IEA Bioenergy

Biomass Torrefaction

Technology Status and Commercialisation, Applications for Torrefied Biomass and its Role in Logistics and Trade

Webinar, 27 Oct 2016

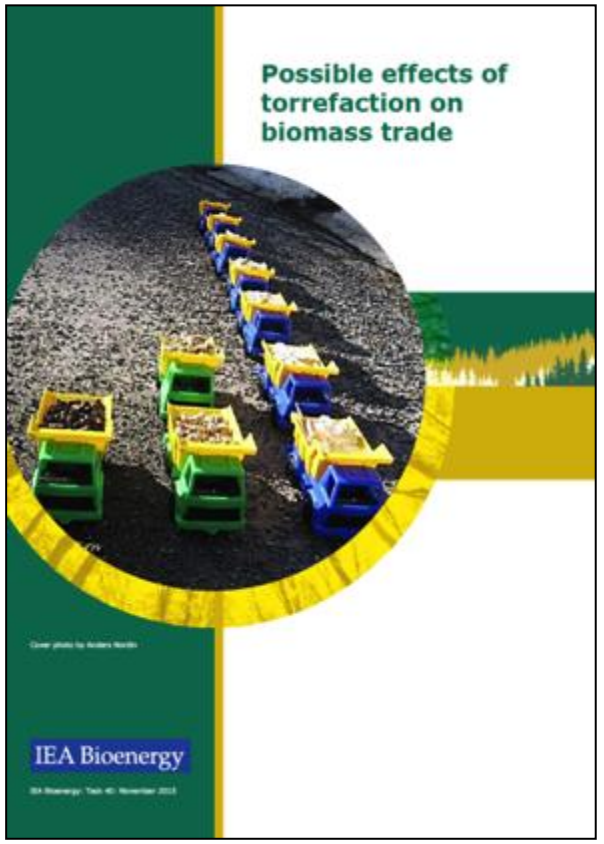
Jaap Koppejan, Managing Director, Procede Biomass BV

Marcel Cremers, Senior Consultant, DNV GL

Michael Wild, President, IBTC

Martin Junginger, Professor Biobased Economy, Utrecht University

Webinar based on two recent reports by tasks 32 and 40



Presenters today

10 min	Introduction to torrefaction, **Jaap Koppejan**, Managing Director, Procede Biomass BV and Task leader IEA Bioenergy Task 32 (Biomass Combustion and Cofiring)
15 min	Status of commercialisation, **Marcel Cremers**, Senior Consultant, DNV-GL
15 min	Possible implications on bioenergy trade, **Michael Wild**, President, International Biomass Torrefaction Council
20 min	Q&A, **Martin Junginger**, Professor Biobased Economy, Utrecht University and Task leader, IEA Bioenergy Task 40 (Biomass Trade)

Torrefaction is like roasting coffee beans….

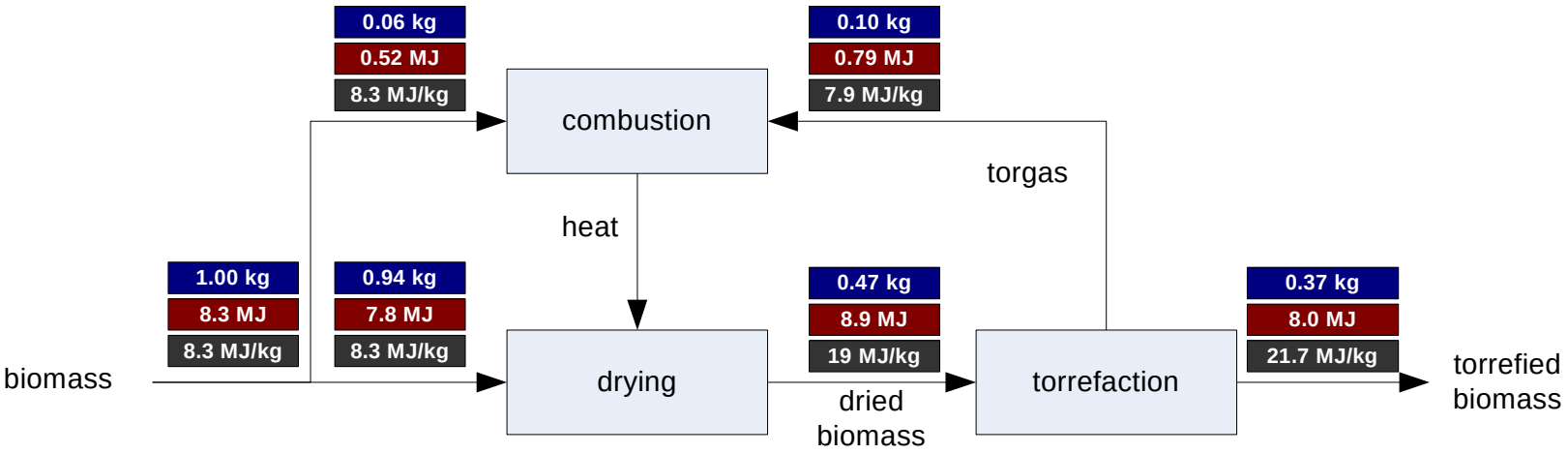
- Heating biomass to 250-300 °C in absence of oxygen
- Drying + removal of part of the volatiles

roasting

Claims made for Torrefaction

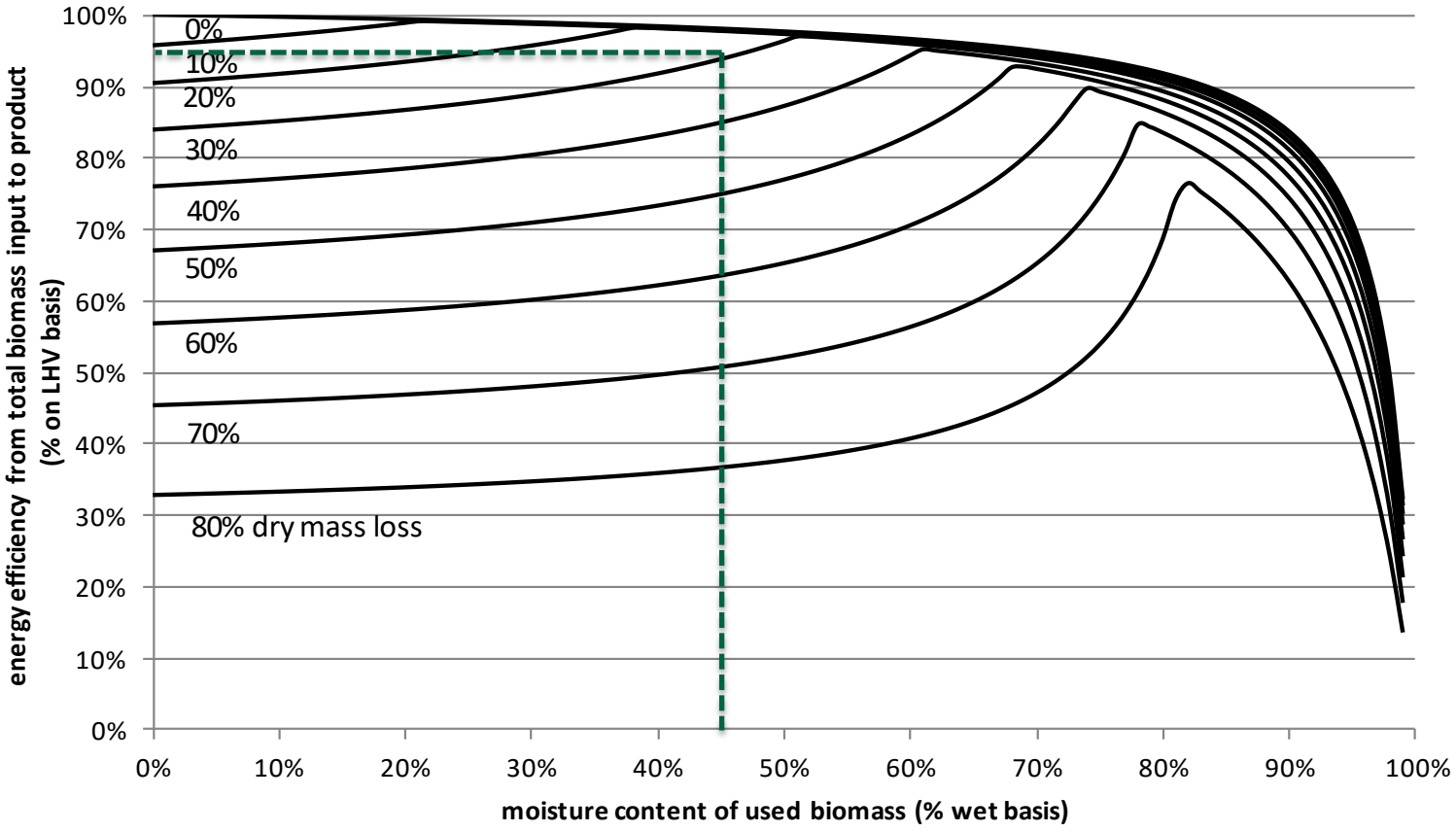
1. Volumetric energy densification brings significant cost reductions in transport and handling
2. Broader feedstock basis - geographically + types of raw material
3. Limited or no biodegradation of product when stored
4. Large variety of applications
5. Reduces CAPEX&OPEX at end user – Immediate use in existing coal fired plants –grindability, (water resistance?)....
6. Combustion and gasification behaviour more compatible to coal than raw biomass, high cofiring shares possible
7. Can be made to measure to clients requirements
8. Helps developing the market towards commoditisation

Heat energy balance (LHV basis)



Assumptions: fresh clean wood (0,5% ash content, 50% moisture content) as raw material and a dryer requiring 2.9 MJ per kg of water evaporated

Thermal energy efficiency can easily be over 90% for 30% dry mass loss



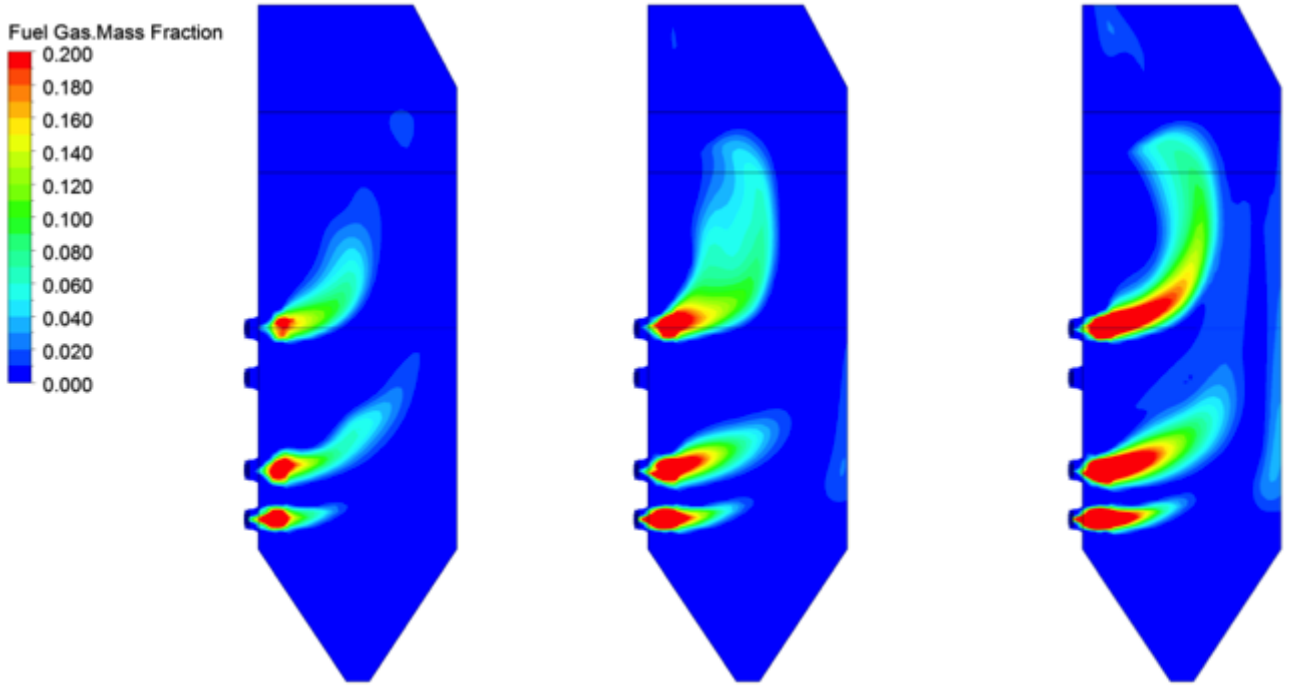
IEA Bioenergy

www.ieabioenergy.com

Technical challenges remaining

- Water resistance not as good as wanted
- Pelletisation is difficult for material with high torrefaction degree, both high durability and good grindability is difficult to achieve
- Several process owners are unable to produce adequate product at constant quality
- Torrefied wood pellets can generate larger amounts of explosive fine dust than wood dust
- Ash content increases and alkali concentration can go above technical limits for boilers (but Cl may selectively go down)

Flame shape in a PC boiler



100% coal 50% coal/50% TWP 100% TWP

Source: Koppejan et.al., Extrapolation of co-firing results to large scale boilers using CFD calculations, SECTOR D7.8, 2014

Status of commercialisation

Marcel CREMERS, PhD

Senior Consultant, Green Thermal Power
DNV GL - Energy

Current situation – available production capacity

Available installed capacity 100-250 ktons/y (facilities > 5 ktons/y)

Typical demonstration scale facility is 3-5 t/h (25-40 ktons/year)

Most built in 2010-2014

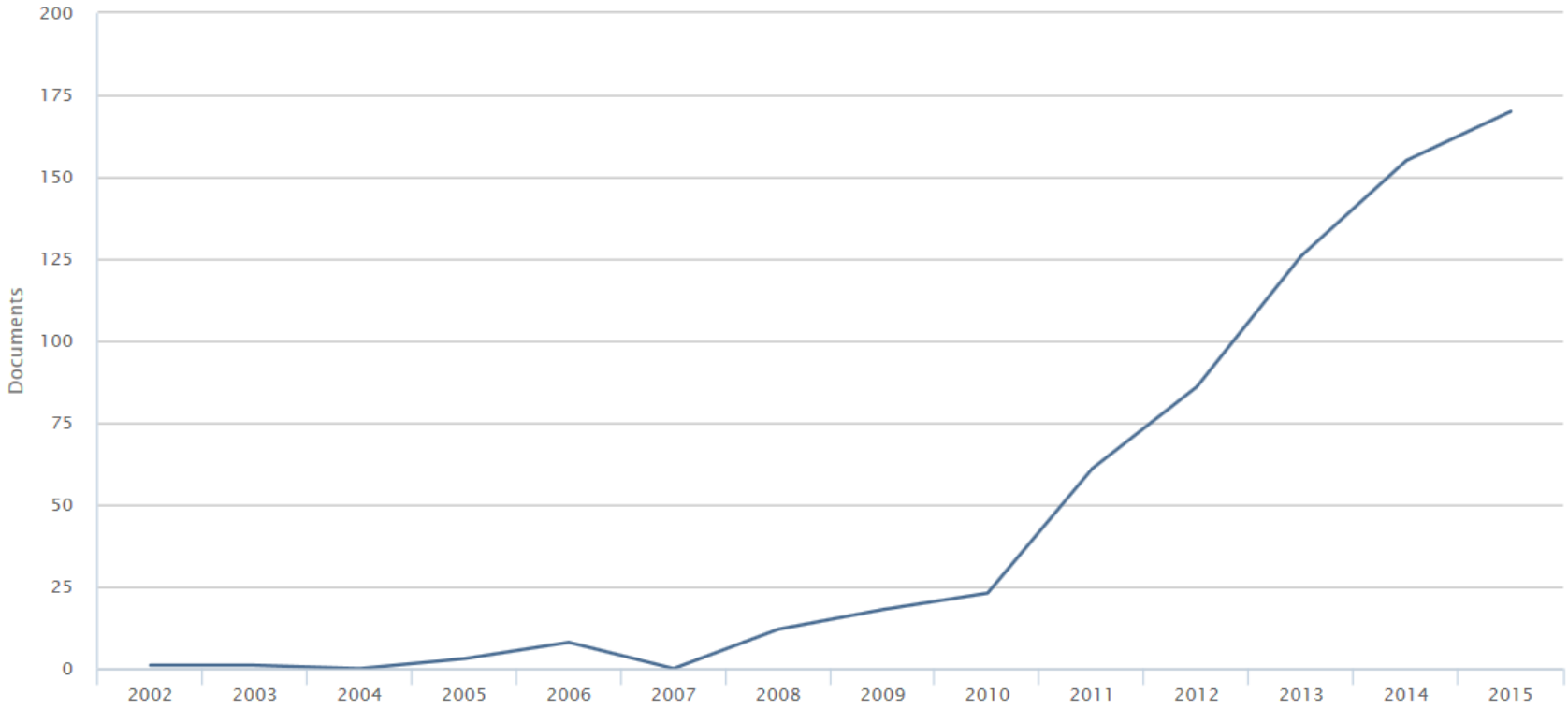
Few plants currently operational due to market conditions

Interviews (2014): Progress rating 5.7 out of 10

Status of torrefaction initiatives as of early 2015

Developer	Technology	Location(s)	Production capacity (ton/a)	Scale and status Pilot scale: 0.05- 0.55 tph Demo scale: 0.5- 2 tph Commercial scale: > 2tph	Full integration (pre-treatment, torrefaction, combustion, heat cycle, densification)	Status
Clean Electricity Generation (UK)	Oscillating bed	Derby (UK)	30,000	Commercial scale	Yes	Available/operational
Horizon Bioenergy (NL)	Oscillating belt conveyor	Steenwijk (NL)	45,000	Commercial scale	Yes	Dismantled
Solvay (FR) / New Biomass Energy (USA)	Screw reactor	Quitman (USA/MS)	80,000	Commercial scale	Yes	Available/operational
Topell Energy (NL)	Fluidised bed	Duiven (NL)	60,000	Commercial scale	Yes	Mothballed
Torr-Coal B.V. (NL)	Rotary drum	Dilsen-Stokkem (BE)	30,000	Commercial scale	Yes	Available/operational
Airex (CAN/QC)	Cyclonic bed	Bécancour (CAN/QC)	16,000	Demonstration scale		Available/operational
Agri-Tech Producers LLC (USA/SC)	Screw reactor	Allendale (USA/SC)	13,000	Demonstration scale	Yes	Scheduled to be built
Andritz (AT)	Rotary drum	Frohnleiten (AT)	10,000	Demonstration scale	Yes	Out-of-service
Andritz (DK) / ECN (NL)	Moving bed	Stenderup (DK)	10,000	Demonstration scale		Unknown
BioEndev (SWE)	Dedicated screw reactor	Holmsund, Umea (SWE)	16,000	Demonstration scale	Yes	Available (2015)
CMI NESA (BE)	Multiple hearth	Seraing (BE)	Undefined	Demonstration scale		Unknown
Earth Care Products (USA)	Rotary drum	Independence (USA/KS)	20,000	Demonstration scale		Available/operational
Grupo Lantec (SP)	Moving bed	Urnieta (SP)	20,000	Demonstration scale		Unknown
Integro Earth Fuels, LLC (USA)	Multiple hearth	Greenville (USA/SC)	11,000	Demonstration scale		Unknown
LMK Energy (FR)	Moving bed	Mazingarbe (FR)	20,000	Demonstration scale		Unknown
River Basin Energy (USA)	Undefined	Laramie (USA/WY)	Undefined	Demonstration scale		Available/operational
Teal Sales Inc (USA)	Rotary drum	White Castle (USA/LA)	15,000	Demonstration scale		Available/operational
Torrec (FI)	Moving bed	Mikkeli (FI)	10,000	Demonstration scale		Available/operational
Agri-Tech Producers LLC (US/SC)	Screw reactor	Raleigh (USA/NC)	Undefined	Pilot stage		Available/operational
Airex (CAN/QC)	Cyclonic bed	Rouyn-Noranda (CAN/QC)	Undefined	Pilot stage		Available/operational
Airex (CAN/QC)	Cyclonic bed	Trois-Rivières (CAN/QC)	Undefined	Pilot stage		Available/operational
Arigna Fuels (IR)	Screw reactor	County Roscommon (IR)	Undefined	Pilot stage		Available/operational
CENER (SP)	Rotary drum	Aoiz (SP)	Undefined	Pilot scale		Available/operational
Terra Green Energy (USA)	Multiple hearth	McKean County (USA/PA)	Undefined	Pilot scale		Available/operational
Wyssmont (USA)	Multiple hearth	Fort Lee (USA/NJ)	Undefined	Pilot scale		Unknown
CEA (FR)	Multiple hearth	Paris (FR)	Undefined	Laboratory scale		Available/operational
Rotawave, Ltd. (UK)	Microwave	Chester (UK)	Undefined	Laboratory scale		Unknown
Bio Energy Development & Production (CAN)	Fluidised bed	Nova Scotia (CAN/NS)	Undefined	Unknown		Unknown

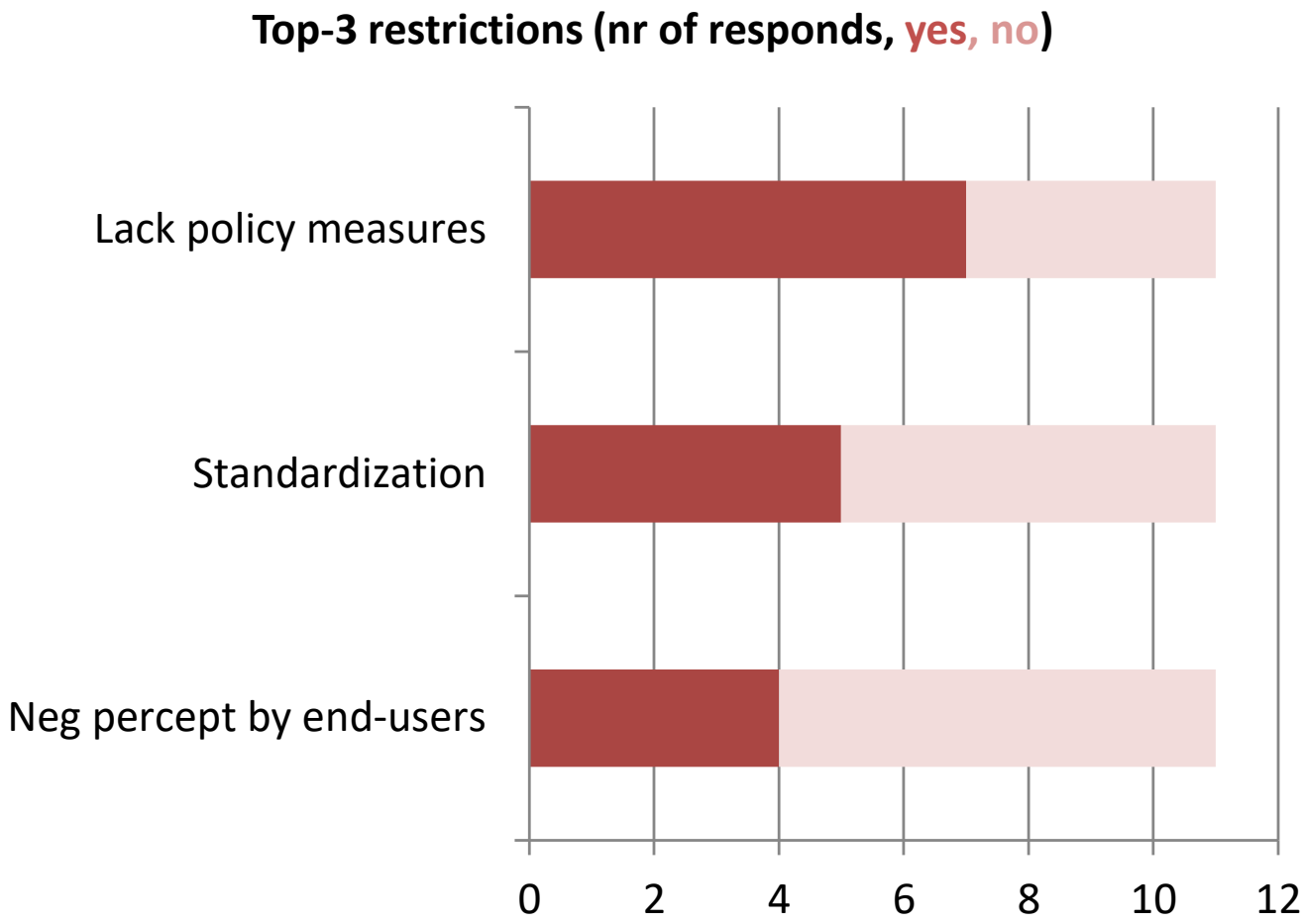
Current situation - research



IEA Bioenergy

www.ieabioenergy.com

Restrictions



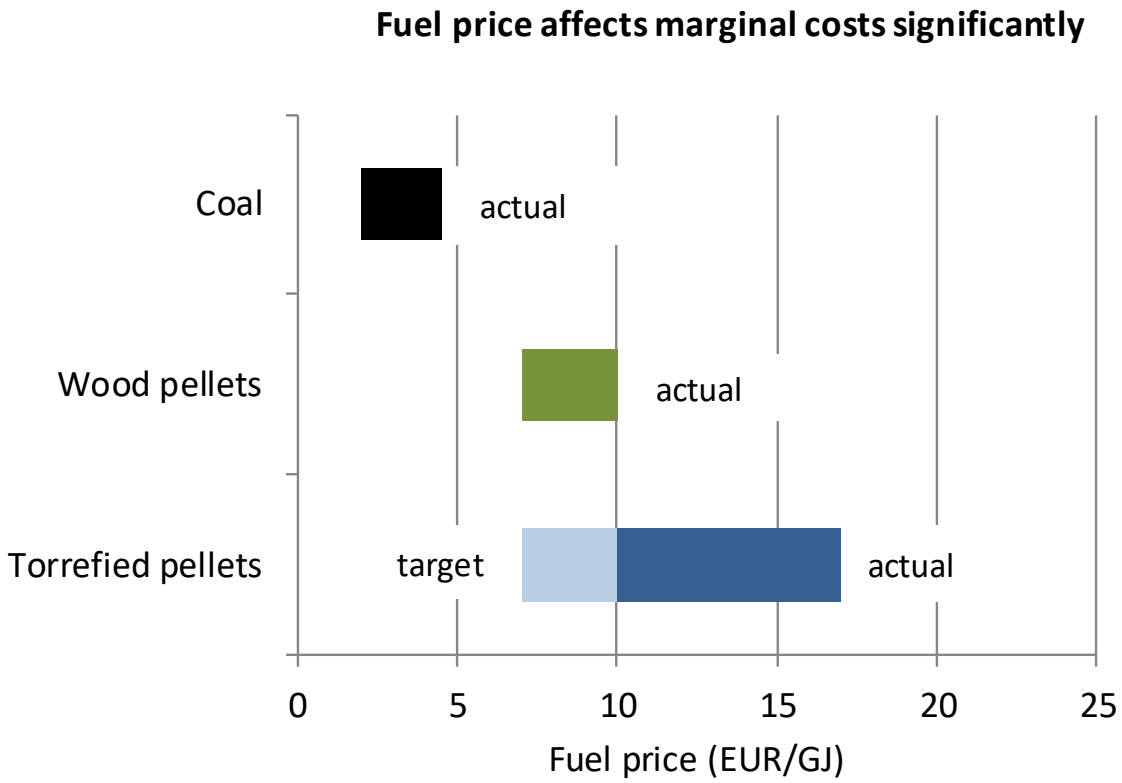
Policy measures

Primary instruments

- Innovation subsidy
- Renewable energy subsidy

Cost recovery gap

- Price parity with coal (fuel, CO_2)
- Competition with wood pellets



Standardization

- Necessity for trading
- Quality specification
- REACH
- MSDS
- Sustainability (GHG)

DRAFT INTERNATIONAL STANDARD
ISO/DIS 17225-8

ISO/TC 238 | Secretariat: SIS
Voting begins on: 2016-01-14 | Voting terminates on: 2016-04-14

Solid biofuels — Fuel specifications and classes —

Part 8:
Graded thermally treated and densified biomass fuels

Biocombustibles solides — Classes et spécifications des combustibles

ICS: 27.190; 75.160.10

PREVIEW

ISO/CEN PARALLEL PROCESSING

This draft has been developed within the International Organization for Standardization (ISO), and processed under the **ISO lead** mode of collaboration as defined in the Vienna Agreement.

This draft is hereby submitted to the ISO member bodies and to the CEN member bodies for a parallel five month enquiry.

Should this draft be accepted, a final draft, established on the basis of comments received, will be submitted to a parallel two-month approval vote in ISO and formal vote in CEN.

To expedite distribution, this document is circulated as received from the committee secretariat. ISO Central Secretariat work of editing and text composition will be undertaken at publication stage.

THIS DOCUMENT IS A DRAFT CIRCULATED FOR COMMENT AND APPROVAL. IT IS THEREFORE SUBJECT TO CHANGE AND MAY NOT BE REFERRED TO AS AN INTERNATIONAL STANDARD UNTIL PUBLISHED AS SUCH.

IN ADDITION TO THEIR EVALUATION AS BEING ACCEPTABLE FOR INDUSTRIAL, TECHNOLOGICAL, COMMERCIAL AND USER PURPOSES, DRAFT INTERNATIONAL STANDARDS MAY ON OCCASION HAVE TO BE CONSIDERED IN THE LIGHT OF THEIR POTENTIAL TO BECOME STANDARDS TO WHICH REFERENCE MAY BE MADE IN NATIONAL REGULATIONS.

RECIPIENTS OF THIS DRAFT ARE INVITED TO SUBMIT, WITH THEIR COMMENTS, NOTIFICATION OF ANY RELEVANT PATENT RIGHTS OF WHICH THEY ARE AWARE AND TO PROVIDE SUPPORTING DOCUMENTATION.

Reference number
ISO/DIS 17225-8:2015(E)

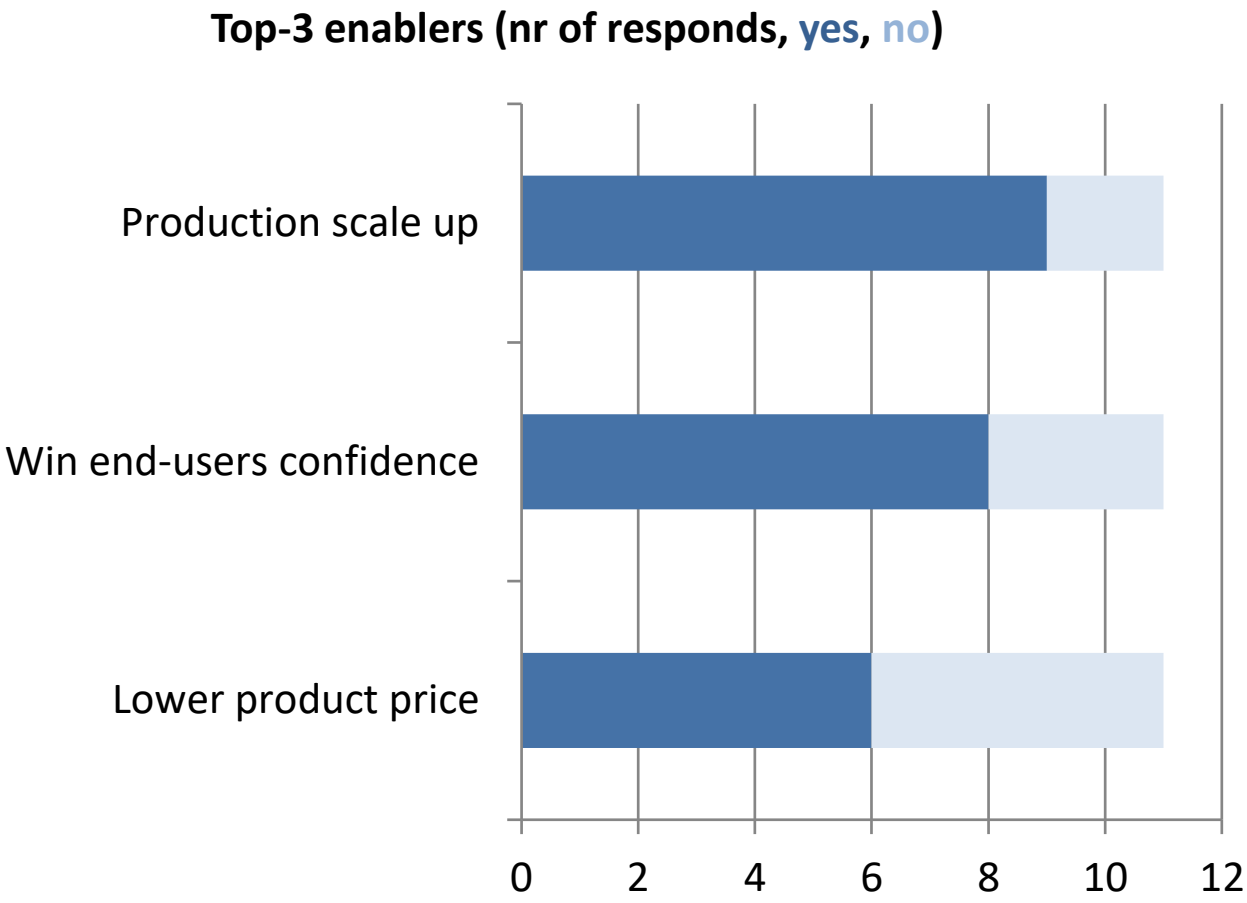
IEA Bioenergy

www.ieabioenergy.com

Negative perception by end-users

2003-2007	2008-2012	2012-2015
Co-firing commercial	New initiatives	IBTC
Lab scale (ECN)	Demo-scale	Product quality
Promising results	Huge claims	Availability
	Financial crisis	Off-take contracts
	Focus on torrefaction	Wood pellet market
	Process control	chicken and egg

Enablers


Top-3 enablers (nr of responds, yes, no)
Production scale up
Win end-users confidence
Lower product price
0
2
4
6
8
10
12

Production scale up

Demand	Production
600 MWe coal plant 10% co-firing 6000 eoh	Demo plant 25-40 ktons/y Partly utilized
150 ktons/y torrefied pellets	Global production capacity < 150 ktons/y
	Wood pellets 50-200 ktons/y per facility

Picture of balance: openclipart, designer Enhy

Win end-users confidence

- Identify (niche) markets: developing the chain
- Realistic promises
- Quality assurance
- Health and safety (pros and cons)
- Tradability & standardization

Bring down price

Price comparable with wood pellets, what should be feasible?

Commercial (target) price in USD/GJ

	Wood pellets	Torrefied pellets	Savings
Cost of biomass	4,28	4,28	0,00
Cost of electricity	0,60	0,74	0,14
Cost of labor	0,47	0,47	0,00
Financial costs	1,01	1,49	0,48
Other costs	0,40	0,43	0,03
Cost price at production site	6,76	7,41	0,65
Inland logistics from the plant to the port	1,12	0,57	-0,55
Deep sea shipment	2,04	1,28	-0,76
Cost price delivery harbor	9,92	9,26	-0,66

Reference: IEA Bioenergy task 32 status report (2012)

Breaking chicken-egg problem

- Specific offset markets (e.g. energy, (steel)industry, bio-economy)
- Develop the chain
- Alternative feedstock types

Figure: The Torr-Coal plant in Dilsen-Stokkem (Belgium). Courtesy Torr-Coal

Example (in development):

Arsari bio-based economy project REBUILD

Kalimantan, Indonesia

JV of

- Arsari Enviro Industri, and
- A.Hak Renewable Energy

Torrefaction technology supplier

- Torr-Coal International

https://www.youtube.com/watch?v=srqq6ox2wkw

Implications on international trade

Michael Wild

President, International Biomass Torrefaction Council

Products available today

Source: Andritz AG

Torrefaction Implementation Indicator

Torr-gas Handling and Utilisation	done
Continuous torrefaction	done
Predictability and consistency of product	for many raw materials
Densification	mostly done
Feedstock flexibility	mostly done
Plant Safety	done
Indoor storage	done
Outdoor storage	in optimisation
Standardisation of product	ISO TS close
Safety along supply chain	in progress
Trade Registrations and Permissions	in progress
Co-firing trials	done in EU
Co-firing burn tests	several done
Co-firing full scale	mostly open
Heat application trials	in progress
Further industrial applications trials	open

Conditions for trade

- Will character of torrefied fuel permit using existing logistical infrastructure?
- Is there proof of non hazardousness or are special safety measures to be advised?
- How about standardization and trading documents?
- Is there demand?
  - Where is torrefied biomass a proven fuel
  - Where are reasonable potentials seen

Water uptake

ACB - Weather test prelim. results briquettes

Method:

Briquettes (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

21 rainfalls have been documented during storage time,
3 rainfalls with > 20 mm/m^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

Small-scale outdoor storage

- High pellet durability essential for improved weather resistance in time
- Slight degradation outer surface; inner content pile intact

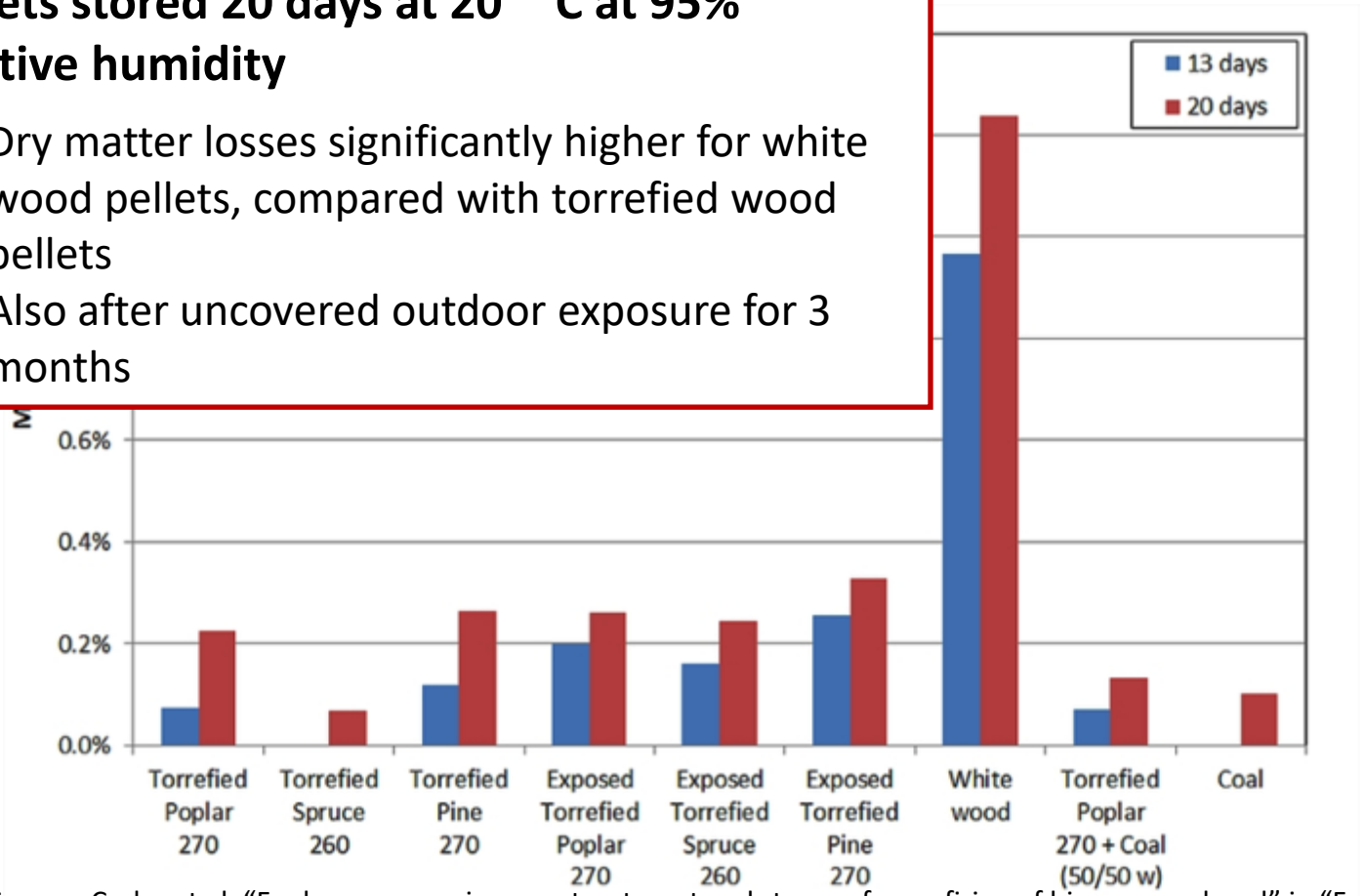
Source: SECTOR, ECN

IEA Bioenergy

Biological Degradation

Pellets stored 20 days at 20° C at 95% relative humidity

- Dry matter losses significantly higher for white wood pellets, compared with torrefied wood pellets
- Also after uncovered outdoor exposure for 3 months

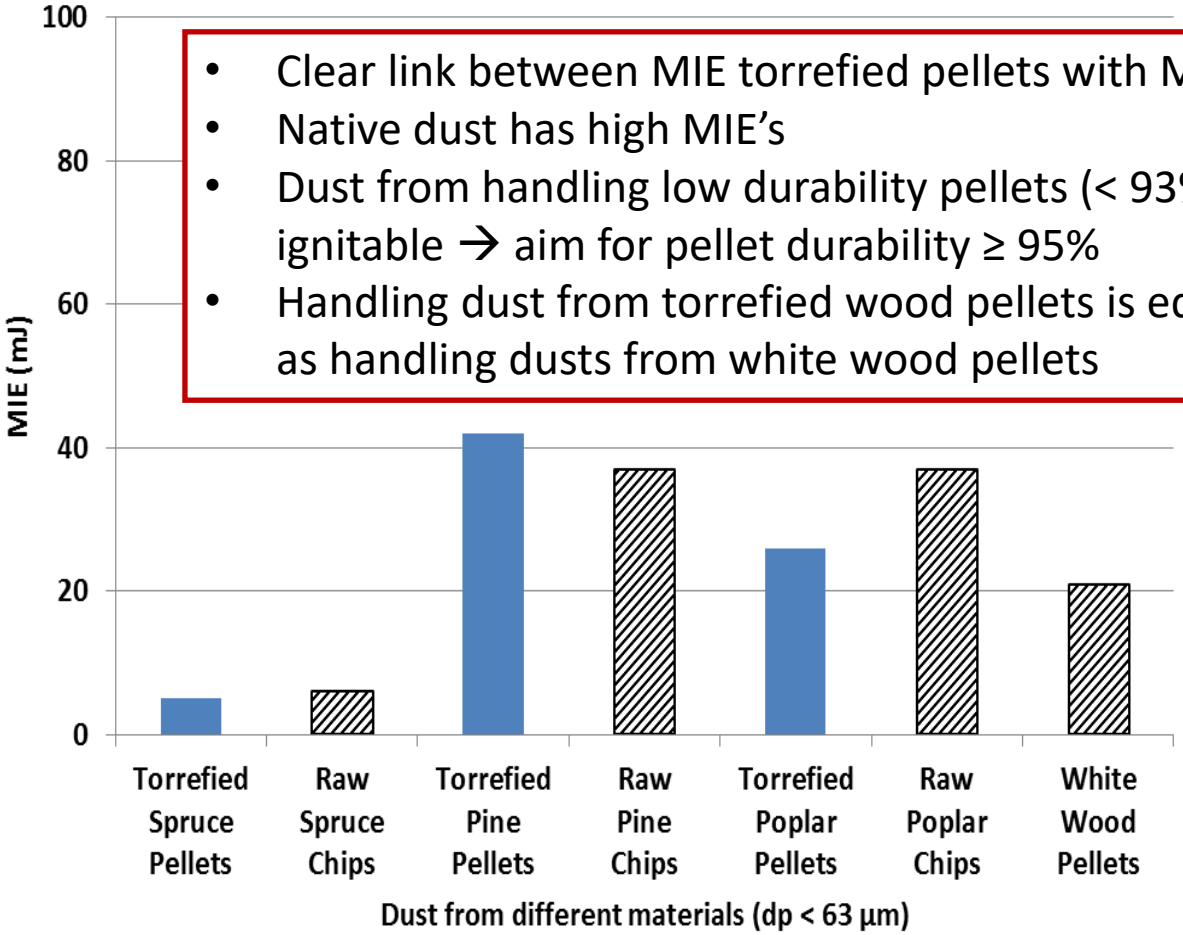


Source: Carbo et al. "Fuel pre-processing, pre-treatment and storage for co-firing of biomass and coal" in "Fuel Flexible Energy Generation" ed. J. Oakey, 2015

Minimum Ignition Energy (MIE)

Pulverised torrefied pellets vs. pulverised raw biomass chips (ind. off)

- Clear link between MIE torrefied pellets with MIE raw material
- Native dust has high MIE's
- Dust from handling low durability pellets (< 93%) is more ignitable → aim for pellet durability ≥ 95%
- Handling dust from torrefied wood pellets is equally ignitable as handling dusts from white wood pellets



Source: Carbo et al. "Fuel pre-processing, pre-treatment and storage for co-firing of biomass and coal" in "Fuel Flexible Energy Generation" ed. J. Oakey, 2015

Leaching/Eluation, Ecotoxidity

BET Surface is reduced

	Probe 1 R	Probe 1 P	Probe 2 R
Spezifische Oberfläche (m^2/g)	1,96	1,72	1,19

Daphnientests >1/8 dilution of Eluate below the analytical limit of determination

Proof of non toxic character of leaching water against fish DIN 38412-31

IEA Bioenergy

www.ieabioenergy.com

Source: Torrlog

Quality - Standardisation

- **ISO 17225:** Solid biofuels – Fuel specifications and classes Part 8: Graded thermally treated and densified biomass fuels

Technical Specification release expected in Q4 2016

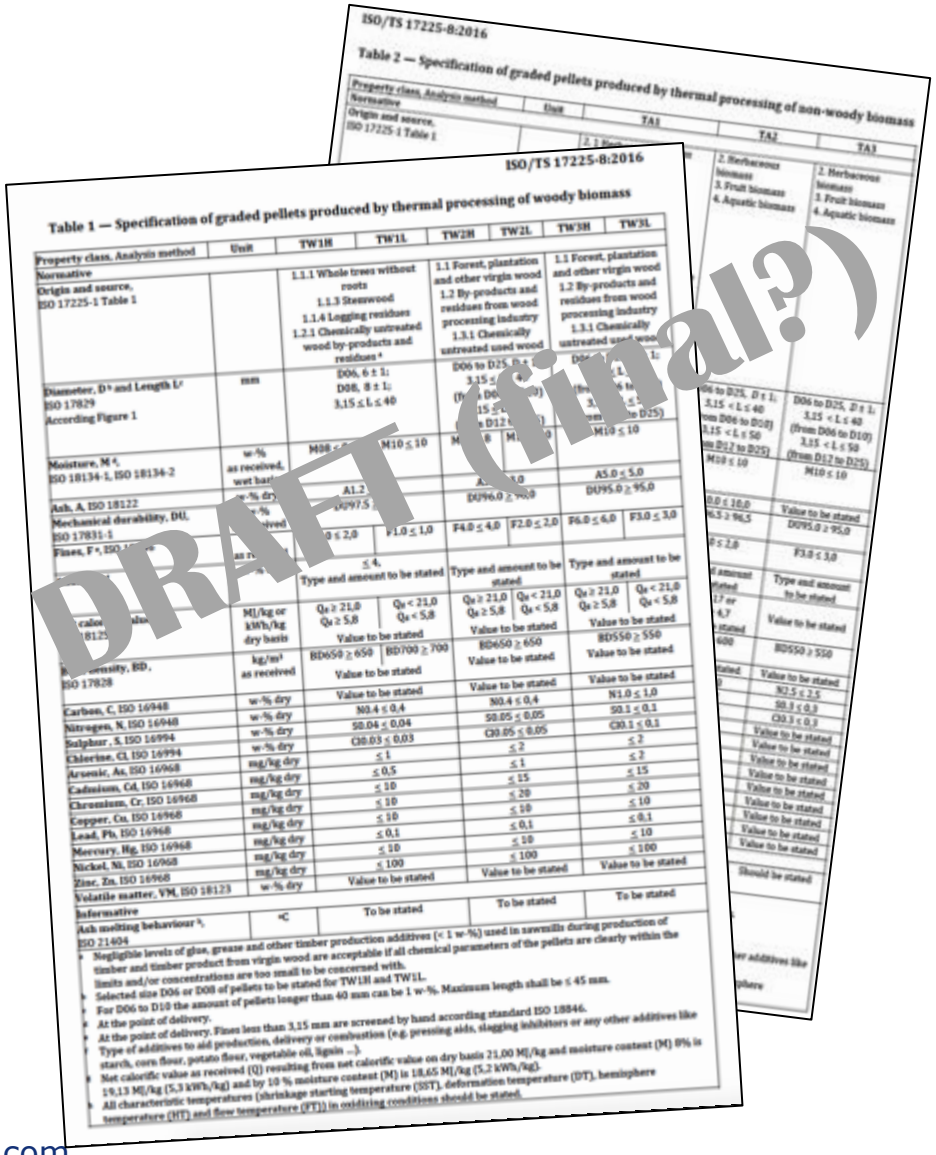
Different Classes (NCV, Durability, Bulk Density, Volatile Matter etc.)

Parameters yet to be defined:

Grindability

Water resistance

Energy balance



IEA Bioenergy

www.ieabioenergy.com

Broadening Feedstock Basis

- ISO 17225 TS does define product classes derived from **wood** and product classes from **non woody** biomass
- Torrefaction is clearly seen as **door opener** to the use of by-products from a wide range of agro food industries or/and feedstock from energy plantation such as grasses, fast growing
- By this torrefaction is **addressing the key cost component** in a bioenergy value chain, the feedstock costs and can bring this down substantially.
- This can also be the starting point for **new value chains** into Chemical Industry, torrefaction forming first part of raw material processing into high value product lines

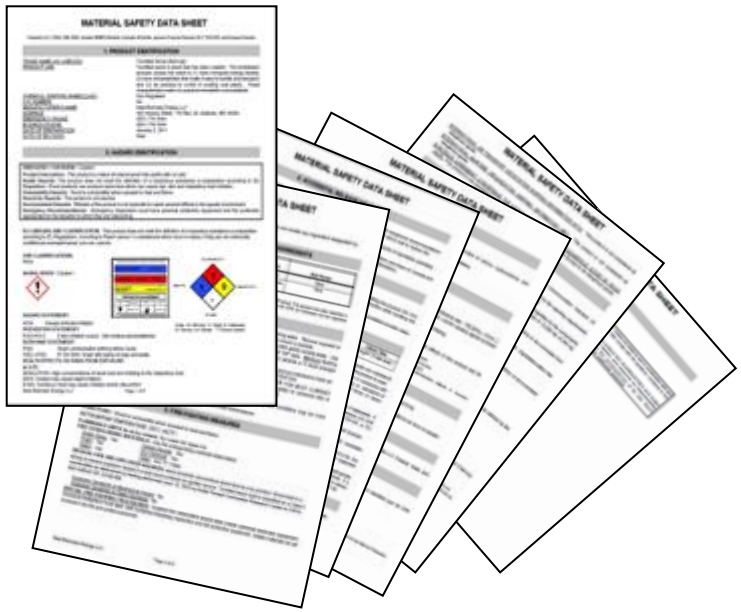
Documentation, Permissions and Registrations

MSDS with SECTOR

REACH

Substance Information

Exchange Forum “SIEF”

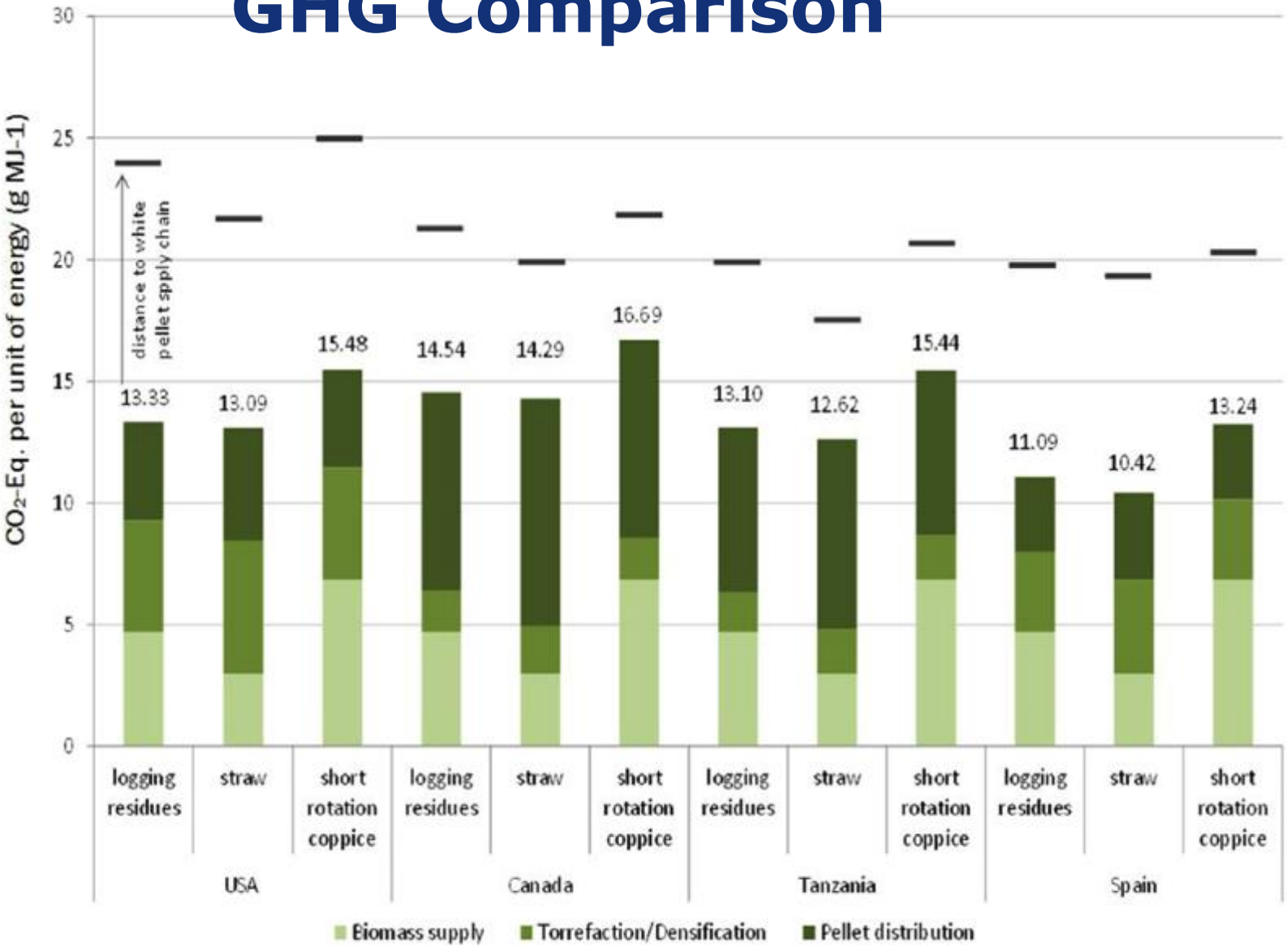


IMO 4.1&4.2 testing negativ

(no need to be classified as flammable solid material or as a self heating substance)

All testing to date results in: equal or superior to wood pellets

GHG Comparison



IEA Bioenergy

www.ieabioenergy.com

Source: D. Thrän, DBFZ

Topell Energy

Strictly private & confid

Succesfull large scale co-firing test proves benefits of Topell Energy's torrefied pellets

Background on co-firing test	Test results
• Successful large scale co-firing test in Q4 2013 • Partners included ECN and utility companies RWE/Essent, Vattenfall/Nuon and GDF SUEZ • Total of 2,300 tons were co-fired at a 5% - 25% co-firing rate[1] at the Amer power plant of RWE/Essent in the Netherlands	Confirmation of superior characteristics of torrefied pellets No adverse effect on milling and combustion detected Low dust formation Torrefied biomass can replace coal in power plants

RWE The energy to lead · NUON VATTENFALL · GDF SUEZ ECN

RWE/Essent AMER-9 experience

- Consortium:Topell, Essent, NUON, GdF Suez, ECN as part of Dutch TKI Pre-treatment Project
- Maximum 25 wt% co-milling on weight basis; 5 wt% co-firing
- 2300 tons of Topell torrefied pellets during November & December '13
- Observations: No significant issues
- ECN conducted lab-scale characterisation of pellets and provided consultancy to mitigate risks during commercial operation

* Source: Press release Topell/Essent, Feb '14

NUON/Vattenfall Buggenum experience*

- Maximum 70% co-gasification on energy basis achieved at 90% nominal load without major modifications
- 1200 tons of torrefied pellets during 24 hours trial
- Observations:
  - Relatively low durability led to significant dust formation
  - Low durability disadvantageous during outdoor storage
  - Low Minimum Ignition Energy (MIE)
- ECN conducted lab-scale test programme to characterise pellets and provided consultancy to mitigate risks during commercial operation

* Source: N. Padban, Central European Biomass Conference, Jan '14, Graz; ECN

DONG Studstrup-3 experience

- Two units with total capacity of 714 MW_e and 986 MW_{th}
- Dedicated milling on MPS roller mill adapted for either coal or white pellets
- 200 tons of Andritz/ECN torrefied spruce pellets during 8 hours trial
- Co-firing share: 33 wt%
- Observations:
  - No dust formation during unloading
  - Sufficiently high durability; no issues with dust formation in chain conveyors
  - Normal Minimum Ignition Energy (MIE)
- ECN conducted lab-scale characterisation of pellets

Source: ECN

Non Power Applications

Steel Industry	Replacement of coking coal Pulverized coal Fossil fuels
Chemical/Petro -chemical	Gasification Chemicals from Biomass
Pulp&Paper	Use in lime sludge kilns Coal substitute for Energy
Non Metallic Minerals	Substitution of conventional fuels in kilns
Heating	District heating Commercial heating & process heat

Non Power Applications by Sector

Industries	Biomass use as of 2012 and percentage of total consumption	Prediction for 2025	
		Biomass	Torrefied biomass
Iron and steel	0.15 EJ (1%)	2.0 %	0.4 % (60 PJ)
Chemical and petrochemical	0.06 EJ (1%)	1.5 %	Low
Pulp and paper	2.20 EJ (36%)	38–40 %	1.5 % (90 PJ)
Non-metallic minerals (glass, ceramic, cement)	0.40 EJ (2%)	3.0–3.5 %	0.8 % (150 PJ)
Transport equipment and fabricated metal products, machinery and equipment	0 PJ (0%)	0.1 %	Low
Total	2.80 EJ (0.7 %)	30 %	10 % (300 PJ)

Non Power Applications by Region

Region	Current industrial biomass use and proportion of the total biomass consumption for energy (IEA)	Prediction of consumption by industry in 2025		
		Biomass	Torrefied biomass	Most attractive industries for torrefied-biomass use
EU-28	1 EJ (9%)	13%	5–10%	Pulp and paper, non-metallic minerals
Africa	0.8 EJ (32%)	35%	Low	
Asia	2 EJ (5%)	7%	0.5–1%	Iron and steel, pulp and paper
Canada	0.3 EJ (10%)	13%	2–3%	Pulp and paper, non-metallic minerals
US	1 EJ (11%)	14%	2–3%	Non-metallic minerals, pulp and paper
Australia	0.1 EJ (11%)	15%	1–2%	Pulp and paper
Brazil	1.5 EJ (42%)	43%	1–1.5%	Iron and steel, pulp and paper, non-metallic minerals
Japan	0.1 EJ (3%)	3.5%	0.5–1%	Non-metallic minerals, pulp and paper

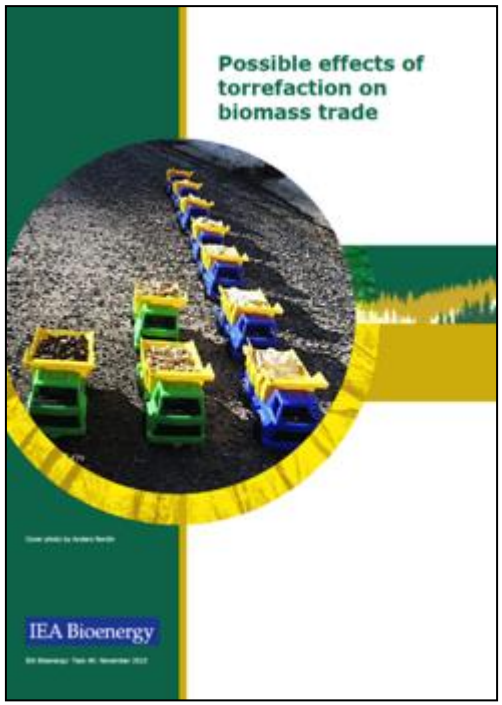
Where we are today

- ✓ *Quality defined ISO TS*
- ✓ *Handling & Storage advantage in logistics verified*
- ✓ *Cost reductions shown*
- ✓ *Acceptability and advantages in co-firing verified by utilities*
- ✓ *Other industrial applications in testing*
- ✓ *Non Woody Biomass successfully tested*
- ✓ *Tradable product is available*
- ✓ *Several technologies, More than 1 producer*
- ✓ *Final prices to be calculated on basis of offtake, but surely competitive*

Download the Reports

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

www.ieabioenergytask32.com



Marcel Cremers, Marcel.Cremers@dnvgl.com
Michael Wild, michael@wild.or.at

IEA Bioenergy

www.ieabioenergy.com

Questions?

Thank you for your attention

IEA Bioenergy

Contact Details

jaapkoppejan@procede.nl

marcel.cremers@dnvgl.com

michael@wild.or.at

h.m.junginger@uu.nl

IEA Bioenergy Website
www.ieabioenergy.com

Contact us:
www.ieabioenergy.com/contact-us/