UNIVERSITY of GUELPH

CHANGING LIVES IMPROVING LIFE

PROS AND CONS OF TORREFACTION OF WOODY BIOMASS

By

A. Dutta, PhD, P.Eng
Assistant Professor

Mathias A. Leon, D.Eng
Industrial Research Fellow

School of Engineering
University of Guelph

UNIVERSITY of GUELPH

CHANGING LIVES IMPROVING LIFE

BACKGROUND

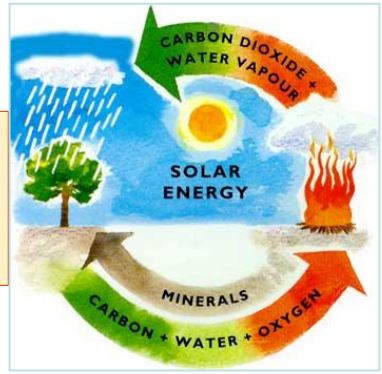
Depleting fossil fuel resources and GHG/Global Warming

↓

Renewable energy, sustainable fuels

↓

Biomass ➲ Carbon-neutral, local fuel; energy security



↓

Technology barriers to their utilization as energy source

↓

Torrefaction

UNIVERSITY of GUELPH

CHANGING LIVES IMPROVING LIFE

PROPERTIES OF WOODY BIOMASS

- Low energy density/heating value (low fixed carbon content ~45%)
- High moisture content (~50%)
- High volatile matter content (~70%)
- Low ash content; high alkali metal content (Na, K) (low Cl content compared to herbaceous biomass)
- More oxygen content (needs less air for stoichiometric combustion)
- Hygroscopic (absorbs moisture)
- Non-uniform (wide range of shapes, sizes and types)

UNIVERSITY of GUELPH

CHANGING LIVES IMPROVING LIFE

ISSUES WITH WOODY BIOMASS AS FUEL

- Low calorific value, high moisture content
- Low energy density
  - ➲ too bulky, not economical to transport over long distances
- Non-homogeneous
  - ➲ Wide variations in combustion properties (Fixed C, VC, inorganic constituents, moisture, calorific value)
  - ➲ Wide variations in sizes, shapes and types (handling and storage difficulties)
- Low combustion efficiency, smoking during combustion

UNIVERSITY of GUELPH

CHANGING LIVES IMPROVING LIFE

ISSUES WITH WOODY BIOMASS AS FUEL

- Difficult to pulverize like coal (poor grindability)
- Hygroscopic (absorbs moisture during storage)
- Significant inorganic matter content (mainly Ca, Si and K)
  - ➲ ash-related problems (sintering, fusion, agglomeration)
  - ➲ coal generally has a much higher ash content, but biomass ash is more prone to slagging & fouling

Torrefaction can address most of these issues to a reasonable extent.

UNIVERSITY of GUELPH

CHANGING LIVES IMPROVING LIFE

TORREFACTION

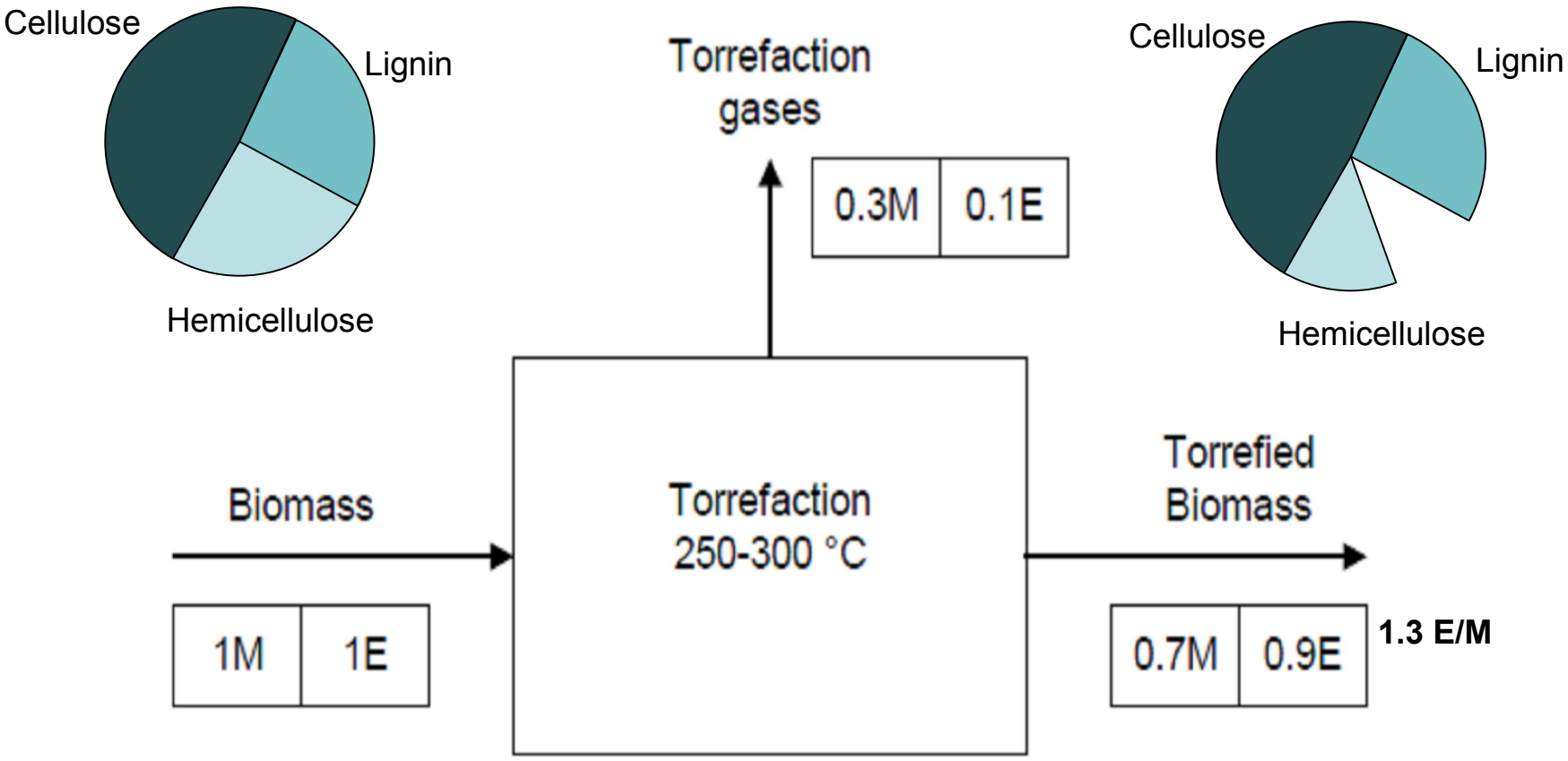
- A thermochemical treatment process, similar to roasting or mild pyrolysis
- To separate water, some VOCs & hemicellulose in woody biomass, leaving only cellulose & lignin to produce a charcoal-like carbonaceous residue ➲ **Torrefied wood**.
- VOCs and hemicellulose are combusted to generate process heat ➲ required to sustain the process.
- Warm lignin acts as a binder if TW is pelletized.
- Depending on the process time, the TW yield varies between 66% and 75%.

UNIVERSITY of GUELPH

CHANGING LIVES IMPROVING LIFE

TORREFACTION

- Energy density increases as ~70% biomass remains with 90% of its original energy content



UNIVERSITY of GUELPH

CHANGING LIVES IMPROVING LIFE

CONDITIONS FOR TORREFACTION

- Temperature of 200-300^{o} C
- Near atmospheric pressure
- Absence of oxygen/air
- Low heating rate (residence time of 30 min – 2 hrs)

UNIVERSITY of GUELPH

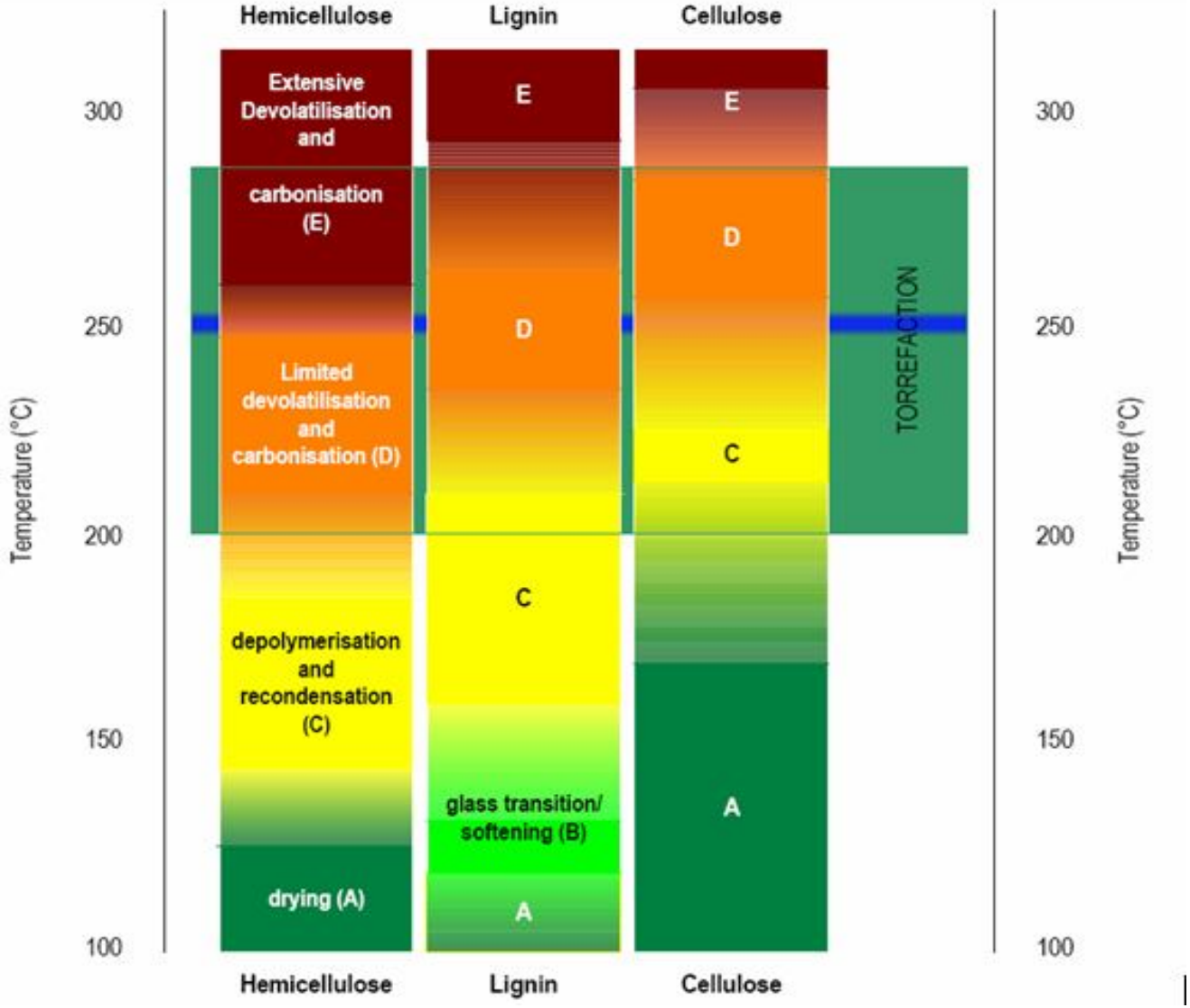
CHANGING LIVES IMPROVING LIFE

CONDITIONS FOR TORREFACTION

Temperature regime

At lower temp., limited devolatilisation & carbonization of hemicellulose.

At higher temp., vigorous decomposition of hemicellulose into volatiles, leaving a char-like residue. Lignin and cellulose show limited devolatilization and carbonization.

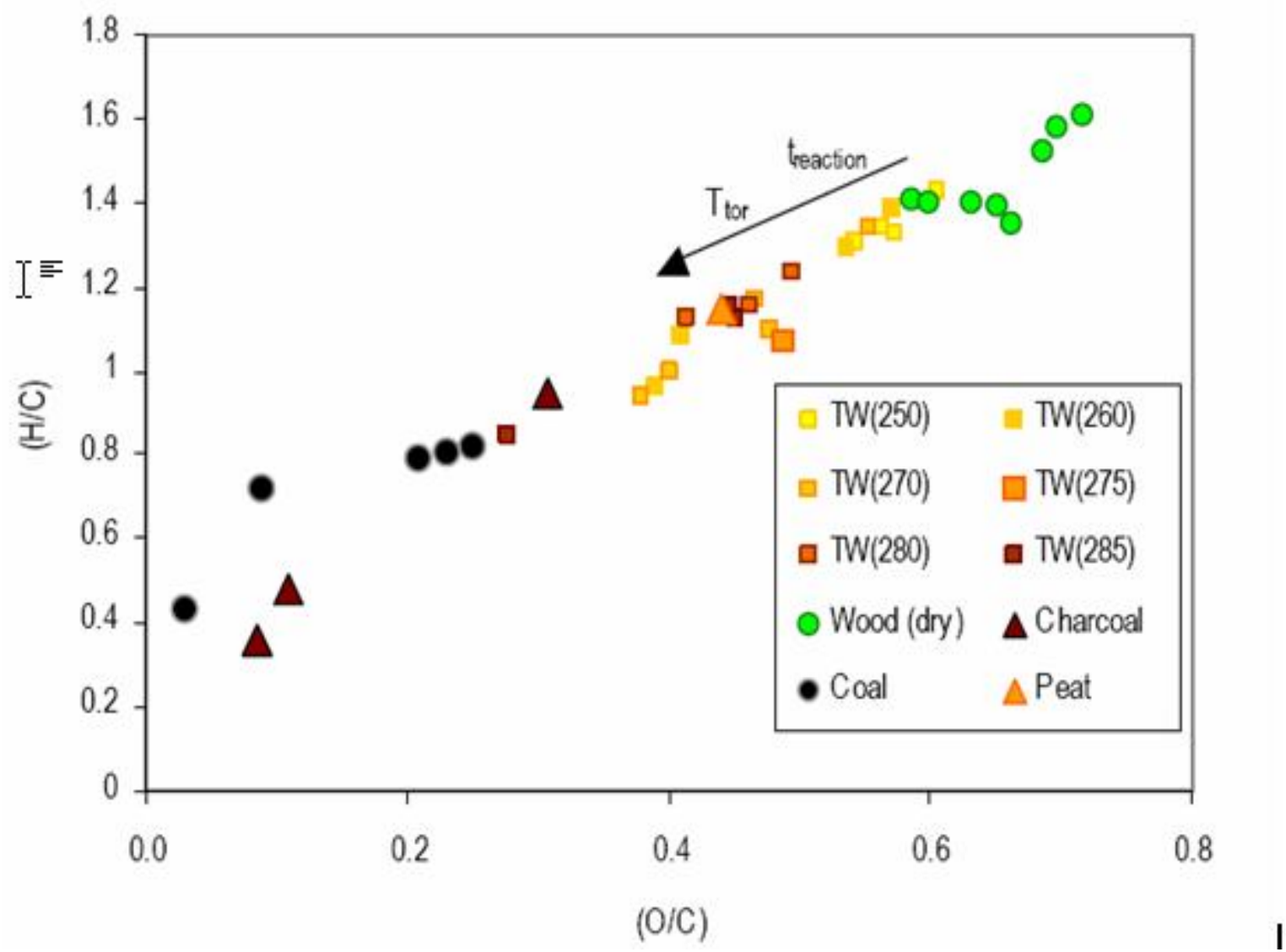


UNIVERSITY of GUELPH

CHANGING LIVES IMPROVING LIFE

CHARACTERISTICS OF TORREFIED BIOMASS

Van Krevelen diagram for torrefied wood



UNIVERSITY of GUELPH

CHANGING LIVES IMPROVING LIFE

BENEFITS OF TORREFACTION

Torrefaction

- improves the physical characteristics of biomass, and thus the overall economics of the biomass utilization process for energy production.

Torrefied product is a homogeneous solid fuel with:

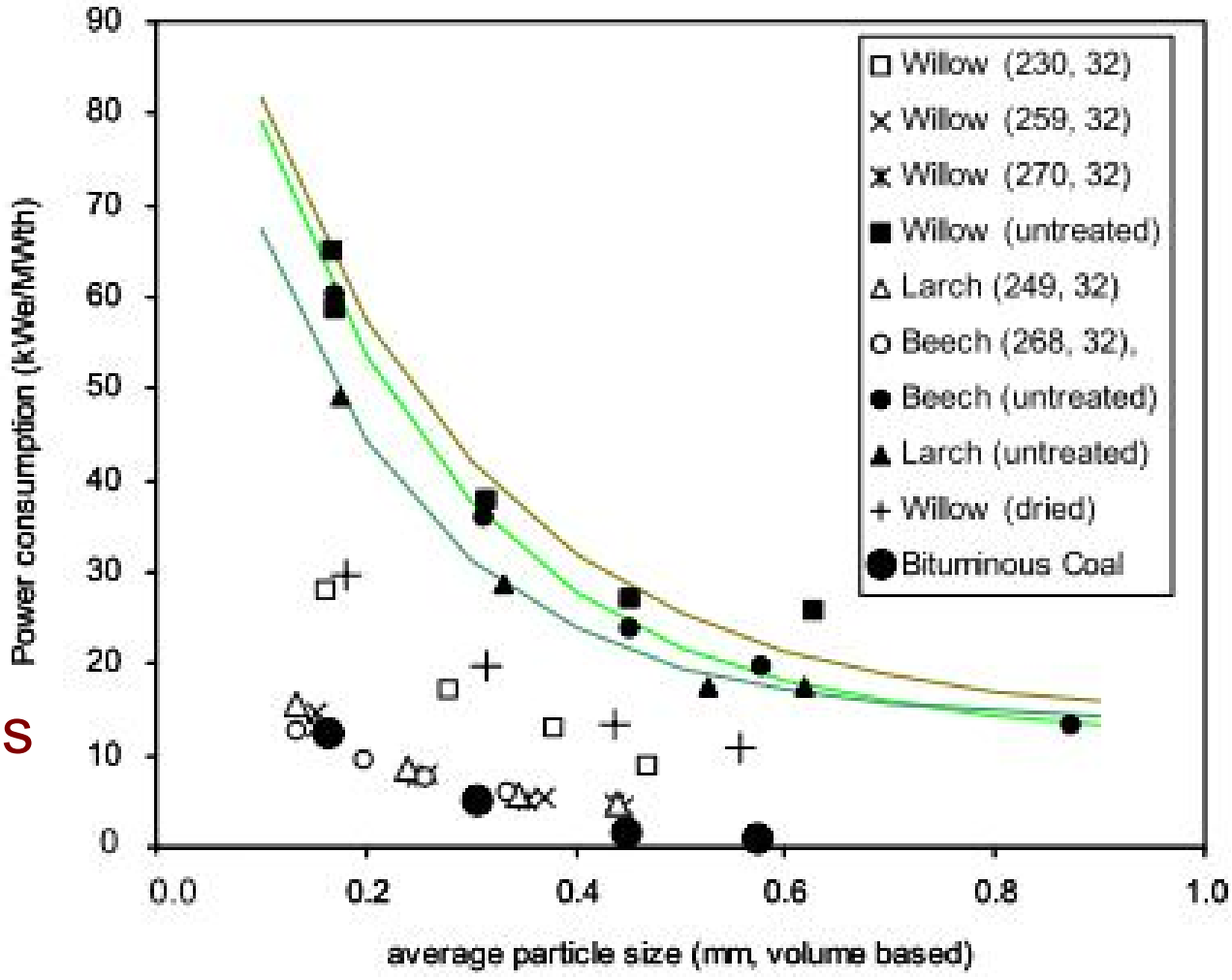
- Higher energy content (per unit volume) and
- Lower moisture content

UNIVERSITY of GUELPH

CHANGING LIVES IMPROVING LIFE

BENEFITS OF TORREFACTION

- Makes biomass friable
  - ✓ 80-90% less energy consumption for grinding



Specific power consumption (milling/grinding)

UNIVERSITY of GUELPH

CHANGING LIVES IMPROVING LIFE

BENEFITS OF TORREFACTION

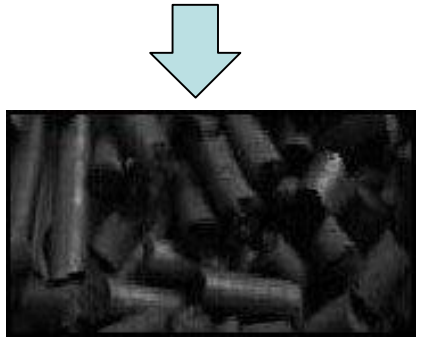
- Makes biomass hydrophobic
  - ✓ Transport and material handling is less expensive & easier
  - ✓ Outdoor storage possible ➲ Less expensive storage option
  - ✓ Significant loss of energy due to re-absorption of moisture in biomass (pellets) is saved
- Negligible biological activities (decomposition, mould)
  - ✓ Longer storage life without fuel degradation
- Low O/C ratio ➲ higher yield during gasification
- Smoke producing compounds removed

UNIVERSITY of GUELPH

CHANGING LIVES IMPROVING LIFE

BENEFITS OF TORREFACTION

- Homogeneous output from mixed biomass



Homogeneous Fuel

- Torrefied biomass: More homogeneous physical & chemical properties
- Allows sourcing of different types of woody biomass for pelletizing in a single device ➲ improves economics of pelletization
- Possibility of utilizing different types of local woody biomass for energy use in a single combustion equipment ➲ improves fuel availability, supply reliability; reduces fuel cost
- Reduced handling and storage cost

UNIVERSITY of GUELPH

CHANGING LIVES IMPROVING LIFE

BENEFITS OF TORREFACTION

- Makes *pelletization* easier
  - Lignin fraction increases (by 10-15%)
  - More fatty structures developed, helps in binding
- Torrefied pellets have more strength
  - 1.5 to 2 times impact load
  - Does not disintegrate easily during handling & storage
- Economics are in favour

UNIVERSITY of GUELPH

CHANGING LIVES IMPROVING LIFE

PROCESS FLOW BEFORE TORREFACTION

Biomass collection

Tree logs

Transportation

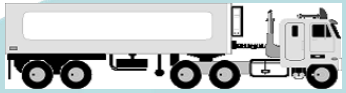
Moisture: 35%
Bulk density: 400 kg/m^3
Energy density: 6.5 GJ/m^3

Wood Chips

Chipping

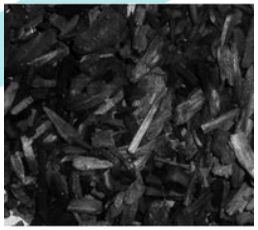
Moisture: 8%
Bulk density: 700 kg/m^3
Energy density: 11 GJ/m^3

Wood Pellets



Pelletizing

Torrefied woodchips



Torrefaction

Moisture: 4%
Bulk density: 300 kg/m^3
Energy density: 7.5 GJ/m^3

Bulk density: 800 kg/m^3
Energy density: **16 GJ/m^3**

Torrefied Pellets

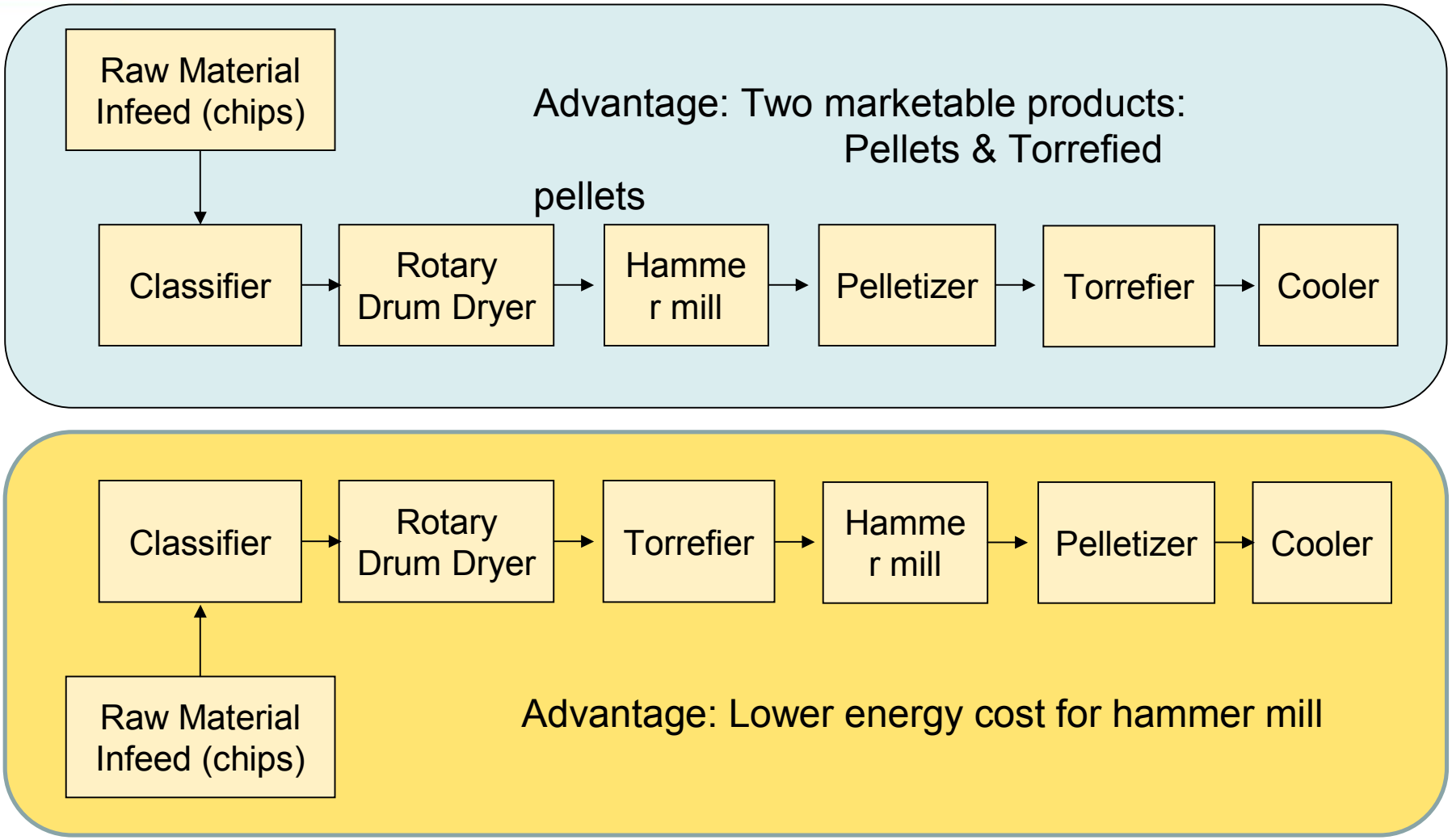
Torrefaction

Pelletizing

UNIVERSITY of GUELPH

CHANGING LIVES IMPROVING LIFE

TYPICAL TORREFACTION PROCESS FLOW



UNIVERSITY of GUELPH

CHANGING LIVES IMPROVING LIFE

TORREFIED WOOD PELLETS COMPARED TO COAL

	Coal	Torrefied Pellets
Heating Value	25 GJ/T	22 GJ/T
Ash	10%	3%
Sulphur	3%	0.1%
Nitrogen	1.5%	0.2%
Chlorine	0.05%	0.01%

Indicative values: can change depending upon the type of biomass and coal

Grindability comparable to coal; combustion reactivity comparable to wood.

UNIVERSITY of GUELPH

CHANGING LIVES IMPROVING LIFE

DRAWBACKS OF TORREFACTION

- Low vol. density enhancement
  - Volume of torrefied biomass is reduced only slightly, ~ 10-20% lower than the dried feedstock
- Despite higher calorific values, energy density is not improved significantly (~5 GJ/m^3)
- Although small, some of the energy content in original biomass is lost (~10%)
- Torrefaction does not reduce corrosive deposits on boiler tubes (all ash components of biomass are still present in TB)
- Limited knowledge on process performance, properties of torrefied product and composition of volatiles
- No commercial torrefaction unit in operation yet

UNIVERSITY of GUELPH

CHANGING LIVES IMPROVING LIFE

APLICATION/MARKET FOR TORREFIED BIOMASS

Residential and commercial heating

Power generation

- Biomass Co-firing in large scale coal-fired power plants
- Competes with coal in terms of price as well as performance
- Higher co-firing rates possible (compared to biomass)
- Most practical option to meet provincial mandate to phase out coal by 2014

Steel production

- TB with LHV in the range of 25 MJ/kg required

Biomass-to-liquid fuel

- Transportation fuels (Fischer–Tropsch process)

Export

- Large markets exist in US & Europe

UNIVERSITY of GUELPH

CHANGING LIVES IMPROVING LIFE

SUMMARY

- Issues with wood as fuel: Low LHV, high moisture, low energy density, non-homogeneous, hygroscopic, poor grindability
- Torrefaction addresses most of these issues, delivering a fuel comparable to coal
- Torrefaction: thermochemical treatment process at 200-300°C to separate water, VOCs & hemicellulose in woody biomass
- Torrefied biomass:
  - ✓ Higher energy, lower moisture content; better grindability
  - ✓ Transport, handling & storage advantages due to higher bulk & energy density, homogeneity, hydrophobic property
  - ✓ Drawbacks: low vol. & energy density enhancement; no commercial unit in operation yet.
- A competitive fuel when co-firing with coal in power plants.

UNIVERSITY of GUELPH

CHANGING LIVES
IMPROVING LIFE

Thank you.