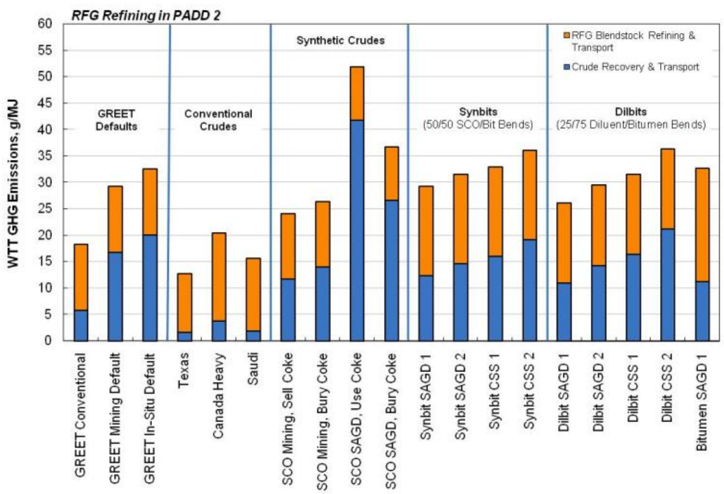
For better or worse?
Improving conventional fuel baseline emissions estimates for use in transport fuels LCA



CRC workshop on life cycle analysis of biofuels
Argonne National Laboratory
October 18th, 2011

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The need for accurate baseline emissions

- Low carbon fuel standards aim to reduce the GHG intensity of transport fuels
  - CA LCFS requires 10% reduction from baseline emissions
- Without accurate baseline estimates, difficult to know if goals are met
  - *"What is not measured is not managed"*
- Variability and uncertainty does not only affect alternative fuels

Reasons for variability in crude oil emissions

- Variation in field quality
  - Depth, size, age, pressure, crude quality
- Variation in production technologies
  - Injection of fluids (steam, CO_2)
- Variation in regulatory stringency
  - Monitoring, control, emissions limits

Source: Wikipedia

Previous work – GREET (2011)

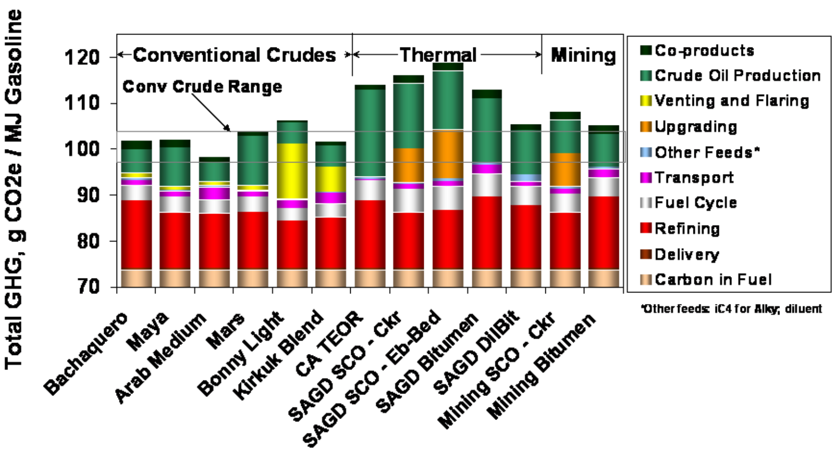
- Early LCA model for alternative fuels
  - Meant to represent industry-wide average conditions
  - Modified version (CA-GREET) used in CA LCFS
- Simple treatment of crude oil emissions
  - Efficiency + fuel mix approach
  - Crude oil production:

    98% efficient

    Fuel mix is 61.9% natural gas, 15% diesel, etc.

Previous work – Jacobs Consultancy (2009)

- Consultant report with detailed LCA modeling of oil sands and some conventional crudes



PRO

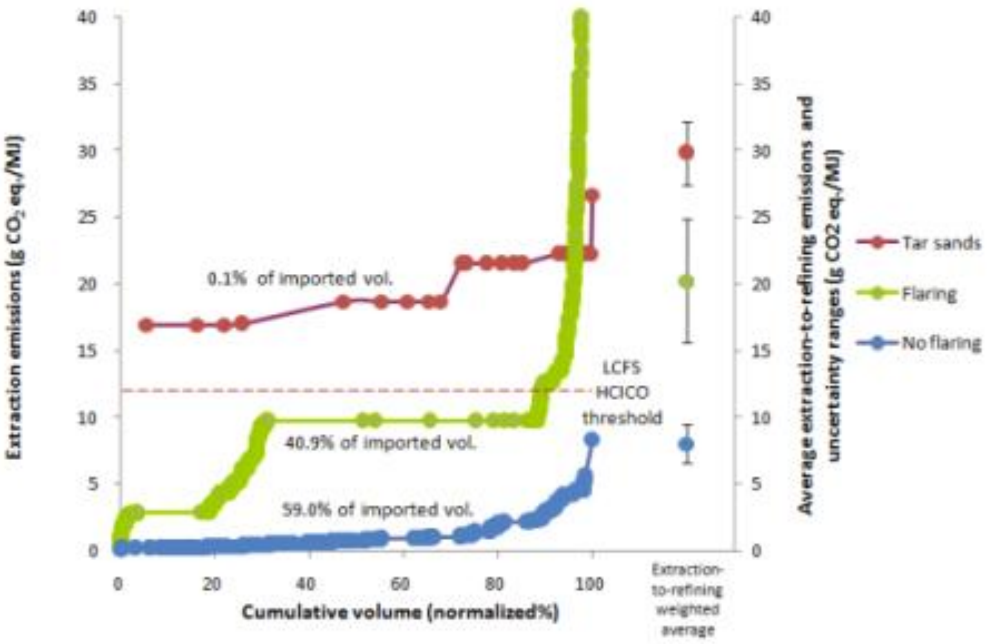
- Significantly improved conventional crude oil model
- Excellent refinery modeling
- Features WOR, GOR, gas injection, water injection, venting and fugitives

CON

- Simple treatment of oil sands production
- Project selection not useful for industry average
- Modeling is not fully transparent

Previous work – EnergyRedefined (2010)

- Field-by-field LCA of oil sands and conventional oil (correlations)



PRO

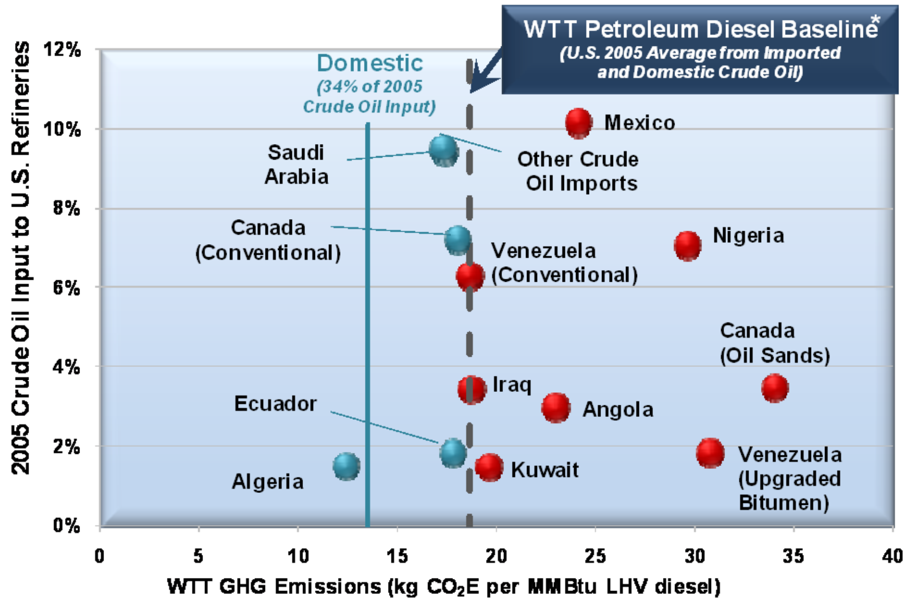
- Extremely detailed database
- Uses engineering fundamentals
- Clearly separates flaring and non-flaring emissions

CON

- Black box (no methods explanation)
- Dataset is detailed but inaccessible – uncertainty about data quality and vintage

NETL study (Skone and Gerdes, 2008) (Gerdes & Skone 2009)

- LCA disaggregated at crude oil type for US imports
- Major focus on refining modeling



PRO

- Much improved compared to previous DOE efforts
- Significant refinery modeling (uses public data sources e.g., PADD)
- Includes all major US imports (as compared consultancy reports focus on heavy crudes)

CON

- Methodological explanation is lacking in some areas
- Oil sands modeling is more simple than ideal

Common problems with previous work

- High-level models treat oil production in a simple fashion
  - Acceptable when goals of LCA were less ambitious
- Detailed models have been problematic from regulatory perspective
  - Unable to be verified or audited
  - Opacity can lead to disagreement
  - Stakeholders unable to use or modify for guiding decisions

Addressing these problems with a public model

- Funding from California Air Resources Board & EU to develop fundamentally new model
  - Post-doctoral research associate building the model(Hassan El-Houjeiri)
- Engineering-based bottom up LCA model
  - Input oil project properties, produce GHG emissions estimate

Goal: To develop the standard tool for use in assessing GHG emissions from oil and gas operations

Five model objectives

1. Build a rigorous, engineering-based model of GHG emissions from oil production operations
2. Use disaggregated data, where possible, to provide maximum accuracy and flexibility
3. Use public data where possible
4. Document sources for **every** equation, parameter, and input assumption
5. Provide model that is free to access, use, and modify by any interested party

Model scope

Exploration

↓

Drilling and development

↓

Production and lifting

↓

Separation and surface processing

↓

Waste treatment and disposal

↓

Shipping and transport

Modular structure separates stages but links flows from sheet to sheet

Classification and significance cutoffs

Sensitivity and estimated magnitude

Main stage	Process	Sub-process	Emissions		ants	Sensitivity code	Estimated magnitude
Separation and surface processing	Fluid separation	Oil-water-gas separation	Oil-water-gas separatio			**	~ 0.1 g
			Oil-water-gas separation with heater treaters	s.1.1.c1	-	**	~ 0.1 g
			Associated gas venting	s.1.1.v1		****	~ 10 g
			Associated gas flaring	s.1.1.c2	Variations in flare efficiency	****	~ 10 g
			Fugitives from separation	s.1.1.v2	-	***	~ 1 g
	Solid/fluid separation	Solid separation from fluids	Solids removal from separation	s.2.1.e1	-	*	<= 0.01 g
	Gas handling	Gas handling	Produced gas dehydration	s.3.1.e2	-	*	<= 0.01 g
			Produced gas venting and flaring	s.3.1.v1	-	***	~ 1 g
			Produced gas transport	s.3.1.c1	-	*	<= 0.01 g
	Water treatment and disposal	Water treatment	Produced water cleanup	s.4.1.e1	-	**	~ 0.1 g
			Produced water handling and pumping	s.4.1.e2	-	**	~ 0.1 g
		Water reinjection and disposal	Produced water reinjection	s.4.2.e1	-	***	~ 1 g
			Produced water disposal (offsite)	s.4.2.e2	-	**	~ 0.1 g
	Storage	Storage (on site)	Storage pumping energy	s.4.1.e1	-	*	<= 0.01 g
			Tank assembly and installation	s.4.1.c1	-	*	<= 0.01 g
			Evaporative and fugitive emissions	s.4.1.v1	Covered and uncovered tanks	**	~ 0.1 g
			Raw materials embodied energy	s.4.1.m1		*	<= 0.01 g
			Land use impacts	s.4.1.l1	-	*	<= 0.01 g

> 100 sources

Classification by type

c Combustion
e Electricity
v Venting
m Embodied
l Land use

Model coverage and modeling philosophy

- Model coverage
  - Primary production, secondary production, enhanced oil recovery
  - Thermal EOR, CO_2 EOR, Other gas injection (N_2 etc.)

- Modeling philosophy
  - Use simplest models that capture key (first-order) physical phenomena
  - We are not designing a facility, but modeling must move beyond simple multipliers

Example: Pipeline modeling

Sources of pressure drop:

1. Frictional losses during transport
2. Net elevation gain (or loss)
3. Pressure differences between inlet and outlet

D'Arcy-Weisbach w/ Moody friction factor

$$\Delta P = f \frac{L}{D} \frac{\rho V^2}{2}$$

$$\frac{1}{\sqrt{f}} = -2 \log \left(\frac{\epsilon}{3.7065 D} - \frac{5.0452}{N_{re}} \log A \right)$$

$$N_{re} = \frac{VD}{\mu}$$

Pipeline parameters

1. Length (L)
2. Diameter (D)
3. Roughness (ε)
4. Pump efficiency (η)

Fluid parameters

1. Fluid velocity [f(Q,D)]
2. Crude viscosity [f(API)]

Source: Takacs (2005)

Complexity, data demands, accuracy

- Increased model complexity requires more input data
  – Pipeline model requires 6 pieces of data
- Are we increasing complexity of model beyond that justified by the available data?
  – "Garbage in, garbage out"?
- Simpler models also make these assumptions implicitly (but not in a transparent fashion)

Performing analysis with model

- Model will run with no crude-specific data inputs
  - Rely on representative default values
  - Produce a “default” crude oil GHG emissions profile
- Inputting crude-specific data inputs will improve accuracy of estimate for a field or crude blend
  - Operators have all required data (trivial)
  - Gaining access to data could be difficult

Use of model for regulation

- Model could be used in a variety of ways
  - More accurate calibration of baseline emissions
  - More accurate accounting for changes in crude oil mix
  - Screening and assessment of high carbon intensity crude oils [HCICOs]
  - Assessment of new crude oils or alternative technologies
- Move away from “default” values toward more specific assessment

Initial industry feedback

- Active feedback sought from industry
  - First document for review (scoping plan) October 2011

- Questions before model building begins in earnest:

1. Are we including all processes and sources of interest?
2. Are we including the correct level of process detail?
3. Insights into including parameter defaults?
4. Are significance criteria satisfactory?

Next Steps

- Progress on crude oil model underway
- Goals for model progress
  - First version underway [early 2012]
  - Rigorous industry and peer review – Stakeholder review process [early 2012]
  - Incorporate feedback and produce final model [mid 2012]