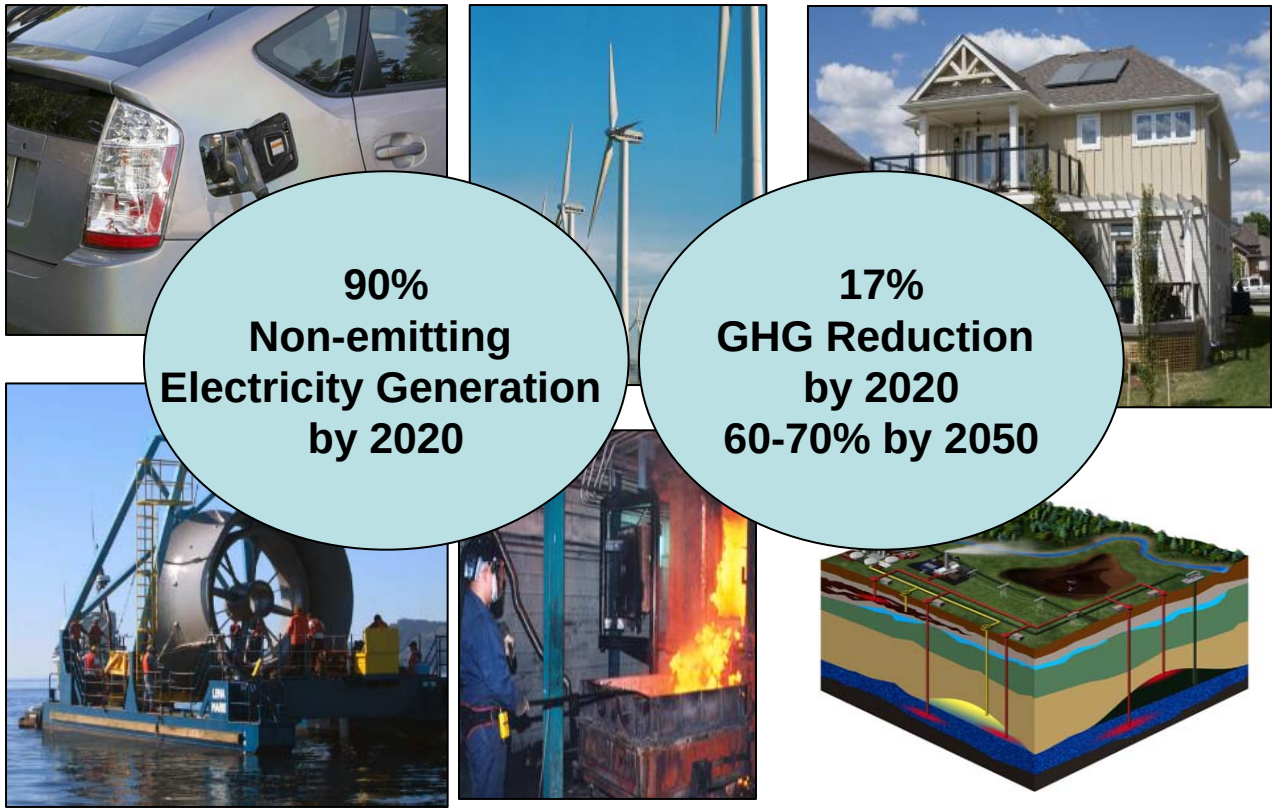
Heavy Oil Upgrading
from mine to motor

C Fairbridge, J Chen, P Rahimi, E Little
Devon, Alberta, Canada

August 1, 2011
Heavy Oil Working Group
Energy and Climate Partnership of the Americas

Targets, mandates, action plans and LCFS



A Low Carbon Fuel Standard seeks to reduce the carbon footprint of transportation fuel production by 10% by 2020.

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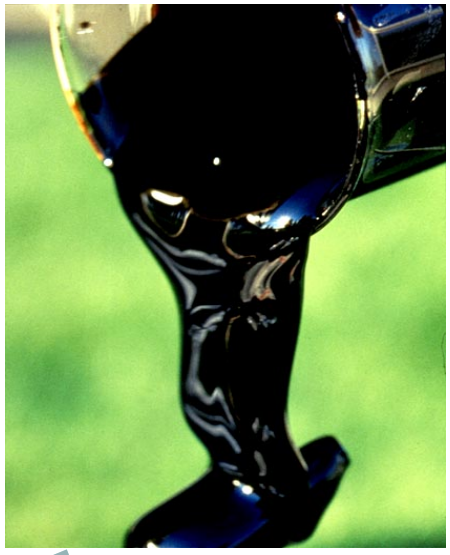
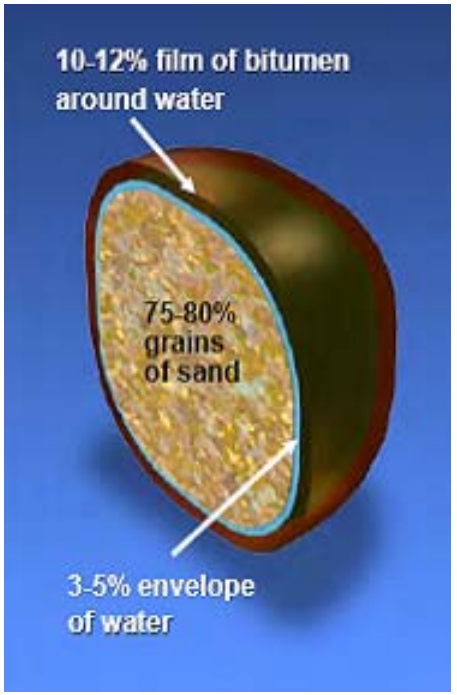
Oil Sands

Extra-heavy oil derived from oil sand is a viscous petroleum consisting of millions of different molecules. The final energy products derived from oil sands are transportation fuels: gasoline, jet fuel, and diesel fuel. An evolution of technologies in advanced combustion engines and in transportation fuels is anticipated, motivated by concerns for human health and the environment – to reduce criteria air contaminants and to mitigate climate change resulting from personal mobility.





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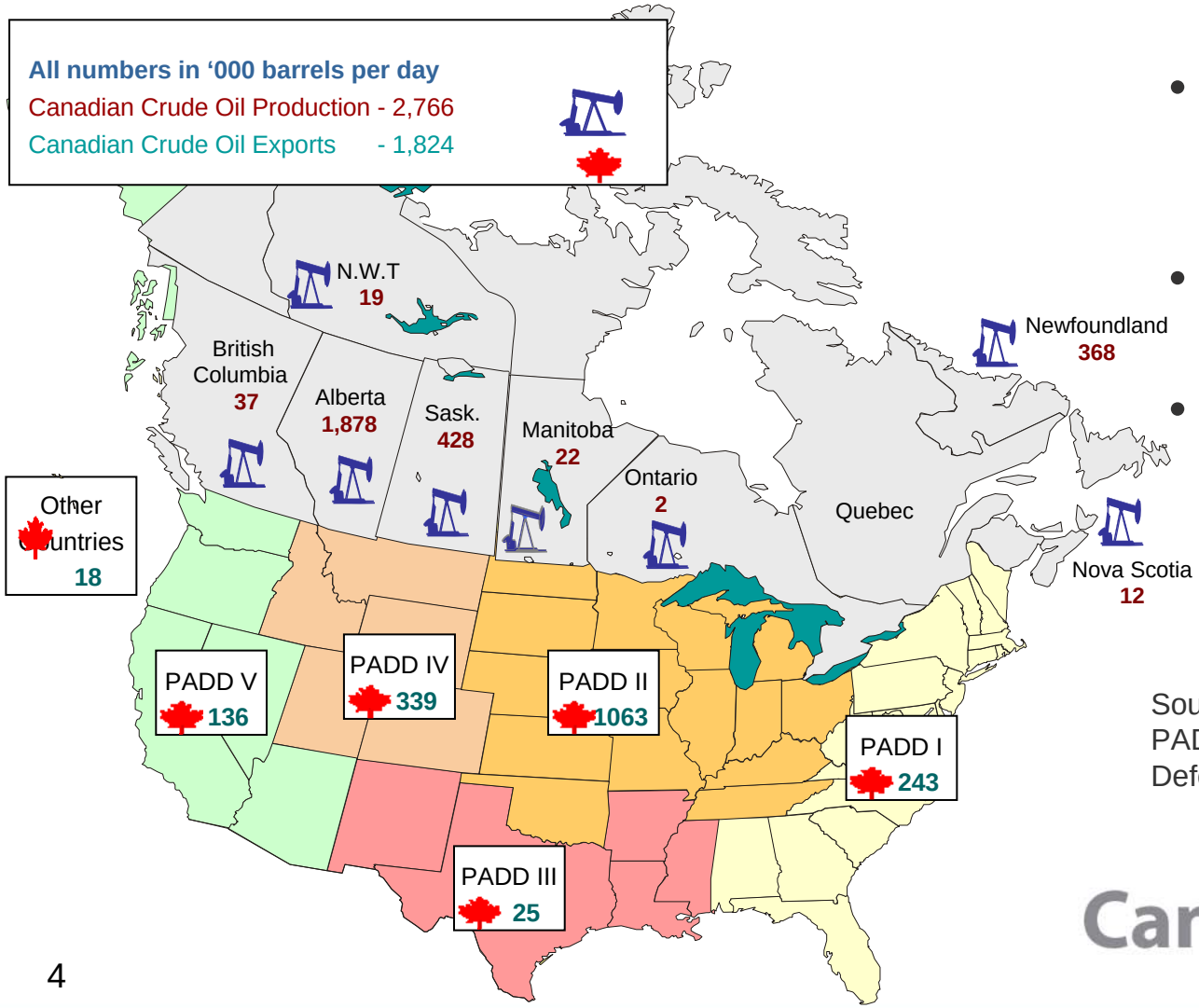
Canadian Crude Oil Exports - 2007



- Oil sands supply over half of Canada's crude exports
- This share is projected to grow over time
- US companies are among the largest investors in oil sands operations

Source: Statistics Canada, 2007 data
PADD = US Petroleum Administration for Defense Districts

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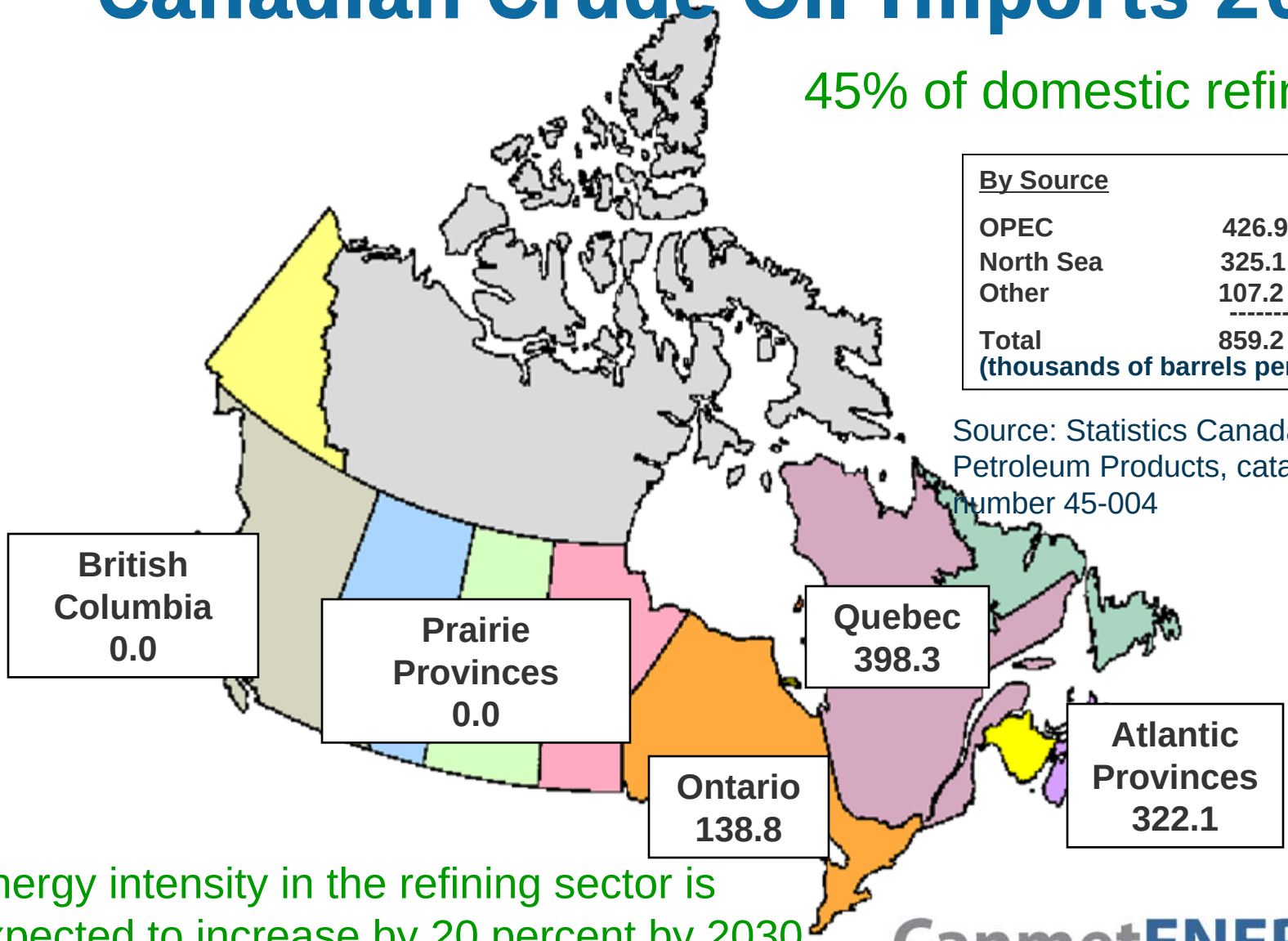
Canadian Crude Oil Imports 2007

45% of domestic refinery feed



By Source	
OPEC	426.9
North Sea	325.1
Other	107.2
Total	859.2

(thousands of barrels per day)

Source: Statistics Canada, Refined Petroleum Products, catalogue number 45-004

Energy intensity in the refining sector is expected to increase by 20 percent by 2030 as the crude oil mix becomes heavier.

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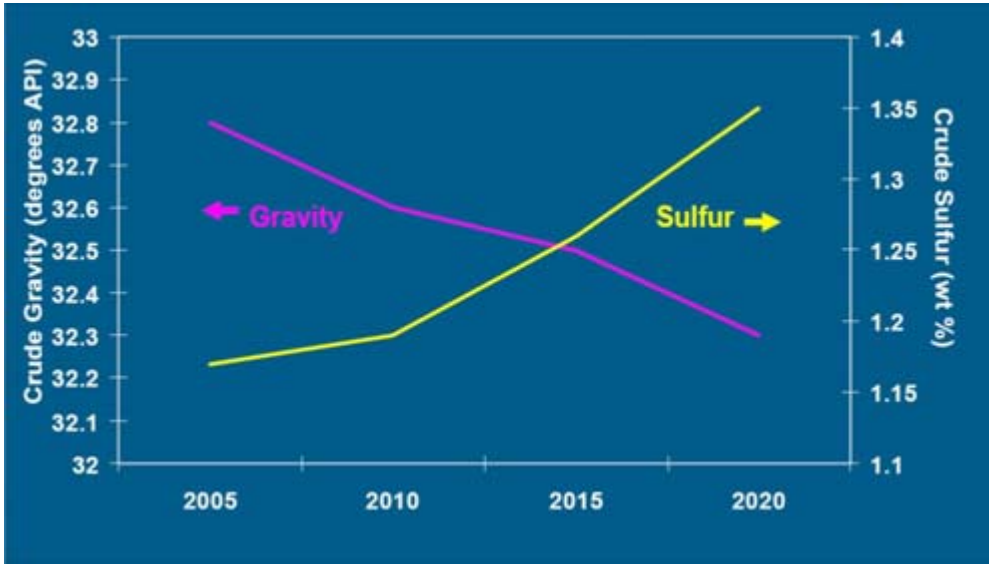
Importance of Heavy Oil Conversion Technology Development 2010-2030

Considering the forecasted demand for crude oil and the increasing density of petroleum sources globally, investment in heavy oil conversion technologies to upgrade increasing amounts of residue (i.e. that portion of crude oil boiling above 523ºC) will be required for Canadian imports by 2030.



Avery 2008, Albemarle Presentation, Devon AB

Energy intensity in the refining sector is expected to increase by 20 percent by 2030 as the crude oil mix becomes heavier.

An Air Quality Impact Study of Canada's Oil and Natural Gas Industry, January 6, 2009– Clearstone Engineering, New Paradigm Engineering, RMW Ventures

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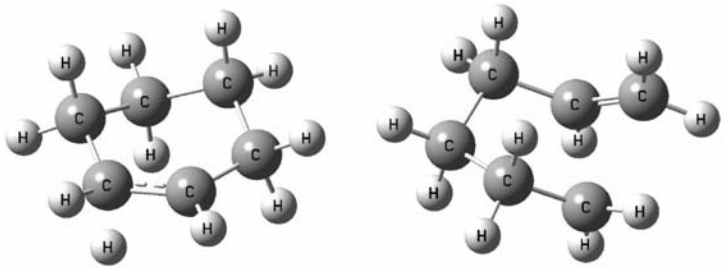
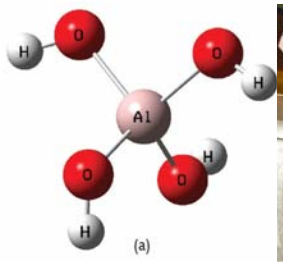
Bitumen Conversion Technology Research at CanmetENERGY Devon

- Adapting or developing technologies to reduce energy consumption and/or air emissions when converting petroleum into products
- Advanced characterization of oil sands crude and heavy oils to improve understanding of chemical processing, fouling, corrosion and crude compatibility
- Developing standard methods
- Collaborating with the Government of Alberta to maintain process scale-up capabilities and pilot plants





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Revenue based on density - higher hydrogen content more valuable

Production cost based mostly on viscosity but also on the amount of water handled

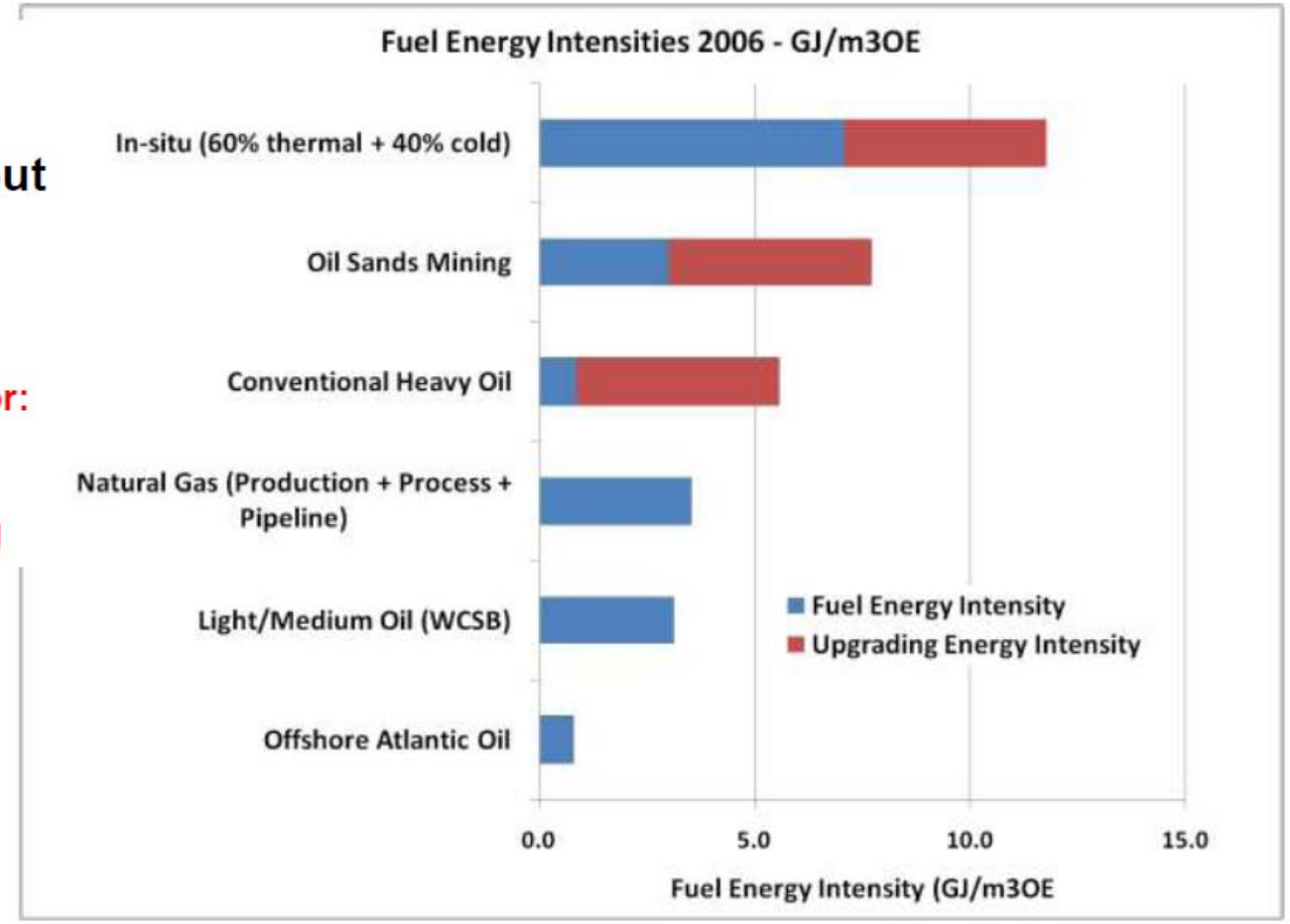
Conversion cost based on sulfur content, asphaltene content, acid number, metals content

Transportation cost based on diluent purchase

Energy intensity

1 m^3OE ~ 40 GJ
So 10 GJ/m^3OE ~
Is about 25% of the input energy in the product
1 GJ/m3OE ~ 2.5%

NB Equivalent input/output for:
Coal Power ~300%
Nuclear ~ 1700% once thru without fuel rod reprocessing



Source: Clearstone et al - An Air Quality Impact Study of Canada's Oil and Natural Gas Industry – October, 2008

Emerging Upgrading Technologies

Integrated Upgrading/Gasification System in SAGD Operations

In situ Upgrading

- THAI and CAPRI processes
- ET DSP (Electro-Thermal Dynamic Stripping Process)

ETX Systems Inc. *IYQ Upgrading Technology*

Alberta Innovates: Energy and Environment Solution *Hydrocarbon Upgrading Demonstration Program (HUDP)*

- gasification technology being developed by Pratt & Whitney
- Arorincle process
- enhanced solvent deasphalting
- plasma gasification process

Emerging Upgrading Technologies

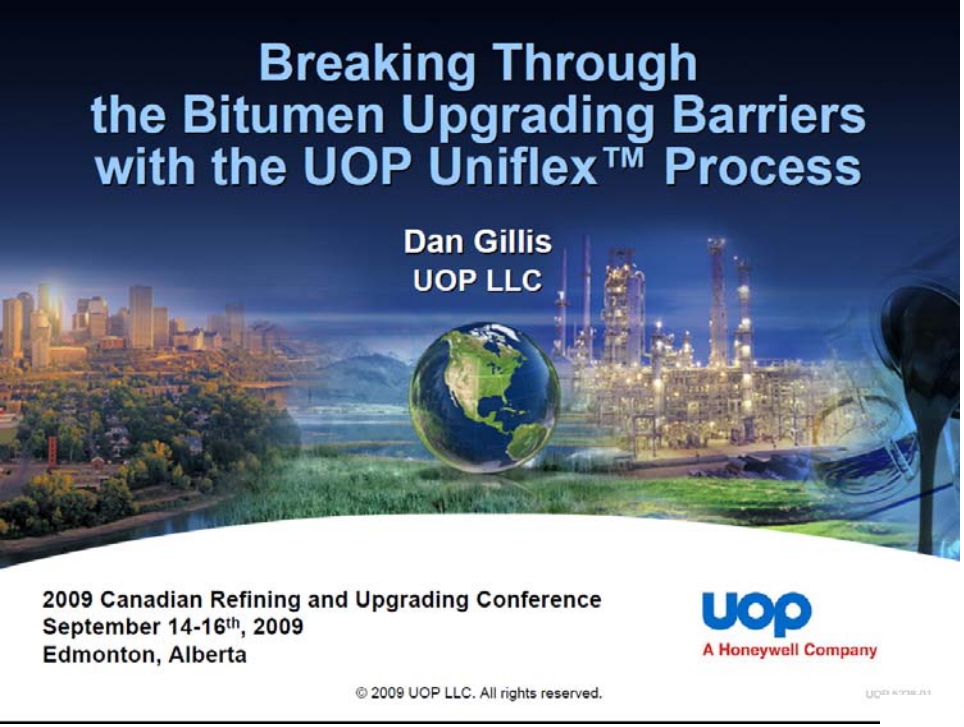
NIOC/Research Institute of Petroleum Industry (RIPI) Heavy Residue Hydroconversion (HRH) – refinery or well head

Ivanhoe Energy Inc. Heavy-to-Light (HTL) upgrading process

Slurry hydrocracking

- UOP Uniflex process (resid slurry hydrocracking)
- Veba combicracking process
- HDH Plus (originally by PDVSA and now also with Axens and IFP)
- EST (ENI Slurry Technology)

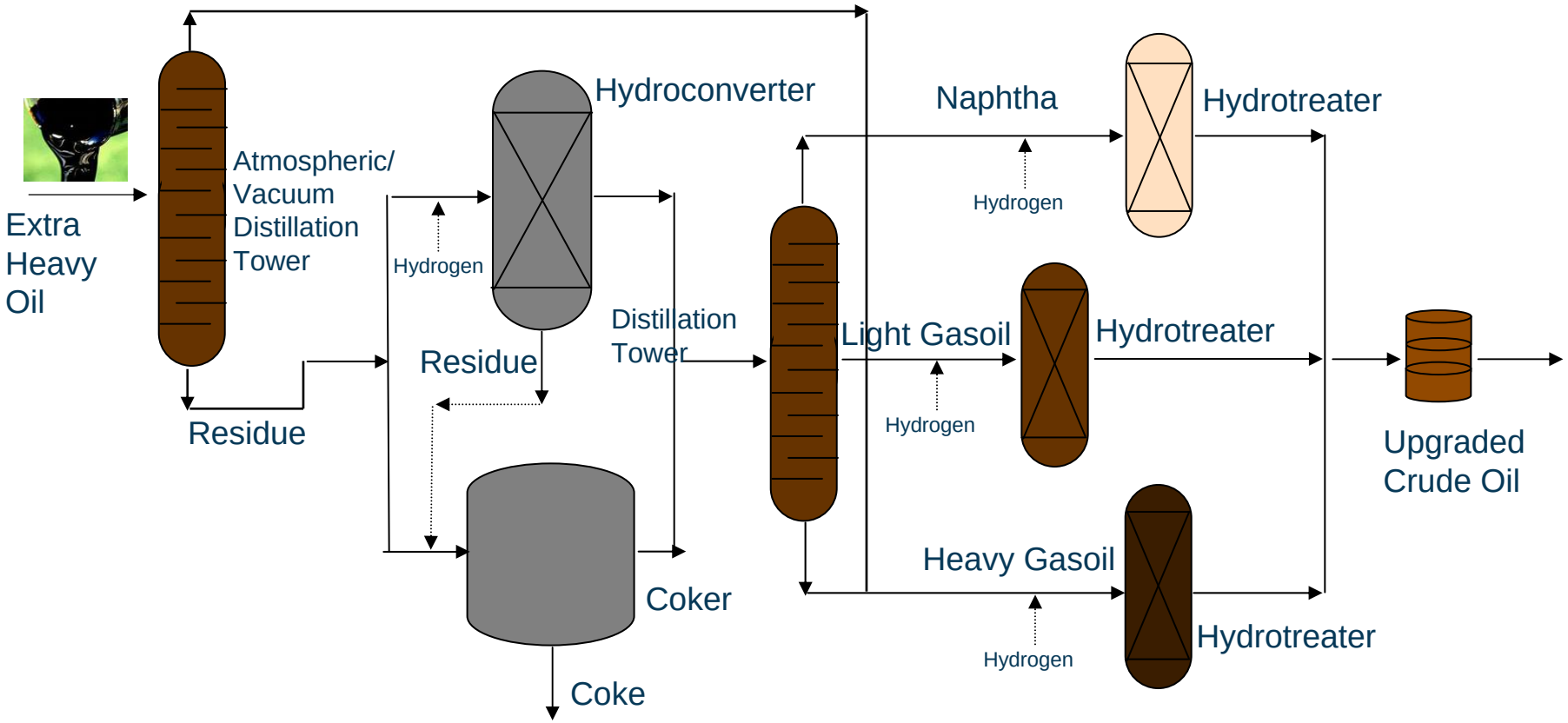
Solvent deasphalting (SDA)



http://canmetenergy-canmetenergie.nrcan-rncan.gc.ca/eng/oil_sands/publications.html?2010-001D

CanmetENERGY Upgrading and Refining Conference held every three years.
Next: September 2012

Heavy Oil Conversion to Upgraded Crude Oil



The goal is to reduce the impact on air quality not only of heavy oil production, but also of transportation fuel consumption, by researching energy transformation chemistry and advanced combustion for internal combustion engines.

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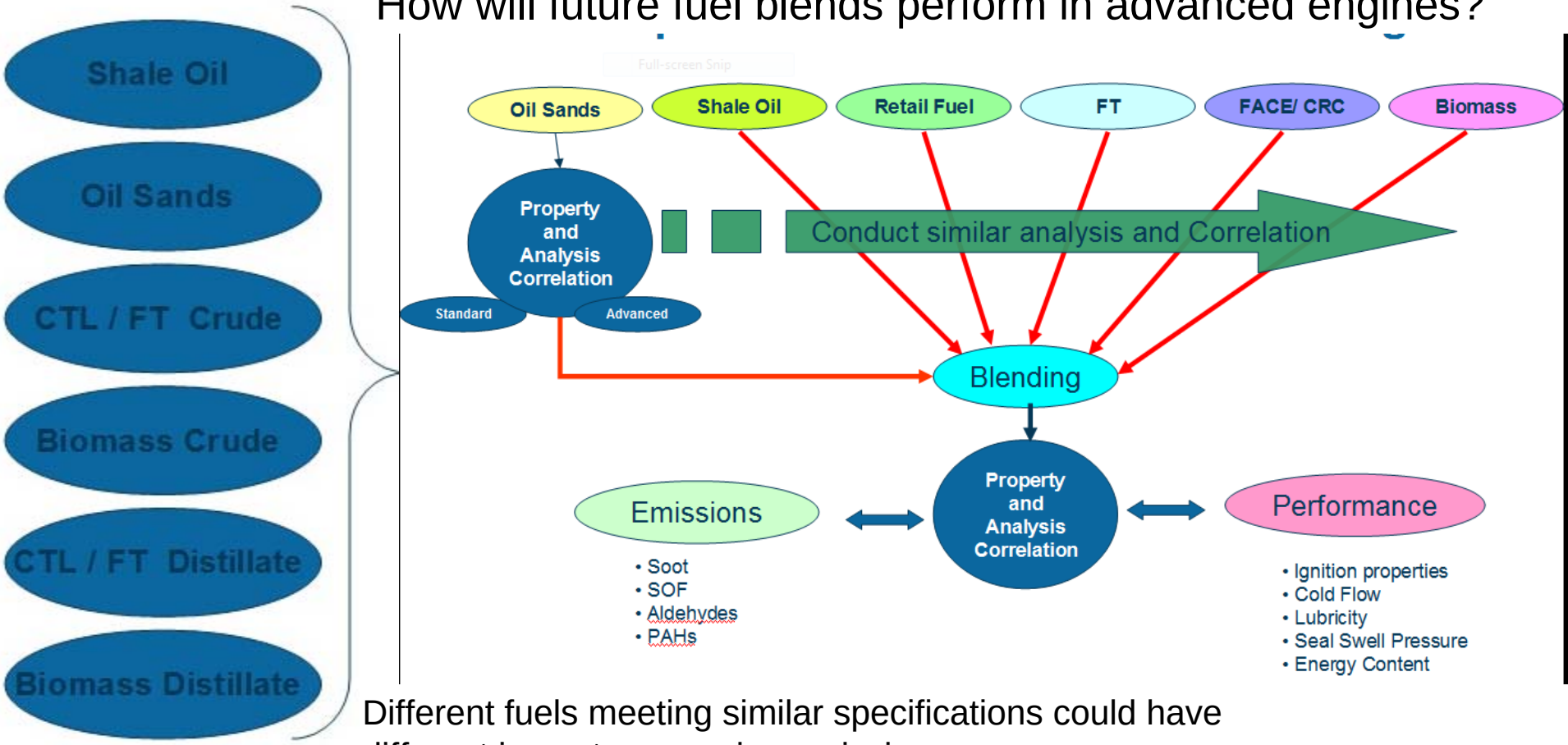
"Up to 10% of a refinery's carbon footprint is from the fouling in preheating trains…"

The fouling "problem is likely to worsen as refineries process greater volumes of heavier crude."

Opportunity Crudes Report II Technologies & strategies for meeting evolving market & environmental challenges. Hydrocarbon Publishing Company

Future Transportation Fuels

How will the future crude matrix be processed?
How will future fuel blends perform in advanced engines?



Different fuels meeting similar specifications could have different impacts on engine emissions.

What fuel chemistry will enable advanced combustion engines?

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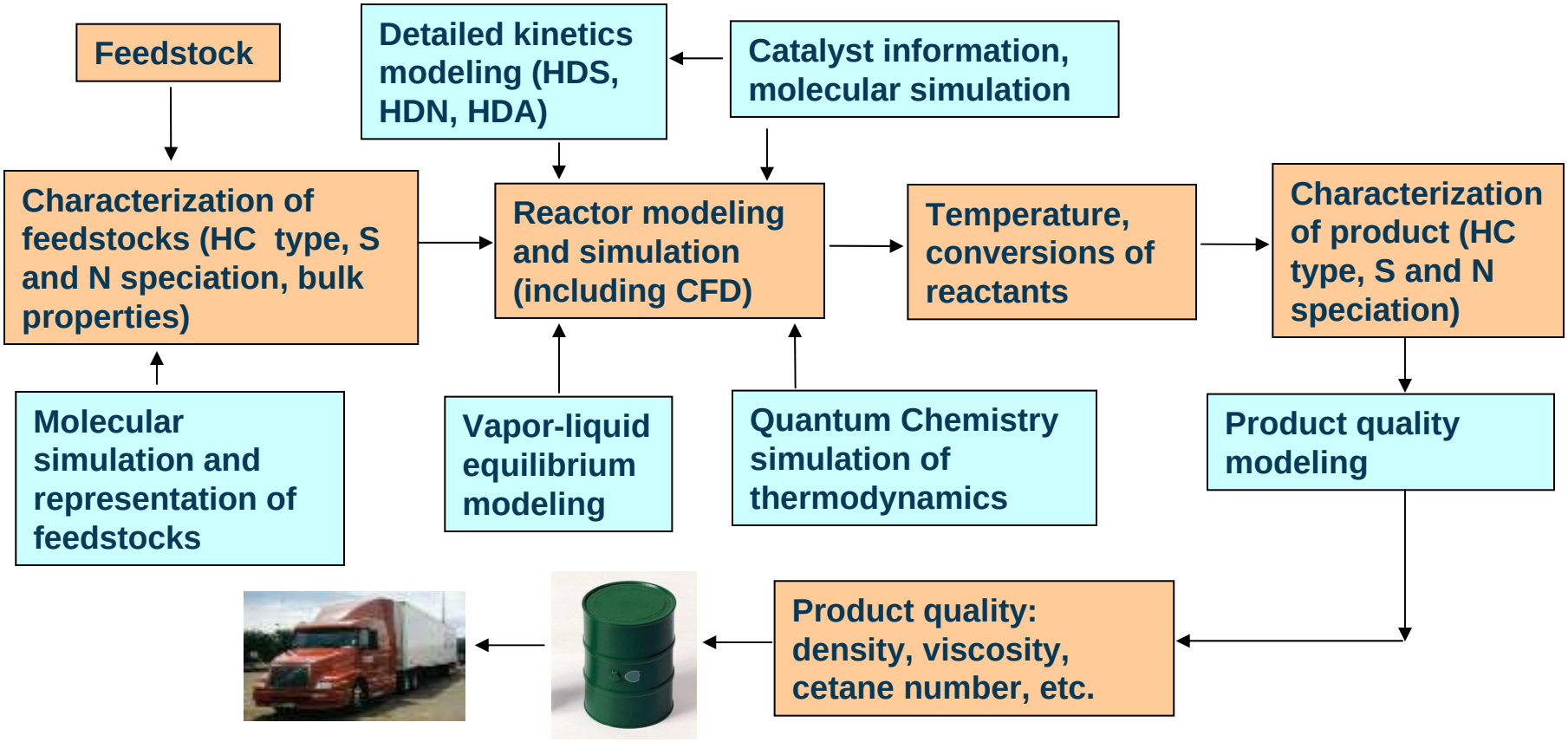
Petroleum Conversion to Transportation Fuel



The anticipated outcome is a smooth transition of extra-heavy oil products into existing and future markets with minimal negative local and global environmental impacts.

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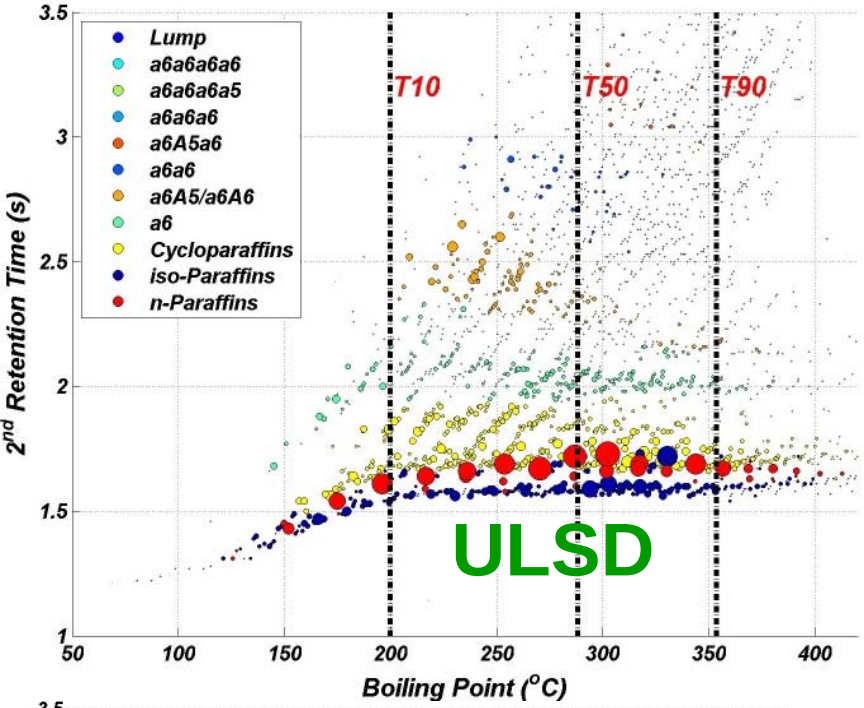
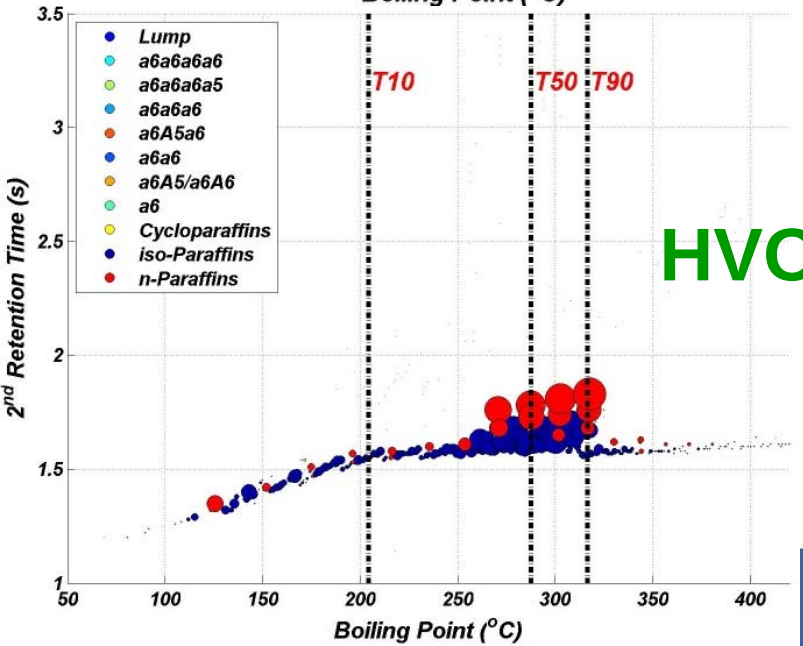
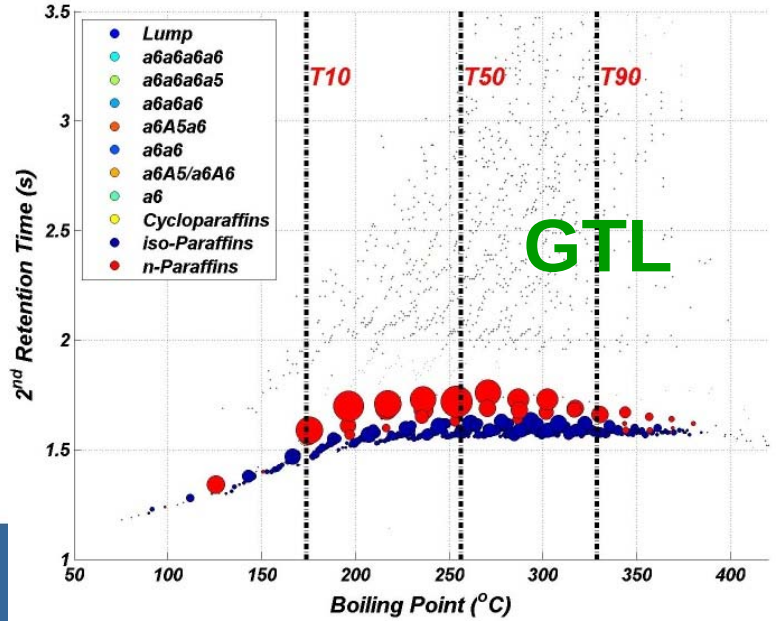
Future Diesel Fuel?







Life Cycle Assessment of Oil Sands Technologies

Dr. Joule Bergerson

Chemical and Petroleum Engineering
Centre for Environmental Engineering Research and Education
Institute for Sustainable Energy, Environment and Economy

Motivation for Research

Policies such as California's Low Carbon Fuel Standard

- First-of-kind to use LCA to *enforce* policy
- Requires more sophisticated tools and frameworks

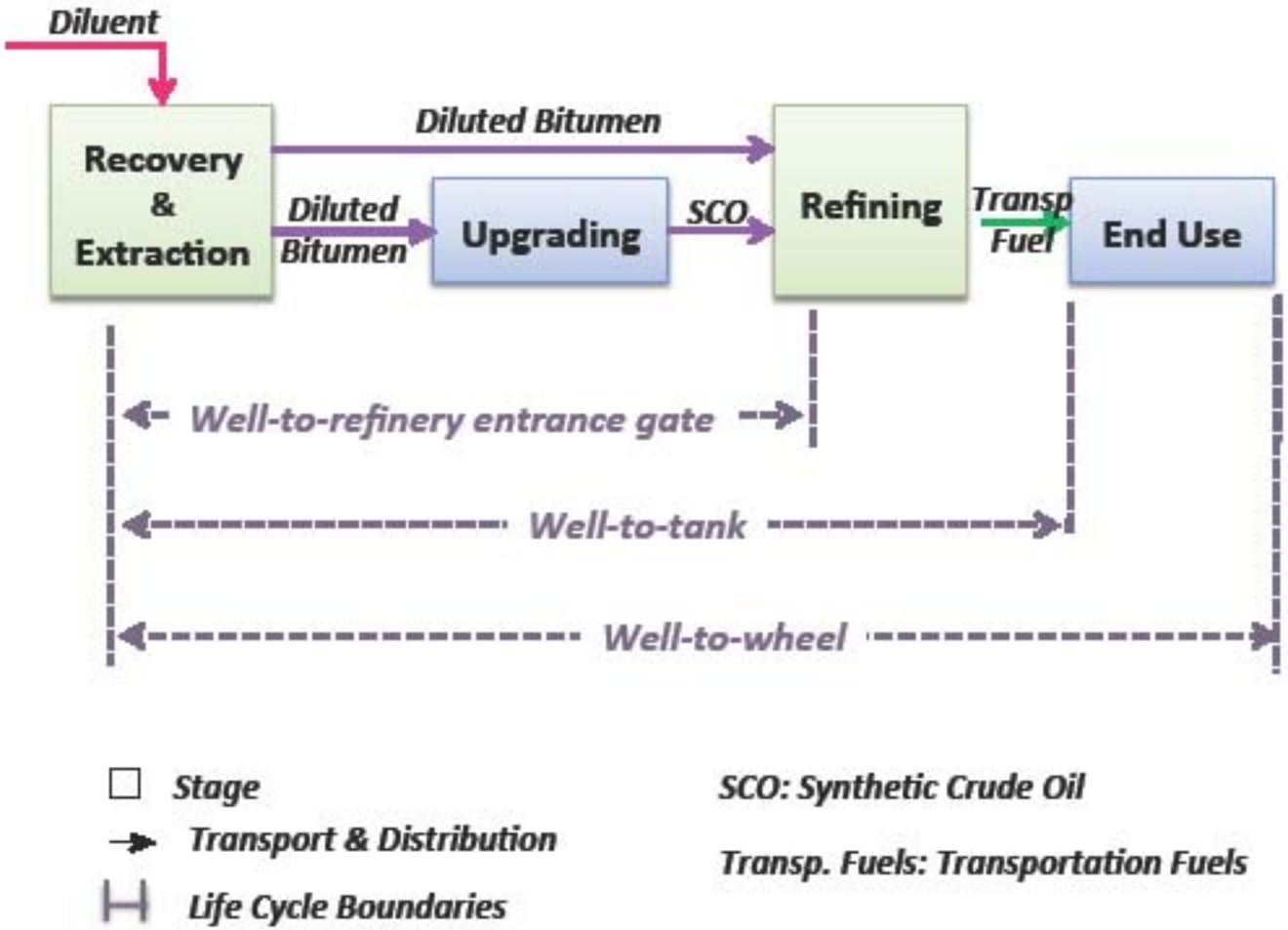
Development of a LC tool for oil sands technologies can inform

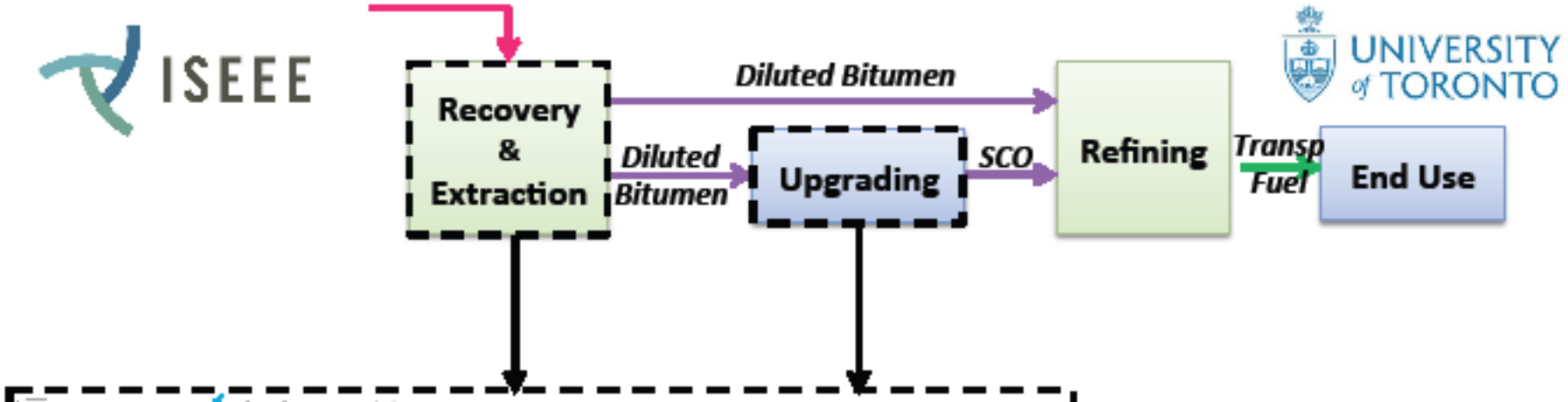
- LCA-based polices
- Oil sands operations and investment decisions
- Emerging technology evaluation
- R&D investment

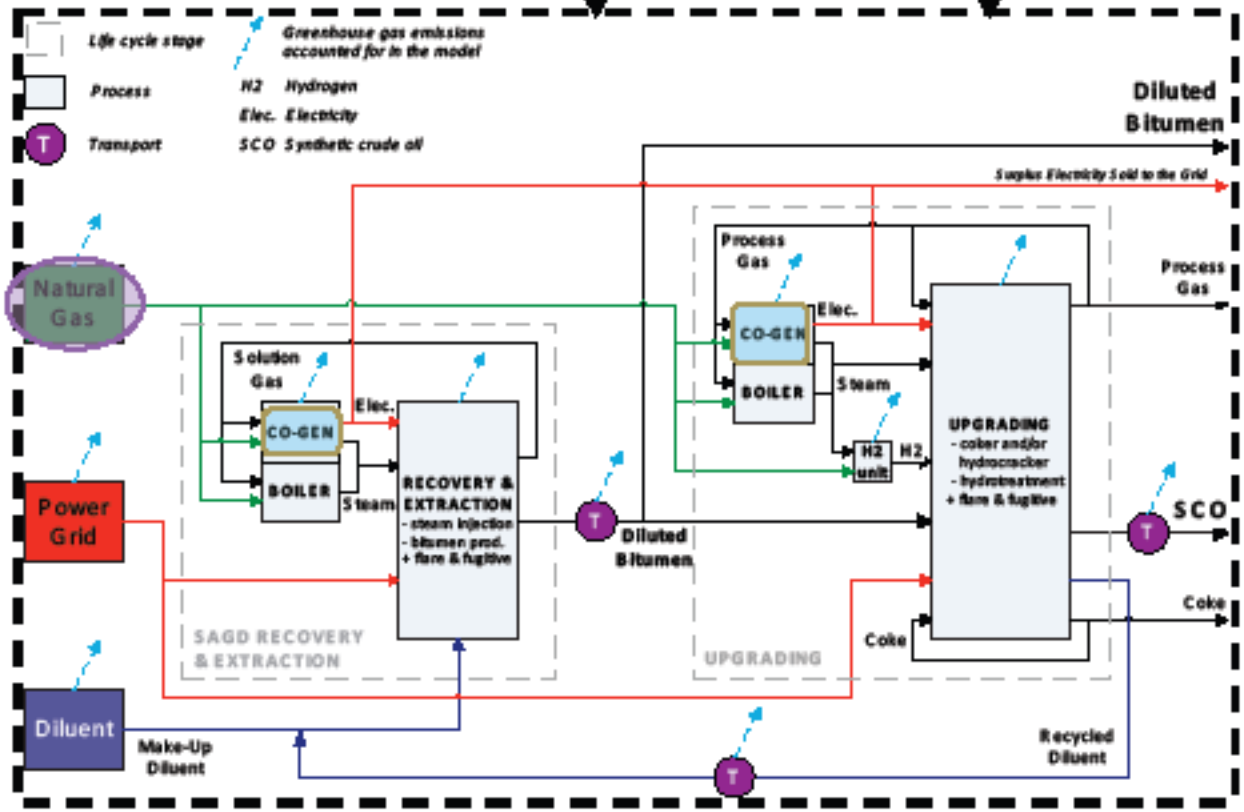
LCAOST Research Team

Toronto: Dr. Heather MacLean
Jennifer McKellar
Diana Pacheco
Sylvia Sleep

Calgary: Dr. David Keith
Dr. Joule Bergerson
Jessica Abella
Nic Levy
Matt Ceh
Graeme Marshman


Diluent
Recovery & Extraction
Diluted Bitumen
Diluted Bitumen
Upgrading
SCO
Refining
Transp Fuel
End Use
Well-to-refinery entrance gate
Well-to-tank
Well-to-wheel
Stage
Transport & Distribution
Life Cycle Boundaries
SCO: Synthetic Crude Oil
Transp. Fuels: Transportation Fuels





GHOST Model

Cogeneration

Role of By-Products / Replacement of Natural Gas

Green**H**ouse gas emissions of current **O**il **S**ands **T**echnologies

Research at CanmetENERGY - Devon

- Air quality – technologies to meet and ensure compliance with air standards
- Oil sand crude oil conversion – how to reduce air emissions while improving quality and quantity of product converted to final clean transportation fuels.
- Future fuels for transportation – using new sources and technologies to produce fuels for advanced combustion engines

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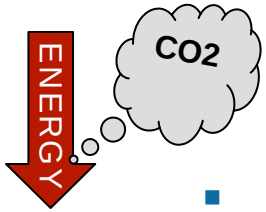
Key Challenges

Chemical & Physical



Treatments

Near term

- Managing carbon dioxide and criteria air contaminants through the production, conversion and end use of hydrocarbon energy vectors through improved molecular understanding of complex hydrocarbon molecules
- Advancing characterization to improve understanding of chemical reactions, fouling, corrosion and conversion
- Devising standard methods for evaluation and characterization
- Influencing the design plants to refine multiple feedstocks
- Reducing water use in the production and conversion of petroleum
- Managing the increasing need to convert heavier crudes on a global scale as light and medium crudes are depleted.

Long term

- Stabilizing carbon dioxide and criteria air contaminants through the production, conversion and end use of hydrocarbon energy
- Increased regulation push and pull for best available technologies used by industry

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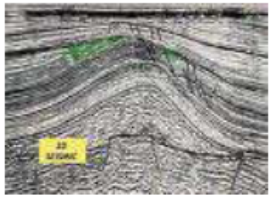
Key Challenges

Bruce Peachey

Traditional Paradigms



Exploration

Conventional Oil & Gas Production

Gas Plants

Increasing O&G Scope and Complexity

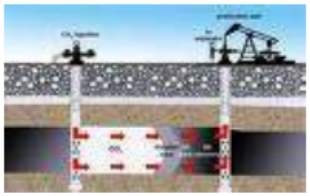
Thermal Heavy Oil

Oilsands Mining

Environment

Unconventional Gas

Oil Shales

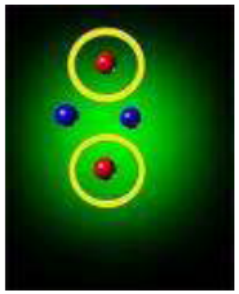


Enhanced Recovery

Upgrading, Refining & Petrochemicals

Oil & Gas Transportation

Alternative Fuels



End-use Options

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