TORREFIED WOOD
A New Emerging Energy Carrier

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WOOD PELLET ASSOCIATION OF CANADA

Presentation

- History of Torrefaction
- Torrefaction as a Technology
- Status of Torrefaction Worldwide
- The WPAC Torrefaction Project
- Torrefied Pellet Product Specification
- European SECTOR Project

HISTORY OF TORREFACTION

Commodities	Temperature ^{o}C	Started
Beans (coffee), nuts, seeds (hot air)	+190 to 280	1000 A.D. (Ethiopia) 1971 (Starbucks)
Thermo- wood (outdoor furniture, decks) (Steam, hot air, oil)	+ 180	1980th (Finland)
High calorific biofuels (wood, agro-mtrl) (Steam, nitrogen)	+ 250 to 290	1987 (experimentation) 2000 (targeted research) 2004 (proof of concept) 2009 (pilot scale) 2010 (demonstration) 2015 (commercialization)

10 Phases of Torrefied Pellets Production

A. Pre-torrefaction reactions

1. Fractionation to size (if required)
2. Conventional pre-drying of feedstock

B. Inside torrefaction reactor (inert condition)

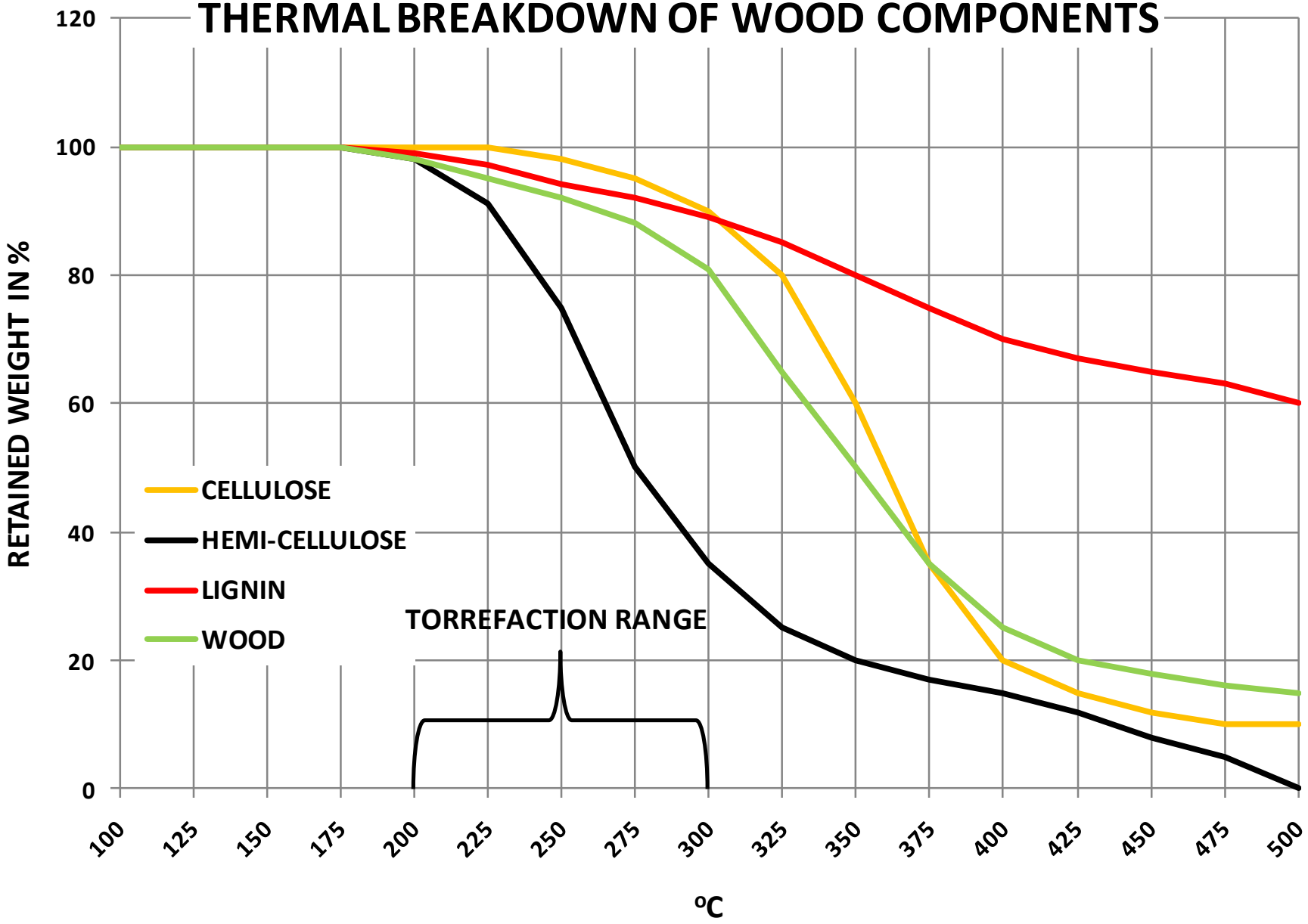
3. Evaporation of residual moisture
4. Heating of feedstock up to +100oC
5. De-polymerization of hemi-cellulose

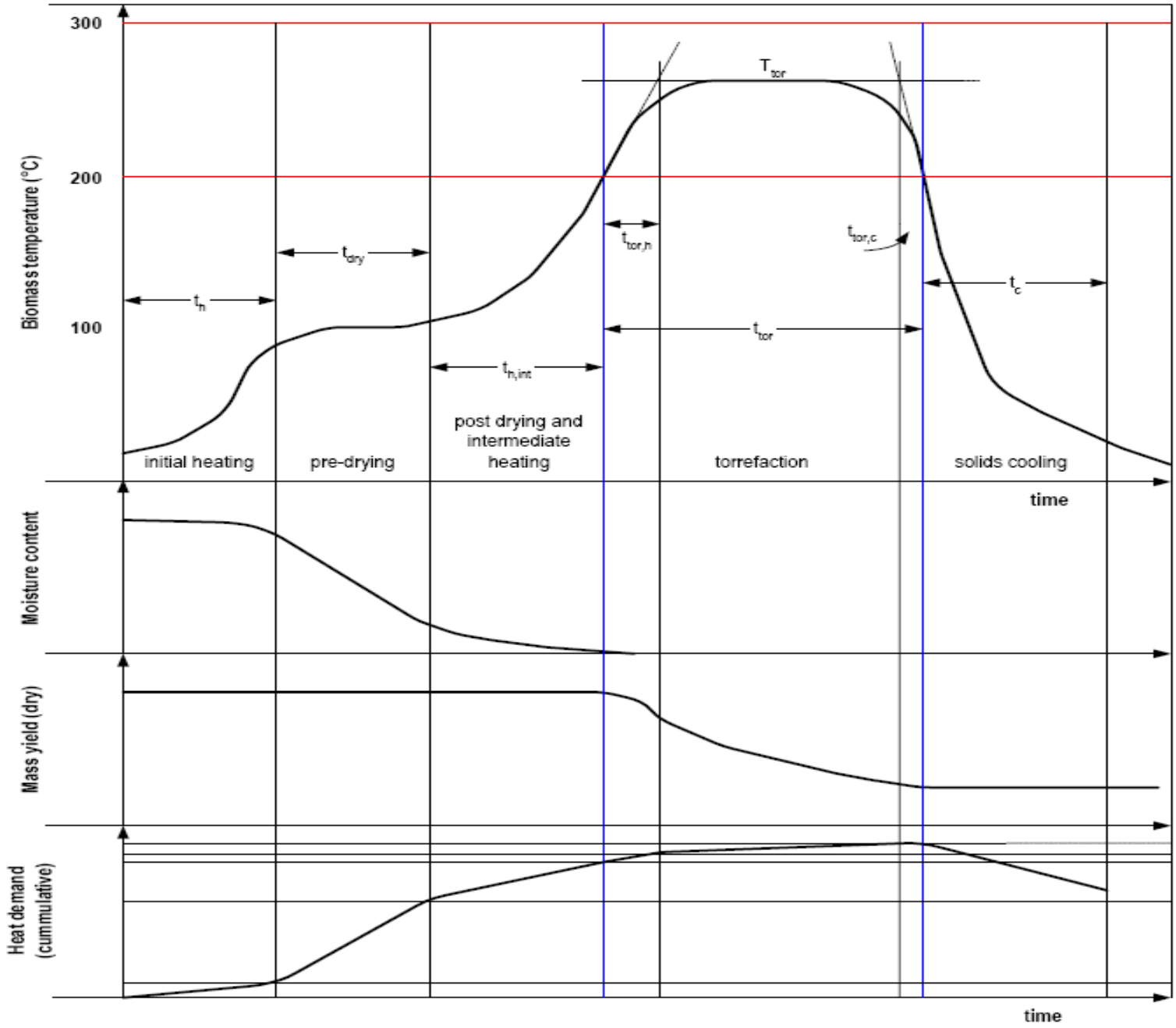
C. Post-torrefaction reactions (inert condition)

6. Cooling and re-polymerization
7. Crushing to size
8. Conditioning
9. Densification to pellets

D. Post-conditioning

10. Cooling and dust removal


THERMAL BREAKDOWN OF WOOD COMPONENTS
RETAINED WEIGHT IN %
120
100
80
60
40
20
0
CELLULOSE
HEMI-CELLULOSE
LIGNIN
WOOD
TORREFACTION RANGE
100
125
150
175
200
225
250
275
300
325
350
375
400
425
450
475
500
°C


300
200
100
Biomass temperature (°C)
T_{tor}
t_{dry}
t_h
$t_{tor,h}$
$t_{tor,c}$
t_c
t_{tor}
$t_{h,int}$
post drying and intermediate heating
initial heating
pre-drying
torrefaction
solids cooling
time
Moisture content
Mass yield (dry)
Heat demand (cummulative)
time

TORREFACTION REACTION PRODUCTS

BIOMASS

SOLID TORREFIED MATERIAL 70% of weight

- ORIGINAL AND MODIFIED SUGARS
- NEW POLYMERS
- CHAR
- ASH

LIQUID CONDENSIBLES 20% of weight

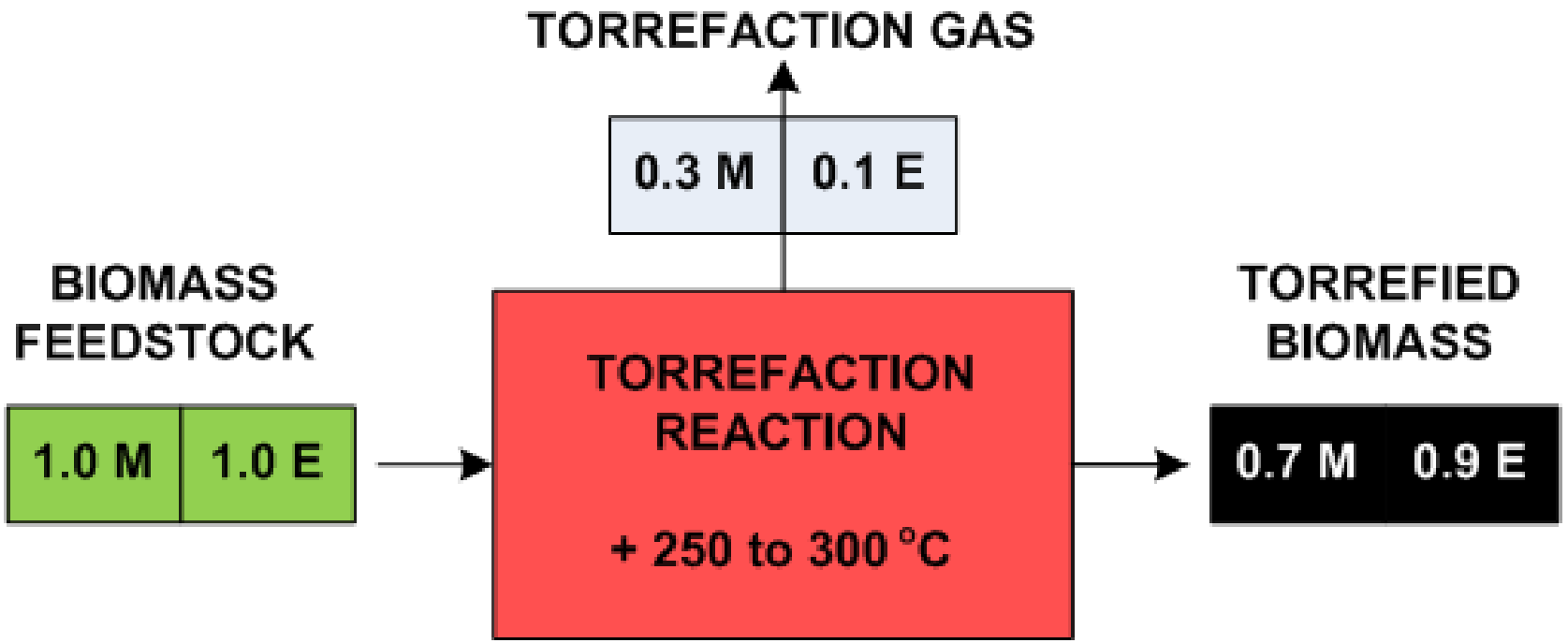
- WATER
- ORGANICS
- LIPIDS

NON-CONDENSIBLE GAS 10% of weight

- CO_2
- CO
- CH_4
- H_2
- TRACE OF OTHER HIGHER ORGANICS

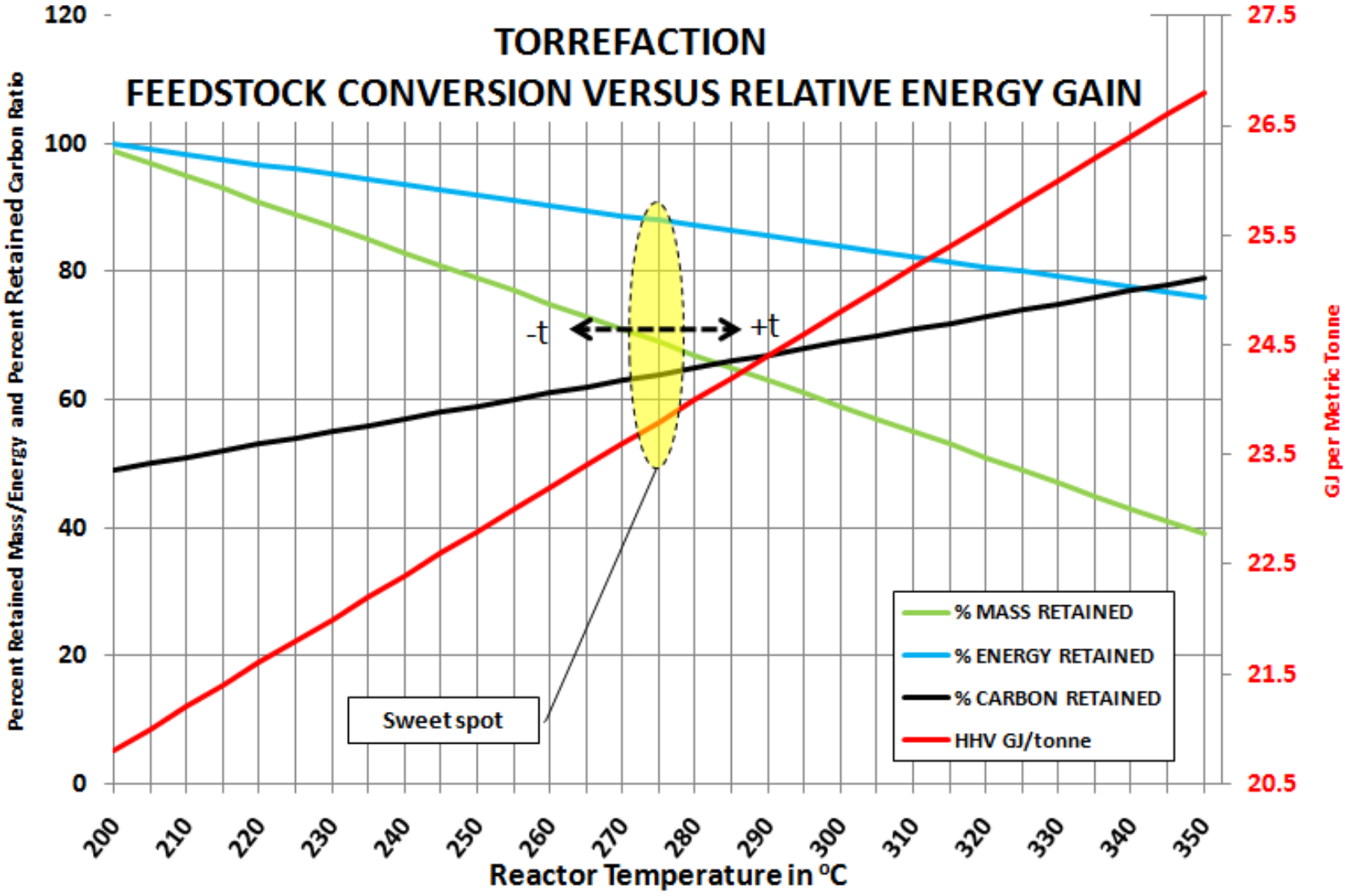
MASS AND ENERGY BALANCE

(MATERIAL ONLY)



TORREFACTION

FEEDSTOCK CONVERSION VERSUS RELATIVE ENERGY GAIN



EXAMPLES OF TECHNOLOGIES & TECHNOLOGY PROVIDERS

TORREFACTION

INDIRECT HEATING (THROUGH WALL)

AUGER	AGRITECH ALLIED BLOWER FOX COAL PICHENEY
DRUM	TORR-COAL

DIRECT HEATING (HOT GAS TO BED)

GAS-LOOP WITH HEAT EXCHANGER (No O_2)

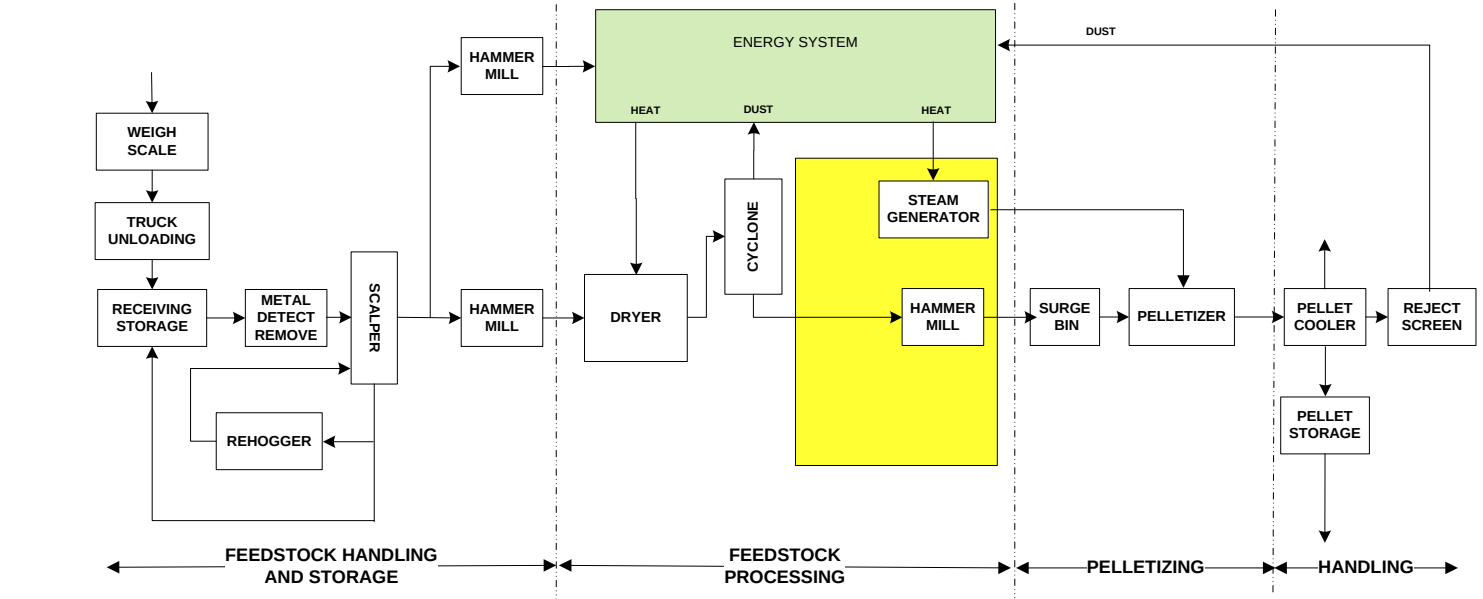
MOVING BED	ECN
VIBRATING BELT	STRAMPROY
MULTIPLE HEATING ZONE	WYSSMONT INTEGRO CMI-NESA
DRUM	ROTAWAVE

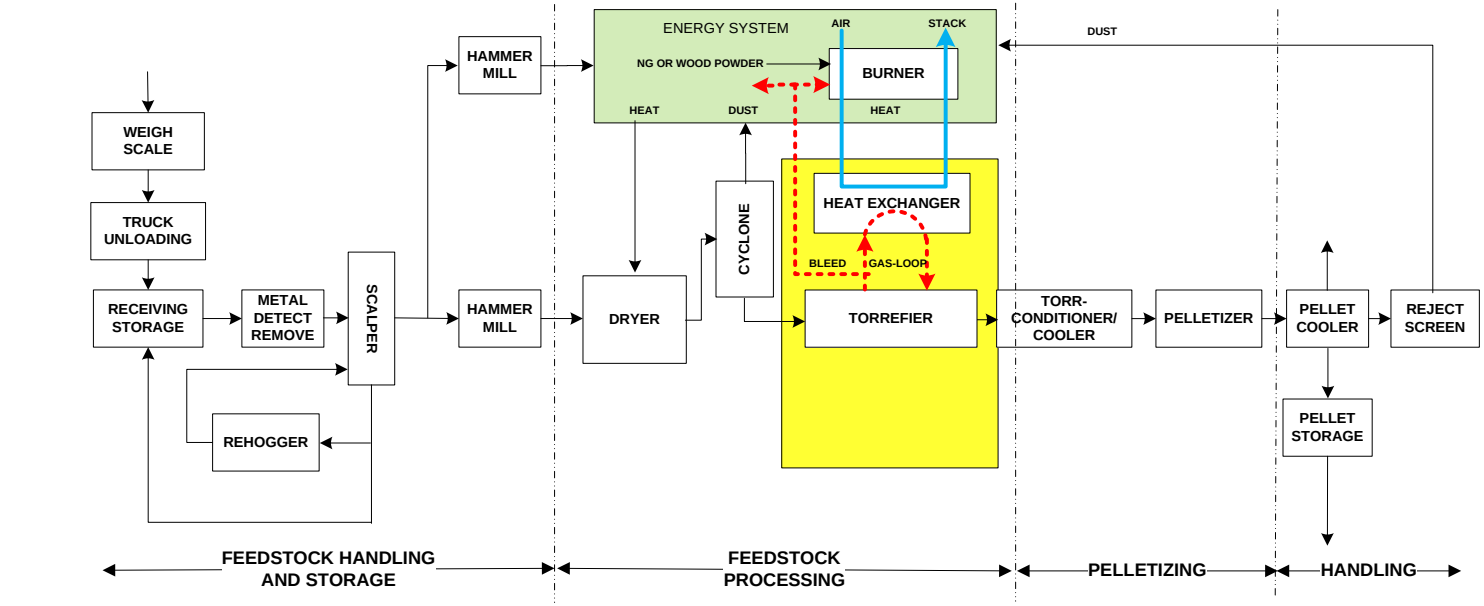
GAS-LOOP LINKED TO BURNER (Low O_2)

TUNNEL	ALTERNA
MOVING BED	THERMYA
TORBED	TOPELL

COMMERCIALIZATION PROJECTS (selected)

Party	Demo tech	Target date	Capacity tonne/h	Party	Demo tech	Target date	Capacity tonne/h
Torr-coal	Torr-coal	2010/11	4.5	Agritech	Torre-tech	2011	5
4Energy	Stramproy	2010/11	5.5	RFT	RFT	2012	5
Torrsys	Torrsys	2011/12	5	Stramproy	Stramproy	2010/11	5.5
EBES	ACB	2012	1.5	New Earth	ECO-PYRO	2012	2
Integro	Wyssmont	2010/11	2	ECN	BO2	2012	5
Konza	Konza	2012	10	IDEMA	Thermya	2011	2.5
Topell	Torbed	2011	8	Atmosclear	Airless	2011	5
ETPC	BioEndev	2013	4.5	Diacarbon	Diacarbon	2014	8
BTG	BTG	2014	5	CanBiocoal	Rotawave	2011	12
Foxcoal	Foxcoal	2010/11	4.2	C2SKY		2011	5
Biolake	ECN	2011	5	WPAC	TBA	2012	5


WEIGH SCALE
TRUCK UNLOADING
RECEIVING STORAGE
METAL DETECT REMOVE
SCALPER
REHOGGER
HAMMER MILL
HAMMER MILL
ENERGY SYSTEM
HEAT
DUST
HEAT
DRYER
CYCLONE
STEAM GENERATOR
HAMMER MILL
DUST
SURGE BIN
PELLETIZER
PELLET COOLER
REJECT SCREEN
PELLET STORAGE
FEEDSTOCK HANDLING AND STORAGE
FEEDSTOCK PROCESSING
PELLETIZING
HANDLING


WEIGH SCALE
TRUCK UNLOADING
RECEIVING STORAGE
METAL DETECT REMOVE
SCALPER
REHOGGER
HAMMER MILL
HAMMER MILL
ENERGY SYSTEM
AIR
STACK
NG OR WOOD POWDER
BURNER
HEAT
DUST
HEAT
DRYER
CYCLONE
HEAT EXCHANGER
BLEED
GAS-LOOP
TORREFIER
DUST
TORR-CONDITIONER/ COOLER
PELLETIZER
PELLET COOLER
REJECT SCREEN
PELLET STORAGE
FEEDSTOCK HANDLING AND STORAGE
FEEDSTOCK PROCESSING
PELLETIZING
HANDLING

Implementation Challenges

A. Particle size

1. Mass flow limitation

B. Consistency of feedstock particle size

2. Heat Transfervariations = uneven carbonization
3. Clogging or channeling of mass flow

C. Closing of gas-loop

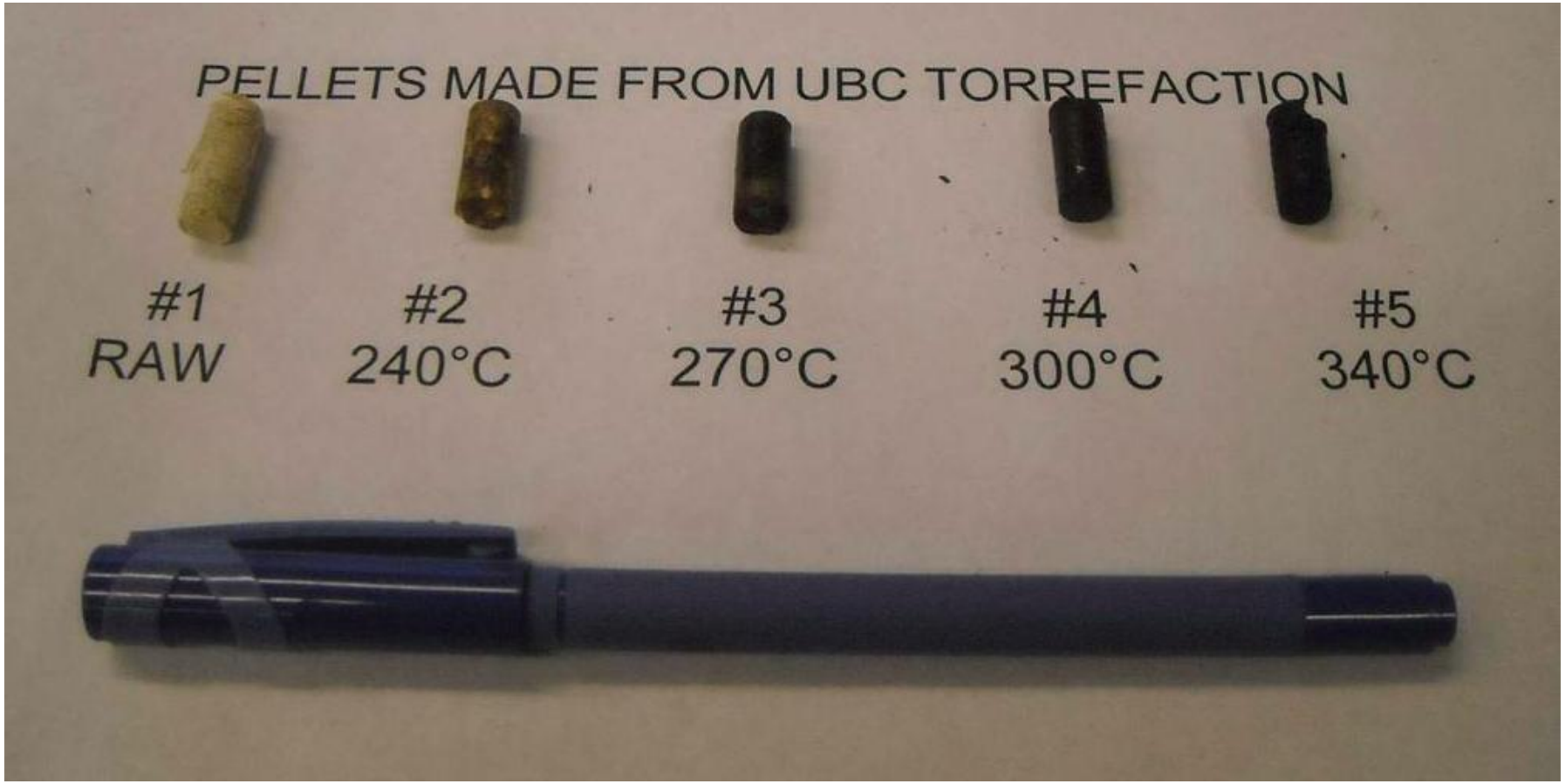
4. In-effective use of volatile calorific content
5. Condensation in ductwork

D. Reactor vessel

6. Control strategy (time & temperature)
   - moisture variations, particle size, volatile content
7. Fouling

E. Densification

8. High temperature of feedstock
9. Highly reactive dust (risk of fires and explosions)


PELLETS MADE FROM UBC TORREFACTION
#1
RAW
#2
240°C
#3
270°C
#4
300°C
#5
340°C

PRODUCT SPECIFICATION - COMPARATIVE DATA						
Parameter	Measure	Wood	Wood Pellets	Torrefied Pellets	Charcoal	Fossil Coal
Calorific value (HHV)	GJ/metric tonne	9 to 12	17 to 20	21 to 24	26 to 30	17 to 30
	BTU/lbs	3,833 to 5,150	7,296 to 8,584	9,013 to 10,300	11,160 to 12,876	7,296 to 12,876
Moisture	% of weight	30 to 50	4 to 10	1 to 5	1 to 5	10 to 15
Fixed carbon	% of weight db	20 to 25	20 to 25	28 to 35	85 to 87	50 to 55
Volatiles	% of weight db	70 to 75	70 to 75	55 to 65	10 to 12	15 to 30
Bulk Density	kg/m^3	200 to 250	650 to 725	700 to 800	180 to 240	800 to 850
Hardgrove Grindability Index	HGI			> 45		> 50
Deflagration index (K_{st})	bar.m/sec	100	140 to 160	> 160 ?	> 180	120 to 140
Electrostatic propensity		Low	Moderate	High	Very high	Moderate
Hygroscopic properties		Hydrophilic	Hydrophilic	Hydrophobic ?	Hydrophobic ?	Hydrophobic
Leaching		Yes	Yes	Yes	Yes	Yes
Self-heating		Moderate	High	?	Extreme	High
Off-gassing		Extreme	Extreme	?	Extreme	High
Oxygen depletion		Extreme	Extreme	?	Extreme	High

1000 Btu/lb = 2.33 gigajoules per tonne (GJ/t)

1 GJ/tonne = 429.2 Btu/lbs

WPAC TORREFIED PELLETS PROJECT

- 5 metric tonne per hour (30-35,000/y)
- Integration with existing pellet plant (Premium Pellet Ltd in Vanderhoof, BC)
- Selection of technology in August 2011
- Operating during 2012
- Financing; federal, provincial, private
- Seeking collaboration with power company

THE "SECTOR" PROJECT IN EUROPE

- European industry/research torrefaction project
- **Management by German Biomass Research Center (DBFZ)**
- **Colaboration Consortimum members**

RWE	**EON**	**BIOS**
Vattenfall	**ECN**	**BE2020**
Topell	**TFZ**	**TUW**
ETPC	**DBFZ**	**TUHH**
VTT	**DTI**	**Procede**
IFK	**OFI**	**IEN**
CENER	**DB**	**DRC/WPAC**

THE "SECTOR" PROJECT IN EUROPE

- Driving torrefaction to large scale commercialization
- Broad range of feedstock (wood, agro)
- 10% co-firing = 100 Mt dry feedstock = 1,000 torrplants (100k/ea)
- Development of recipes for a few standard qualities of fuel
- Development of standard testing methods
- Development of large scale safe handling and storage
- Value chain evaluation of large scale deployment policies
- Development of LCA model and sustainability criteria (env/soc)

THE "SECTOR" PROJECT IN EUROPE

- **Potential Canadian Participation**
  - **Sharing of results from R&D in industry, institutes and universities**
- **Benefits to the Canadian economy and industry**
  - **Europe is largest market for Canadian pellets**
  - **Staying close to demand by large users of next generation biofuels**
  - **Exchange of experts and expert knowledge**
    - **Feedstock evaluation, torrefaction, logistics, combustion, sustainability**
  - **Avoid "re-inventing the wheel"**
  - **Stay alert of potential trade barriers before they happen**
  - **Technological feed-in to the WPAC Torrefaction Project**
  - **Participation in Round-Robin tests of materials and test methodologies**

Torrefied Pellets – Silver Bullet ?

The SECTOR and the WPAC Projects will likely to tell us.