Advances in Oil Sands LCA

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Motivation for LCAOST Project

2006

Development of life cycle tools for oil sands technologies can inform

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

2007

Policies such as California's Low Carbon Fuel Standard

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

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LCAOST Project Objective

To improve the scientific understanding of the life cycle environmental implications of current and developing oil sands technologies so as to support public and private sector choices about major investments in oil sands technologies as well as to drive further research and development.

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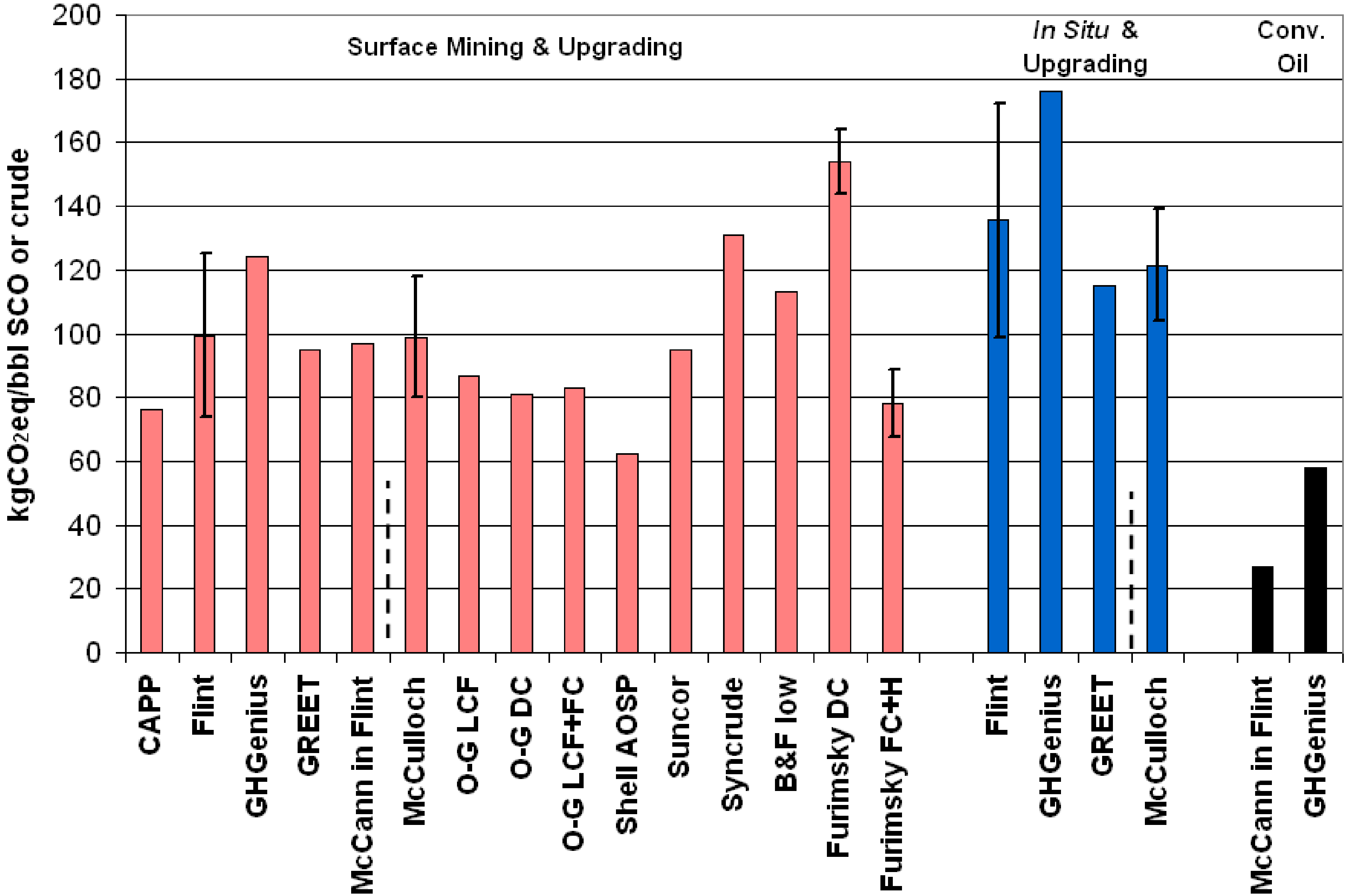
Previous Work on LCA of Oil Sands



Source: Charpentier, Bergerson and MacLean, ERL, 2009.

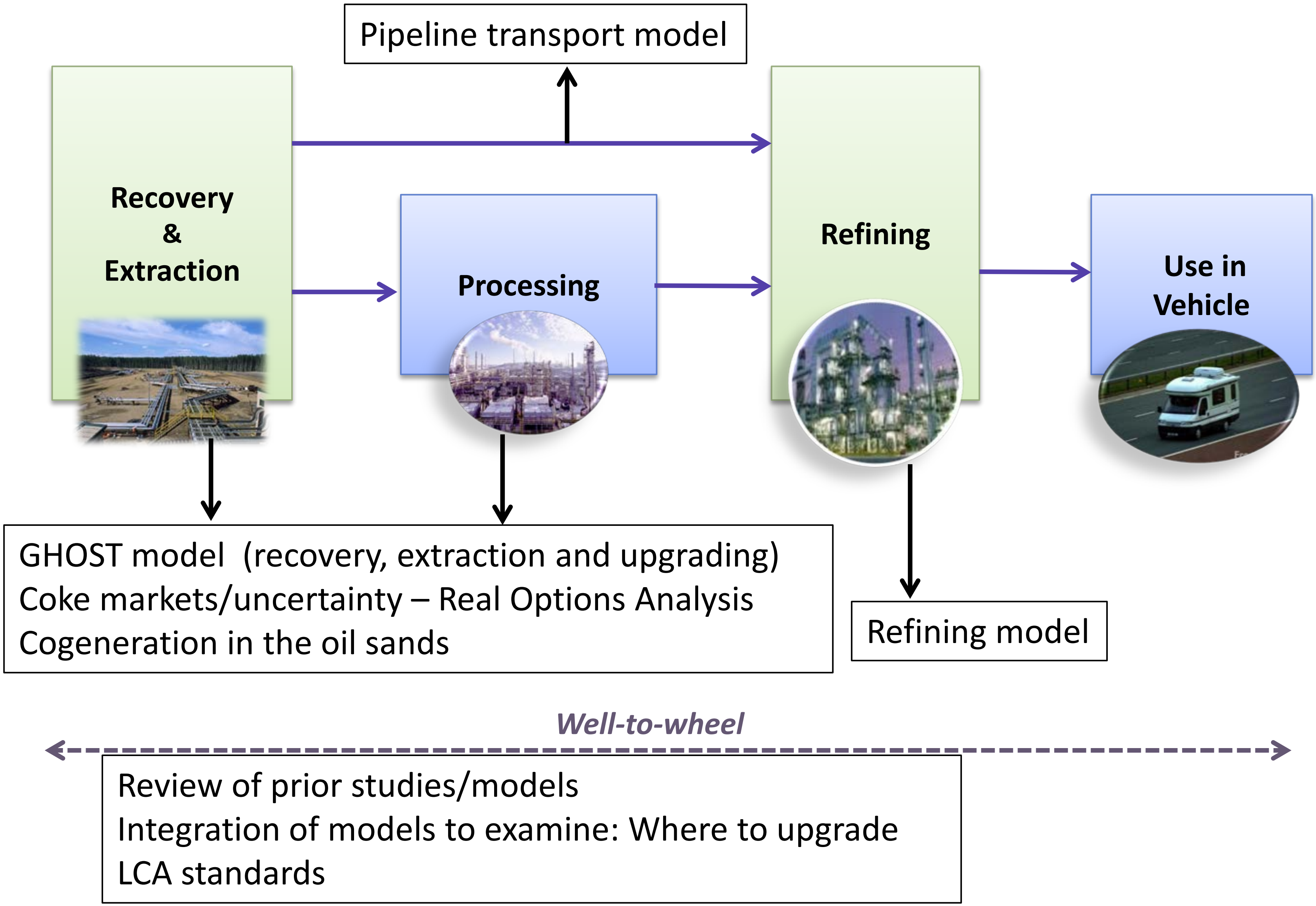
LCAOST Project (2006-2014)

- Collaborative project: U. of Calgary, U. of Toronto
- 3 phases and a variety of sponsors

Phase 1	NRCan
Phase 2	NRCan and Alberta Innovates: Energy and Environment Solutions
Phase 3	NCE Carbon Management Canada

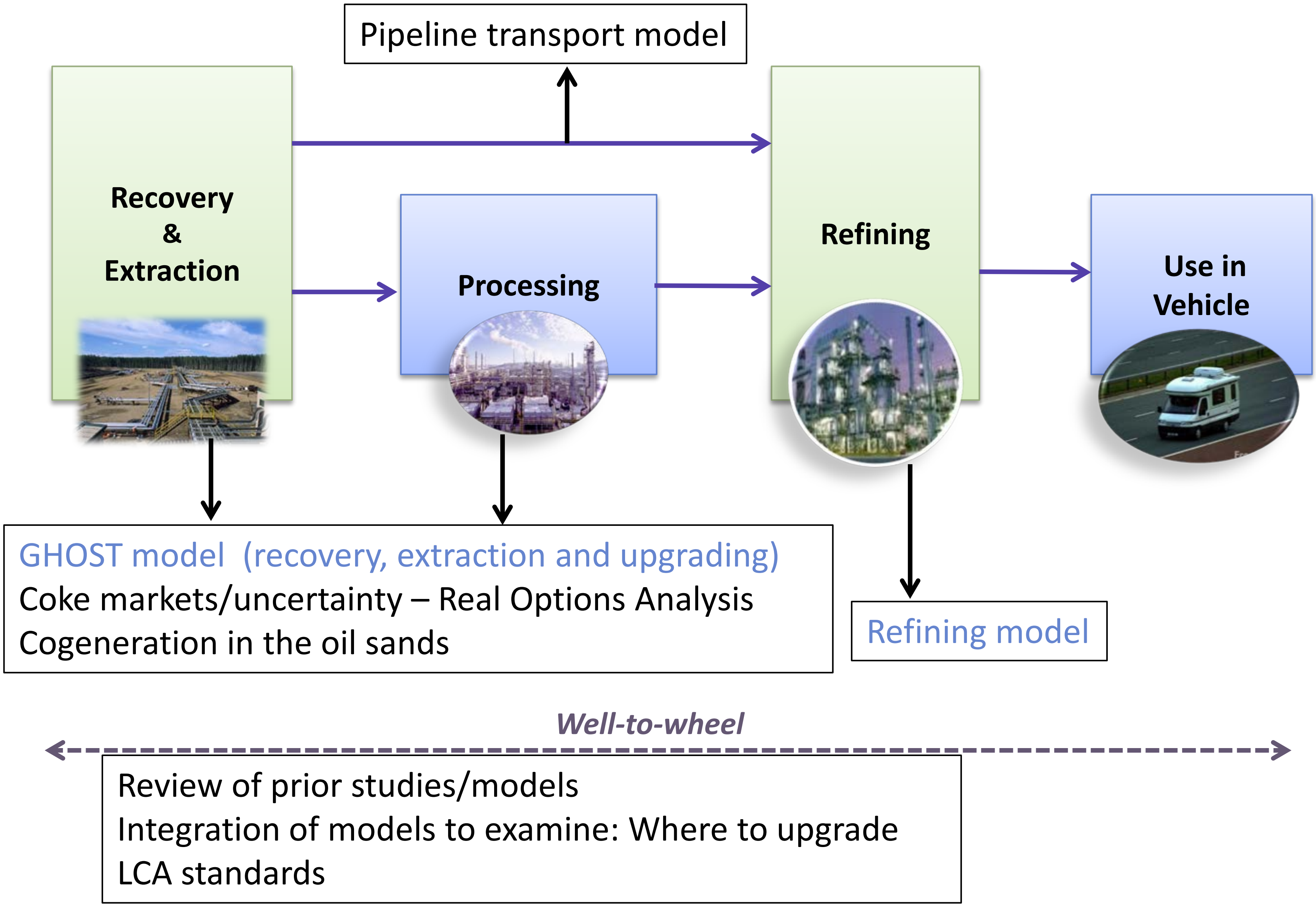
- All phases involve considerable interaction with industry ‘partners’ (including minor funding from industry)

Completed LCAOST sub-projects



In Situ and Upgrading image from Suncor Energy Inc. image library

Completed LCAOST sub-projects



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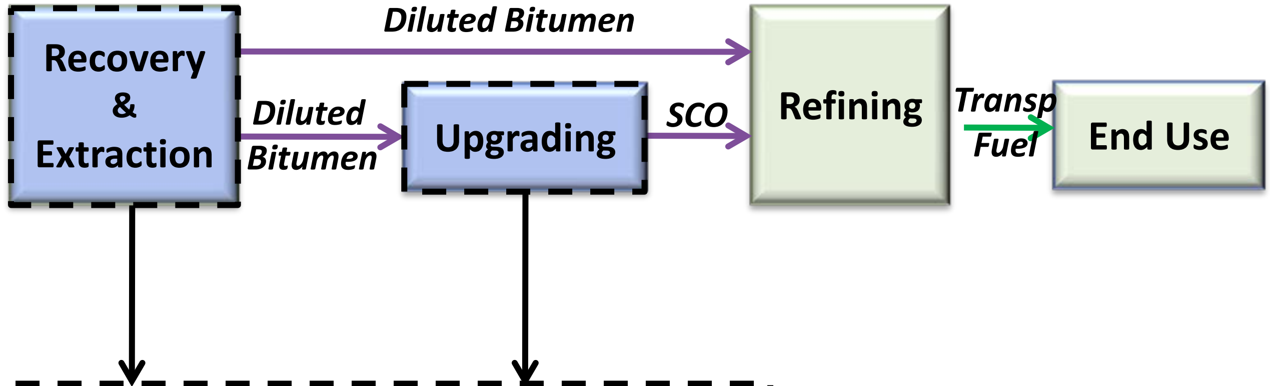
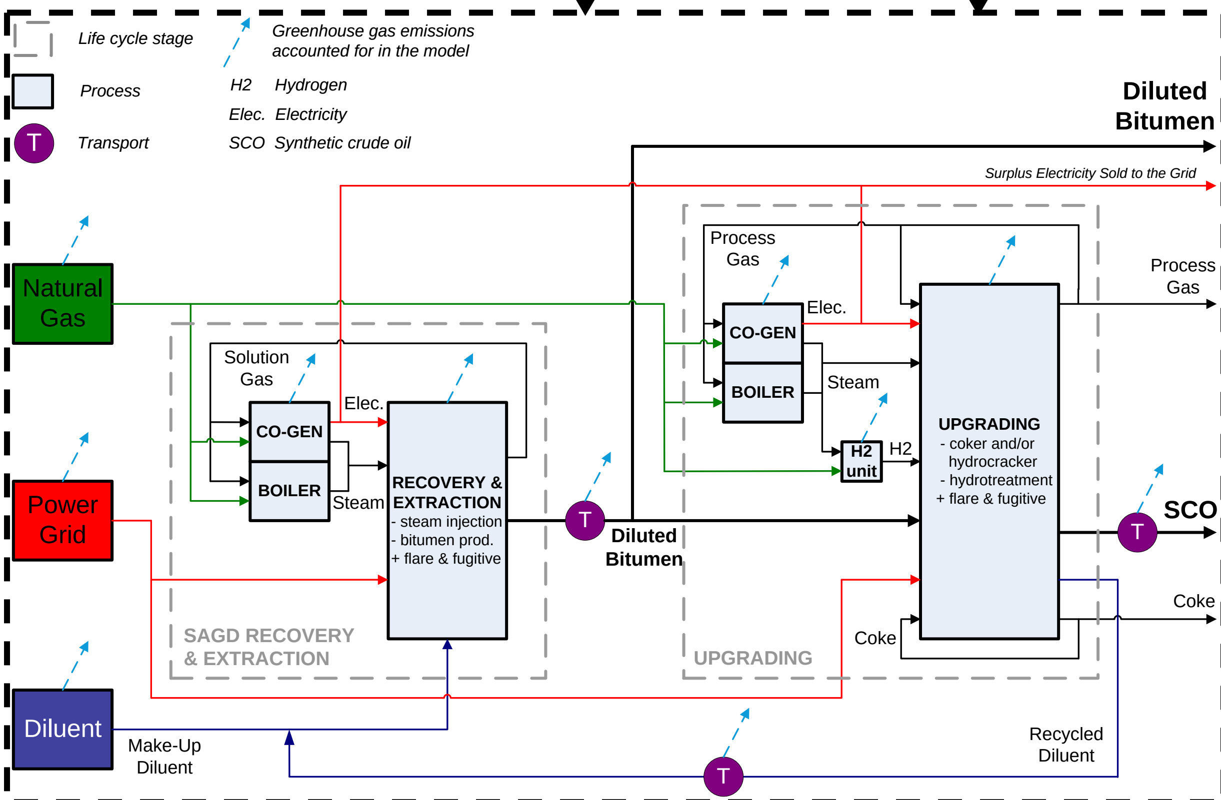




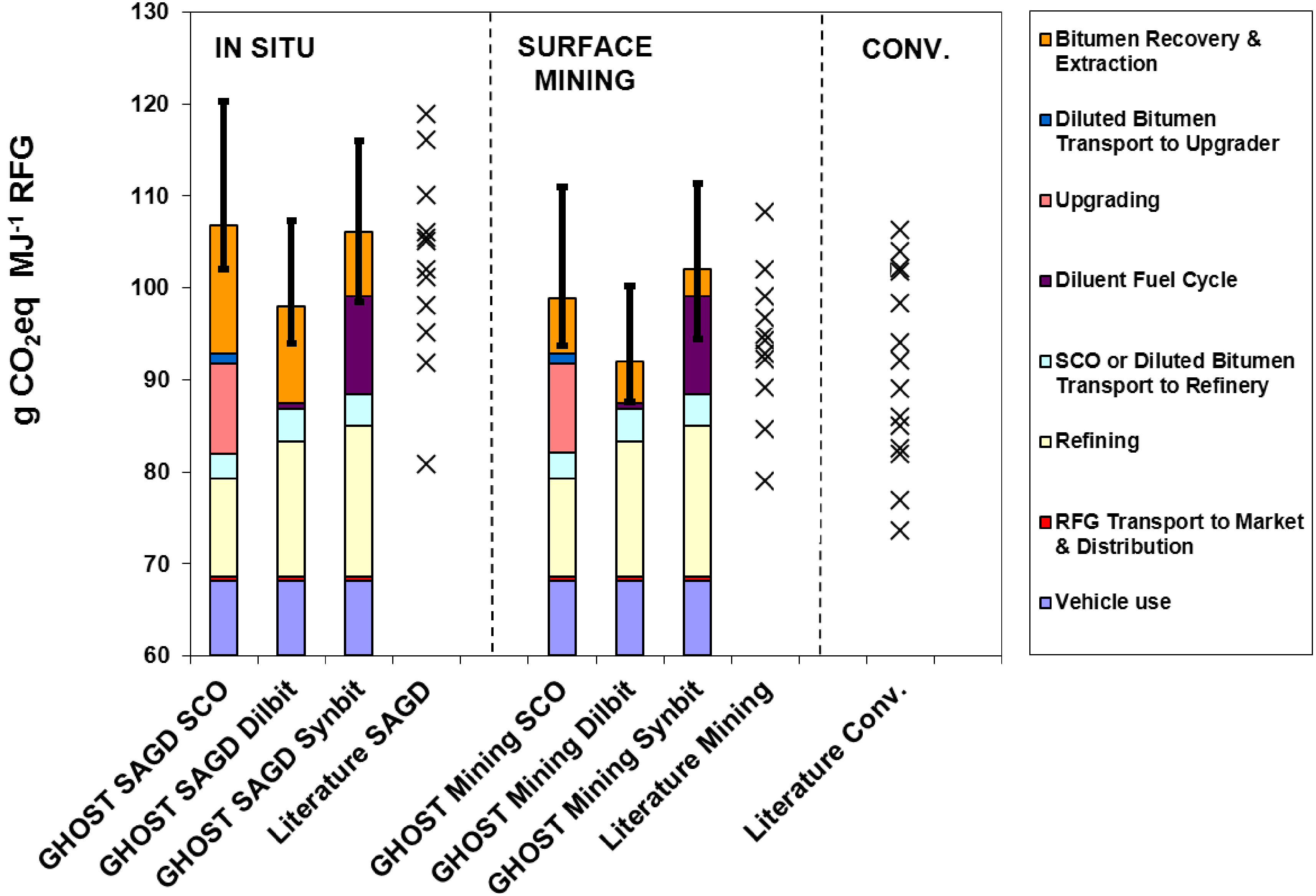
GHOST Model

(**G**reen**H**ouse Gas Emissions of **O**il **S**ands **T**echnologies)

GHOST Model

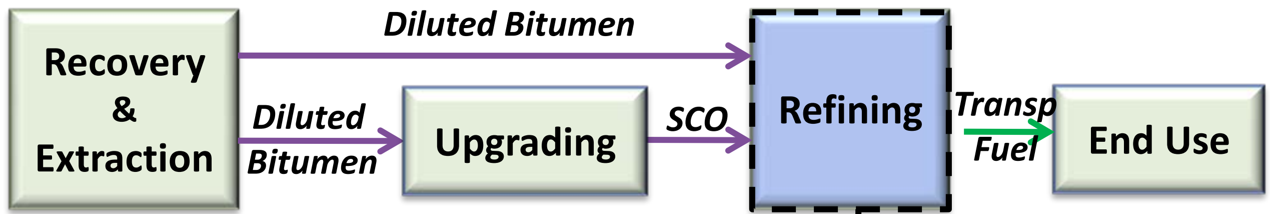
- Excel based software tool that characterizes life cycle energy use and GHG emissions associated with **existing** oil sands technologies
- Explores ranges of key parameters informed by:
  - Public data (e.g., EIAs, Sustainability Reports, ST-43)
  - Bottom-up data (through NDAs)
  - Direct industry feedback on reasonable ranges for each parameter

SURFACE MINING RECOVERY & EXTRACTION	***Range***	*Example project*
Electricity used by the process (kWh/m^3 bitumen)	**50 - 100**	60
Diesel (L /m^3 bitumen)	**7 - 15**	10
Flared hydrocarbon emissions (kg CO_2eq/m^3 bitumen)	**0 - 15**	2
Fugitive methane emissions (kg CO_2eq/m^3 bitumen)	**3 - 24**	10
1- NO COGENERATION CASE		
Efficiency - boiler η_B	**80% - 85%**	80%
Natural gas input (m^3/m^3 bitumen)	**20 - 80**	50
2 - COGENERATION CASE		
Efficiency - gas turbine η_{GT}	**30% - 35%**	30%
Efficiency - HRSG exhaust heat recovery η_{HR}	**50% - 60%**	50%
Efficiency - HRSG direct firing duct burners η_{DB}	**95%**	95%
Total electricity produced (kWh/m^3 bitumen)	**240 - 2,400**	1,200

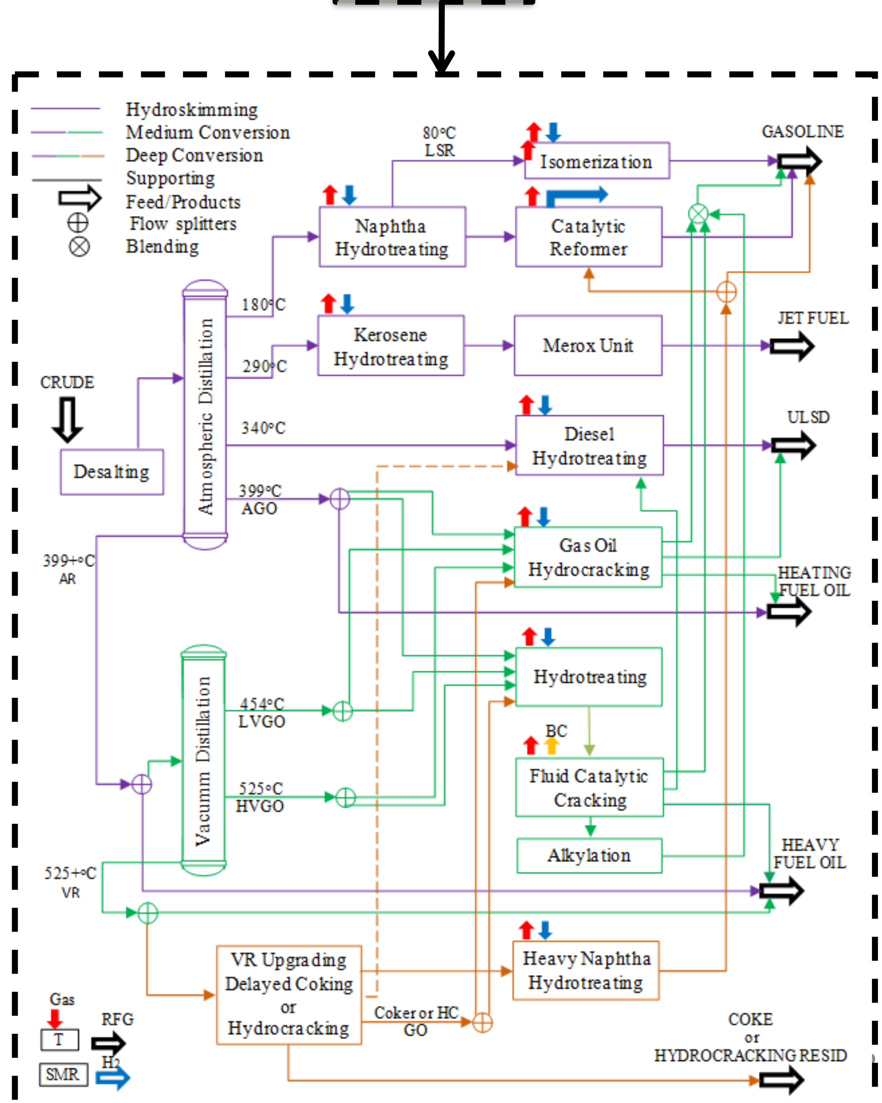


Charpentier, A., Kofoworola, O., Bergerson, J., & MacLean, H.L. *Life Cycle Greenhouse Gas Emissions of Current Oil Sands Technologies: GHOST Model Development and SAGD Application.* Environmental Science & Technology. September 2011. V. 45, 9393–9404.

Bergerson, J., Kofoworola, O., Charpentier, A., Sleep, S., & MacLean, H. Life Cycle Greenhouse Gas Emissions of Current Oil Sands Technologies 2: In Situ and Surface Mining Applications. Environmental Science & Technology. 2012, V. 46, 7865−7874.



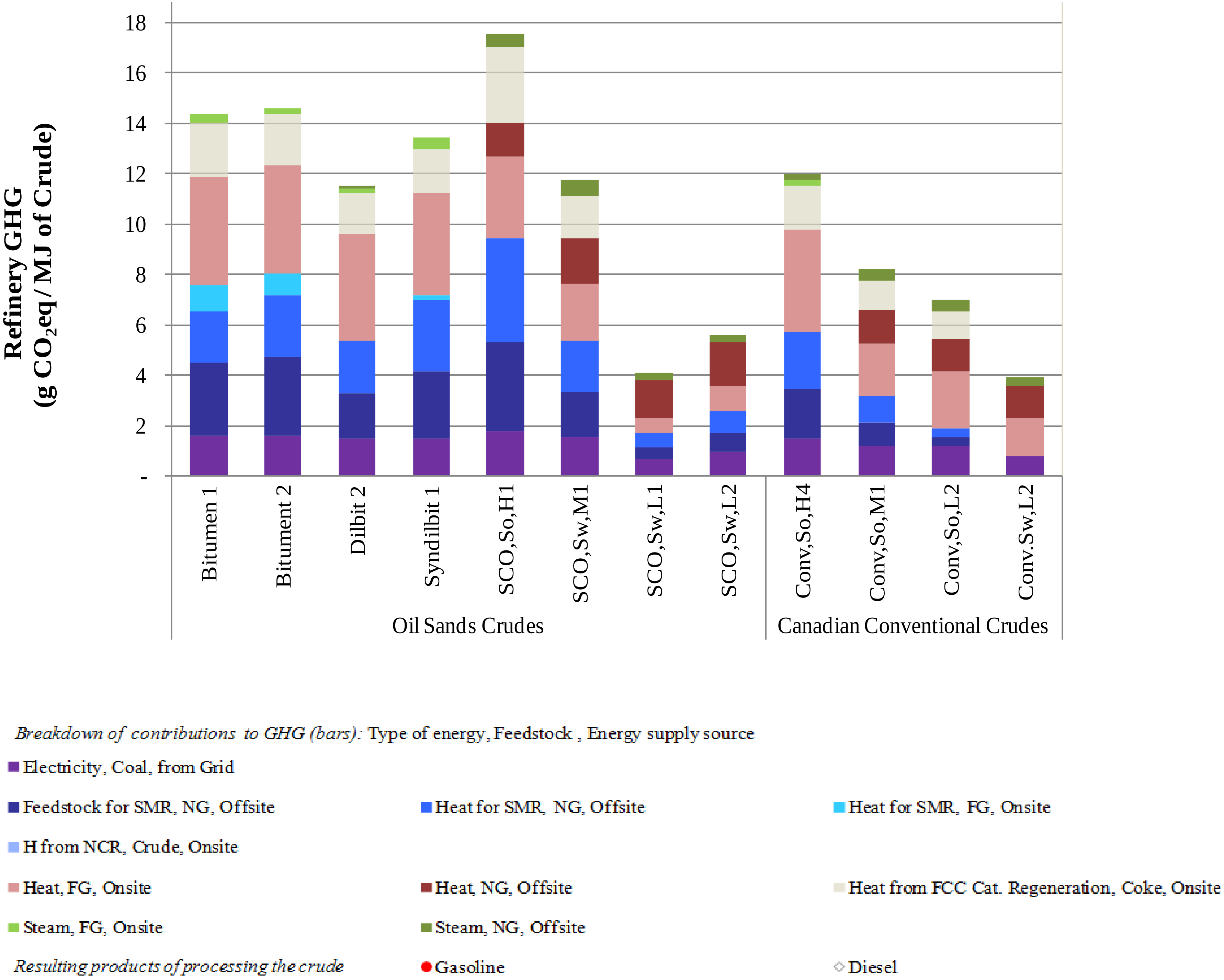
Refinery Model

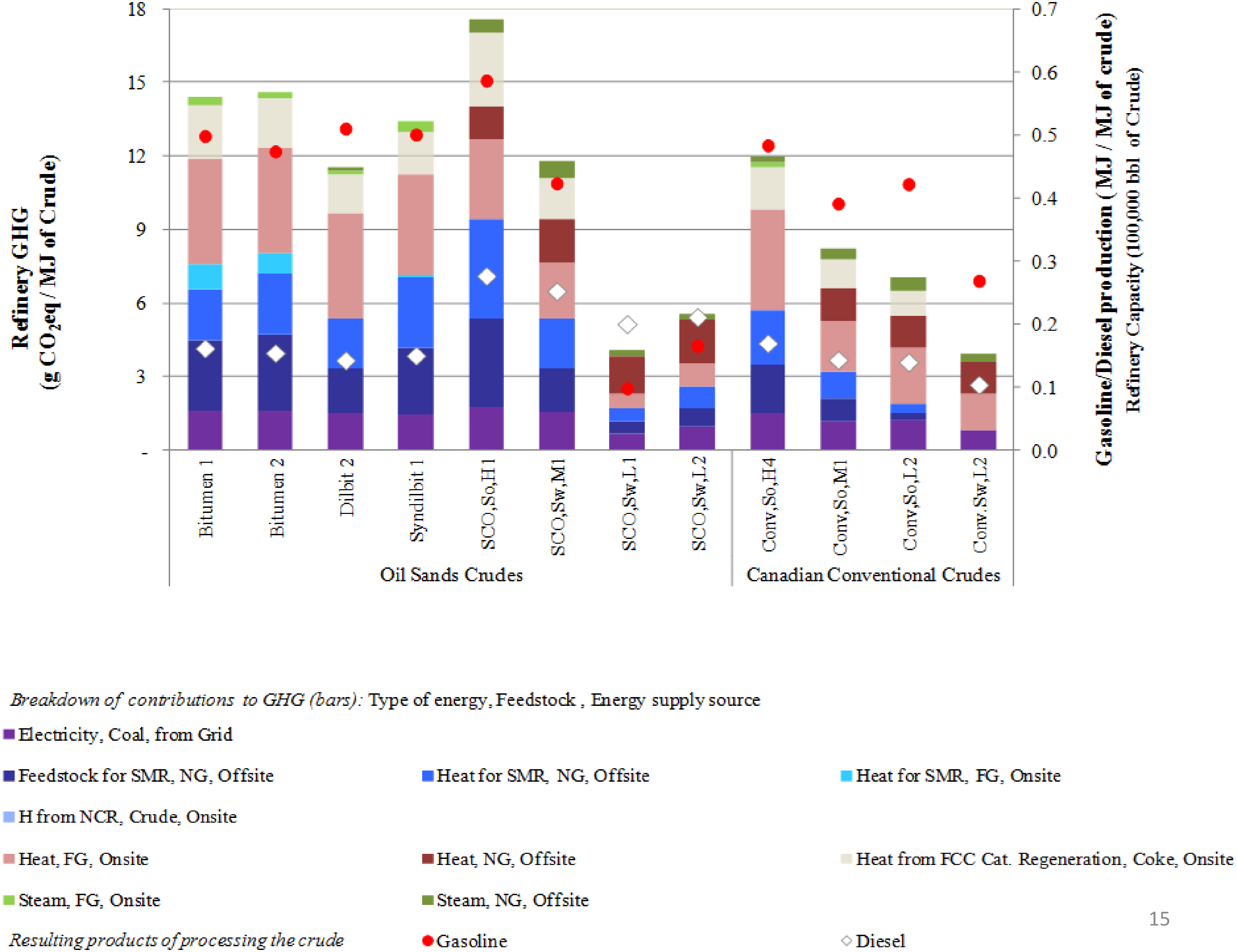


Jessica Abella and Joule Bergerson. *Environ. Sci. Technol.* 2012, 46, 13037−13047.

Refinery Model

- Refining emissions not adequately represented in previous life cycle models/studies
- Developed a refinery model based on linear programming and LCA techniques
  - 3 categories of refineries
  - 10 combinations of process units
  - Process unit parameters
    - Assay information (e.g., H content)
    - Energy requirements
    - Yield of intermediate products (RIPPs)
    - RIPP specifications (API gravity, S, N and H)


Refinery GHG
(g CO2eq/ MJ of Crude)
18
16
14
12
10
8
6
4
2
-
Bitumen 1
Bitument 2
Dilbit 2
Syndilbit 1
SCO,So,H1
SCO,Sw,M1
SCO,Sw,L1
SCO,Sw,L2
Conv,So,H4
Conv,So,M1
Conv,So,L2
Conv.Sw,L2
Oil Sands Crudes
Canadian Conventional Crudes
Breakdown of contributions to GHG (bars): Type of energy, Feedstock , Energy supply source
Electricity, Coal, from Grid
Feedstock for SMR, NG, Offsite
Heat for SMR, NG, Offsite
Heat for SMR, FG, Onsite
H from NCR, Crude, Onsite
Heat, FG, Onsite
Heat, NG, Offsite
Heat from FCC Cat. Regeneration, Coke, Onsite
Steam, FG, Onsite
Steam, NG, Offsite
Resulting products of processing the crude
Gasoline
Diesel



Refinery GHG
(g CO2eq / MJ of Crude)
Gasoline/Diesel production (MJ / MJ of crude)
Refinery Capacity (100,000 bbl of Crude)
18
15
12
9
6
3
-
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Bitumen 1
Bitumen 2
Dilbit 2
Syndilbit 1
SCO,So,H1
SCO,Sw,M1
SCO,Sw,L1
SCO,Sw,L2
Conv,So,H4
Conv,So,M1
Conv,So,L2
Conv.Sw,L2
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Steam, NG, Offsite
Resulting products of processing the crude
Gasoline
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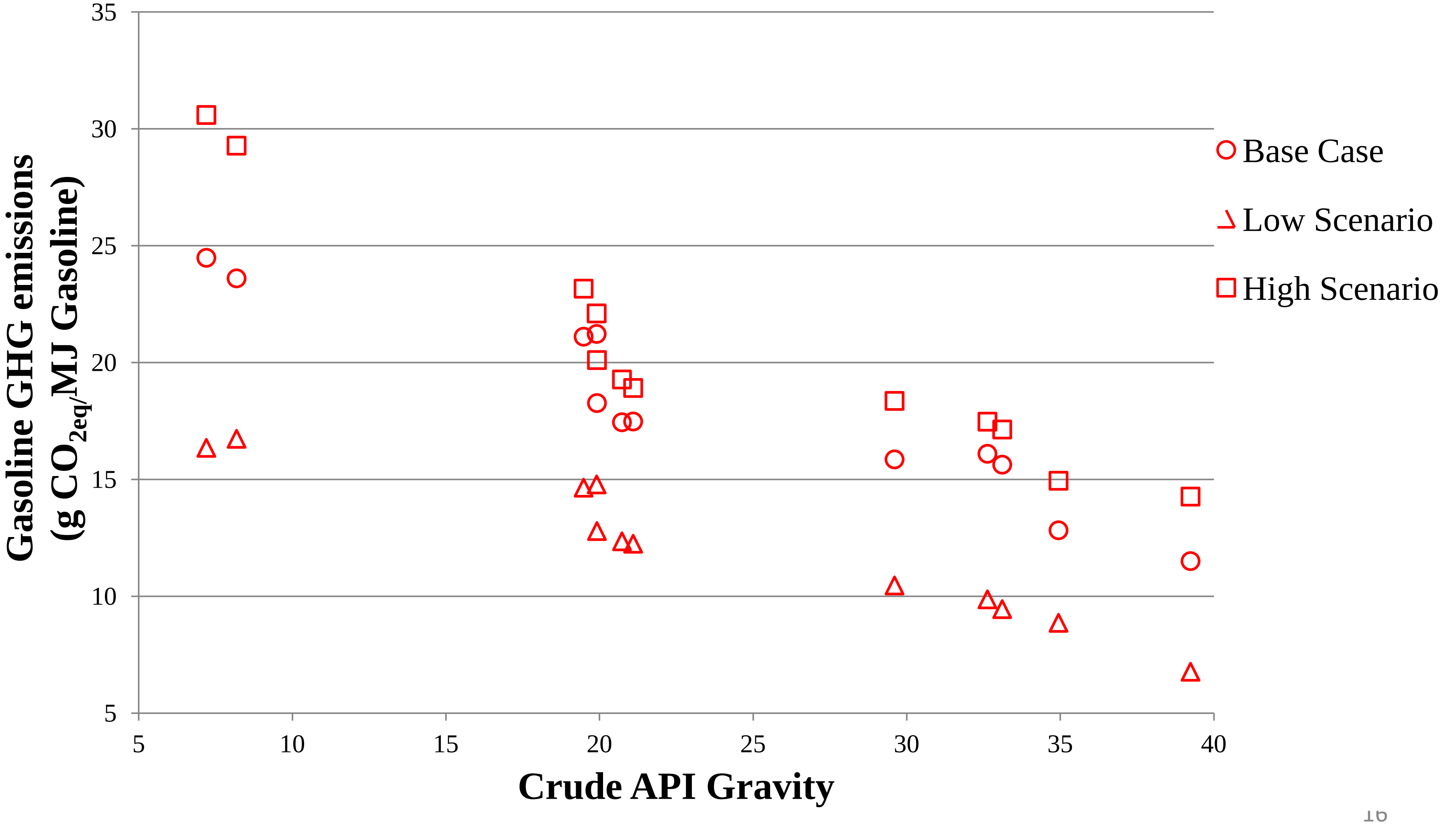
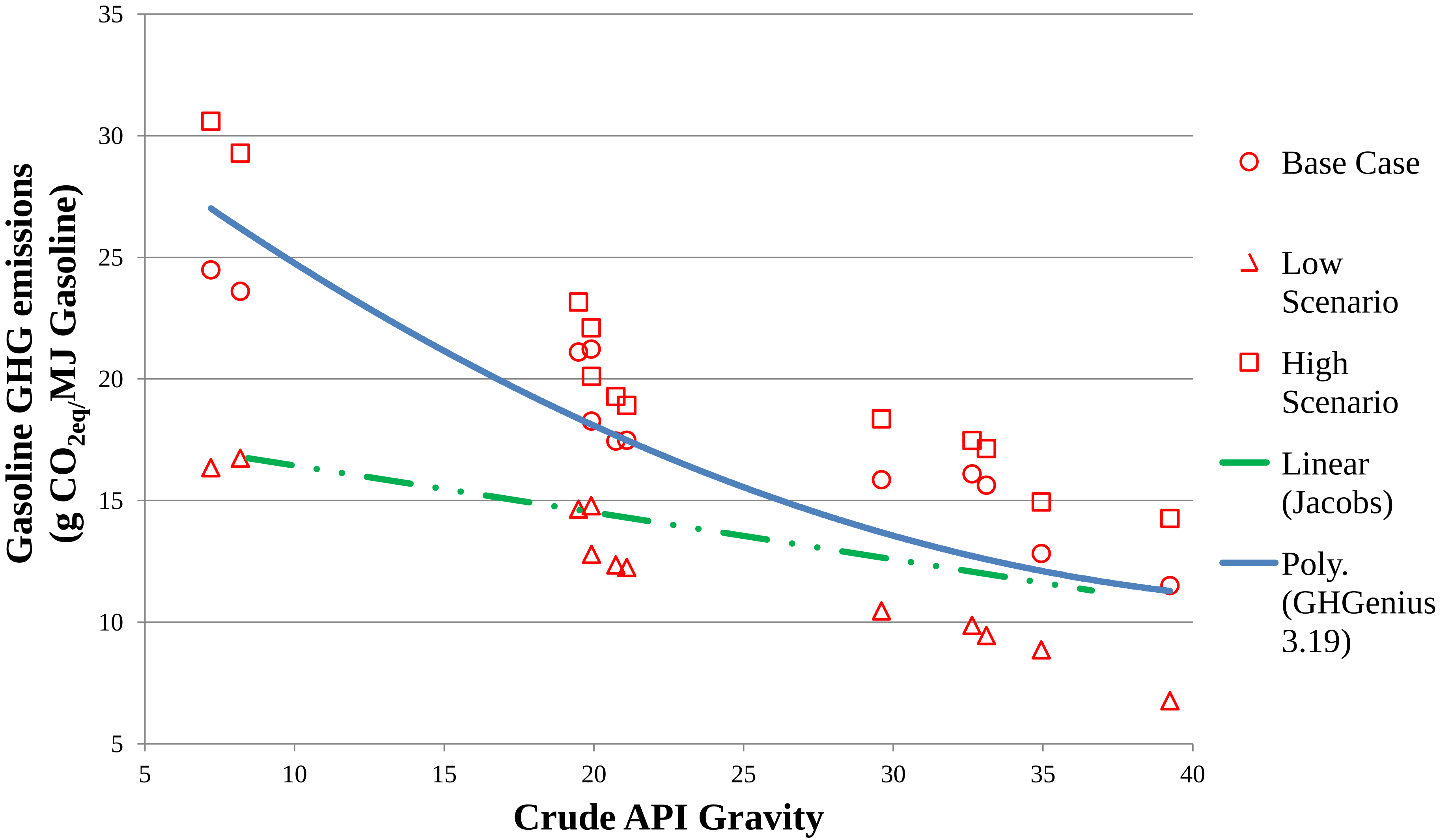
API as a Predictor?



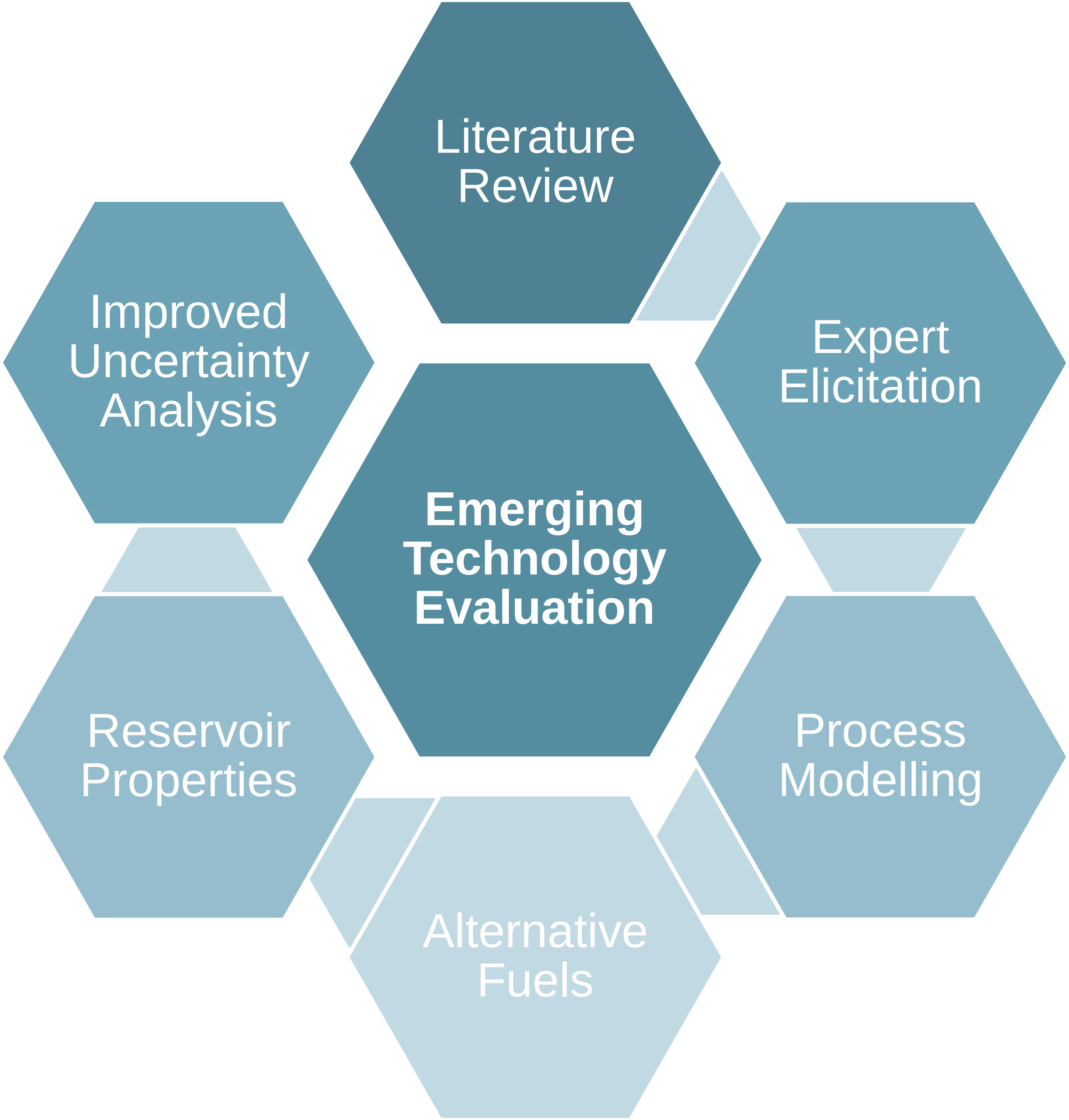
API as a Predictor?

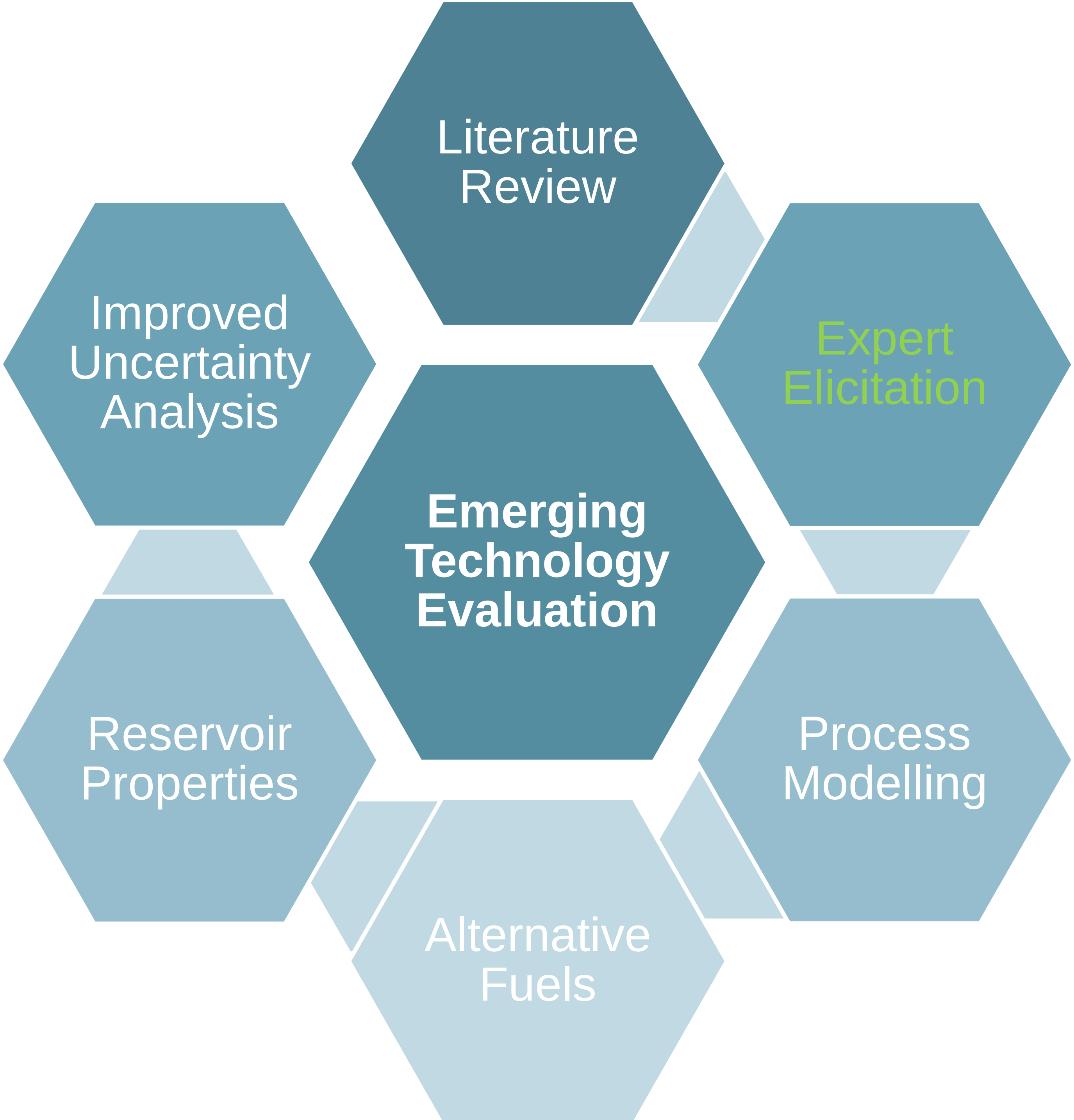


LCA of Emerging Technology Evaluation

- Important to guide the RD&D process
  - Avoid surprises
  - Ensure that the goals of innovation will be achieved

- Challenges
  - Proprietary data
  - Disproportionately high uncertainty
    - Comparison with mature technologies
  - Lab scale → commercialized technology
  - Potential for disappointment


Literature Review
Improved Uncertainty Analysis
Expert Elicitation
Emerging Technology Evaluation
Reservoir Properties
Process Modelling
Alternative Fuels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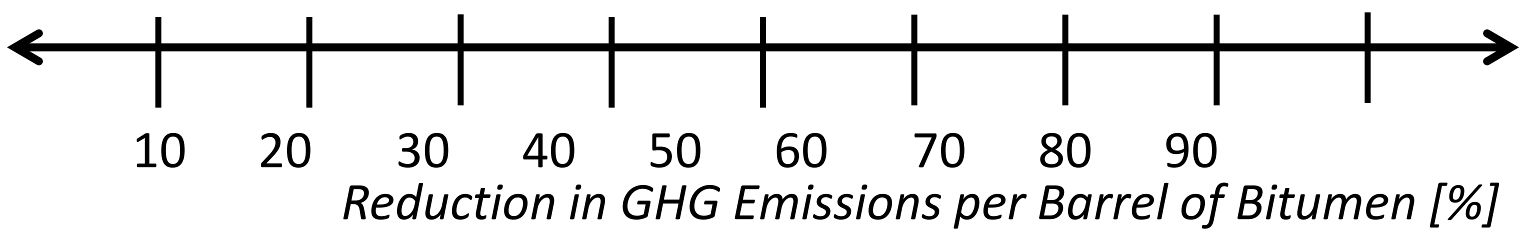
Expert Elicitation

- Used when available data are poor quality or when data are unavailable
- **Objective:** develop a framework to estimate the GHG and cost implications of these emerging technologies, and to assess how industry-wide activities might change in the next 20 years
- Process:
  1. Workshop for industry representatives
     - Learn the fundamentals
     - Discuss how to participate
     - Anonymous responses to some initial questions
  2. Online survey
     - Part 1. Industry trends, GHG predictions
     - Part 2. Emerging Technologies
  3. Follow-up workshop to verify results
  4. Enhance & improve life cycle models

Expert Elicitation – sample question

What reduction (if any) in **GHG emissions per barrel of bitumen** produced do you think will be achieved by 2032 at more than one commercial mining project through incremental process changes?



Optional comments

Please identify and [...]tors you believe will have the most impact on cSO[...]032. Use the "other" card for factor(s) not listed and [...]entify[...]at the bottom of the screen (with their ra[...]kings).

Increase: New technology implemented; Decrease: N/A

Increase: More solvent available; Decrease: Solvent availability constrained

Increase: Heightened concerns about water use; Decrease: Reduced concerns about water use

[...]ance of this [...]: [...]ge Increase

Most Imp[...]

Increase: No concerns about input transport; Decrease: Input transport constrained

Increase: More incentives/ subsidies; Decrease: Fewer

Increase: Price higher; Decrease: Price lower

Increase: Price higher; Decrease: Price lower

Increase: Ratio increase; Decrease: Ratio decrease

[...] Important

Increase: Stricter restrictions on GHG emissions; Decrease: Looser restrictions

Increase: Perception stronger and more important among consumers; Decrease: Perception decreased or less important to consumers

- New technology
- Solvent availability
- Water use concerns
- Input transport capacity
- Gov't incentives/subsidies
- Natural gas price
- Oil price
- Natural gas/oil price ratio
- GHG mitigation regs
- CCS use
- "Dirty oil" perception
- Reservoir quality
- Other

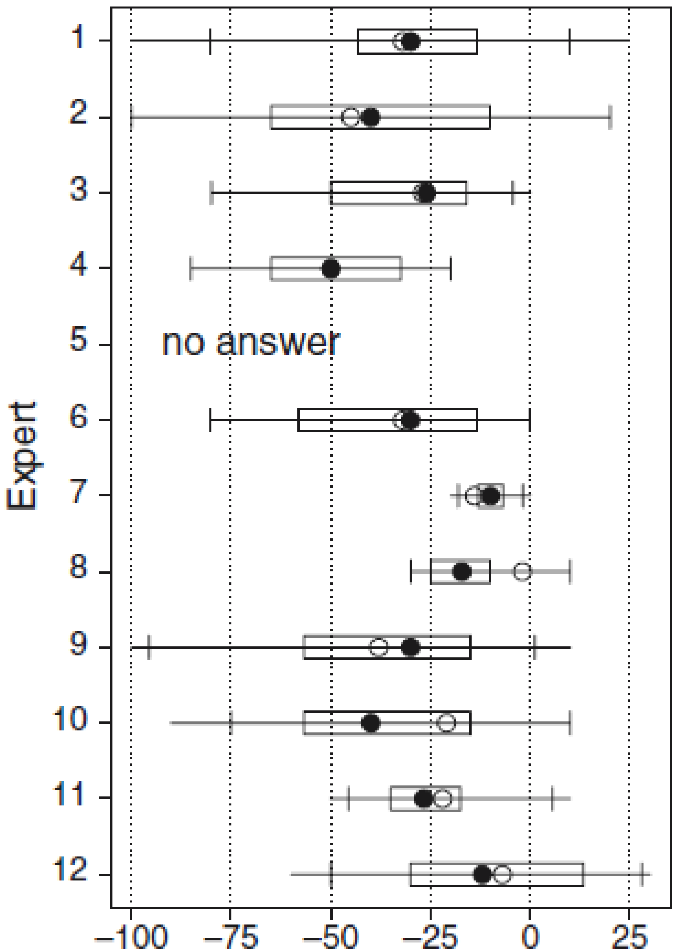
O[...]ional comm[...]

Increase: Higher quality reservoirs (i.e., less steam required) being produced; Decrease: Lower quality reservoirs being produced

[...]Situ Operation Efficiency

Expert Elicitation Expected Outcomes

Expert Elicitation – Sample Output
Zickfeld et al. (2007)



Percentage Change from Baseline (%)

- Verify elicitation output results with experts in follow-up workshop

- Input findings to life cycle model

- Develop estimates for trends in emissions over the next 20 years, evaluate potential of emerging technologies, identify tradeoffs

Preliminary Insights

- Phase 1: 13 responses to survey from Industry, Government and Academia
- Diversity of views across experts
- Several incremental opportunities, game changers are further away and are more subject to confidentiality issues

Concluding Thoughts

- LCA is a powerful tool to help structure how we think about complex environmental issues

- LCA should continue to be used as a tool for informing policy and product development
  - HOWEVER, there are limits to the appropriate use of this tool that must be addressed to achieve fair, reliable and predictable policies

- KEY ISSUES:
  - Unintended consequences
  - Uncertainty in LCA
  - Complexity of accounting, verification and compliance requirements

- Moving forward in assessing oil sands environmental performance, the focus should be on prioritizing the most:
  - Efficient (cost-effective) and
  - Effective (most progress toward the goal) solutions

Current Project Team

Calgary: Dr. Joule Bergerson
Dr. Oguz Akbilgic
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Jessica Chan
Christian Hovsepian
Andrea Orellana

Toronto: Dr. Heather MacLean
Dr. Jennifer McKellar (now at UOIT)
Diana Pacheco
Sylvia Sleep
Margaret Zhong
Daniel Haaland

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- Ontario Graduate Scholarship
- Oil Sands Industry Consortium

Thank you!

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http://iseee2.ca/projects/lcaost/