TORREFIED WOOD
A New Emerging Energy Carrier

presented to

Clean Coal Power Coalition CCPC

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Staffan Melin

Research Director

WOOD PELLET ASSOCIATION OF CANADA

Outline

- History of Torrefaction
- Torrefaction as a Technology
- Status of Torrefaction Worldwide
- The WPAC Torrefaction Project
- Torrefied Pellet Product Specification
- WPAC Serving the Power Industry

HISTORY OF TORREFACTION

Commodities	Temperature oC	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 (France)

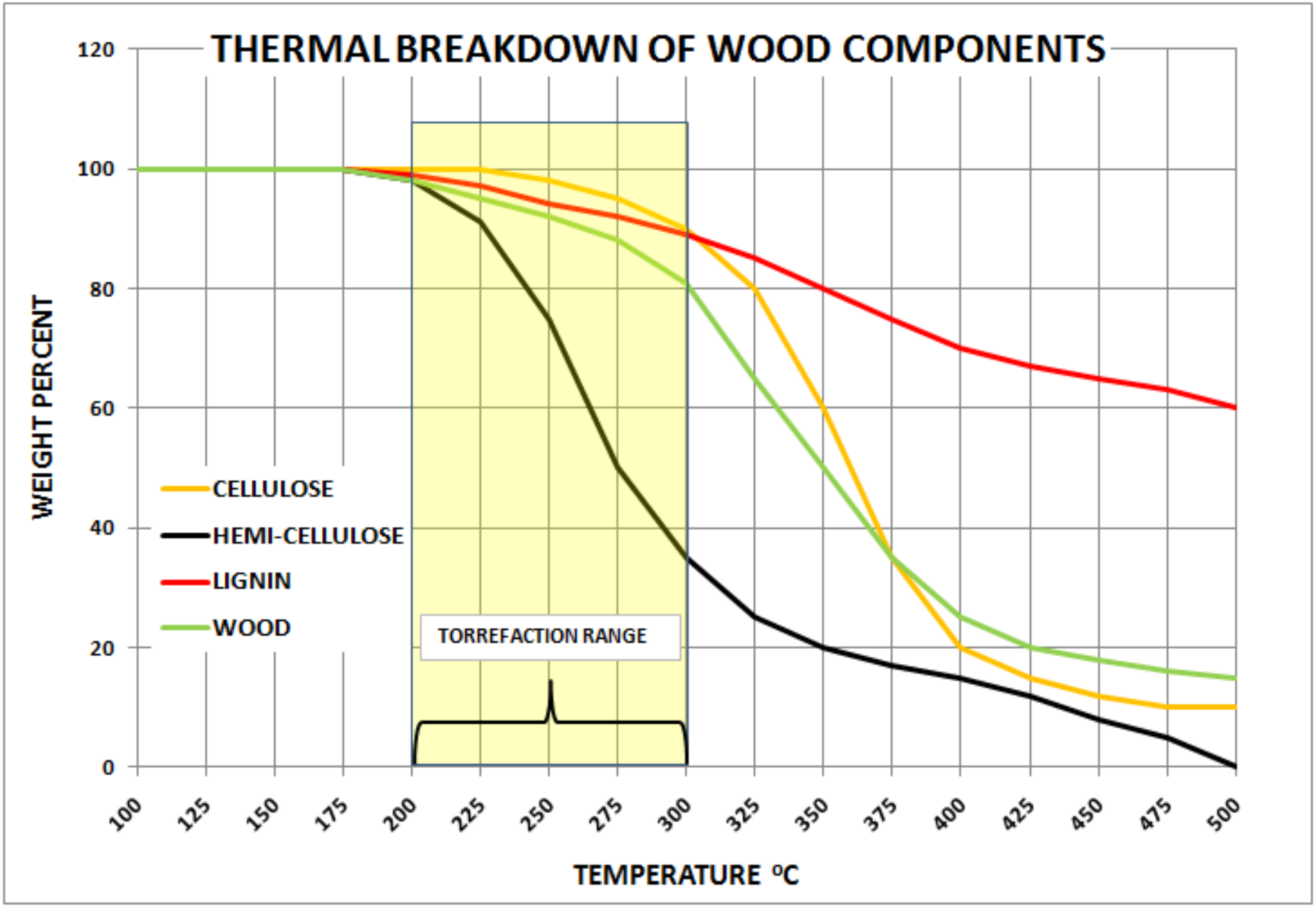
TORREFACTION PATENTS

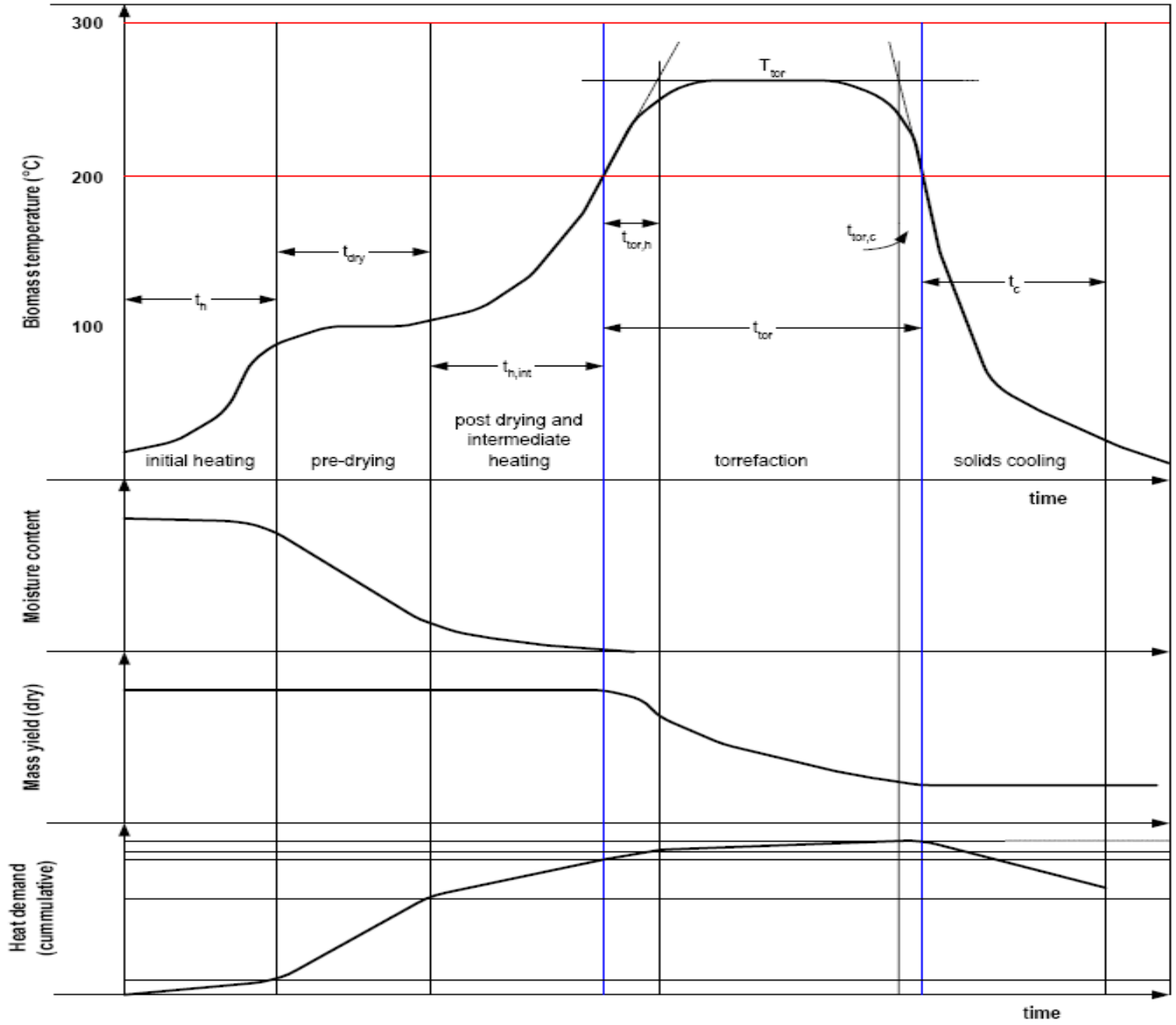
Jurisdiction	Valid patents	Applications	Expired / Abandoned	Total
Canada	0	7	2	9
US	1	13	2	16
European	0	6	2	8
World	0	12	3	15

Assignee	Valid patents	Applications	Notes
ECN	0	4	Same patent, 4 jurisdictions. Also one rejected application
Wyssmont	0	2	Same patent (US & Canada)
Thermya	0	4	Same patent, 4 jurisdictions
Torr-Coal	0	4	Same patent, 4 jurisdictions
North Carolina State Univ.	0	1	US only. Agri-tech is licensee

The 10 Phases of torrefied pellet production

- A. Pre torrefaction reactor
    1. Fractionation to size (if required)
    2. Conventional pre-drying of feedstock
- B. Inside reactor (inert condition)
    3. Evaporation of residual moisture
    4. Heating of feedstock up to + 250 to 280°C
    5. De-polymerization of hemi-cellulose
- C. Post torrefaction reactor (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
WEIGHT PERCENT
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
TEMPERATURE °C


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

TORREFACTION REACTION PRODUCTS

BIOMASS

SOLID TORREIED MATERIAL
80% of weight

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

LIQUID CONDENSIBLES
15% of weight

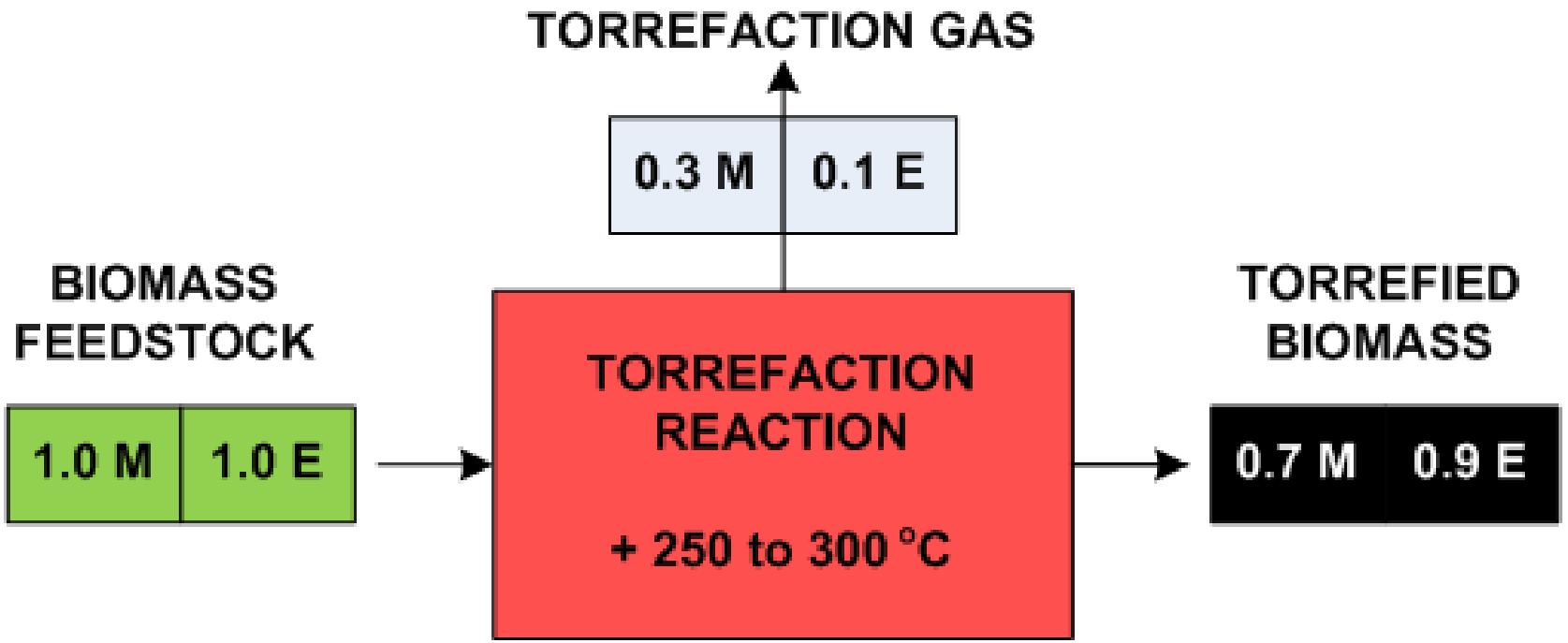
- WATER
- ORGANICS
- LIPIDS

NON-CONDENSIBLE GAS
5% of weight

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

MASS AND ENERGY BALANCE

(MATERIAL ONLY)



EXAMPLES OF TECHNOLOGIES & TECHNOLOGY PROVIDERS

TORREFACTION

INDIRECT HEATING (THROUGH WALL)

AUGER	AGRITECH ALLIED BLOWER FOX COAL PICHENEY
DRUM	TORR-COAL

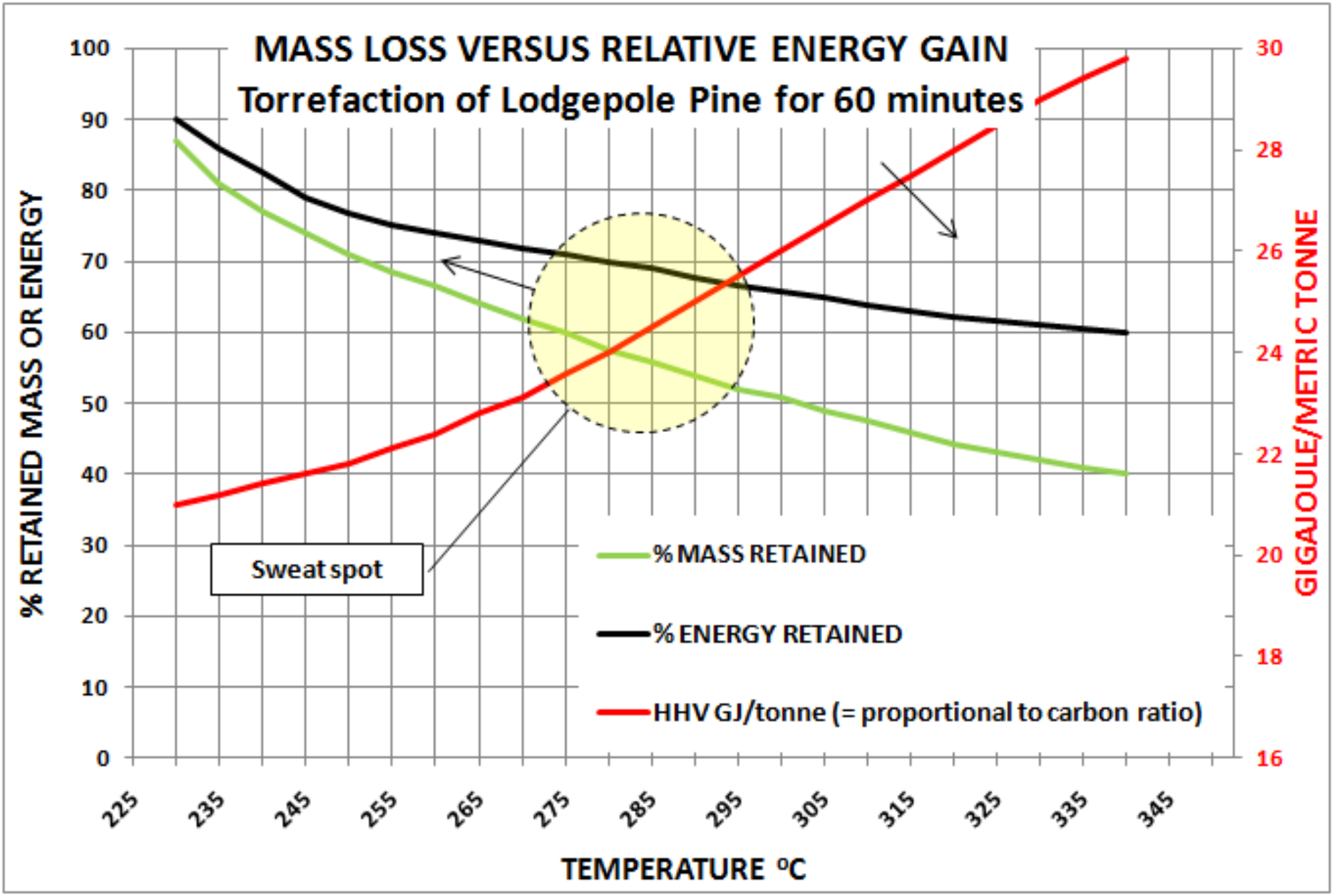
DIRECT HEATING (HOT GAS TO BED)

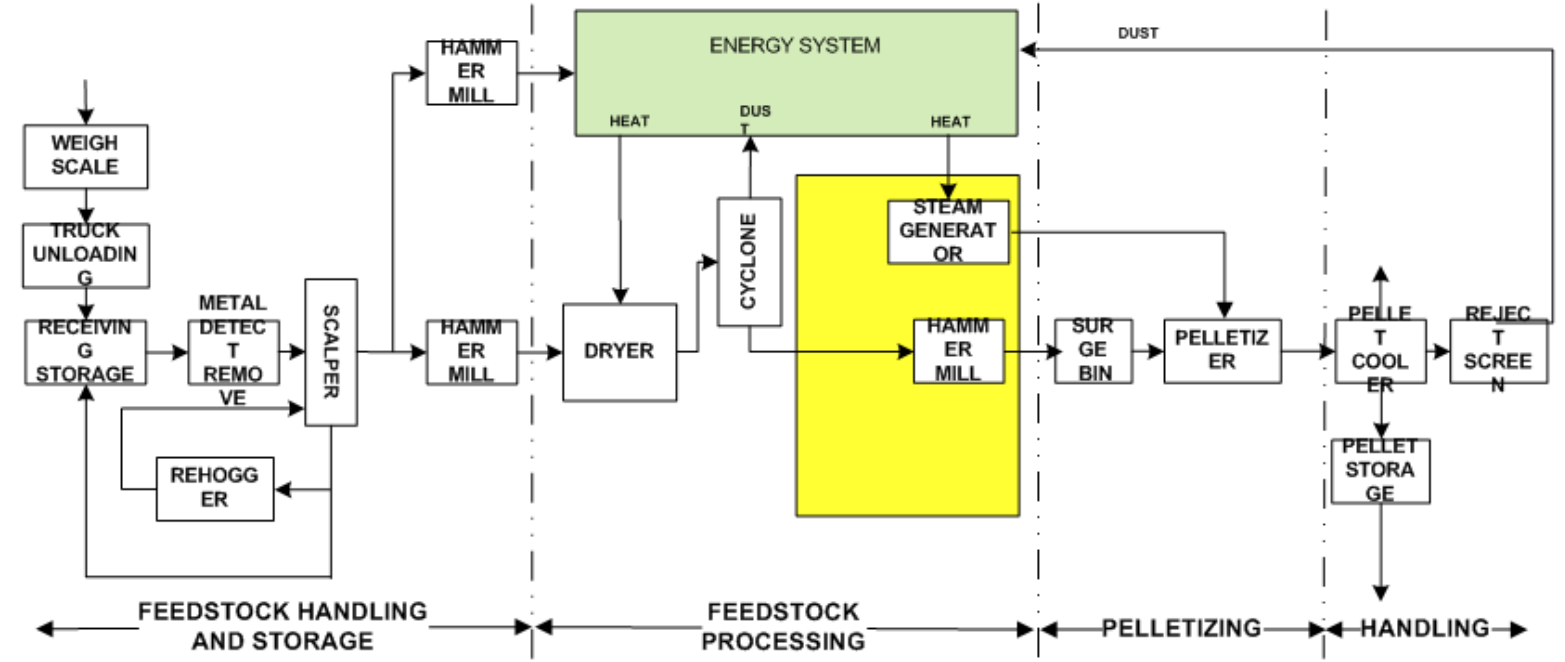
GAS-LOOP WITH HEAT EXCHANGER (No O_2)

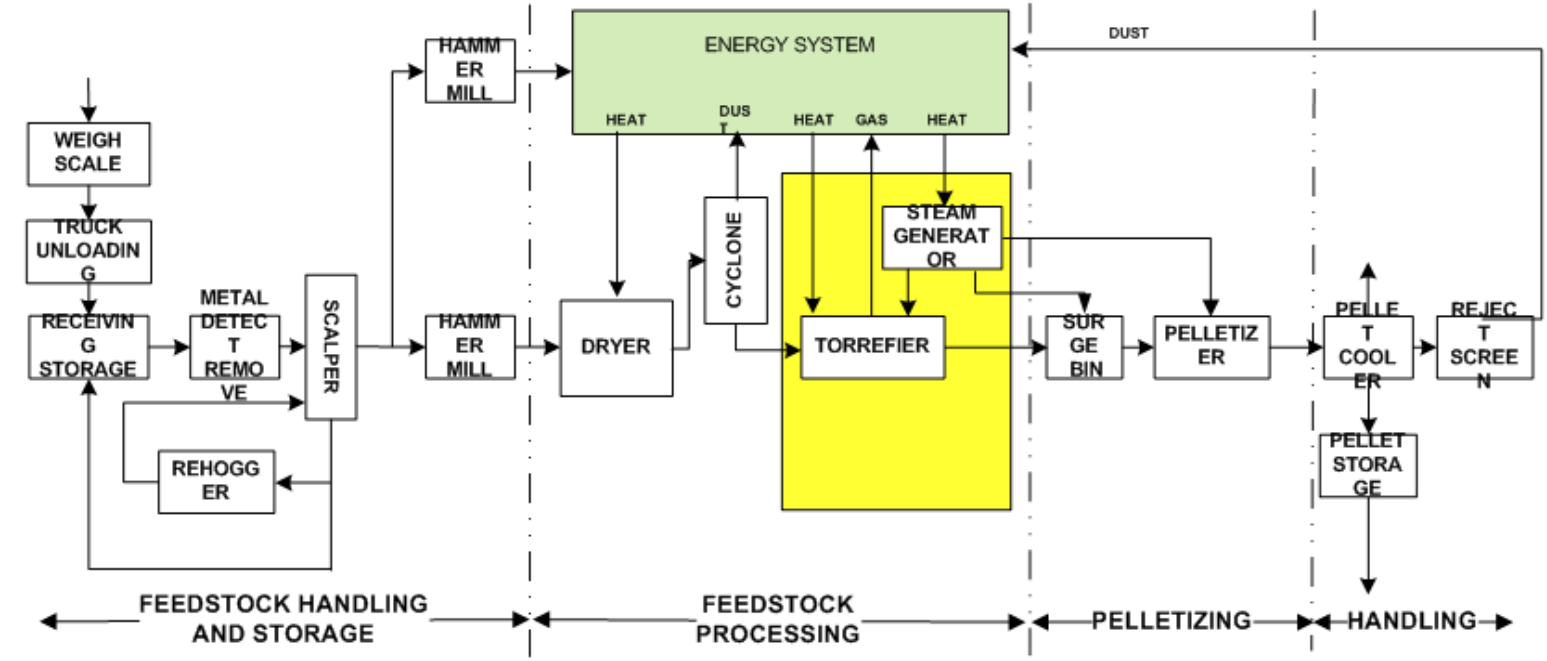
MOVING BED	ECN
VIBRATING BELT	STRAMPROY
MULTIPLE HEATING ZONE	WYSSMONT INTEGRO CMI-NESA
DRUM	ROTAWAVE

GAS-LOOP LINKED TO BURNER (Low O_2)

TUNNEL	ALTERNA
MOVING BED	THERMYA
TORBED	TOPELL


MASS LOSS VERSUS RELATIVE ENERGY GAIN
Torrefaction of Lodgepole Pine for 60 minutes
% RETAINED MASS OR ENERGY
GIGAJOULE/METRIC TONNE
TEMPERATURE °C
Sweat spot
% MASS RETAINED
% ENERGY RETAINED
HHV GJ/tonne (= proportional to carbon ratio)
100
90
80
70
60
50
40
30
20
10
0
30
28
26
24
22
20
18
16
225
235
245
255
265
275
285
295
305
315
325
335
345


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
SURGE BIN
PELLETIZER
PELLET COOLER
REJECT SCREEN
PELLET STORAGE
DUST
FEEDSTOCK HANDLING AND STORAGE
FEEDSTOCK PROCESSING
PELLETIZING
HANDLING


WEIGH SCALE
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FEEDSTOCK HANDLING AND STORAGE
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PELLETIZING
HANDLING

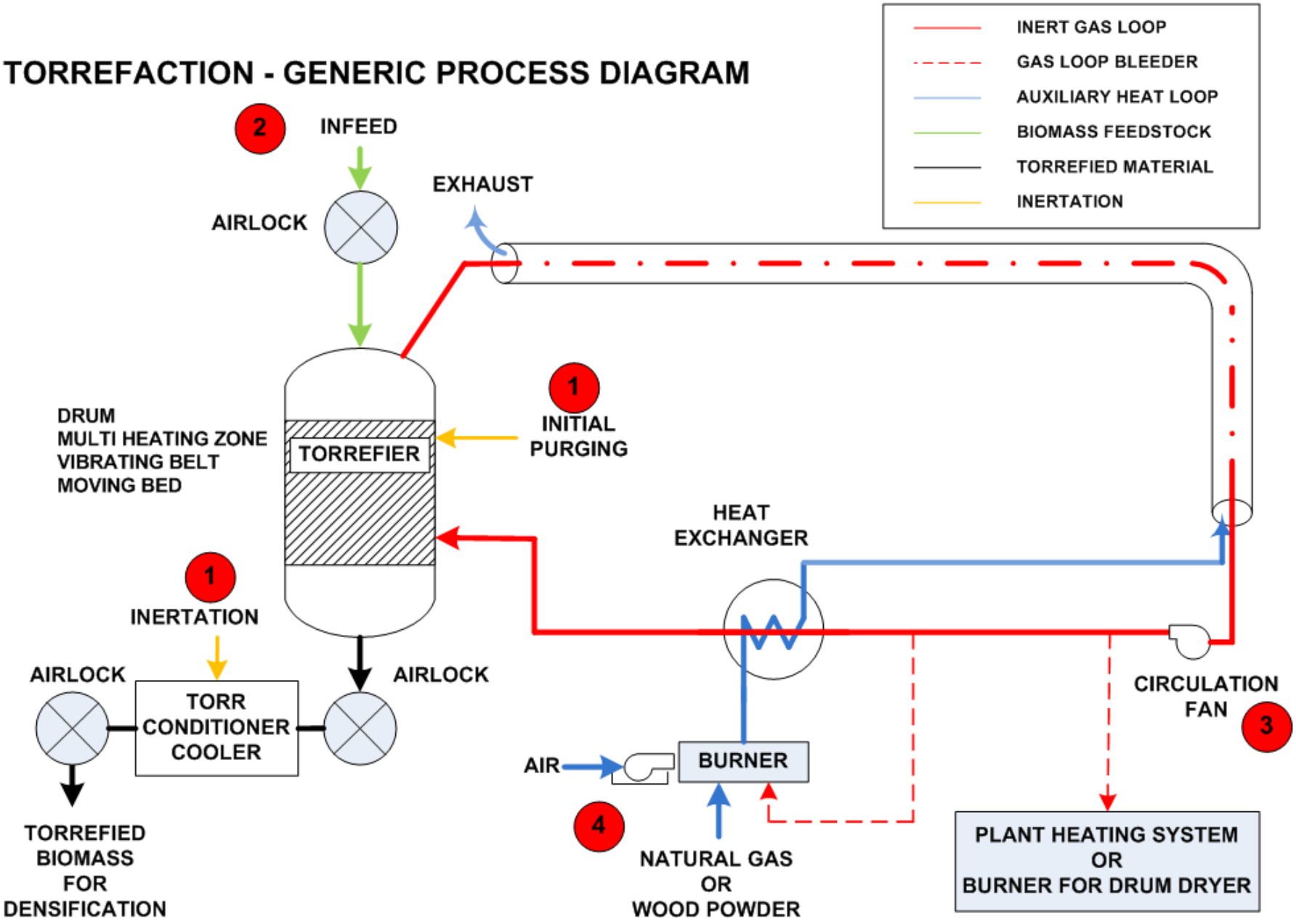
COMPARISON OF TORREFACTION TECHNOLOGY PRINCIPLES

Technology Characteristics			Pros						Total Pro	Potential challenges			Total Con	Overall Rating
Technology	Indirect heating	Direct heating	Proven technology	Proven scalability	High heat transfer	Good temperature control	Acceptance of fines	Acceptance of large particles		Sealing of reactor	Un-even treatment	Fouling		
ROTARY DRUM	X	X	X					X	2		X	X	2	0
MOVING BED		X			X			X	2		X	X	2	0
SCREW	X		X					X	2	X	X	X	3	-1
MULTIPLE HEATING ZONE		X	X	X	X	X	X	X	6	X			1	5
FLUIDIZED BED		X	X	X	X		X		4				0	4
MICROWAVE	X	X			X	X		X	3				0	3

COMMERCIALIZATION PROJECTS (selected)

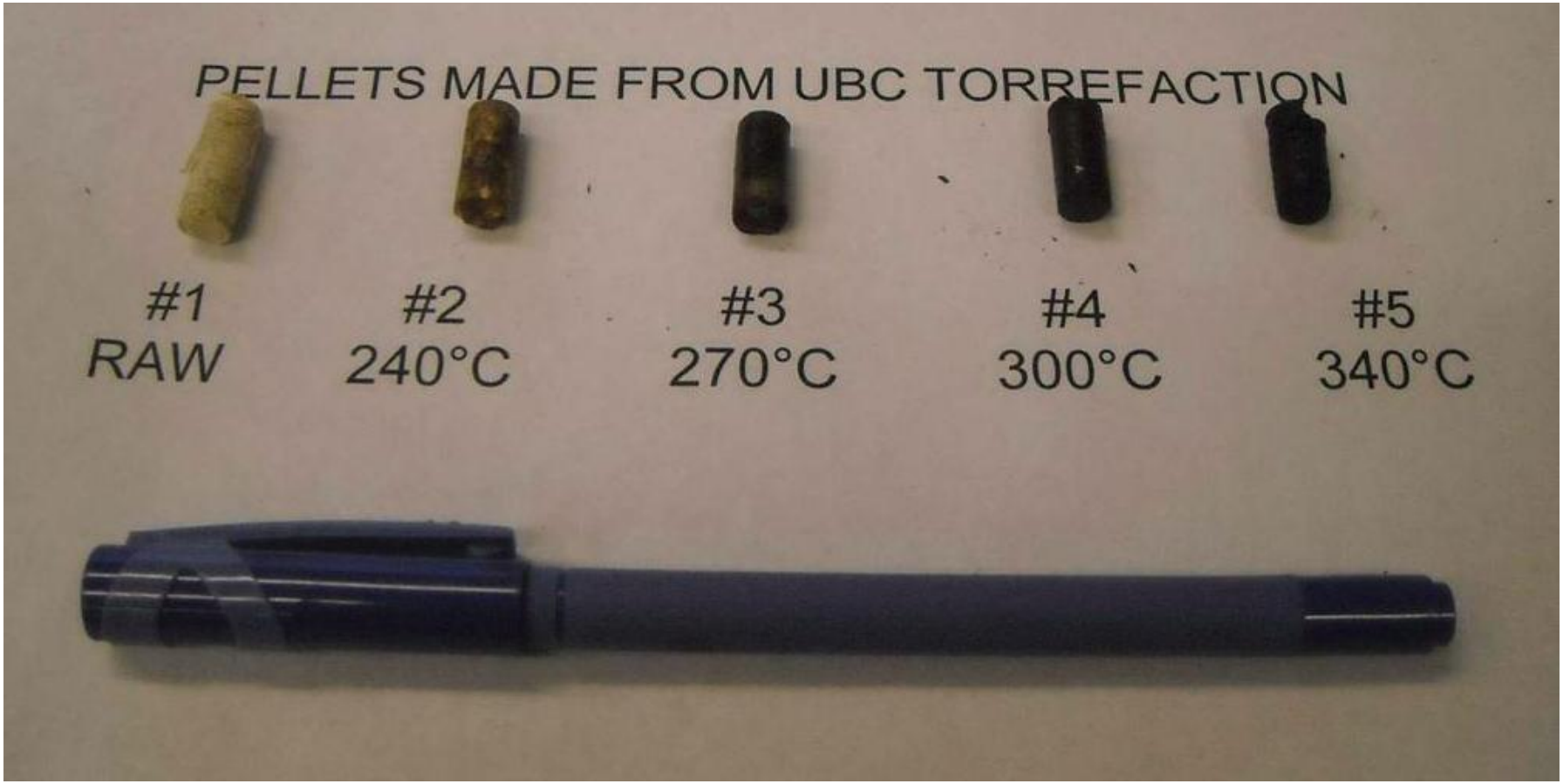
Party	Demo tech	Target date	Capacity tonne/h	Party	Demo tech	Target date	Capacity tonne/h
Torr-coal	Torr-coal	2010/11	4.5	Agritech	Torre-tech	2011	5
4Energy	Stramproy	2010/11	5.5	RFT	RFT	2012	5
Torrsys	Torrsys	2011/12	5	Stramproy	Stramproy	2010/11	5.5
EBES	ACB	2012	1.5	New Earth	ECO-PYRO	2012	2
Integro	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

TORREFACTION - GENERIC PROCESS DIAGRAM



Implementation challenges

- Particle size
    - mass flow limitation
- Consistency of feedstock particle size
    - Heat transfer variations = uneven carbonization
    - Clogging or channeling of mass flow
- Closing of gas-loop
    - In-efficient use of volatile calorific content
    - Condensation in ductwork
- Reactor vessel
    - Control strategy (time & temperature)
        moisture variation, particle size, volatile content
    - Fouling
- Densification
    - High temperature of feedstock
    - Highly reactive dust (risk of explosions and fires)


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

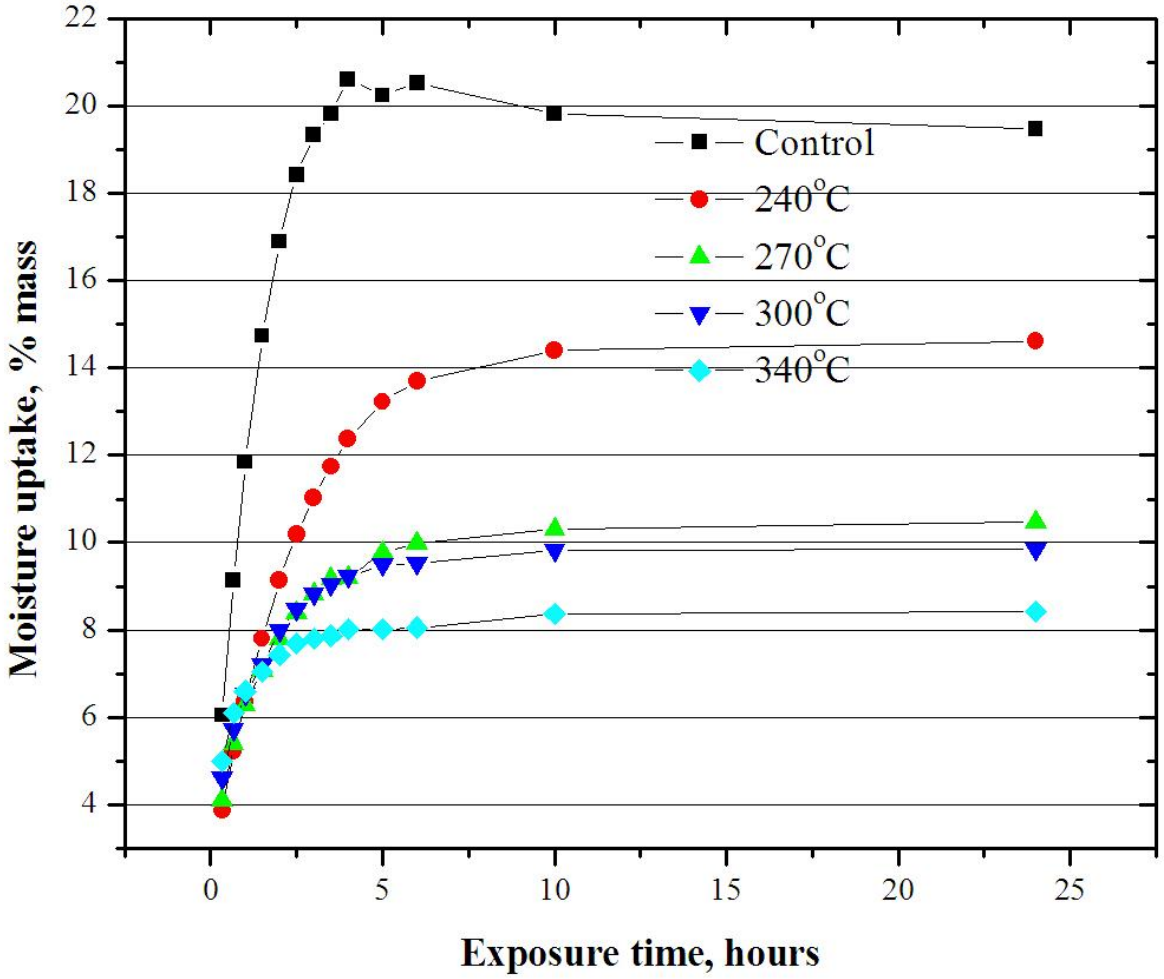
PRODUCT SPECIFICATION - COMPARATIVE DATA

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	tonne/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

HYDROPHOBICITY @ RH 90% AND +30°C



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 April 2011
- Operating during 2012
- Financing; federal, provincial, private
- Seeking collaboration with power company

WPAC SERVING THE POWER INDUSTRY

- Seeking collaboration with power company
  - Contract to take production volume
  - Large scale testing of characteristics of
    - Handling (dust, hydrophobicity, wettability)
    - Electrostatic propensity of dust
    - Storage (self-heating, off-gassing, leaching)
    - Grindability
    - Combustion (co-firing with coal)
    - Fouling, slagging and corrosion
  - Development of detailed physico-chemical profile


WPAC like to be part of your industry
Thank you for your attention

TECHNOLOGY COMPARISON

Technology	Indirect heating	Direct heating	Pros	Cons
Rotary drum	X	X	Proven technology	Lower heat transfer Less plug-flow Difficult temp control Drum sealing Scalability unproven
Moving bed		X	Simple reactor High heat transfer	Pressure drop limitations (fines) Channeling Difficult temp control Scalability unproven
Screw	X		Proven technology Plug-flow	Hot spots Lower heat transfer Shaft sealing Scalability unproven
Multiple heating zone		X	Proven technology Close to plug-flow Good heat transfer Good Temp control Fines acceptable Proven scalability	Shaft sealing Large dimension
Fluidized bed		X	Proven technology Good heat transfer Proven scalability	Particle size limitations Attrition of material No plug-flow