GA no 282826

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

Deliverable No. D10.3

Proceedings of the Workshops

Annex 2

TORREFACTION – INTERNATIONAL OVERVIEW OF DEVELOPMENTS IN THIS NOVEL TECHNOLOGY

Michael Wild
Wild&Partner LLC, Vienna, Austria
IBTC, Brussels, Belgium

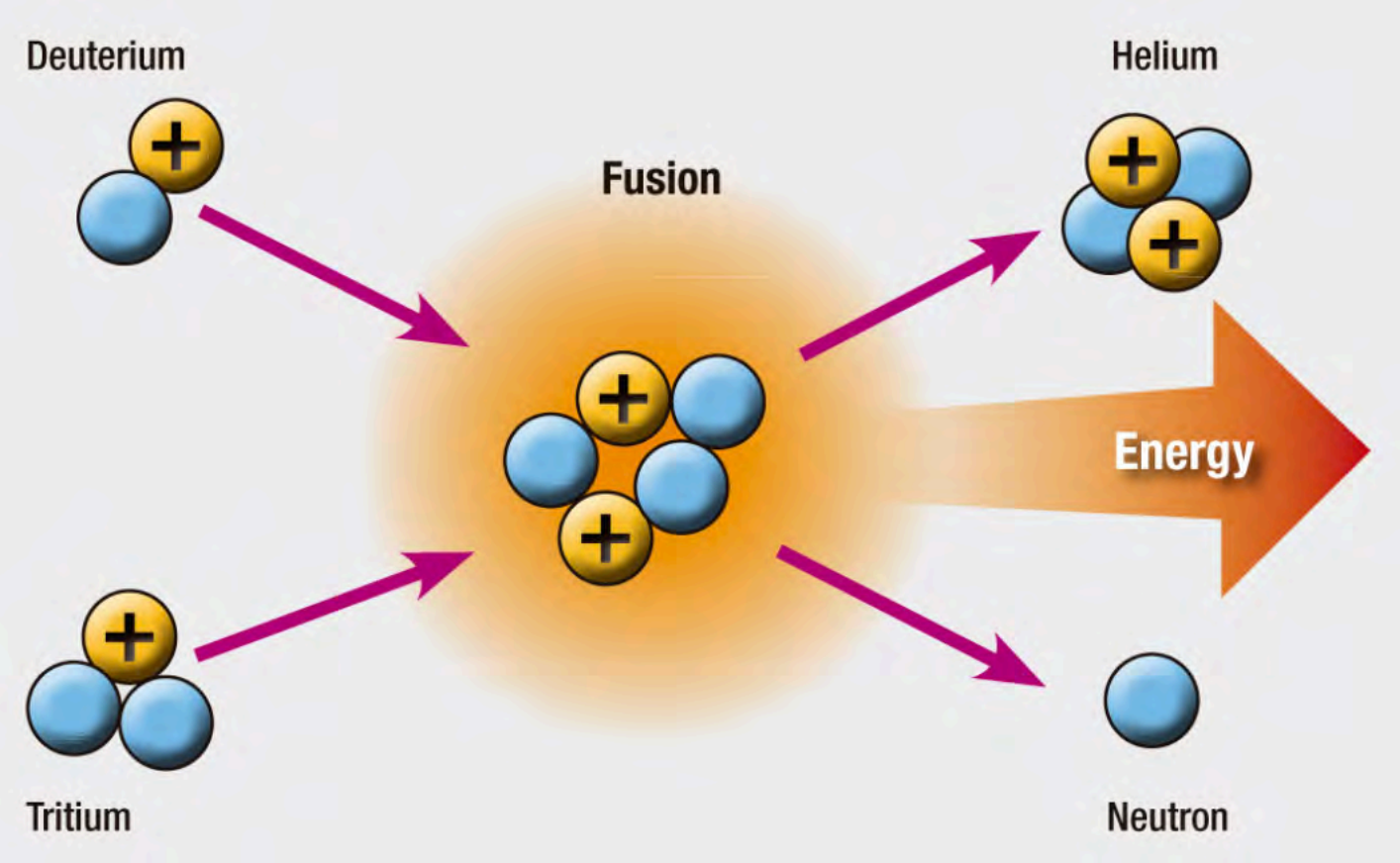
Picture: M.Englisch

Graz, January 17th 2014

Wild,M., International overall view of developments in the torrefaction sector; presentation at IEA task 40 torrefaction workshop at CEBC, Graz, 15-17.1.2014

1960ies

NUCLEAR FUSION
THIS IS THE ENERGY OF THE FUTURE
AND IT IS JUST AROUND THE CORNER



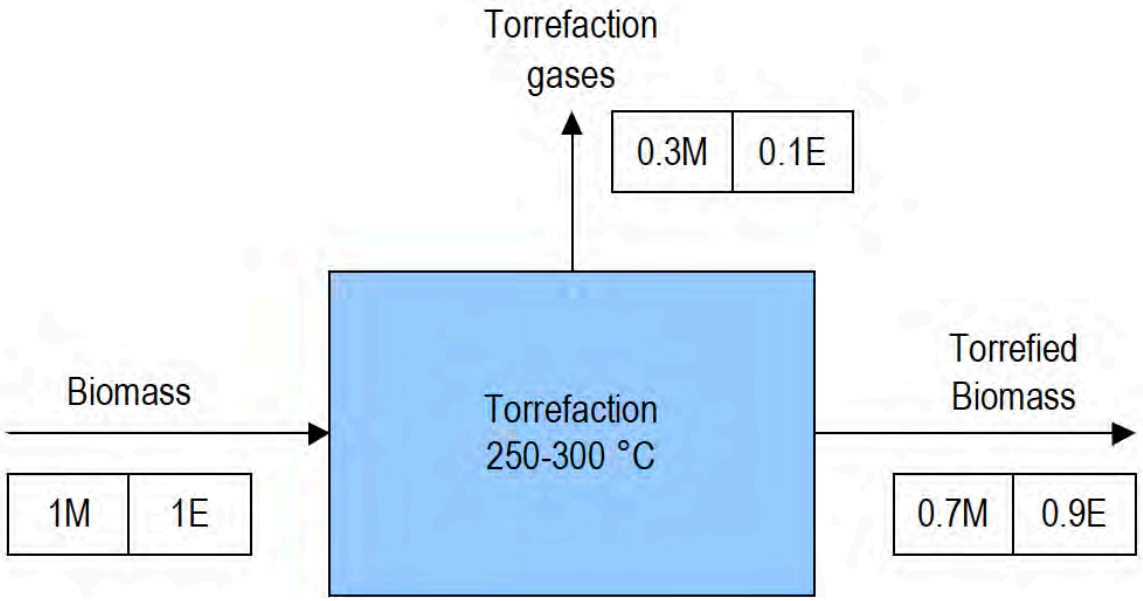
2014

W&P

.....AND IT ALWAYS WILL BE

2007

TORREFIED BIOMASS IS THE SOLID RENEWABLE FUEL OF THE FUTURE



Source:P.C.A. Bergman

2014

...AND IT IS AVAILABLE **NOW**

Loading at Production Site

Source: ACB Entwicklungs GmbH

Loading at Production Site

Source: NewBiomassEnergy

Loading at Production Site

Very limited dusting and breakage

Source: NewBiomassEnergy

Loading at Production Site

Source: NewBiomassEnergy

Loading to the Vessel

Truck – hopper – conveyor belts

Source: NewBiomassEnergy

Loading to the Vessel

Truck – hopper – conveyor belts

Source: NewBiomassEnergy

Dusting less or compareable to WWP

Loading MV HENNY on order of NEW BIOMASS ENERGY

Source: NewBiomassEnergy

Metering at unloading

Source: NewBiomassEnergy

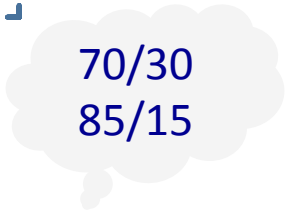
Mission of companies in Torrefaction

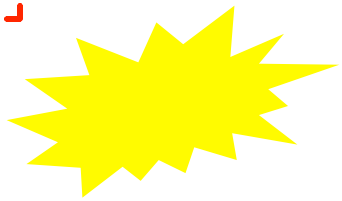
- Produce the best solid biomass in terms of
  - Application efficiency and variability
  - Supply chain efficiency
  - Cost effectiveness
  - Storeability
  - Carbon efficiency
  - Tradeablity
- Make remote biomass accessible to the market
- Help in creating a **win - win - win** situation for **producer - trader - consumer**

Why Torrefaction

1. Significant cost reductions in transport and handling
2. Broader feedstock basis - geographically + types of raw material
3. Almost 0 biodegradation of product when stored
4. Large variety of applications
5. Reduces CAPEX&OPEX at enduser – Immediate use in existing coal fired plants –grindability, water resistance....
6. Combusts cleaner, gasifies easier and cleaner
7. Can be made to measure to clients requirements
8. Helps developing the market towards commoditisation

More than 1 issue to be solved





Drying

Torrefaction

Densification
(Pellets,Briquetts)

Energy
Supply

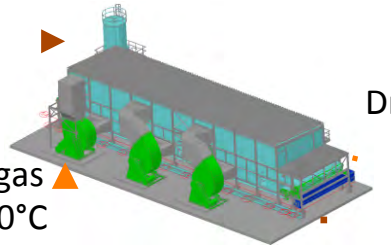
Continuous Densification Today

Source: Andritz AG

The torrefaction process (example ACB)

Fresh biomass

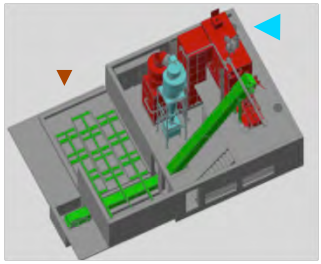
Fresh biomass fuel



Flue gas
T=300°C

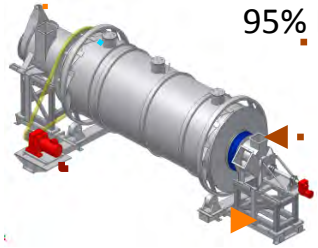
Dryer offgas

Dried biomass
95% DS



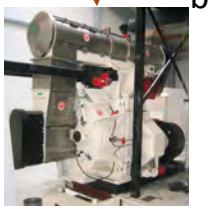
ACB gas
T=280°C

Flue gas
T=400°C



ENERGY SUPPLY
Biomass +
lean gas incineration

Torrefied biomass



Torrefied biomass

ACB Process development supported by:

klima+ energie fonds

Source ANDRITZ AG, Design W&P

Fresh biomass

DRYING

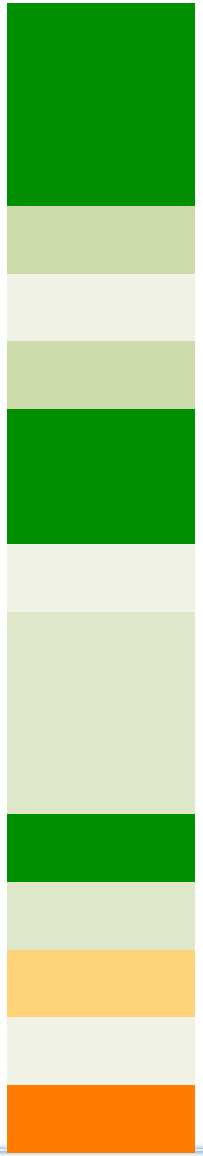
TORREFACTION

PREPARATION(milling) of torrefied material

DENSIFICATION of torrefied material

ACB Fuel

Torrefaction Implementation Thermometer



Torgas Handling	done
Torgas Utilisation	done
Continuous torrefaction	done
Predictability and consistency of product	mostly done
Densification	in optimisation
Feedstock flexibility	mostly done
Safety in plant	done
Indoor storgae	done
Outdoor storage	in optimisation
Standardisation of product	in progress
Safety along supply chain	in progress
Trade Registrations and Permissions	in progress
Co-firing trials	done
Co-firing burn tests	in progress
Co-firing full scale	mostly open
Heat application trials	in progress
Heat application acceptance	completely open

Bringing together the performing companies in Torrefaction

- Promoting the uptake of torrefied biomass for Energy
- All issues of common interest which are not under competition
- Regulatory Barriers, general permissions along supply chain
- Link to Policy
- Safety and Health
- First contact for everybody interested in Biomass Torrefaction

INTERNATIONAL BIOMASS TORREFACTION COUNCIL

AEBIOM
EUROPEAN BIOMASS ASSOCIATION

IBTC Full Members

KAHL

ANDRITZ

AREVA

Arigna Fuels Ltd
Manufacturers of Quality Smokeless Fuels

BIOLAKE

cmi

Electrabel
GDF SUEZ

RIVER BASIN ENERGY INC

Rotawave

TORR COAL

Topell Energy

TORBED
Energy technologies

IBTC Supporting Members

Advanced Torrefaction Systems, LLC

ECN
Your energy. Our passion.

energy valley

DNV·GL

CPL INDUSTRIES

#bio

epi

SAB

MIKTECH

BioEndev

www.aebiom.org/blog/ibtc/ calderon@aebiom.org

INTERNATIONAL BIOMASS TORREFACTION COUNCIL

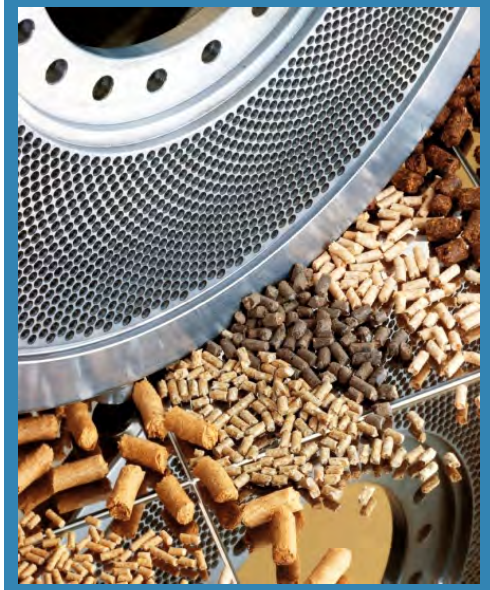
KAHL

Amandus Kahl GmbH & Co. KG in Hamburg (Germany) plans, designs, and builds machines, plants, and turnkey production plants for conditioning and compaction of various materials for a range of industrial processes in the biomass, feed, food, chemical and recycling industry.

Besides AMANDUS KAHL, the companies SCHULE MÜHLENBAU, NEUHAUS NEOTEC and HEINEN FREEZING belong to the Kahl-Group (650 employees in total).

In recent years, numerous trials were carried out in our technology centre on the pelleting of torrefied wood and torrefied biomass as well as of steam explosion products in order to gain experience and data for upscaling the pelleting plant to a commercial scale (> 10 t/h) with flat die pelleting presses. Amandus Kahl installed the pelleting line for Topell (NL) and installs plants for other contractors in North America.

Together with Neuhaus Neotec, Amandus Kahl carries out research work on the torrefication of wood and biomass pellets using a modified coffee roaster.



INTERNATIONAL BIOMASS TORREFACTION COUNCIL

ANDRITZ





Andritz Torrefaction Technologies

- **Two Main Technology Platforms**

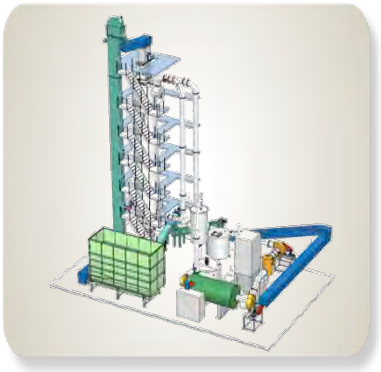
Large plants: up to 700.000 t/a per line	Small / medium plants: 50.000-250.000 t/a
Andritz/ECN Torrefaction Design	**Andritz ACB® Torrefaction Design***
Industrial Demoplant (1t/h) in Denmark starting up in 3rd quarter 2012	Industrial Demoplant (1t/h) in Austria in operation from 4th quarter 2011.
Pressurized, moving bed reactor Andritz/DTI Pelleting plant	Rotating, indirectly heated drum reactor Briquetting plant
Key Features: Scale up to huge capacities possible (experience from Pulp & Paper) Feed material: Wood Chips/Forest Residuals	**Key Features:** Simple process concept specially developed for decentralized plants Flexibility in feed material

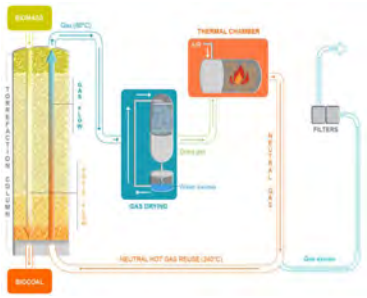
Supplying turn key plants 50.000 to 250.000mt/a

separation@andritz.com www.andritz.com

INTERNATIONAL BIOMASS TORREFACTION COUNCIL

AREVA





- **AREVA is the leading global provider of products and services related to nuclear power.**
- **The group is also a major player in renewables energy ; AREVA Renewables provides advanced technology solutions in offshore wind, concentrated solar power, energy storage and bioenergy.**
- AREVA Bioenergy acquired the “Thermya” torrefaction technology in July 2012. Thermya was a French engineering company funded in 2002, specialized in biomass conversion.
- This acquisition is in line with AREVA Renewables’ strategy to increase the technological content of its portfolio, and allows to widen the range of products addressing the biomass to energy market.
- **AREVA Bioenergy has since been engaged into a full process and product development approach to deliver industrial-scale EPC torrefaction plants, and is currently constructing a 2.5 tons per hour prototype plant.**
- **The AREVA Biomass Torrefaction Process relies on a direct heating, moving bed technology. It implements a continuous thermal treatment in a torrefaction column, where two flows move vertically in opposite directions.**

AREVA Biomass Torrefaction – Key Advantages

- **A process that can be fine-tuned to reach the desired output product specifications.**
- **A process that offers an optimized heat and mass balance**
  - Direct heating of the biomass by neutral gas ensures that no unnecessary mass or calorific potential is lost.
  - In standard operating conditions, the process produces a biocoal that still contains 95% of its energy potential.
- **A process than ensures an homogeneous production and a constant quality of product**
  - Continuous process guaranteeing that biomass particles are torrefied to the core and to the same extent.
- **A robust process that offers the lowest possible operating and maintenance costs**
  - Low temperature of torrefaction, direct temperature exchange between gas and biomass
  - Very few moving parts
- **A process that avoids the formation of tars and pyrolitic juices**

INTERNATIONAL BIOMASS TORREFACTION COUNCIL

Arigna Fuels Limited

Arigna Fuels Ltd
Manufacturers of Quality Smokeless Fuels

- Family owned mining business based in Arigna since late 1800's
- First briquetting plant was built in 1937 and used a pitch binder
- Smokeless Briquetting Process using starch based binder developed in Arigna and Patent granted in 1992
- Now Irelands largest manufacturer of coal based smokeless fuel , built up after the closure of the coal mines in 1990.
- Our interest in renewables to date has centred on development of wind farms on our old opencast mine sites.
- 50 employees, €20m turnover , 20% export

INTERNATIONAL BIOMASS TORREFACTION COUNCIL

BIOLAKE

Biolake BIOpellets

Status overview:

- Successful trials have been conducted to torrefy herbaceous biomass such as straw and miscanthus
- Industrial pellet test were successful, durable BIOpellets can be produced without a binder
- The system operates auto thermal on the ablated torrefaction gas after the initial start-up
- Now working on process control automation of the BTSystem
- Testing more biomass types

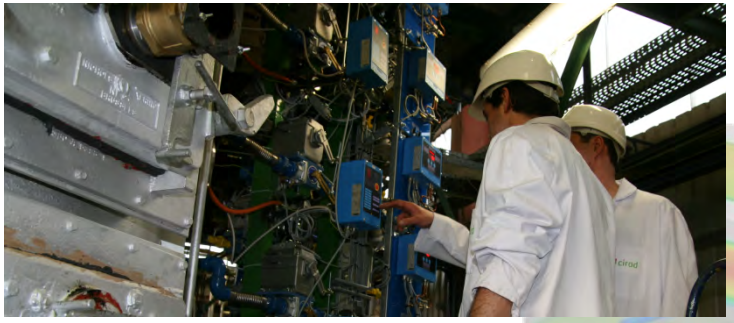
Highlights of the BTS system

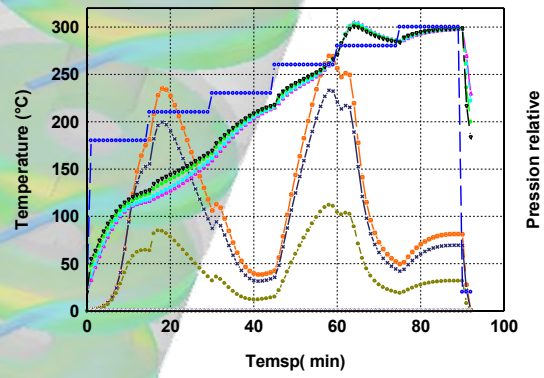
- Modular system with a capacity of 7,000 ton/year output for each line, scaling up by adding more lines
- Low transport cost of the raw biomass, torrefaction system can be placed near the biomass source
- System suitable for a wide variety of biomass sources

www.Biolake.nl

Nesa

(http://www.cmigroupe.com/en/p/sustainable-development)





Since 2009, Extensive RD program in Partnership with CEA and Cirad to industrialize the most promising technology in line with the market expectations

INTERNATIONAL BIOMASS TORREFACTION COUNCIL

RIVER BASIN ENERGY INC

River Basin Energy

- Founded in 2008 to develop advanced fuels for coal power stations.
- Commercialising biomass fuel production globally to replace coal with bio-coal in thermal power stations as well as supplying high quality coal fuels upgraded from low-rank coal reserves.
- A leading supplier of enhanced fuels for existing thermal power plants in regions where asset utilisation and a low carbon footprint are of importance to utilities and generators.
- Liberates biomass fuel supply for coal power assets through application of unique and efficient upgrading technology.
- Provides the most effective solutions to decarbonize existing coal burning utilities, while keeping operational cost and generation performance at current levels without the need for significant capital spending.
- Bridges the gap between;
  - The capability of forest owners and coal miners who supply feedstock with complex sourcing and quality attributes; and
  - The need of power generators for standard, reliable and appropriate fuel sources.

INTERNATIONAL BIOMASS TORREFACTION COUNCIL

Rotawave

Rotawave Biocoal

- Rotawave Biocoal has developed and patented an innovative microwave assisted torrefaction process to convert biomass into biocoal.
- This Targeted Intelligent Energy System (TIES) ensures consistent product from a wide range of feedstocks.
- Industrial scale pelletisation trials have been successfully completed
- Full scale co-firing trials of our biocoal have shown that coal substitution is possible with out major modification to the coal power station.
- A 100,000 MT/annum TIES is under construction in the USA. A total of 1.7m tonne per annum capacity is planned by 2017.
- The system has a small footprint, and can be easily retrofitted to white pellet plants
- Biocoal has a high energy density and can be stored outside, this means transport and handling costs are significantly reduced.

www.rotawave.com

INTERNATIONAL BIOMASS TORREFACTION COUNCIL

Topell Energy

Topell Energy

- Topell Energy develops and sells torrefaction technology
- Proof of technology with test reactor(2009)
- Built full scale demo plant in Duiven, The Netherlands (2010)
- Start-up Duiven plant and failure to ramp up (2011-2012)
- Re-design Duiven plant (H1 2013)
- Proof of concept at industrial scale, including large scale co-firing test (H2 2013)
- International roll-out of Topell Torrefaction System (2014)

INTERNATIONAL BIOMASS
TORREFACTION COUNCIL

TORR COAL

Company information.

The Torr-Coal Group was founded in 2005 to develop a torrefaction technology for pure and impure biomass.

In 2010 our own demonstration plant, capacity 30.000 t/y, started the deliveries of Torr®Coal powder and Torr®Coal pellets based on pure biomass.

We are now ready to introduce this technology in the market.

Presently the Group is one of the leading providers of torrefaction technology solutions in the world.

Torr-Coal technology.

Torr-Coal Group has developed a partly patented, continuous torrefaction process, from different types of raw material till the end product. The process centres around a rotary drum reactor with a state of the art process control system.
The technology allows us to produce a highly consistent, stable product with excellent fuel properties.
The own demonstration plant has been intensively in use, since 2.5 years, to produce quantities for large scale co-firing and for gasification. Also the production of test quantities of different raw materials, as well as providing the necessary data to optimize both product quality and the design of our industrial scale production plant.

Environment.

Replacing fossil coal by torrefied wood pellets decreases the total CO2 emissions, decreases the demand of imported energy sources and enhances local economy.

Applications.

Torr®Coal bio-fuels are suitable for use:

- in conventional coal fired energy plants
- in gasification units.

INTERNATIONAL BIOMASS TORREFACTION COUNCIL

energy valley

Mission

Energy Valley's mission is to encourage, incite, facilitate and connect companies, knowledge institutes and government bodies to develop projects together and make real progress in clean, reliable and innovative energy.

Energy Valley Foundation

The Energy Valley Foundation is a network organisation working together with public and private partners to explore regional growth opportunities in the energy sector. The institute acts as an intermediary to accelerate projects, promote knowledge sharing and strengthen the northern energy region.

The institute is made up of a team of energy professionals who, in consultation with the Supervisory Board and relevant government bodies, support initiative-takers in implementing energy projects. The focus lies on energy innovations which link up directly with national and international energy ambitions and regional strengths.

Strategic Partners

Torrefaction

Torrefaction is one of the key technologies in our future sustainable energy system. Energy Valley supports initiatives that develop and market torrefaction technologies, a.o.:

- Biolake
- Wood Spirit
- Dutch Torrefaction Association

Bio Based Energy

- Innovative conversion technology
  - Energy: Thermo- and biochemical conversion (digestion, torrefaction, pyrolysis, gasification)
  - Green chemistry and bio refinery
  - Feedstock
  - Biomass and waste streams
  - Innovative biomass: aquatic biomass

Energy Valley Region

- **Feedstock** is available
  - Biomass: agri and related industries
  - Logistical advantages
- **Technology** is available
  - Knowledge: Universities of Applied Science, University Groningen, Carbo Hydrate Competence Centre
  - Projects in entire innovation chain
- **Application**
  - Chemical industry is present
  - Ambition toward sustainability
- Favourable **Conditions**
  - Stimulation of economic development
  - Sustainability policy
  - Space

DNV GL Energy and upgraded biomass

- We consider ourselves as an independent party to supply investors, suppliers, and end-users with dedicated upgraded biomass technical and business support to integrate upgraded biomass processing technologies (primarily torrefaction and steam explosion) in the biomass supply chain while ensuring the availability, reliability, sustainability and profitability of the generation of electricity and heat

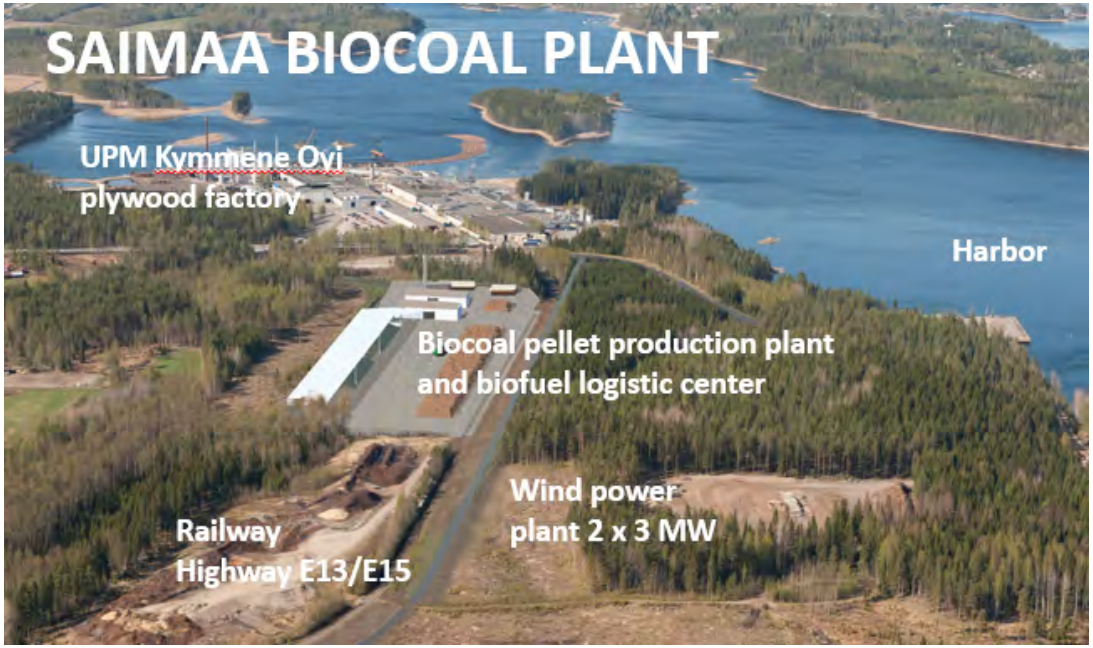
- DNV GL Energy continuously tracks and evaluates the development of torrefaction and steam explosion technologies and commercial parties that bring torrefaction and steam explosion to the next level.

- Our biomass upgrading services include technology verification, technical due diligences, tendering assistance, process and design reviews, co-firing feasibility studies / operational impact studies, guarantee measurements, measurement campaign support, risk assessments

INTERNATIONAL BIOMASS TORREFACTION COUNCIL

MIKTECH

Miktech Ltd.



BIOSAIMAA

- Miktech is an innovation and technology center in Mikkeli, eastern Finland. It provides various business development services for technology companies and coordinates diverse projects. Miktech coordinates Biosaimaa cluster that aims at the establishment of a commercial scale (200 000 t/a) biocoal production plant to Ristiina as one of its key projects.
- The construction of a torrefaction technology pilot plant capacity of 10 000 t/a started in Mikkeli in October 2013. It is expected to be in operation in early 2014. The implementation of the pilot plant is carried out by Torrec Ltd., which aims to develop and commercialize torrefied wood pellet production technology.

INTERNATIONAL BIOMASS TORREFACTION COUNCIL

CPL INDUSTRIES

CPL Industries

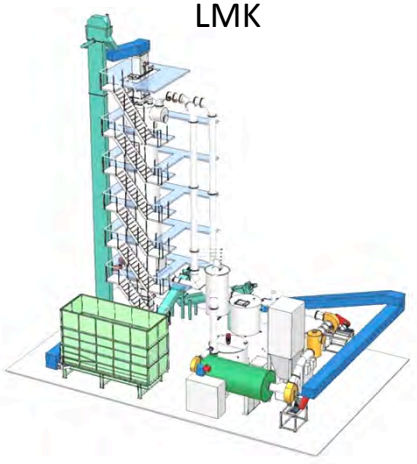
CPL has been making coal since the 1940s, with the production of their first Phurnacite plant. But since then, the company has grown to encompass a range of industries, from charcoal and activated carbon, to gardening and renewable energy. Their wealth of industry knowledge, combined with enormous manufacturing capabilities and a team of expert staff has helped to position CPL at the forefront of the European solid fuel industry. They also maintain a successful and growing European export business, exporting over 60,000 tonnes every year into major markets in France, Germany and Ireland.

CPL is focused on the future, with emphasis on developing technologies, notably in the field of torrefaction. Our development of innovation technologies happens through our own research and through partnerships:

CPL Immingham

Ingelia

LMK



For further information on our plans to develop a pyrolysis plant in Ireland modifying biomass (c 100kt pa) to provide 100% biomass fuels and biomass for blended products see: www.cplindustries.co.uk

INTERNATIONAL BIOMASS TORREFACTION COUNCIL

ECN
Your energy. Our passion.

Energy Research Centre of the Netherlands

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

INTERNATIONAL BIOMASS TORREFACTION COUNCIL

BioEndev

BioEndev AB

- BioEndev is an engineering spin-off company originating from R&D at Umeå University, Sweden
- Torrefaction has been the focus area since 2004 and BioEndev was started in 2007
- Since then and utilizing the flexible first pilot plant, BioEndev developed its own proprietary torrefaction technology, subsequently demonstrated in the 2nd generation pilot plant during 2013The technology is now to be demonstrated in a (24h/7d) industrial demonstration unit (IDU) located in Holmsund, 15 minutes east of Umeå. The plant will be inaugurated this year and brought up to a full capacity of 16 000 t/yr during the autumn 2014

- The innovative (patented) process solutions governs:
  - high product quality (more hydrophobic and durable pellets/briquettes)
  - a cost efficient production
  - low investment costs
  - high product yield
- The BioEndev initiative is carried out in close collaboration with a number of highly qualified and experienced partners, benefitting from the long tradition of biomass handling and conversion experiences in Sweden

INTERNATIONAL BIOMASS TORREFACTION COUNCIL

#bio
www.hashtagbio.com

Biocoal from straw - supply chains from Ukraine

Unused straw Ukraine > 16 million tons

#bio working with large Agricultural holdings

Our own technological solutions developed in-house

Mobile installations to bring processing onto farms.

We aim to sell finished product in bulk not torrefaction machinery

Completing proof of concept/ first commercial plant for 2014

5 year plan to build in partnership large capacity in Ukraine of ½ million tonnes a year

Good logistical links to

Poland (via rail)

Klaipeda

Black Sea

Danube

All Ukraine (via rail)

INTERNATIONAL BIOMASS TORREFACTION COUNCIL

Electrabel GDF SUEZ

Pilot Group Clean Coal

- Torrefaction is meant for producing bio-coal able to substitute fossil coal
  - → for biofuel production
  - → for power generation in pulverised coal power plant
- Torrefaction is being developed for <u>two key purposes</u>:
  1) Get rid of the difficulties of milling fibrous biomass such that coal mills can be used
  2) Increasing the energy density of biomass for efficient and economic transport
- But <u>problems</u> !!!
  1) Torrefaction increases energy to mass density but not necessarily volumetric density
  2) So, pelletisation (6x denser) is needed and must be organised in a continuous process
  - → the torrefied material must be cooled down before pelleting to avoid fire
  - → pelletisation do not necessarily deliver high durability pellets because the binder=lignine is eliminated within the torrefaction process
  - → Difficult to optimize the production process with a high capacity on a continuous way
  3) Torrefied product generate much fine dust that is more explosive than wood dust and the product can also produce self heating that makes transport risky in containers/trains
  4) Torrefaction consumes part of the carbon and concentrates the minerals and alkali
- <u>Consequences</u>
  1) Most of the process owners are unable to produce adequate product
  2) There is a tendency to decrease torrefaction T to keep lignine but then fibrous character is not suppressed and the product is not black but green
  3) Ash content increases and alkali concentration can go above technical limits for boilers

Making the product tradeable

Quality – Standardisation

New Work Item ISO 238 WG 2
ISO 17225: Solid biofuels – Fuel specifications and classes – Part XX: Graded torrefied pellets

Comments will be collected by national standardisation committees

Please address also IBTC with comments and requirements

Grindability
Water resistance
Energy balance

Property class, Analysis method	**Unit**	**TW1**	**TW2**	**TW3**
Origin and source, ISO 17225-1		1.1.1 Whole trees without roots 1.1.3 Stemwood 1.1.4 Logging residues 1.2.1 Chemically untreated wood residues [a]	1.1 Forest, plantation and other virgin wood 1.2 By-products and residues from wood processing industry	1.1 Forest, plantation and other virgin wood 1.2 By-products and residues from wood processing industry
Diameter, D [b] **and Length L** [c] ISO 17829 According Figure 1	mm	D06, 6 ± 1; 3,15 ≤ L ≤ 40 D08, 8 ± 1; 3,15 ≤ L ≤ 40	D06, 6 ± 1; 3,15 ≤ L ≤ 40 D08, 8 ± 1; 3,15 ≤ L ≤ 40	D06 6 ± 1; 3,15 ≤ L ≤ 40 D08 8 ± 1; 3,15 ≤ L ≤ 40
Moisture, M, EN 14774-1, EN 14774-2	as received, w-% wet basis	M10 ≤ 10	M10 ≤ 10	M10 ≤ 10
Ash, A, ISO 18122	w-% dry	A2.0 ≤ 2,0	A5.0 ≤ 5,0	A10.0 ≤ 10,0
Mechanical durability, DU, ISO 17831-1	as received, w-%	DU97.5 ≥ 97,5	DU96.5 ≥ 96,5	DU96.5 ≥ 96,5
Fines, F [d], ISOWD XXXXX (hand sieving)	w-% as received	F1.0 ≤ 1,0	F1.0 ≤ 1,0	F1.0 ≤ 1,0
Additives [e]	w-% dry	Type and amount to be stated	Type and amount to be stated	Type and amount to be stated
Net calorific value, Q, ISO 18125	dry, MJ/kg or kWh/kg	Q20, Q ≥ 20 Q5.6,Q ≥ 5,6 Value to be stated	Q20, Q ≥ 20 Q5.6,Q ≥ 5,6 Value to be stated	Q19, Q ≥ 19 Q5.3,Q ≥ 5,3 Value to be stated
Bulk density, BD , ISO 17828	kg/m^3	BD650 ≥ 650 Value to be stated	BD650 ≥ 650 Value to be stated	BD650 ≥ 650 Value to be stated
Nitrogen, N, ISO 16948	w-% dry	N0.5 ≤ 0,5	N0.5 ≤ 0,5	N1.0 ≤ 1,0
Sulphur , S, ISO 16994	w-% dry	S0.3 ≤ 0,3	S0.3 ≤ 0,3	S0.5 ≤ 0,5
Chlorine, Cl, ISO 16994	w-% dry	Cl0.03 ≤ 0,03	Cl0.05 ≤ 0,05	Cl0.1 ≤ 0,1
Arsenic, As, ISO 16968	mg/kg dry	≤ 2	≤ 2	≤ 2
Cadmium, Cd, ISO 16968	mg/kg dry	≤ 1	≤ 1	≤ 1
Chromium, Cr, ISO 16968	mg/kg dry	≤ 15	≤ 15	≤ 15
Copper, Cu, ISO 16968	mg/kg dry	≤ 20	≤ 20	≤ 20
Lead, Pb, ISO 16968	mg/kg dry	≤ 10	≤ 10	≤ 10
Nickel, Ni, ISO 16968	mg/kg dry	≤ 10	≤ 10	≤ 10
Zinc, Zn, ISO 16968	mg/kg dry	≤ 200	≤ 200	≤ 200
Volatile matter, VN	w-% dry, ash free	VN ≤ 75 Value to be stated	VN ≤ 75 Value to be stated	VN ≤ 75 Value to be stated
Ash melting behaviour [f], CEN/TS 15370-1 [4]	°C	To be stated	To be stated	To be stated

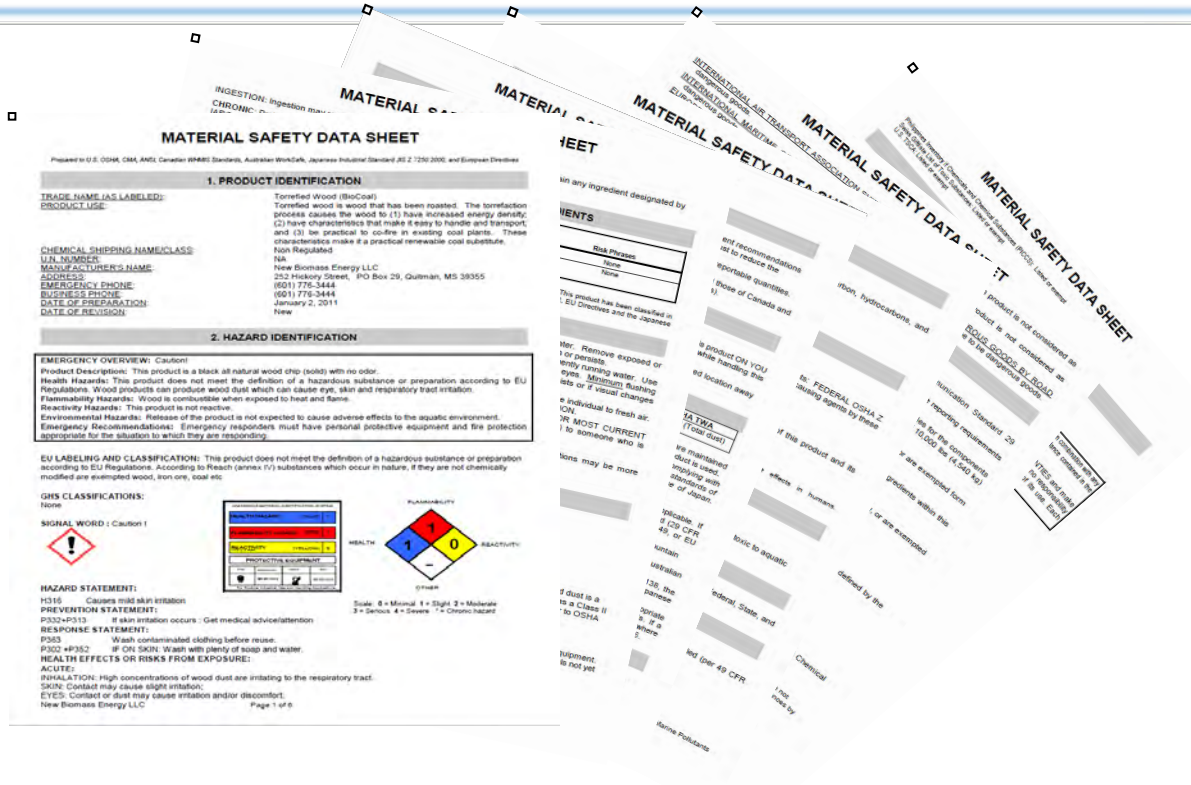
Documentation, Permissions and Registrations

MSDS

REACH

Customs CODE EU

IMO, IMSBC code



Department of Homeland Security/US Coast Guard 3 years permit

To develop/receive this extensive tests have been carried out:
Results all equal or superior to wood pellets

Water Uptake

ACB - Weather test prelim. results briquettes

Briquette Quality before and after:

Method:
Briquetts (D=70mm, spruce, production 10.04)
filled in a box of 1,4 m height and been stored outside

After 43 days of storage box has been dismantled and briquette quality evaluated

Rainfall during storage time:

21 rainfalls have been documented
3 rainfalls with > 20 mm/m2

Sample 1

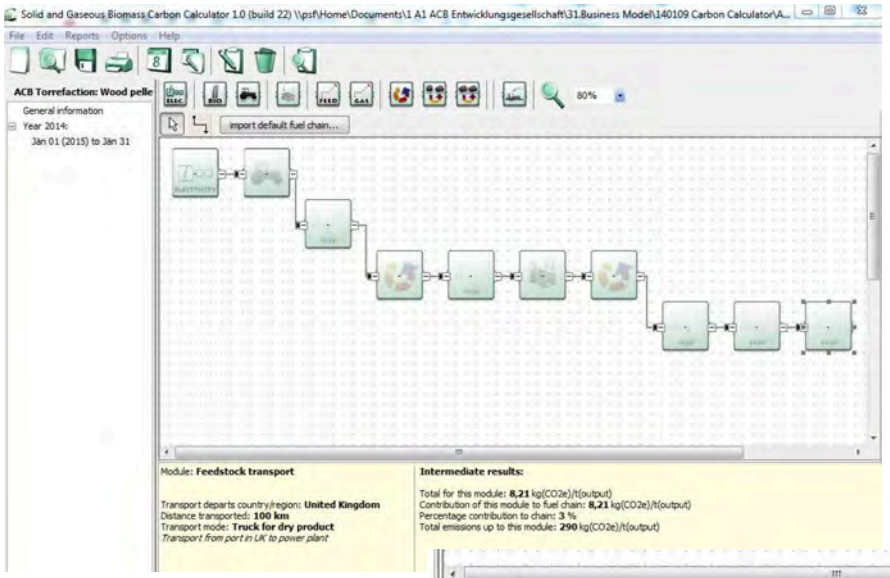
Sample 2

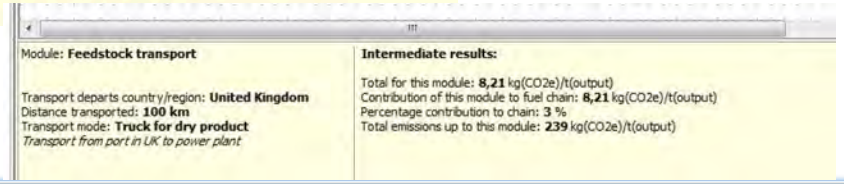
Sample	Diameter [mm]	TG [%]	DS [%]	Water uptake [%]	Durability [%]	Density [kg/dm³]
Original Sample	71	25	97%	2	96	1,14
Sample 1	71	25	92%	1	84	1,14
Sample 2	71	25	93%	1	91	1,16

CO2 Value Comparison

Comparison of White Wood Pellets with Torrefied Wood Pellets supplied from South East USA to UK

CO2 Emissions along supply chain calculated with OFGEM Solid and Gaseous Carbon Calculator are in the same range and directly compareable on CPT basis





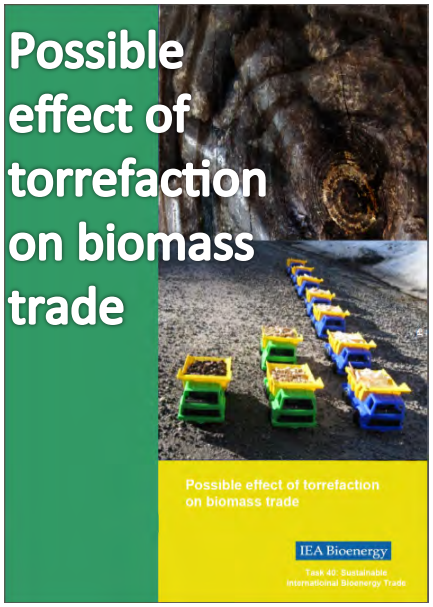
Torrefied vs Wood pellets
290kgCO2/t vs 239kgCO2/t @
17 vs21GJ/t
13,8kg/GJ vs 14,05kg/GJ

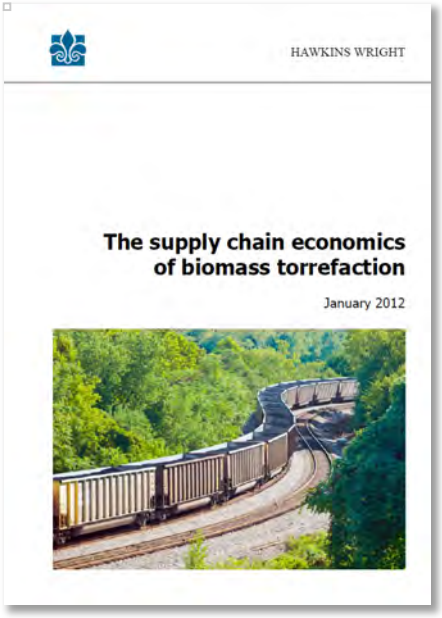
Conclusion

- torrefied biomasses are available to the market and do offer best cost benefit ratio of solid biomasses
- Product quality well defined by ISO standard soon
- Test burns in both power and heat applications will be done extensively in the next 12 month
- 2014 will see first torrefaction lines sold to customers
- ISO standard covering torrefied product will clearly define quality
- „Performers“ in Torrefaction are willing and able to provide technology and product of consistant quality
- Further cost reductions by upgrading of very low cost biomasses

International Biomass Torrefaction Council

http://www.aebiom.org/blog/ibtc/





Download from:
http://www.bioenergytrade.org/

Contact: John Bingham
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Thank you for paying attention

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http://www.aebiom.org/blog/ibtc/

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Densification of torrefied materials

Experiences from the EU research project SECTOR

Wolfgang Stelte

Center for Biomass and Biorefinery

Danish Technological Institute – DTI

SECTOR

Production of Solid Sustainable Energy Carriers from Biomass by Means of TORrefaction

SEVENTH FRAMEWORK PROGRAMME

Densification of torrefied materials

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- Torrefaction
  - Mild roasting of biomass in an inert atmosphere (270-310 °C / 5-20 Min)
  - Removal of water and volatiles from biomass → Increased heating value
  - Increased C/O ratio: better combustion / fuel properties
  - Fibers are converted into a brittle material → Easy to grind (coal mill)
  - Dry product with hydrophobic characteristics
    → Biomass with "coal like" properties

- Densification
  - Pelletization or Briquetting processes
  - Increase density and reduce dust formation
  - Lowering transportation and handling costs
  - Standardized size

Densification of torrefied materials

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- Densification is a very important process step
  - 200-300 kg/m^3 → 600-750 kg/m^3
  - Improving handling (less dust and more clean fuel)
  - Increasing energy density (lower transportation costs)
  - Standardized size and shape (automated feeding, trading)

Densification of torrefied biomass can be a challenge

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- Densification process
  - High energy uptake of pellet mill up to 150 kWh/t (usually 50-60 kWh/t for wood pellets)
  - Heat generation in pellet mill (risk of fire / dust explosion)
  - Lower capacity of the press
  - More wear on equipment parts
- Pellet quality
  - Durability
  - Self heating
  - Density
  - Hydrophobicity
  - Storage of torrefied pellets
  - Dust

Issues are closely linked to

- Biomass feedstock
- Torrefaction parameters
- Pelletization parameters
- Can be different case by case

Requires knowledge and further studies

SECTOR Project

DANISH TECHNOLOGICAL INSTITUTE

Production of **S**olid Sustainable **E**nergy **C**arriers from Biomass by Means of **Tor**refaction – **SECTOR**

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

SECTOR Production of Solid Sustainable Energy Carriers from Biomass by Means of TORrefaction

University of Stuttgart Germany · ECN · DANISH TECHNOLOGICAL INSTITUTE · Deutsches Biomasseforschungszentrum gemeinnützige GmbH · DBFZ · ofi · VTT · JEN · e·on · SLU Swedish University of Agricultural Sciences · RWE The energy to lead · VATTENFALL · Topell Energy · UMEÅ UNIVERSITET · cener centro nacional de energías renovables FUNDACIÓN CENER CIEMAT · PROCEDE · DOOSAN Doosan Power Systems · HELMHOLTZ CENTRE FOR ENVIRONMENTAL RESEARCH – UFZ · Technologie- und Förderzentrum im Kompetenzzentrum für Nachwachsende Rohstoffe · TU WIEN · bioenergy2020+ · BIOS BIOENERGIESYSTEME GmbH

Objectives and motivation of the SECTOR project

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

SECTOR Project

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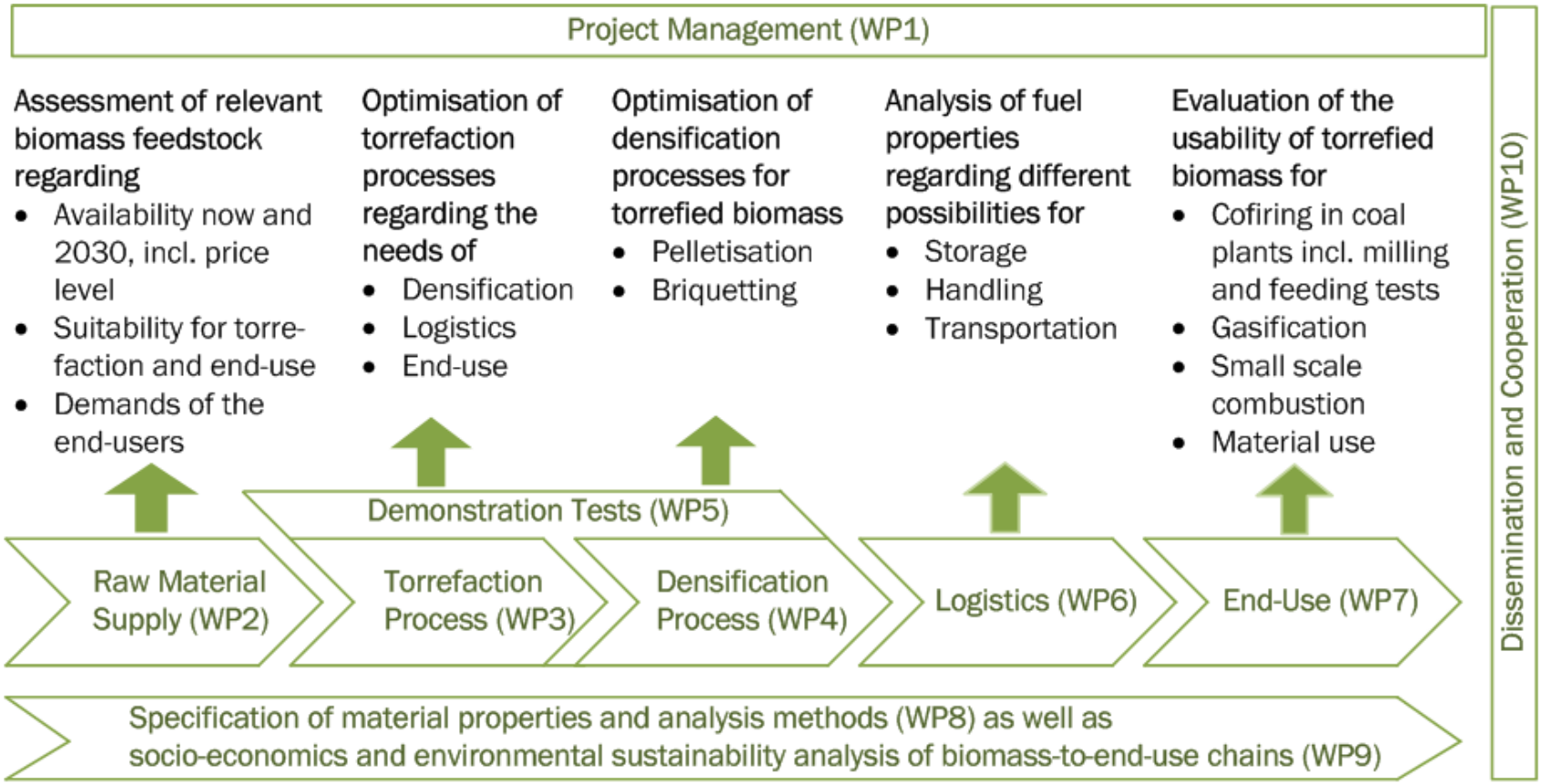

→ SECTOR Project is dealing with the whole chain from raw materials, process development, applications, product quality assessment and sustainability

Improving densification processes

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Densification Technology available in SECTOR project

- Laboratory scale
  - Single pellet press → Screening of new materials, processing parameters and additives
- Pilot scale
  - Pilot plants for pellet production → process optimization and scale up
  - Pilot plant for briquette production → process optimization and scale up
- Production scale
  - Full scale production facilities → production of sufficient material to be used in logistics and firing tests

Lab scale densification

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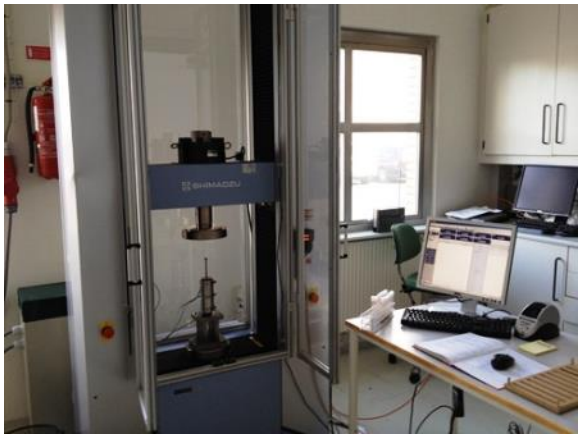
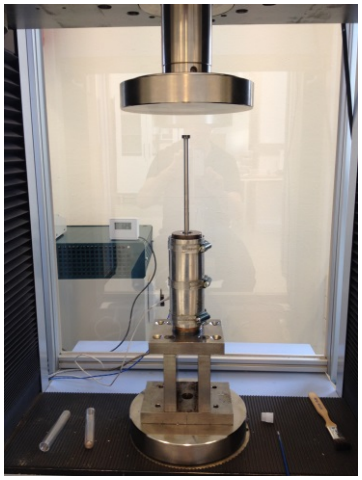
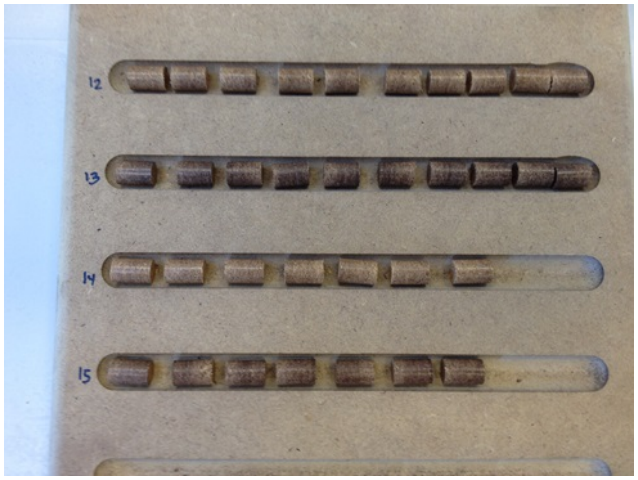
Single pellet press tool: Fast and only few grams of material needed

Set-up allows variation of: Temperature, pressure, particle size, moisture, and additive addition







Determination of: Compression energy, friction and quality analysis of pellets

Earlier tests have shown correlation between friction and energy consumption of industrial scale pellet press

Lab scale densification

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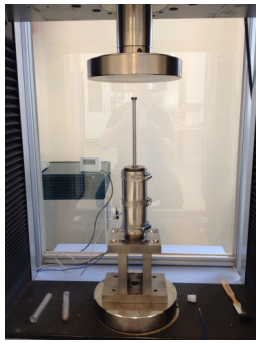
- Testing of torrefied materials provided by SECTOR partners
- Parametric study to identify key parameters and optimization

Key parameters for densification of torrefied biomass

- Biomass species (i.e. hardwoods, softwoods, straws, mixed resources)
- Torrefaction degree (mass yield as function of reaction time and temperature)
- Material moisture content
- Densification temperature
- Press channel design



Lab scale densification

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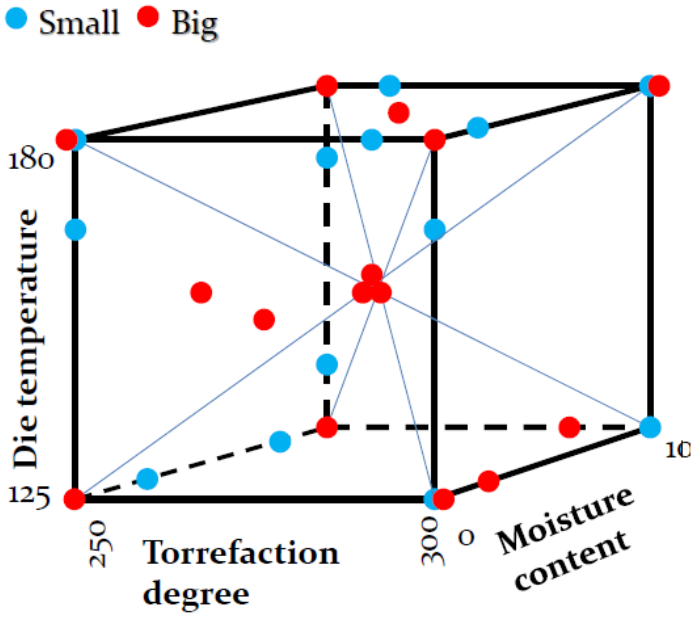
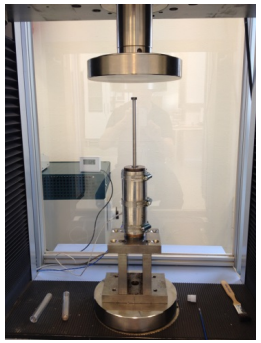
Parametric study – which parameters are the important ones

Design of experiments

- Torrefaction degree expressed as mass yield (90.5% - 71.1%)
  - Temperature 250 to 300 °C
- Moisture content (0 to 10%)
- Die temperature (125-180˚C)
- Particle size(small / big)





Lab scale densification

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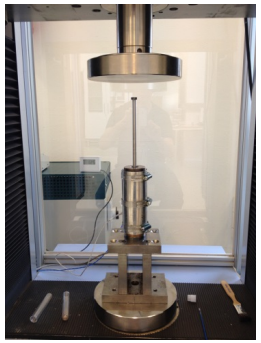
Some selected results from lab tests

- High torrefaction degree → increase of friction (power consumption of press) & decreased mechanical strength (durability)
- Increase of moisture content and temperature → reduce friction and improve mechanical strength of pellets
- Species related differences → some species are easy to pelletize after torrefaction others are more challenging
- Press channel length is an important parameter to optimize pellet quality and energy consumption of process



Pilot scale densification

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Images: Torrefaction demo plant at CENER in Aoiz, Spain

Pilot scale pelletization facilities in SECTOR are available at

ECN, SLU and CENER

CENER NATIONAL RENEWABLE ENERGY CENTRE

Pilot scale densification

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Parameter		Beech	Pine	Straw	Poplar
Anhydrous weight loss	% dry basis	14-22	14-19	13-22	14-23
Bulk density	kg/m^3	620-700	610-650	590-710	610-630
Durability	%	96.2-97.2	90.9-95.4	84-97.6	95.0-97.1
Moisture content	%	3.7-5.6	5.2-6.2	3.8-8.5	7.6-8.2
LHV	GJ/t (daf)	19.6-20.7	20.1-20.5	19.3-19.6	N.D.
C	% (daf)	52.0-54.3	53.5-54.2	50.5-51.5	N.D.
H	% (daf)	~6.0	5.8-6.2	~6.2	N.D.
N	% (daf)	0.12-0.18	0.12-0.14	0.58-0.77	N.D.
Ash content	% (db)	1.6-1.8	0.6-0.8	4.8-6.0	N.D.
Volatile content	% (db)	75.6-80.5	76.0-80.0	~74.8	N.D.

CENER | NATIONAL RENEWABLE ENERGY CENTRE

Pilot scale densification

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Torrefied beech Torrefied pine Torrefied straw Torrefied poplar

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Briquetting of torrefied biomass

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Pilot trials in cooperation with C.F. Nielsen A/S and the Energy Centre of The Netherlands (ECN)

ECN

C.F. Nielsen

Briquetting of torrefied biomass

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- Torrefaction:
  - Reactor: Pilot Reactor at Energy Center of The Netherlands (ECN)
  - Moving bed principle (Drying and Torrefaction Section)
  - Capacity 50 kg/h – Continuous operation
  - 3 Batches: 240, 260 and 280 °C / 30 Minutes residence time
  - Raw material: Spruce chips (max 45x45x15 mm)

Feeding of biomass
on top of the reactor

Torrefaction Section
of the reactor

ECN

Briquetting of Torrefied Spruce

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Fuel	Ash (550°C) % (db)	H_2O (105°C) %	Volatiles % (db)	C % (db)	H % (db)	N % (db)	O % (db)	HHV MJ/kg	Yield %
Spruce	0,36	12,6	81,2	49,2	6,3	0,1	46,1	20,2	100
Spruce 240°C	0,32	2,5	80,1	50,8	6,4	0,1	45,4	20,4	94,5
Spruce 260°C	0,39	2,3	76,75	53,2	6,2	0,1	42,9	21,5	85
Spruce 280°C	0,4	0,6	70,9	56,3	6,2	0,1	40,1	22,7	73

Data from ECN

Spruce 240 °C 260 °C 280 °C

Increase of heating value and C/O Ratio

ECN

Briquetting of torrefied biomass

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- Results

Spruce 240 °C 260 °C 280 °C

Briquetting torrefied biomass

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- Results

Raw material		Spruce (fresh)	240 C	260 C	280 C	
Density (raw material)	*kg/m3*	153	181	157	162	
Moisture	*%*	13,4	5,2	4,3	4,8	Decrease of MC and particle size
Particle size min	*mm*	1x1	0,1x0,1	0,1x0,1	0,1x0,1	
Particle size max	*mm*	10x5	5x2	5x2	5x2	
Process						
Power consumption	*A*	70	85	85	80	
Die Temperature	*C*	160	165	200	205	Stable power consumption and capacity
Strokes per min	*1/min*	269	269	269	269	
Strokes number	*n*	13	9	16	17	
Capacity (measured)	*kg/h*	600	660	600	600	
Product						
Diameter	*mm*	59	59	60	59,5	
Length	*mm*	155	115	162	159	
Volume	*cm3*	424	314	450	442	Stable pellet quality
Weight	*g*	446	318	456	444	
Density (briquette)	*kg/m3*	1053	1012	1013	1005	

- **Thank you for your attention!**

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SECTOR

Production of **S**olid Sustainable **E**nergy **C**arriers from Biomass by Means of **TOR**refaction

SEVENTH FRAMEWORK PROGRAMME

SECTOR

Production of Solid Sustainable Energy Carriers from Biomass by Means of TORrefaction

Characteristics of torrefied products and their dependence on process conditions

Ute Wolfesberger-Schwabl

OFI – Österreichisches Forschungsinstitut für Chemie und Technik






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

Topics

Fuel analysis

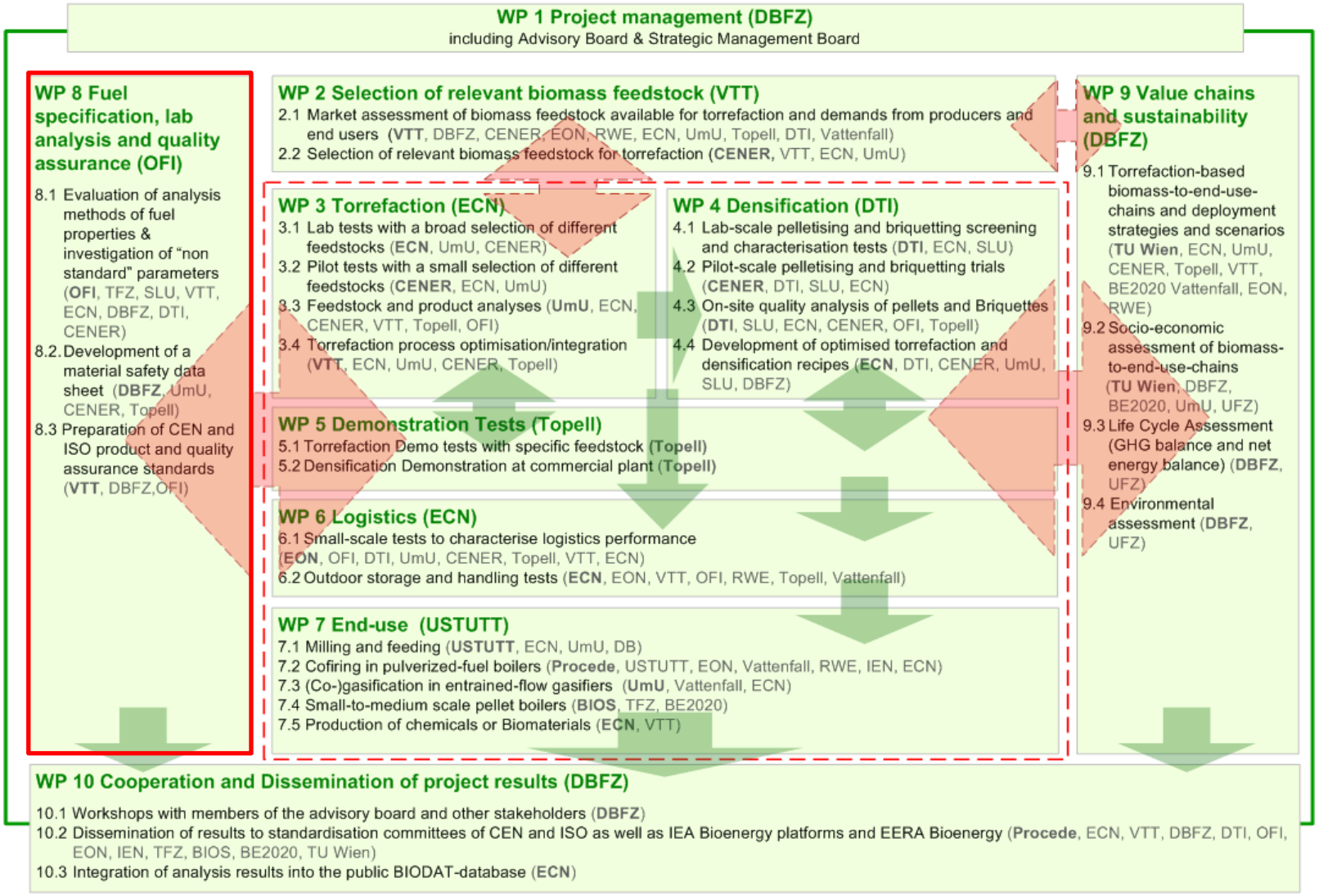
Analysis methods

Dependencies on process conditions

Method development

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

SECTOR - project



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

Characterization of torrefied material I

- Fuel characterization of torrefied materials and corresponding raw materials (62 samples - chips and pellets)
- Parameter
  - Moisture content (ar)
  - Ash
  - Volatile content
  - Net calorific value
  - Carbon content
  - Hydrogen content
  - Nitrogen content
  - Sulfur content
  - Chlorine content

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

Characterization of torrefied material II

- Round Robin test
  - Applicability of biomass standards
  - 43 Participants
  - 18 Countries
  - 11 Parameter
  - 19-41 participants per Parameter

Parameter	Method/ Standard
Bulk density	acc. EN 15103
Mechanical durability	acc. EN 15210-1
Moisture content	acc. EN 14774-1 or 2
Ash content	acc. EN 14775
Calorific value	acc. EN 14918
Content of chlorine and sulphur	acc. EN 15289
Content of volatile matter	acc. EN 15148
Content of carbon, hydrogen, nitrogen	acc. EN 15104
Content of major elements	acc. EN 15290
Content of minor elements	acc. EN 15297
Ash melting behaviour	acc. CEN/TS 15370

(http://www.sector-project.eu - Results)

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

Material - data

- Raw material

	Moisture, M_{ar} w-%$_{ar}$	Ash, A w-%$_d$	Net calorific value, Q_{net} MJ/kg$_d$	Volatile Matter, VM w-%$_d$	Carbon, C w-%$_d$	Hydrogen, H w-%$_d$	Nitrogen, N w-%$_d$	Sulfur, S w-%$_d$	Chlorine, Cl w-%$_d$
Spruce	14,8	0,3	18,7	85,0	49,5	6,8	0,2	0,005	0,005
Willow	14,9	1,5	18,0	83,3	47,9	6,3	0,3	0,022	0,002
Pine (a)	10,4	0,6	18,4	86,8	49,2	6,9	0,2	0,008	0,008
Pine (b)	10,7	0,3	19,1	84,6	49,8	6,3	0,1	0,011	0,009
Poplar (a)	12,0	0,8	18,0	84,4	47,4	6,5	0,1	0,016	0,008
Poplar (b)	10,7	0,9	18,2	84,0	48,1	6,7	0,1	0,013	0,024
Beech	12,3	0,8	18,1	83,4	48,1	6,1	0,2	0,011	0,004

- Material raw and at different torrefication temperatures

Spruce-raw

Spruce 240° C

Spruce 260° C

Spruce 280° C

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

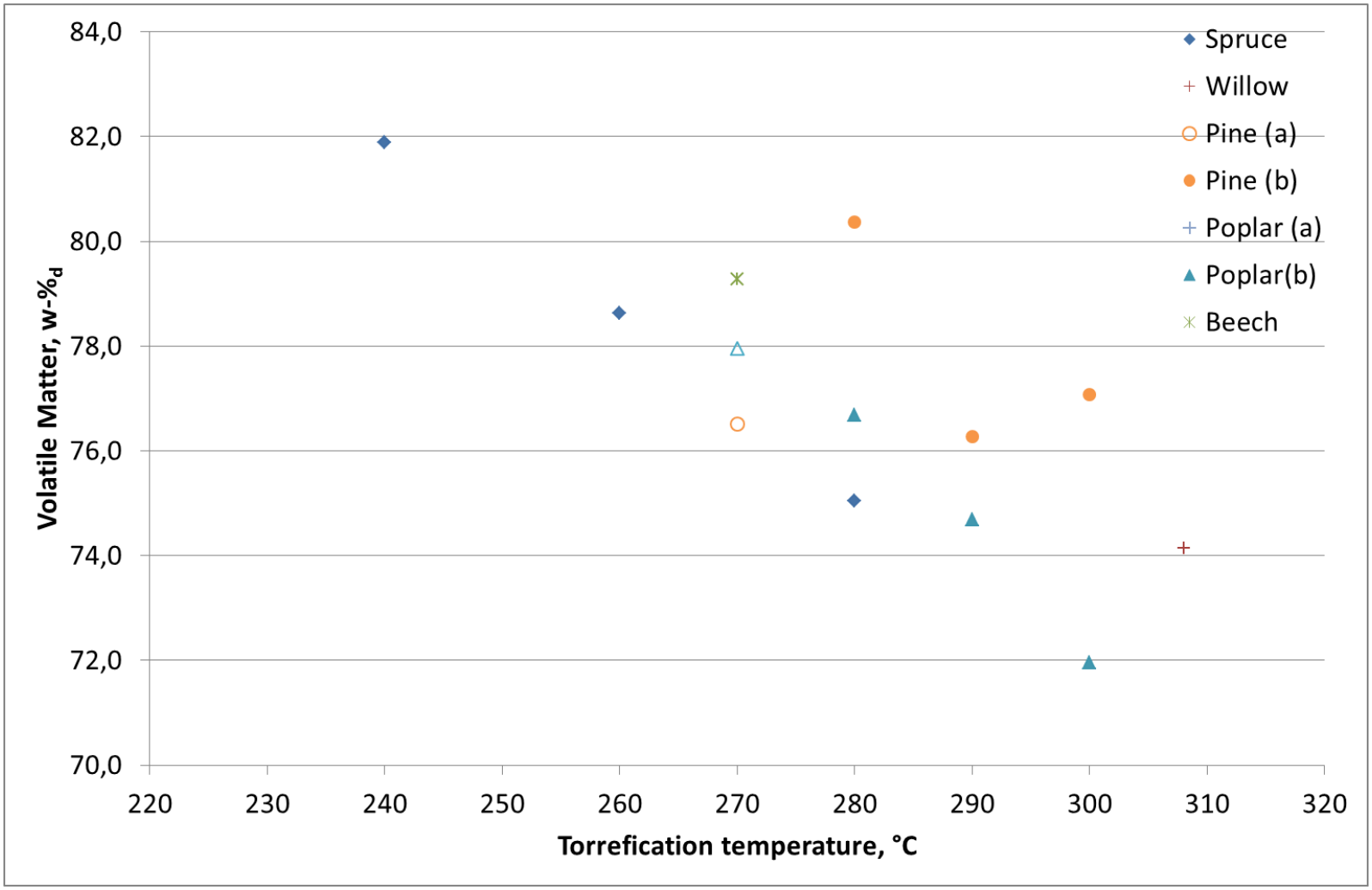
Material - experimental matrix

- Torrefication temperature
- Different wood types - different origins

Torrefication Temperature (° C)	Spruce	Willow	Pine (a)	Pine (b)	Poplar (a)	Poplar (b)	Beech
240	**x**						
260	**x**						
270			**x**		**x**		**x**
280	**x**			**x**		**x**	
290				**x**		**x**	
300		**x**		**x**		**x**	
Pellet diameter (mm)	8	8	6	6	6	6	6

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

Torrefication temperature - Volatile matter



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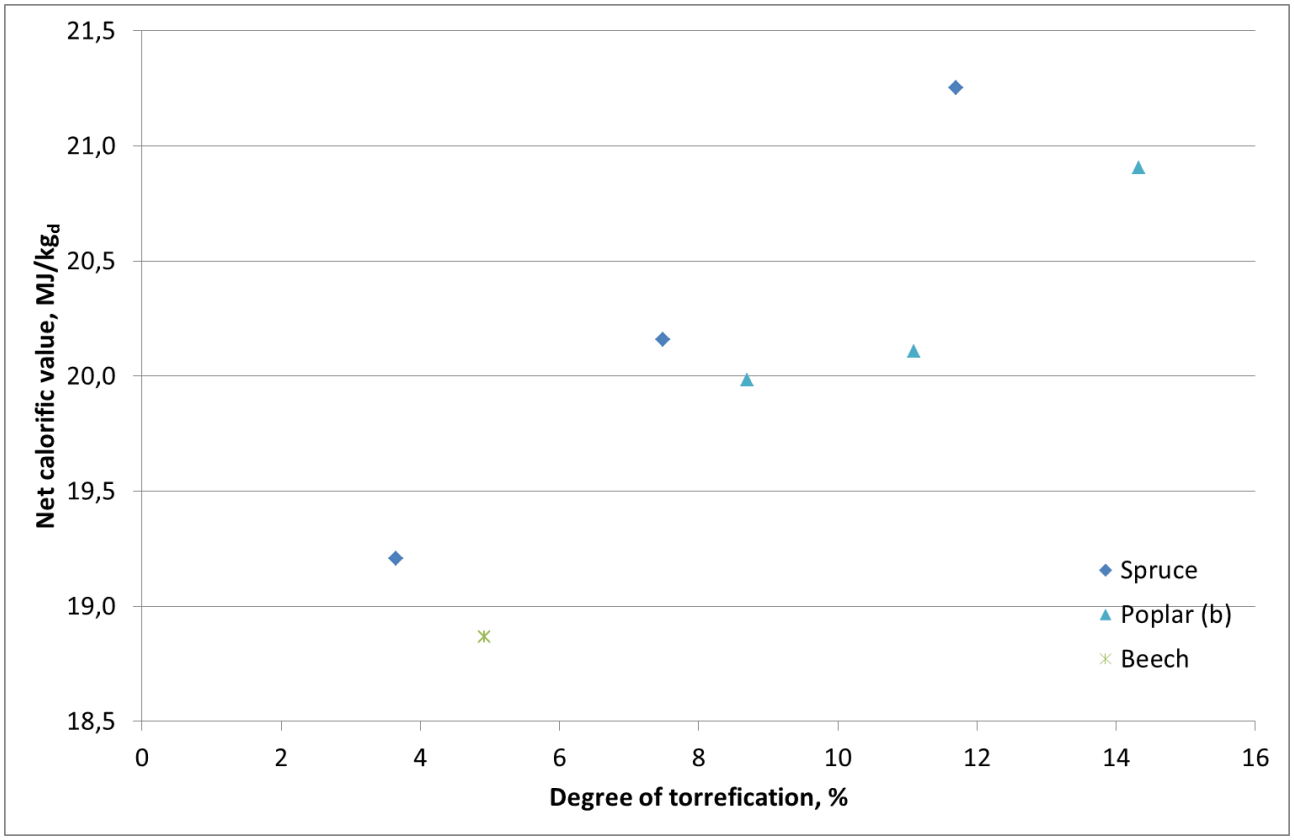
Degree of torrefication

- $$Degree\ of\ torrefication = 100 - \frac{VM_{torr}}{VM_{raw}} \times 100$$

VM_{torr} … Volatile matter torrefied material [%]; VM_{raw} … Volatile matter raw material [%]



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

Further methods

- Different behavior of torrefied pellets
  - Grindability,
  - Leaching behavior,
  - Hardness
  - …
  - Water absorption (Method (a); Method (b))
  - Storage (Exposure tests)

- Within SECTOR project – second Round Robin with new developed methods

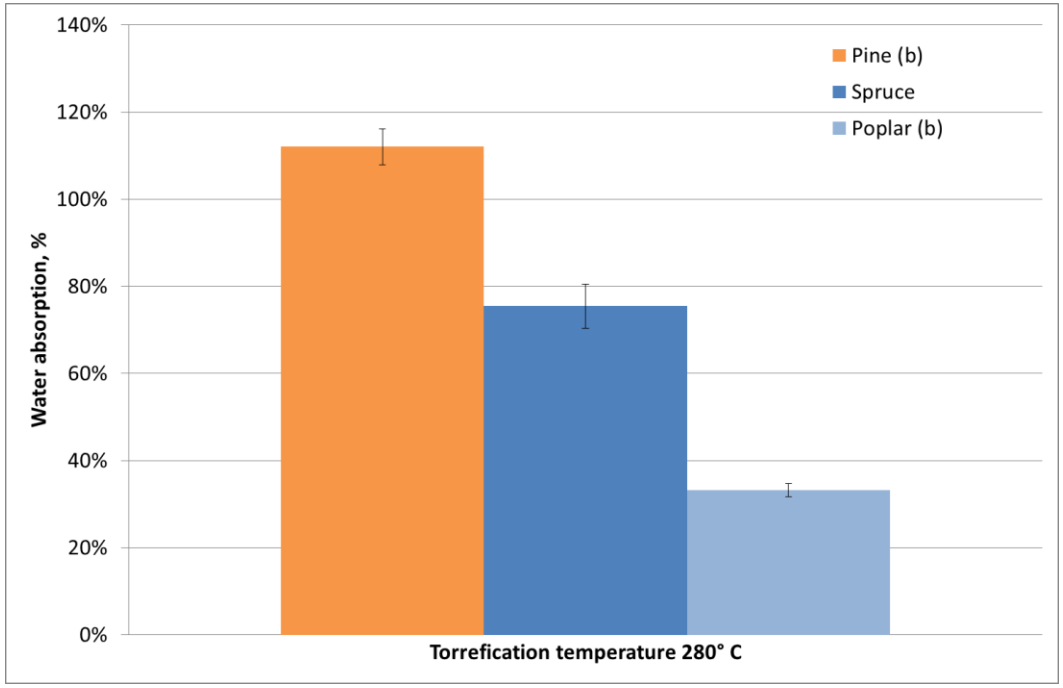
The research leading to these results has received funding from the European Union Seventh Framework Programme FP7/2007-2013 under grant agreement n° 282826

Water absorption (a)

- Water immersion test with torrefied pellets (280° C torrefication temperature)

15 g sample Container with mesh inset

Triplicates in water (15 min) Draining 10 min



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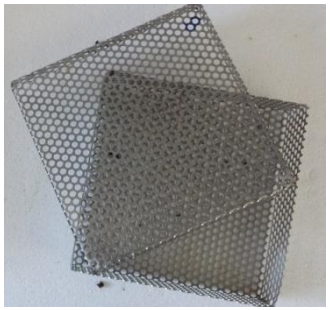
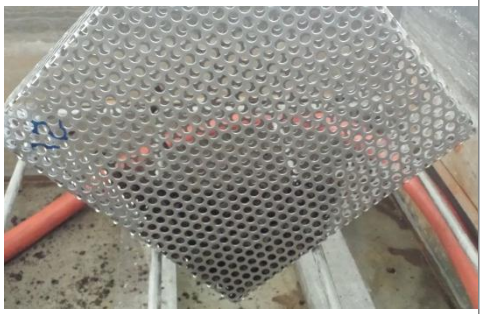
Water absorption (b)

- Water immersion test with mechanical durability tests

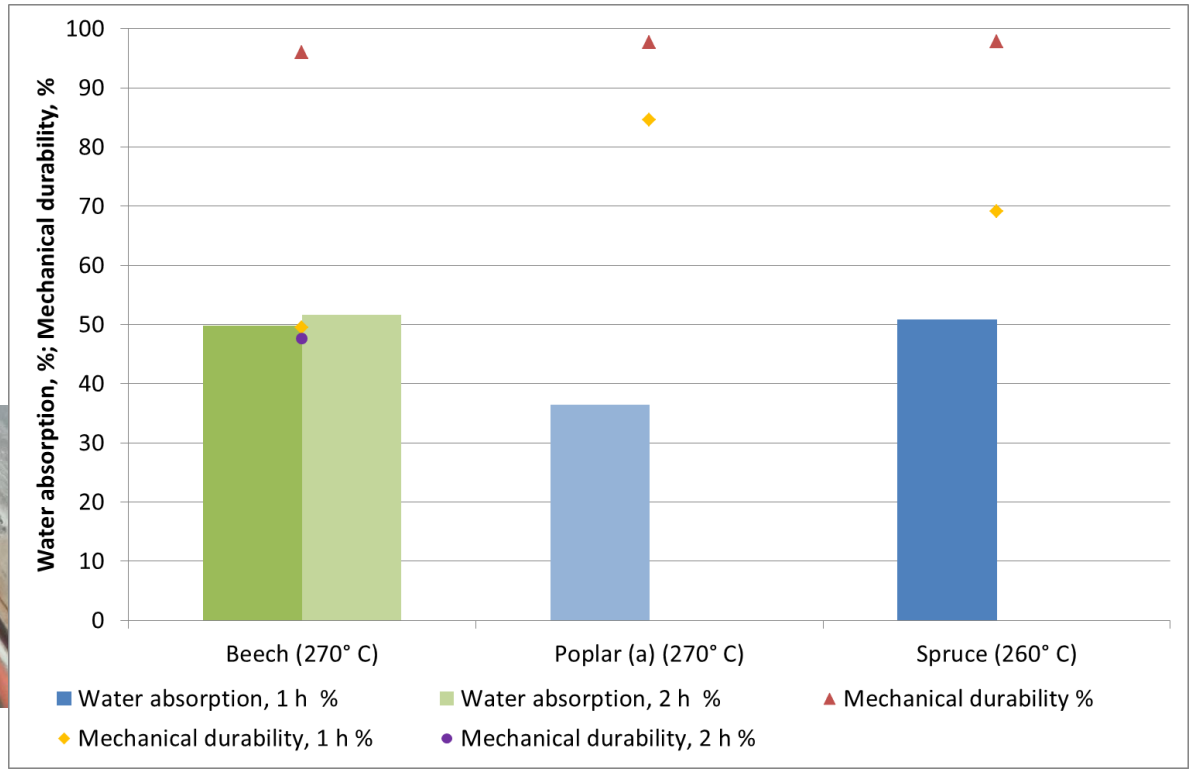


Metall sample box

Immersion in water for 1 h/2 h



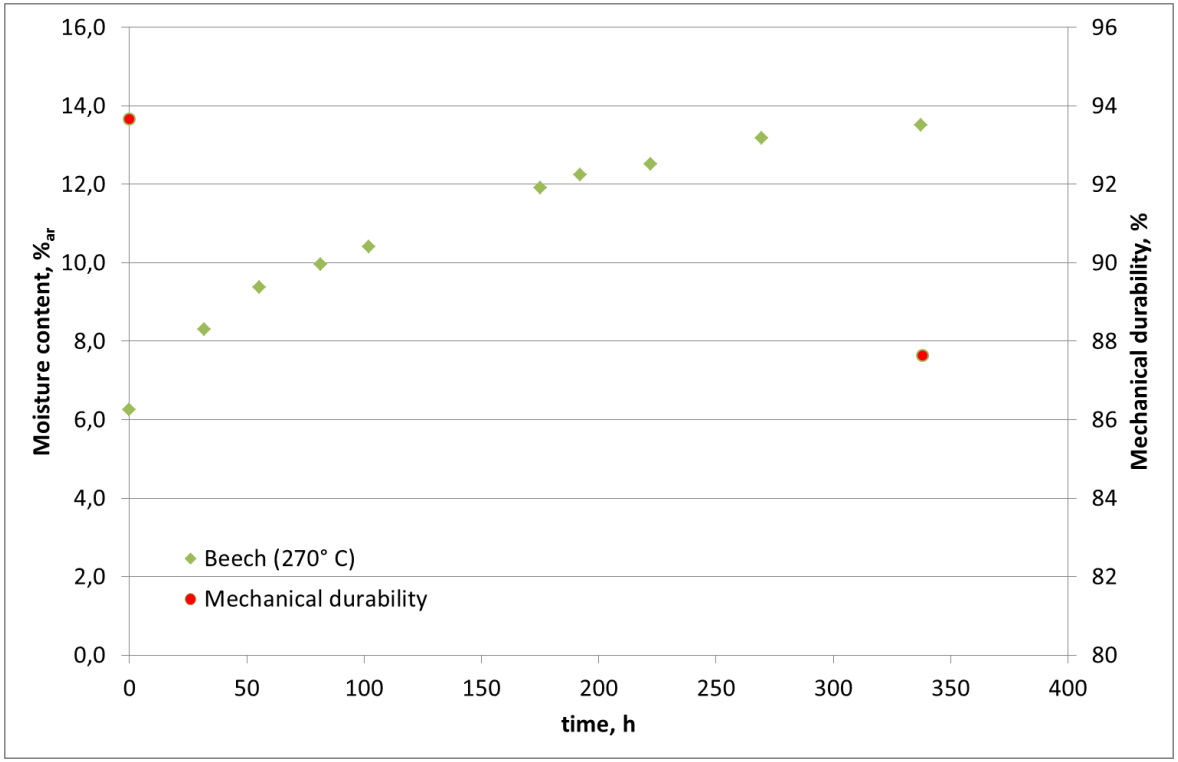
Sample draining 1 h
Drying 105° C
Mechanical durability



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

Exposure test

- Defined climatic properties – saturated K_2SO_4 solution; app. 95,5 % rel. Hu (at 23° C) – exposure for 14 days



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

Conclusion & outlook

Analysis methods

- Applicable for torrefied material (RR I)
- Planned RR II for new developed methods

Dependencies on process conditions

- Increasing degree of torrefication – increase net calorific value
- Higher torrefication temperature – lower volatile matter
- Difference between wood origin and types

Further methods

- Three different methods for the water behavior of torrefied pellets considered
- Water absorption reduces the mechanical durability

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

thank you very much for your attention

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

ENERGY

Advantages and drawbacks for international trade of torrefied products

Dr. Mark Beekes

January 17th, 2014

Central European Biomass Conference

15th to 18th January 2014, Graz, Austria

SAFER, SMARTER, GREENER

Combining two major players

- Founded 1864
- Høvik, Norway
- 10,400 employees

Dedicated competences in:

- Tankers
- Offshore Classification
- Power & Transmission
- System certification

DNV GL Group

- Shared ambition for quality and innovation
- Head office in Høvik
- 17,100 employees

A leading company in:

- Classification
- Oil & Gas
- Energy
- Business Assurance

- Founded 1867
- Hamburg
- 6,700 employees

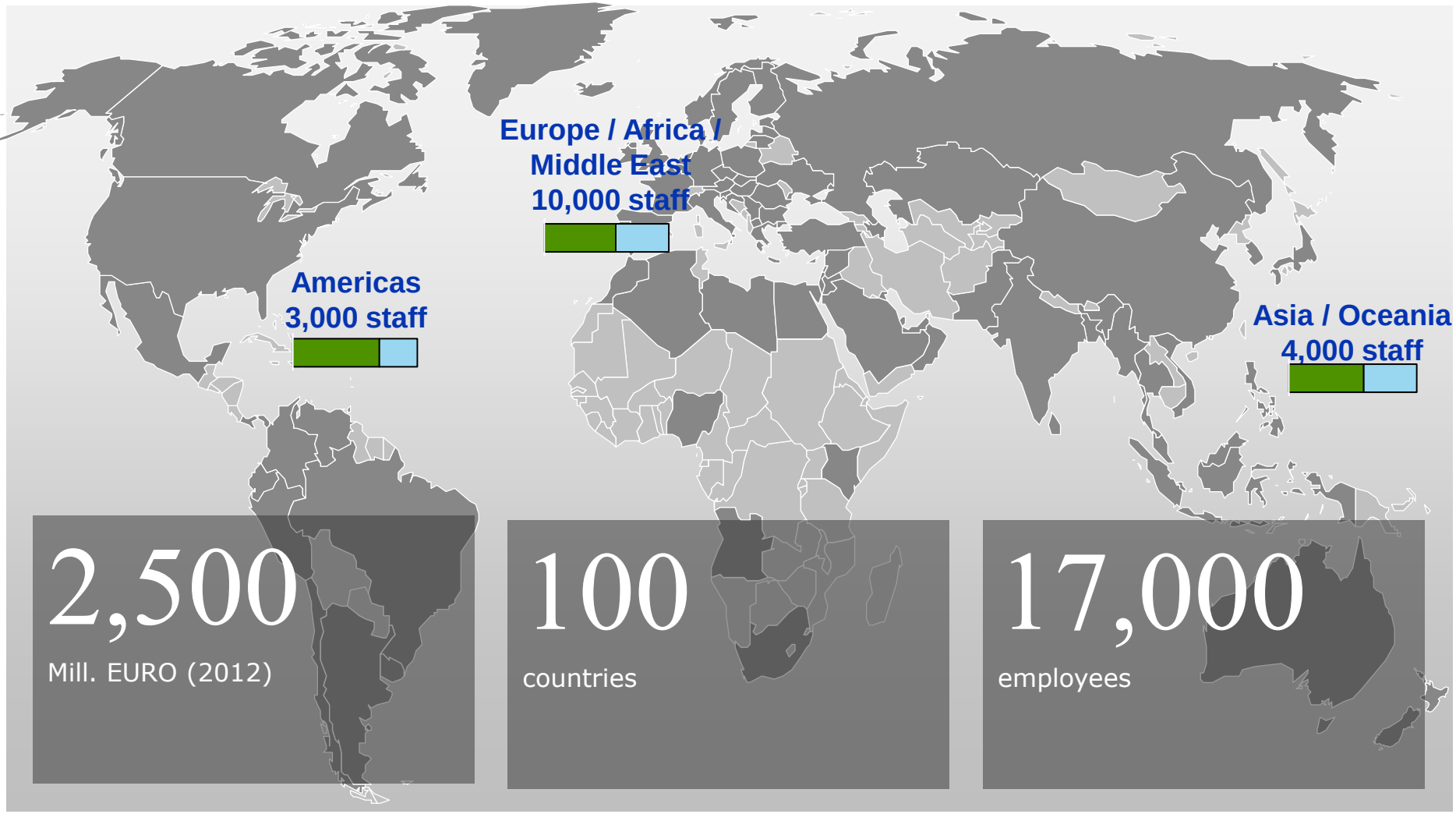
Dedicated competences in:

- Container ships
- Energy efficiency
- Marine warranty
- Renewables

DNV GL - Energy

- DNV GL - Energy offers innovative solutions to customers across the energy value chain, ensuring reliable, efficient and sustainable energy supply, now and in the future.
- 2,800+ experts across all continents
- A heritage of nearly 150 years
- Headquartered in Arnhem, the Netherlands

Global delivery capability and strong presence



DNV GL - Energy and upgraded biomass

- We consider ourselves as an independent party to supply investors, suppliers, and end-users with dedicated upgraded biomass technical and business support to integrate upgraded biomass processing technologies (primarily torrefaction and steam explosion) in the biomass supply chain while ensuring the availability, reliability, sustainability and profitability of the generation of electricity and heat

- DNV GL - Energy continuously tracks and evaluates the development of torrefaction and steam explosion technologies and commercial parties that bring torrefaction and steam explosion to the next level.

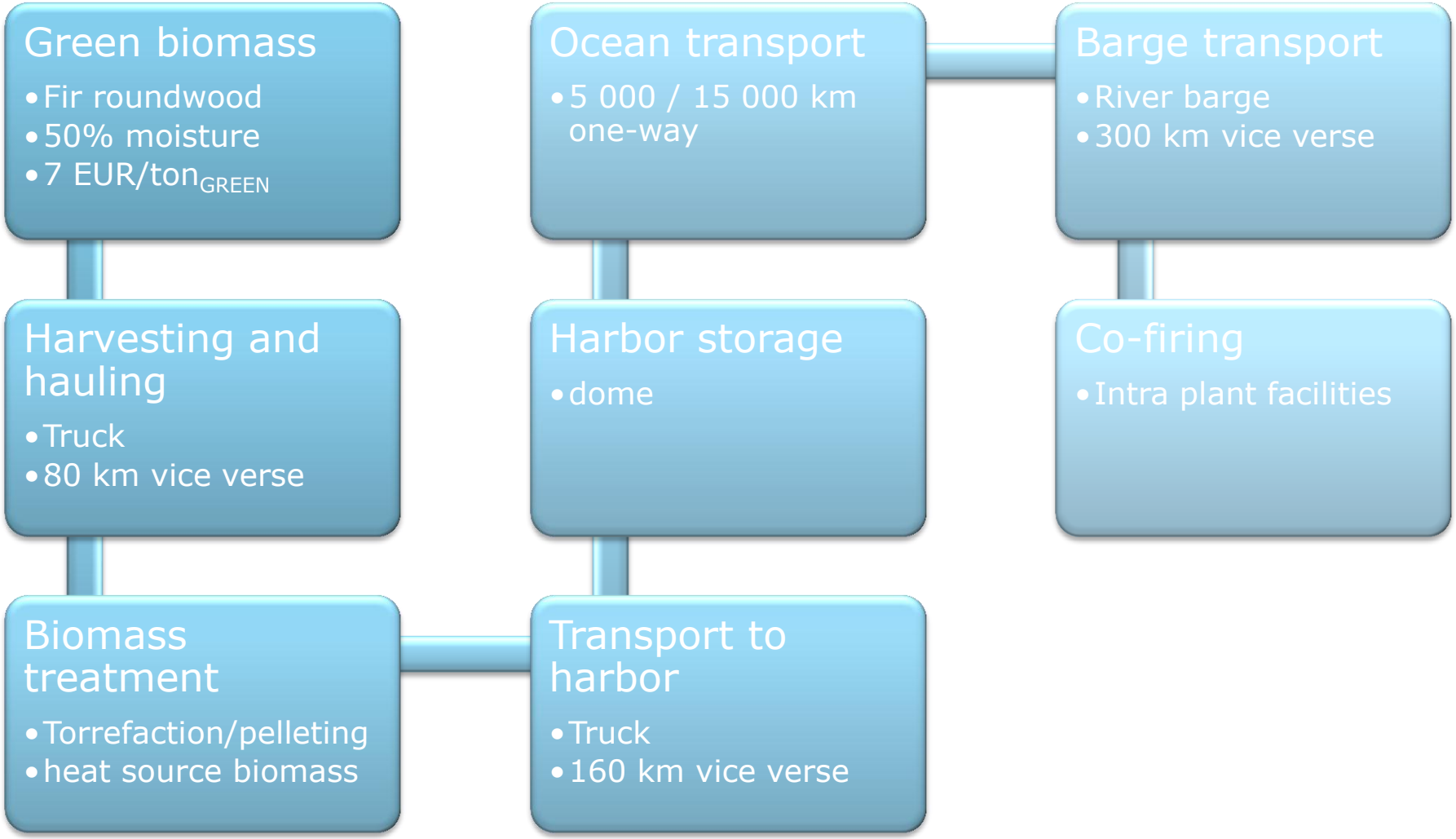
- Our biomass upgrading services include technology verification, technical due diligences, tendering assistance, process and design reviews, co-firing feasibility studies / operational impact studies, guarantee measurements, measurement campaign support, risk assessments

Case study

- Evaluation of chains for wood pellets and torrefied pellets
  - Originating from green biomass Canada/US
  - Pellet production near to biomass source
  - Transported to a pulverized coal fired power station in the Netherlands

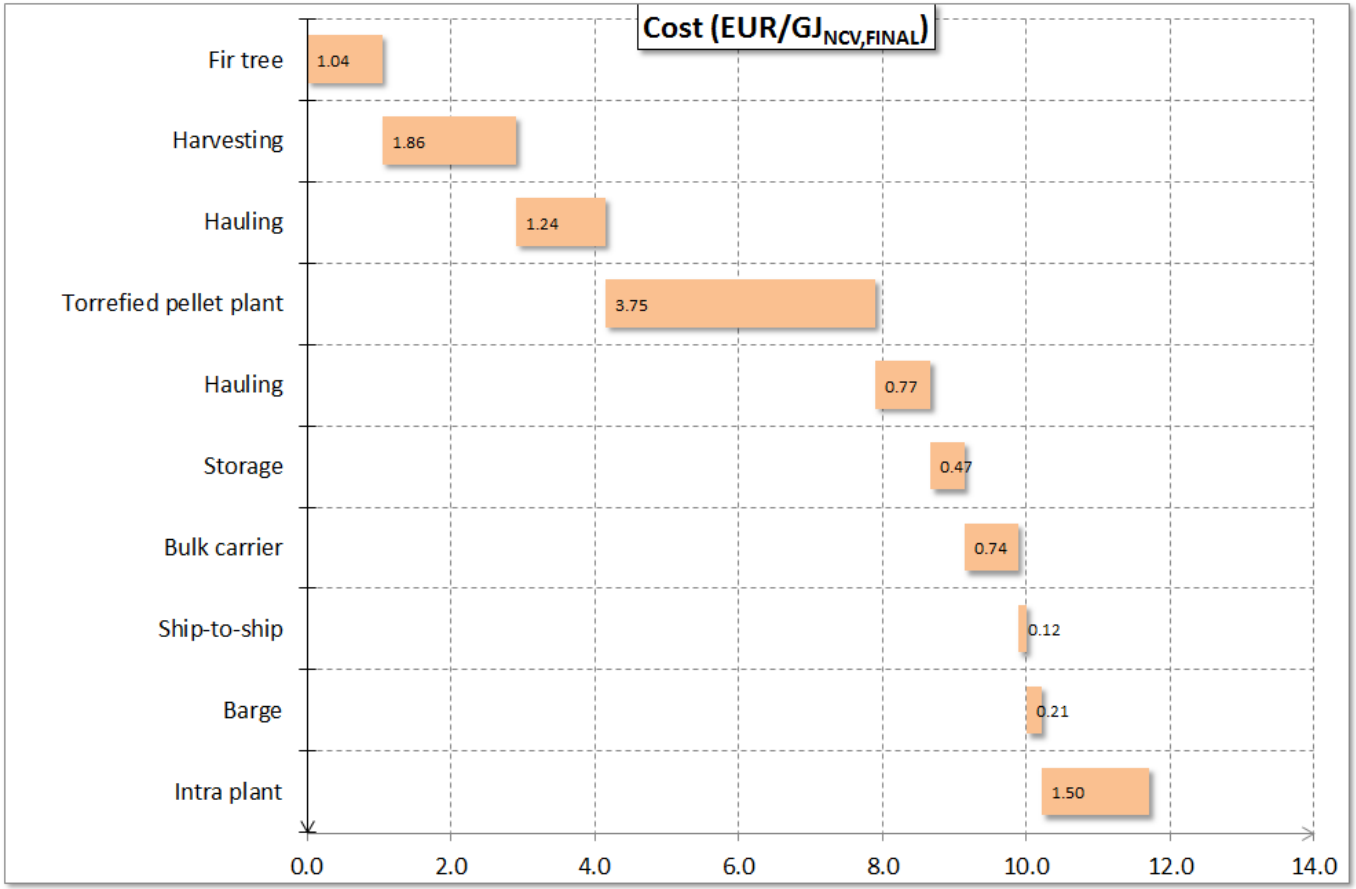
- Items of study
  - Basis cost price
    - Impact of ocean carrier distance
  - CO_2 intensity levels
    - Impact of ocean carrier distance

Supply and consumption chain



Biomass supply chain - costing

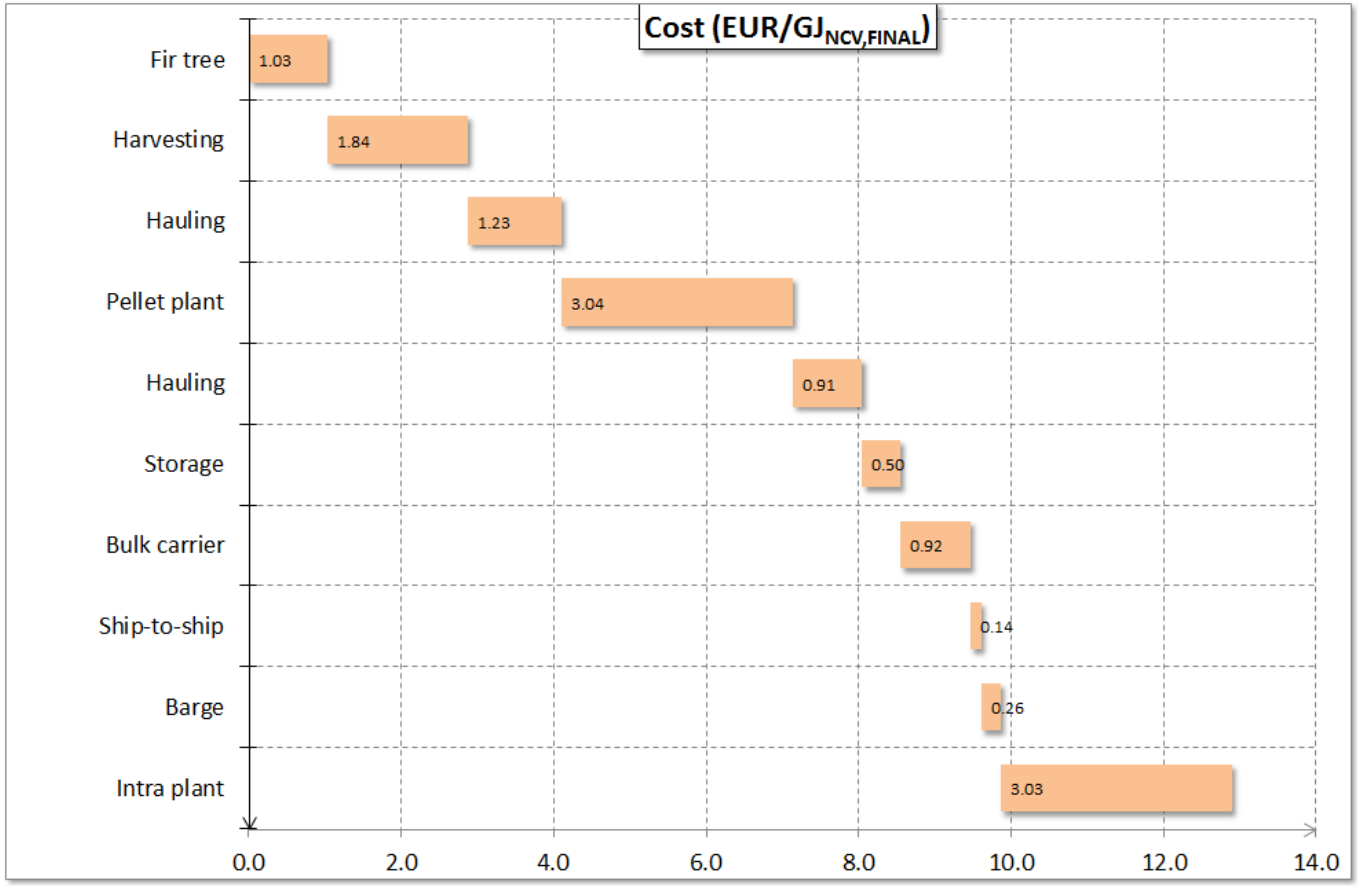
- Torrefied pellets (delivered and consumed at power plant)



- *Bulk carrier distance 5000 km*

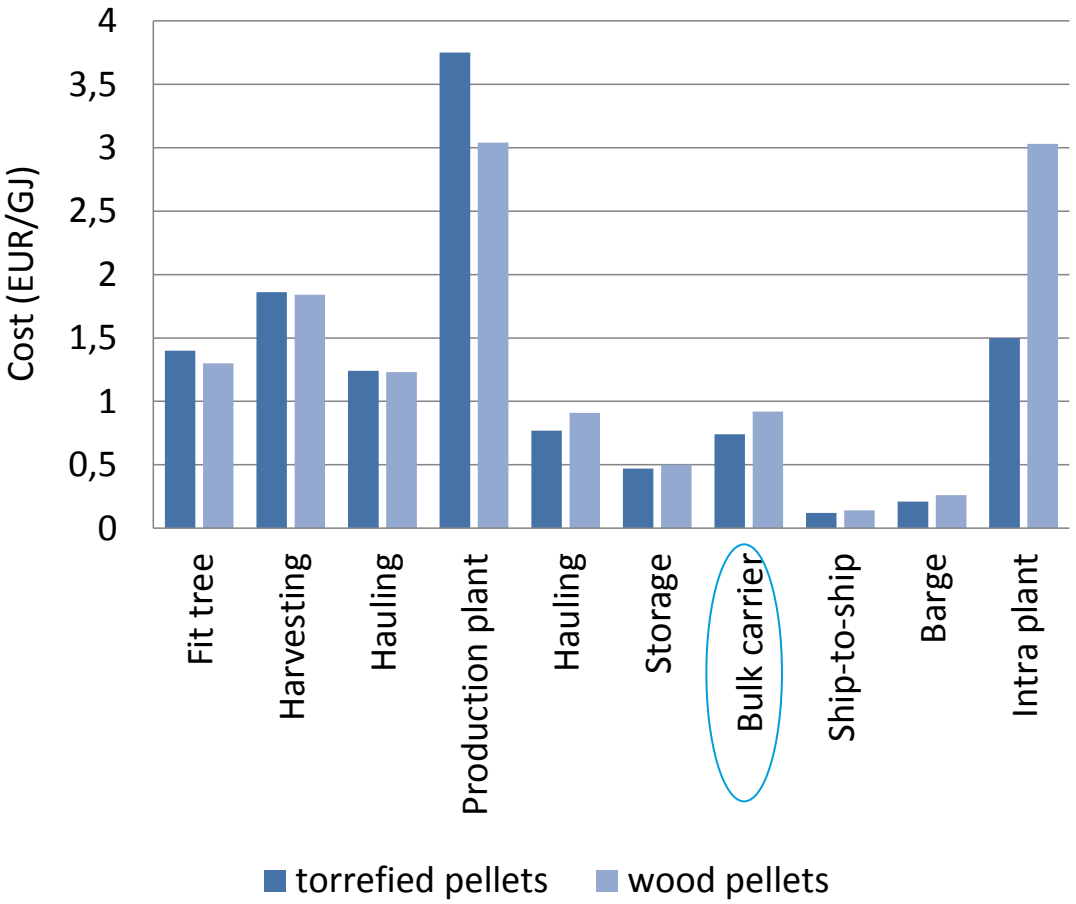
Biomass supply chain - costing

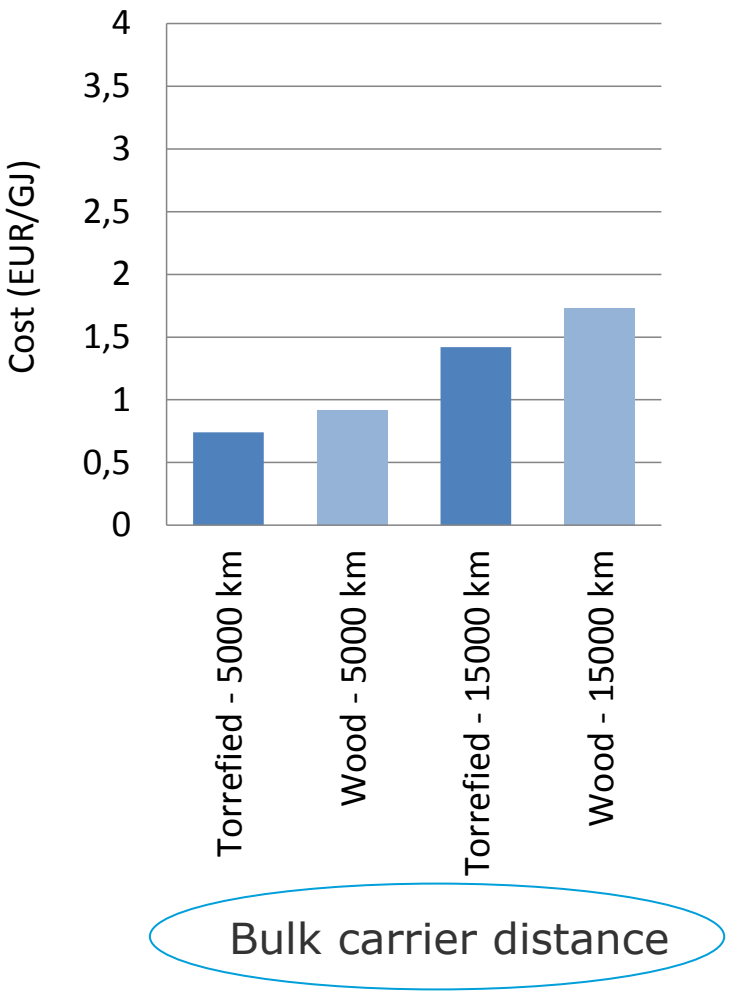
- Wood pellets (delivered and consumed at power plant)



- *Bulk carrier distance 5000 km*

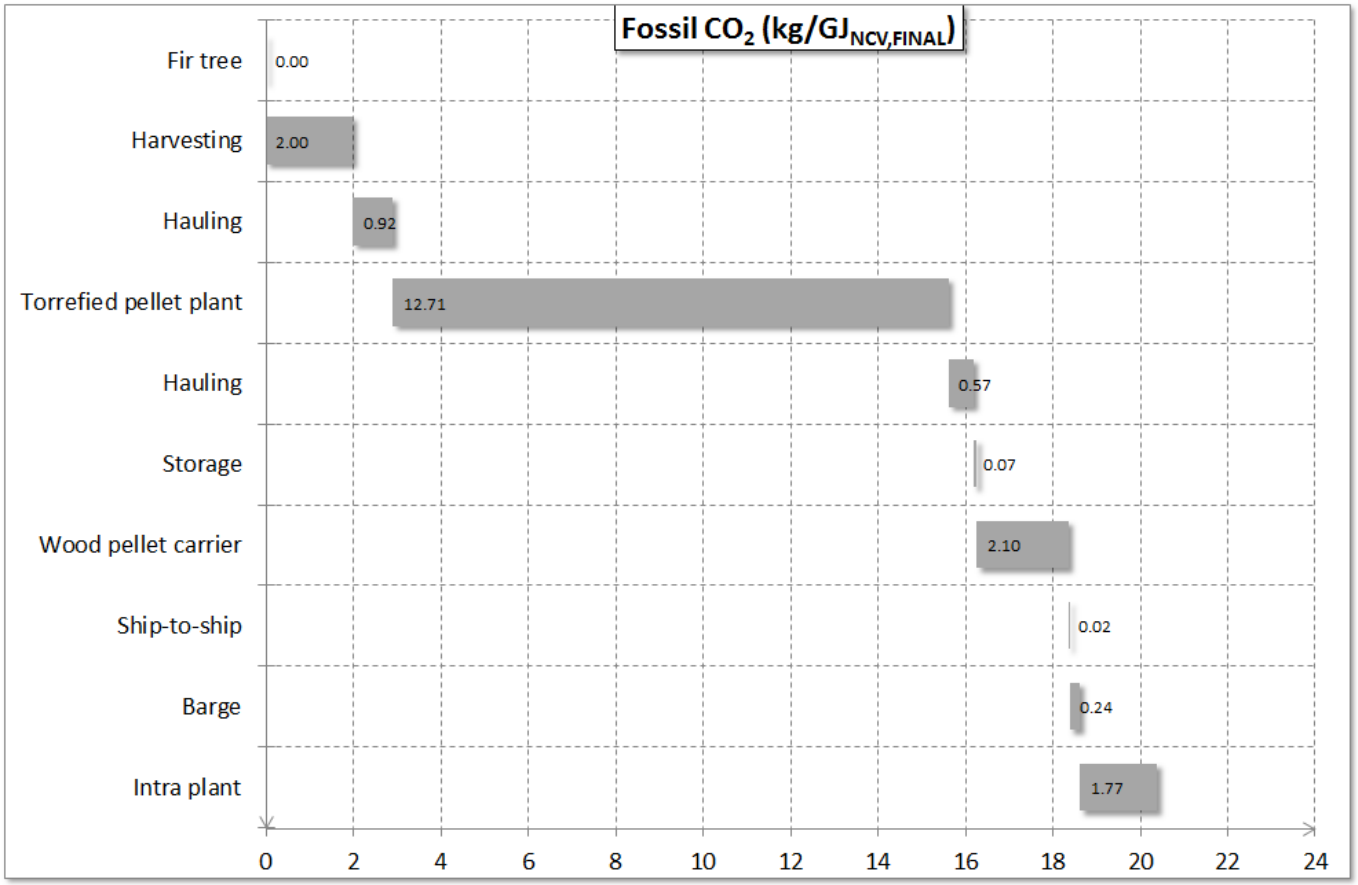
Comparison torrefied and wood pellets





Biomass supply chain - CO_2

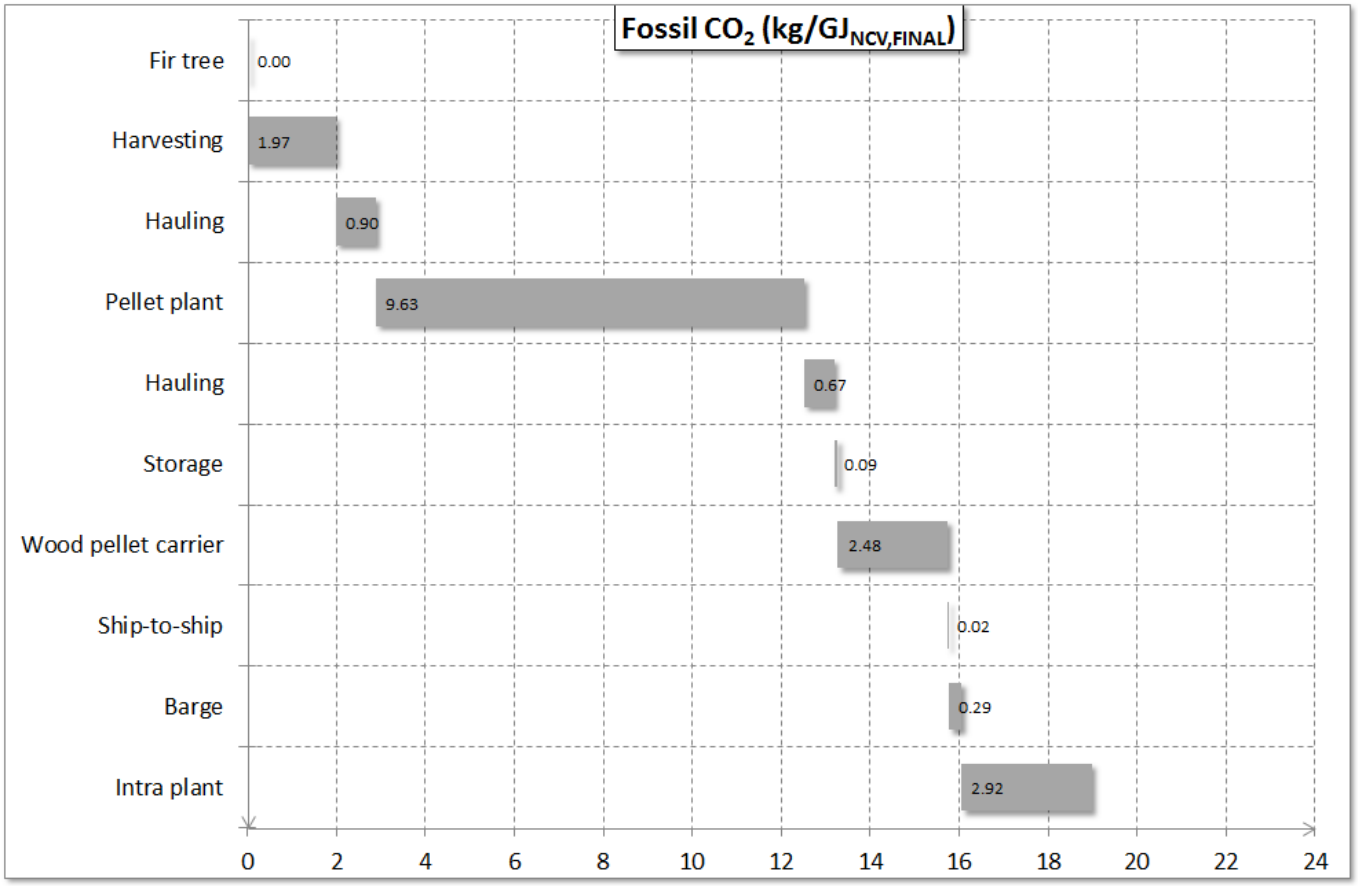
- Torrefied pellets (delivered and consumed at power plant)



- *Bulk carrier distance 5000 km*

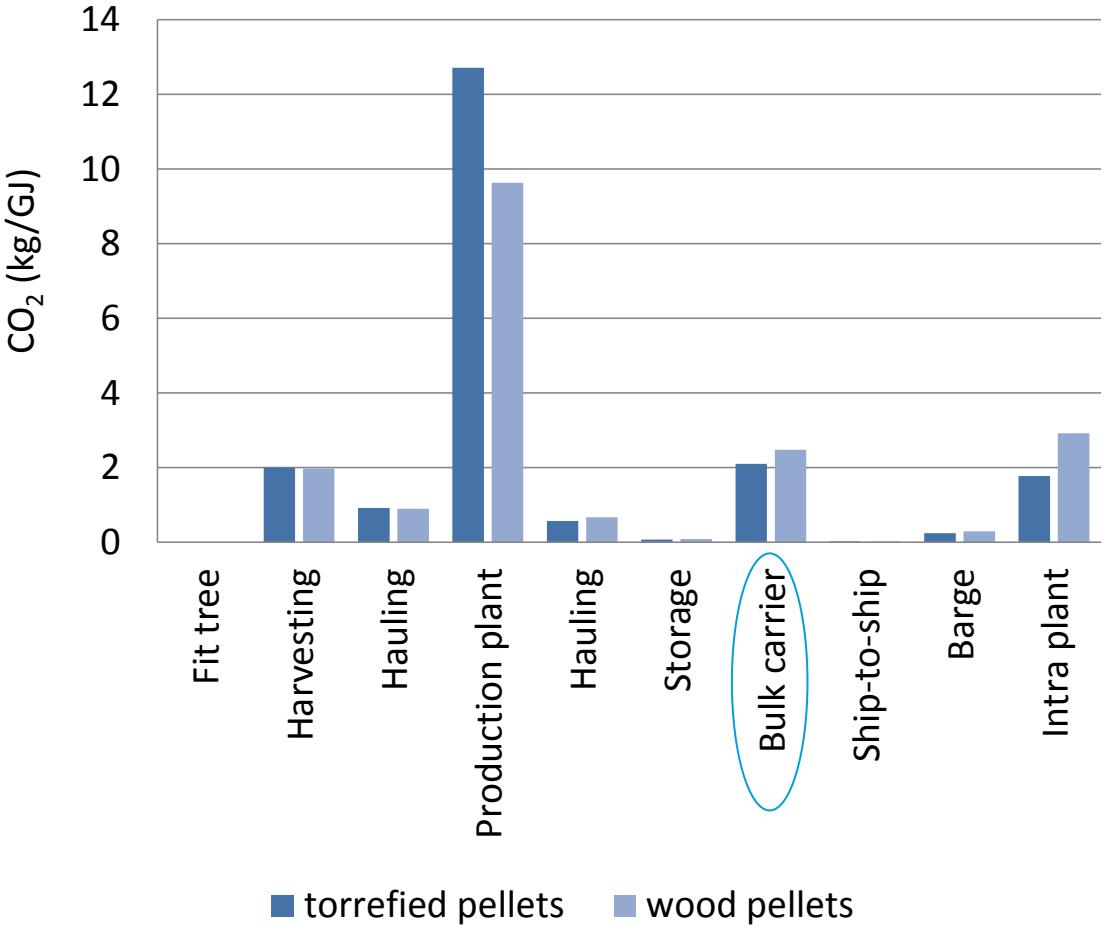
Biomass supply chain – CO_2

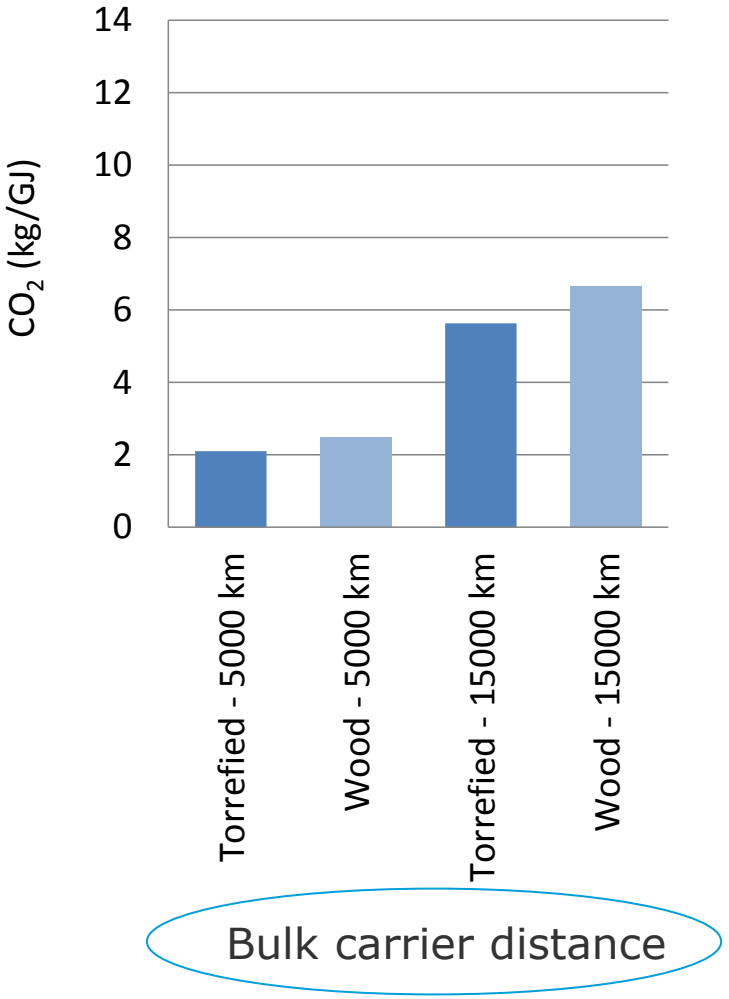
- Wood pellets (delivered and consumed at power plant)



- *Bulk carrier distance 5000 km*

Comparison torrefied and wood pellets





Conclusions

- Supply chain cost torrefied pellets same order of magnitude as wood pellets (case)
- Total production cost of torrefied pellets and wood pellets is 7.1 and 5.9 per GJ
- Cost of logistics (transport, storage and transshipment) is 15-20% lower for torrefied pellets
- Cost associated with investment at power plant is significantly lower for torrefied biomass
- The primary fossil CO_2 source in whole supply chain is that of biomass processing
- Ocean freight accounts for 10-30% of total emitted CO_2
- There is a need for harmonization of the assumptions made

Thank you for your attention

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SAFER, SMARTER, GREENER

First experiences from large scale co- gasification tests with refined biomass fuels

Presentation at Central European Biomass Conference
International workshop: Torrefaction of biomass
17th January 2014, Graz, Austria

Nader Padban, Vattenfall R&D

Date: 17th January 2014

SECTOR

Production of **S**olid Sustainable **E**nergy **C**arriers from Biomass by Means of **TOR**refaction

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

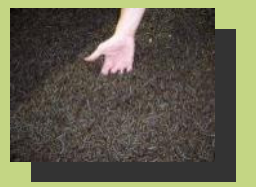
A European R&D Project funded within the Seventh Framework Programme by the European Commission

Task 7.3 (Co-) gasification in entrained-flow gasifiers (-UmU-, Vattenfall, ECN)

[Vattenfall will carry out the co-gasification tests in the Buggenum Power Plant that is owned and operated by N.V. Nuon Energy (Nuon) which is a third party to Vattenfall.]





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

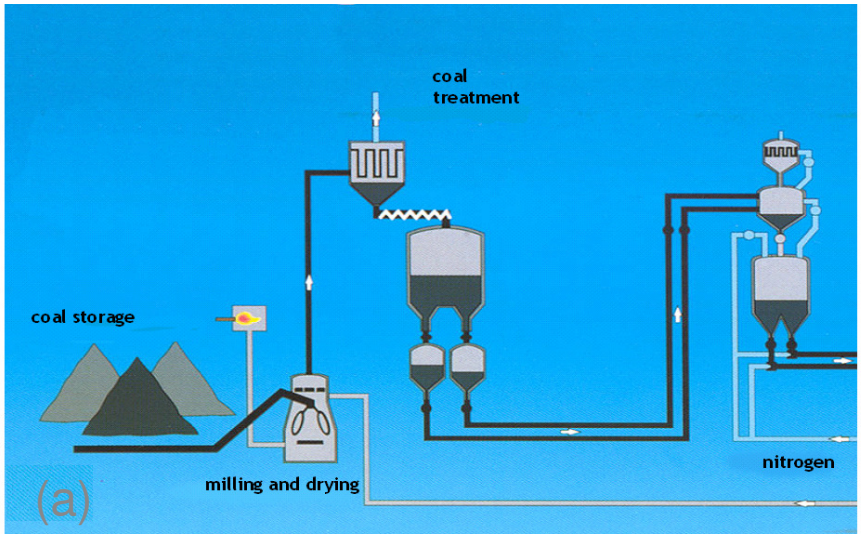
Plant

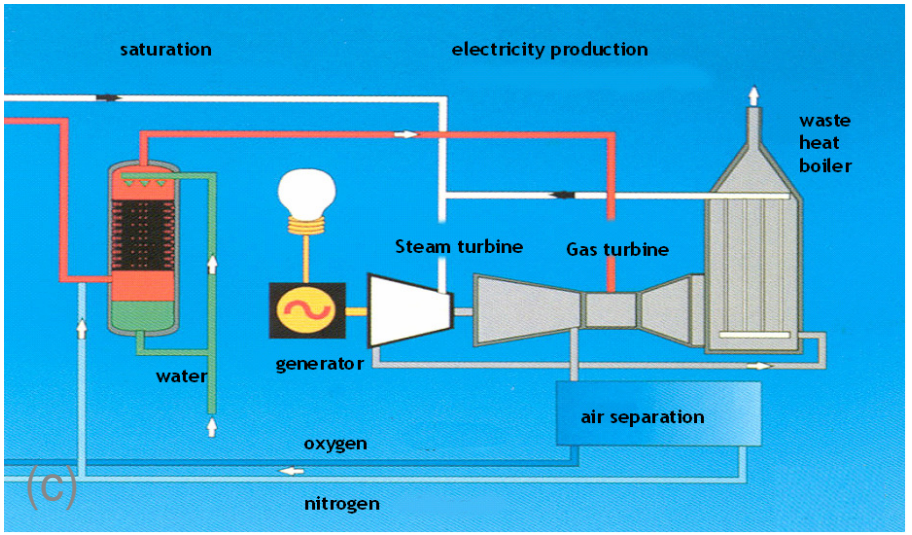
Willem Alexander Centrale

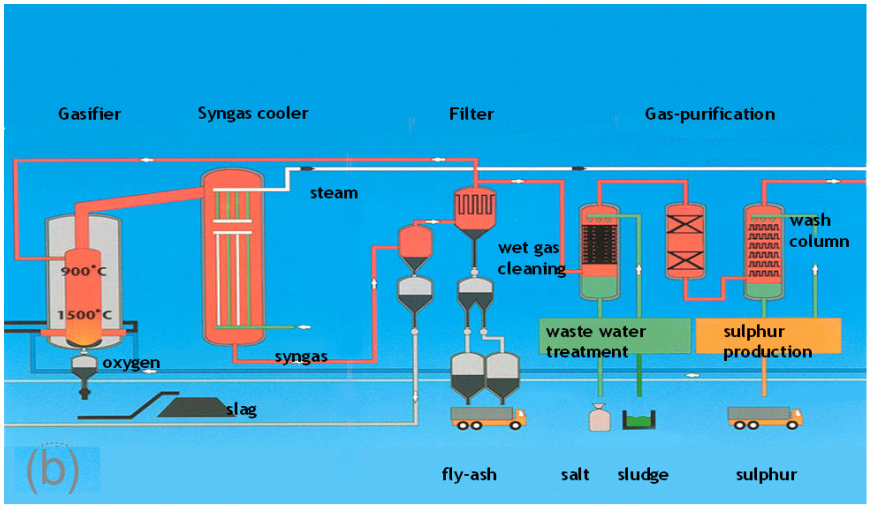
Buggenum

- 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: ~1500 tons
  - Steam explosion product: ~5000 tons
- The plant closed down at April 1st 2013.

Process Scheme WAC Buggenum







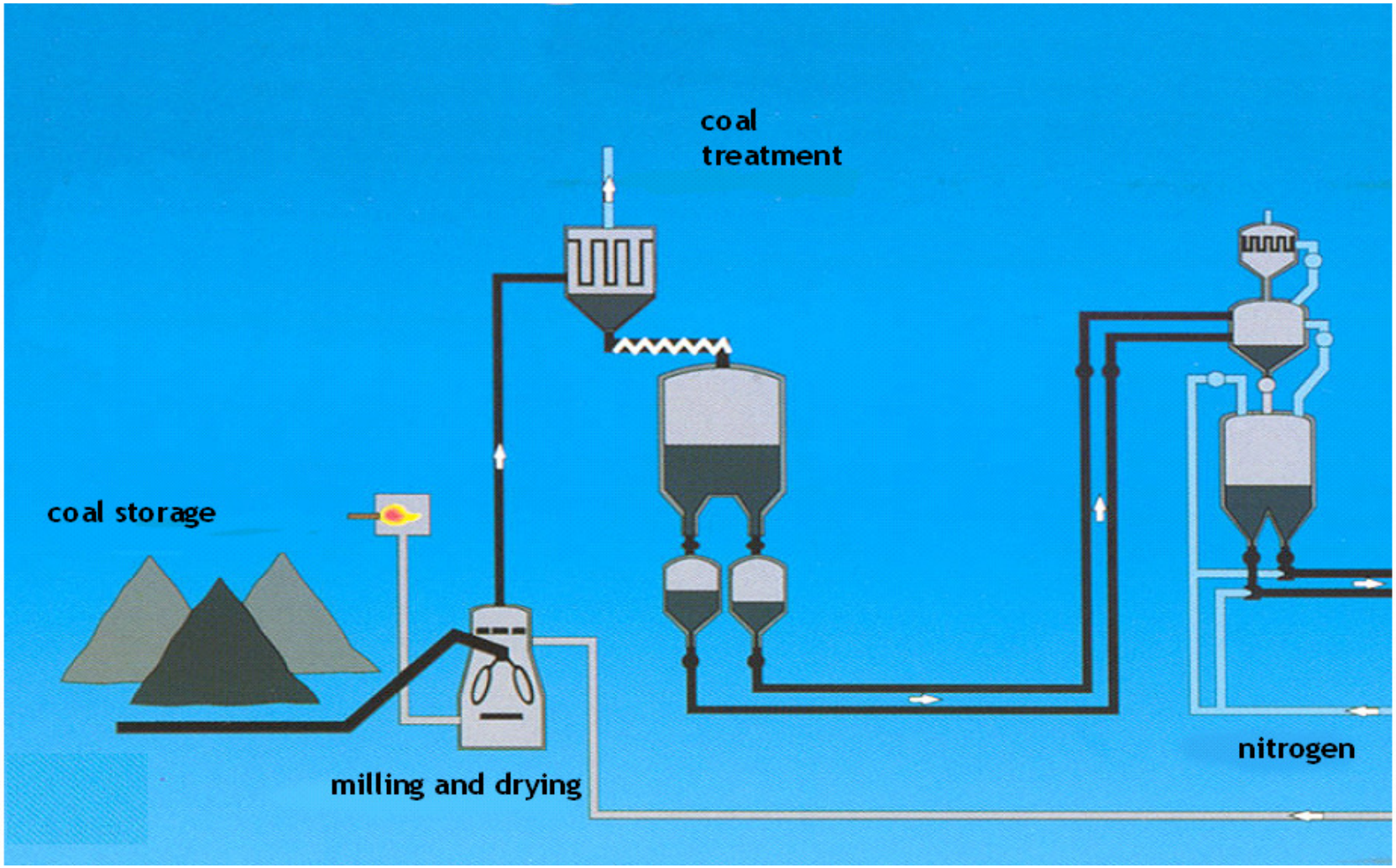
a) Fuel handling/ preparation

b) Gasification/ gas cleaning

c) Steam and Electricity generation

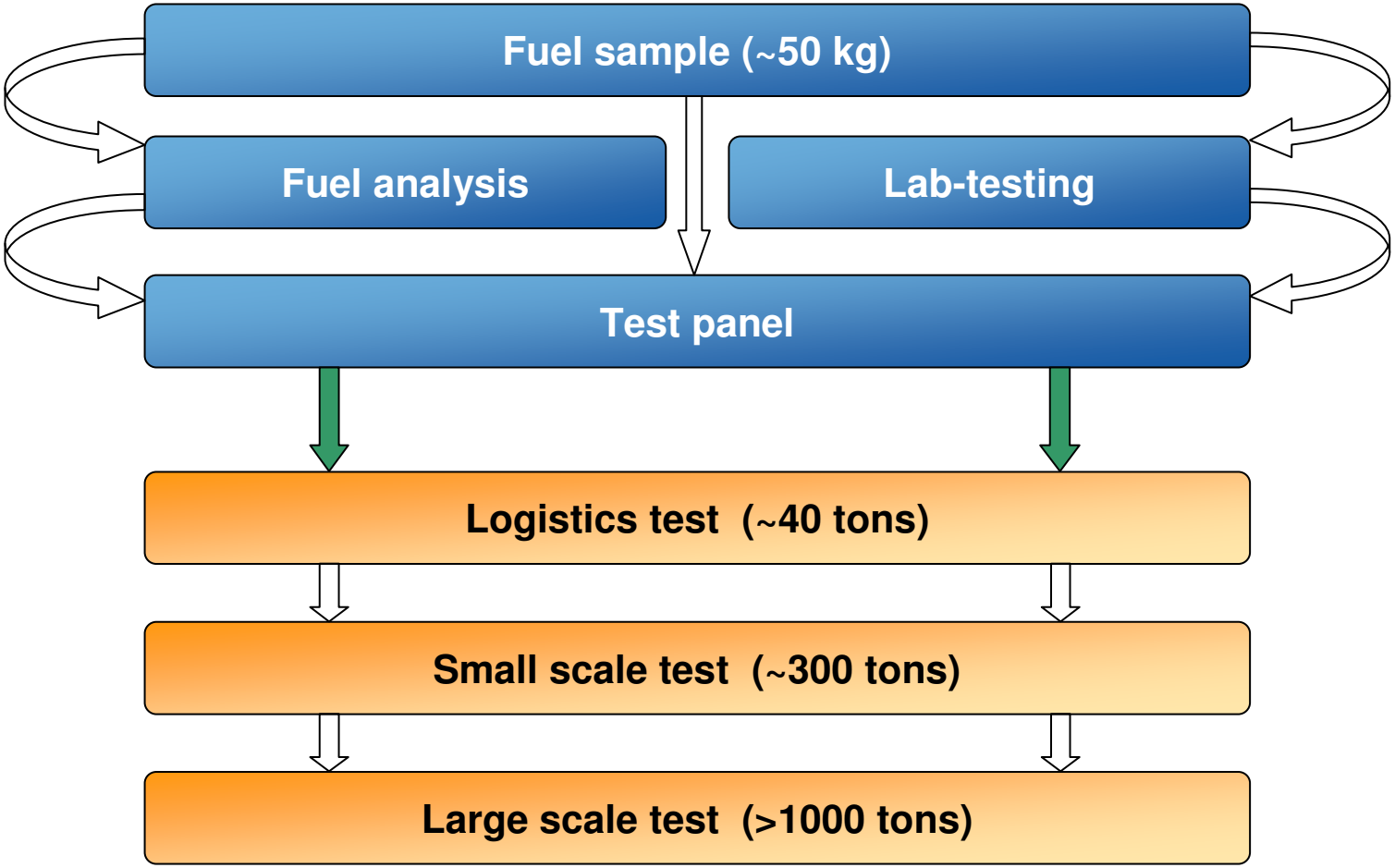
VATTENFALL

Process Scheme WAC Buggenum



VATTENFALL

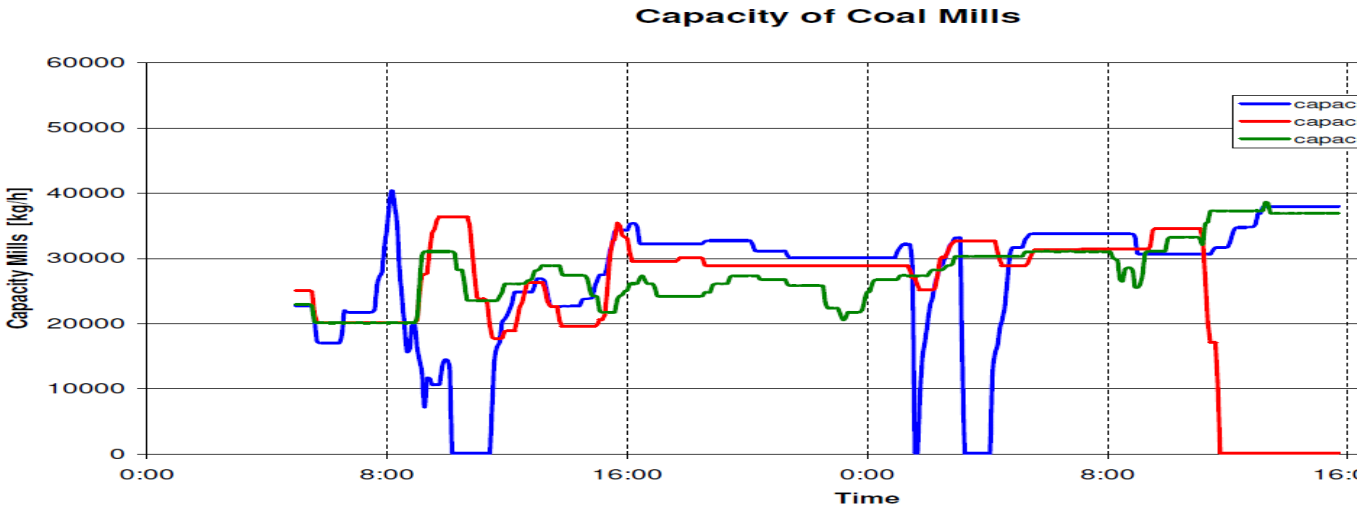
Test campaign – Test protocol for new fuels

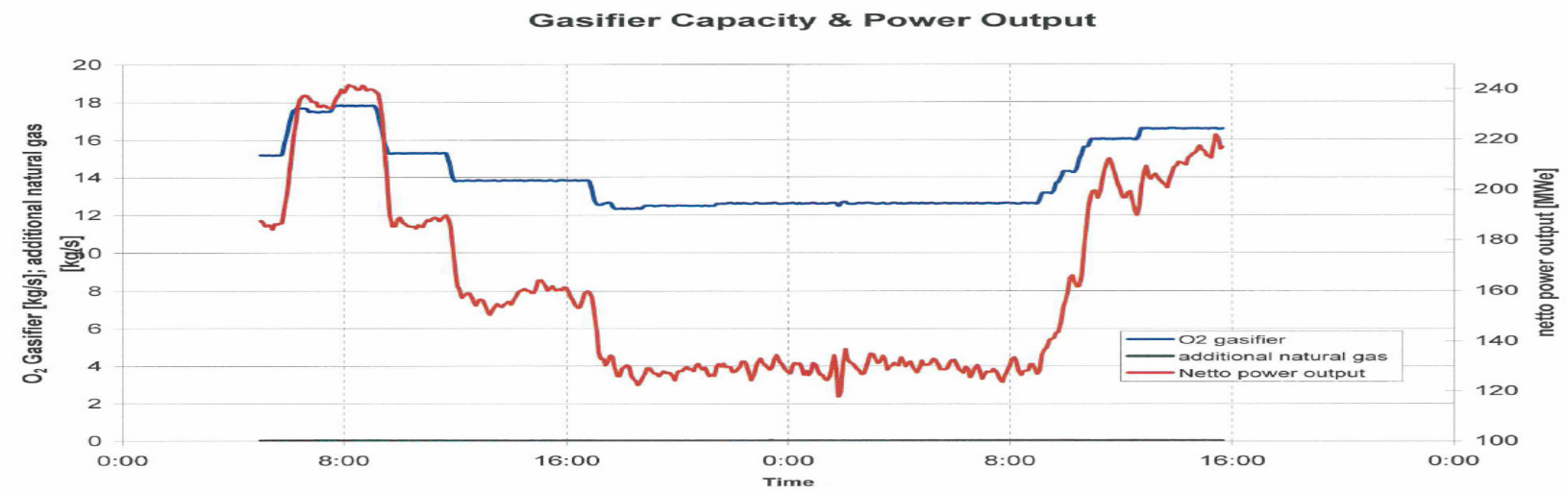


Excution

- 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

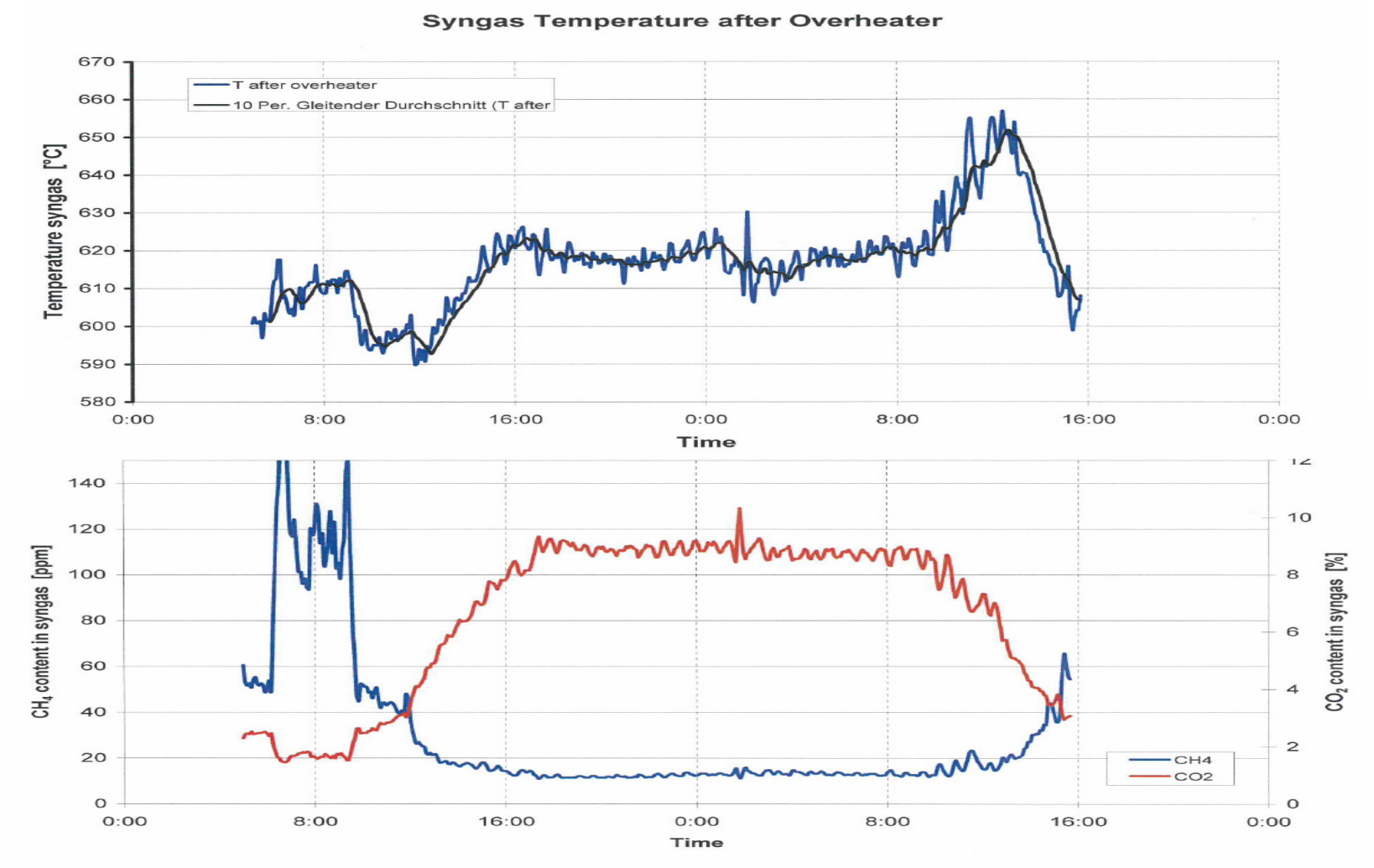
Mill capacities and plant output





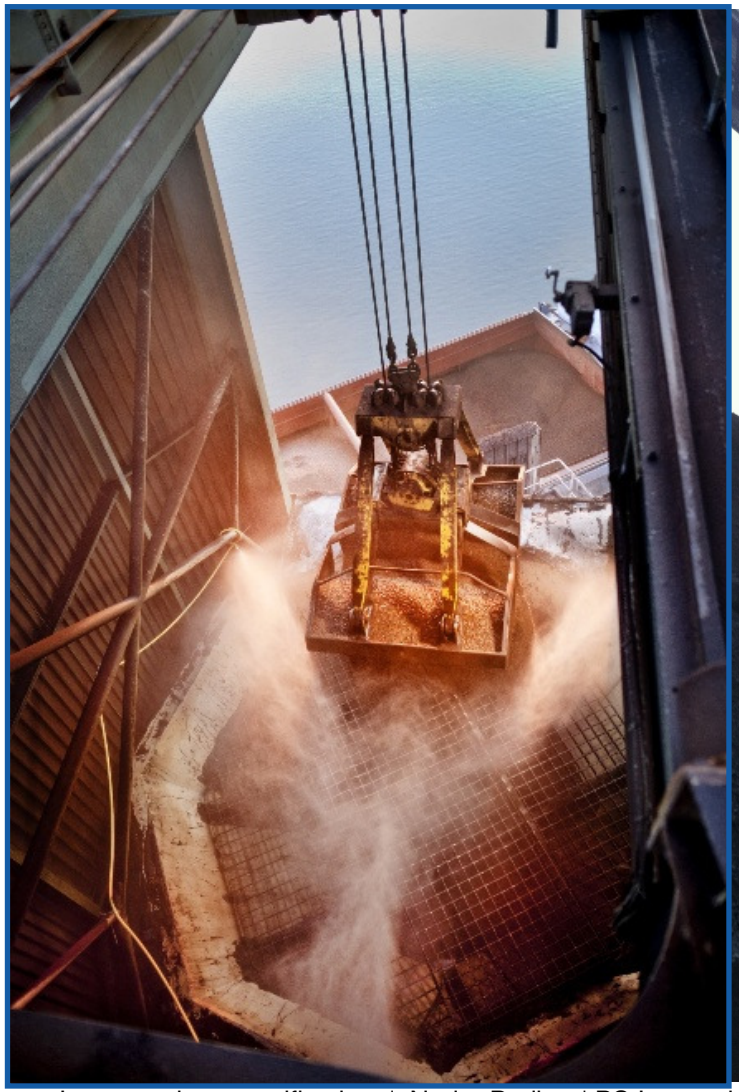
VATTENFALL

Temperature and gas composition



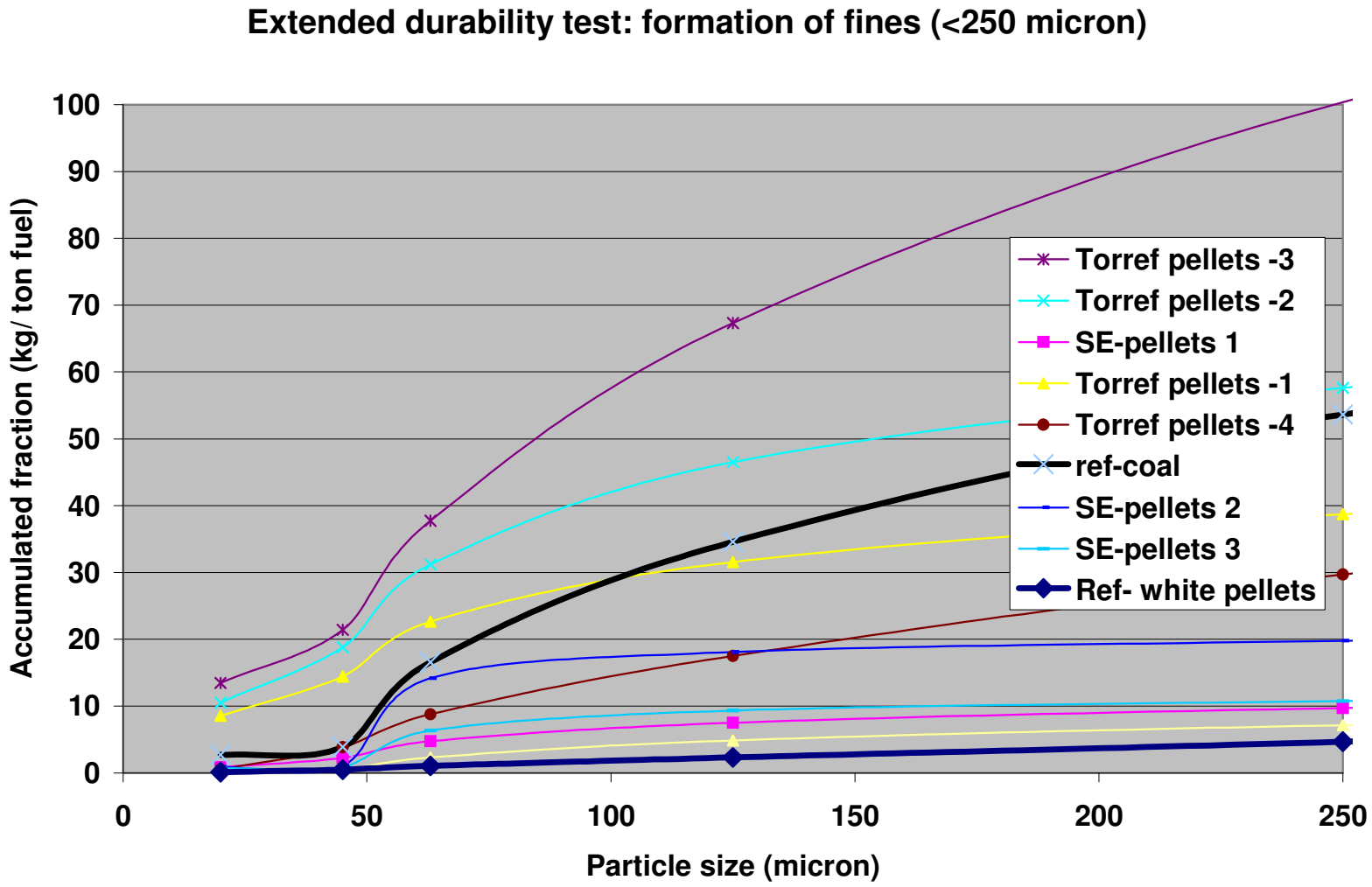
VATTENFALL

Main issue: dust formation



VATTENFALL

Dust formation- Lab scale



VATTENFALL

Product quality: state of the art

Aim	Challenges	Outcome
Imitate physical properties of hard coal	Determine… …relevant parameters and related risks …possible performance upstream …downstream limitations/mitigations	A supply-chain balanced fuel specification

Status

	Dust	Water resistance	Smell	Milling capacity	LHV (MJ/kg)
Steam explosion	✓/✓/✓	✓/✓/✓	✗ Open storage not accepted close to residential	✓ Derating at high load	18.5-20
Torrefaction	✗/✗/?	✓/✗/?	✓/?/?	-/✓/?	20-22.5

Note: Size of sign indicate size of test: lab/demo/full-scale

➔Steam explosion fuel proven today, at relevant co-firing rate, with minor downstream modifications
➔If dust problems solved for torrefaction, properties probably superior compared to steam explosion BUT at the cost of higher feedstock losses

Main conclusions

- Tested torrefied pellets had a lower mechanical durability than normal wood pellets resulting in a high dust formation during handling.
- The minimum ignition energy (MIE) for the dust from torrefied fuel was too low.
- Long term outdoor storage of torrefied material requires an improvement in weather and water resistance of the pellets.
- No big technical challenges were observed during conveying, sluicing and milling of the 70% mixture.
- It was estimated to be possible to achieve 90% of the plant nominal capacity without major modification in fuel feeding system.
- A higher heating value in the pellets was connected to better milling property but a less advantageous dust formation behavior.

Thank you for your attention!

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Andritz Torrefaction Technologies

Summary of pilot plant operation in Austria and Denmark

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Andritz Torrefaction Technologies
Content

- Andritz torrefaction technology platforms, Status
- Vertical Reactor Design; DemoPlant in Denmark
  - Design overview
  - Summary pilot operation
- ACB Process; Demo Plant in Austria
  - Design overview
  - Summary pilot operations
  - Product Data sheet
- Andritz sales activities for commercial ACB plants
  - Pilot Test operation in Frohnleiten
  - Basic engineering

Andritz Torrefaction Technologies

Two technology platforms

Large plants: up to 700.000 t/a per line	**Small / medium plants: 50.000-250.000 t/a**
Vertical Pressurized Reactor Design	**ACB® Torrefaction Design***
Industrial Demo plant (1t/h) in Denmark started up in 3rd quarter 2012	Industrial Demo plant (1t/h) in Austria in operation from 4th quarter 2011.
Pressurized, moving bed, tray type reactor & pelleting plant	Rotating, indirectly heated drum reactor & briquetting plant
Key Features: Scale up to large capacities is possible Feed material: Wood Chips/Forest Residuals	**Key Features:** Simple process concept specially developed for decentralized plants Flexibility in feed material

*ACB Process is developed by the ABC Entwicklungs GmbH with support from the ACB consortium consisting of ANDRITZ POLYTECHNIK Wild&Partner

Andritz Torrefaction Technologies

Pilotplants 2014: change in operation!

2011-2013:
Pilot plant operation to develop torrefaction process, proof the concept and optimize all process steps

2014 ff:
Pilot plant operation to demonstrate customer specific applications and raw materials

Srd Stenderup, DK:

Plant on standby and can be started on demand within 48h.

ACB Frohnleiten, A:

Plant handed over to Frohnleiten (ABL)

1) **Commercial production of briquettes for local sale**

2) **Trial operation to support Andritz sales**

Andritz Torrefaction Technologies

Sdr. Stenderup Torrefaction Demo-Plant

Capacity: 1 Ton/Hour

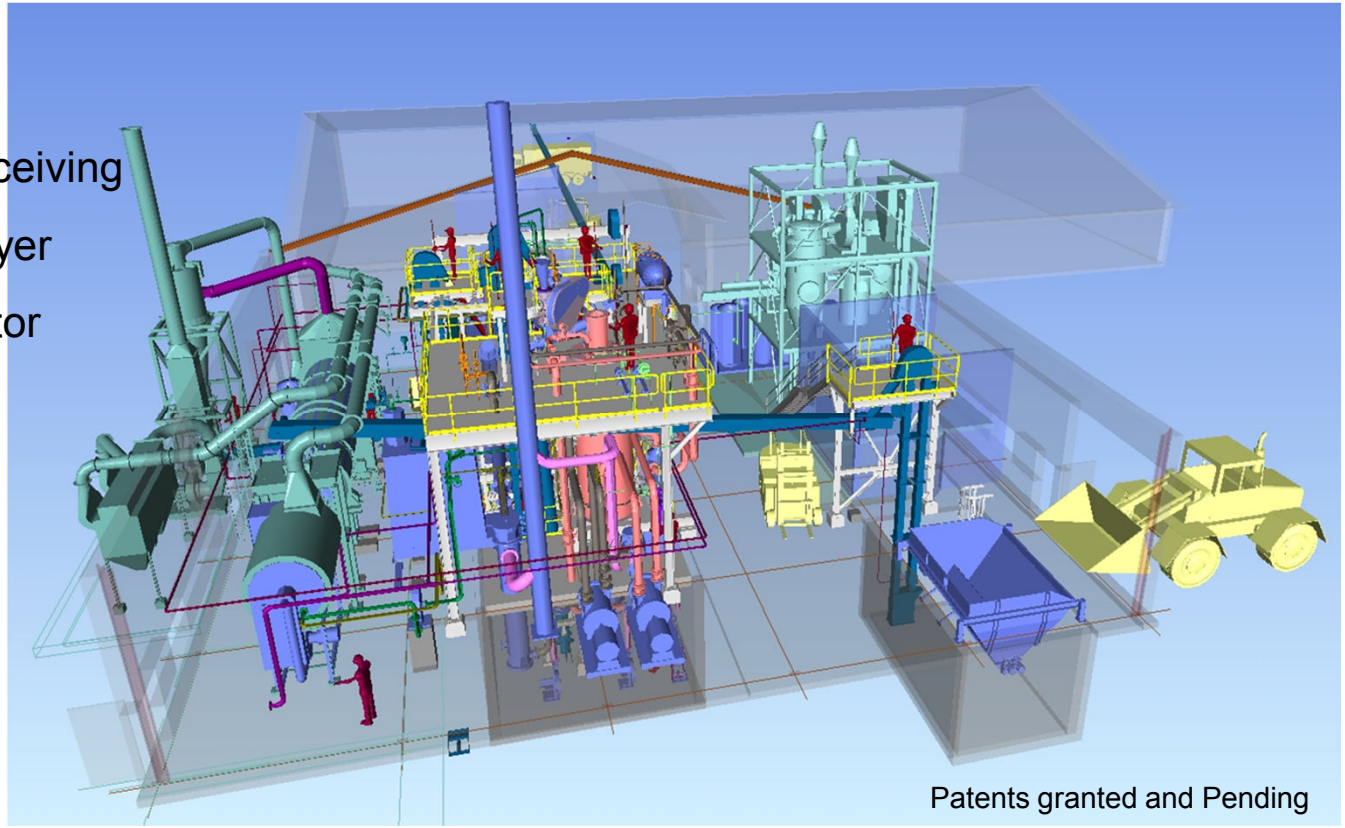
Process steps:

Biomass (Wood Chip) Receiving

Biomass Drying: Drum Dryer

Torrefaction: vertical reactor

Pelletizing

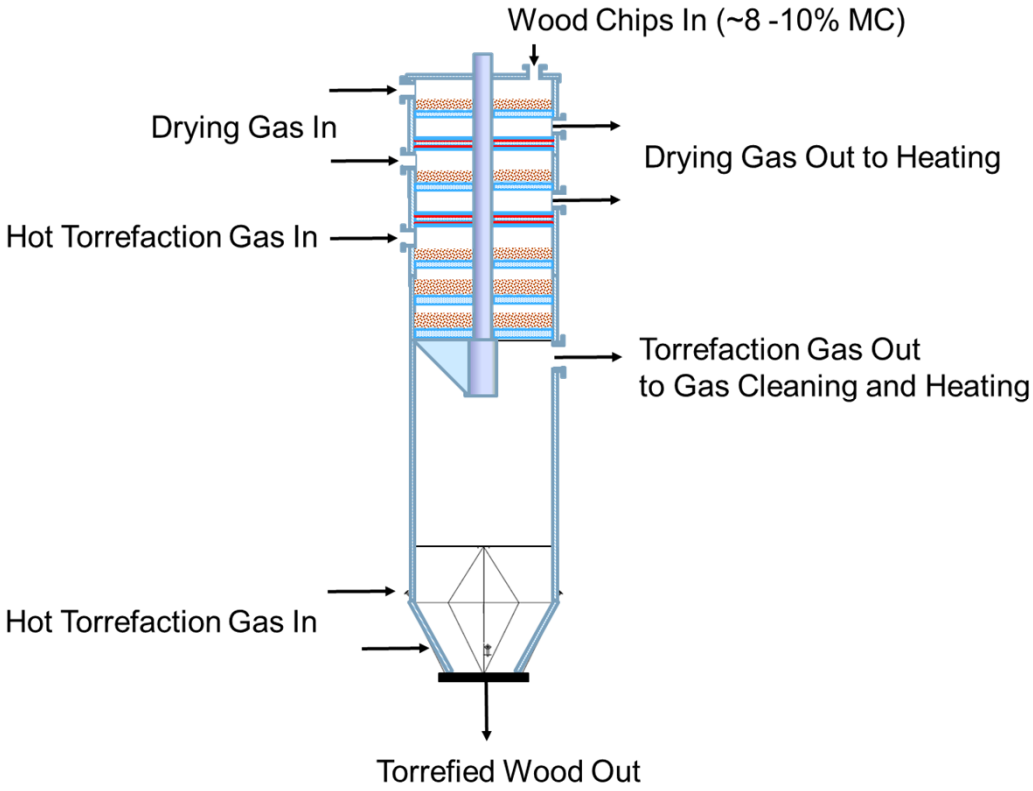


Patents granted and Pending

Andritz Torrefaction Technologies

Sdr. Stenderup: Torrefaction System:

- Blends ECN and Andritz technologies (Patents Granted and Pending)
- Pressurized for more effective heat transfer due to higher gas flows, lower velocities and pressure drop for increased capacity .
- Provides a separation between the final drying zone and the beginning of torrefaction
- Includes a co-current torrefaction zone
- Lends itself to scale up to large single unit capacities



Patents granted and Pending

ANDRITZ Separation

Andritz Torrefaction Technologies

Sdr. Stenderup: Pelleting plant

Much of the work in the last months has been focused around optimizing the pelleting process.

Pellets have been produced without using binders or lubricants other than steam and water for conditioning.

Specific power is higher than for white wood pelleting.

Bulk Density > 660 kg/m3
Durability > 96 %
HHV > 21 MJ/kg

Hydrophobicity >> White Pellets

ANDRITZ Separation

Andritz Torrefaction Technologies
Sdr. Stenderup: Pilot operation

Biomass species being tested:

- Spruce
- Cedar
- Eucalyptus
- Beech
- Poplar

100 tons of torrefied pellets produced in 11/2012
→ Cofiring test at customer with 25% ratio

200 tons of torrefied pellets produced in 2013
→ Customer combustion tests in 1Q 2014

Summary:
-torrefaction temperature in the range of 275-285°C is the preferred range for good grindability and energy content

-densification easier with hardwood than softwood

-technology successfully proven → plant on stand-by for customer tests

ANDRITZ Separation

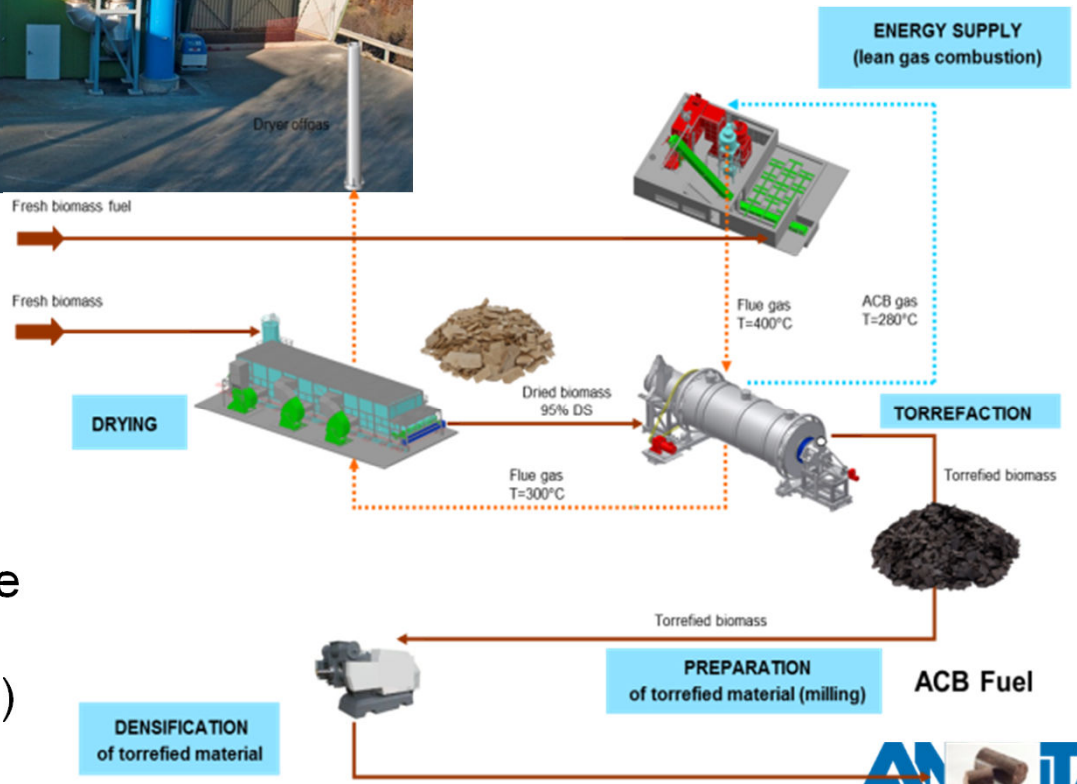
Andritz Torrefaction Technologies

The ACB Pilot Plant, Frohnleiten, A

Comissioning: 4th quarter 2011
Capacity: 1 t/h
Taken over by customer
Further tests possible

Process steps:

- Biomass reception
- Biomass drying (BDS)
- Torrefaction reactor (drum)
- POLYTECHNIK Step grate furnace (ACB gas utilization)
- Briquetting (D= 50mm, 75mm)



Andritz Torrefaction Technologies

Pilot operation

History / Timeline:

- Commissioning Phase I (Drying, Torrefaction, Energy supply)**:** **Sept. 2011**
- Operation in campaigns Phase I: **Sept 2011 – July 2012**
- Start erection Phase II (Briquetting, Container-Storage)**:** **May 2012**
- Operation in campaigns Phase II: **Sept. 2012 – Jan 2013**
- Continuous operation (3d/w; 24h/d): **since Jan 2013**

Operation:

Total operating hours:	approx. 3000h;
Personnel:	2 operators / shift;
Total plant el. energy consumption:	approx. 250 kW
Biomass fuel consumption:	depending on DS of feed (down to 400 kWth)
Throughput:	max. 1050 kg product/h

Andritz Torrefaction Technologies

Pilot operation

Processed Feedstock:

- Spruce, pine; P30 chips, mini chips; MC: 25% to 60%
- Saw mill residues (mixed softwood); MC: 50% to 60%
- Hardwood: beech, aspen, birch, ash, alder; P30 chips; MC: 40% to 50%

Andritz Torrefaction Technologies

ACB Pilot operation: Measurement campagnes

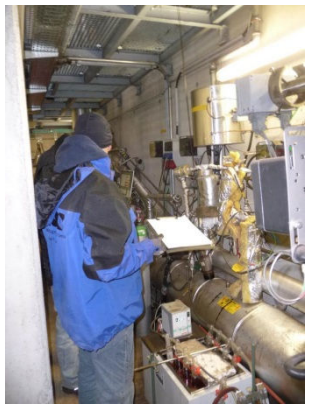
Emission measurement in offgas to stack: all limits OK

Parameter	Authority limit (half-hourly average)	Reached value
CO [mg/m3]	<100	80
NOx [mg/m3]	<250	35
Dust [mg/m3]	<20	7

Performance / Capacity Test Sept 2013: using P 30 spruce chips

Parameter	Contractual value	Reached value
Production capacity [kg/h]	>1000	1027
Bulk density of product [kg/m³]	>650	695
Torrefaction degree [%]	>10%	10.4%

ACB Gas measurements with beech and spruce chips: extensive measurement campagne (FID, FT-IR, GC, RGA) accomplished by BIOS Bioenergiesysteme GmbH



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Results

Dependencies of Torrefaction degree: *TG = 1 - volatiles torr / volatiles raw*

1) mainly dependend on process temperature: tested range: 260-310°C
2) difference for different species (e.g. hardwood higher TG at same temperature)
3) Retention time: tested range: 20-50 min
4) Particle size

Briquetting parameters depend on torrefaction degree:

- **Briquette density decreases with in creasing TG**
- **Hydrophobicity increases with increasing TG**
- **No clear tendency for Durability**

  - Higher TG leads to better water resistancy but less density!
  - No clear dependency of durability

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ACB Fuel Data sheet (typical data for soft wood)

Product data showing data acc. „TW1“ from proposal for new standard for Solid biofuels Fuel specification and classes – Part 8: Thermally treated and densified biomass fuels

Parameter	unit	norm	product
shape	cylindrical		
Diameter	mm	-	50 mm +/- 5; 75 mm +/-5
Length	mm	-	1x - 1,5x Diameter
MC	% wb	EN 14774-1	2-5
GCV	MJ/kg db	EN 14918	20-23*
NCV	MJ/kg db	ISO 18125	19-22*
Volatiles	m%	EN 15148	65-75*
Ash	m%	EN 14775	0,5-1
Bulk density	kg/m3	ISO 17828	680-720
Durability	%	EN 15210-2	2-5
N	m%	ISO 16948	<0,3
S	m%	ISO 16994	<0,1
Cl	m%	ISO 16994	<0,01

*possible ranges → different TG → different mass loss

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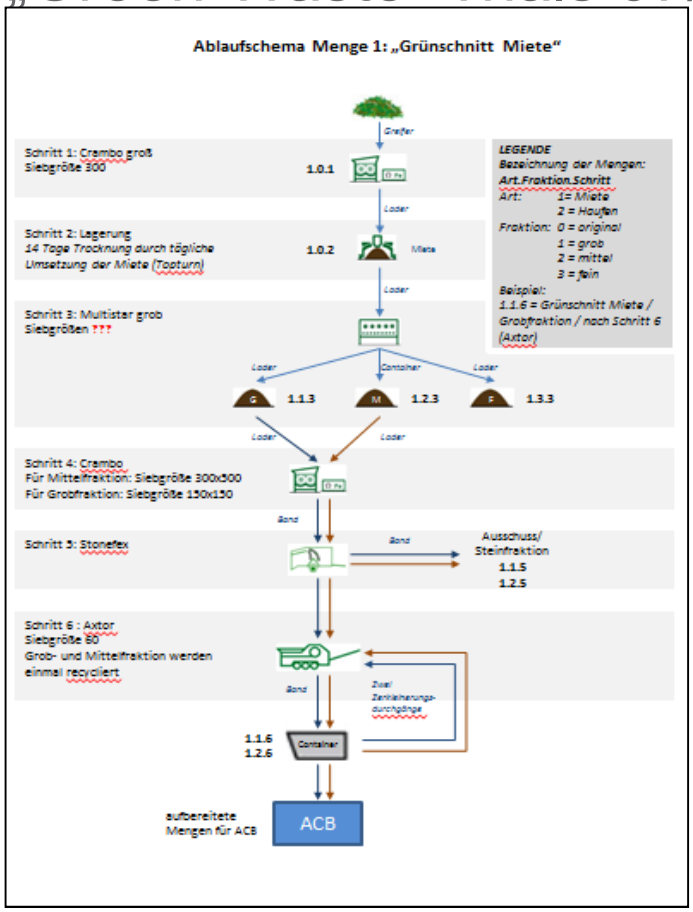
„Green-Waste“ Trials 07/08 2013



Separation

Briquett-Data „Green waste“:

Bulk density:	~770 kg/m³
Durability*:	~95%
MC %:	<4%
Torrefaction-degree:	~20%

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„forest residues“ Trials 09 2013

Feed Material: forest residues: tops, branches (with needles)

Feedmaterial preparation: screening (40mm) to get rid of coarse materials

Torrefaction with 2 different temperature settings

Briquetting (Frohnleiten) and Pelleting (Sdr Stenderup) trials

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grassy biomass („straw“) Trials 10/11 2013

1) Feedmaterial preparation: debaling, size reduction, washing, dewatering




2) Conveying tests

3) Torrefaction tests: temperature variation (260-310°C)

4) ACB-Gas measurements

5) Briquetting trials: onsite

6) Pelleting trials: externally


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ACB commercial plant design

A successful biomass project is based on three pillars:


Raw material supply


Process / Equipment


Product take-off

ANDRITZ

Andritz is ready to provide turn-key (electro-mechanical) solutions for the entire production process.

With the ACB pilot plant, the risks of the overall project can be minimized by testing the whole value chain

Main key parameters to be considered for plant design:

1. Raw material testing → lab-tests, pilot-tests, pilot-production
2. Plant concept / plant integration → Engineering studies

ANDRITZ Separation

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ACB pilot test operation

*„Andritz can offer extensive lab and on site pilot testing to assess torrefaction behavior of specific biomass feedstock to provide a solid base for **process design and guarantees**“*

Tests:

Laboratory test: min 10 kg of feedstock required
→ Determination of specific torrefaction properties by TGA and small scale lab torrefaction

Pilot tests: min 100 m3 of feedstock required
→ Material handling and drying evaluation → design of pretreatment
→ Mass and Energy data derived from industrial pilot operation
→ Determination of detailed product quality (pellets, briquetts, gas)
→ Assessment of specific emission or corrosion behavior

Pilot production: up to 500 t product from specific or locally sourced feedstock

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ACB commercial plant concepts

Engineering contracts for basic plant engineering under consideration of all project specific frame conditions such as:

- Feedstock (MC, HV, composition such as ash, Cl, S..)
- Product specifications
- Existing facilities (integrated system solutions)
- Specific costs and tarifs
- Emission regulations, specific standards,…
- …

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