



QUEEN'S INSTITUTE FOR ENERGY
& ENVIRONMENTAL POLICY

Setting the Stage

Emerging bioenergy opportunities in the Great Lakes Corridor

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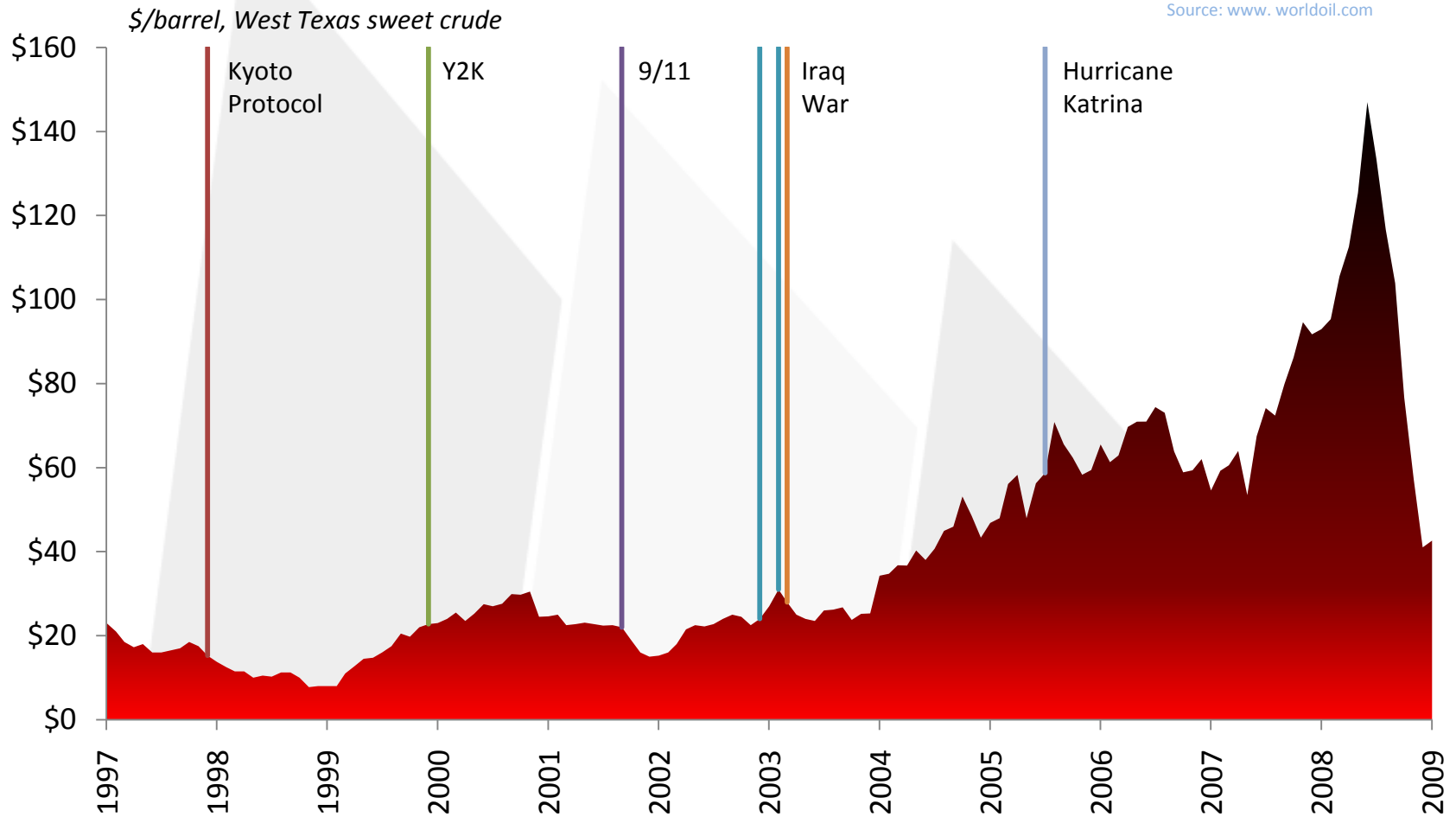
Speaker background

- Degrees in Forestry/Wood Science from Toronto (B.Sc.F. 1992, M.Sc. 1995, Ph.D. 2001)
- International experience:
 - ▶ Food and Agriculture Organization of the UN
 - ▶ International Energy Agency Bioenergy Implementing Agreement
- Postdoctoral Fellow and Research Associate at UBC
 - ▶ Environmental Security & Energy issues
 - ▶ Policy recommendations to national gov't /international orgs
 - ▶ Focus on policy/technology interface

Today's talk

- Introduction
- Bioenergy technologies
 - ▶ Residential use
 - ▶ Industrial use
 - ▶ Biorefining approaches
- Regional approach
 - ▶ USA
 - ▶ Germany
 - ▶ Sweden
- Summary

Oil Prices and World Events



Why bioenergy?

- Energy security: Significant increases in global (and Canadian) energy demand; political instability in key oil producing regions
- Environment: One of a suite of 'renewable & sustainable' energy technologies that can reduce GHG emissions over fossil energy
- Employment: Bioenergy is viewed as a 'new' product that can complement existing forestry and agriculture
- High energy prices: Oil has topped US\$ 140/barrel in recent months (although, not so high now!)

Residential bioenergy

Residential bioenergy options:

- Open fires
- Traditional wood stoves
- Charcoal
- Wood pellets



Efficiency of energy recovery

Residential heat generation

| | 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 |

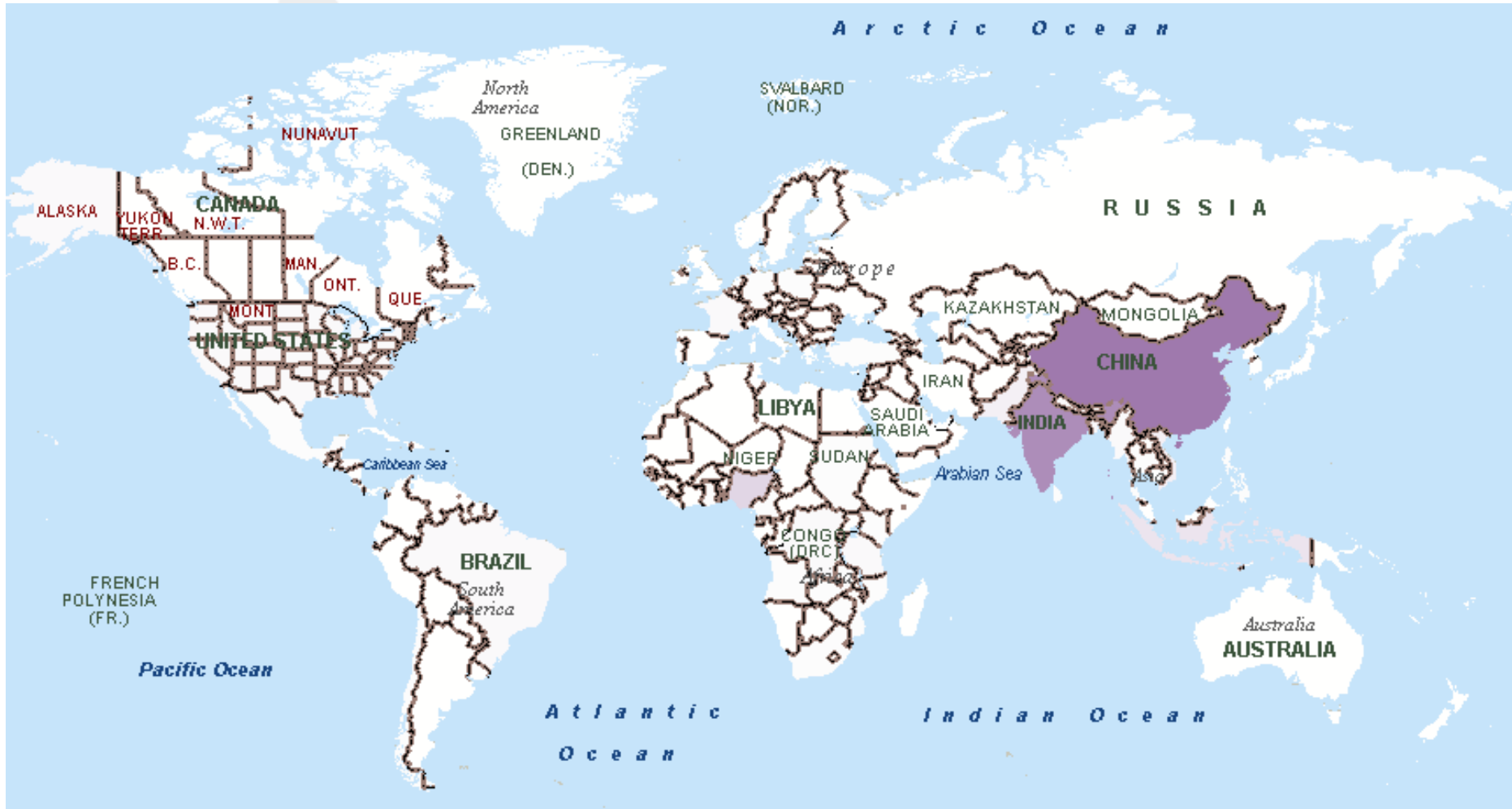
Sources: Karlsson, Gustavsson 2003; Mabee et al. 2001

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

Residential bioenergy use

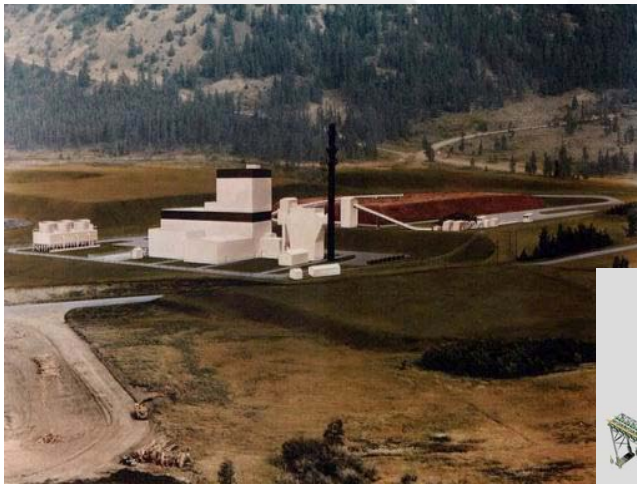
per country, TJ

Source: IEA 2007



- >10 million TJ
- 7.5-10 million TJ
- 5-7.5 million TJ
- <5 million TJ

Industrial bioenergy



Industrial bioenergy options:

- Combined heat & power
- Power boilers
- Gasification
- CHP + Heat recovery systems



Efficiency of energy recovery

Industrial heat and power generation

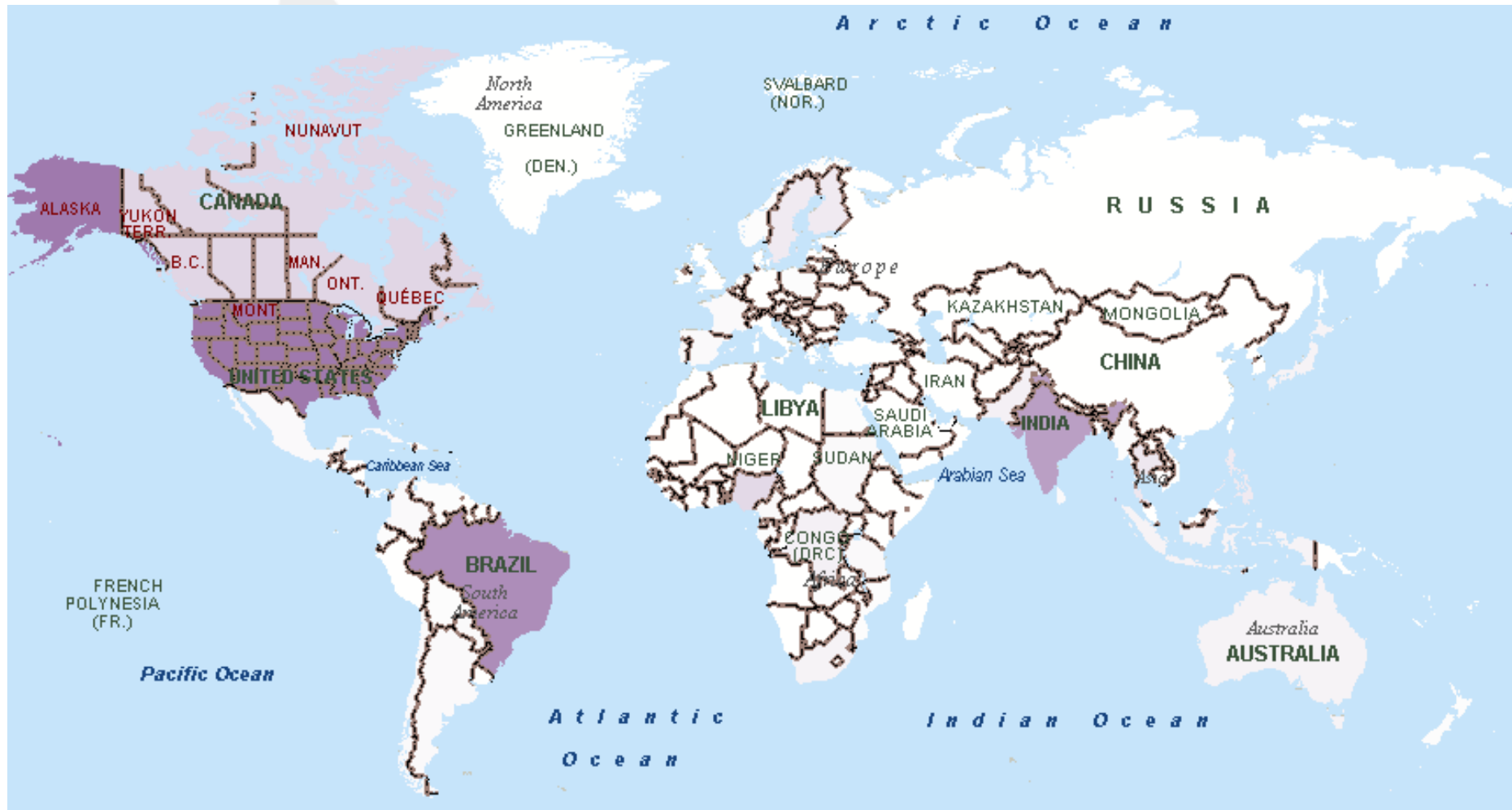
| | Conversion efficiency (η_e) | Avg. energy recovered (GJ/bdt wood) |
|---------------------------------|------------------------------------|-------------------------------------|
| Combined Heat & Power (CHP) | 0.30 - 0.44 | 6 - 8.8 |
| Steam-turbine power boiler | 0.40 | 8 |
| Gasifier/power generator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

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

Industrial bioenergy use

per country, TJ

Source: IEA 2007



- >1.2 million TJ
- 0.8-1.2 million TJ
- 0.4-0.8 million TJ
- <0.4 million TJ

Biomass-to-electricity

per country, GWh

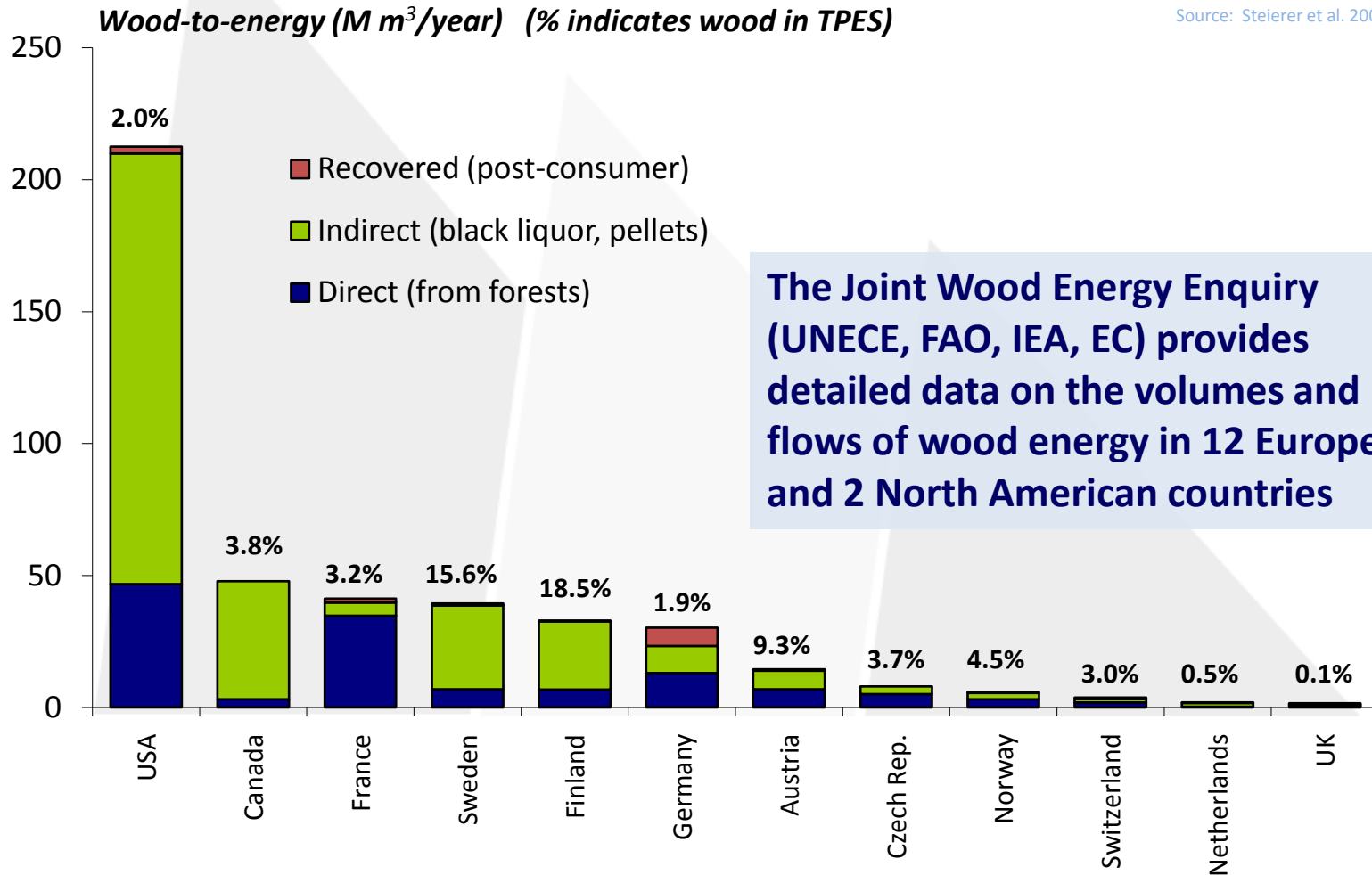
Source: IEA 2007



Wood-to-energy

Joint Wood Energy Enquiry (IEA, FAO, EC, UNECE)

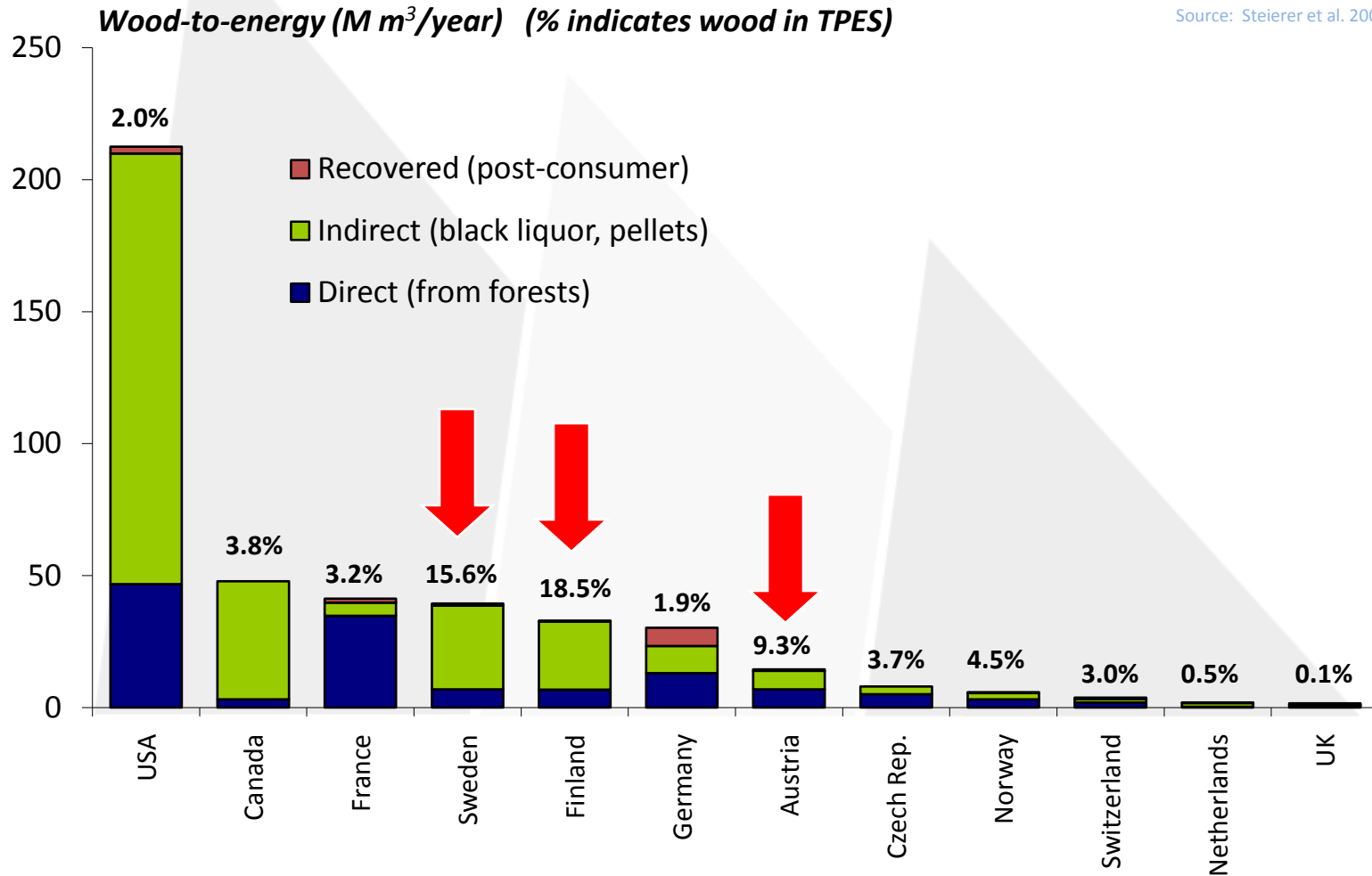
Source: Steierer et al. 2007



Wood-to-energy

Joint Wood Energy Enquiry (IEA, FAO, EC, UNECE)

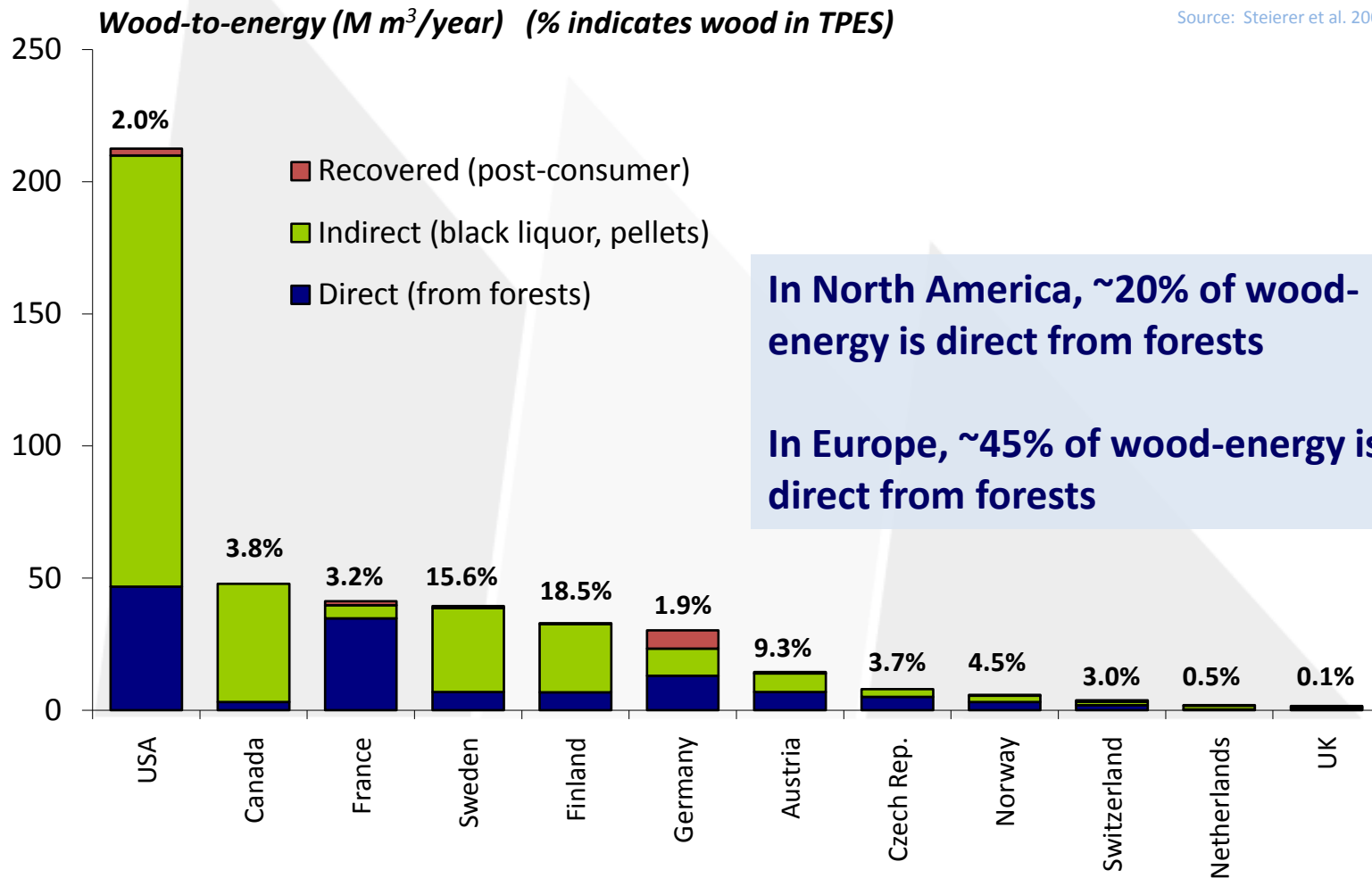
Source: Steierer et al. 2007



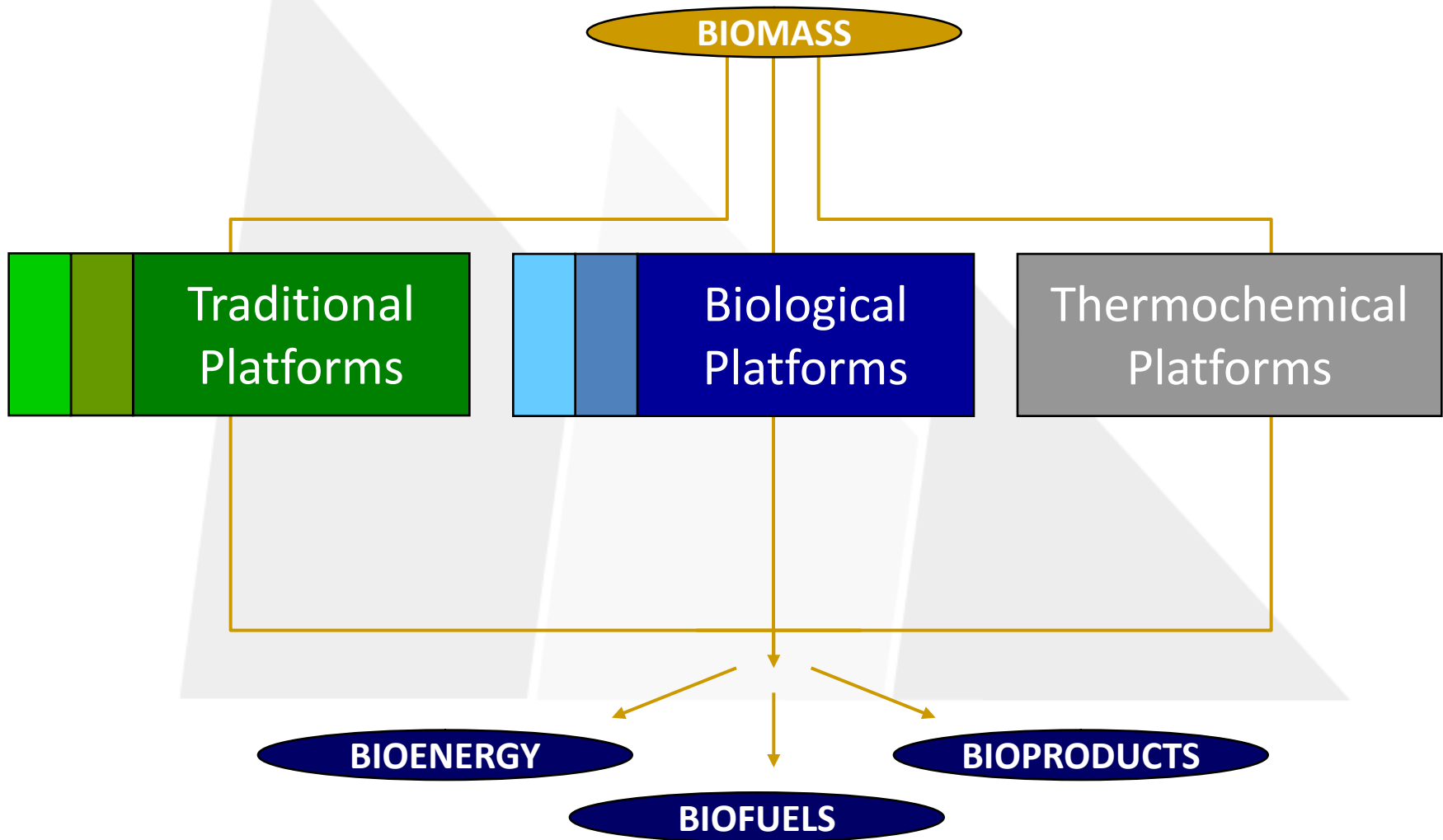
Wood-to-energy

Joint Wood Energy Enquiry (IEA, FAO, EC, UNECE)

Source: Steierer et al. 2007



Biorefining Platforms



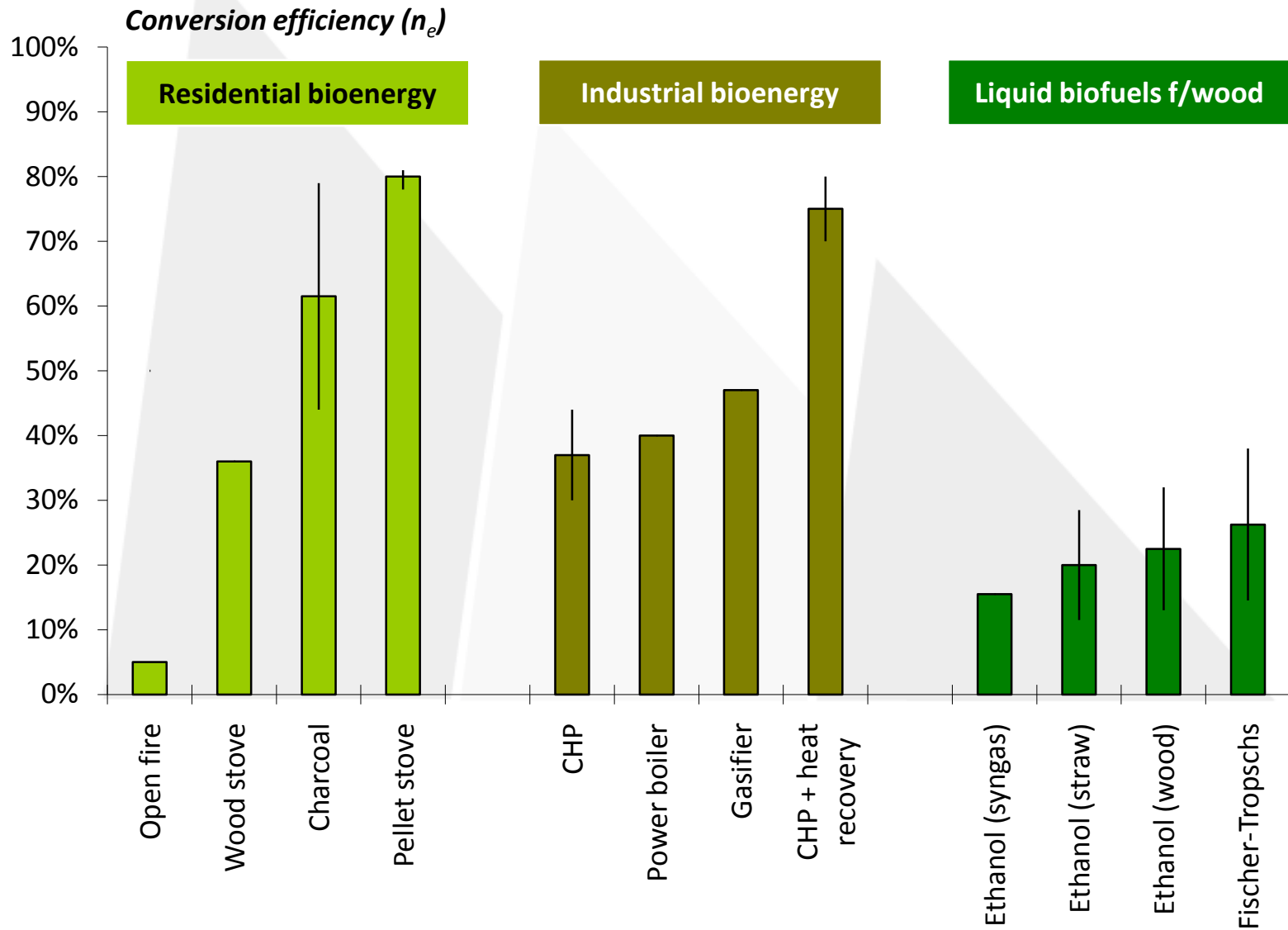
Efficiency of energy recovery

Biofuel generation w/o 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 |
| | | |
| <i>Straw-to-ethanol</i> | <i>109 - 270</i> | <i>2.3 - 5.7</i> |

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

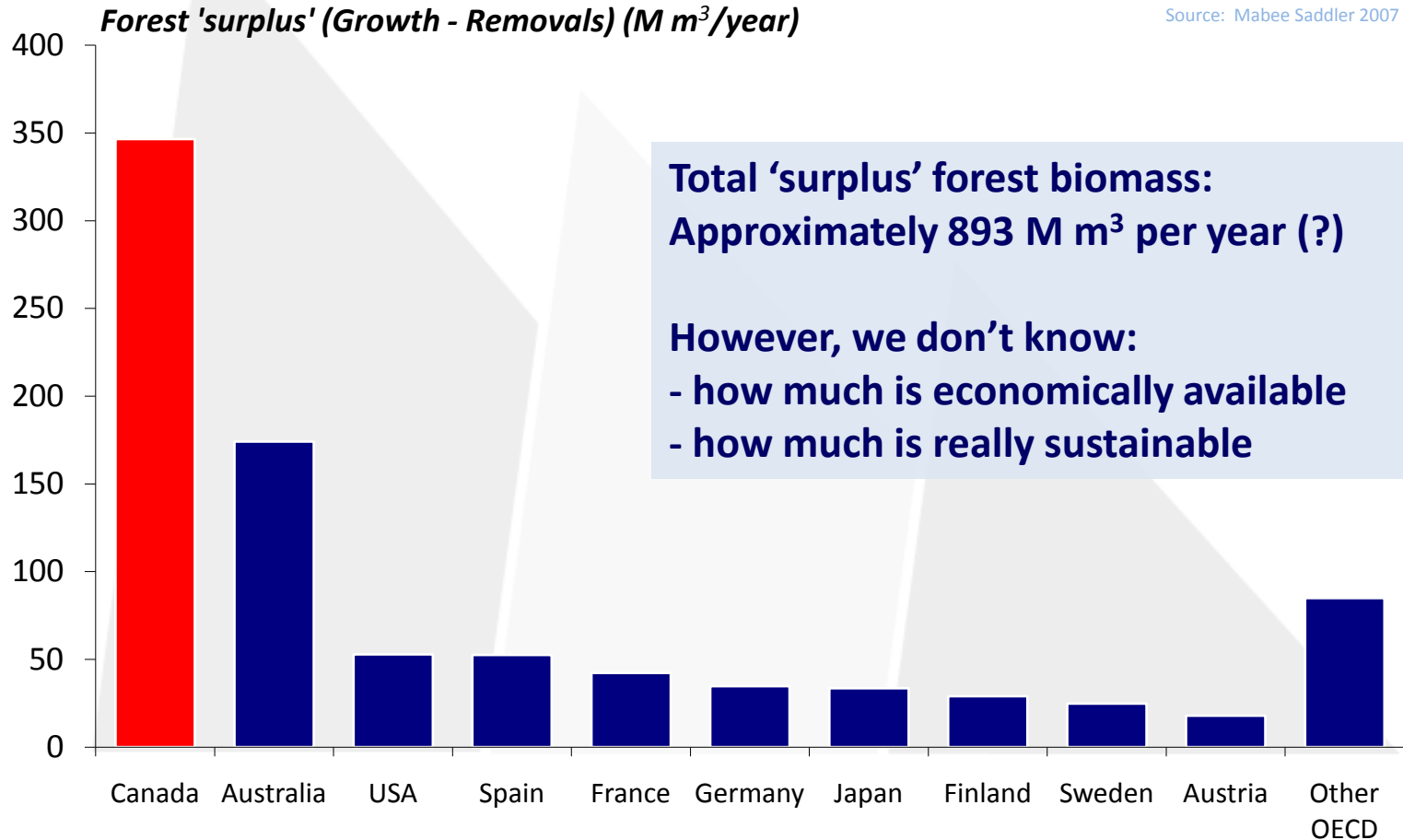
Comparing efficiencies



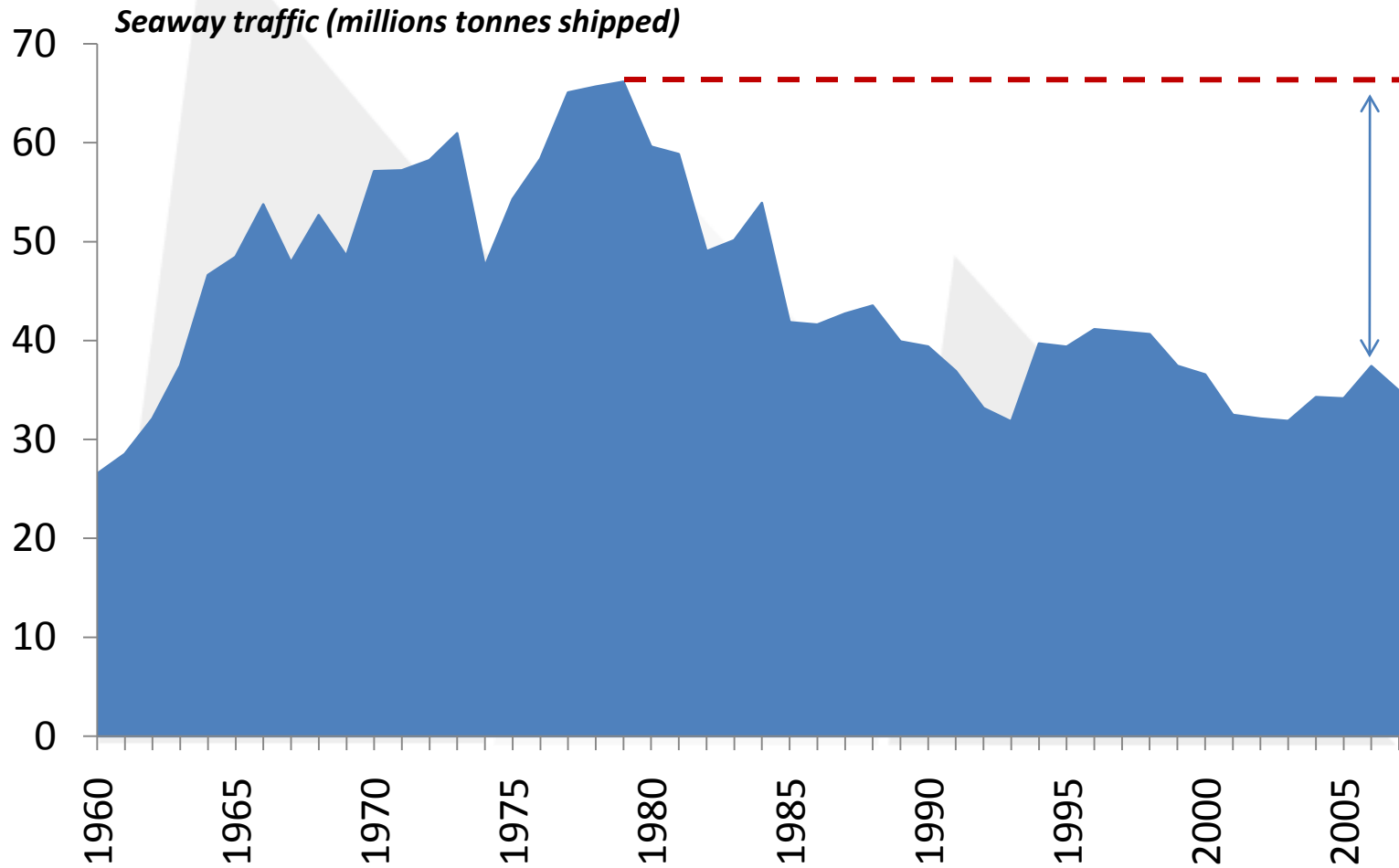
Forest biomass (OECD)

OECD Countries – FAO & National Data

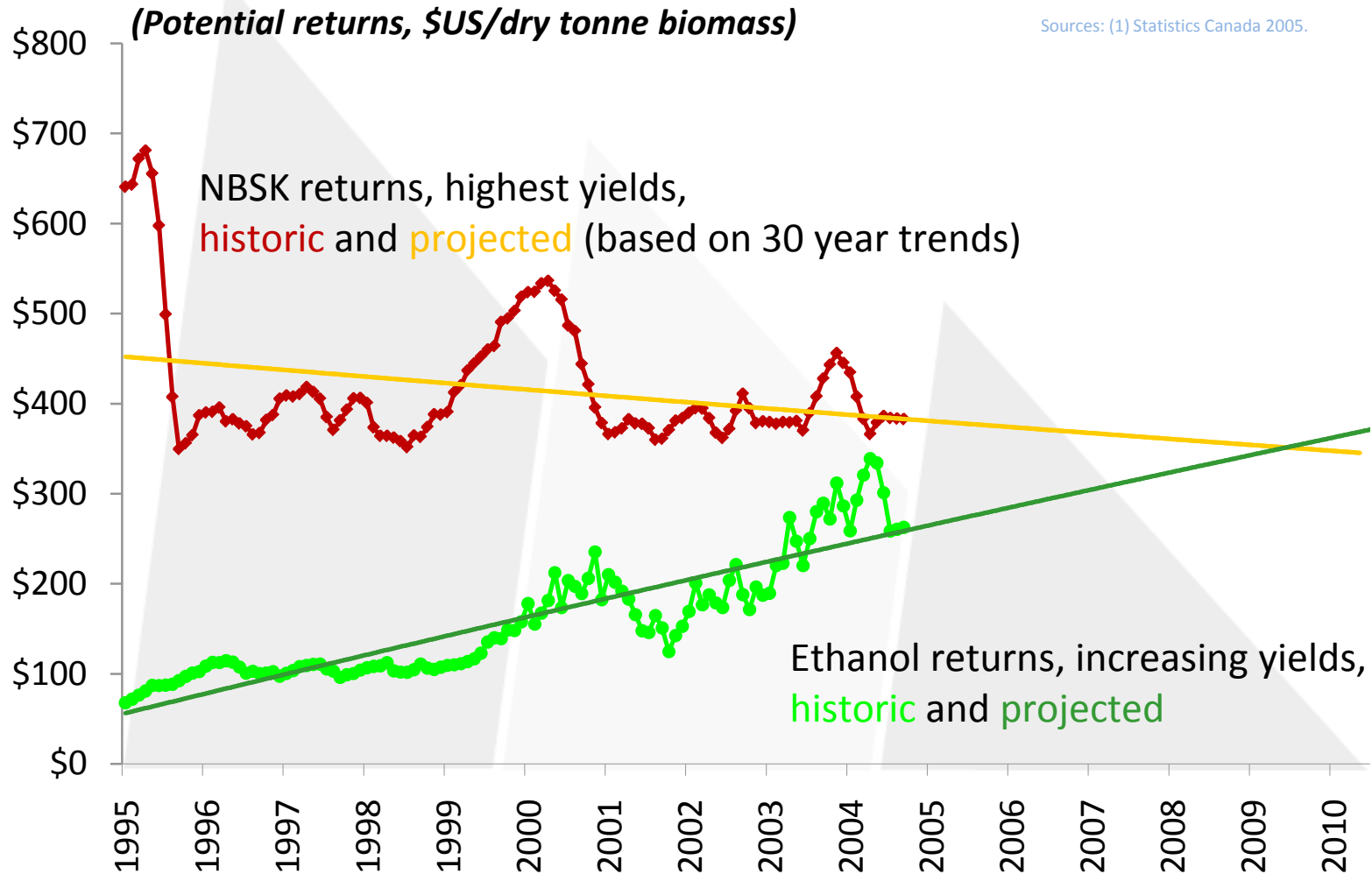
Source: Mabee Saddler 2007



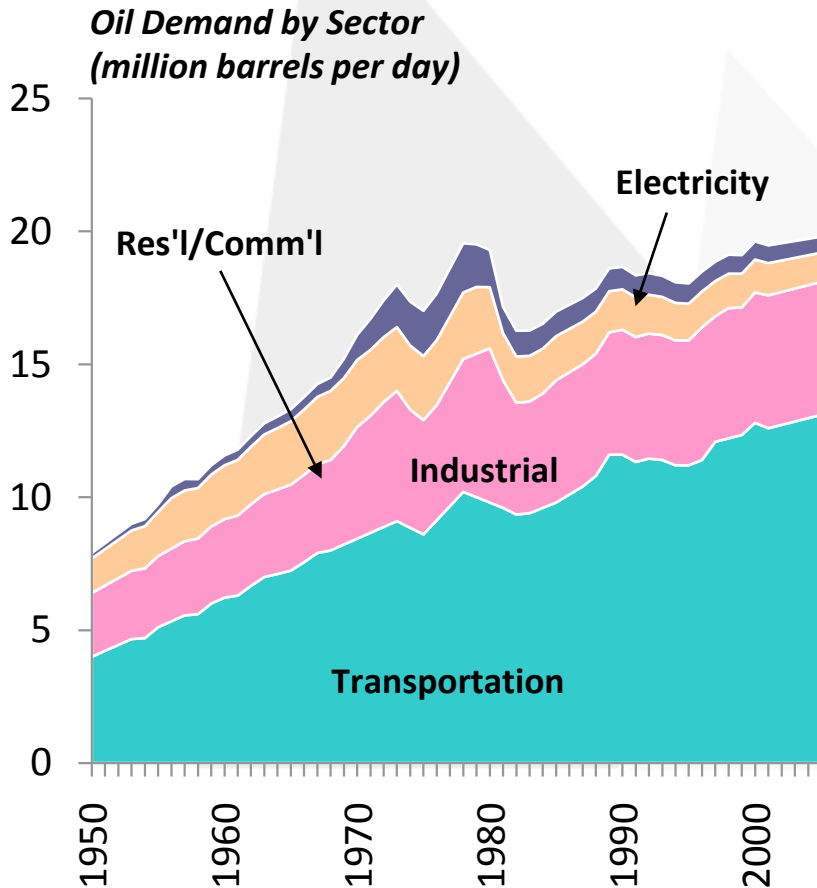
Corridor opportunities



Bioenergy vs. Forest products

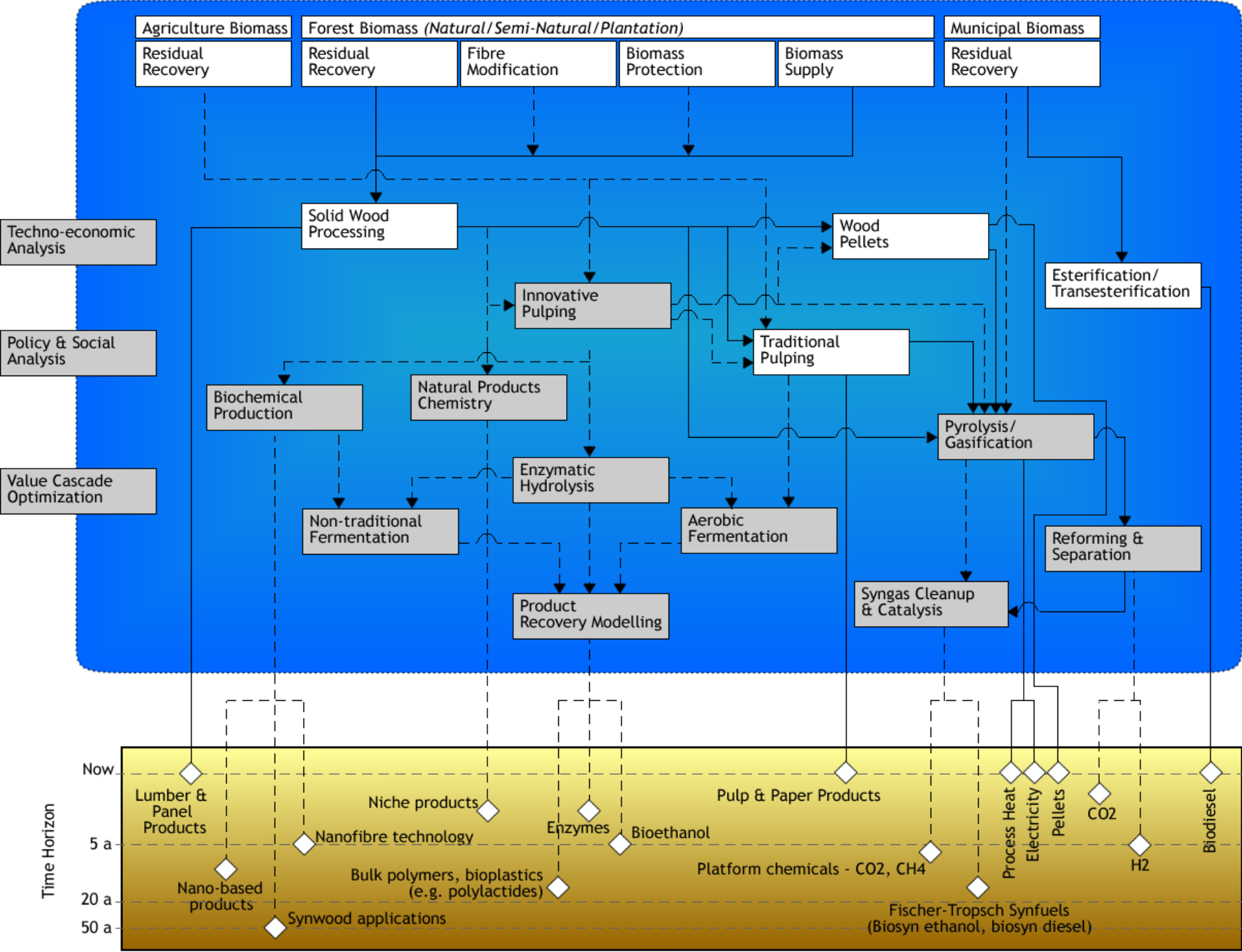


Oil refinery



Traditional oil refining:

- ~68-70% transportation sector (i.e. gasoline, diesel)
- ~21% industrial processing
- ~5% ind. plastics, chemicals (over 2,000 refinery products)
- ~4% residential/ commercial heating
- <3% electricity generation



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 |

Bioenergy policy issues

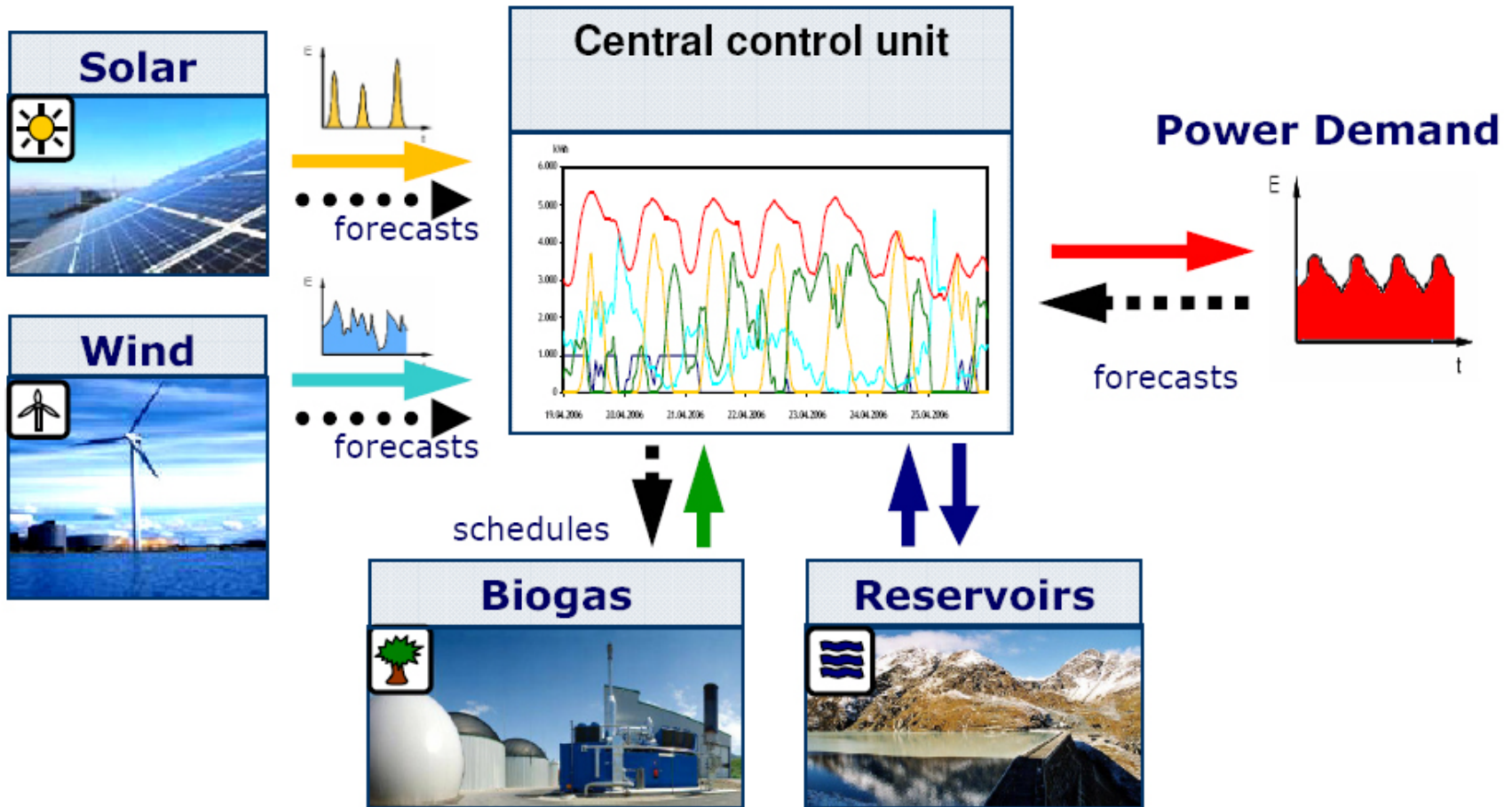
- Not clearly differentiated from renewable energy goals and policies in most cases (*although some Provinces are better*)
- Interdisciplinary nature of bioenergy requires multiple agencies to collaborate in traditional government systems (*i.e. natural resources, environment, energy, interior, transport, etc.*)
- Confusion exists over performance metrics (*i.e. economics, GHG emissions, energy balance, contribution to TPES, etc.*)
- Need for coordination between stakeholders

Germany

- Implemented the *KombiKraftwerk* (Combined Power Plant) project in 2007
- Showed that 36 decentralized wind, hydro, solar, and biogas energy plants could supply electricity around the clock, regardless of weather conditions or demand
- Scaled to meet 1/10,000th of the electricity demand in Germany
 - ▶ Provide annual electricity requirements of a small town with 12,000 households
 - ▶ Three companies – Enercon GmbH, Schmack Biogas AG, SolarWorld AG

Germany

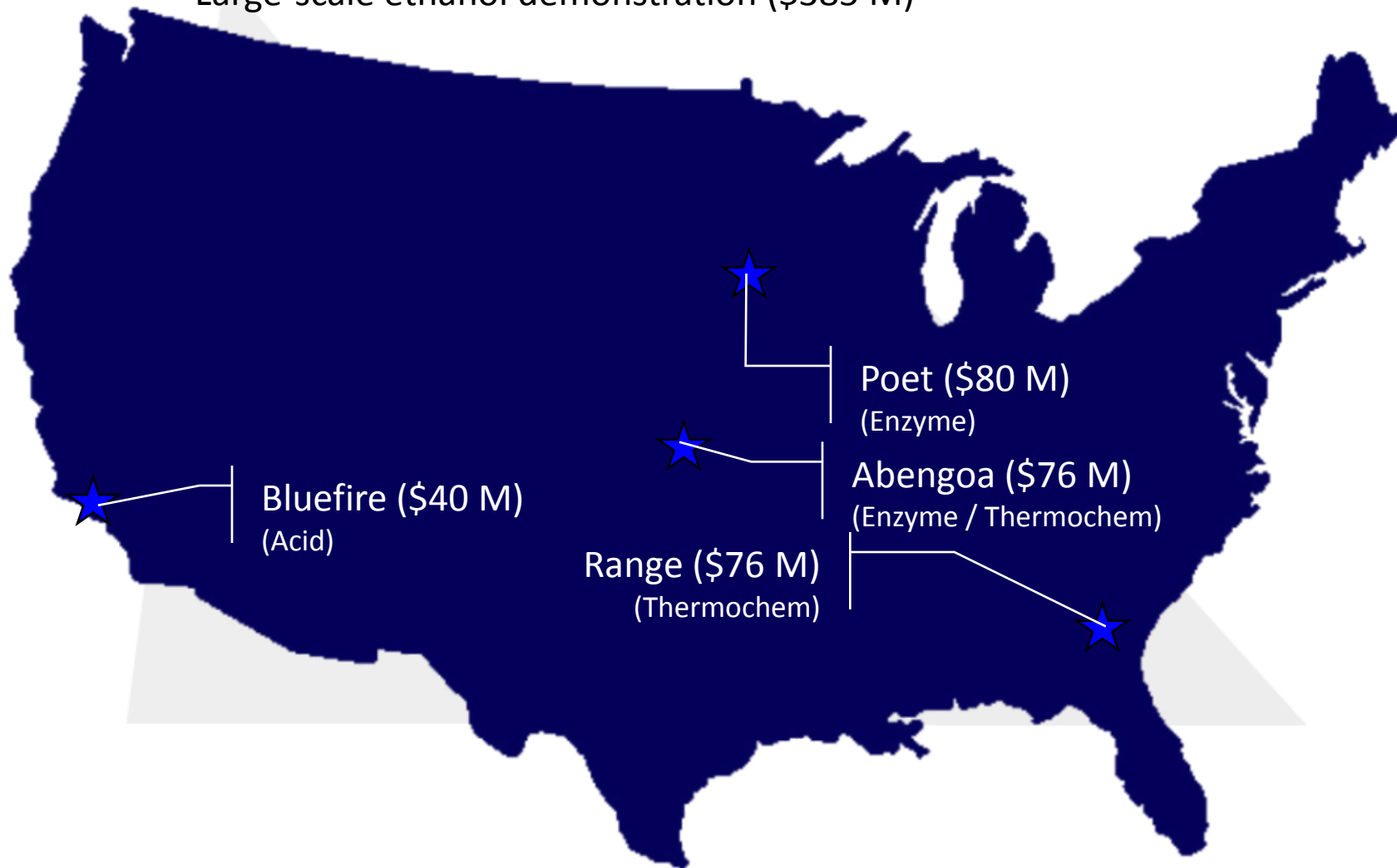
Combined Power Plant



Source: <http://www.kombikraftwerk.de>

USA - Cellulosic ethanol I

Large-scale ethanol demonstration (\$385 M)



USA - Cellulosic ethanol II

Smaller-scale biorefineries (\$114 M)

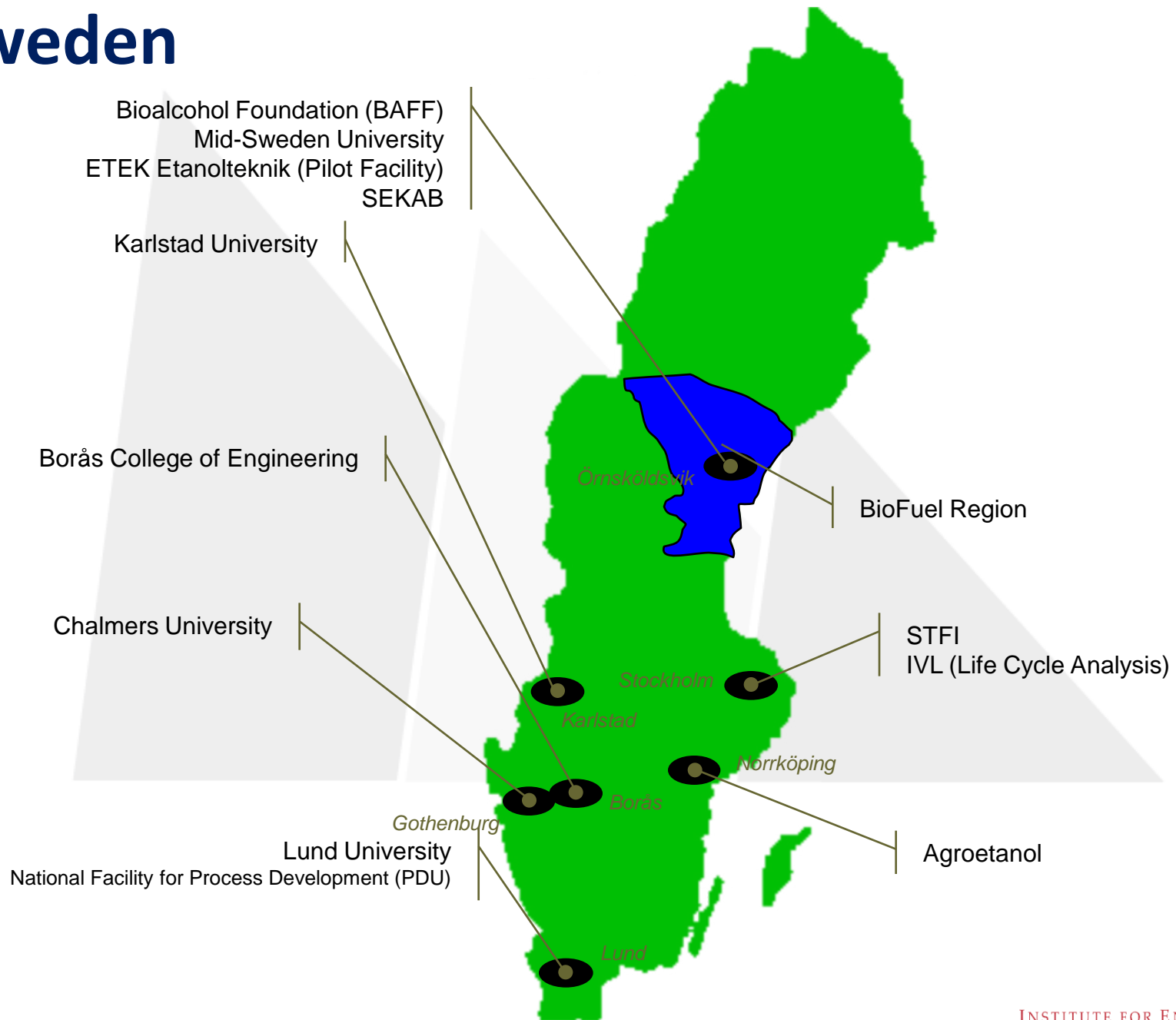


USA - Cellulosic ethanol II

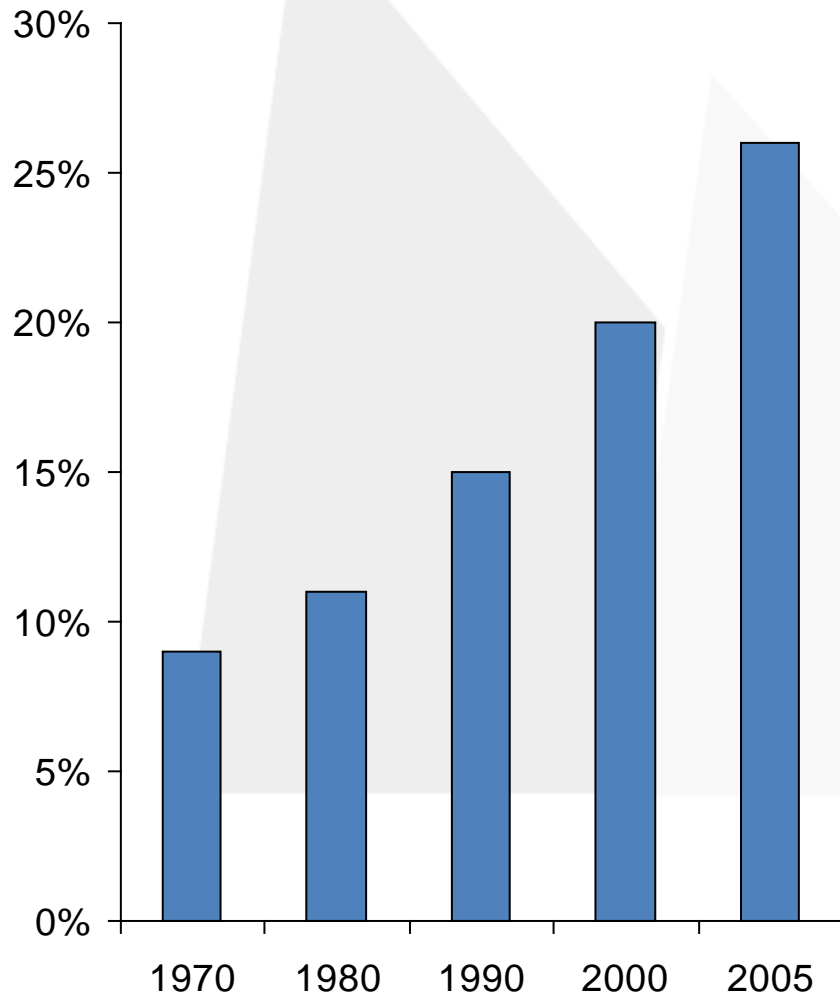
Smaller-scale biorefineries (\$114 M)



Sweden



Sweden



Major bioenergy uses include

- Combined heat and power
- District heating
- Biogas production for fuel
- Biogas train (Linköping to Västervik)
- Biogas, biodiesel buses
- Bioethanol cars, buses

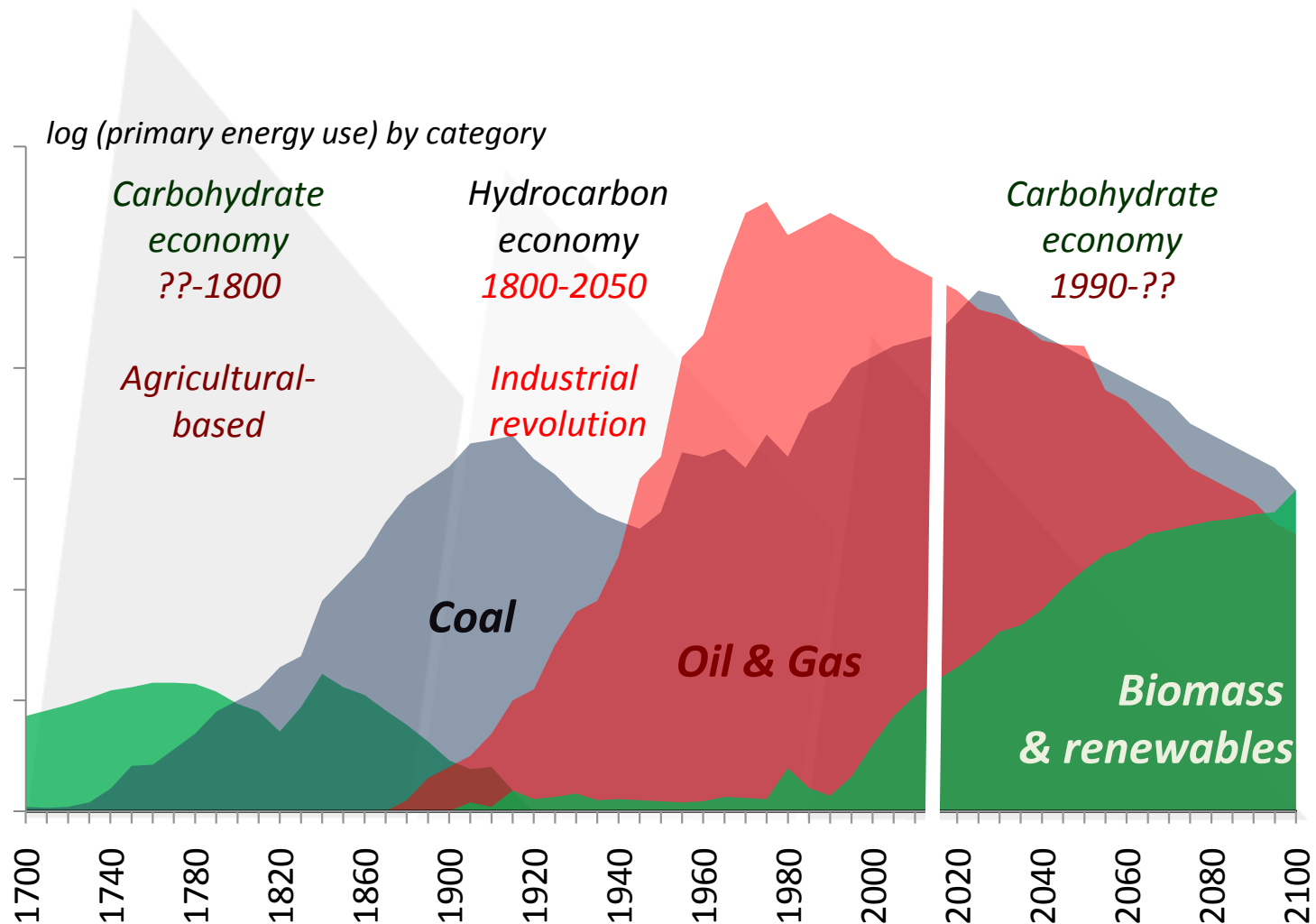
Sweden

- BioFuel Region:
 - ▶ A role model region in the process of implementing a renewable transport system based on biomass
 - ▶ Self sufficient in transport fuels by 2020
 - ▶ Industrial and regional growth
 - ▶ Maintain the know-how leadership
 - ▶ 15 Municipalities
 - ▶ 2 Counties
 - ▶ 3 Universities
 - ▶ 1 County Council
 - ▶ 2 National Authorities
 - ▶ 200 individuals
 - ▶ Companies

Take-home messages

- Research is still required, including development of better data describing **biomass availability in forests** and trade-offs between **traditional forest products and bioenergy**
- Clearer **bioenergy policy goals** would help define the size of the opportunity for forests
- Policy impacts include an increased role for biofuels as well as bioenergy in the form of heat and power; this may result in great **increases to forest biomass demand**
- Criteria for pursuing a bioenergy future - wood-based systems should:
 - ▶ **Improve energy balance** over food-based biofuels
 - ▶ **Reduce GHG emissions** over petroleum fuels and food-based biofuels
 - ▶ Help deal with local impacts of **climate change**
 - ▶ Help support **local economies**

Looking back and forward...



Acknowledgements

- IEA Bioenergy Task 39
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Questions?



Thank you!



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