NATURAL RESOURCES CANADA - INVENTIVE BY NATURE

Reducing GHG Intensity of Bitumen and Synthetic Crude Oil using Biomass

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About CanmetENERGY

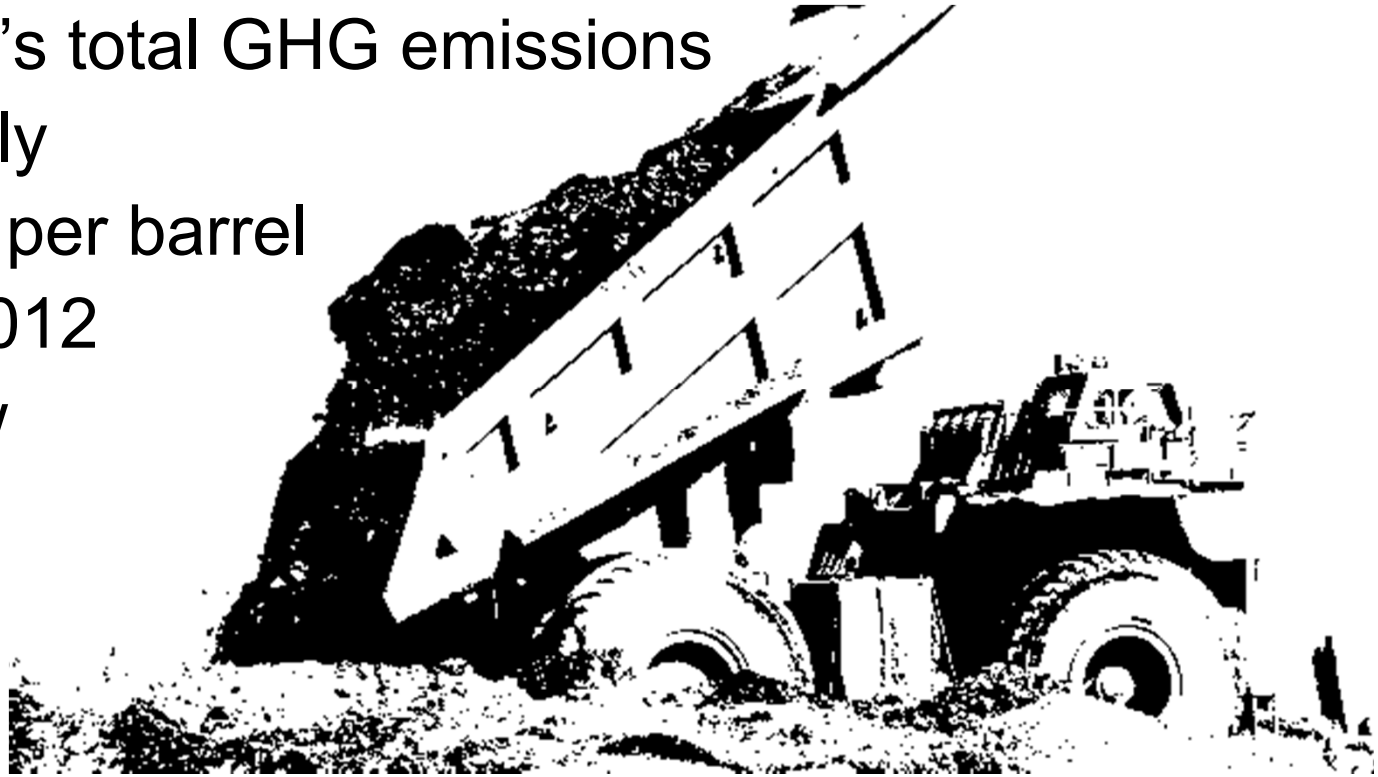
CanmetENERGY is the science and technology branch of Natural Resources Canada and operates three labs across Canada with over 450 scientists, engineers and technicians

The Bioenergy Program at CanmetENERGY-Ottawa assists industry to develop cleaner, more energy-efficient biomass conversion processes

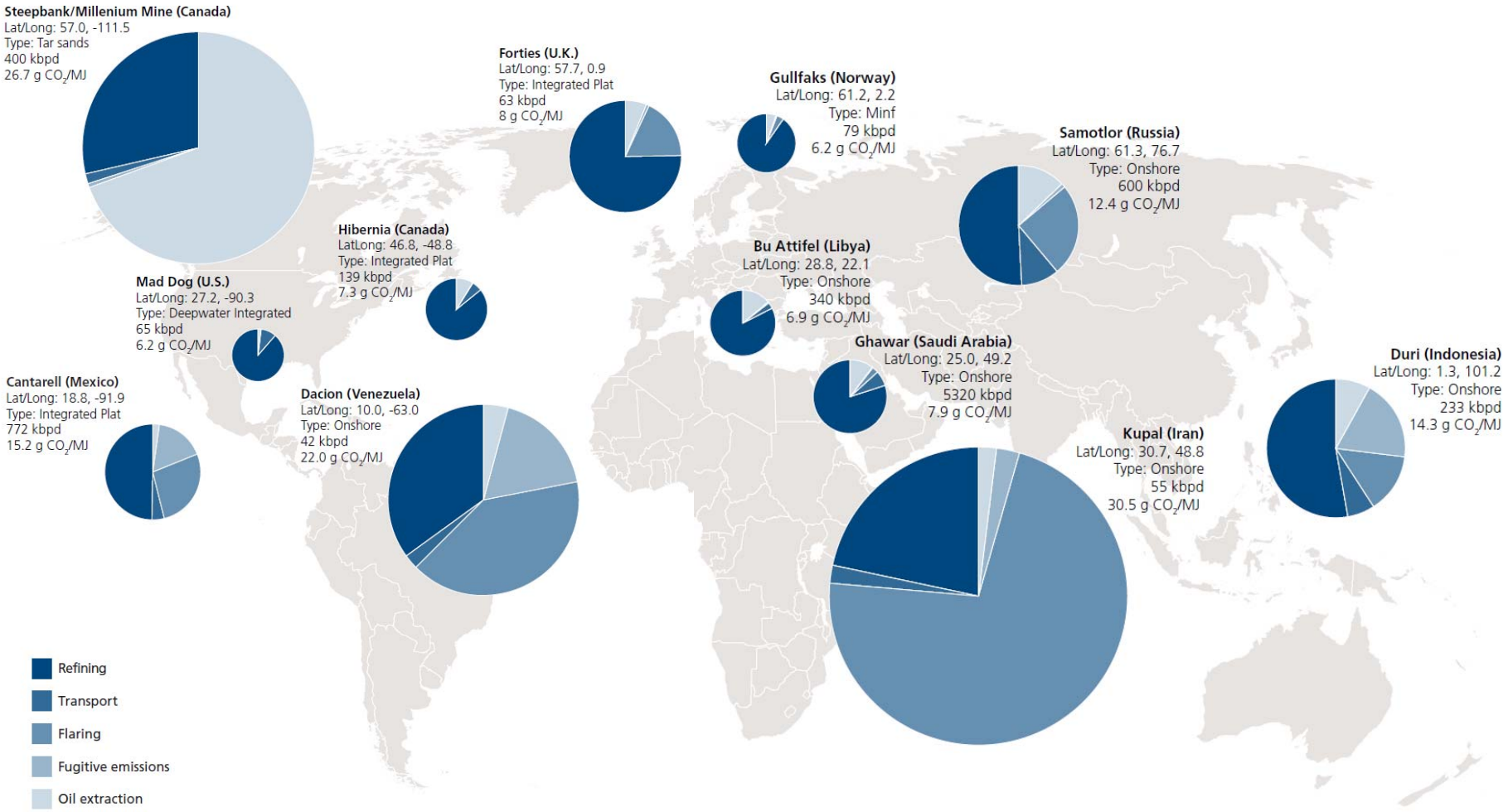
Reducing GHG Intensity of Bitumen and Synthetic Crude Oil using Biomass

Canada's oil sands resources

- Strategic importance with 98% of Canada's proved oil reserves (170 billion bbl)
- Majority of Canada's oil production ~ 2.9 Mbpd in 2014
- Over $250 billion of capital investment
- 8.7% of Canada's total GHG emissions and 0.1% globally
- GHG emissions per barrel of oil sands in 2012 were 28% below 1990 levels.



Crude Oil Carbon Intensity



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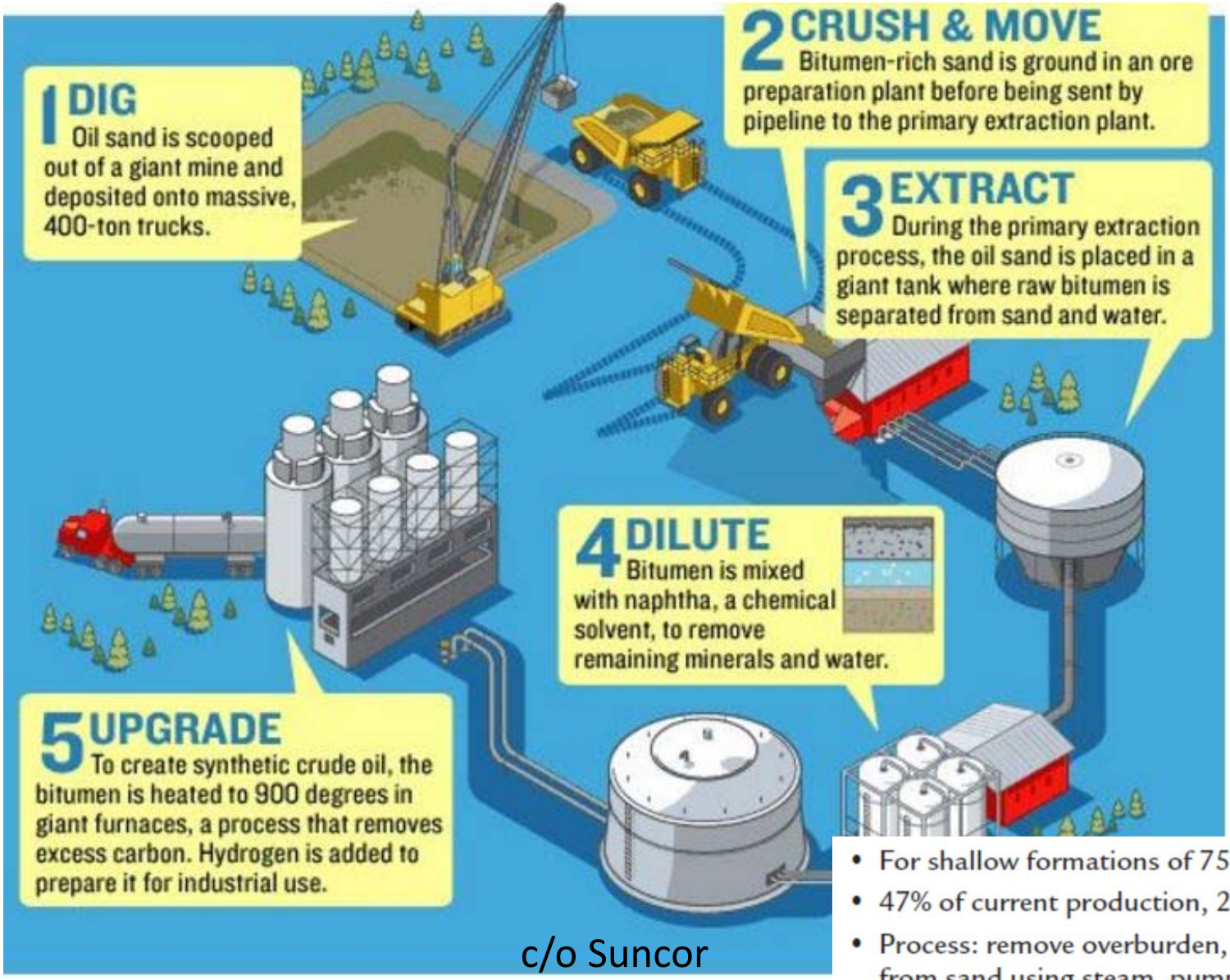
THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

Relative GHGs from Extraction (2)

- Extracting and processing synthetic crude oil from oil sands requires more energy than lighter and more accessible forms of conventional crude oil.
- As a result, production of synthetic crude from oil sands results in more GHG emissions for each barrel of oil produced.
- Key international markets require GHG emissions from oil sands derived products be at par with international regulations such as Low Carbon Fuel Standard and European Fuel Quality Directives

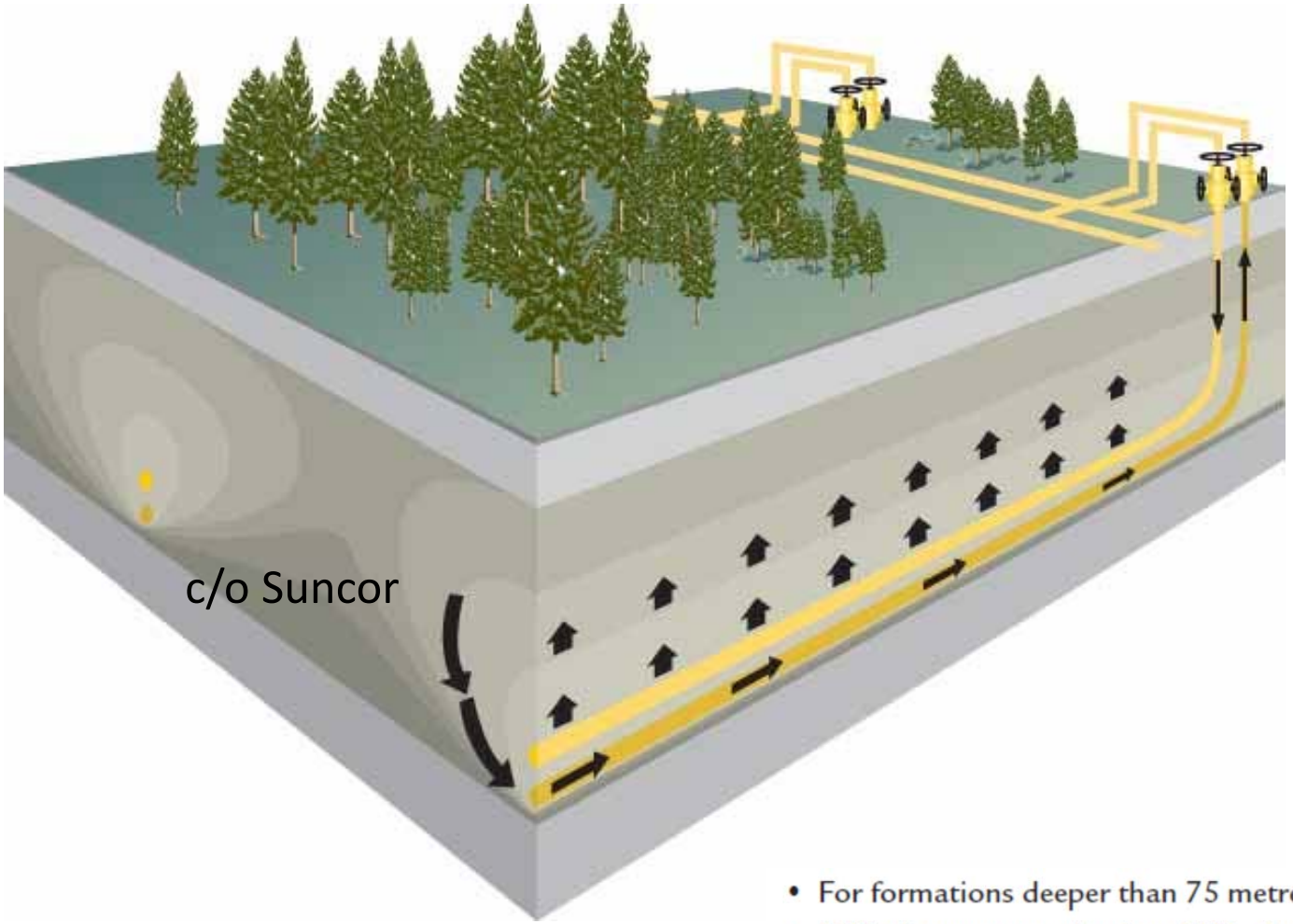
Surface Mining



c/o Suncor

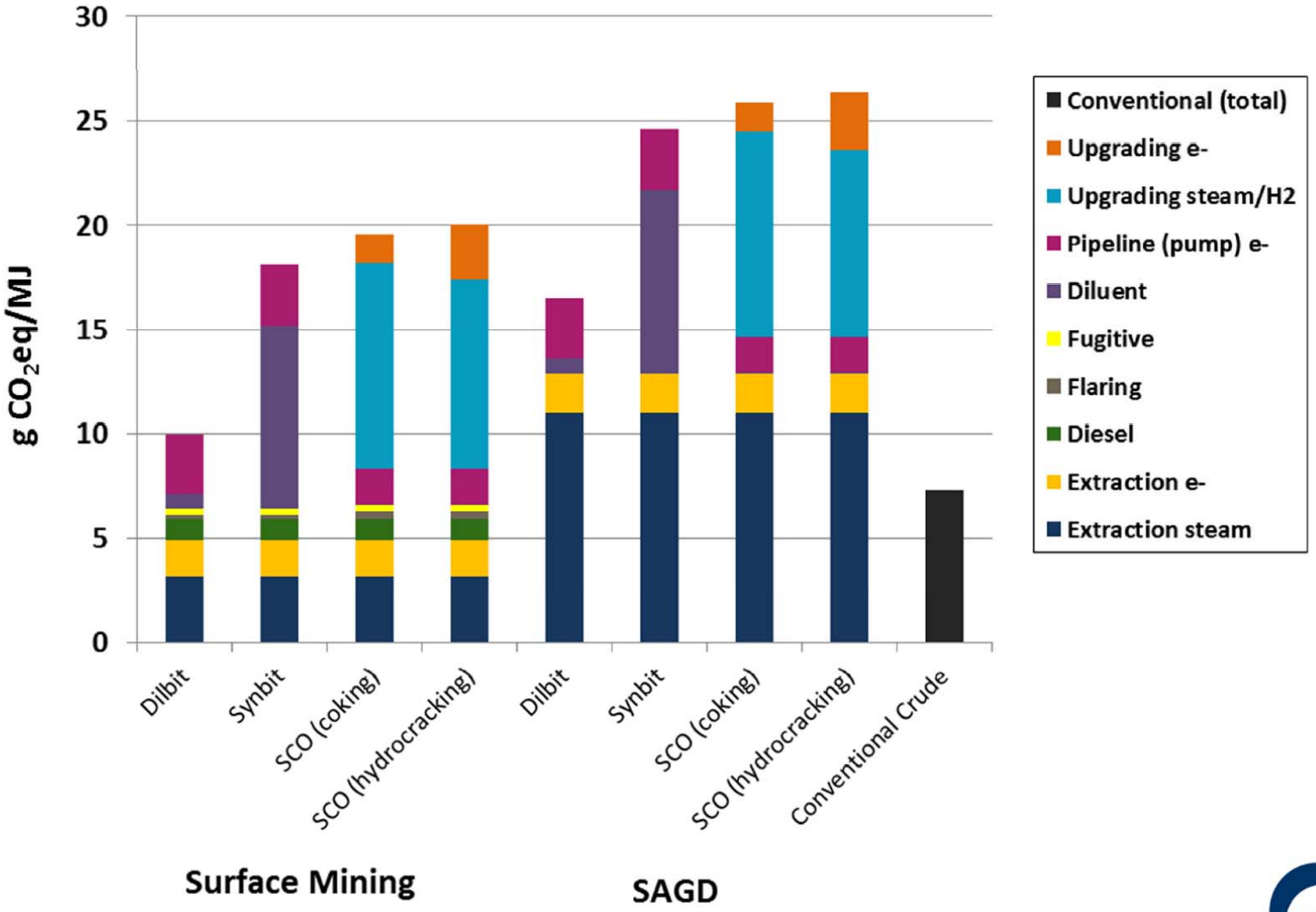
- For shallow formations of 75 metres or less
- 47% of current production, 20% of resources (2013)
- Process: remove overburden, extract oil sands ore, separate oil from sand using steam, pump tailings into settling basins
- Six large projects in Alberta: Syncrude Mining Project, Suncor Base Mine, CNRL Horizon Mine, Athabasca Oil Sands Project – Muskeg River and Jackpine Mine, and Imperial's Kearl Mine

In-situ Extraction



- For formations deeper than 75 metres
- 53% of current production, 80% of resources (2013)
- Process: drill vertical and/or horizontal wells, inject steam to facilitate the flow of oil
- More than 20 projects in Alberta – largest are Cold Lake (Imperial Oil) and Firebag (Suncor)

Well-to-Refinery Gate GHG Emissions

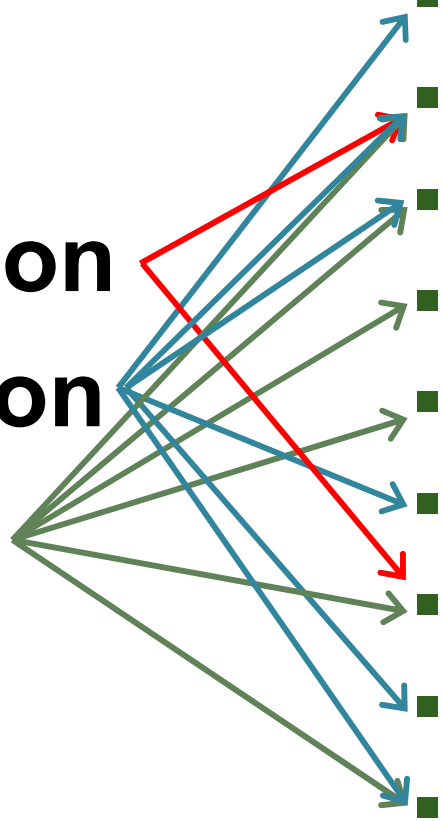


Addressing GHG emissions

- Natural Gas used for steam and hydrogen
  - consumption of 500 PJ/a
  - currently largest GHG contributor but only 10% of cost due to low NG price
- Diluent
  - 300,000 bpd and growing at 8.5% per year (2013)
- Electricity consumption: extraction, pumping, upgrading
  - 2 GWe capacity per Mbpd production
- Diesel
  - surface mining uses 525 million litres per annum

Biomass Opportunities

- **Combustion**
- **Gasification**
- **Pyrolysis**



- Fischer Tropsch Biodiesel
- Biopower
- Bio-Diluent
- Biochar
- Pyrolysis Oil
- Syngas/Bio-RNG
- Bioheat
- Bio-Hydrogen
- High Value Products

CanmetENERGY has expertise and capabilities in biomass combustion, gasification and pyrolysis and experience in techno-economic modelling

Collaborations

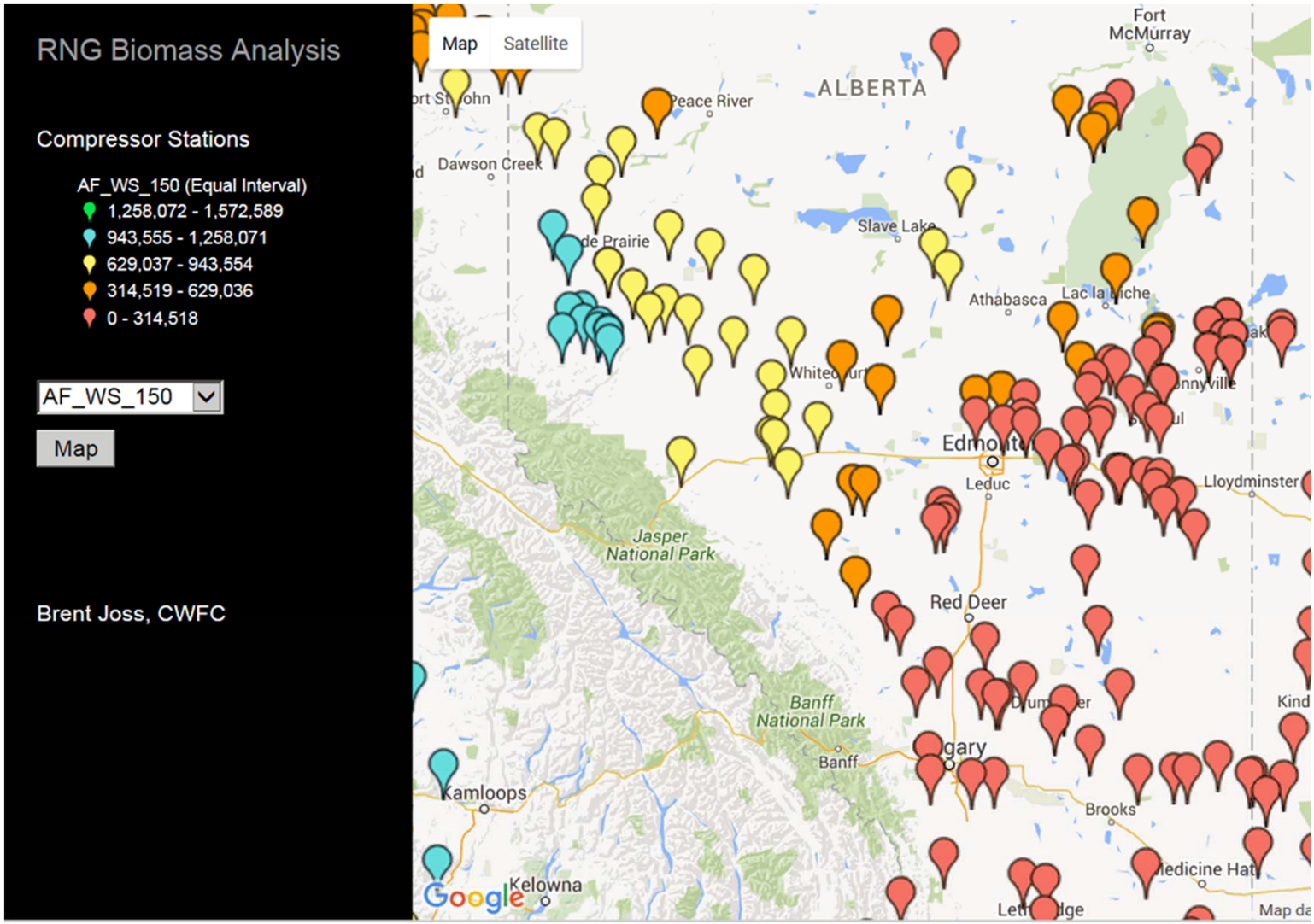
COSIA: Low Carbon Heat and Power Drivers

- To implement fuel or energy alternatives with lower or no GHG emissions having CO2 avoidance cost lower than Natural Gas with Carbon Capture and Storage technologies.
- Approaches:
- Co-produce marketable commodities, concurrent with heat or power that generate revenue and offset the carbon cost
- Generate low emission intensity heat and / or power from alternative energy sources, such as renewables, biomass or non-fossil fuels
- Create low emission heat or power via un-conventional processes

CanmetENERGY First Scan

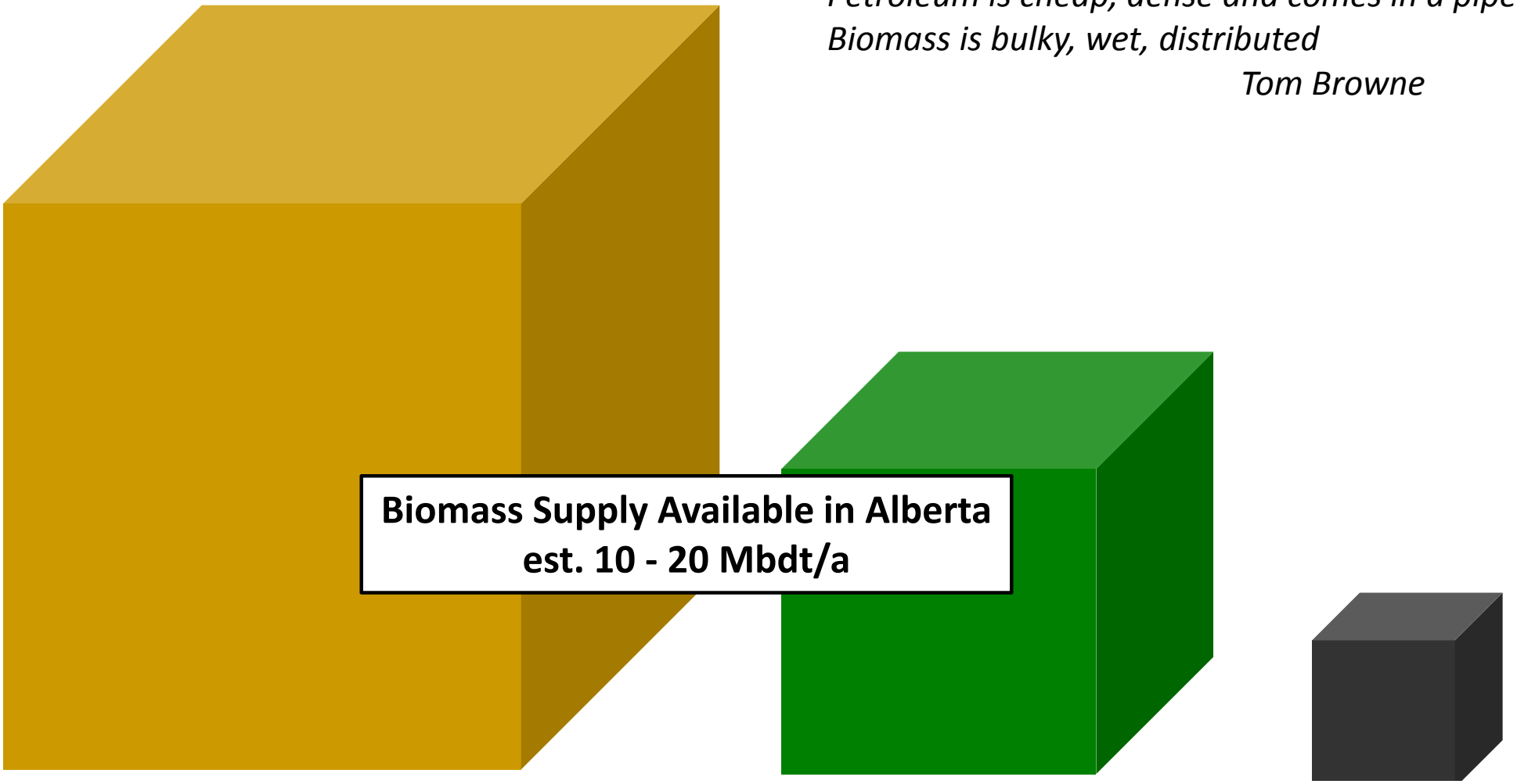
- Do the scales match?
  - Are there additive niches?
- Cost/benefit analyses?
  - Technology
  - Environment
  - Production Disruptions
  - Competing uses

Biomass Supply: CFS and AAFC



Biomass Energy Content

Petroleum is cheap, dense and comes in a pipeline
Biomass is bulky, wet, distributed
Tom Browne



Straw **Wood** **Coal**

Note: All figures in this presentation are based on 2013-14 and “rounded off”

Where would you invest?

- Natural Gas @500 PJ = 25 Mbdt of biomass:
  - Heat and Power – established biomass technologies
  - RNG – up and coming
  - Hydrogen - ?

- Power @ 2 GWe capacity required per Mbpd
  - Extraction, upgrading, pumping…Energy Efficiency Gains?
  - 2 GWe would require 10 M bdt/a biomass
  - Current Alberta capacity ~400 Mwe biopower
  - Largest non-pelletized biomass plant in the world Alhomens Kraft is ~ 250 Mwe
  - Co-firing opportunities

Note: All figures in this presentation are based on 2013-14 and "rounded off"

Where would you invest? contd

- Diesel and diluent production – state of art
  - Fast Pyrolysis – Pathway?
  - Largest Fast Pyrolysis plant is 100 tpd biomass feed
  - Largest renewable diesel plant produced 90 bpd
  - HTL is still at lab scale

- Diesel – surface mining uses 3.5 M b/a
  - Renewable diesel would require ~ 3 M bdt/a of biomass
  - Largest plant to date 90 bpd

- Diluent use is ~300,000 bpd ⬆ (~8% growth)
  - 30,000 bpd diluent production requires 30 M bdt/a of biomass

“Keep your eye on the ball”

- Key international markets require GHG emissions from oil sands derived products **be at par with international regulations** such as Low Carbon Fuel Standards.

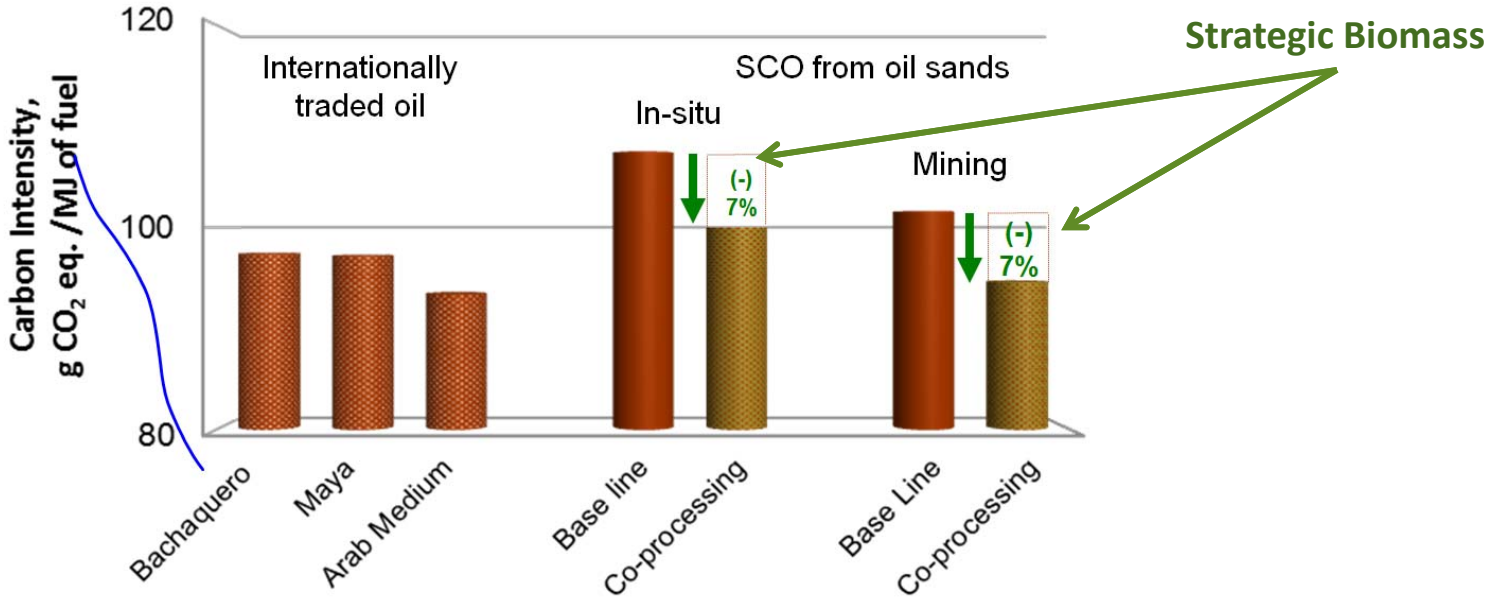
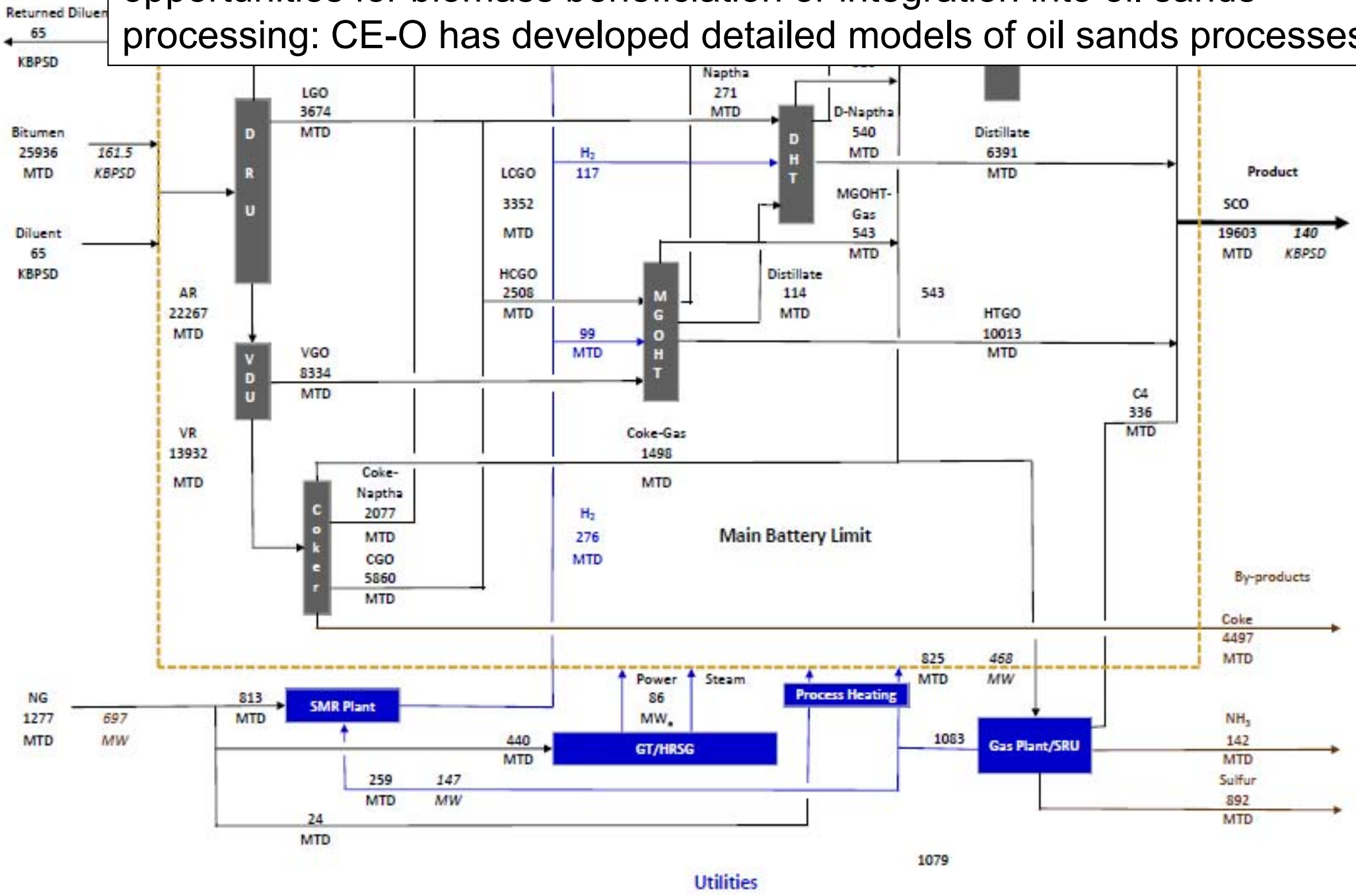


Chart courtesy Murlidhar Gupta

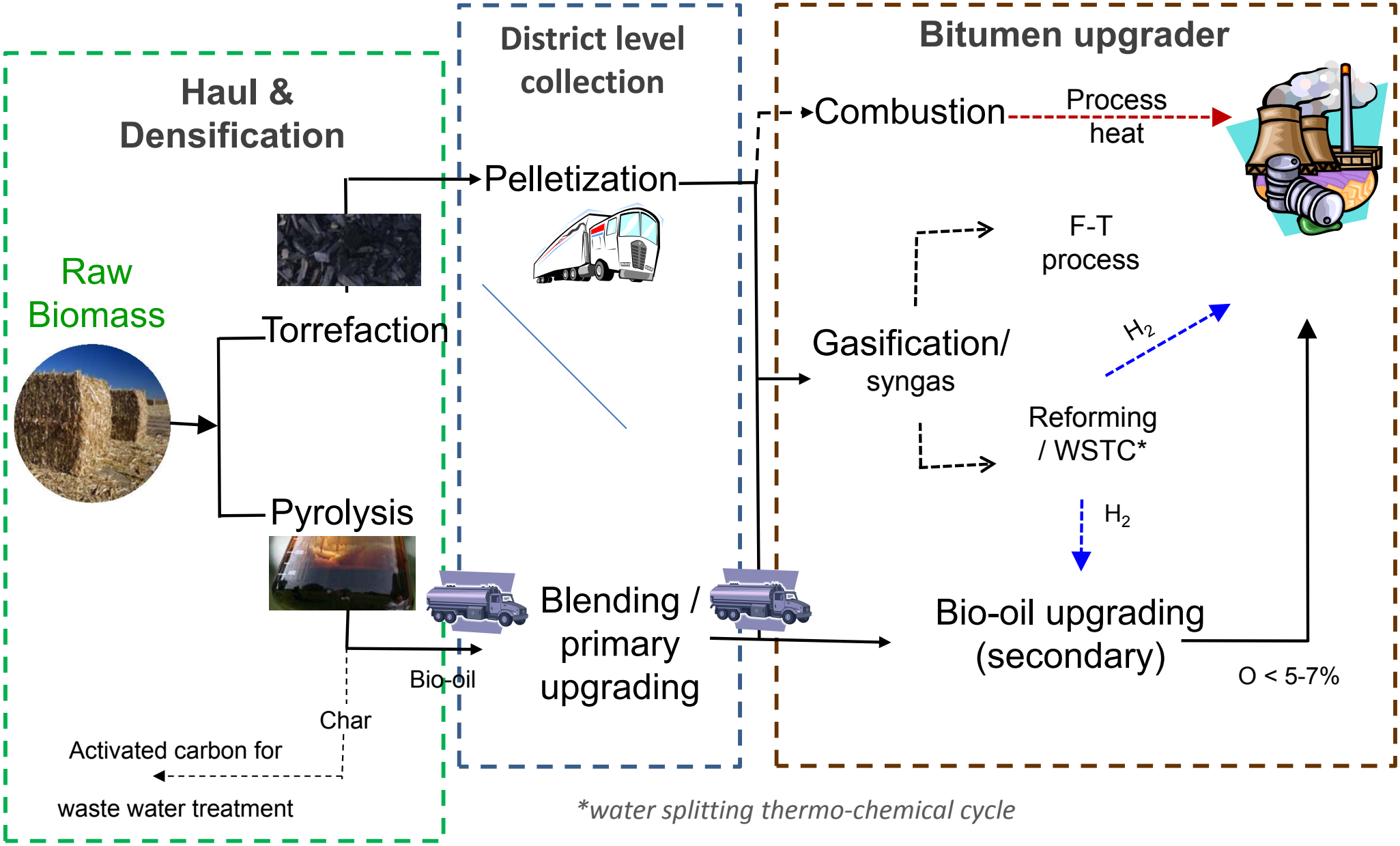
CanmetENERGY: TEA and Process Modelling

- Enable oil sands and heavy oil industry to reduce GHG emissions intensity of bitumen and upgraded crude oil production by integrating renewable biomass-derived products into their operations.
- Help develop mutually beneficial collaboration between Canada's farming & forestry industries and Canada's hydrocarbon industry.
- Alberta-Specific LCAs – Research the life cycle impacts of deploying biomass in Alberta, given the unique attributes of the province.
- Assist governments to establish strategic R&D plans and identify effective measures which would reduce GHG emissions.

FOR C: Current CFS-supported CE-Ottawa work to evaluate specific opportunities for biomass beneficiation or integration into oil sands processing: CE-O has developed detailed models of oil sands processes



Proposed biomass co-utilizations in oil sands operations†



**water splitting thermo-chemical cycle*

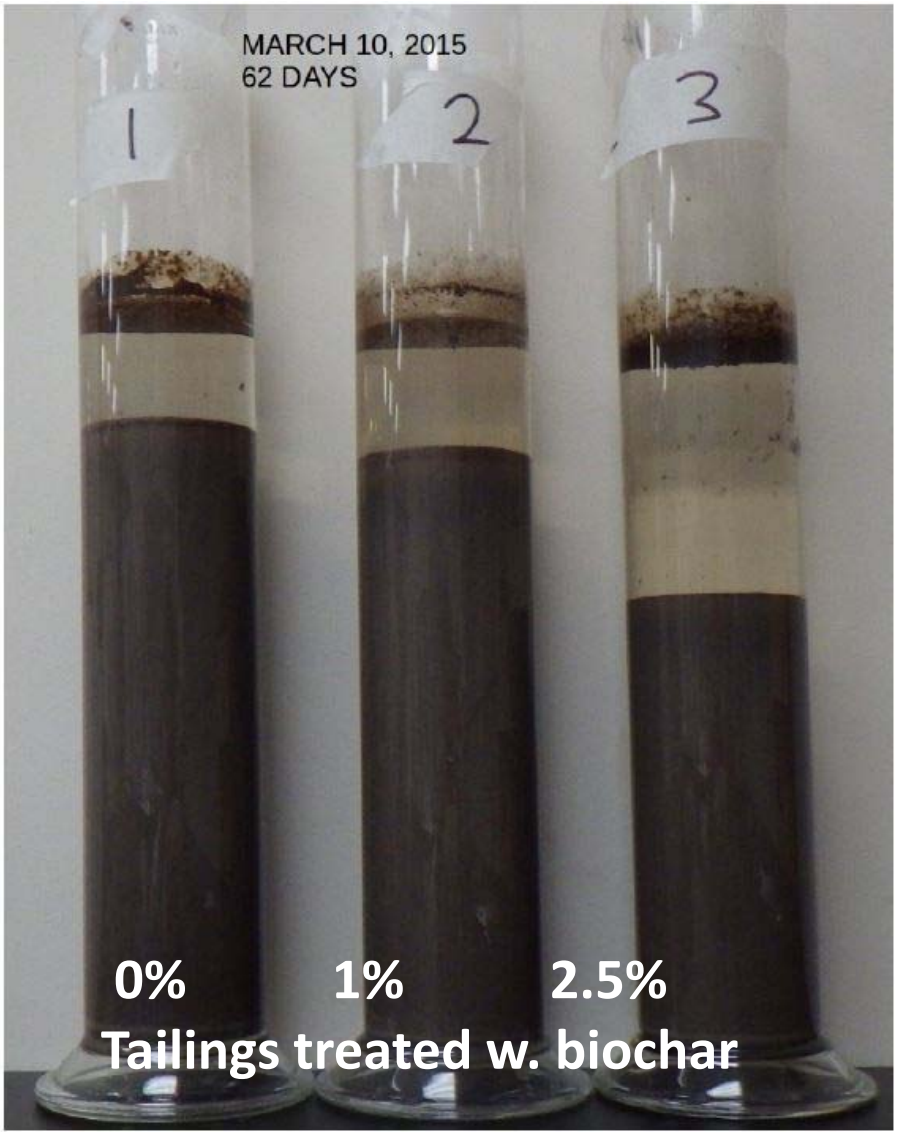
† Link to ECI 2013 conference http://dc.engconfintl.org/cgi/viewcontent.cgi?article=1033&context=bioenergy_iv

Additive Niches

- Biomass Co-processing for Beneficiation of Oil Sands Input/Output Streams
  - Beneficiation refers to using biomass to improve the characteristics or performance of an input stream rather than replacing the input stream.
  - Pyrolysis oil treatment of limestone used to reduce sulphur emissions from coke combustion can significantly improve efficiency at lower Ca/S ratios
  - Use of biochar (and possibly lignin) to increase sedimentation rate of fine oil sands tailings.

- Close Integration of Biomass Thermal Conversion with Oil Sands Upgrading
  - E.g. standalone steam-based biomass gasification plant for production of energy and/or hydrogen can be complex and capital intensive. This could potentially be addressed by using a slip/exhaust stream from existing “oil sands process” steam to “drive” the biomass gasification process.

Remediation of Oil Sands Tailings Ponds



Biochar derived from softwood feedstock was employed in the current study. Spent biochars were re-carbonized at 550 °C and were reutilized. Biochar was found to remove organic bitumen and inorganic mineral ash from the SCT. In the course of two cycles, the biochar's fixed carbon content decreased from 88 wt.% (db) to 40.8 – 41.9 wt.% (db) and correspondingly, the ash content increased from 1.4 to ~56 wt.%. The results indicate that the biochar accelerates the settling rate and with progression of time, the settling rate slows down for all the treatments studied including control. Recarbonized (regenerated) biochar exhibits similar trends in term of SCT settling rate as noted with fresh biochar.

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BIOCLEANTECH

can play an important role in improving the environmental performance of Canada's oil sands

can enable development of expertise in development and application of sustainable, low GHG, biomass technologies

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Work with us

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