Key Issues in Torrefaction Process Plant Design and Operation

B. Greenwood **(Andritz Inc)**
B. Stromberg **(Andritz Inc)**
A. Eyer **(Andritz Inc)**
D. Thamer **(Andritz AG)**
K. Trattner **(Andritz AG)**
A. Melsen **(Andritz A/S)**
P. Høgh **(Andritz A/S)**
J. Kiel **(ECN)**
F. Verhoeff **(ECN)**
S. Leiser **(ECN)**
J. Dahl **(DTI)**
G. Hastrup **(DTI)**
H.O. Hansen **(DTI)**
P.D. Jensen **(DTI)**

June 2013
ECN-L--13-041

ANDRITZ
Pulp & Paper

Key Issues in Torrefaction Process Plant Design and Operation

21st European Biomass Conference and Exhibition: Session Reference: 4AO.8.2

Brian F. Greenwood and et.al.

What is torrefaction?

Torrefaction of biomass can be described as a mild form of thermal conversion (controlled carbonisation) at temperatures typically ranging between 250-300 °C in the absence of oxygen. During torrefaction the biomass properties are changed to obtain a much better fuel quality (increased heating value) for combustion, gasification and co-firing in conventional coal-fired power plants and steel industry. Low calorific components are transferred to the gas phase as water, CO_2, CO and various organic acids are transferred into the gaseous phase..

The torrefaction objective is to improve the energy properties of biomass within a defined residence time and temperature less than 300 °C.

Source ECN, Kiel et.al.

ANDRITZ Pulp & Paper

Andritz Torrefaction Technologies

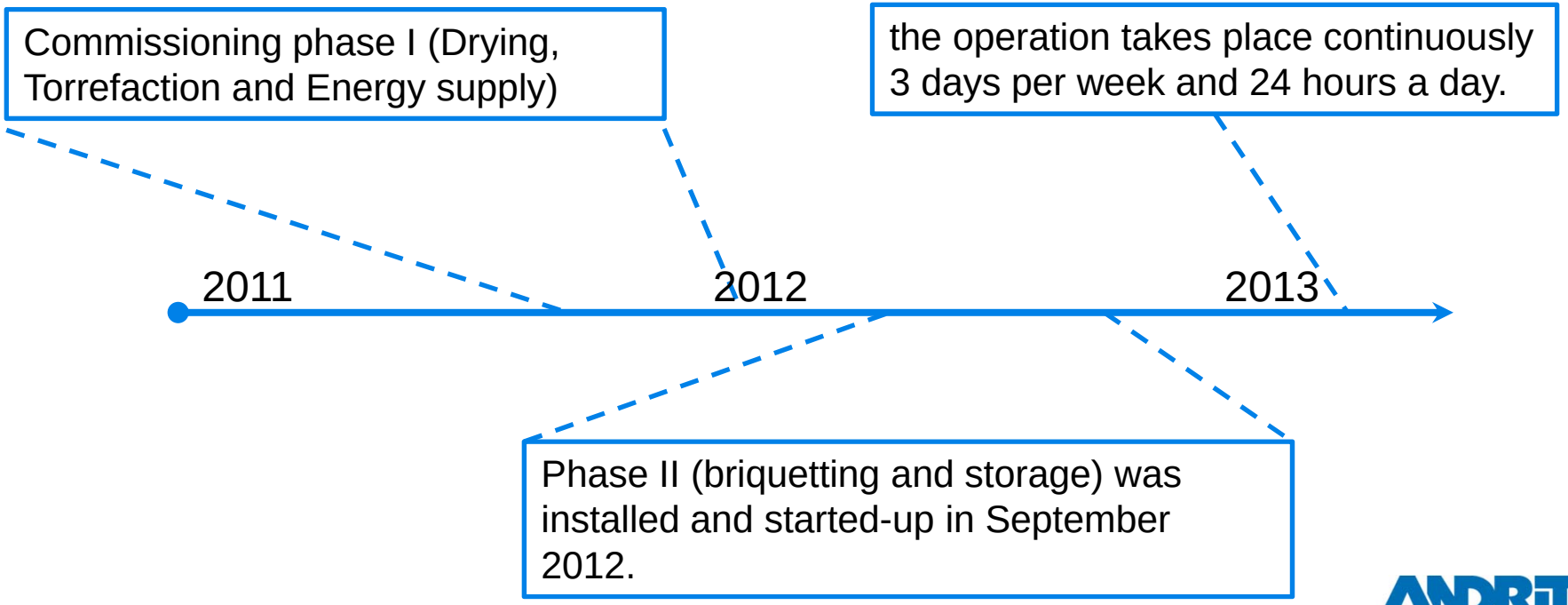
- **Two Main Technology Platforms**

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 started 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

ANDRITZ Pulp & Paper

The ACB History and Presence

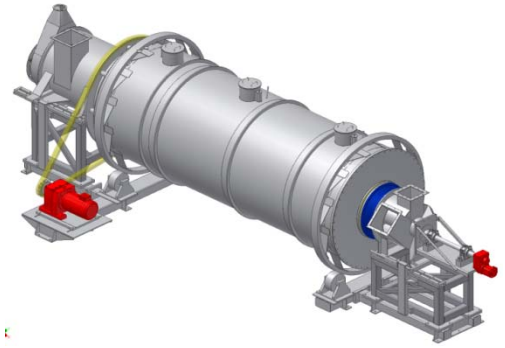
- The ACB process (ACB: Accelerated Carbonized Biomass) was developed by an Austrian based consortium consisting of **Polytechnik**, **Wild & Partner** and scientific support by **OFI**, led by **Andritz AG** and started in 2007.
- Development work was backed by the **Austrian Research Promotion Agency** with resources from the **Austrian Climate Fund**.



Torrefaction of biomass – ACB® Process

Small capacity reactor systems for 50,000 t/a per line

Torrefaction of biomass at 250-300°C under inert conditions

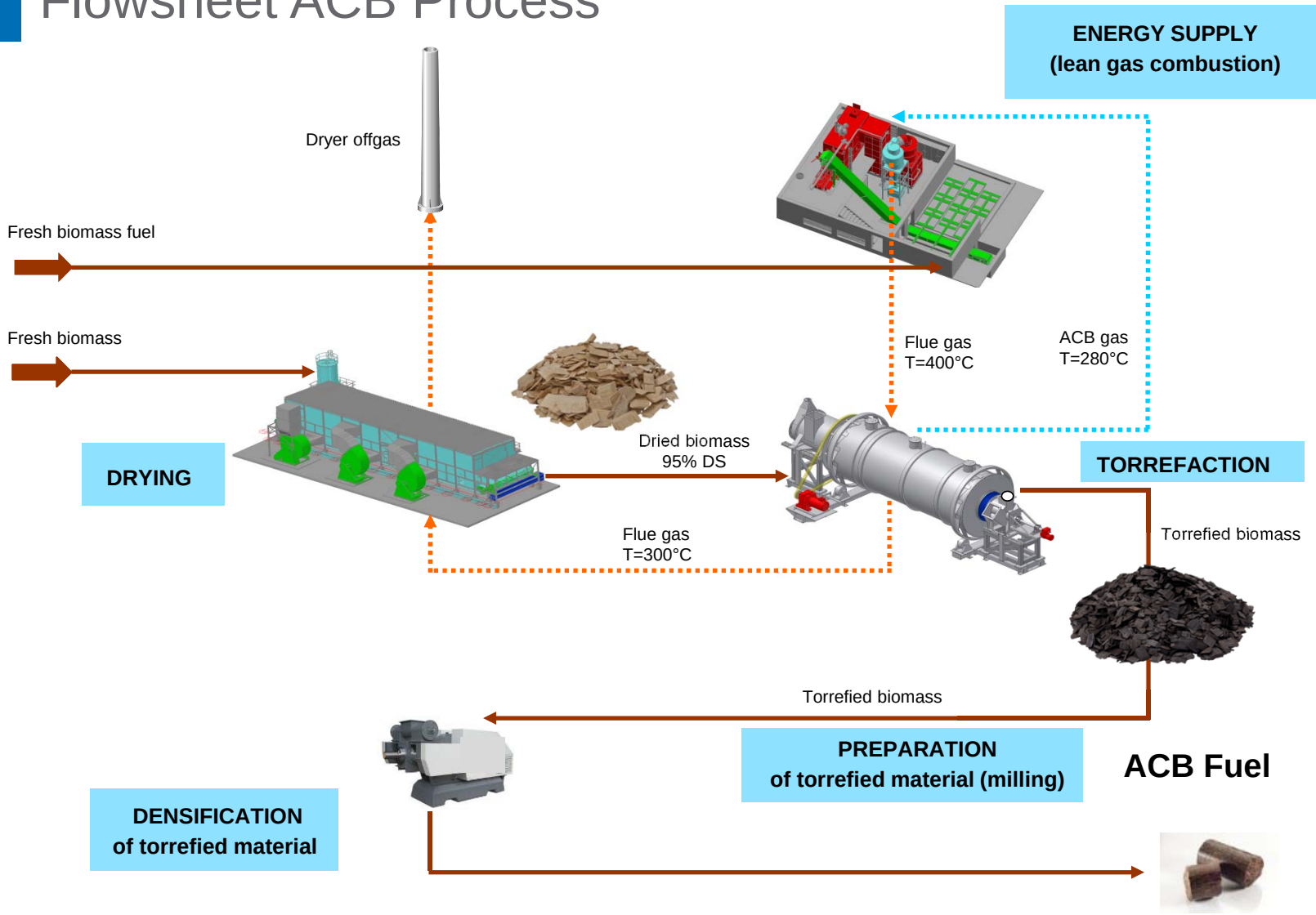


- Rotating, indirectly heated drum
- Prevention of condensation problems due to gas flow pattern
- Flexibility in terms of allowable particle size
- No clogging, channeling or increase in pressure drop
- Oxygen infiltration avoided by drum sealing technology
- Construction based on proven Drum Drying System (> 110 such dryers worldwide)

Demo plant for production of 1 t/hr of torrefied briquettes installed in Frohnleiten, Austria

ANDRITZ Separation

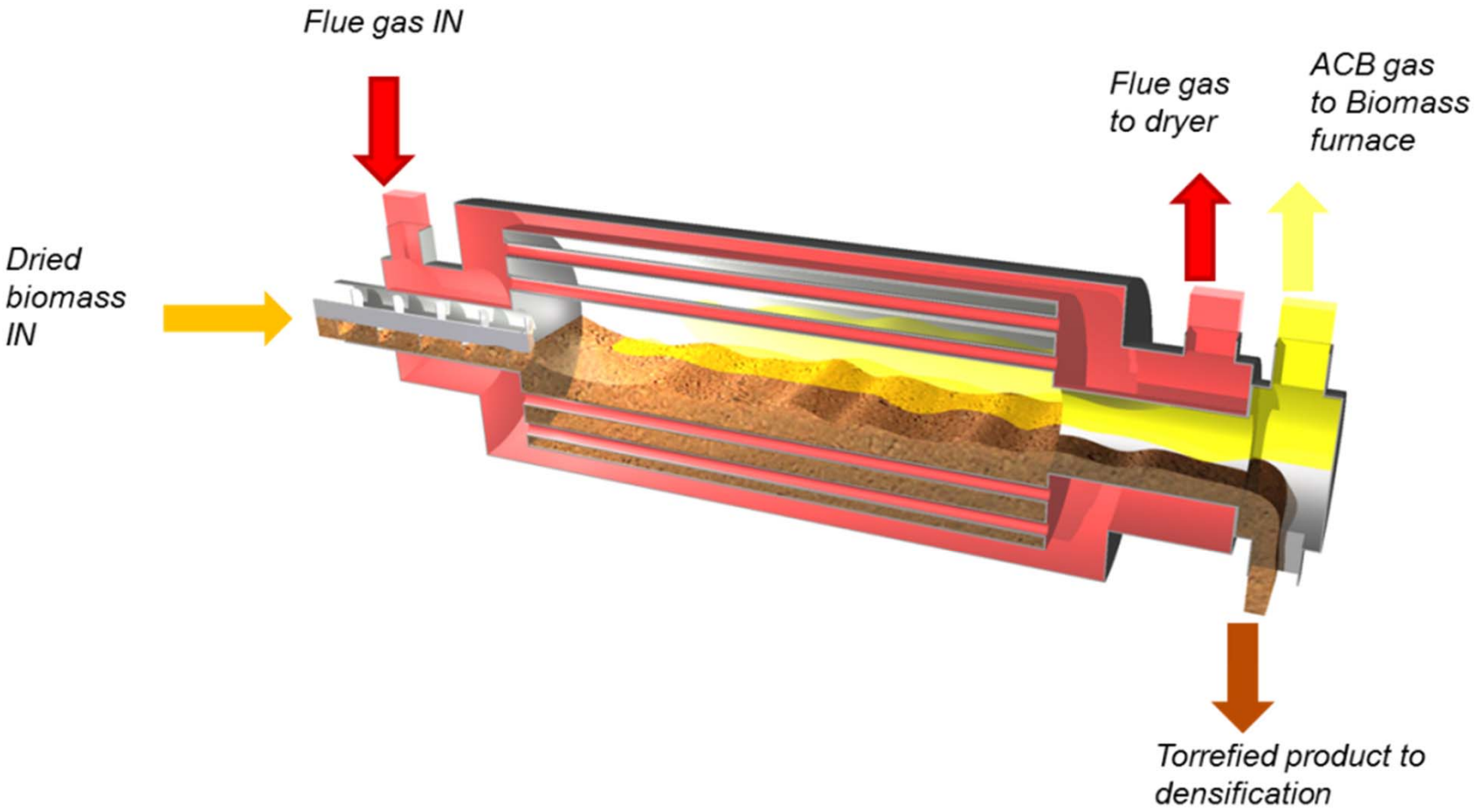
Torrefaction of biomass
Flowsheet ACB Process



ANDRITZ Separation

Torrefaction of biomass

Andritz ACB Process, Austria



ANDRITZ Separation

Torrefaction of Biomass

Densification: Briquetting

Densification by piston press:	Die diameter Ø50 mm and Ø75 mm
Max. capacity (kg/h):	1,15 t/h at die diameter of Ø75 mm
Density (w/o additives)	1,1-1,3 kg/l
Energy consumption (kWh/t)	55 kWh/t @ 1,07 t/h
Durability:	up to 97%
Water uptake(5 min in water):	about 1 m%

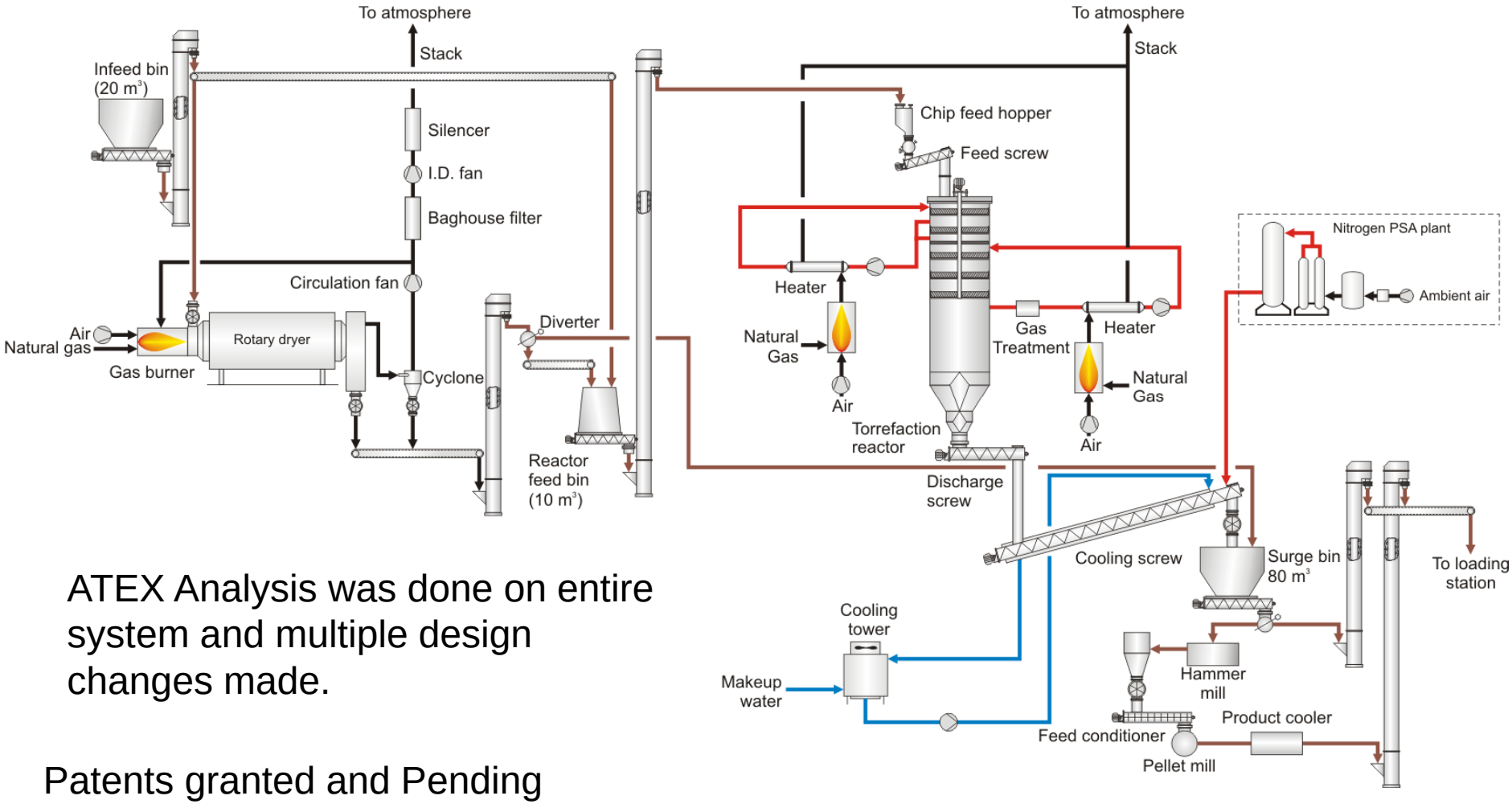
ANDRITZ Separation

Sdr. Stenderup Torrefaction Demo Plant Project

- Andritz has built a 1 Ton/Hour Torrefaction Demo Plant in Sdr. Stenderup, Denmark
- The plant incorporates:
  - Biomass (Wood Chip) Receiving
  - Biomass Drying
  - Torrefaction
  - Pelletizing
- The plant entered commissioning in the 2nd quarter of 2012 and is currently operational.
- The project is partially funded by the **Danish EUDP**, (Energy Technology Development and Demonstration Programme), with a significant majority of the capital funding from Andritz.
- The **Danish Technology Institute** (DTI), and energy companies **Drax** and **Dong** are involved as part of the EUDP team.
- **Energy Research Center of the Netherlands** (ECN) is acting as a consultant to Andritz on the design of the torrefaction technology and will be involved in the commissioning and optimization of the demo plant.

Torrefaction Sdr. Stenderup Demo Plant

Simplified Single Line Flowsheet 1 bdmt/h wood chips



ATEX Analysis was done on entire system and multiple design changes made.

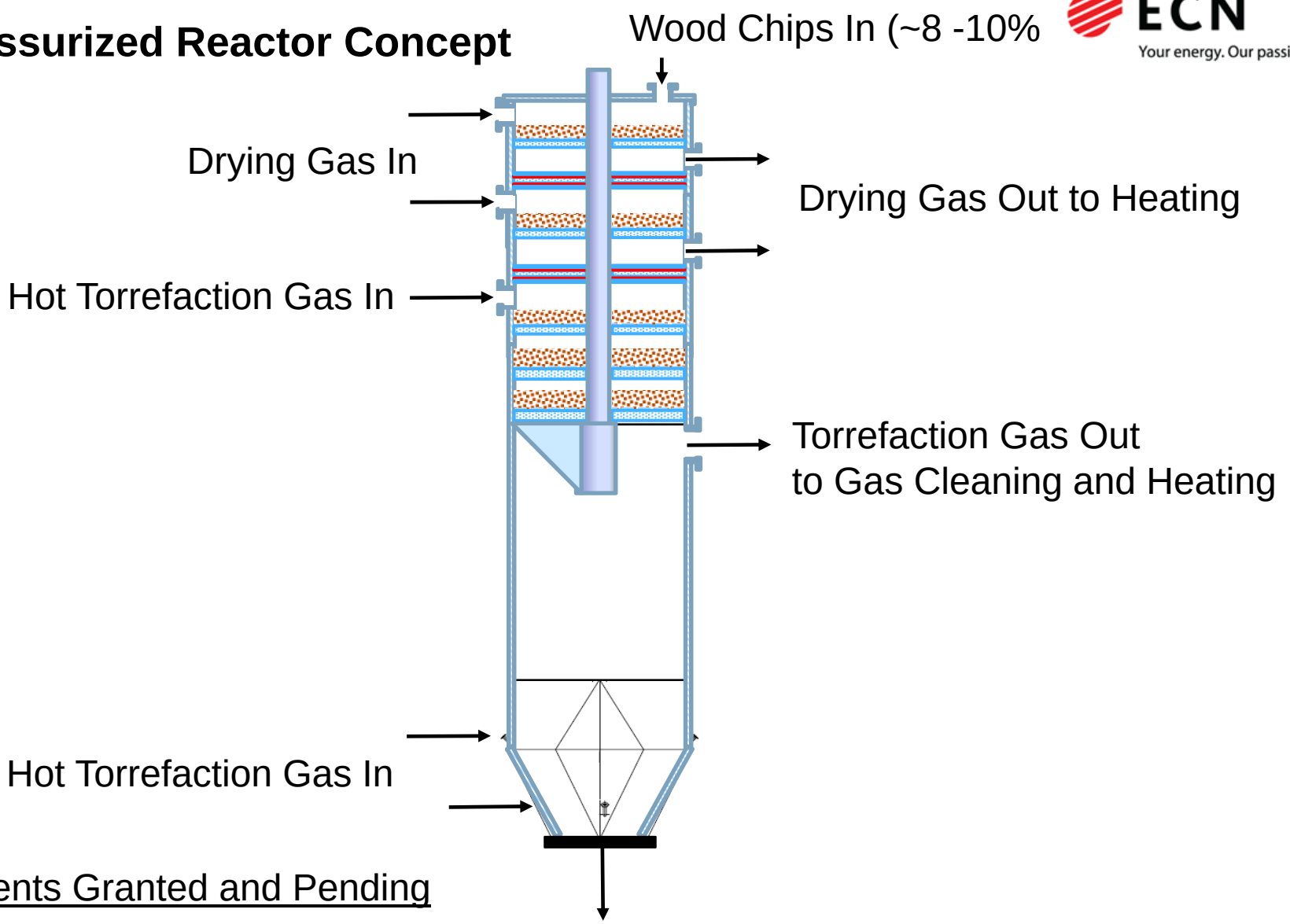
Patents granted and Pending

ANDRITZ Pulp & Paper

Sdr. Stenderup Demo Plant

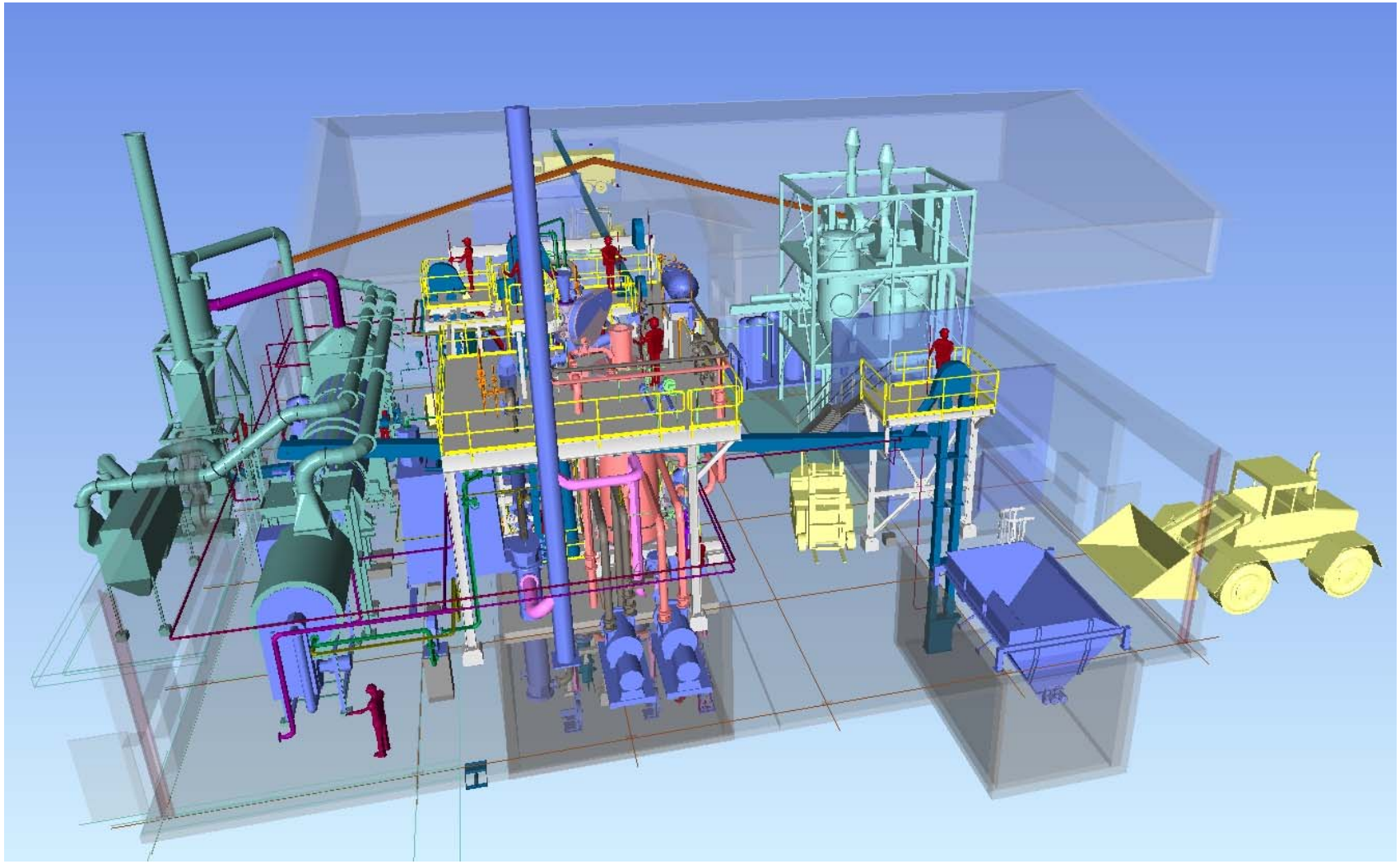
- The Torrefaction System:
  - Blends ECN and Andritz technologies (Patents Granted and Pending)
  - Pressurized for more effective heat transfer due to higher gas flows, lower velocities and pressure drop for increased capacity .
  - Provides a separation between the final drying zone and the beginning of torrefaction
  - Includes a co-current torrefaction zone
  - Provides for removal of heavy organic compounds from the torrefaction gas, minimizing plugging and deposits.
  - Lends itself to scale up to large single unit capacities
    - High fraction of the vessel volume is used for either final drying or reaction.
    - The capacity will increase as the diameter squared.

ECN/Andritz
Pressurized Reactor Concept



Patents Granted and Pending

Sdr. Stenderup Demo Plant Overall View
PDMS used for 3D Modeling and Design



ANDRITZ Pulp & Paper

Sdr. Stenderup Torrefaction Demo Plant Project

Photo April 2012

Torrefaction reactor
during installation lift

Patents granted and Pending

ANDRITZ Pulp & Paper

Sdr. Stenderup Torrefaction Demo Plant Project

Rotary Dryer

Viewed from Feed End

Viewed from Discharge End

Sdr. Stenderup Torrefaction Demo Plant Project

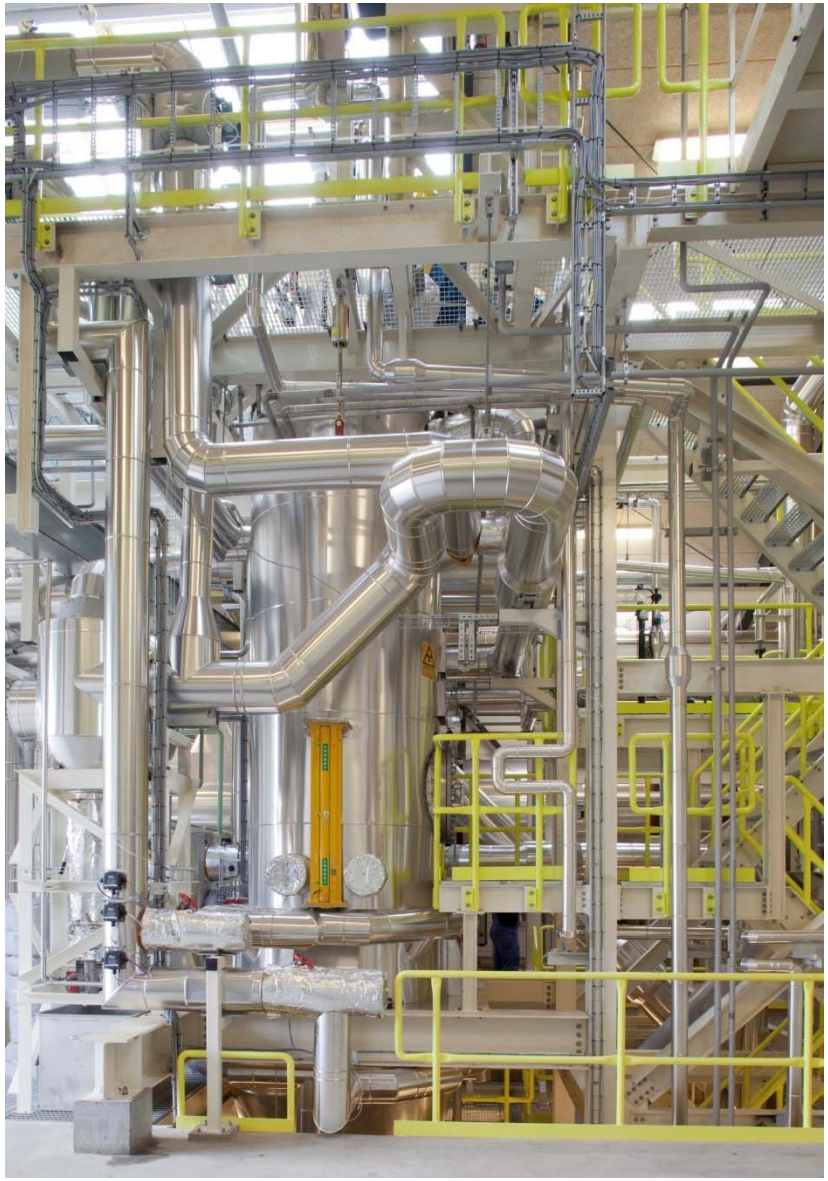
Rotary Dryer

Sdr. Stenderup Torrefaction Demo Plant Project

Torrefaction
Reactor Top Area
View 1

Patents granted
and Pending

Sdr. Stenderup Torrefaction Demo Plant Project



Torrefaction
Reactor Process
Area

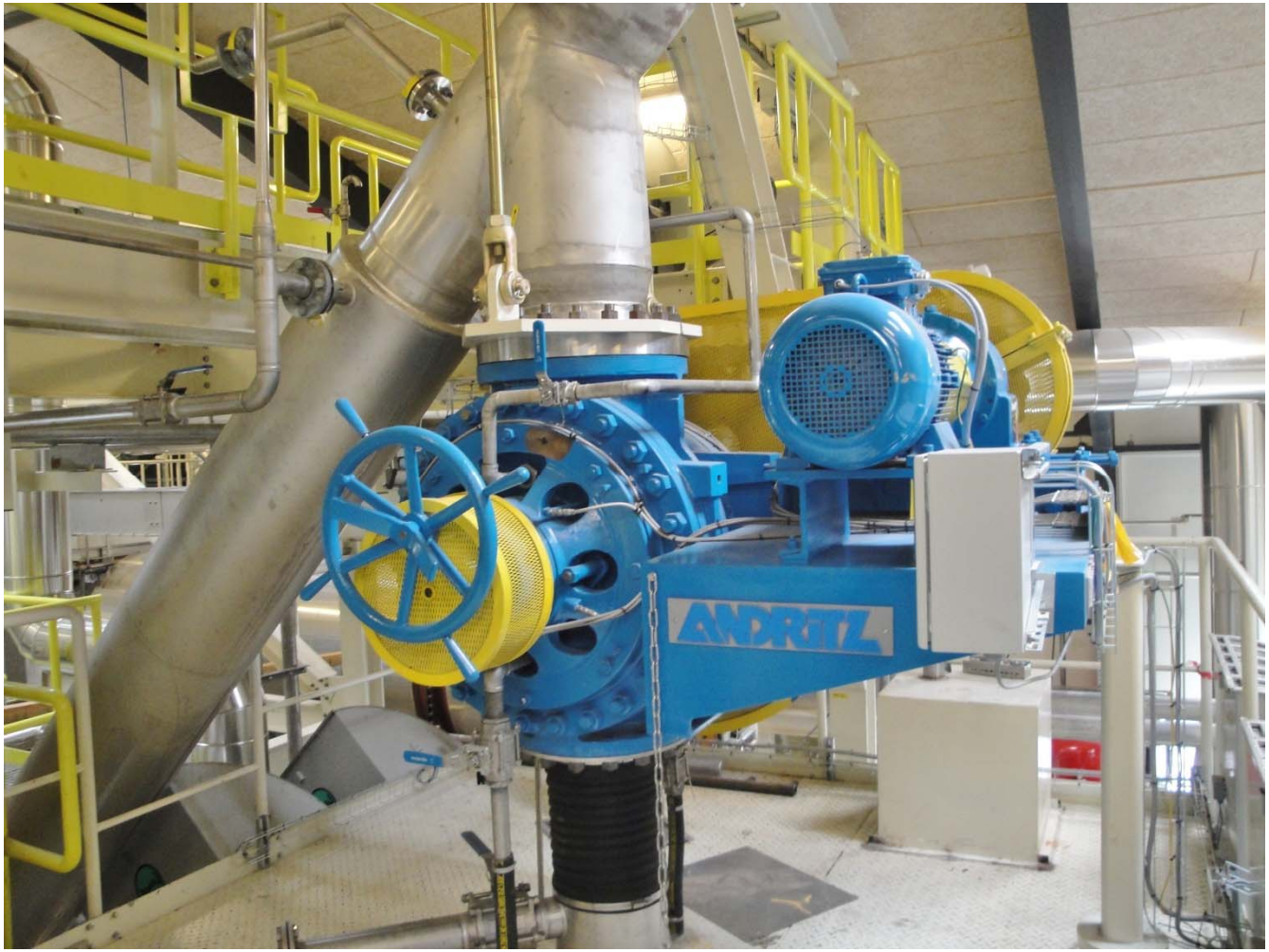
Patents granted
and Pending

Sdr. Stenderup Torrefaction Demo Plant Project

Torrefaction
Pressurized Gas
Circulation
Blowers

ANDRITZ Pulp & Paper

Sdr. Stenderup Torrefaction Demo Plant Project



Upper Part of Torrefied Material Cooling Screw and Discharge Rotary Valve

ANDRITZ Pulp & Paper

Sdr. Stenderup Torrefaction Demo Plant Project
Pellet Press Installation

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 Pulp & Paper

Sdr. Stenderup Torrefaction Demo Plant Project

Operating Engineer, Kristian Larsen controlling the process.

Project Status

- The plant is in operation and producing product for test firings and optimization.
- We are in the process of discussing commercial scale systems.
- We are pleased to discuss your requirements.

Raw Materials run to Date:

Nordic Softwood Mix
Cedar
Eucalyptus
Beech

ANDRITZ Pulp & Paper

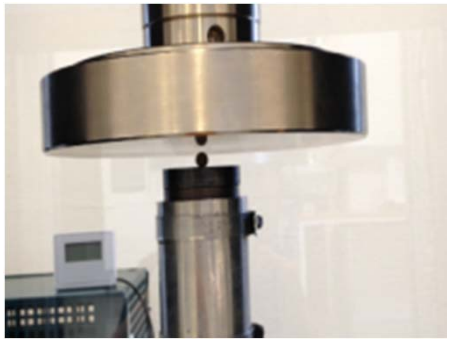
Single Pellet Tests

DANISH TECHNOLOGICAL INSTITUTE

Laboratory scale test method to screen the pelletizing properties of (torrefied) biomass

- Method developed and used by Danish Technological Institute - DTI
- Fast and simple method:
  - Just a few grams of material are needed
  - Adjustment of different pelletizing parameters i.e. Temperature, Moisture, Particle size, Binder addition, Press channel length and inlet design… etc.

→ **Information about Process & Pellet Quality**



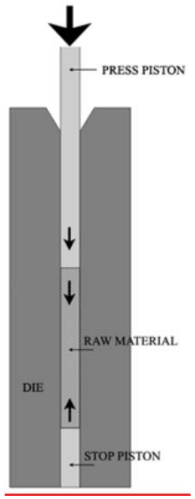
ANDRITZ Pulp & Paper

Single Pellet Tests

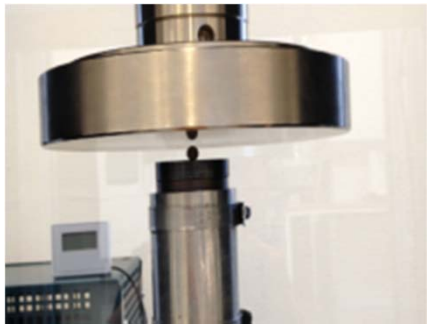
DANISH TECHNOLOGICAL INSTITUTE

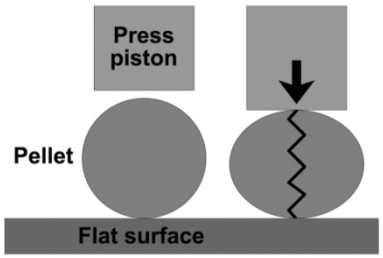
4 parameters are tested:

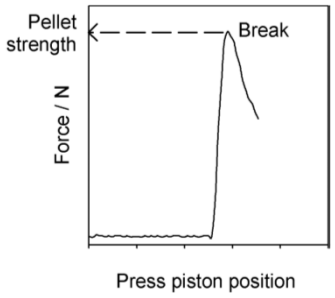
1. Compression of biomass
2. Static & dynamic friction
3. Pellet compression strength
4. Pellet density



Monitoring of forces during compression and extrusion of pellet from press channel







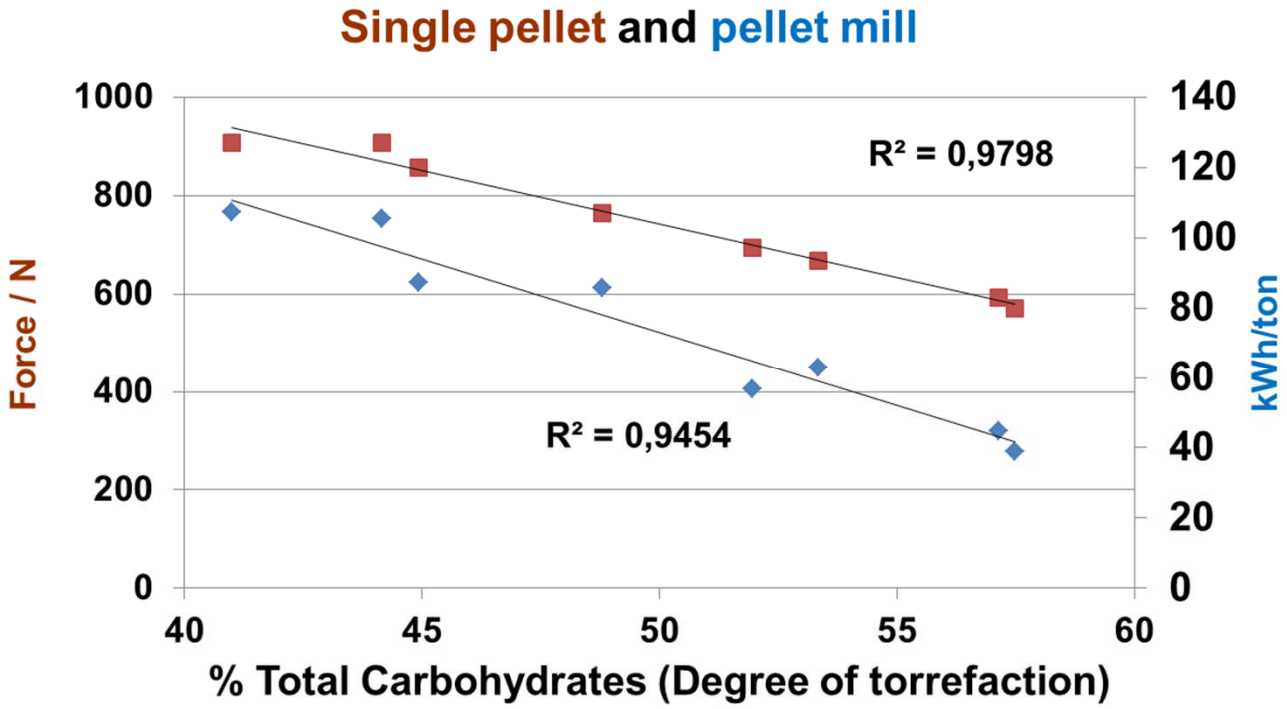
Force required to crush the pellet

→ Results give indication what parameters should be used for pelletization

ANDRITZ Pulp & Paper

Single Pellet Tests vs. Production size mill

DANISH TECHNOLOGICAL INSTITUTE



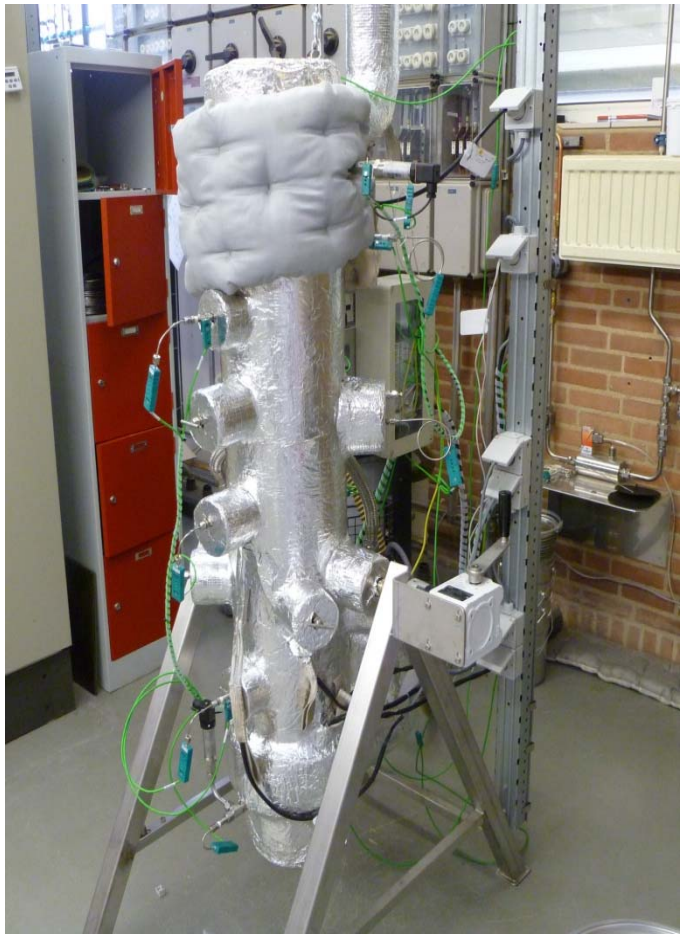
Good correlation between single pellet press and production size pellet mill data

Static friction from single pellet press (N)

Energy consumption of press (kWh/t)

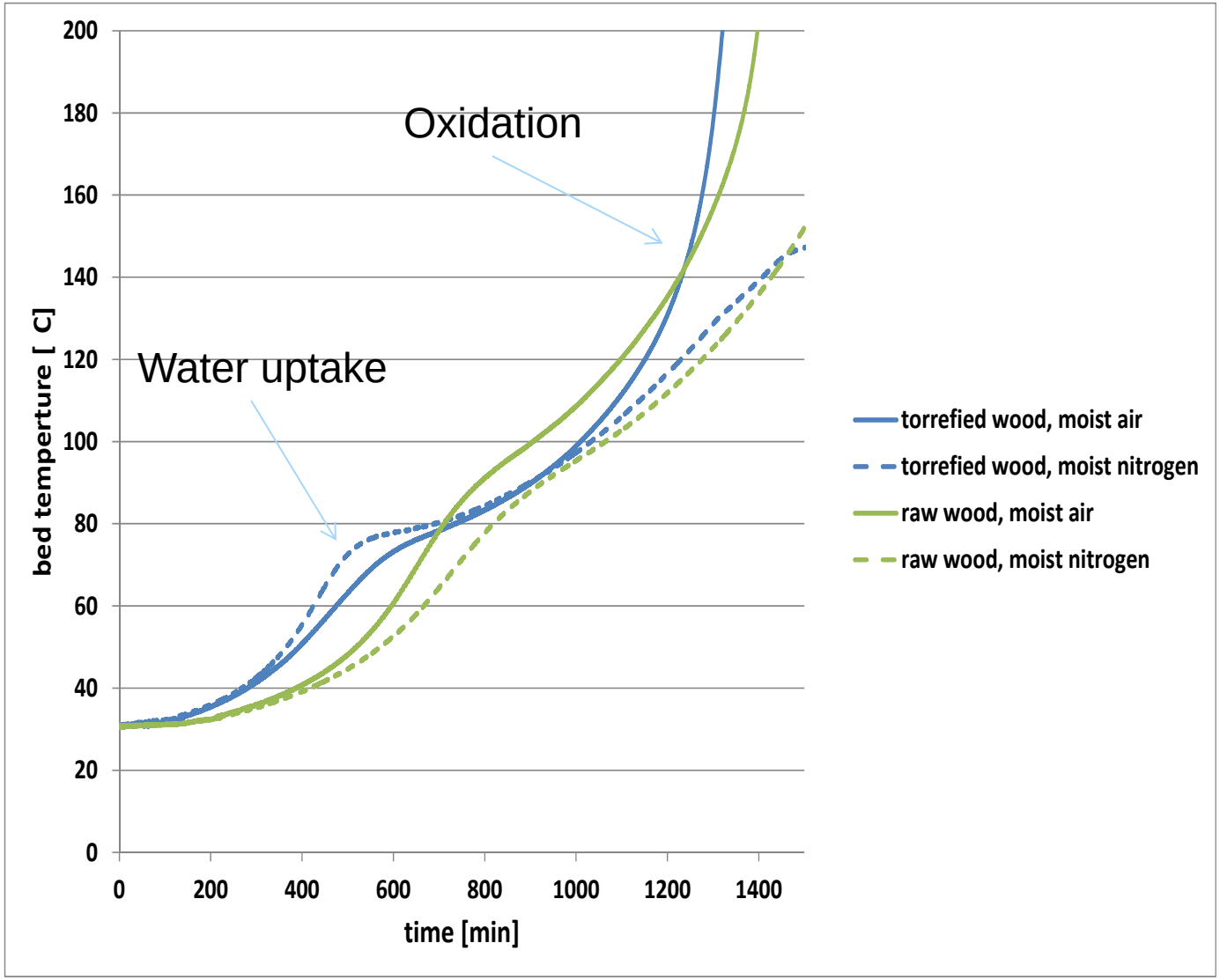
ANDRITZ Pulp & Paper

Self-heating of raw and torrefied biomass

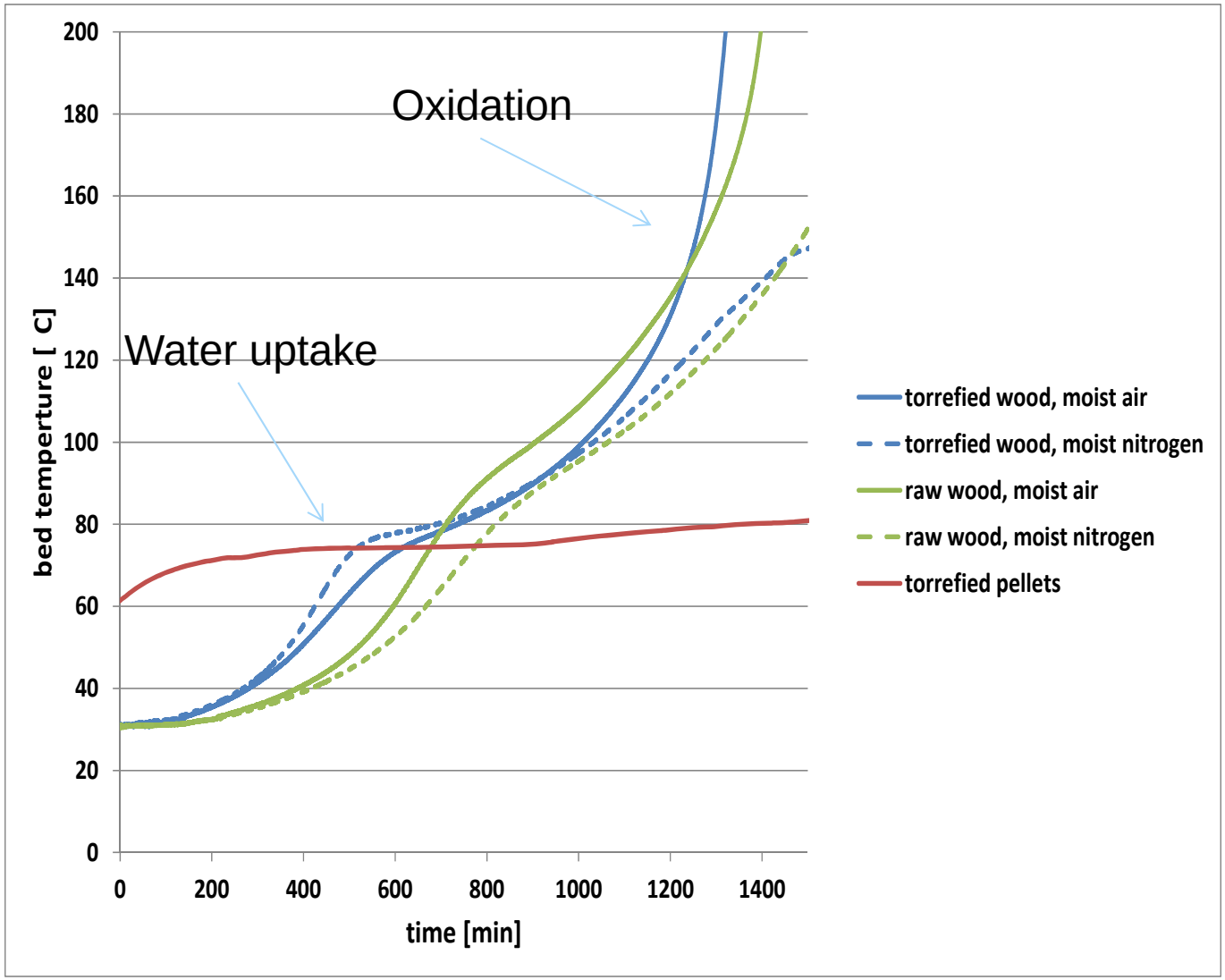


- Adiabatic reactor set-up to simulate stock-piles and storage silos
- Materials are fed pre-dried in the reactor in order to investigate the impact of water uptake
- Reactor is gently purged with air/water vapor or N_2/water vapor mixtures
- Runs with nitrogen are used as reference cases (zero-measurement)

Self-heating of raw and torrefied biomass



Self-heating of raw and torrefied biomass



Weathering Tests

DANISH TECHNOLOGICAL INSTITUTE

The equipment is used to test the effects of the angle of repose of the pile of pellets and potential flow of moisture along the surface layer of the pile by simulated Danish rain and drying periods under controlled conditions

Image 8: Day 20, right side

ANDRITZ Pulp & Paper

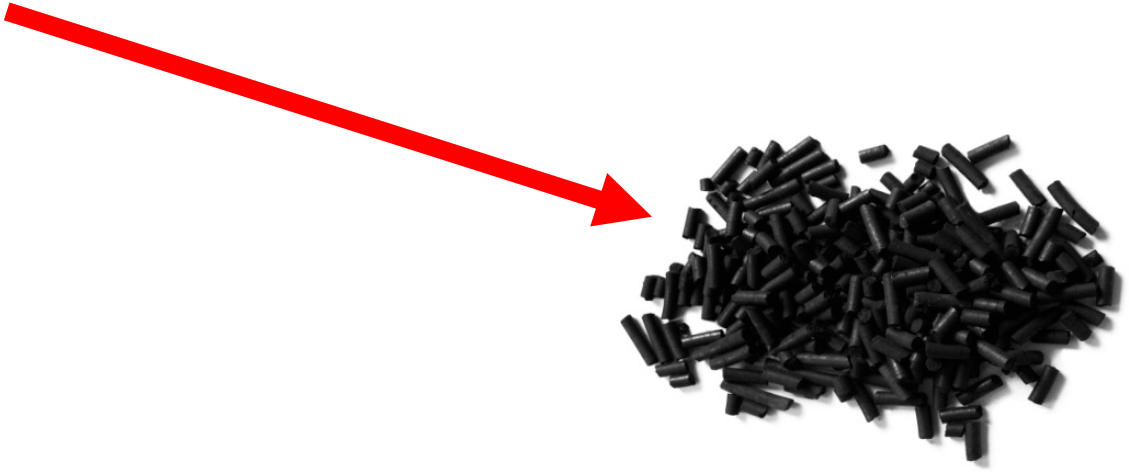
Authors and contributors to the presentation include:

- Brian Greenwood, Bertil Stromberg and Andy Eyer (from Andritz Inc);
- Dr. Doris Thamer and Klaus Trattner (from Andritz AG);
- Allan Melsen and Peter Høgh (from Andritz A/S);
- Dr. Jaap Kiel , Dr. Fred Verhoeff and Dr. Simon Leiser (from ECN);
- Dr. Jonas Dahl, Gitte Hastrup, Hans Ove Hansen and Dr. Peter Daugbjerg Jensen (from DTI).

- Thanks to Project Support Teams and Demo Plant Operators without whom progress would have been much slower.

- Special thanks to all of those entities previously mentioned providing financial support for these developments.

Thank You!



ECN
Westerduinweg 3
1755 LE Petten
The Netherlands

P.O. Box 1
1755 LG Petten
The Netherlands

T +31 88 515 4949
F +31 88 515 8338
info@ ecn.nl
www.ecn.nl