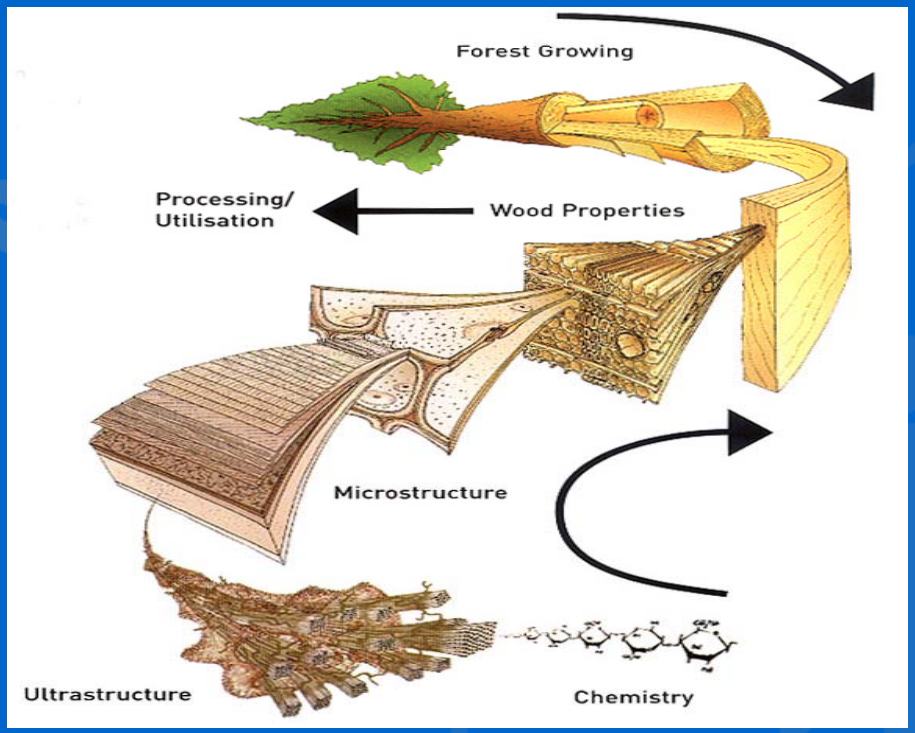

Bioenergy:
Processing and Transport Options and Issues

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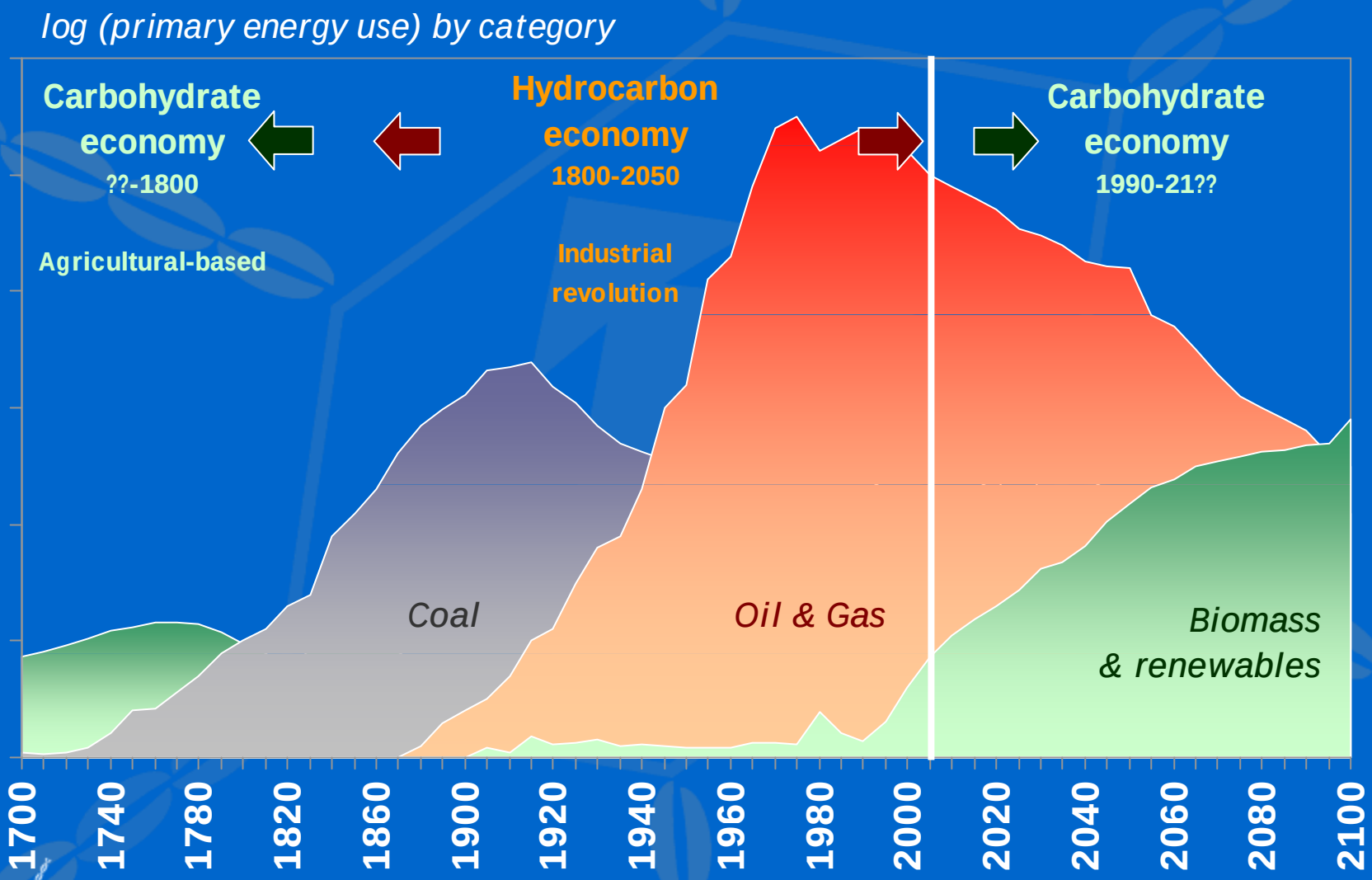
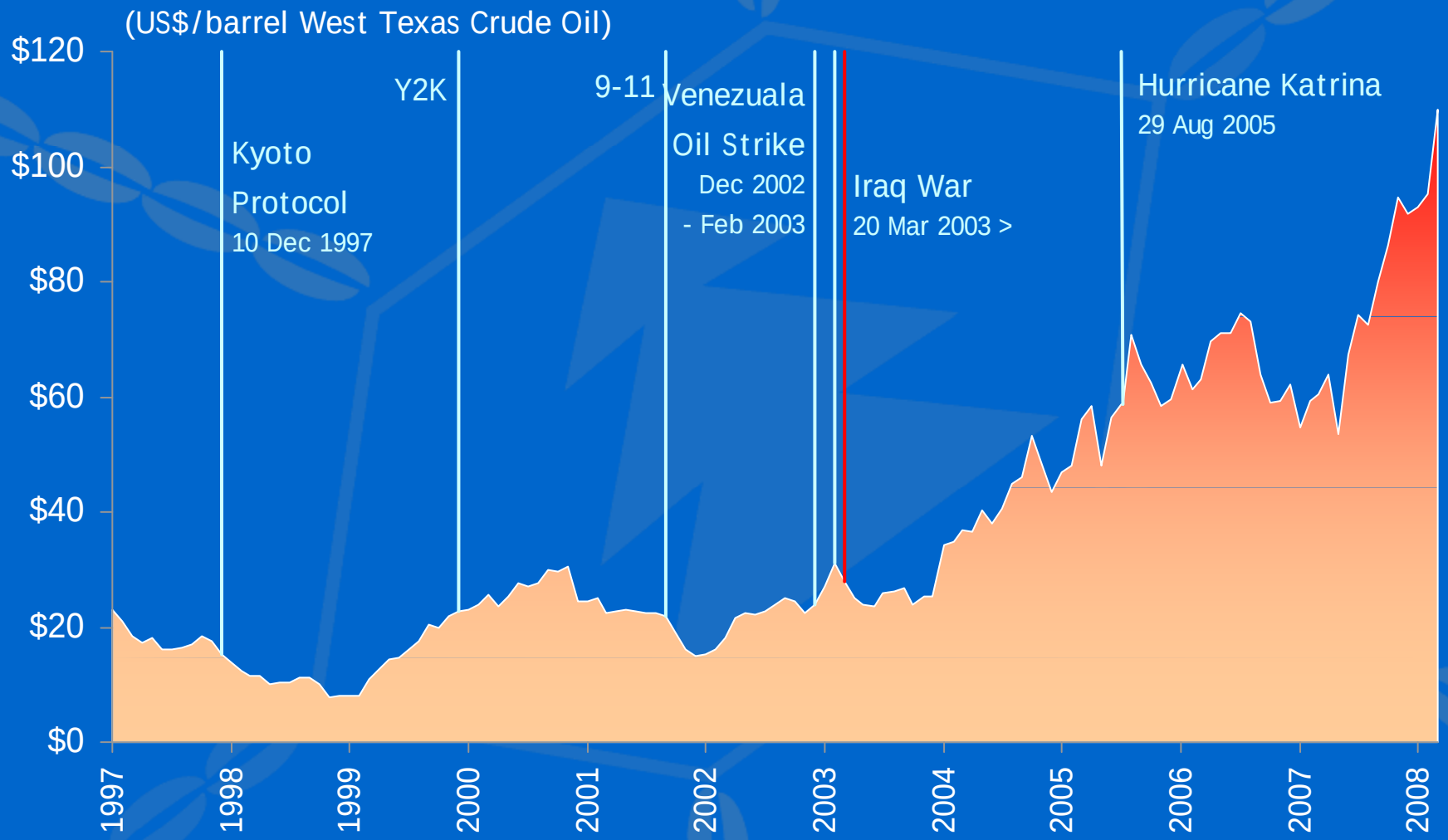
Forest Products Biotechnology at UBC

QIEEP Workshop
June 08-09, 2008
Queen's University, Kingston, ON

Looking back and forward...



Oil & World Events



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Sources: (1) WorldOil.Com. 2004-2008.

Small-scale application

Efficiency of energy recovery

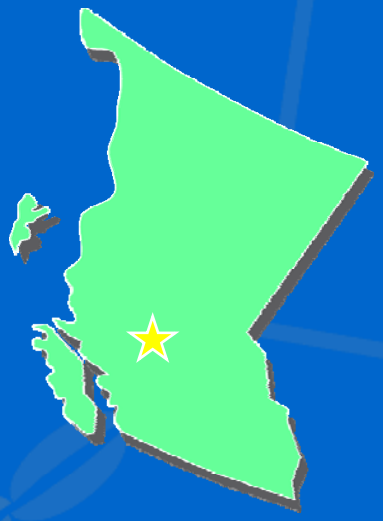
	Conversion efficiency (η_e)	Avg. energy delivered *(GJ/bdt wood)*
Open fire	0.05	1
Traditional wood stove	0.36	7.2
Charcoal	0.44-0.79	8.8-15.7
Wood pellet stove	0.78-0.81	15.6-16.2

Note: Average energy in wood, bone-dry basis: 16-25 GJ/bdtonne

Sources: Mabee et al. 2001; Karlsson, Gustavsson 2003.

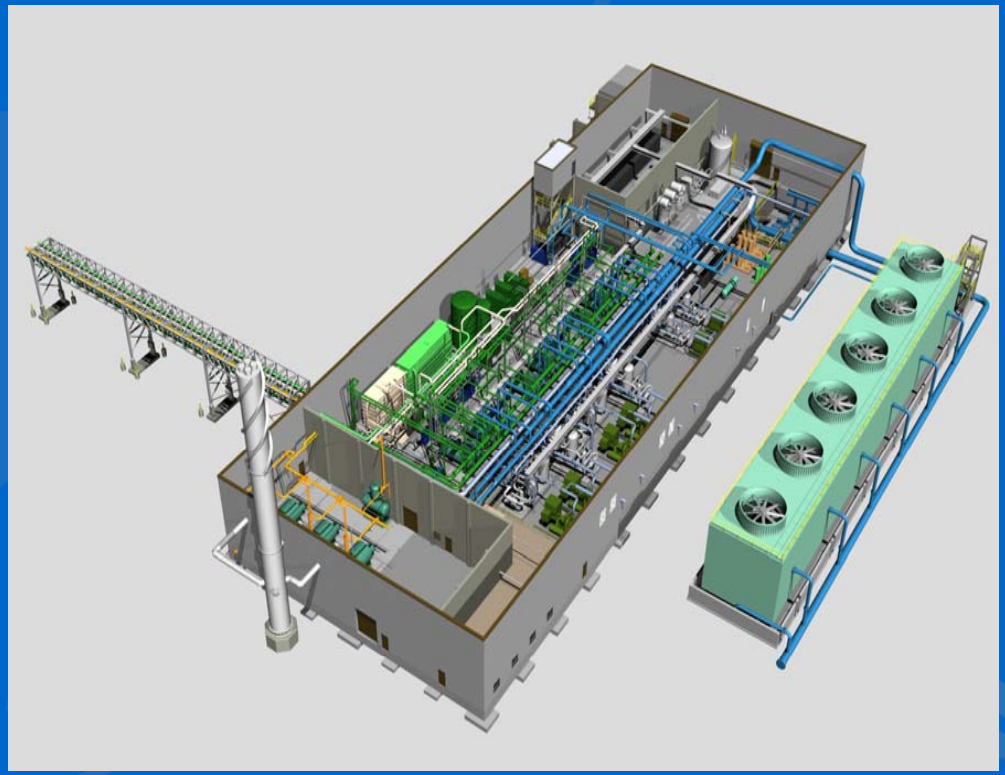
Power generation units

- Combust wood chips or pellets in a power boiler
- Can use mill wastes or hogfuel
- eg: Williams Lake Power Facility, BC (65 MW)



Combined Heat and Power

- Can deliver both heat and power (electricity)
- Can be used in District Heating systems
  - Residential
  - Industrial
  - Institutional
- Allows optimal energy recovery from the feedstock

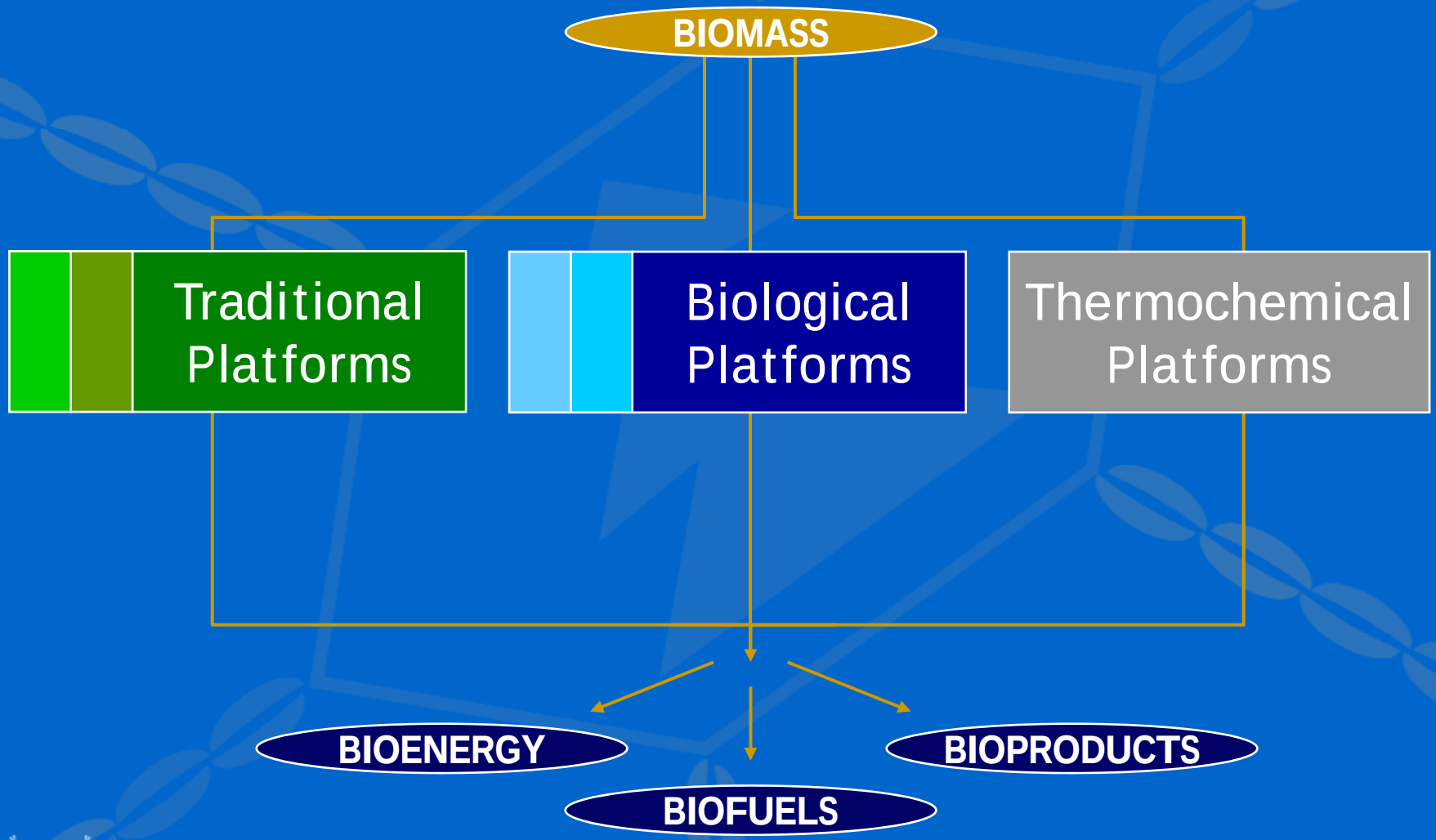


Efficiency of energy recovery

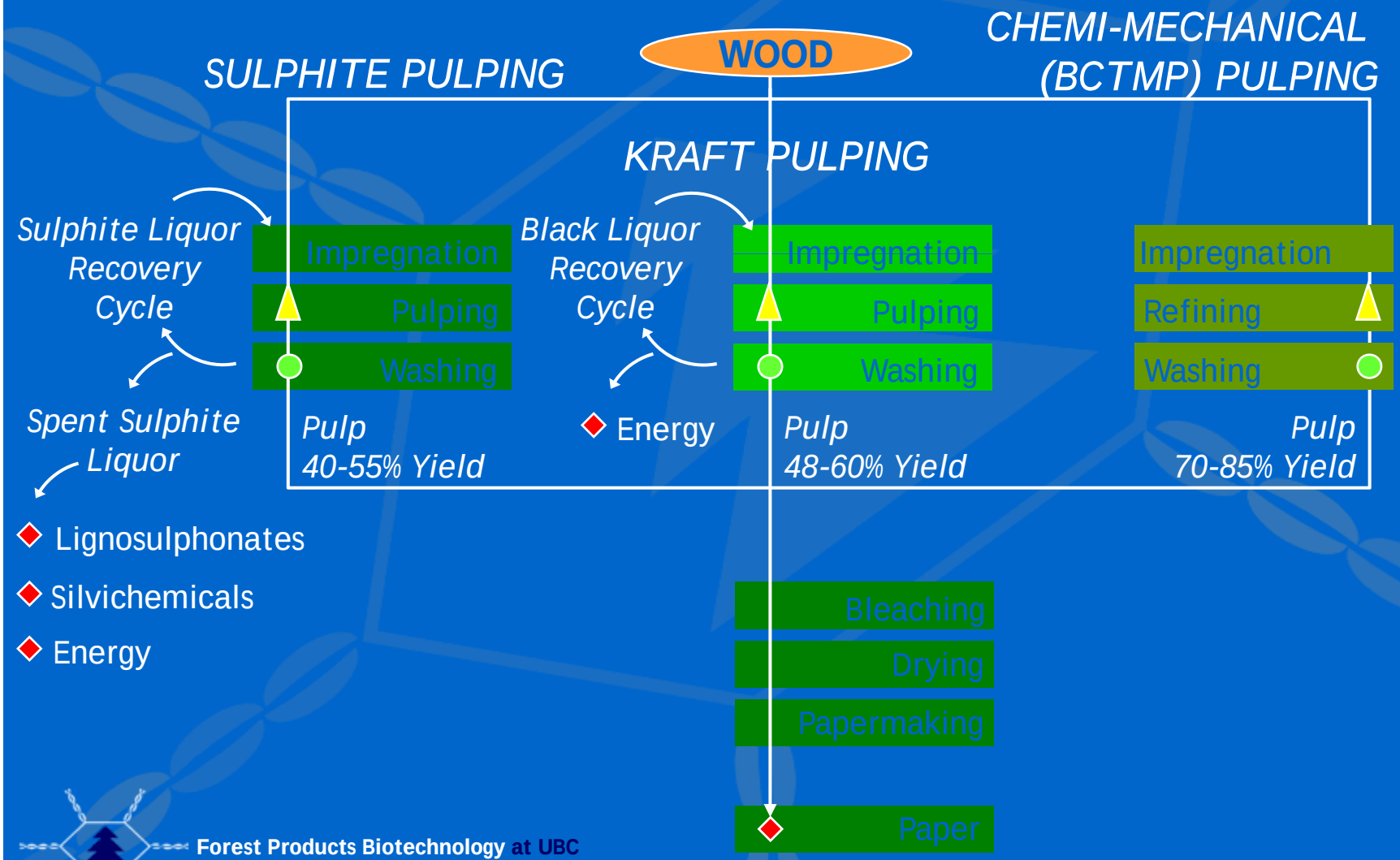
	Conversion efficiency (η_e)	Avg. energy recovered *(GJ/bdt wood)*
Combined Heat & Power (CHP)	0.30 - 0.44	6 - 8.8
Steam-turbine power boiler	0.40	8
Gasifier/power generator	0.47	9.4
CHP with Flue Gas heat recovery	0.70 - 0.80	14 - 16

Sources: Mabee et al. 2001; Karlsson, Gustavsson 2003.

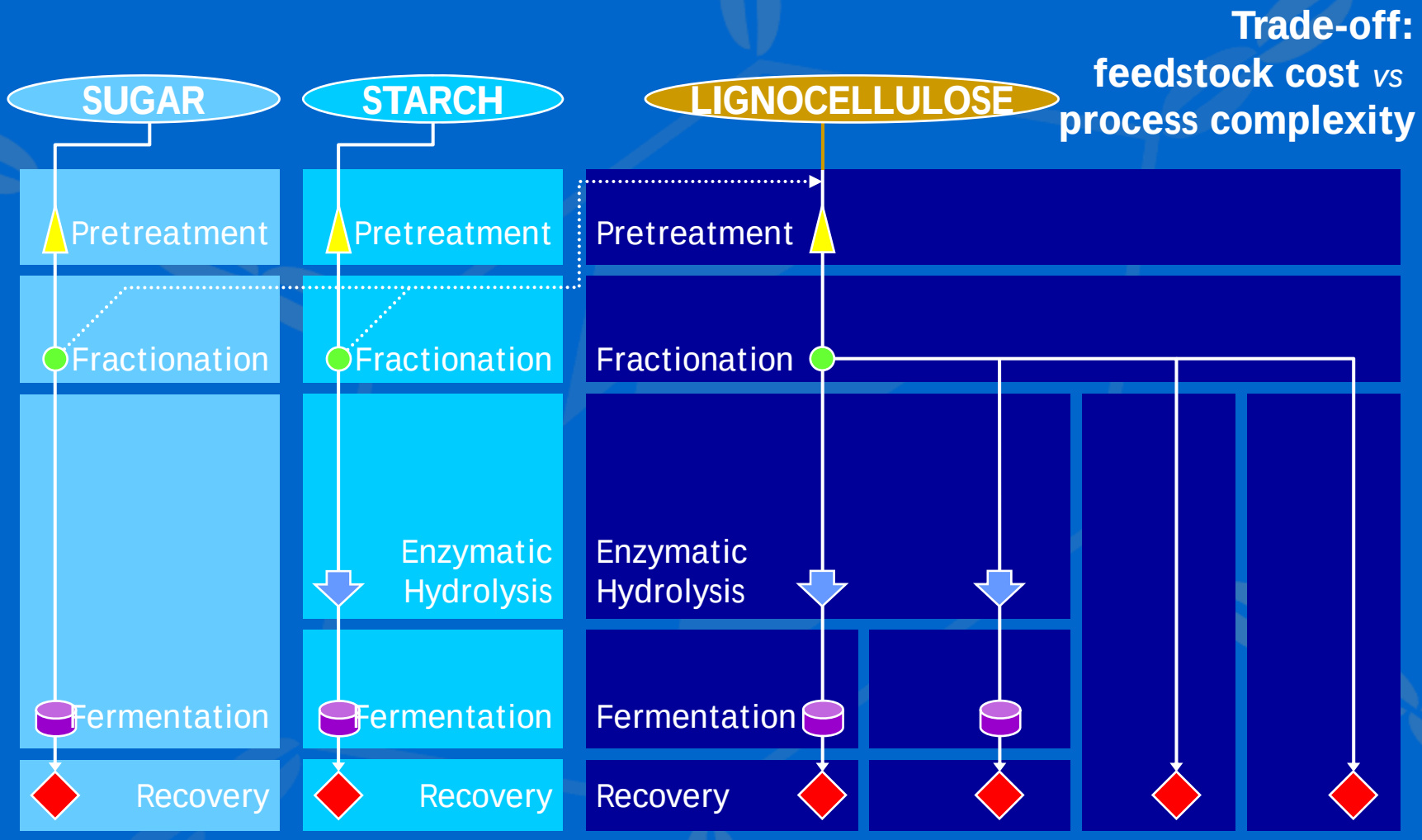
Biorefining Platforms



Pulp and paper 'refinery'



Biological biorefinery



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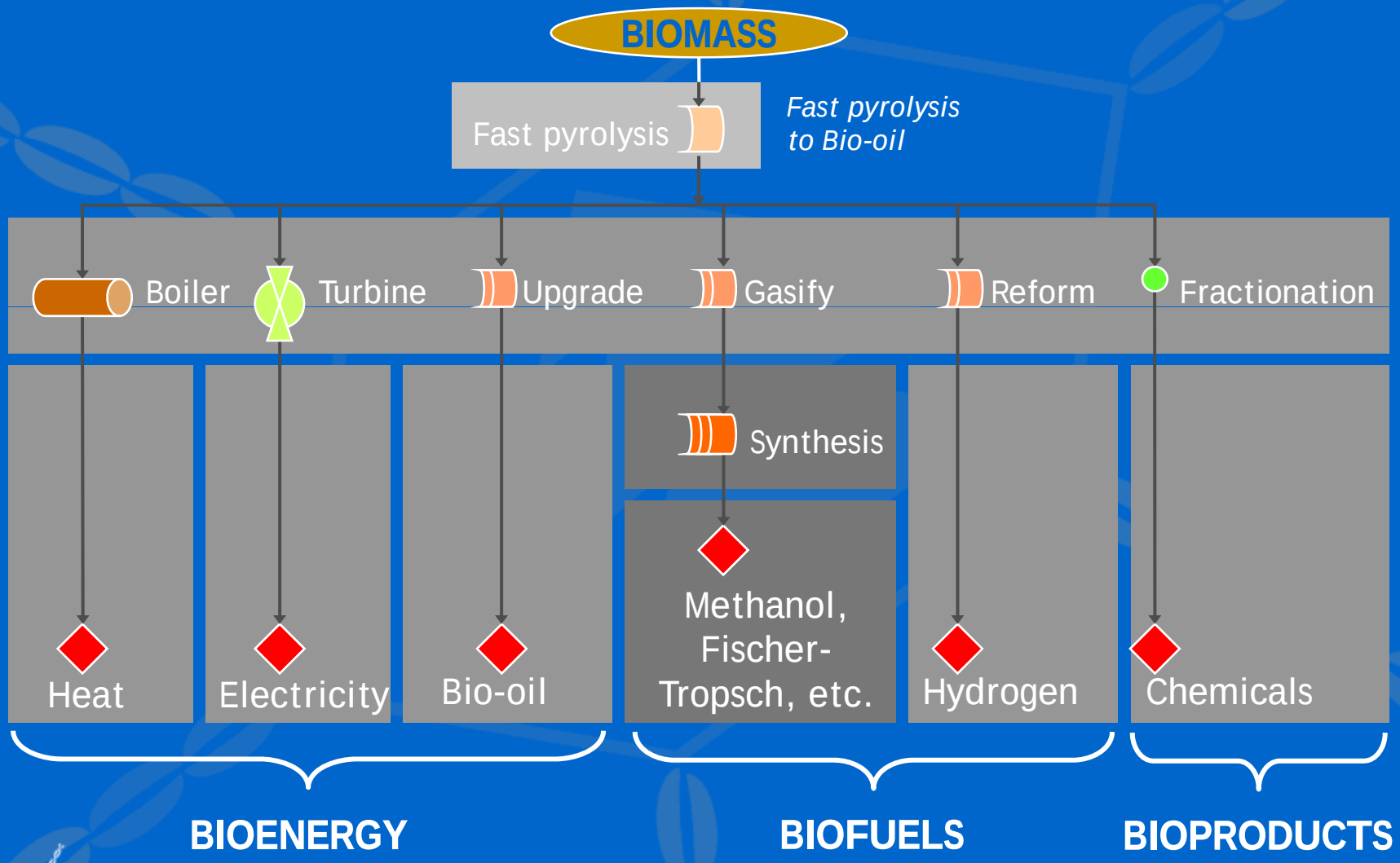
Thermochemical biorefinery



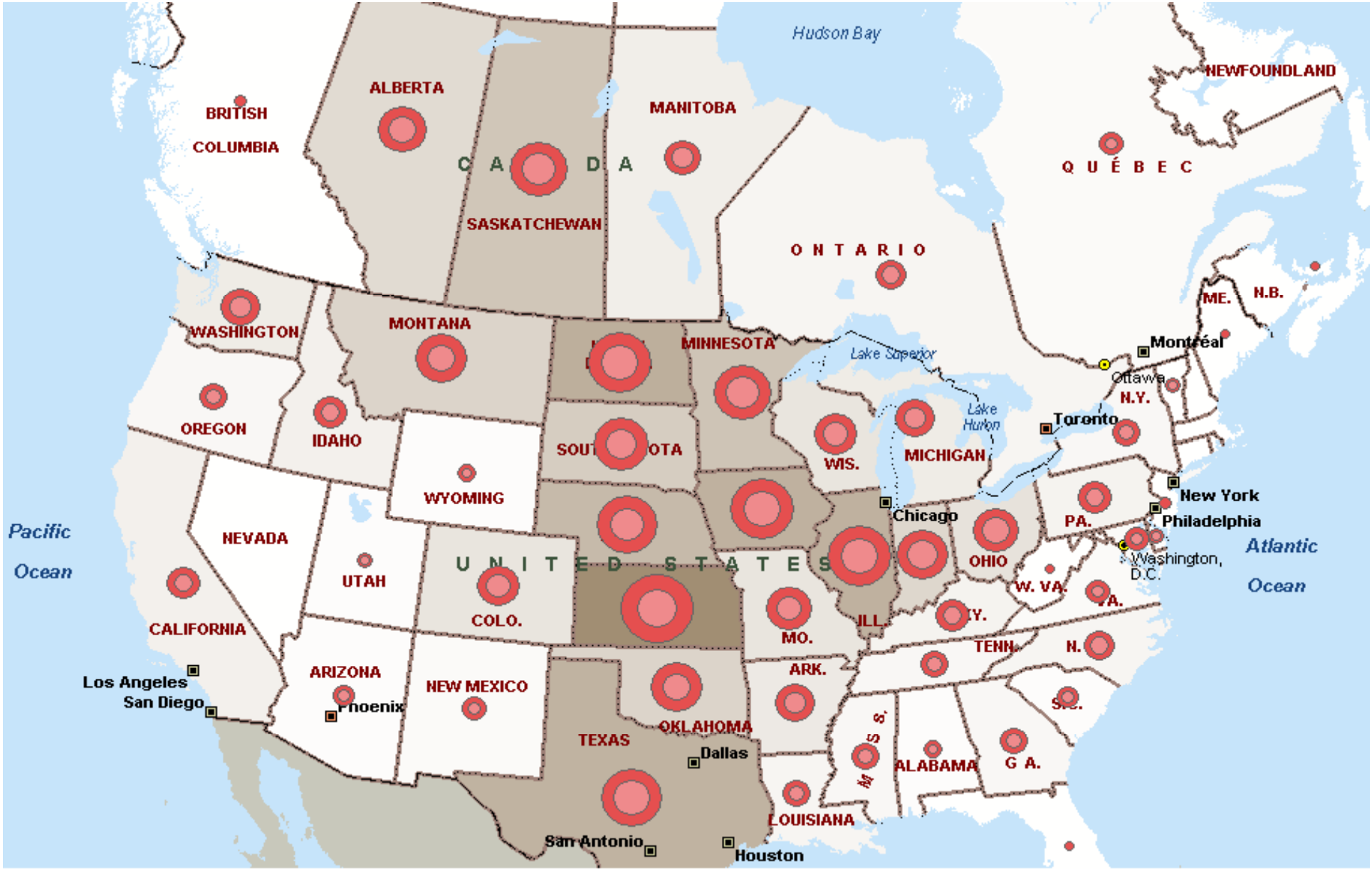
Biorefinery

			Company
Bulk polymers: Polylactide (PLA), 3-hydroxypropionic acid, 1,3-propanediol, etc.	THERMOCHEMICAL	BIOLOGICAL	NatureWorks, DuPont, Cargill
Nutraceuticals: xylitol, arabitol, etc.			Codexis
Platform chemicals: Glycerol, furfural, levulinic acid, succinic acid, etc.			DuPont
Biofuels: ethanol, bio-hydrogen, etc.			Iogen, Abengoa
Biofuels: bio-oil, methanol, ethanol, Fischer-Tropsch, BTL, etc.			Choren
Bioenergy: electricity, steam, combined heat & power (cogen), district heating, wood pellets, etc.			Williams Lake Bioenergy Facility

Efficiency of energy recovery

	Biofuel Yield *(l/bdt wood)*	Avg. energy recovered *(GJ/bdt wood)*
Fischer-Tropsch fuels	75 - 201	2.9 - 7.6
Syngas-to-ethanol	146	3.1
Wood-to-ethanol	124 - 303	2.6 - 6.4
Straw-to-ethanol	*109 - 270*	*2.3 - 5.7*

Sources: Mabee et al. 2006; Spath Dayton 2003; Wingren et al. 2003; Tijmensen et al. 2000; NREL 2000; Putsche 1999.



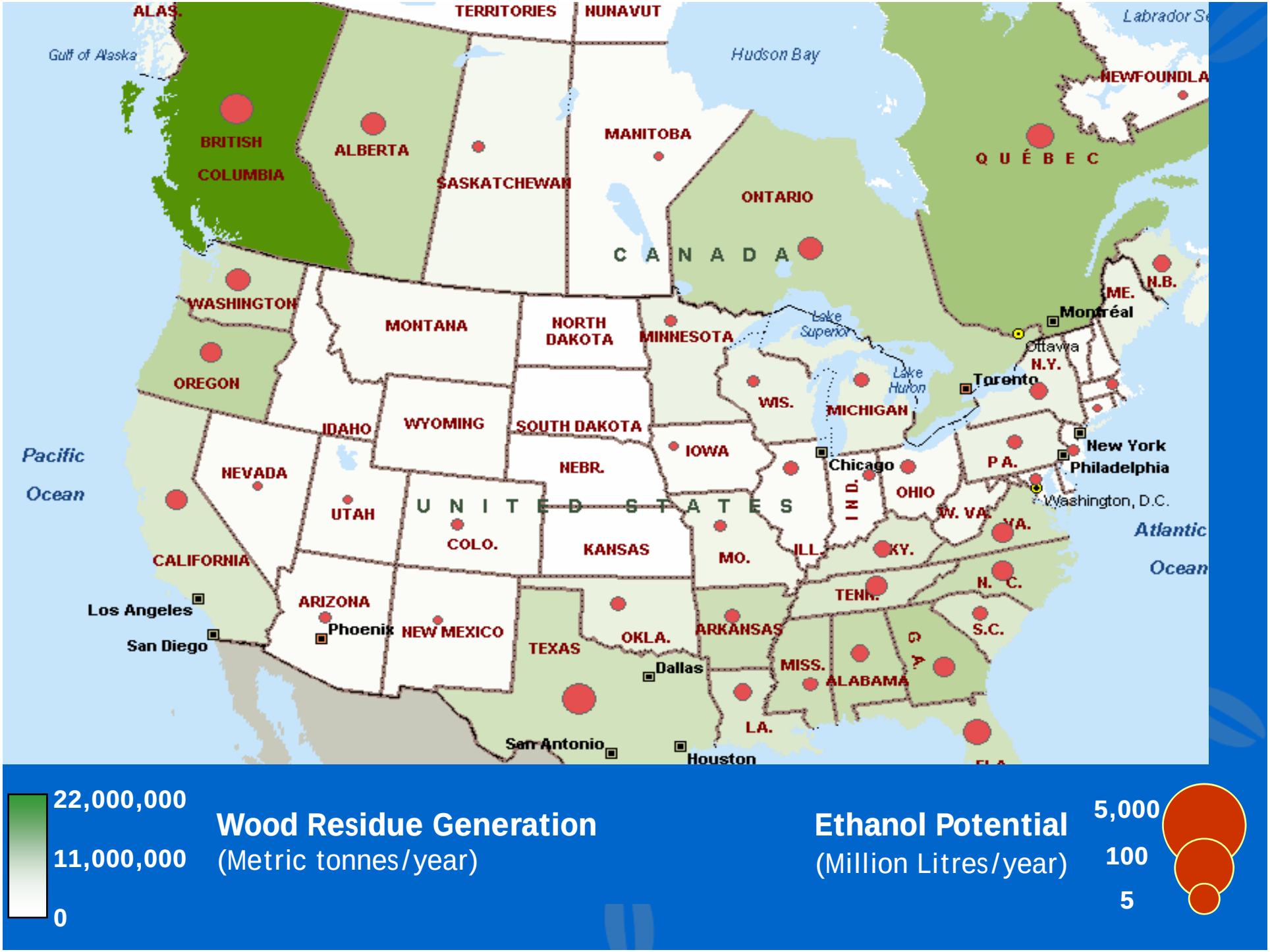
Agricultural Residues 2005 (metric tonnes)

- > 5,000,000
- 4 - 5,000,000
- 3 - 4,000,000
- 2 - 3,000,000
- 1 - 2,000,000
- 0 - 1,000,000

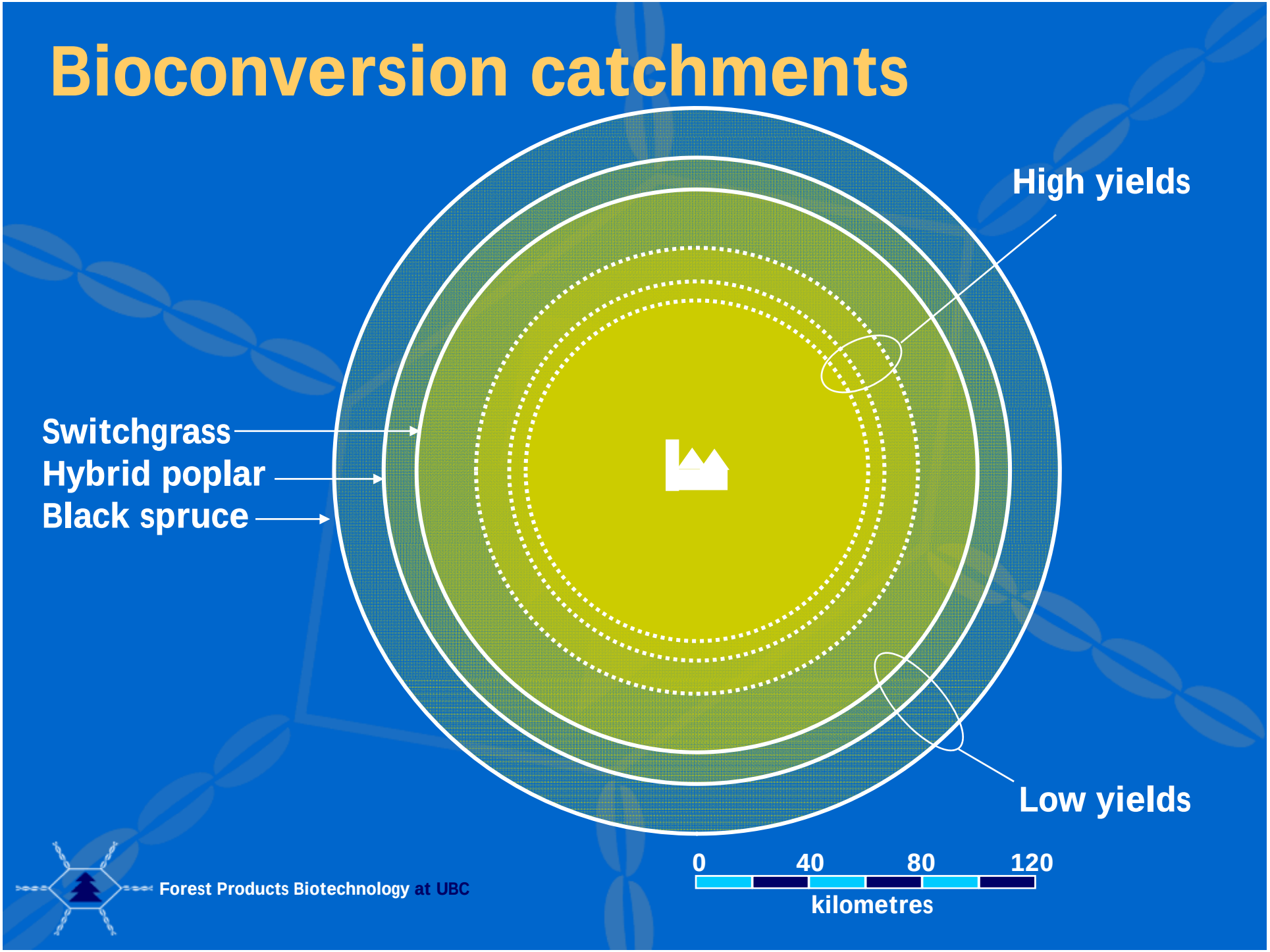
Potential Production of Ethanol (Litres annum^{-1})

6,000,000,000
600,000,000
6,000,000

- Low yields, low residue availability
- High yields, high residue availability


ALAS.
TERRITORIES
NUNAVUT
Labrador Se
Gulf of Alaska
Hudson Bay
NEWFOUNDLA
BRITISH
COLUMBIA
ALBERTA
SASKATCHEWAN
MANITOBA
ONTARIO
QUÉBEC
CANADA
WASHINGTON
MONTANA
NORTH
DAKOTA
MINNESOTA
Lake
Superior
N.B.
ME.
Montréal
Ottawa
N.Y.
OREGON
Lake
Huron
Toronto
WIS.
MICHIGAN
IDAHO
WYOMING
SOUTH DAKOTA
IOWA
New York
Philadelphia
Pacific
Ocean
NEVADA
NEBR.
Chicago
P A.
IND.
OHIO
Washington, D.C.
UTAH
UNITED STATES
W. VA.
VA.
Atlantic
Ocean
COLO.
KANSAS
MO.
ILL.
KY.
CALIFORNIA
TENN.
N. C.
Los Angeles
ARIZONA
S.C.
Phoenix
NEW MEXICO
OKLA.
ARKANSAS
San Diego
TEXAS
MISS.
GA
Dallas
ALABAMA
LA.
San Antonio
Houston
22,000,000
11,000,000
0
Wood Residue Generation
(Metric tonnes/year)
Ethanol Potential
(Million Litres/year)
5,000
100
5

Bioconversion catchments



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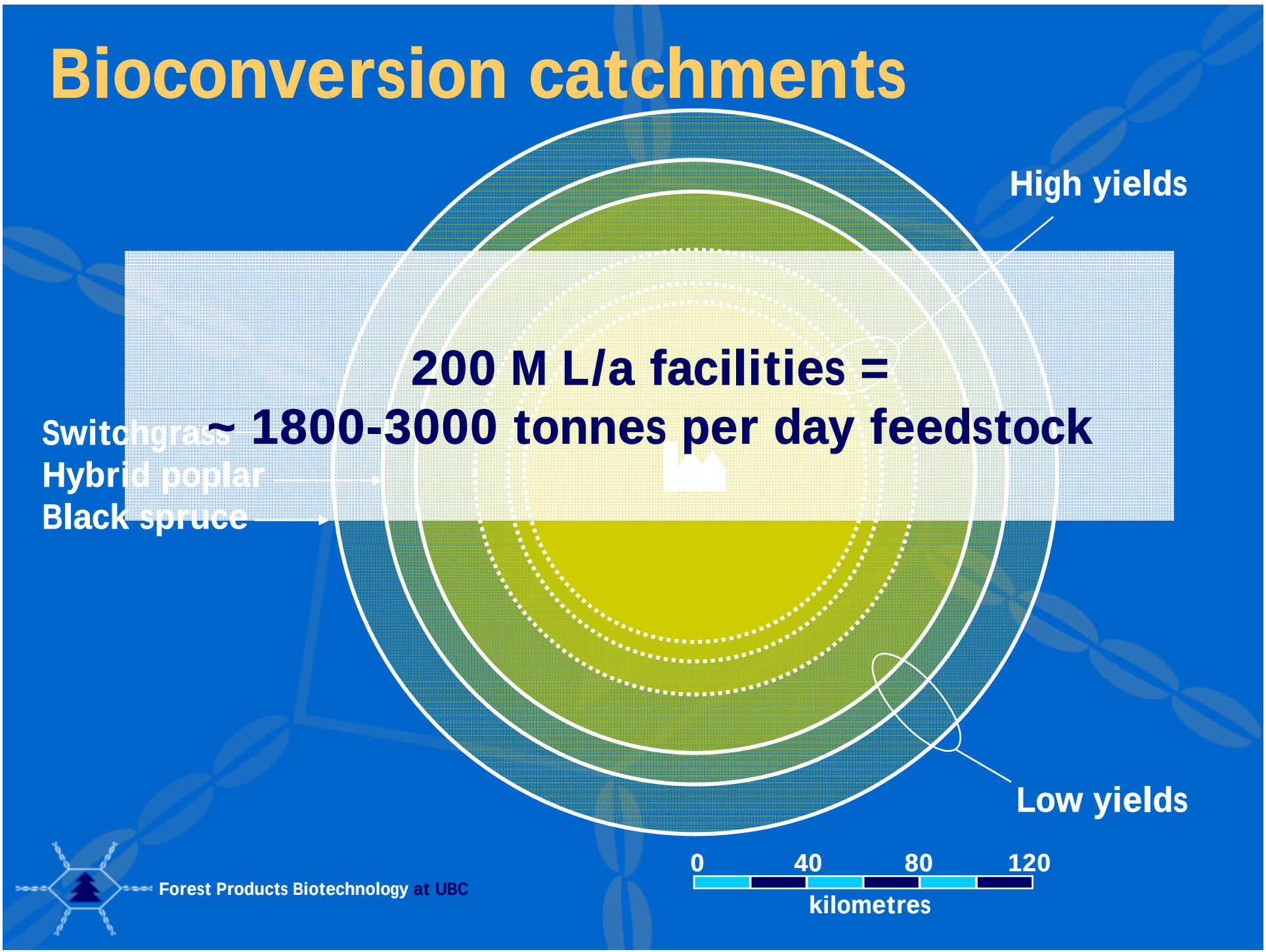
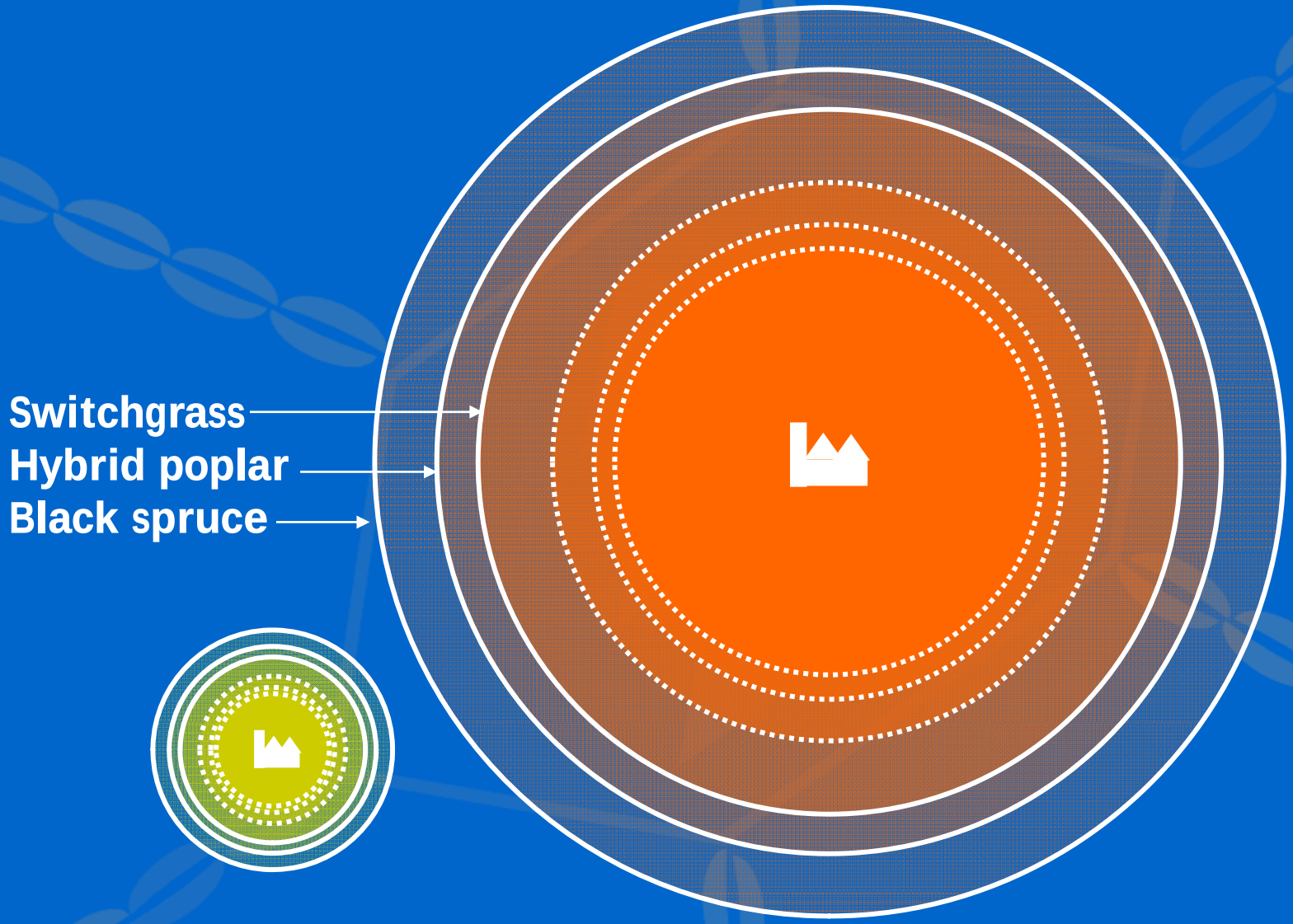
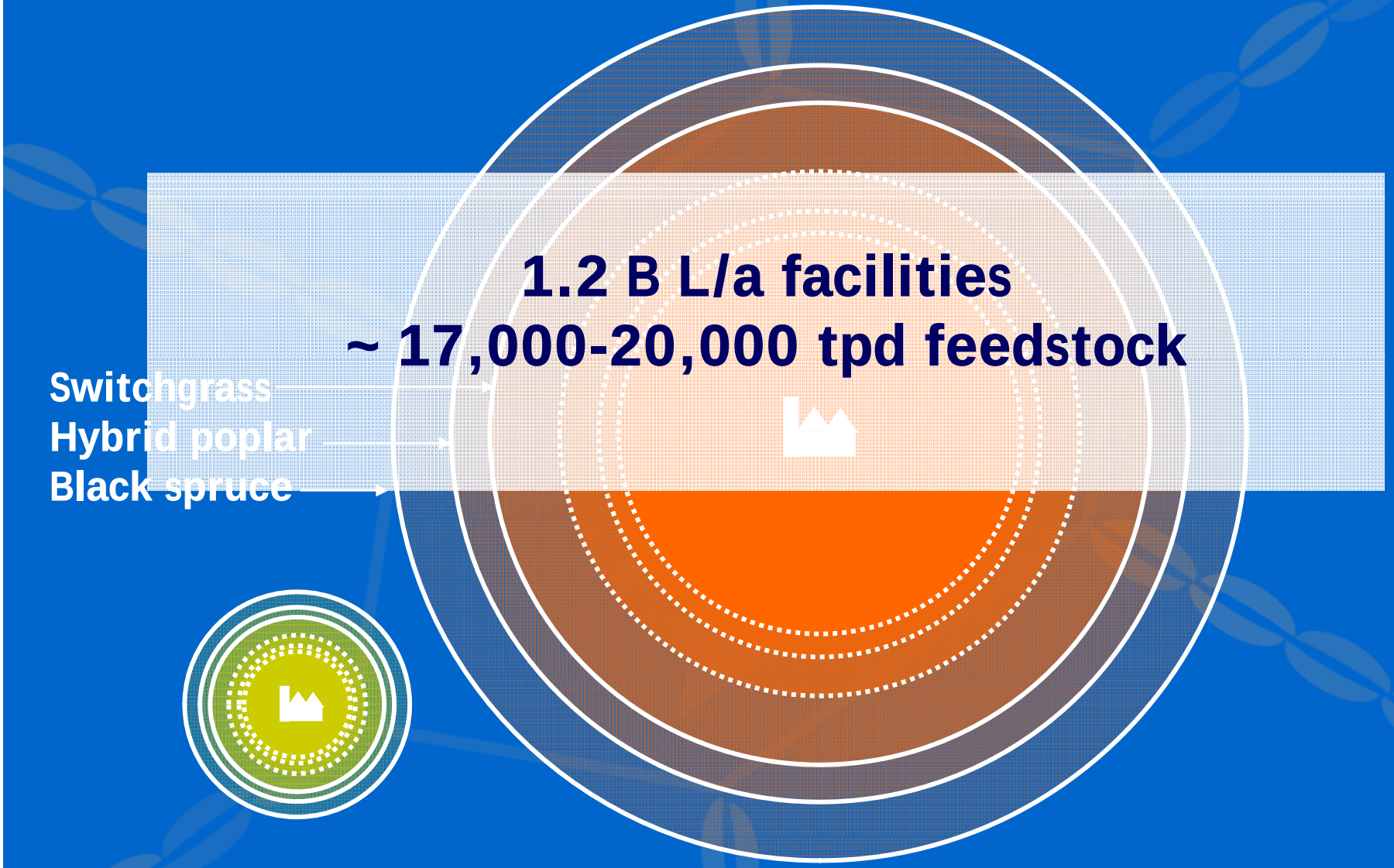
Bioconversion catchments



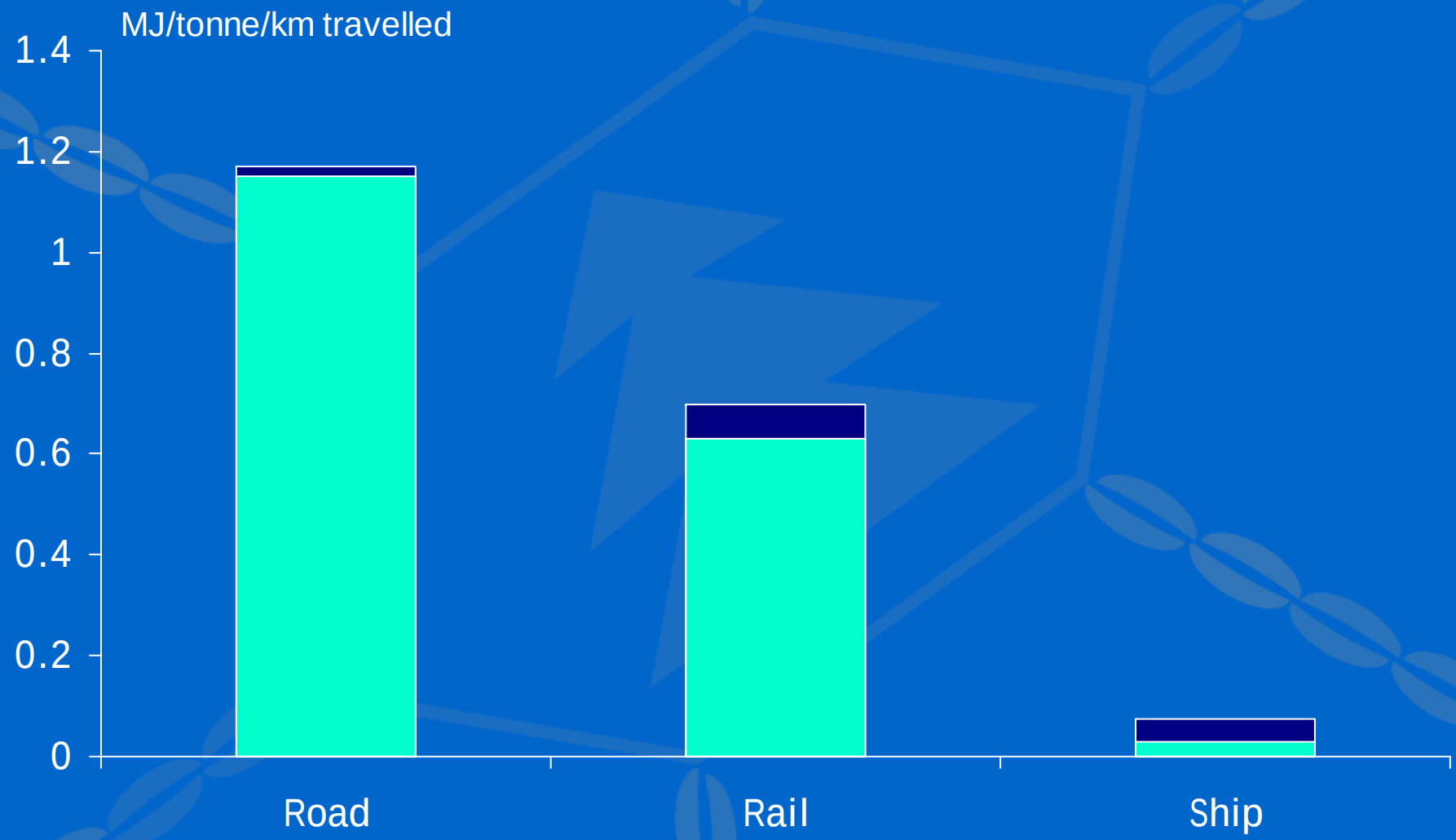
Thermochemical catchments



Thermochemical catchments



Energy cost of transport



Resource-reliant communities

- Majority of resource-reliant communities that have pulp and paper capacity are found in Eastern Canada – most within about 100 km of the Great Lakes basin

Take-home messages

- Bioenergy technologies are varied and display a range of efficiencies (as measured by heat recovery)
- The biorefinery concept can maximize returns and improve the economic performance of bioenergy technologies
- Different technologies operate best at different scales
- Opportunities exist around existing infrastructure in the Great Lakes region

Acknowledgements

- IEA Bioenergy Task 39
- Natural Resources Canada
- NSERC

- Forest Products Biotechnology
- Colleagues and collaborators

Questions?