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Torrefied and hydrothermal carbonised Biomass Products: Co-milling, Combustion and Emission Properties

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Presentation Outline

- **Brief background to Torrefaction & Hydrothermal Carbonization of Biomass**
- **IFK involvement in current projects under the 7th Framework Programme**
  - **SECTOR**
  - **BioBoost**
- **Co-milling test**
- **(Co)-combustion of Torrefaction and HTC Biomass products**
- **Concluding remarks/Outlook**

Biomass Pre-treatment Concepts

//Torrefaction & Hydrothermal Carbonisation//

Biomass Torrefaction

- **Process Parameters**
  - Thermochemical treatment of Biomass
  - Operating temperature : 200 °C to 320 °C
  - Pressure : atmospheric
  - Absence of oxygen
  - Residence time : 10-30 minutes

- **Product Properties**
  - High energy density
  - Hydrophobic behaviour
  - More homogeneous composition compared to feedstock
  - Elimination of biology activity
  - Improved grindability (decomposition of hemicellulose, depolymerization of cellulose structure

Biomass Hydrothermal Carbonisation (HTC)

- **Process Parameters**
  - Thermochemical treatment of Biomass
  - Operating tempearture : 180 °C to 300 °C
  - High pressure steam
  - Pressure: < 20 bar
  - Timescale : 4 to 16 hours

- **Product Properties**
  - High energy density
  - More homogeneous composition compared to feedstock
  - Improved grindability
  - Decrease content of Cl, S, alkali and other inorganic salts

IFK involvement in Current EU research projects on Sustainable Bio-energy Carriers under the 7th Framework Programme

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

Partici-pant no.	Legal name	Short name	Country
1 (Coord.)	Deutsches BiomasseForschungsZentrum gGmbH	DBFZ	GE
2	Technical Research Centre of Finland	VTT	FI
3	Energy Research Centre of the Netherlands	ECN	NL
4	Danish Technological Institute	DTI	DK
5	E.ON New Build and Technology Ltd.	EON	UK
6	University of Stuttgart	USTUTT	GE
7	Austrian Research Institute for Chemistry and Technology	ofi	AT
8	Umeå University	UmU	SE
9	National Renewable Energy Centre	CENER	ES
10	Topell Energy BV	Topell	NL
11	Vattenfall Research and Development AB	Vattenfall	SE
12	RWE Innogy GmbH	RWE	GE
13	Doosan Power Systems Ltd.	DB	UK
14	Procede Biomass BV	Procede	NL
15	Institute of Power Engineering	IEN	PL
16	Technology and Support Centre	TFZ	GE
17	BIOS Bioenergiesysteme GmbH	BIOS	AT
18	bioenergy 2020+	BE2020	AT
19	Vienna University of Technology	TU Wien	AT
20	Centre for Environmental Research	UFZ	GE
21	Swedish University of Agricultural Sciences	SLU	SE

IFK is involved in the work package :

//End-Use Application of Torrefied Biomass//

1. Milling and co-milling tests of different Torrefied biomass
2. Extent of mill capacity losses due to co-milling
3. Feeding Tests
4. Co-firing in Pulverised fuel furnace
    1. Flame stability and fuel reactivity
    2. Fouling & slagging
    3. Fly ash quality (EN 450…)
    4. Flue gas cleaning (SCR, ESP, Fine particles etc.)

BioBoost: Biomass based energy intermediates boosting biofuel production *(BioLiq/HTC processes)*

No	Name
1	Karlsruher Institut fuer Technologie
2	CENTRE FOR RESEARCH AND TECHNOLOGY HELLAS
3	AVA-CO2-Forschung GmbH
4	CHIMAR HELLAS AE
5	ENBW ENERGIE BADEN-WURTTEMBERG AG
6	NEDERLANDSE ORGANISATIE VOOR TOEGEPAST NATUURWETENSCHAPPELIJK ONDERZOEK - TNO
7	GRACE GMBH & CO KG
8	INSTYTUT UPRAWY NAWOZENIA I GLEBOZNAWSTWA, PANSTWOWY INSTYTUT BADAWCZY
9	FH OO FORSCHUNGS & ENTWICKLUNGS GMBH
10	Neste Oil Corporation
11	SYNCOM FORSCHUNGS- UND ENTWICKLUNGSBERATUNG GMBH
12	DSM CHEMICAL TECHNOLOGY R & D BV
13	UNIVERSITAET STUTTGART

IFK is involved in the work package :

// Applications of energy carrier //

1. Milling and feeding tests
2. Tests in dust firing and fluidised bed combustion furnaces
    1. Flame stability and fuel reactivity
    2. Fouling & slagging
    3. Fly ash quality (EN 450…)
    4. Flue gas cleaning (SCR, ESP, Fine particles etc.)
3. Use of Flox burner to verify pyrolysis oil combustion for residential heating

(Co-)Milling Tests

Hardgrove Grindability Index

In accordance with DIN 51742

Hardgrove Grindability Index: DIN 51742

1. Text portion: **50 g** sample of coal.
2. Particle size range of the sample is between **1.18 – 0.6 mm.**
3. The test equipment is run for **60 ± 0.25** revolutions.
4. Ground coal is removed from the test equipment and sieved using **75 µm sieve**.
5. The quantity less than 75µm is converted to a HGI value using a calibration graph.

LC-100 Hardgrove Grindability Tester
Source: Gilson Company INC

Tested Fuels

1. Reference Coals with known HGI of values:
    - 38
    - 57
    - 73
    - 100

Increasing grindability of coals

2. Torrefied Biomass:
    - Low Torrefied Beech Wood
    - Medium Torrefied Beech Wood

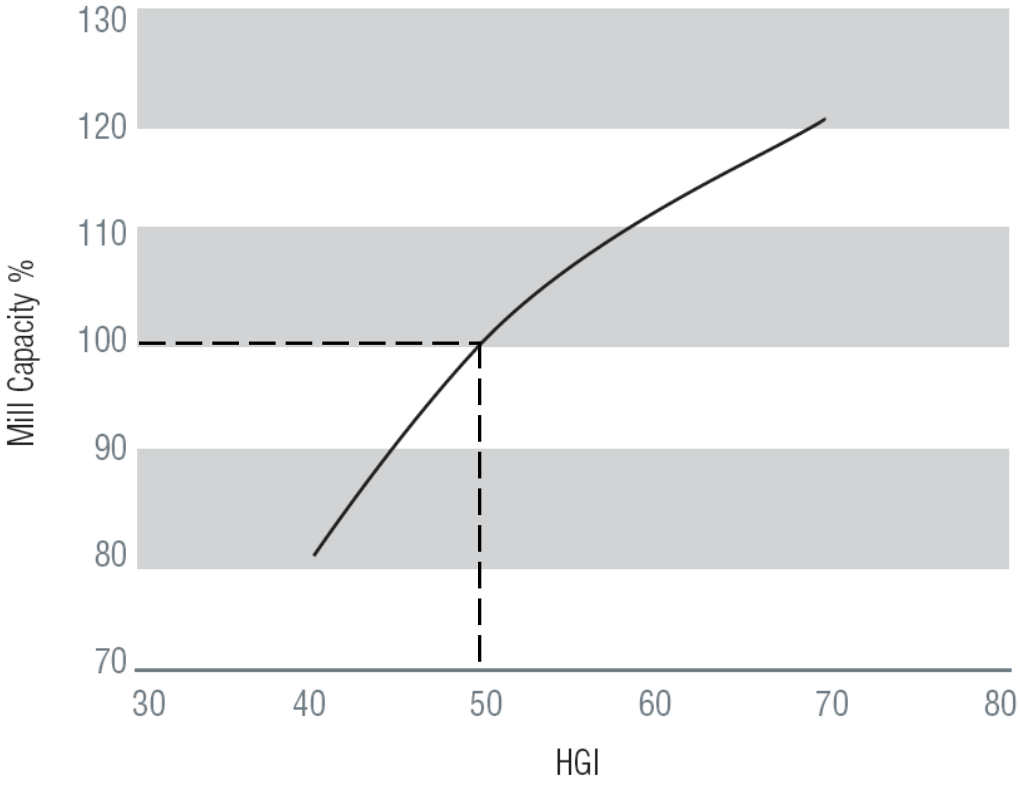
3. Fuel blending in 1:1 mass ratio of all the reference coals and low torrefied Beech wood

Torrefied Beech wood chips

Low Torrefied Beech wood chips

Medium Torrefied Beech wood chips

Mill Capacity vs HGI



The common standard for defining the output of an industrial coal mill when grinding coal with known HGI value are:

1. Output quantity in tonnes/hour
2. 70% less than 75 microns
3. 99.5% less than 300 microns

For most mills this is a HGI value 50

Source: Australian Coal Association Research Program (ACARP, HGI 2008)

Co-milling Test: Hardgrove Grindability Index

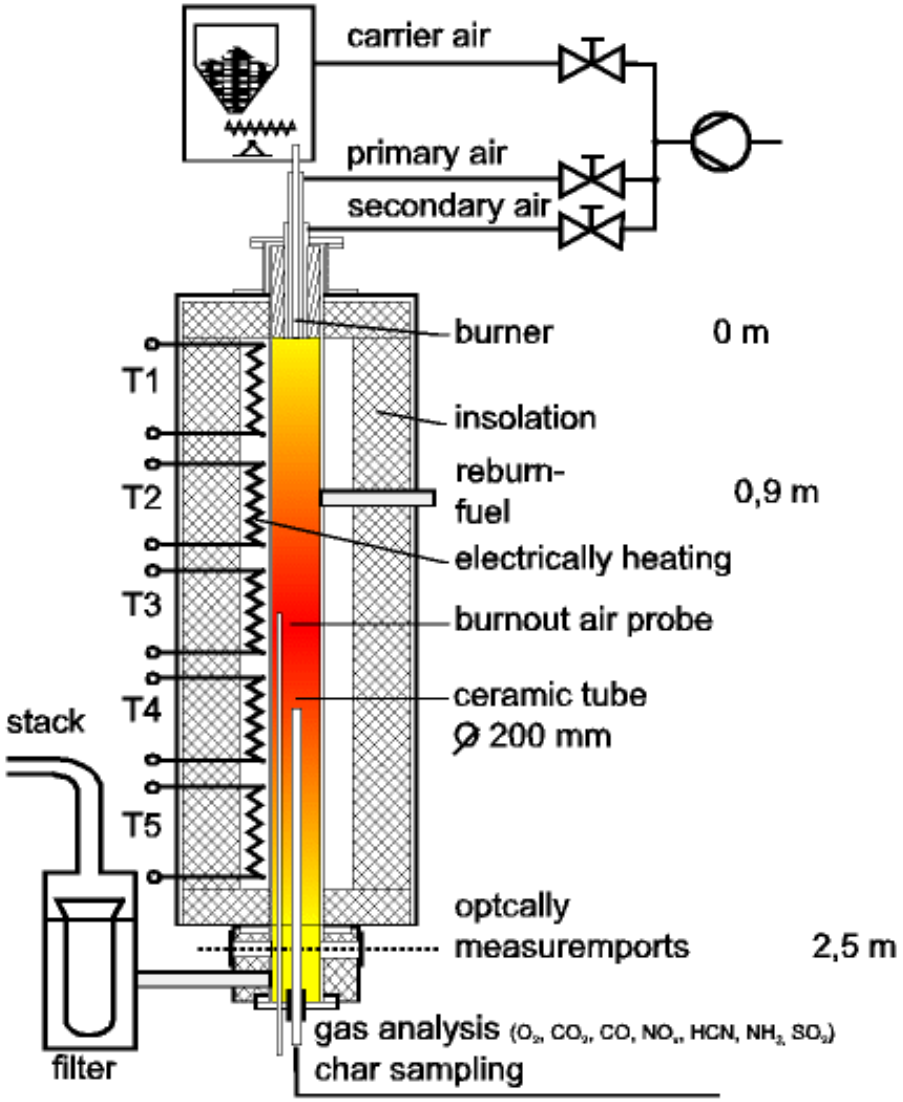
Sample ID	Hardgrove Grindability Index (DIN 51742)
Medium Torrefied Beech woodchips	34-38
Low Torrefied Beech woodchips	23-28

LC-100 Hardgrove Grindability Tester
Source: Gilson Company INC

Fuel Blending 1:1 by mass	HGI	Mill capacity loss
Low Torrefied + Coal HGI 100	48-52	? %
Low Torrefied + Coal HGI 73	31- 35	? %
Low Torrefied + Coal HGI 57	22-25	? %
Low Torrefied + Coal HGI 38	20-23	? %

(Co)-Combustion Tests

Combustion Test in an electrically heated furnace



Boundary conditions

Experiment conditions	**Unstaged combustion**
Fuels	**Torrefied/HTC biomass, bituminous coal**
Air flow through burner	**Constant for all cases (6.7 m^3/h STP)**
Air ratio (overall)	**1.15**
Reactor wall temperature	**1300 °C**

Particle size distribution

Particle size dist.	BW	Low Tor. BW	Medium Tor. BW	HTC BW	El Cerrejon
D10 (µm)	70	58	32	23	38
D50 (µm)	188	150	120	60	50
D90 (µm)	300	300	250	200	87

Proximate and Ultimate analyses

	Beech Wood (BW)	Low Torrefied BW	Medium Torrefied BW	HTC BW	El Cerrejon (bituminous coal)
NCV KJ/Kg [ar]	17374	19690	20352	22250	28000
Moisture ,% [ar]	5.41	2.75	2.55	2.30	1.7
Ash* , % [ar]	1.16	1.18	1.39	0.72	10.2
Volatiles, % [daf]	82.82	78.62	72.89	66.23	39.7
Fixed C, % [daf]	17.23	21.32	27.17	33.58	60.16
C, % [daf]	49.11	51.89	55.30	60.05	79.45
H, % [daf]	6.72	6.57	6.43	6.00	5.22
N, % [daf]	0.13	0.124	0.14	0.12	1.25
S, % [daf]	<LOQ** (0.3)	< LOQ (0.3)	< LOQ (0.3)	< LOQ (0.3)	0.53
O(cal.), % [daf]	44.62	41.7	38.2	30.12	12.00

*) Ash content determination temperatures: 550 °C for biomass; 815 °C for coal

**) <LOQ: Less than the Limit of quantification

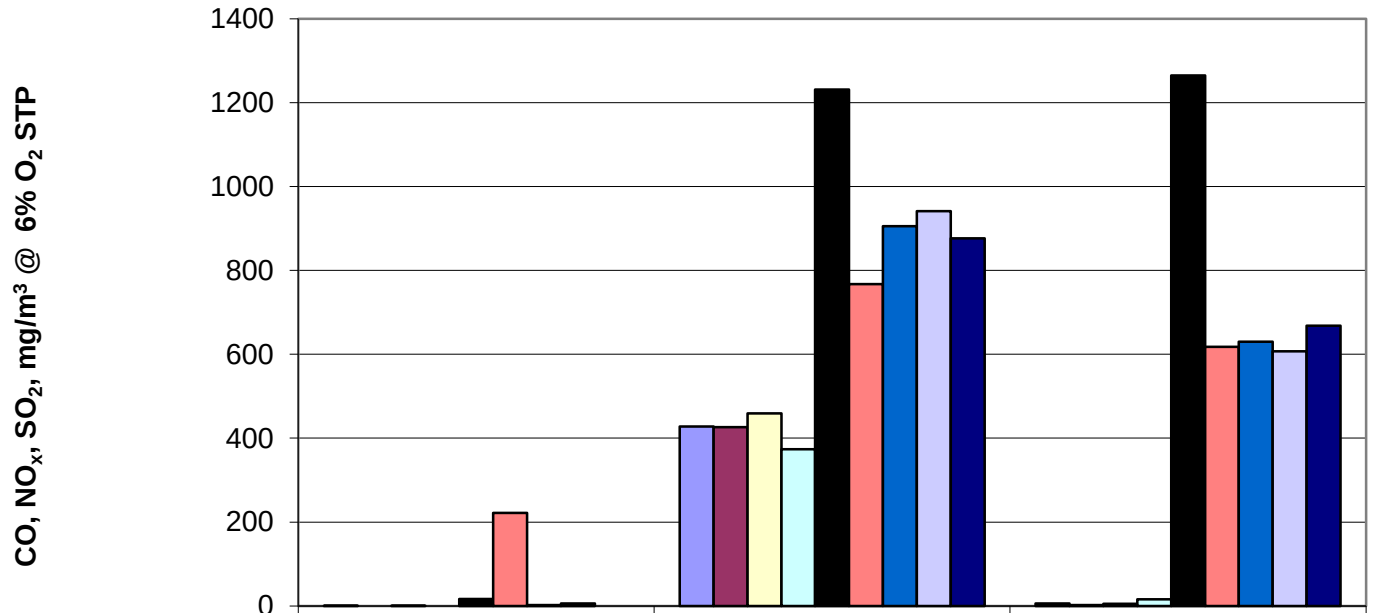
Flue Gas Emission – Unstaged combustion

Fuels	**C_{org} in ash % wf**	**CO @ 6% O_2 wf mg/m³**	**NO_x* @ 6% O_2 wf mg/m³**	**SO_2 @ 6% O_2 wf mg/m³**
EL Cerrejon (EL C)	1.83	17	1231 (290**)	1265
Beech wood (BW)	0.11	1	428	6
Low Tor. BW	< 0.1	0	426	2
Medium Tor. BW	0.39	1	459	5
HTC BW	0.16	0	374	16
EL C + BW	< 0.1	222	767	618
EL C + Low Tor. BW	0.75	2	905	630
EL C + Medium Tor. BW	1.05	6	941	607
El C + HTC	<0.1	0.00	876	668

*) NO_x measured as NO_2

**) Staged combustion

Flue Gas Emission



	CO @ 6% O2 mg/m3	NOx* @ 6% O2 mg/m3	SO2 @ 6% O2 mg/m3
Beech wood (BW)	1	428	6
Low Tor. BW	0	426	2
Medium Tor. BW	1	459	5
HTC BW	0	374	16
EL Cerrejon	17	1231	1265
EL Cerrejon + BW	222	767	618
EL Cerrejon + Low Tor. BW	2	905	630
EL Cerrejon + Medium Tor. BW	6	941	607
El cerrejon + HTC	0	876	668

Concluding Remarks

Milling and co-milling

- HGI of Low-Medium torrefied Beech Wood ranges between **23 and 38**
- In a **1:1 mass ratio,** co-milling of torrefied beech wood and coals with different hardness have shown that, the mill capacity will be reduced. The extent of mill capacity loss is still under investigation.

Co-combustion

- No significant differnce in NOx emission was observed between the raw and torrefied Beech wood.
- Co-combustion of torrefied and HTC biomass (50% thermal share) with coal showed significant reduction in emissions.
  - NOx emission is reduced within a range of about 25 - 30 %.
  - SO_2 emission is reduced by up to 50%

Ongoing/Future R&D Topics at IFK

Continue investigation into:

- Milling and co-milling test of varying Torrefied/HTC biomass
- Extent of mill capacity losses due to co-milling
- Flame stability and fuel reactivity
- Corrosion
- Fouling & slagging
- Fly ash quality (EN 450…)
- Flue gas cleaning (SCR, ESP, Fine particles etc.)

Acknowledgement

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Thank you