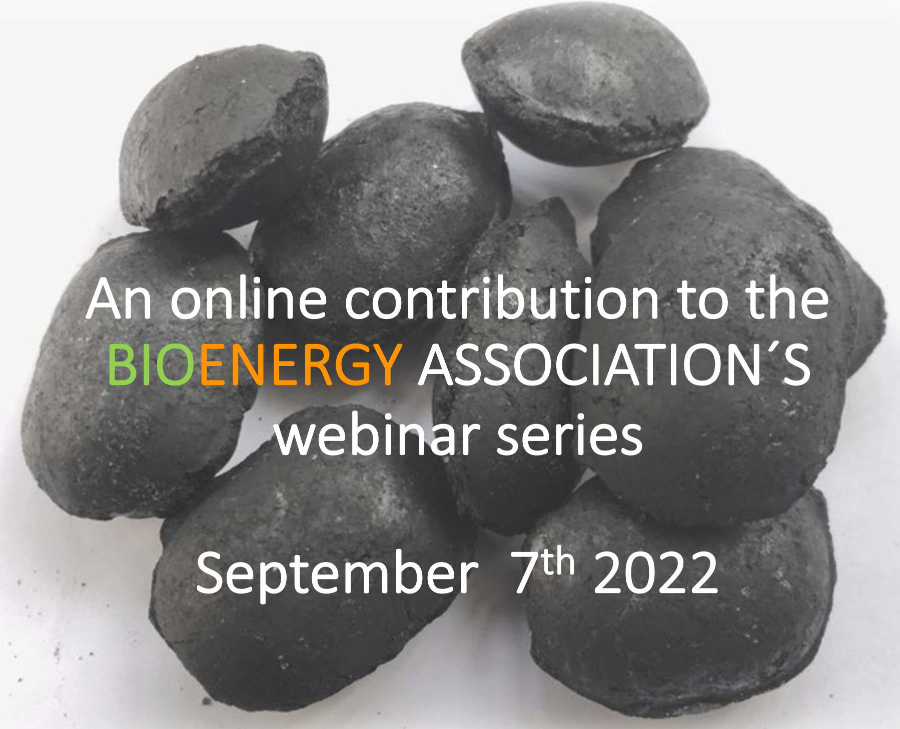
INTERNATIONAL BIOMASS TORREFACTION COUNCIL
A NETWORK OF BIOENERGY EUROPE

W&P

Introduction to BIOMASS TORREFACTION

How torrefied wood fuel could replace coal



An online contribution to the BIOENERGY ASSOCIATION´S webinar series

September 7th 2022

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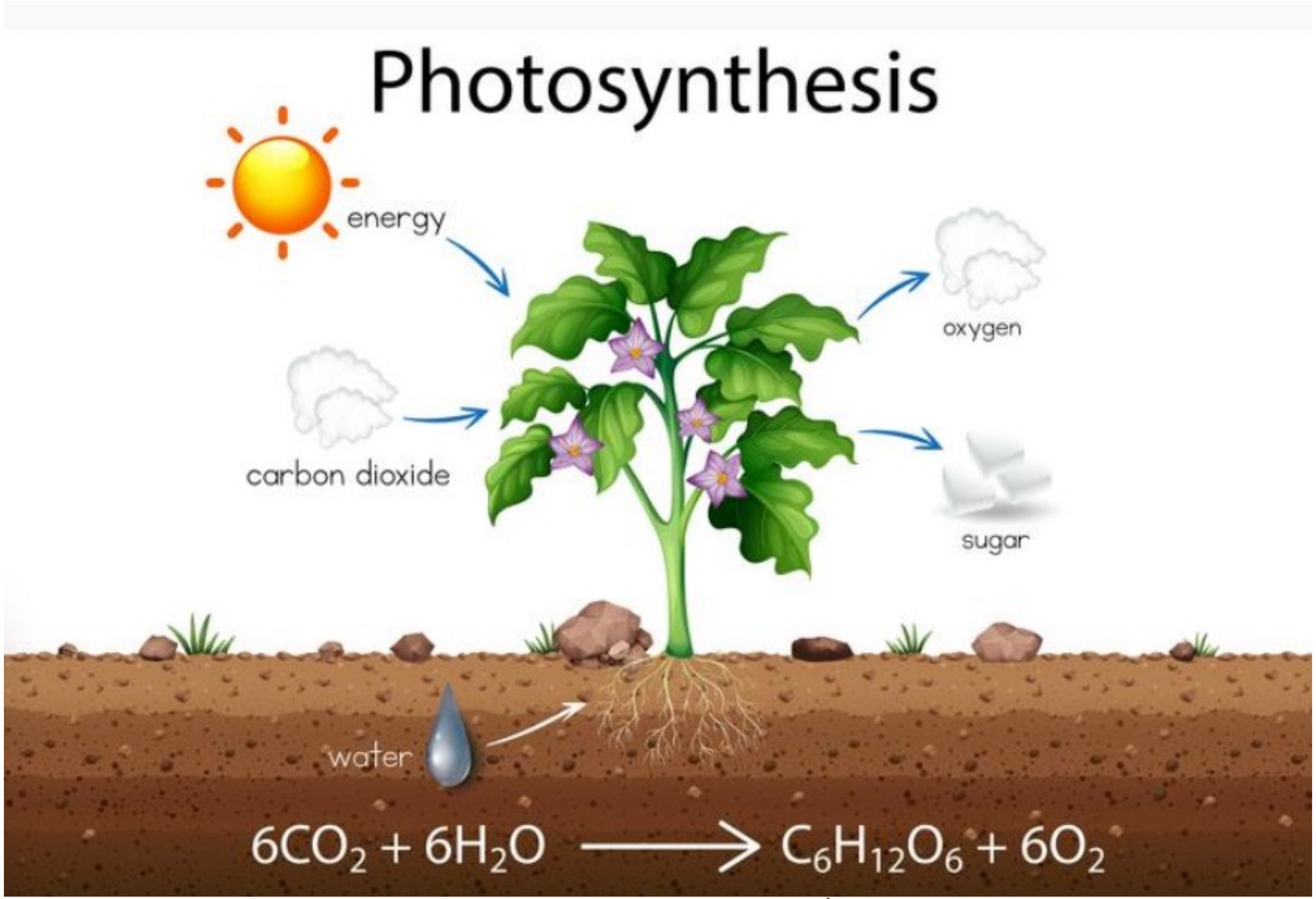
Vienna, Austria

INTRODUCTION TO TORREFACTION OF BIOMASS

1. HOW DOES BIOMAS ARISE AND WHAT IS IT
2. WHAT IS HAPPENING IF BIOMASS IS EXPOSED TO HEAT
3. M&E BALANCE OF TYPICAL PROCESS SETUP
4. COMPARISON OF DIFFERENT CARBONISATION LEVELS
5. INTEGRATED TORREFACTION LINE
6. DIFFERENT REACTOR TYPES
7. POSSIBILITIES IN SETTING UP THE VALUE CHAIN
8. DENSIFICATION AND PRODUCT FORM FACTORS
9. THE PRODUCTS , PRODUCT STANDARDS
10. EXPERIENCES IN COAL POWER AND STEEL INDUSTRY INITIATIVES
11. SUSTAINABILITY
12. INTRODUCTION OF COMPANIES ACTIVE IN BIOCARBON

What is plant biomass and how does it arise



carbon dioxide — water — glucose — oxygen

What is plant biomass chemically

Wood biomass typically has the following elemental composition on a dry mass basis,

- Carbon 50 %
- Oxygen 41%
- Hydrogen 6%
- Nitrogen, Sulfur, Ash 3%

The combustible elements of wood are

- Carbon 88 %
- Hydrogen 12 %

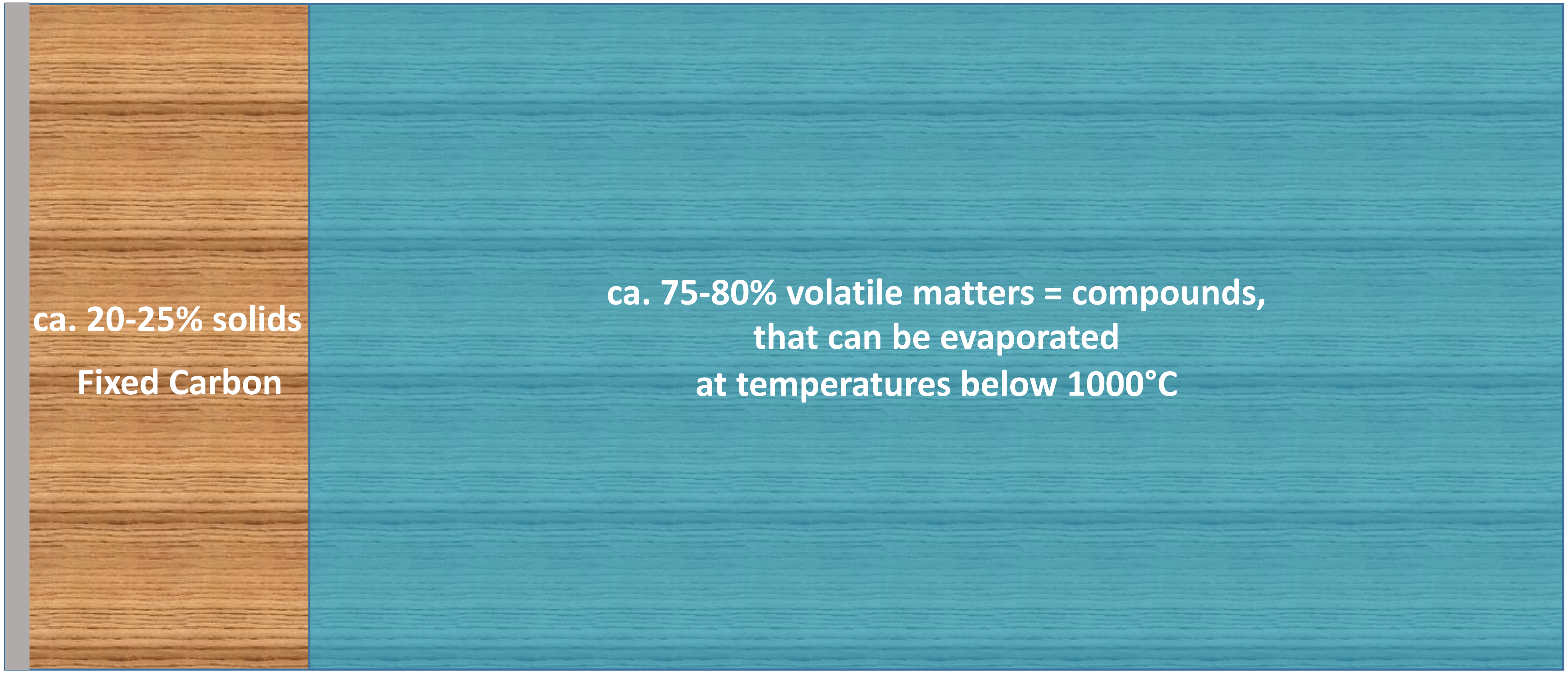
+ the traces of Sulfur 0,02%

The energy ratio of wood combustion is

- Energy from Carbon 67 %
- Energy from Hydrogen 33 %

Torrefaction breaks up and reduces low energy-containing oxygen-rich compounds,

Understanding the basic composition of biomass



minerals=ash
0,3-25%

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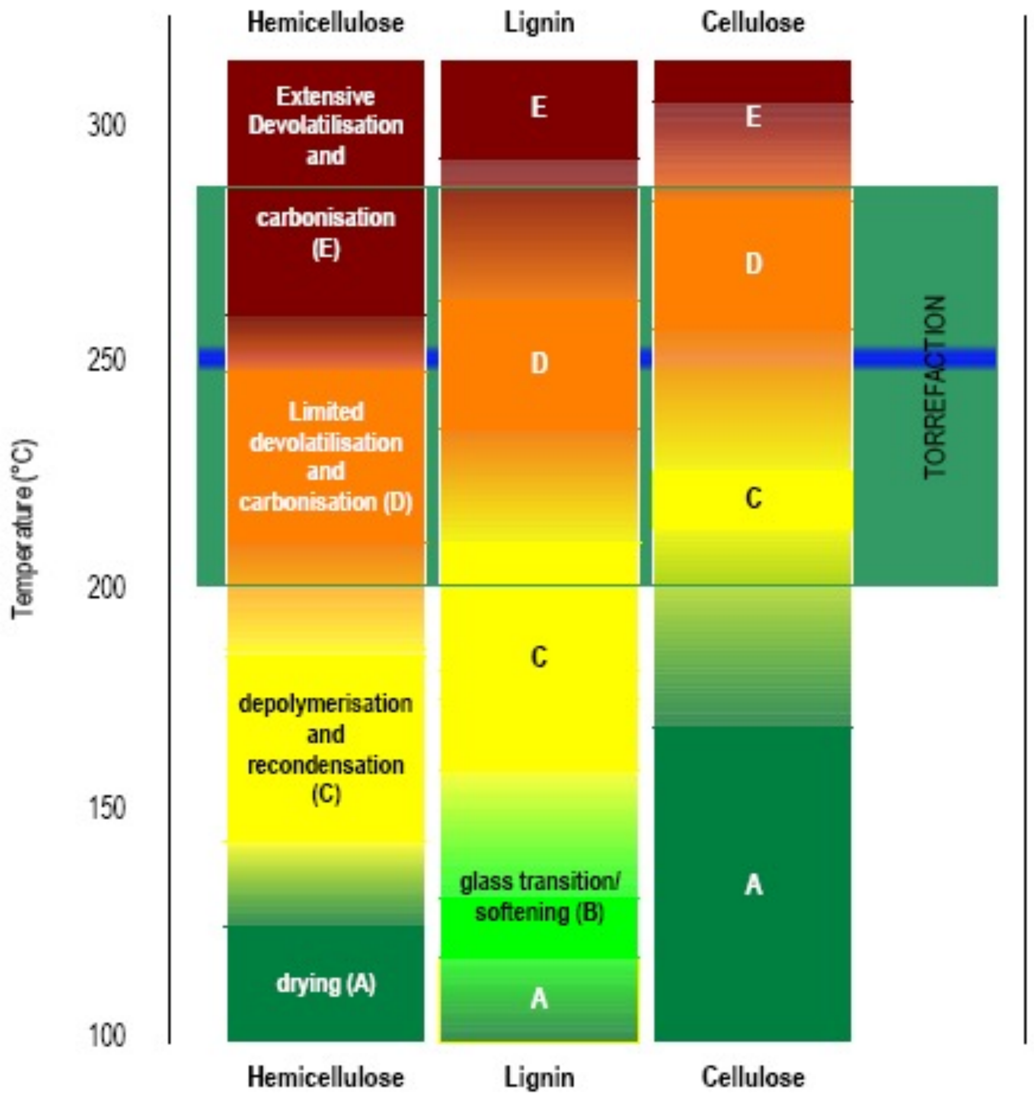
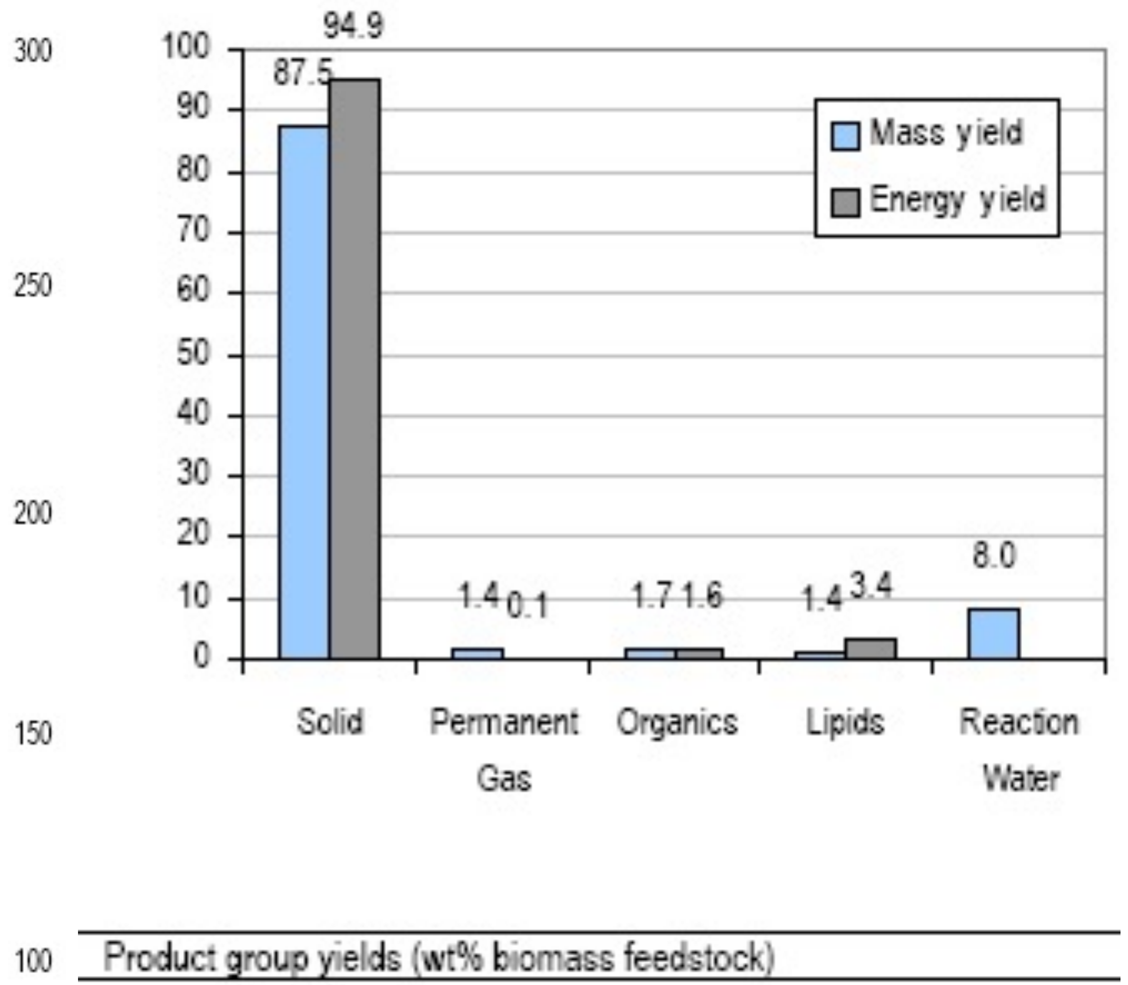
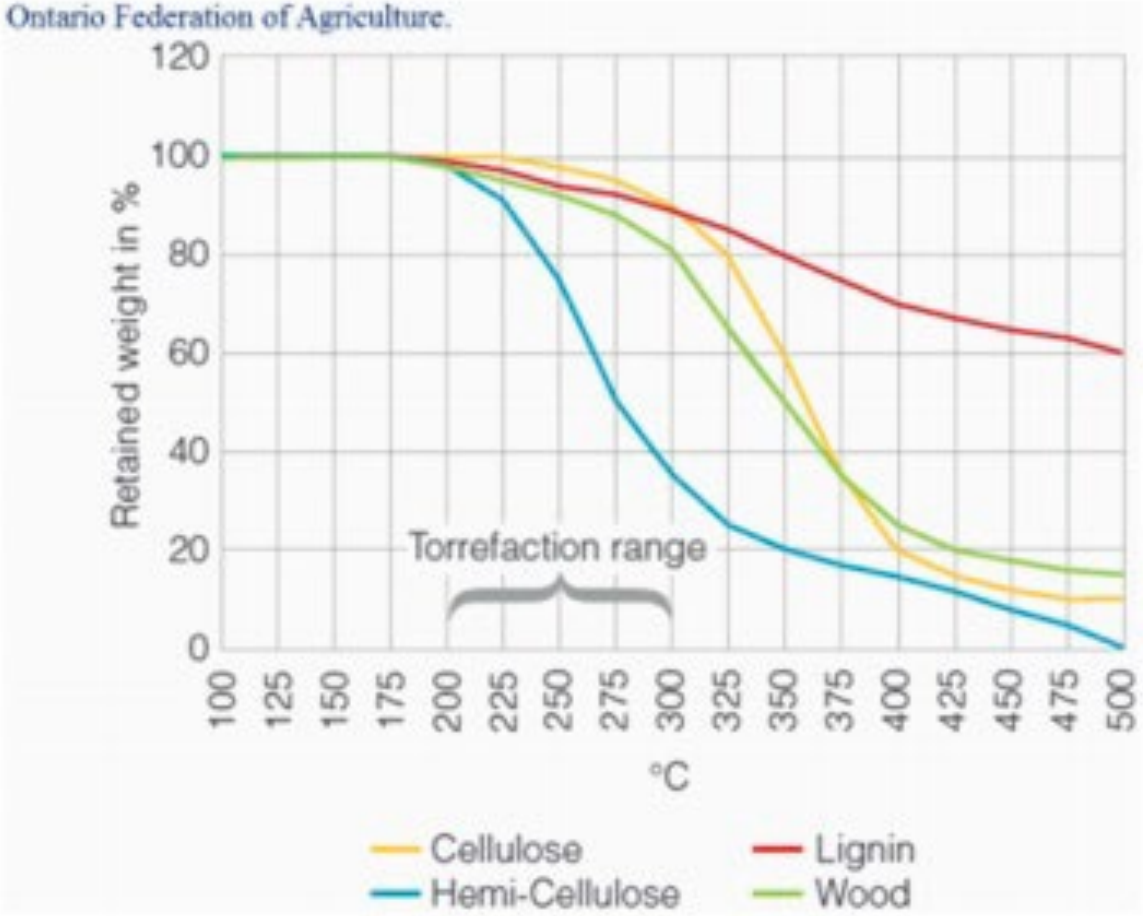
What happens to Biomass under Heat

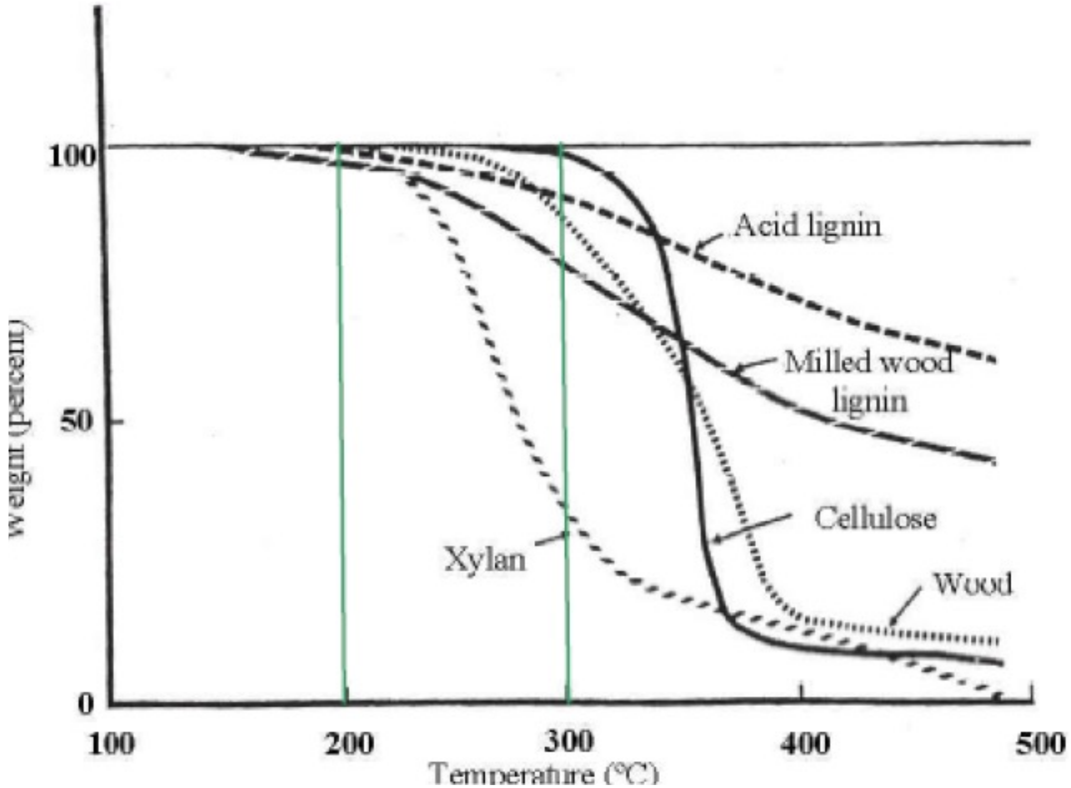




Quelle: ECN report ECN-C-05-013

Decomposition under thermal influence





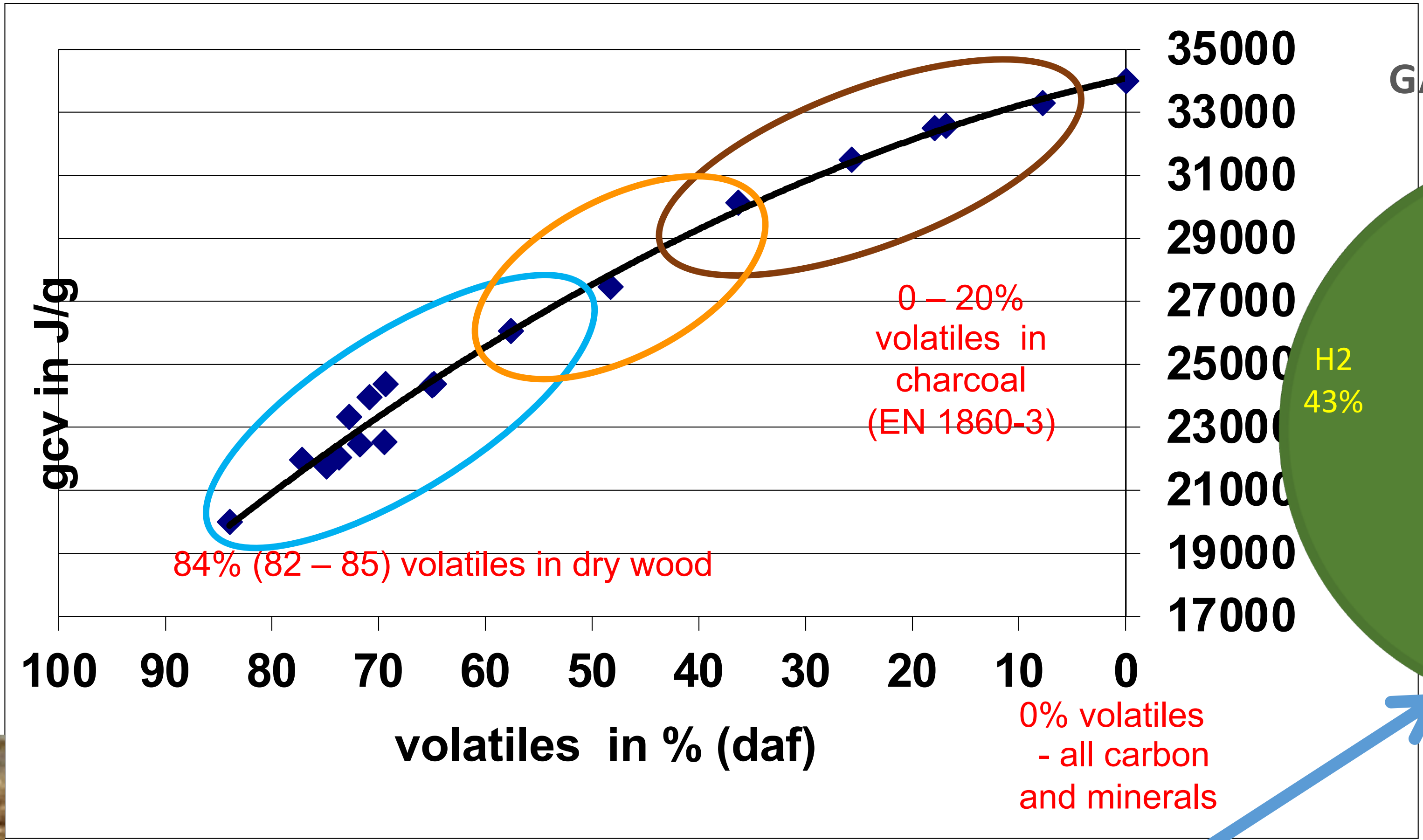
Torrefaction will first lead to Hemi-Celluloses decomposition and only at higher temperatures the Cellulose will follow. Mild torrefaction will also keep a higher proportion of the lignin in tact resulting in better pelletability of product

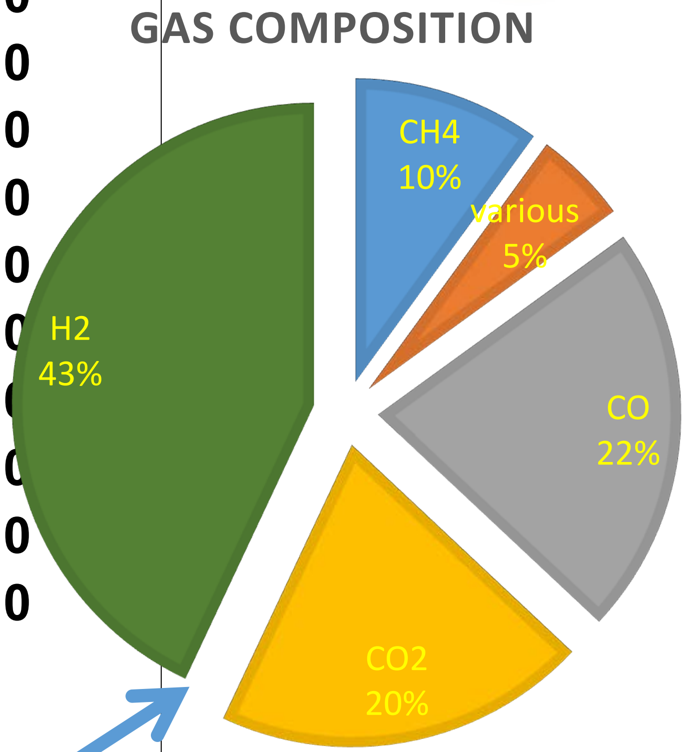
Products/ Process names along the carbonization curve

Carbonisation = High Temp. Torrefaction = Charring

Pyrolyses

Torrefaction





Why do we Torrefy?
Producing a Carbon product for many applications

- ✓Remove moisture
- ✓Feedstock homogenisation
- ✓Broadening feedstock base
- ✓Concentrate calorific value
- ✓Improve storage and handling
- ✓Build on existing coal infrastructure
- ✓Lowers transport costs
- ✓Reduce water uptake
- ✓Fungible products
- ✓Direct steam coal substitute
- ✓Reduce biologic degradation to 0
- ✓Increase grindability
- ✓Better pneumatic transport and burn out characteristics
- ✓Higher combustion temperature
- ✓Higher Carbon concentration
- ✓Renewable input material for all carbon demanding processes
- ✓Increased supply chain efficency
- ✓Value creation
- ✓and many more

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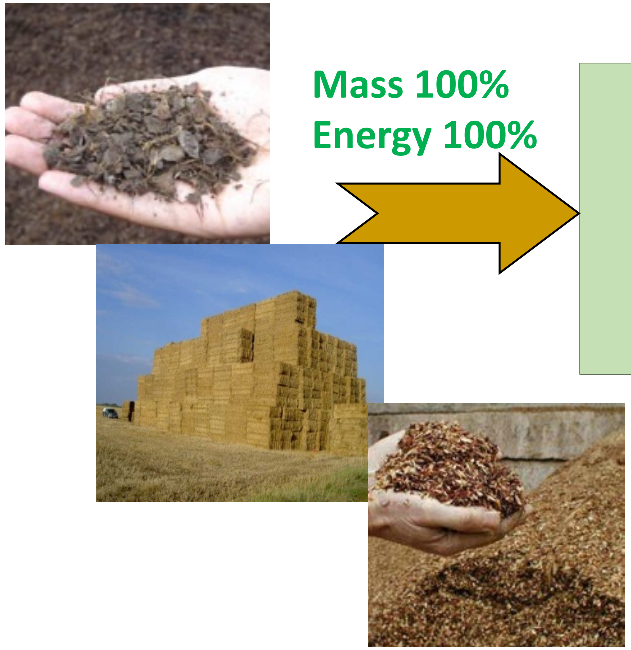
Principle and Simplified M&E Balance

INPUT:

Processing

OUTPUT :



Mass 100%
Energy 100%

reactor and process
temperature: ~ 300˚ - 600 C
residence time: ~ 30 min

Mass 70% (32%)
Energy 85% (53%)

Mass 30% (68%)
Energy 15% (47%)

Pre-dried biomass

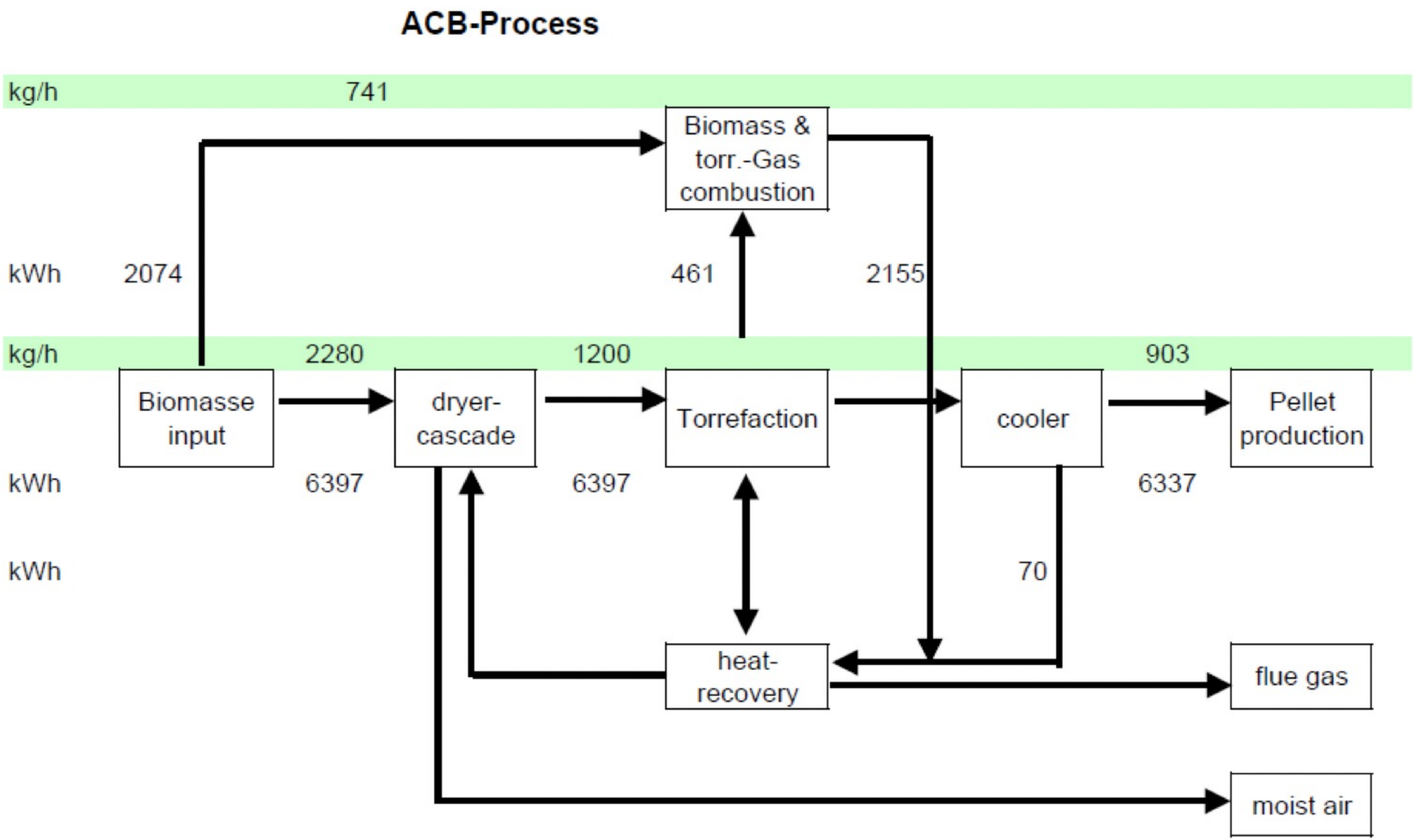
Syn-Gas to Combustion (recirculated)

torrefied Biomass

Values in brackets for high temperature torrefaction

The pro rata much higher mass loss leads to the concentration of energy in the solid products of the process.

M&E Balance belt drier, drum reactor



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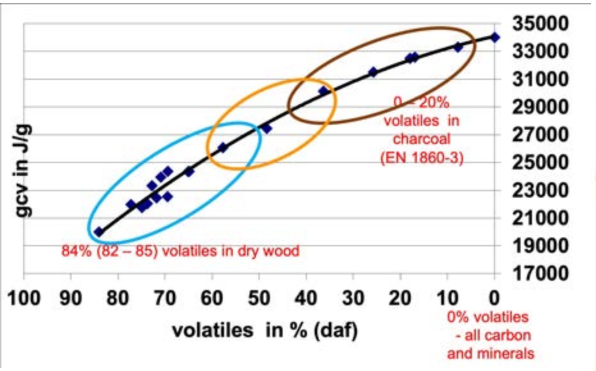
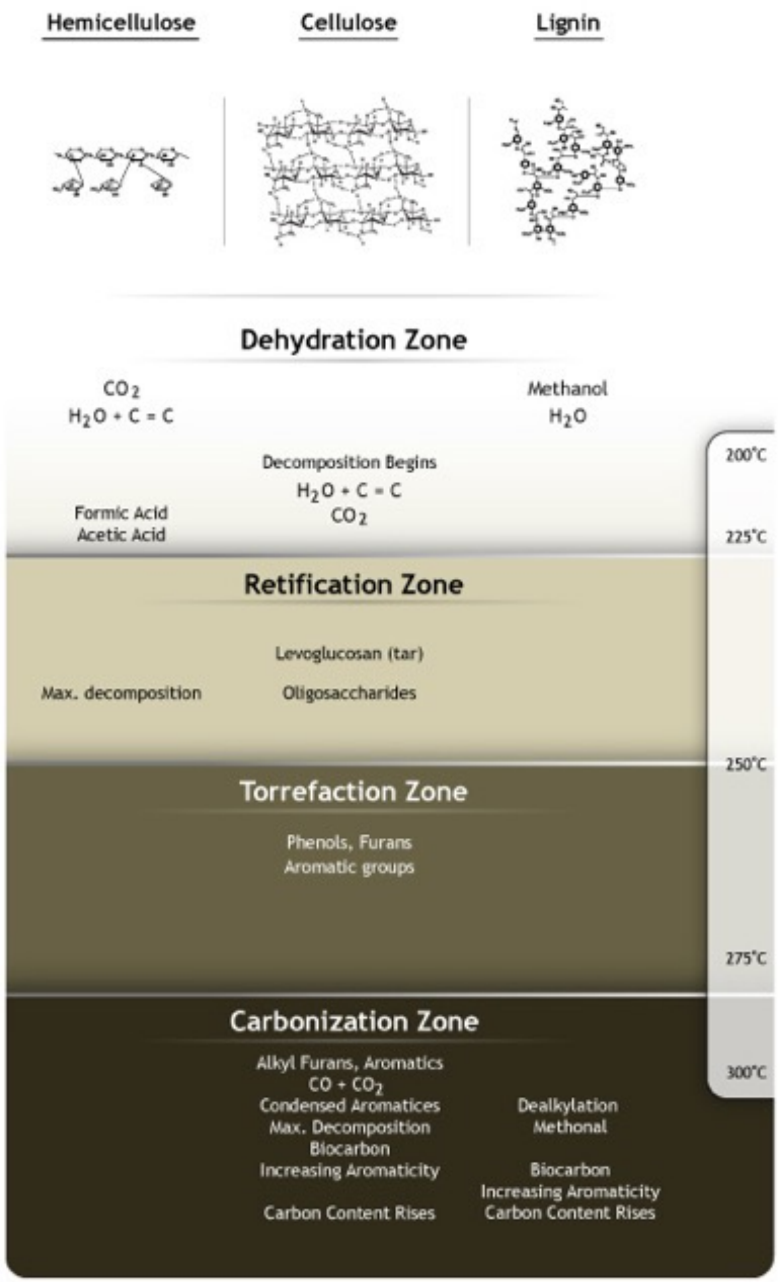
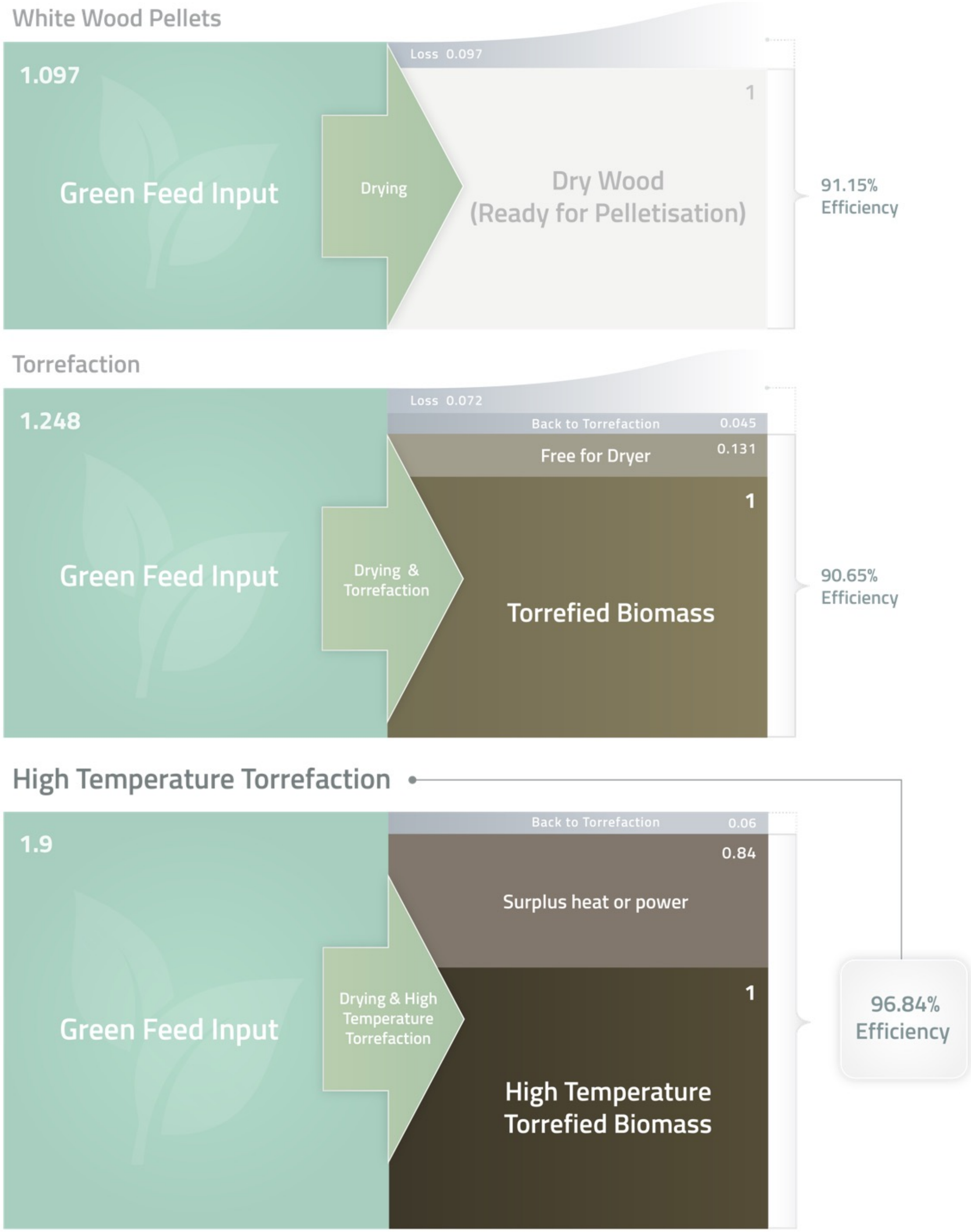
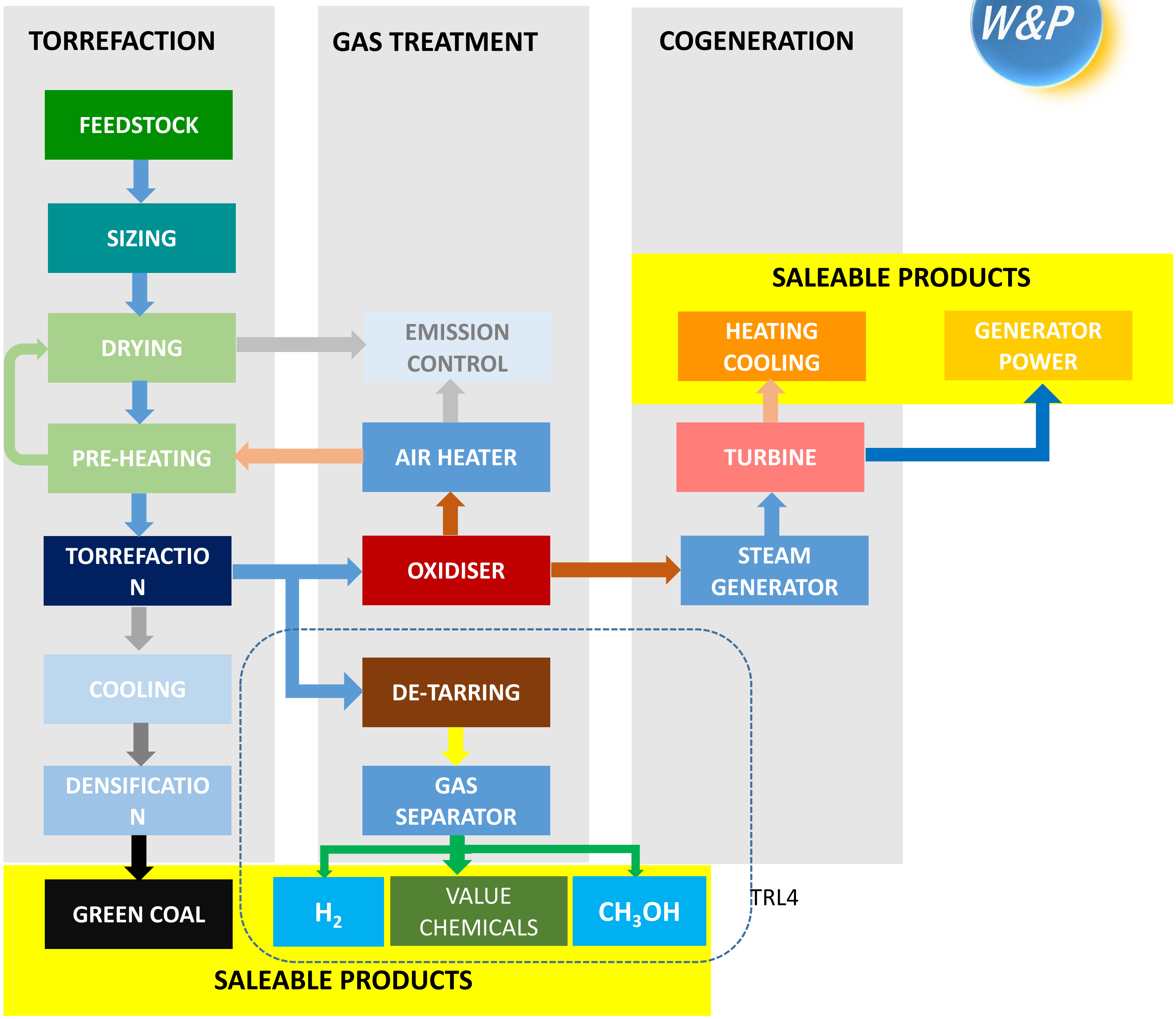
Thermochemical Gradient







Different Carbonisation Levels
Different Product Portfolio



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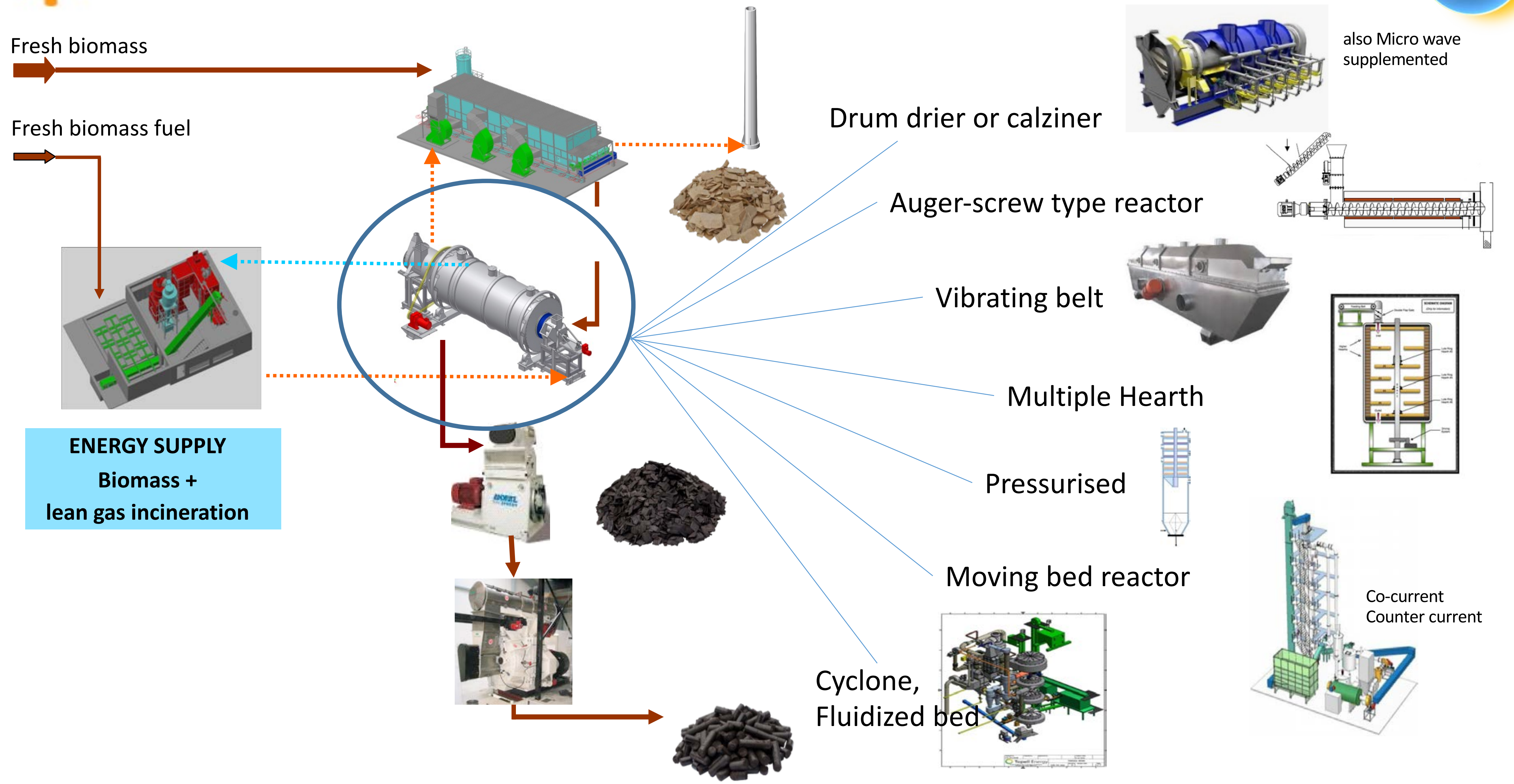
The integrated continuous torrefaction process



Special case „Batch Process“ for demanding applications

A batch process on the example of retorts permits a very precise application of temperature to each particle of biomass by this providing also a very good process control.

Tbatch processes therefore are not primarily oriented to produce a commodity fuel, but to establish itself in the area of special products.

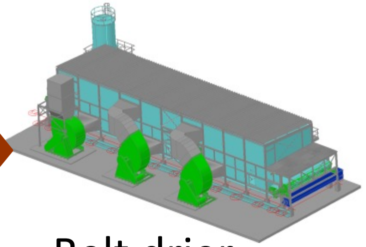
This begins with high-quality barbecue coals and extends to the area of pharmaceutical carbon compounds. Approval for this has already been granted to one of our members.

TRL9 !

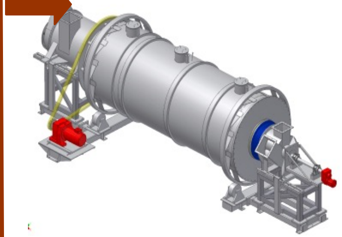
INTRODUCTION TO TORREFACTION OF BIOMASS

Torrefaction in one step or in two steps

DRYING



Belt drier

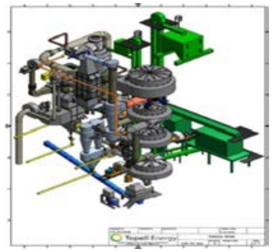


Drum drier

Fresh biomass

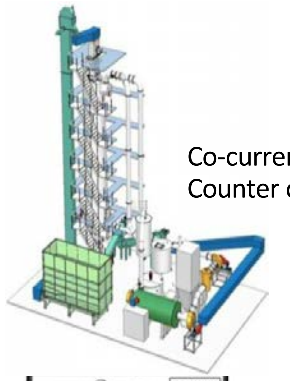
LOW TEMP. TORREFACTION

Cyclone,
Fluidized bed



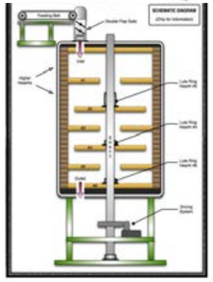
Vibrating belt

Moving bed reactor



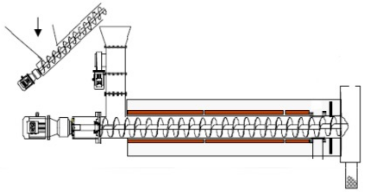
Co-current
Counter current

Multiple Hearth



HIGH TEMP. TORREFACTION

Drum drier or calziner



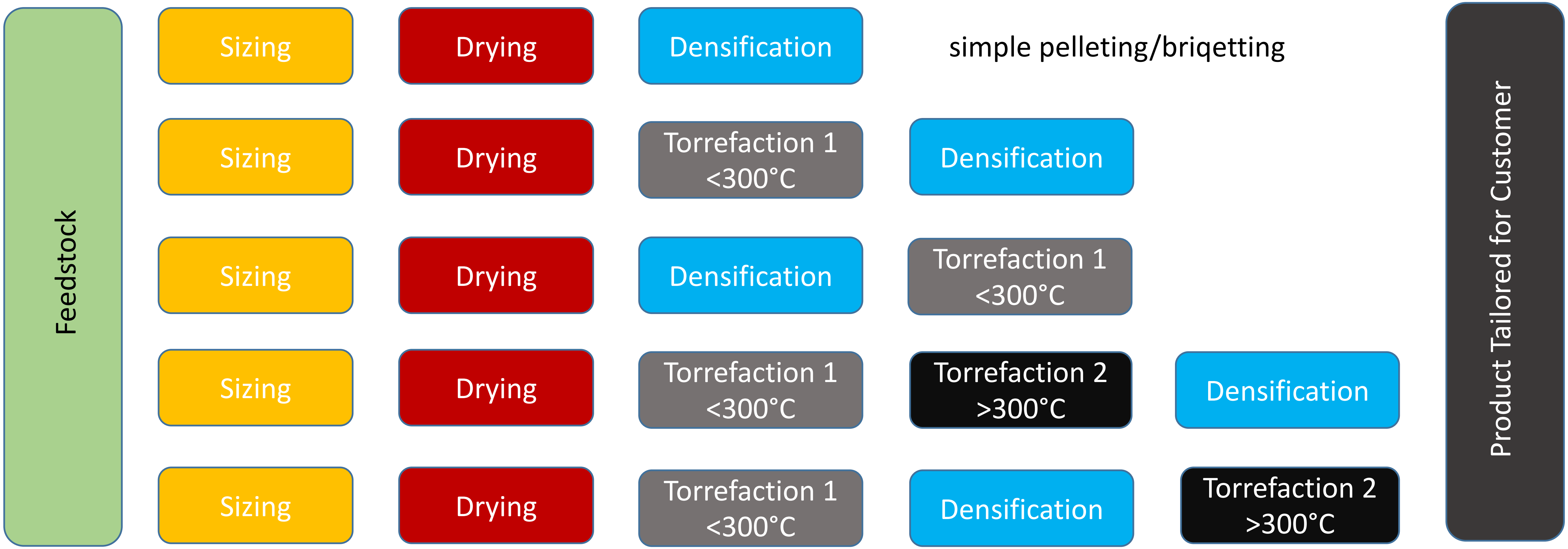
Auger-screw reactor

Batch reactor

A two step approach may be of advantage if very high Carbon concentration in the solid product is the aim.

Process steps in a torrefaction value chain

Basically the value chain is build of up to 5 steps from gate of first processing installation to final deliverd product. While it seems logic that first 3 steps are unavoidably located at place of feedstock origin it may be worthwhile analysing if location of final steps at place of consumption provide advantages



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Typical Product Form Factors

Densification

Biomass once torrefied will have a bulk density of <150kg/m^3
and is prone to form plenty of fines <500microns

Densification is a must for several resons

Reducing risks and costs that go along with powder storage and transportation
Increase of bulk density to make product transportable
Reduction of selfignition risk
Allowing to store in open yards
Ability to use standard bulk carriers (IMSBC prohibits the transport of non densified bulk carbonised biomass)
Possibility to add binders or coatings
Building commodity status

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Diversity of Products

Volume Product: Fuel for Pulverized Coal Power Plants

Value Products:
- Fuel for Heating
- Fuel for Process Energy Needs
- Blast Furnace Injection Carbon (SSAB Brahestad)
- Feedstock for Gasification
- Soil enhancer
- Carbon provider for Plastics industry
- Activated Carbon
- Products for new (niche) markets

Quality – Standardisation

ISO 17225

Solid biofuels -Fuel specifications and classes

ISO TS 17225 - 8:

Part 8: Graded thermally treated and densified biomass fuels

Currently the TS- Technical Specification is in the process of upgrading the to a full Standard

New: Parameter values not realted to mass only but also to energy content

Water sorption and grindability newly included

Discussions in parallel to include non energetic use or to establish supplementing standards i.e. char for metalurgical purposes

ISO/TS 17225-8:2016

Table 1 — Specification of graded pellets produced by thermal processing of woody biomass

Property class, Analysis method	Unit	TW1H	TW1L	TW2H	TW2L	TW3H	TW3L
Normative							
Origin and source, ISO 17225-1 Table 1		1.1.1 Whole trees without roots 1.1.3 Stemwood 1.1.4 Logging residues 1.2.1 Chemically untreated wood by-products and residues [a]		1.1 Forest, plantation and other virgin wood 1.2 By-products and residues from wood processing industry 1.3.1 Chemically untreated used wood		1.1 Forest, plantation and other virgin wood 1.2 By-products and residues from wood processing industry 1.3.1 Chemically untreated used wood	
Diameter, D [b] and Length L [c] ISO 17829 According Figure 1	mm	D06, 6 ± 1; D08, 8 ± 1; 3,15 ≤ L ≤ 40		D06 to D25, D ± 1; 3,15 ≤ L ≤ 40 (from D06 to D10) 3,15 ≤ L ≤ 50 (from D12 to D25)		D06 to D25, D ± 1; 3,15 ≤ L ≤ 40 (from D06 to D10) 3,15 ≤ L ≤ 50 (from D12 to D25)	
Moisture, M [d], ISO 18134-1, ISO 18134-2	w-% as received, wet basis	M08 ≤ 8	M10 ≤ 10	M08 ≤ 8	M10 ≤ 10	M10 ≤ 10	
Ash, A, ISO 18122	w-% dry	A1.2 ≤ 1,2		A3.0 ≤ 3,0		A5.0 ≤ 5,0	
Mechanical durability, DU, ISO 17831-1	w-% as received	DU97.5 ≥ 97,5		DU96.0 ≥ 96,0		DU95.0 ≥ 95,0	
Fines, F [e], ISO 18846	w-% as received	F2.0 ≤ 2,0	F1.0 ≤ 1,0	F4.0 ≤ 4,0	F2.0 ≤ 2,0	F6.0 ≤ 6,0	F3.0 ≤ 3,0
Additives [f]	w-% dry	≤ 4, Type and amount to be stated		Type and amount to be stated		Type and amount to be stated	
Net calorific value, Q_d [g], ISO 18125	MJ/kg or kWh/kg dry basis	Q_d ≥ 21,0 Q_d ≥ 5,8	Q_d < 21,0 Q_d < 5,8	Q_d ≥ 21,0 Q_d ≥ 5,8	Q_d < 21,0 Q_d < 5,8	Q_d ≥ 21,0 Q_d ≥ 5,8	Q_d < 21,0 Q_d < 5,8
		Value to be stated		Value to be stated		Value to be stated	
Bulk density, BD, ISO 17828	kg/m³ as received	BD650 ≥ 650	BD700 ≥ 700	BD650 ≥ 650		BD550 ≥ 550	
		Value to be stated		Value to be stated		Value to be stated	
Carbon, C, ISO 16948	w-% dry	Value to be stated		Value to be stated		Value to be stated	
Nitrogen, N, ISO 16948	w-% dry	N0.4 ≤ 0,4		N0.4 ≤ 0,4		N1.0 ≤ 1,0	
Sulphur, S, ISO 16994	w-% dry	S0.04 ≤ 0,04		S0.05 ≤ 0,05		S0.1 ≤ 0,1	
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	≤ 1		≤ 2		≤ 2	
Cadmium, Cd, ISO 16968	mg/kg dry	≤ 0,5		≤ 1		≤ 2	
Chromium, Cr, ISO 16968	mg/kg dry	≤ 10		≤ 15		≤ 15	
Copper, Cu, ISO 16968	mg/kg dry	≤ 10		≤ 20		≤ 20	
Lead, Pb, ISO 16968	mg/kg dry	≤ 10		≤ 10		≤ 10	
Mercury, Hg, ISO 16968	mg/kg dry	≤ 0,1		≤ 0,1		≤ 0,1	
Nickel, Ni, ISO 16968	mg/kg dry	≤ 10		≤ 10		≤ 10	
Zinc, Zn, ISO 16968	mg/kg dry	≤ 100		≤ 100		≤ 100	
Volatile matter, VM, ISO 18123	w-% dry	Value to be stated		Value to be stated		Value to be stated	
Informative							
Ash melting behaviour [h], ISO 21404	°C	To be stated		To be stated		To be stated	

a Negligible levels of glue, grease and other timber production additives (< 1 w-%) used in sawmills during production of timber and timber product from virgin wood are acceptable if all chemical parameters of the pellets are clearly within the limits and/or concentrations are too small to be concerned with.
b Selected size D06 or D08 of pellets to be stated for TW1H and TW1L.
c For D06 to D10 the amount of pellets longer than 40 mm can be 1 w-%. Maximum length shall be ≤ 45 mm.
d At the point of delivery.
e At the point of delivery. Fines less than 3,15 mm are screened by hand according standard ISO 18846.
f Type of additives to aid production, delivery or combustion (e.g. pressing aids, slagging inhibitors or any other additives like starch, corn flour, potato flour, vegetable oil, lignin ...).
g Net calorific value as received (Q) resulting from net calorific value on dry basis 21,00 MJ/kg and moisture content (M) 8% is 19,13 MJ/kg (5,3 kWh/kg) and by 10 % moisture content (M) is 18,65 MJ/kg (5,2 kWh/kg).
h All characteristic temperatures (shrinkage starting temperature (SST), deformation temperature (DT), hemisphere temperature (HT) and flow temperature (FT)) in oxidizing conditions should be stated.

ISO/TS 17225-8:2016

Table 2 — Specification ... ded pellets produced by thermal processing of non-woody biomass

Unit	TA1	TA2	TA3
	2. 1 Herbaceous biomass from agriculture and horticulture 2.2.1 By-products and residues from food and herbaceous processing industry, chemically untreated herbaceous residues 3.1 Orchard and horticulture fruit 3.2.1 By-products and residues from food and fruit processing industry, chemically untreated fruit residues 4. Aquatic biomass	2. Herbaceous biomass 3. Fruit biomass 4. Aquatic biomass	2. Herbaceous biomass 3. Fruit biomass 4. Aquatic biomass
	D06 to D25, D ± 1; 3,15 < L ≤ 40 (from D06 to D10) 3,15 < L ≤ 50 (from D12 to D25)	D06 to D25, D ± 1; 3,15 < L ≤ 40 (from D06 to D10) 3,15 < L ≤ 50 (from D12 to D25)	D06 to D25, D ± 1; 3,15 < L ≤ 40 (from D06 to D10) 3,15 < L ≤ 50 (from D12 to D25)
	M10 ≤ 10	M10 ≤ 10	M10 ≤ 10
	A5.0 ≤ 5,0	A10.0 ≤ 10,0	Value to be stated
	DU97.5 ≥ 97,5	DU96.5 ≥ 96,5	DU95.0 ≥ 95,0
	F2.0 ≤ 2,0	F2.0 ≤ 2,0	F3.0 ≤ 3,0
	Type and amount to be stated	Type and amount to be stated	Type and amount to be stated
	Q18 ≥ 18 or Q5.0 ≥ 5,0 Value to be stated	Q17 ≥ 17 or Q4.7 ≥ 4,7 Value to be stated	Value to be stated
	BD600 ≥ 600	BD600 ≥ 600	BD550 ≥ 550
	...lue to be stated	Value to be stated	Value to be stated
	N1.5 ≤ 1,5	N2.0 ≤ 2,0	N2.5 ≤ 2,5
	S0.1 ≤ 0,1	S0.2 ≤ 0,2	S0.3 ≤ 0,3
	Cl0.1 ≤ 0,1	Cl0.2 ≤ 0,2	Cl0.3 ≤ 0,3
	≤ 2	≤ 2	Value to be stated
	≤ 1	≤ 1	Value to be stated
	≤ 50	≤ 50	Value to be stated
	≤ 20	≤ 20	Value to be stated
	≤ 10	≤ 10	Value to be stated
	0,1	< 0,1	Value to be stated
	10	≤ 10	Value to be stated
	200	≤ 200	Value to be stated
	be stated	Value to be stated	Value to be stated
	stated	Should be stated	Should be stated

...-%. Maximum length shall be ≤ 45 mm.
...d according standard ISO 18846.
...sing aids, slagging inhibitors or any other additives like
... deformation temperature (DT), hemisphere
...hould be stated.

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Documentation, Permissions and Registrations

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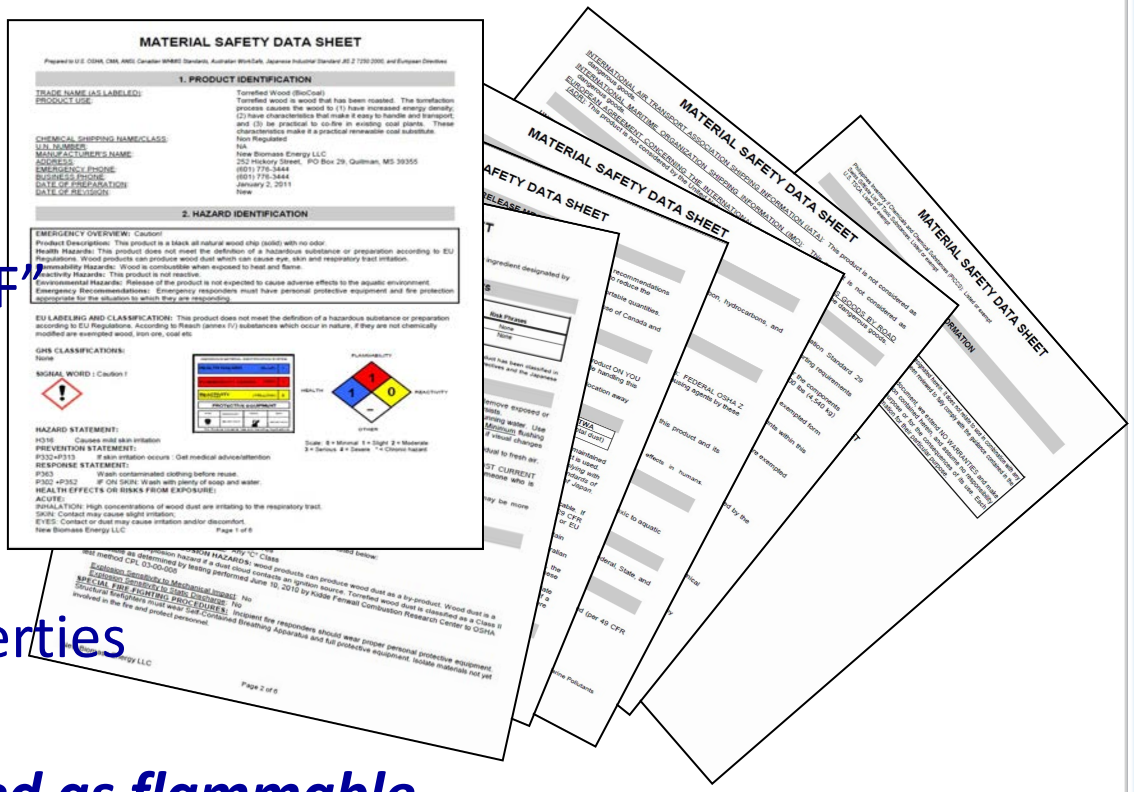
MSDS with SECTOR

REACH
Substance Information Exchange Forum “SIEF”



Working on IMSBC

IMO 4.1 flammability test: not flammable

IMO 4.2 self heating test : No self heating properties

Torrefied material does not 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

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Torrefied Biomass in Power Plants
Combustion Preparation
Storage

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Positive Experience in co-firing

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- 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

Topell Energy · RWE The energy to lead · NUON · VATTENFALL · GDF SUEZ · 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

Technically in all parameters superior to Wood Pellets

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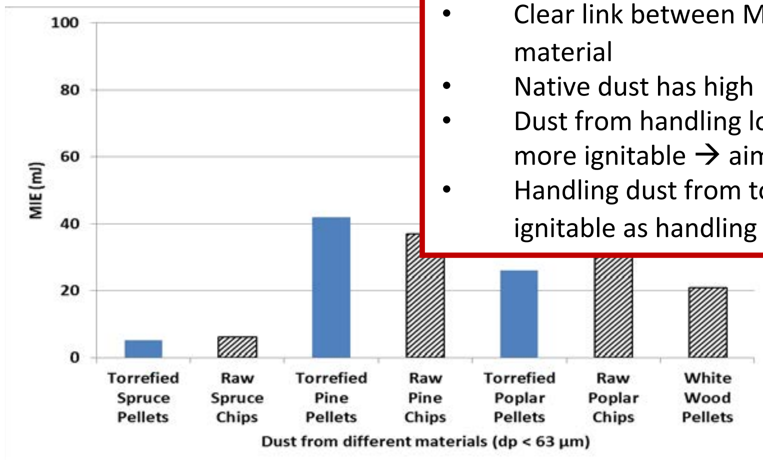
Minimum Ignition Energy Pulverised torrefied pellets vs. pulverised raw biomass chips



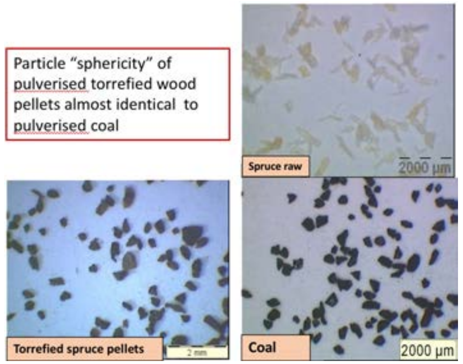
- Clear link between MIE torrefied pellets with MIE raw material
- Native dust has high MIE's
- Dust from handling low durability pellets (< 93%) is more ignitable → aim for pellet durability ≥ 95%
- Handling dust from torrefied wood pellets is equally ignitable as handling dusts from white wood pellets

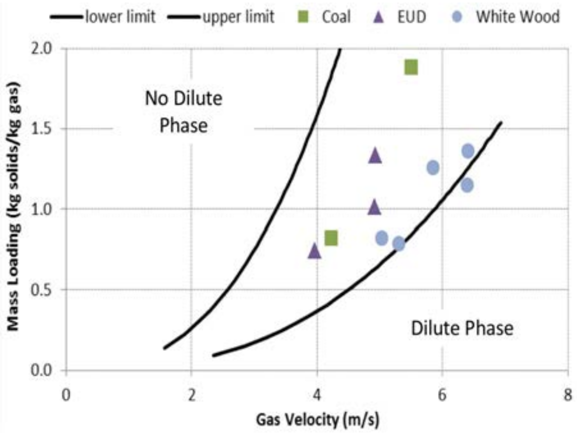
Biological Degradation

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

Fuel Morphology, pneumatic transport





Water Resistance

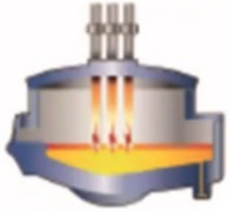
Full water resistance achieved by several producers with or without binders resp. coating

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

Torrefied Biomass in the Steel Industry

Biochar in Pyrometallurgical Applications

EAF



- Slag foaming agent
- Carburizing agent

5-10 kg for foaming
3-10 kg for alloy
500 kg of coke / ton of FeCr

Blast furnace

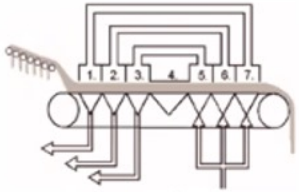
- Reducing agent
- Fuel
- Structural material

300 - 400 kg of coke + 100 - 200 kg pulverized coal / ton of pig iron

SAF

- Reducing agent
- Fuel

Ore/pellet sintering



- Fuel

50 kg of coke dust / ton of sintered pellets

Other possible applications
- Reducing agent in treatment of slags, ores, residues, wastes etc.
- Lime stone activation

Source: Oulun yliopisto

Initiatives in the European Steel Industry

SSAB Raahe's pilot to use the biocoal

Swedish-headed steel producer SSAB has disclosed test results revealing the usage of biocoal in the blast furnace at their SSAB Brahestad steelworks in Finland. Tests show that up to a 10% of biocoal blend is possible, which would reduce fossil carbon dioxide (CO_2) emissions by 100,000 tonnes a year
https://www.ssab.com/News/2019/05/Every-tiny-step-you-take-counts-a-lot
+ pilot trials in the electric arc furnace that belongs to SWERIM (formerly Swerea MEFOS). Among other things, we will be testing different biocoals, smelting properties in different hydrogen-reduced DRIs and different slag processes

Torero by Arcelor Mital cofunded by EU

- Wood waste is converted to biocoal by torrefaction in Ghent plant
- Biocoal replaces fossil powdered coal in a steel mill blast furnace
- Carbon monoxide in blast furnace exhaust fumes is microbially fermented to bioethanol STEELANOL

http://www.torero.eu.
Arcelor Mital projects in France and Spain as continuation of Ghent project

ELKEM Ferrosilicon Alloys
20 % biocarbon in its production in Norway , working towards increasing this to 40 % by 2030

Initiatives in the Canadian Steel Industry

W&P

Iron & Steel Industry, large scale demonstration tests

- ArcelorMittal Dofasco (Hamilton, ON) has conducted demonstration tests using biochar as a substitute for PCI coal, planned in 2021
- Within a few years, the consumption of dry biomass could exceed 100K tonne/yr

Canadian Iron Ore Pellets Production

- ArcelorMittal Mining Canada (Port-Cartier, QC), producer of iron ore concentrate and pellets, uses 220 000 tonnes/yr of coke breeze that could be replaced by biochar
- This corresponds to nearly 1 Mtonne/yr of dry biomass

Ferrosilicon alloys Manufacturing

- Elkem made an announcement in fall 2020 of its plan to build a biocarbon pilot plant in Chicoutimi, Quebec
- Elkem already uses close to 20 % biocarbon in its production in Norway and working towards increasing this to 40 % by 2030

INTRODUCTION TO TORREFACTION OF BIOMASS

1. WHAT IS HAPPENING IF BIOMASS IS EXPOSED TO HEAT
2. M&E BALANCE OF TYPICAL PROCESS SETUP
3. COMPARISON OF DIFFERENT CARBONISATION LEVELS
4. INTEGRATED TORREFACTION LINE
5. DIFFERENT REACTOR TYPES
6. POSSIBILITIES IN SETTING UP THE SUPPLY CHAIN
7. DENSIFICATION AND PRODUCT FORM FACTORS
8. PRODUCT STANDARDS
9. EXPERIENCES IN COAL POWER AND STEEL INDUSTRY INITIATIVES
10. SUSTAINABILITY

Biomass Sustainability Certification Systems

W&P

Certification System	CoC Certificates	Certificates (pellets & chips)	Feedstock	Solid & Liquid	GHG Data
FSC (Forest Stewardship Council) – www.fsc.org	36.727	3231	wood	S	No
PEFC (Program for the Endorsement of Forest Certification Schemes – www.pefc.org	22.142	1255	wood	S	No
RSB (Round table on Sustainable Biomaterials) – www.rsb.org	15	1	wood & agri	S&L	Yes
GGL (Green Gold Lable) - www.greengoldcertified.org	14	14	wood	S	Yes
BetterBiomass - www.betterbiomass.com	94	31	wood & agri	S&L	Yes
ISCC - www.iscc-system.org	3.280	0	wood & agri	L	Yes
SBP (Sustainable Biomas Program) - www.sbp-cert.org	169	169	wood	S	Yes
Red Cert www.redcert.org	1825	0	wood & agri	L	Yes
RSPO (Round table for sustainable Palm Oil) https://rspo.org	2090	0	agri	L	Yes
Bonsucro (Better Sugar Initiative) www.bonsucro.com	140	0	agri	L	Yes

CERTIFIED SUSTAINABLE PALM OIL RSPO

RED cert Gesellschaft zur Zertifizierung nachhaltig erzeugter Biomasse mbH

RSB Roundtable on Sustainable Biomaterials www.rsb.org

ISCC International Sustainability & Carbon Certification

BETTER BIOMASS

PEFC

GGL green gold label

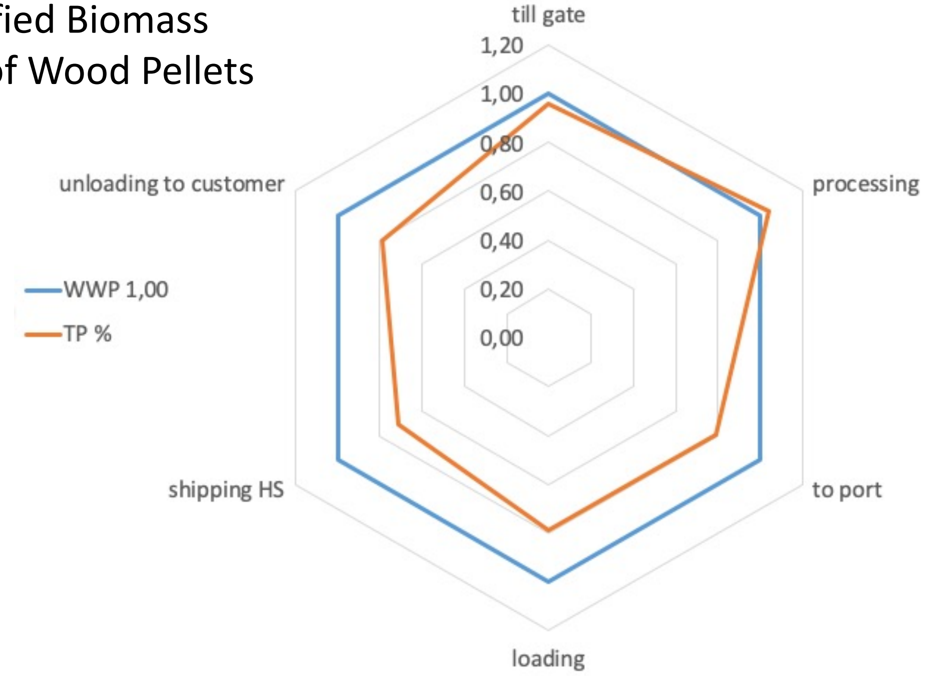
FSC

Based in SPB presentation

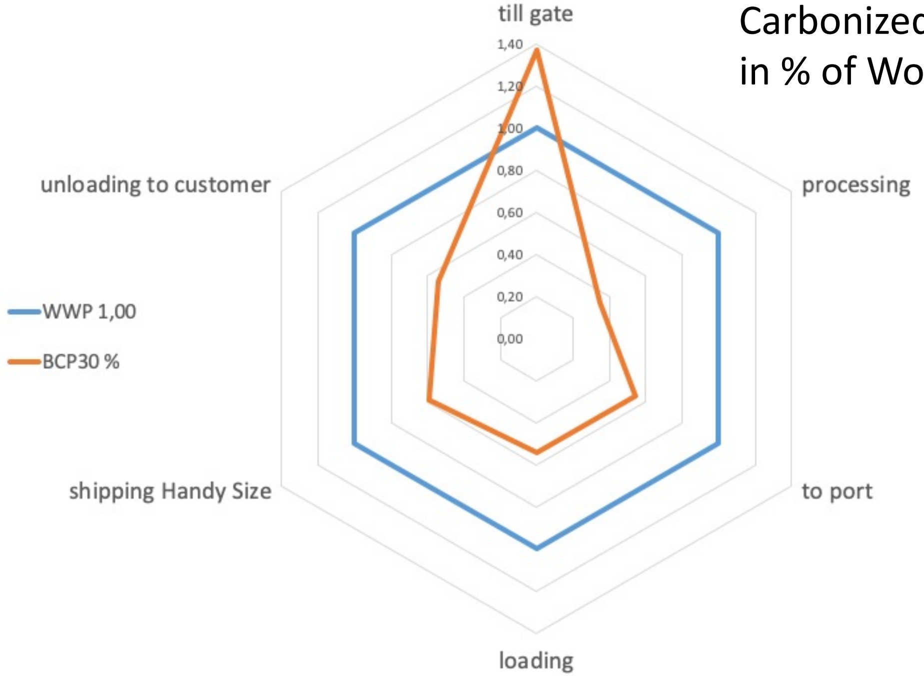
Energy Consumed along the chain

For Torrefied and Carbonized Biomass in % of Wood Pellet chain

Torrefied Biomass
in % of Wood Pellets



Carbonized Biomass
in % of Wood Pellets



	WWP MJ/mt	TP MJ/mt		WWP MJ/GJ	TP MJ/GJ		WWP 1,00	TP %
till gate	627,75	758,47	till gate	35,75	34,17	till gate	1,00	0,96
processing	2.262,72	2.980,04	processin	128,86	134,24	processi	1,00	1,04
to port	36,24	36,24	to port	2,06	1,63	to port	1,00	0,79
loading	16,67	6,46	loading	0,95	0,75	loading	1,00	0,79
shipping HS	987,19	891,21	shipping I	56,22	40,15	shipping	1,00	0,71
unloading to cu	86,07	86,07	unloading	4,90	3,88	unloadin	1,00	0,79
total	4.016,64	4.758,48	total	228,74	214,81	total	1,00	0,94

	WWP MJ/mt	BCP30 MJ/mt		WWP MJ/GJ	BCP30 MJ/GJ		WWP 1,00	BCP30 %
till gate	434,58	1.096,76	till gate	25,97	35,57	till gate	1,00	1,37
processing	2.181,83	1.391,45	processin	130,40	45,13	processi	1,00	0,35
to port	93,76	93,76	to port	5,60	3,04	to port	1,00	0,54
loading	16,67	6,46	loading	1,00	0,54	loading	1,00	0,54
shipping HS	892,70	967,09	shipping I	53,35	31,37	shipping	1,00	0,59
unloading to cu	86,07	86,07	unloading	5,14	2,79	unloadin	1,00	0,54
total	3.705,61	3.641,59	total	221,47	118,44	total	1,00	0,53

INTERNATIONAL BIOMASS TORREFACTION COUNCIL
AN AEBIOM NETWORK

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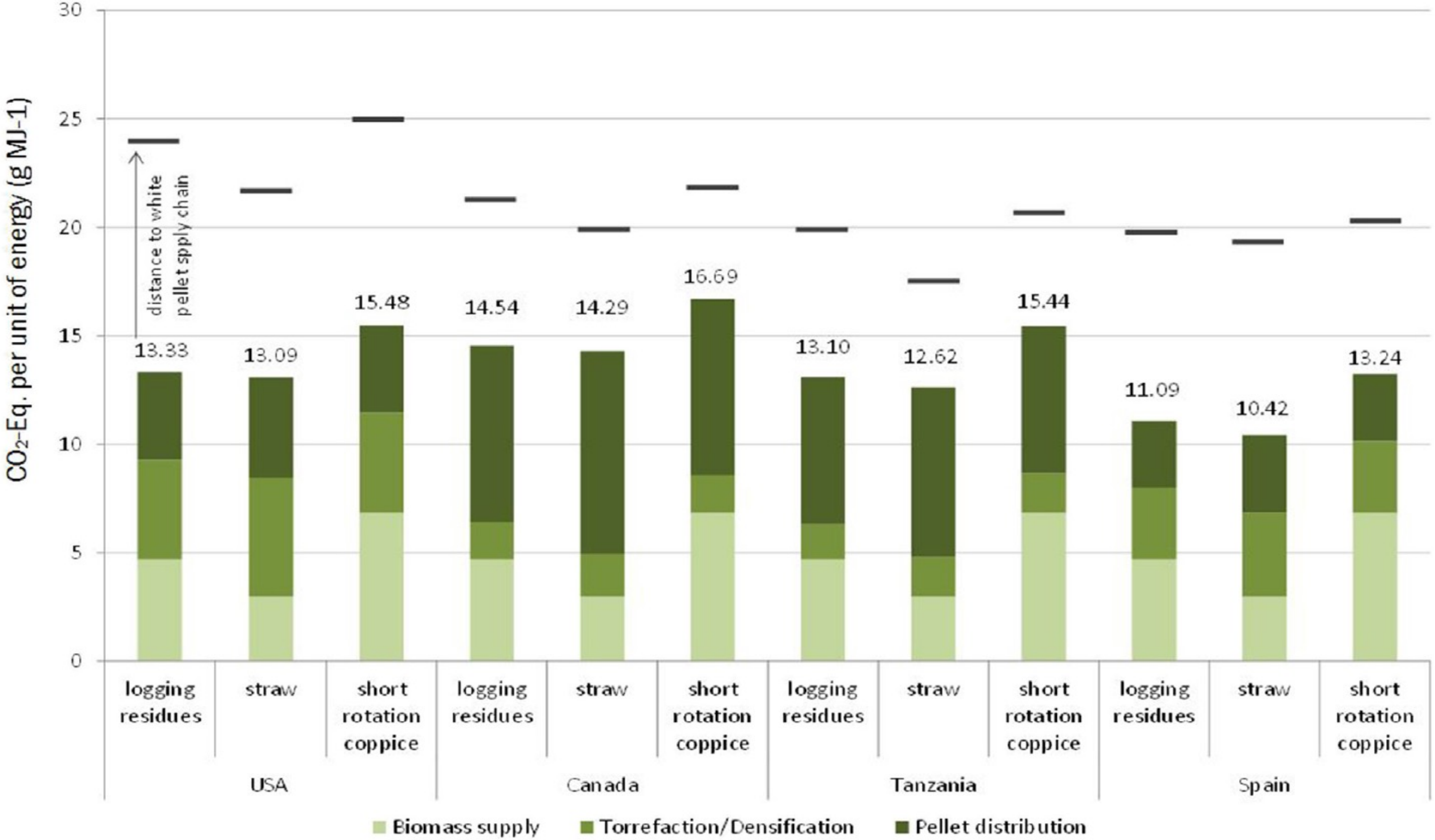
GHG Comparison



Source: D. Thrän, DBFZ

INTERNATIONAL BIOMASS TORREFACTION COUNCIL
A NETWORK OF BIOENERGY EUROPE

IBTC Membership summer 2022

- AFS Advanced Fuel Solutions
- AIREX ENERGY INSPIRED ENERGY
- Arigna Fuels
- CENER
- KAHL
- Wallonie recherche CRA-W
- CPL INDUSTRIES
- CPM EUROPE Your Partner In Productivity
- E COAL ENVIRONMENTALLY EFFICIENT ENERGY
- ECOSTRAT
- ENGIE Lab
- enviva
- MIKSEI MIKKELI
- NATIONAL CARBON TECHNOLOGIES
- NextFuel
- PERPETUAL NEXT
- POLYTECHNIK Biomass Energy
- tsi Responsible Innovation
- C&D CORRUGATING & PAPER
- TNO innovation for life
- TORRCOAL
- W&P
- YILKINS

INTERNATIONAL BIOMASS TORREFACTION COUNCIL
AN AEBIOM NETWORK

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Contact

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Skype: wildwien

APPENDIX I

Some of the known facilities
in construction,
commissioning or operation

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Feedstock Flexibility

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The thermal treatment of the biomass during the torrefaction process can reduce the organically bound chlorine up to 90%

By this Torrefaction is opening up the energy and biocarbon market for agricultural by products, grassy crops and other underutilized biomasses with unacceptable high Chlorine content

This may result in a significant reduction in the feedstock costs
Positive side effect: no sustainability concerns

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Production Facilities

Non exhaustive list

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Company	Project	Location (country)	Status	Planned comissioning	Name plate capacity	Feedstock	Intended NCV	Product form factor (pellet, briquette)
AIREX ENERGY	Surat Thani	Thailand	Under development	Q32020	35.000 tonnes	Rubberwood	21 MJ/kg	Pellets
FUTERRAFUELS	Commercial Scale	Valongo, Portugal	Under construction	Deliveries start in WWP 2021 TP 2022	120.000 TP 55.000 WWP	Eucalyptus and Pine	21 MJ/kg	Pellet
NextFuel	NextFuel Production Facility	Frohnleiten / Austria	In Operation	since 2013	8.000t/a	miscanthuswood chips, B-wood	22-23 MJ/kg	Briquette 70mm diameter
TORR COAL	Dilsen Stokkem	Belgium	In Operation	Since 2011 (2019)	15.000 t/a	Hardwood, Softwood	21-25MJ/kg	Briquettes, Pellets
NextFuel		Finland	engineering	Q3 2022	50.0000t/a	Pine	21 MJ/kg	Briquettes

Production Facilities

Non exhaustive list

Company	Project	Location (country)	Status	Planned comissioning	Name plate capacity	Feedstock	Intended NCV	Product form factor (pellet, briquette)
POLYTECHNIK Biomass Energy	Green Carbon	Üllitz, Germany	In operation	2016	3.000 t/a	mostly hardwoods.	Charcoal/biocoal with Cfix 90-98%.	Charcoal. Size Up to 150 mm.
POLYTECHNIK Biomass Energy	Green Carbon	Zagreb, Croatia	Comissioning	2021	4.500 t/a + 1000 kWe electricity	mostly hardwoods.	Charcoal/biocoal with Cfix 90-98%.	Charcoal. Size Up to 150 mm.
tsi / AMERICAN BIOCARBON	White Castle	USA (Louisiana)	In operation	Since 2017	16.000 tonnes/a	Bagasse	19MJ/kg	Pellets, Briquettes
AIREX ENERGY	Hazelton Biocoal Energy	Canada (BC)	Construction	Q1 2022	100.000 tonnes	Softwood	21 MJ/kg	Pellets
AIREX ENERGY	Becancour	Canada (Qc)	In operation	Since 2016	15.000 tonnes	Softwood	21 MJ/kg	Pellets

Production Facilities

Non exhaustive list

W&P

Company	Project	Location (country)	Status	Planned comissioning	Name plate capacity	Feedstock	Intended NCV	Product form factor (pellet, briquette)
AFS Advanced Fuel Solutions	Oliveira de Azeméis	Portugal	Under construction	2020	100.000mt/a	Softwood	23/30MJ/kg	Pellets
GREENCARBON	Arkangelsk oblast	Russia	Under permissioning	Q2 2023	2 x 40.000 mt/a	Softwood	21-25MJ/kg	Pellets
Oregon torrefaction		USA (Oregon)	Under construction	Q3 2019	90.000mt/a	Softwood	21-22,5MJ/kg	Pellets, Briquettes
Boreal Bioenergy	McBride, BC	Canada	Project closing	na	250.000 to be increased	Softwood	21-23MJ/kg	
Arsari	Kalimantan	Indonesia	In final negotiation	delayed	80.000 to be increased	Softwood	21MJ/kg	Briquettes, Pellets
HM3 Energy Inc.	Troutdale	USA (Oregon)	Under construction		100.000 mt/a	Softwood		TorrB® torrefied biomass briquettes

Production Facilities

Non exhaustive list

Company	Project	Location (country)	Status	Planned comissioning	Name plate capacity	Feedstock	Intended NCV	Product form factor (pellet, briquette)
Yilkins	Ruurlo Demo	NL	In operation	2019	5.000mt/a	Softwood	21/30MJ/kg	Pellets
National Carbon	California 1+2	USA	Under permissioning	Q2 2023	2 x 100.000 mt/a	Softwood	21-23MJ/kg	Pellets, Briquettes
National Carbon		USA (Minnesota)	In operation		90.000mt/a	Softwood	21-30MJ/kg	Pellets, Briquettes
AGI Capital	Nehoiu	Romania	Pellet Mill upgrade	Q2 2023	120.000	Softwood	21-23MJ/kg	Pellets, Briquettes
CEG	UK	Indonesia	In operation	2016	40.000	Mixed wood	21MJ/kg	Pellets
Perpetual Next	Baltania	Estonia	In commissioning		180.000 mt/a	Softwood	21MJ/kg	Pellets

Characterisation of Torrefaction Reactor types

Reactor Type	Advantages	Limitations	Special Adjustments
Rotary drum dryers	• Various methods to control torrefaction process (length, slope angle, rotation speed, temperature, filling level) • Drum can be direct and indirect heating • Available for all temperature ranges • Uniform heat transfer • Ability to take wide range of biomass sizes and waste types • Classification of particles - Smaller particles will pass faster • Widely proven technology for biomass drying and heating •	• Lower heat transfer • Poor temperature control • May increase fines due to friction between biomass and drum wall • Typical unit capacity is at 10-12 t/h input, or 5 t/ h torrefied product, no experience with larger drums in biomass high temperature treatment	• Indirect heated drums are standard for torrefaction • Baffles or tube bundles increase heat transfer and efficiency and simplify control • Calciner style reactors with very good temperature control
Moving bed reactor	• Relatively simple, low cost reactor • High throughput capacity • No moving parts • Also applicable for materials of lower density • Good heat transfer • Simple control by temperature and volumetric throughput	• Difficult temperature control respectively control of homogenous heat distribution in the bed • Risk of gas channel formation in biomass leading to non-uniform torrefaction • unfortunate partial compression of biomass particles can lead to pressure drops resulting in system shut down	

Reactor Type	Advantages	Limitations	Special Adjustments
Belt Dryer in form of Vibrating belts	• Better temperature control • Ability to take wide range of biomass sizes • Easy control of residence time through the speed and length of the belt respectively vibration frequency • Proven technology in biomass drying industry	• Homogenous particle size necessary • Not suitable for materials of low bulk density • Limited upscaling potential since capacity is dependent on the surface area of the belt (other systems are volume dependent) • Potential of clogging with torrefaction tars of open belt structures • Temperature limitation • System has many mechanical parts, which increases maintenance costs • Large footprint	• Steel belts only - because of high temperatures • vibrating belt
Multiple Hearth Drier	• Ability to take wide range of biomass sizes • Scalable technology (8 m of diameter possible)	• increased risk of torrgas condensation • making process less sustainable and gas combustion leads to moisture production in the flue gas. This gives a lower efficient combustion of the flue gas	

Characterisation of Torrefaction Reactor types

W&P

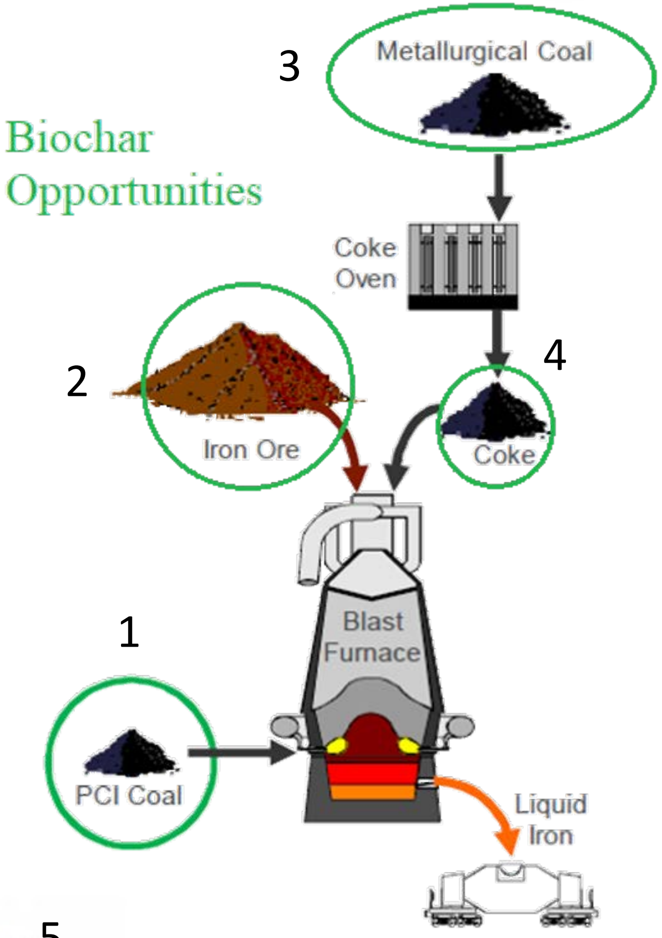
Reactor Type	Advantages	Limitations	Special Adjustments
Microwave reactors	• Radiation based heat transfer instead of convection and conduction • High heat transfer and fast torrefaction • Heat transfer less dependent on the size of the biomass particle - ability to use large size biomass • Very responsive in the control • Modular	• Used mostly in preservation of timber for outdoor application • Unproven technology for drying or torrefaction of biomass - effects of rapid heating of biomass not known • Electric energy main source • Uniformity of biomass heating seems problematic • Requires integration with other conventional heaters to achieve uniform heating	
Cyclone technology	• Low residence time (<100 s) • Large throughput due to fast heat transfer and low residence time • Scalable technology (to 25 t/h) • No moving parts (low maintenance)	• High utility fuel demand for preconditioning (sizing) of feedstock • Homogenous, small particle size necessary • Volumetric reactor capacity is limited • High temperature leads to a greater loss of volatiles • Risk of tar formation due to relative higher loss of volatiles	

Reactor Type	Advantages	Limitations	Special Adjustments
Heating screw reactors (augers)	• Relatively cheap reactor • Better biomass flow • Ability to take wide range of biomass sizes • Proven technology	• Unequal torrefaction as mixing inside biomass stream through screw channel is limited • Need for thermo-oil as heat transfer medium • Limited heat-transfer to inner layers of the biomass stream • Limited scaling potential as the ratio of screw sur-face area/biomass volume is less attractive with larger screws • Risk of tarr condensation in cooler and char formation in overheated zones	

Torrefied Biomass in the steel making industry

Millions of tonnes of biomass/biochar will be needed to replace fossil fuel carbon

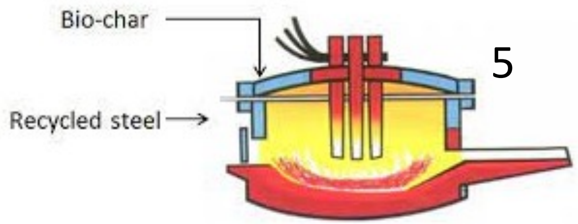
1. Iron ore briquettes or pellets contain ca. 4% carbon at 580 mil tonnes market size
2. Up to 25% replacement of pulverized coal injection (PCI) in blast furnace ironmaking
3. Up to 100% replacement of coke breeze for the induration of iron ore pellets
4. 5% substitution of metallurgical coal in cokemaking (slot ovens)
5. Replacement of coke briquettes by biochar briquettes
6. Up to 100% replacement of injection carbon (for slag foaming) and charge carbon (heat) in electric arc furnace (EAF) steelmaking



On average, it is estimated that the global steel industry uses about 2 billion tonnes of iron ore, 1 billion tonnes of metallurgical coal

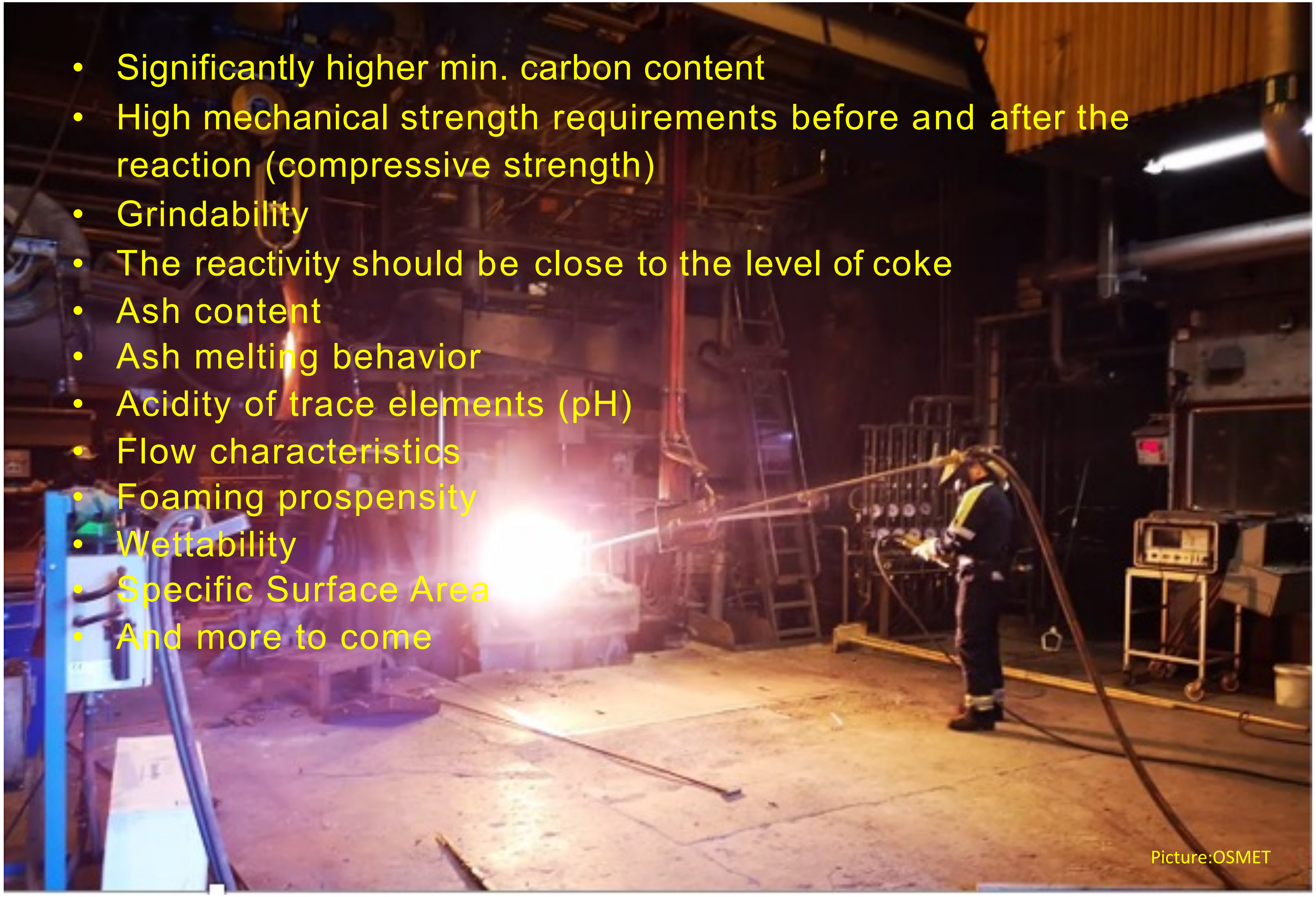
The biocarbon is mainly used as a reductant,

for example: **$2\ Fe_2O_3 + 3C \longrightarrow 4\ Fe + 3\ CO_2$**



Additional Requirements to Fuels

- Significantly higher min. carbon content
- High mechanical strength requirements before and after the reaction (compressive strength)
- Grindability
- The reactivity should be close to the level of coke
- Ash content
- Ash melting behavior
- Acidity of trace elements (pH)
- Flow characteristics
- Foaming prospensity
- Wettability
- Specific Surface Area
- And more to come



Picture:OSMET