supporting small-scale experimentation and analysis.

Yanagida, Takashi

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Most important career stations:
Takashi Yanagida studied bioengineering at University of Tsukuba, Japan, finishing his PhD in 2005. He started his professional work on biomass energy as a post-doctoral fellow at Advanced Industrial Science and Technology (AIST) untill Aug. 2011, and at Hiroshima University as an assistant professor untill Feb. 2014, then moved to Forestry and Forest Products Research Institute (FFPRI), Japan.

Position today:
senior researcher, specializing in system evaluation of biomass energy at FFPRI (since 2015)

Statement

In Japan we have quite a lot of wood potential in rural area and with our research we want to upgrade the forestry residues to a high quality homogeneous wood fuel with high heating value and hydrophobicity especially for the use in small scale furnaces.

ORGANIZER

The DBFZ (German Biomass Research Centre)

Organizer of the Side-Event is the DBFZ Deutsches Biomasseforschungszentrum gemeinnützige GmbH.

Our Mission

The DBFZ was established by the former German Federal Ministry of Food, Agriculture and Consumer Protection (BMELV) with the aim of establishing a central scientific research institution covering all the fi elds relevant to bioenergy, to bring together the findings of the highly diverse German research community in the sector. The scientific mission of the DBFZ is to support the efficient integration of biomass as a valuable resource for sustainable energy supply based on wide-ranging applied research. The mission incorporates technical, ecological, economic, social policy and energy business aspects all along the process chain, from production, through supply, to use. The DBFZ drives and supports the development of new processes, methodologies and concepts in close cooperation with industrial partners. It also maintains close links with public-sector research bodies in Germany in the agricultural, forestry and environmental sectors, as well as with European and global institutions. Working from this broad research base, the DBFZ is also tasked to devise scientifically sound decision-making aids for government policy-makers.

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The European Biomass Conference and Exhibition

Host of the Side-Event "Thermally treated Bioefuels" is the European Biomass Conference and Exhibtion (EUBC&E)

The Conference

The European Biomass Conference and Exhibition (EUBCE) is a world class annual event which, since 1980, is held at different venues throughout Europe. It is Europe‘s largest international conference focused on biomass combining a highly-respected international scientific conference with an industrial exhibition and gathers participants from research, industry, policy and business of biomass.

Mission & Vision:

The EUBCE provides a high-level Scientific Programme, Parallel events and it atttracts Participants from a wide ranging background: researchers, engineers, technologists, standards organisations, policy and decision makers, financing institutions Research & industrial exhibitors.

EUBCE - The European Biomass Conference and Exhibition
ETA s.r.l. - Single-member private limited liability company
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23rd European Biomass Conference & Exhibition