Life Cycle Well to Wheels Assessment of GHG Emissions from North American and Imported Crude Oils

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Workshop Comparing Approaches to Life Cycle
Analysis of Crude Oil
Centre for European Policy Studies
Brussels
March 21, 2011

Premise

- **GHG regulations will impact crude choice for producing transportation fuels**
- **Crudes are different**
- **GHG associated with crude production depends on reservoir and production methods**
- **GHG from refining depends on crude properties and refining intensity**

Agenda

- 2009 AERI Study
  - Background and project objectives
  - Methodology
  - Life Cycle analysis
    - Crude production
    - Upgrading and refining
    - Life Cycle well-to-wheels fuel cycle
  - Observations
- New developments
  - Changes in worldwide flaring
  - Advancements in bitumen production technology
  - EU crude oil pathway LCA

2009 Project Objectives – Fair and Balanced Assessment of Oil Sands vs. Conventional Crude Oils

- Sponsor: Alberta Energy Research Institute – now called Alberta Innovates Energy and Environment Solutions (AI-EES) (part of the Government of Alberta, Canada)
- Steering team
  - Industry
  - Academia
  - Government
- Develop a robust life cycle analysis comparison of oil sands versus conventional crudes processed in US
- Address limitations in prior life cycle work by using subject matter expertise and sound technical / engineering approach
- Vet results publicly

Life Cycle Assessment Comparison of North American and Imported Crudes

Prepared For

Alberta Energy Research Institute

July 2009

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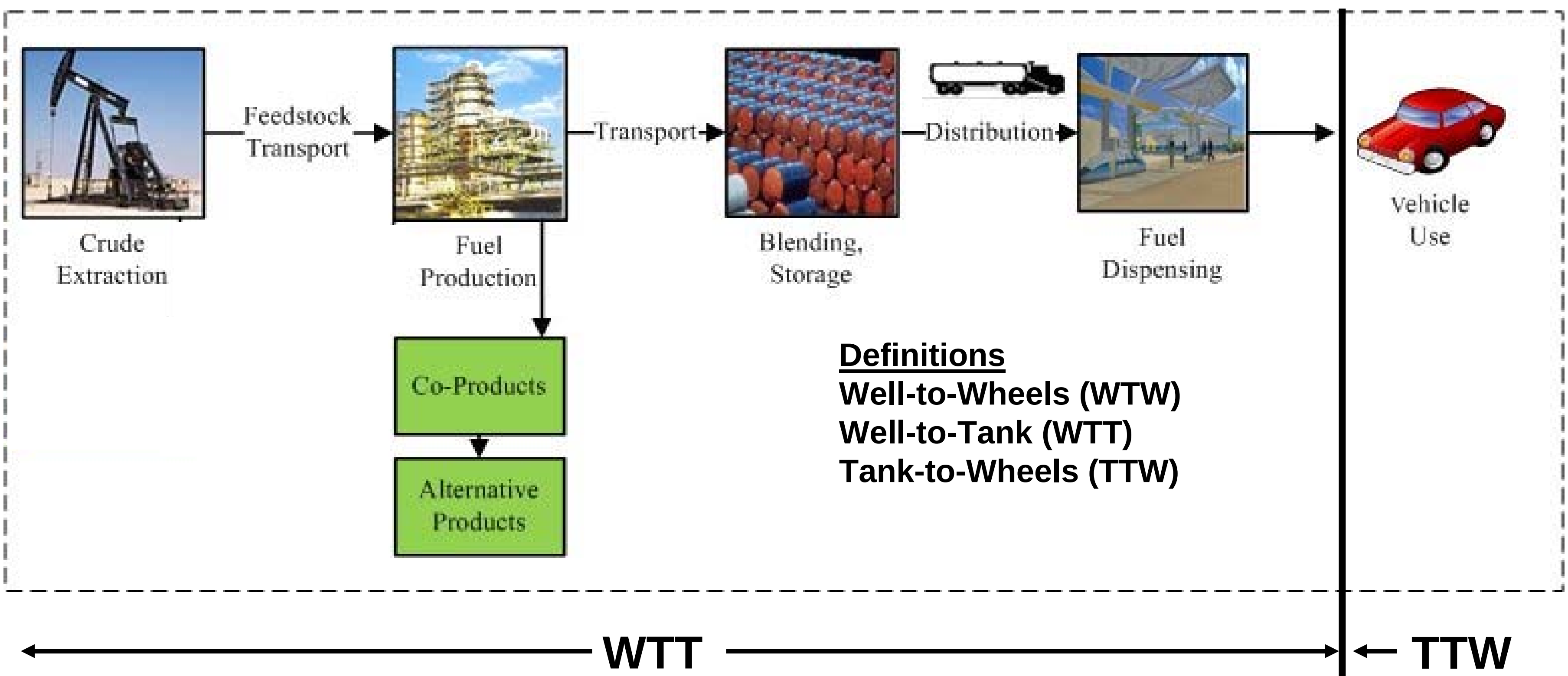
Life Cycle Associates

Well-to-Wheels Life Cycle Assessment



WTW Life Cycle Emissions = WTT + TTW

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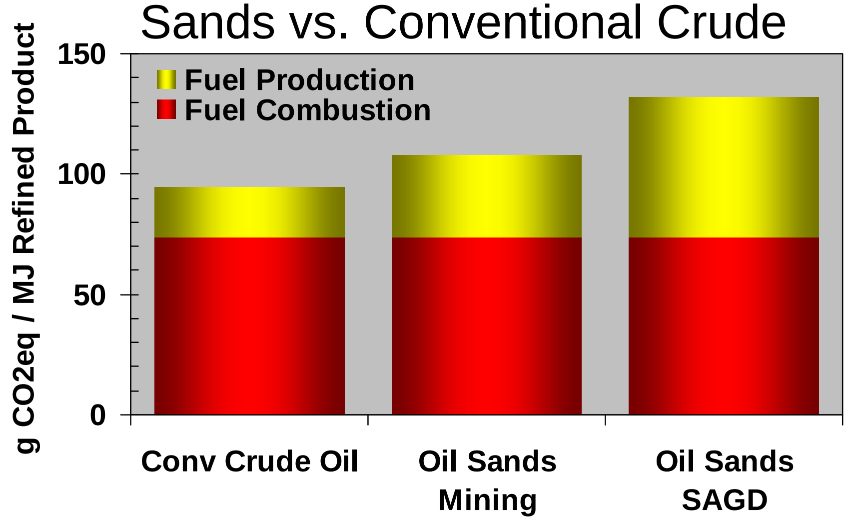
Limitations of Some Prior Life Cycle Analyses

- Incomplete and out-dated information
- Simplified, generic model representations
- Incomplete well-to-wheels analysis
- Excessive aggregation
  - No differentiation on crude properties
  - No differentiation on refinery configuration
- Inconsistent boundary conditions

Prior Life Cycle Analyses of Oil Sands vs. Conventional Crude

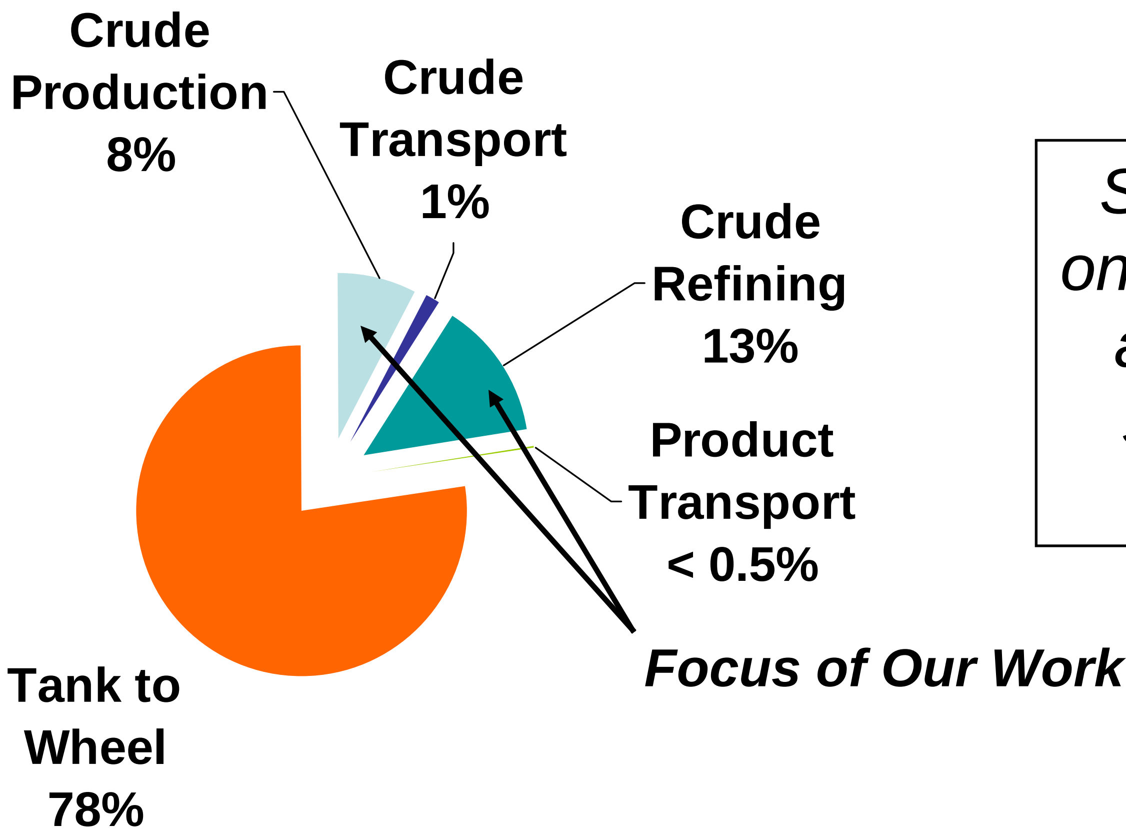


A Low-Carbon Fuel Standard for California Part 1: Technical Analysis, Project Directors: Alexander E. Farrell, UC Berkeley and Daniel Sperling, UC Davis, 2007

Prior work shows 14-41% higher WTW emissions for oil sands vs. "conventional" oil

Crudes and refineries are not created equal

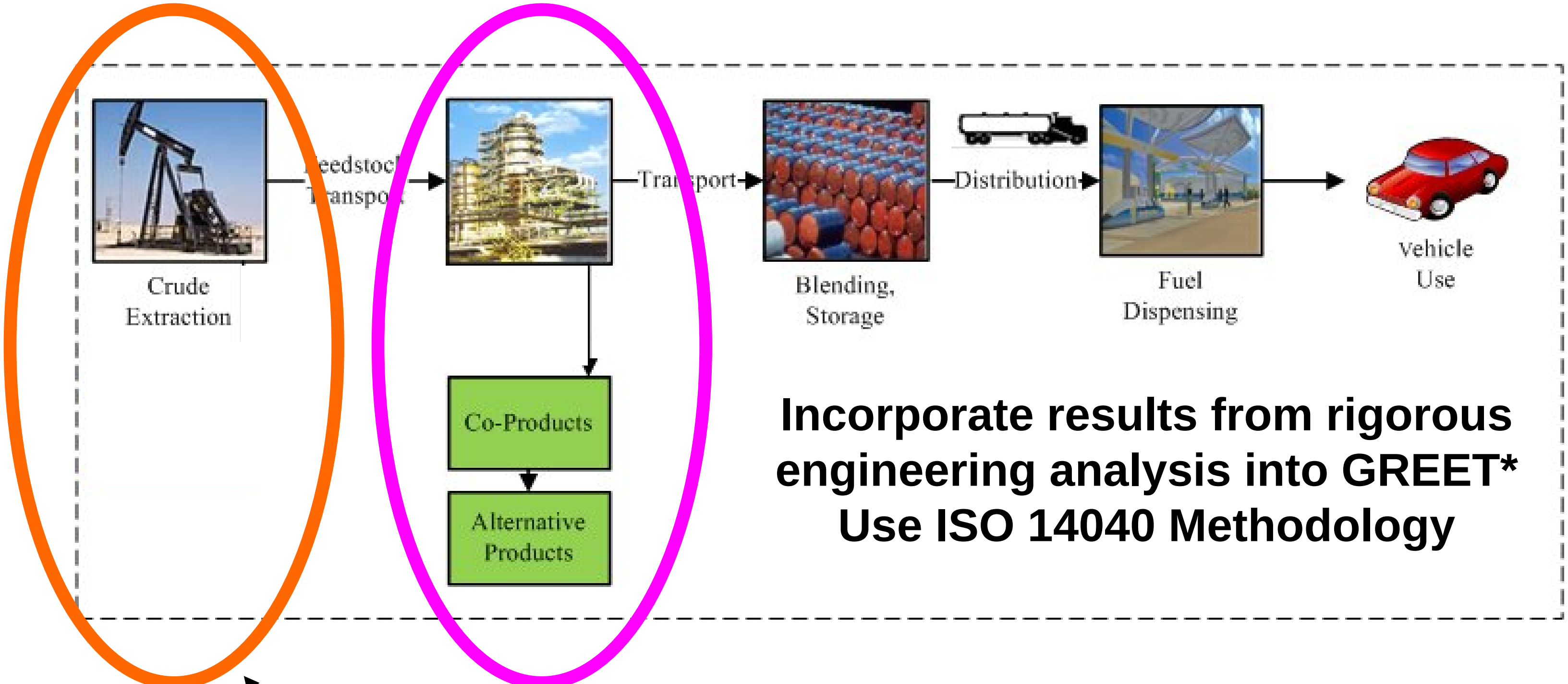
GHG Contributions from Well-to-Wheels Life Cycle Analysis



Study emphasis is on areas significantly affected by crude source, type and quality

Source: CARB – Detailed California-Modified GREET Pathway for Ultra Low Sulfur Diesel (ULSD) from Average Crude Refined in California, January 2009

Study Focus – Enhance Life Cycle Modeling with Crude Specific Estimates of Energy / GHG Emissions



Incorporate results from rigorous engineering analysis into GREET* Use ISO 14040 Methodology

<u>Crude & Bitumen Production</u>

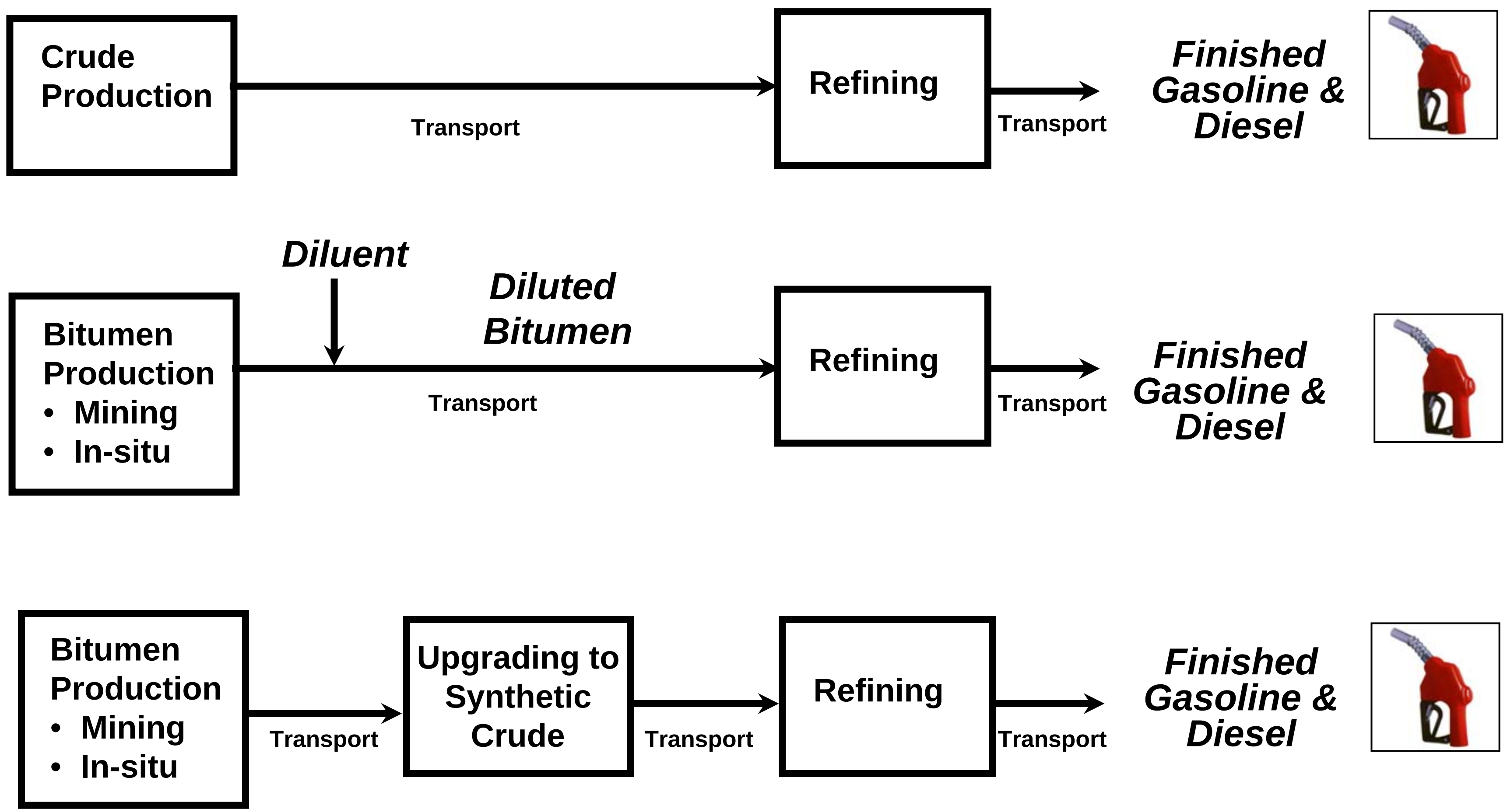
- **Specific crudes evaluated**
- **Public & Jacobs data**
- **Rigorous modeling**

<u>Upgrading and Refining</u>

- **Reflect crude and product variations**
- **Jacobs experience**
- **Rigorous modeling**

**GREET: Greenhouse gases, Regulated Emissions, and Energy use in Transportation*

Crude & Bitumen Systems Considered



Key Crude Production Issues

- **Wide variation in specific crude and bitumen production GHG emissions**
  - **Crude / bitumen properties**
  - **Reservoir characteristics**
    - Depth
    - Water to oil ratio
    - Gas to oil ratio
  - **Flaring and venting of produced gas**
  - **Treatment of produced water and gas**
  - **Production method and technology**
    - ➢ primary, secondary, tertiary

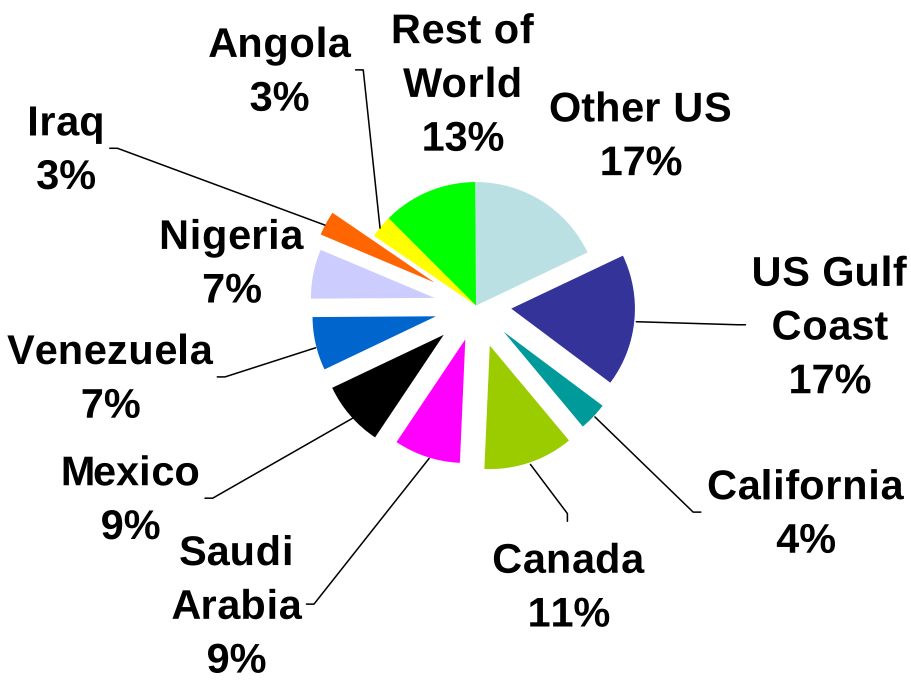
Public availability of accurate, comprehensive production data is often limited

Crudes Considered Reflect Typical US Basket

Study Crudes

- Bachaquero – Venezuela
- Maya – Mexico
- Arab Medium – Saudi Arabia
- Mars – US Gulf Coast
- Bonny Light – Nigeria
- Kirkuk – Iraq
- Kern River – California
- Oil Sands Bitumen – Canada

2007 Average US Crude Basket



Source: EIA

Concept 1 – Crude Oil and Bitumen Properties Lie on a Continuum

Viscosity, cP	API°	Oil Type		Density, g/cm^3
		Condensate		
	45	Light Oil		0.802
>100	20	**Heavy Oil**	Viscous Oil	0.934
10,000	10	**Extra Heavy Oil**		1.000
>10,000	0	**Bitumen/Oil Sands**		1.076

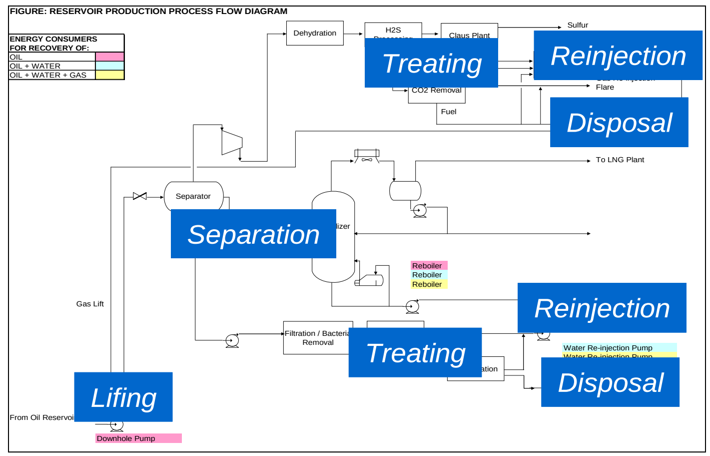
Dusseault, M.B. and Shafiei, A. 2011. Oil Sands. Ullmann's Encyclopedia of Industrial Chemistry, Wiley-VCH Verlag GmbH & Co. KGaA, Weinheim

- Bitumen is another type of crude oil
- Properties fall on a continuum
- Less light components
- More resid and carbon

Address Key Issues by Modeling Crude Production

- **Jacobs crude oil production model used to predict GHG emissions for specific crudes**
- **Public data supplemented with Jacobs in-house knowledge**
- **Allows user to evaluate impact of key variables and carry out sensitivities**

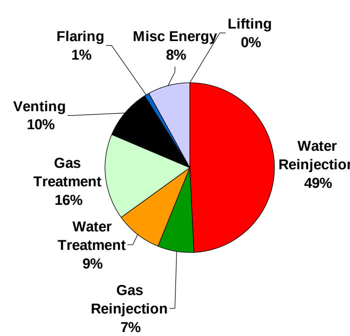
Jacobs Crude Production Model



Variable Inputs

Crude Description		
Crude Name		Generic
Production Rate	bpd	545
Properties		
API		30.0
SG		0.8762
Sulfur	wt%	2.0
Heating value		LHV
Crude Heating Value	GJ/Bbl	5.82
Reservoir Characteristics		
Reservoir Pressure	psi	3,000
Reservoir Temperature	°F	200
Reservoir Depth	ft	5,000
Production Characteristics		
Gas/Oil Ratio	scf/bbl	1,000
Water/Oil Ratio	bbl/bbl	10.0
Gas Lift		No
Gas Lift Rate	SCFB	0.0
Diluent Lift - Use if API below:		25.0
Produced Gas Composition (mol%)		
Source for Gas Composition		Default
Input Gas Compositon		
CH_4	mol%	79.74%
C_2H_6	mol%	14.95%
C_3H_8	mol%	4.98%
CO_2	mol%	0.00%
H20	mol%	0.33%
Gas Heating Value - LHV	BTU/SCF	1,082
Gas Heating Value - LHV w/o CO2	BTU/SCF	1,086
Venting of Produced Gas		
Vent Loss	%	0.5%
Fugitive Loss	%	0.5%
Reinjection of Gas and Water		
Gas Reinjection: % of Gas After Vent/Fugitive	%	50.00%
CO2 Separaton		No
CO2 Reinjection: %	%	100.00%
Water Reinjection: % of Produced Water	%	100.00%
Treatment of Reinjected Water		Yes
Treatment of Discharged Water		Yes
Disposal of Non-Reinjected Gas		
Amount of Non-Reinjected Gas	scf/bbl	500.0
Proportion of Gas to Flare	%	1.0%
Proportion of CO2 to Flare/Vent	%	50.0%
Flaring of Produced Gas		
% Combusted	%	99%
% Non-Combusted	%	1%
Fuel for Drivers and Heaters		
Downhole Pump Driver		Natural Gas
Water Reinjection Pump Driver		Natural Gas
Compressor Driver		Natural Gas
Fired Heaters		Natural Gas
Water Treatment		Natural Gas
Amine Treater - Fired Heaters		Natural Gas
Amine Treater - Drivers for Motors		Natural Gas

CO_2e Outputs by Category



Reservoir Characteristics for Conventional Crude Basket in Study

Petroleum Reservoir	Avg Depth,	Pressure,	Thermal Steam to Oil	Water to Oil	Produced Gas,	Flared Gas (Wrld Bnk Rpt Table 4)	N2 Injection
	ft	psi	bbl /bbl	bbl /bbl	scf / bbl	(m3 gas/bbl)	scf / bbl
Bachaquero	5,100	500	0.5	0.25	90	2.0	-
Maya	9,500	1,600	-	3	340	0.6	1,200
Arab Medium	6,100	3,000	-	2.3	650	0.8	-
Mars	14,500	5,500	-	5.5	1,040	0.6	-
Bonny Light	8,700	4,300	-	2	840	27.0	-
Kirkuk	7,500	3,000	-	2	600	11.0	-

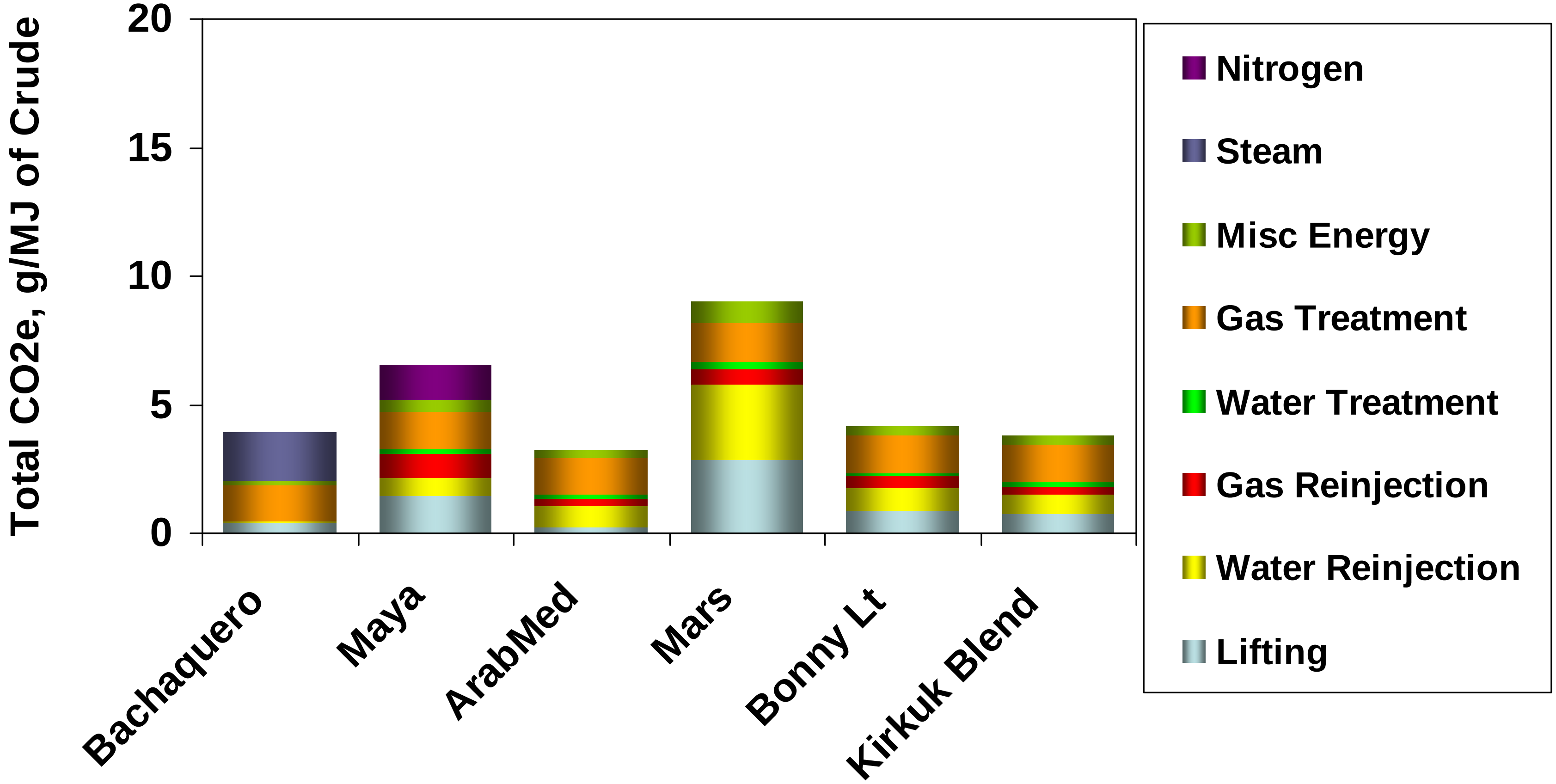
Assumed

From Reservoir Data

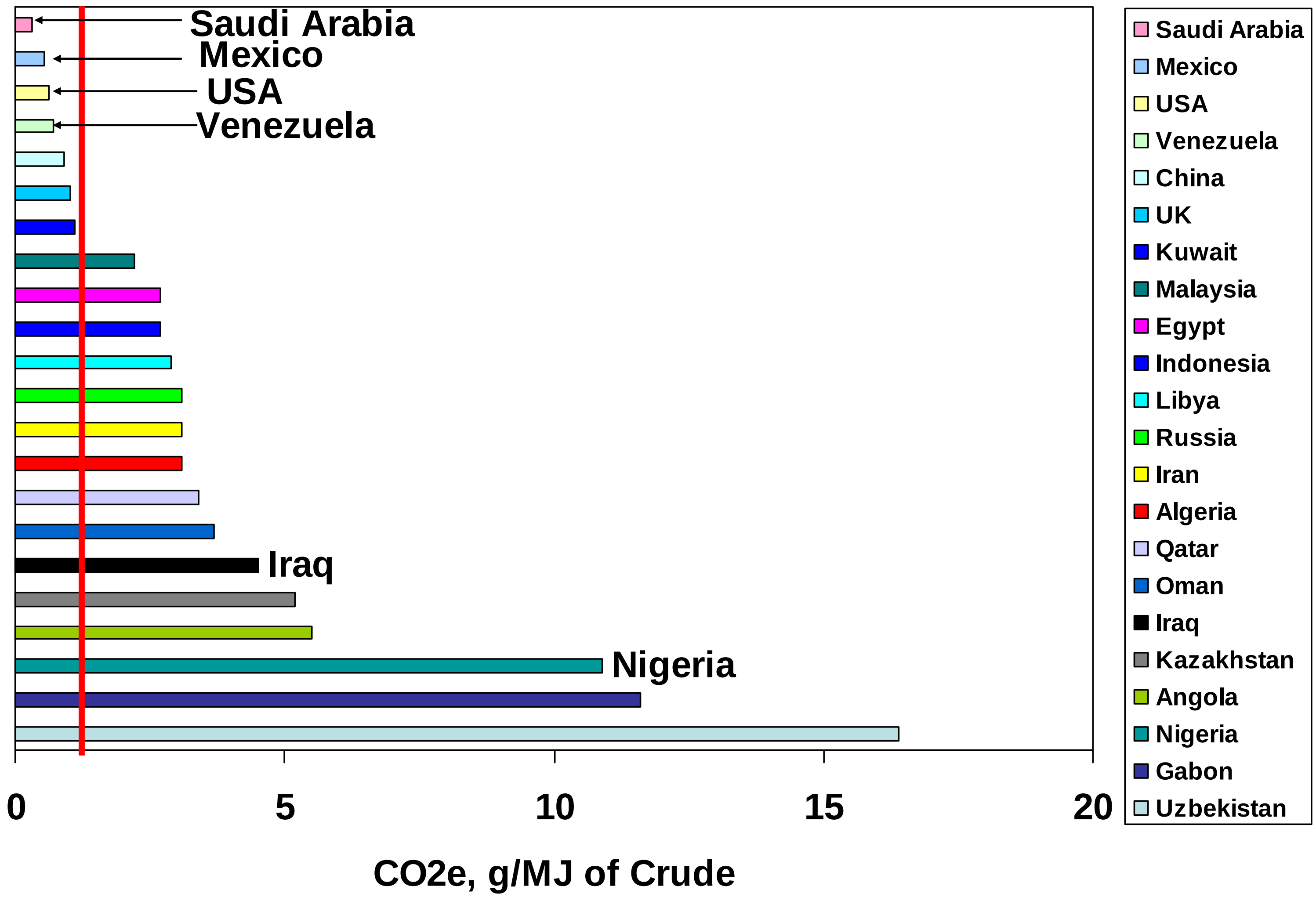
Reservoir Source: Pennwell- Published in Oil & Gas Journal, December 24, 2007 GOR and reservoir pressure, WOR from literature
Flaring data from World Bank: Gas flaring data from A Twelve Year Record of National and Global Gas Flaring Volumes Estimated Using Satellite Data, Final Report to the World Bank, May 30, 2007, and Global Gas Flaring Estimates, NOAA, 2007,

Using World Bank Report Table 4 in this study

Crude Oil Production Carbon Intensity – Before Accounting for Flaring

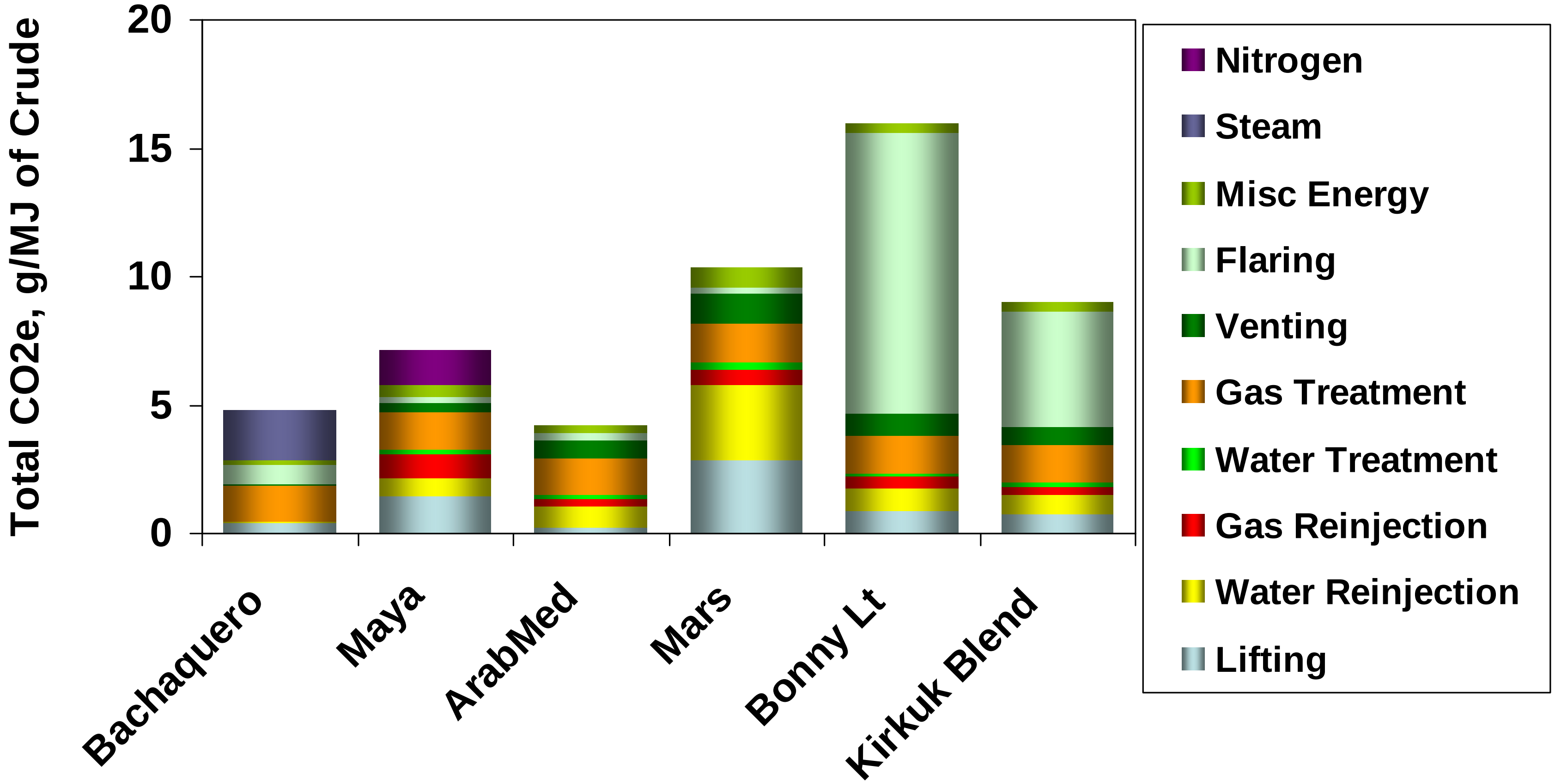


Gas Flaring in Crude Production



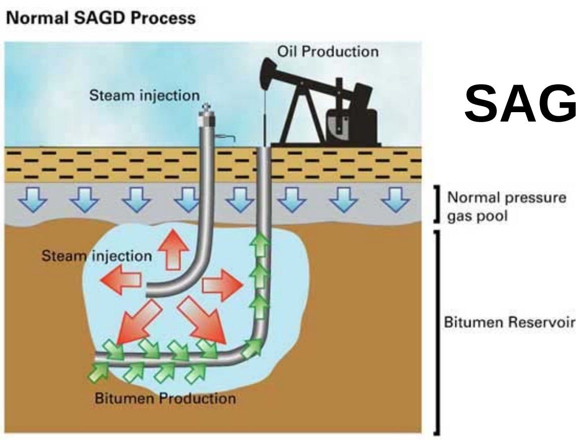
A Twelve Year Record of National and Global Gas Flaring Volumes Estimated Using Satellite Data - Final Report to the World Bank - May 30, 2007

Emissions With Flaring

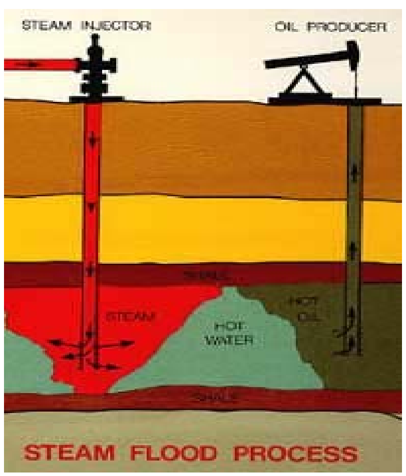


Using World Bank Report Table 4 for this figure

Heavy Crude Production Methods



SAGD



CA Thermal

- Bitumen
  - SAGD – steam assisted gravity drainage
    - Primary energy is natural gas to generate steam for injection
    - Key parameter is steam to oil ratio: bbls of cold water/bbl of oil
  - Mining
    - Primary energy is diesel fuel to power equipment
    - Natural gas and electricity are used to separate bitumen from clay
    - Study does not include land use or methane release in mine preparation
  - May import or self-generate electricity and export electricity to the grid
- California heavy crude oil
  - Uses an older somewhat less efficient thermal method than SAGD
  - Primary energy is natural gas

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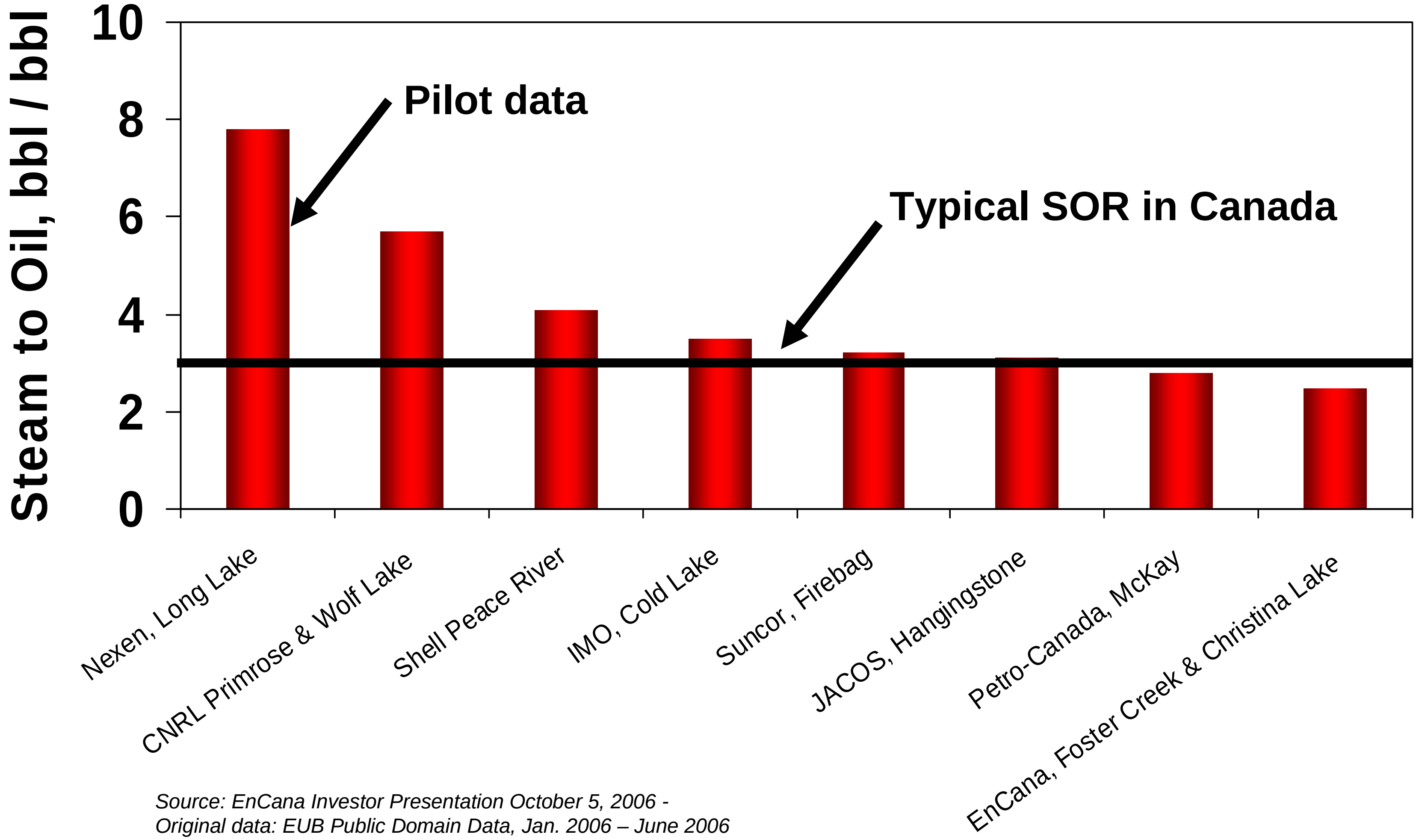
Canadian Bitumen Production in 2008

- 1.31 MM BPD total bitumen
- 0.73 MM BPD mined bitumen all to upgraders
- 0.58 MM BPD in situ (mainly thermal) production ~ 92% to refining

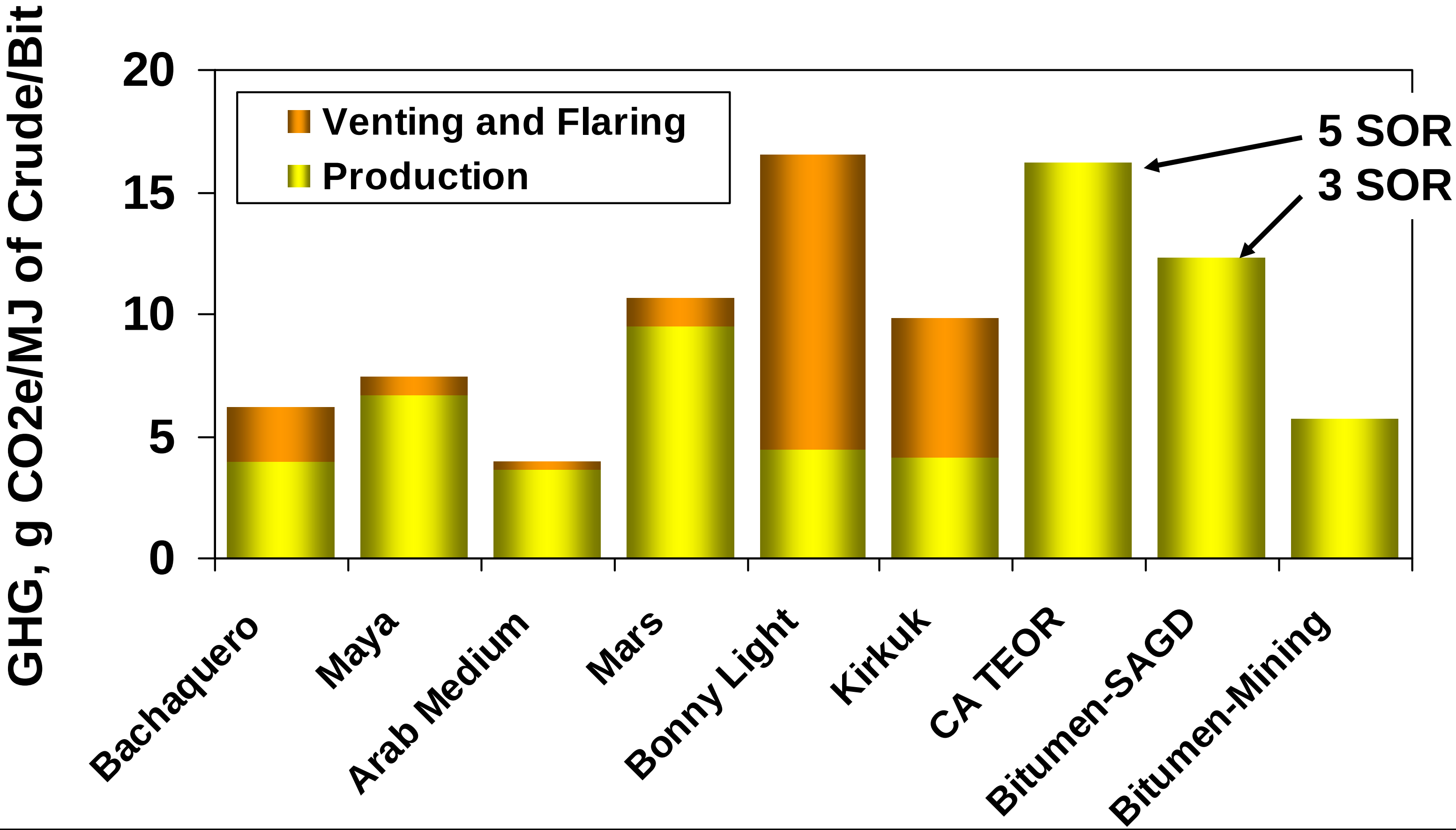
ERCB - Alberta's Reserves 2008 and Supply/Demand Outlook 2009-2018 – June 10, 2009

Bitumen Range of Steam to Oil Ratio (SOR)



Source: EnCana Investor Presentation October 5, 2006 -
Original data: EUB Public Domain Data, Jan. 2006 – June 2006

Concept 2 - Crude Oil and Bitumen Production Carbon Intensities Overlap

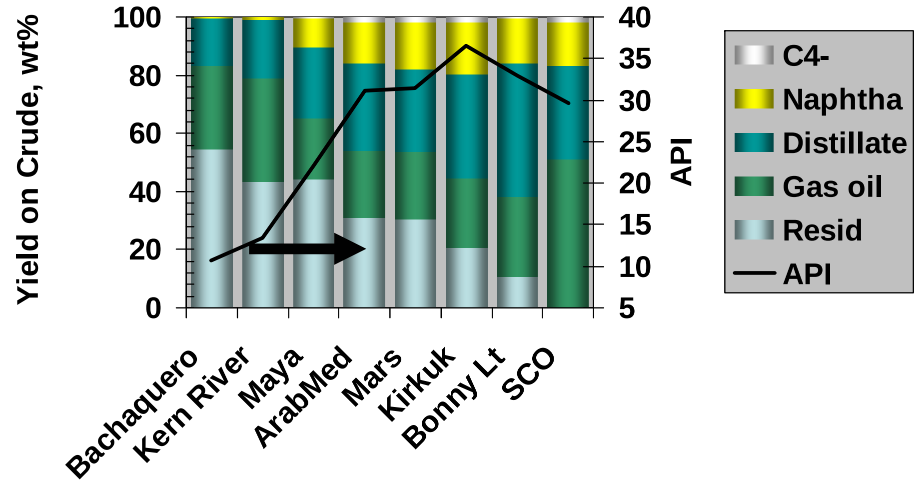


Emission range for heavy crudes overlaps range for some conventional crudes

Key Upgrading & Refining Issues

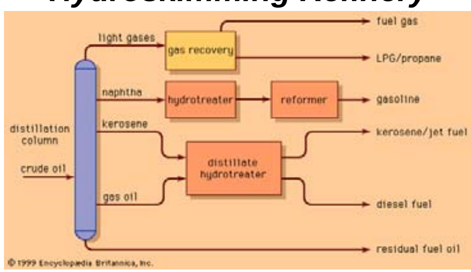
- **Crude quality and product requirements impact**
  - Processing complexity
  - Hydrogen addition
  - Energy consumption
  - Product yield and quality
  - Co-products such as coke
- **Refinery configuration and technology**
  - Level of conversion
  - Product slate

Crude Quality Varies

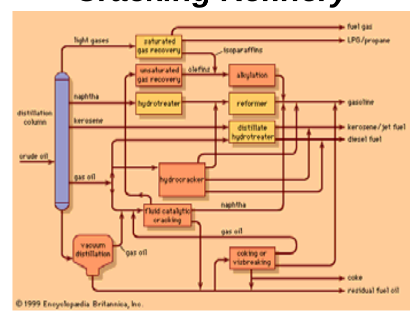


Refining Configurations Vary

Hydroskimming Refinery



Cracking Refinery



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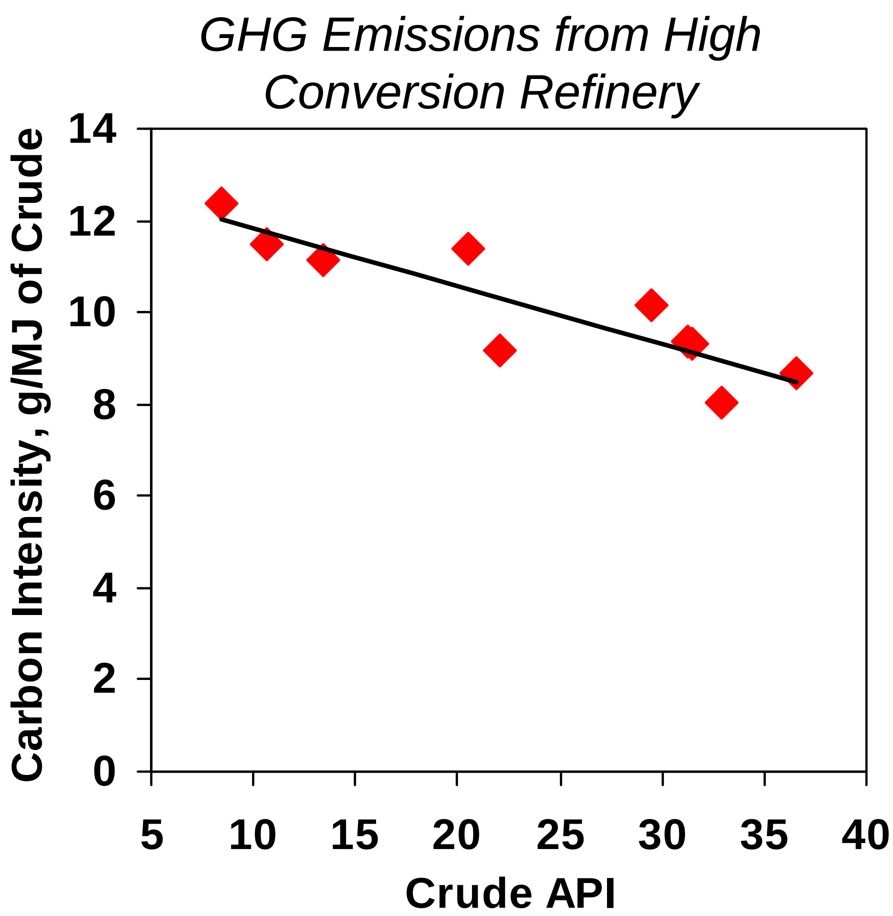
Concept 3 - Refining GHG tracks with API Gravity



- **Refining GHG emissions highly dependent on crude gravity**

  (API = 141.5/density – 131.5)

- **Emissions depend on conversion – line will shift up or down depending on conversion**

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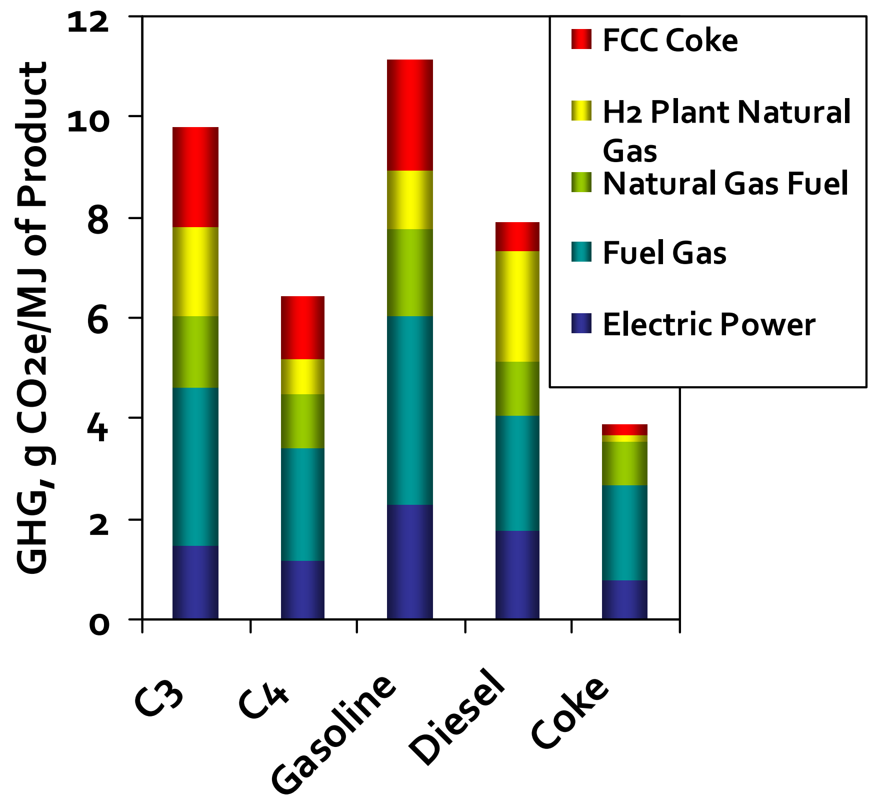
Concept 4 – Each Product Pays It's Fair Share of GHG

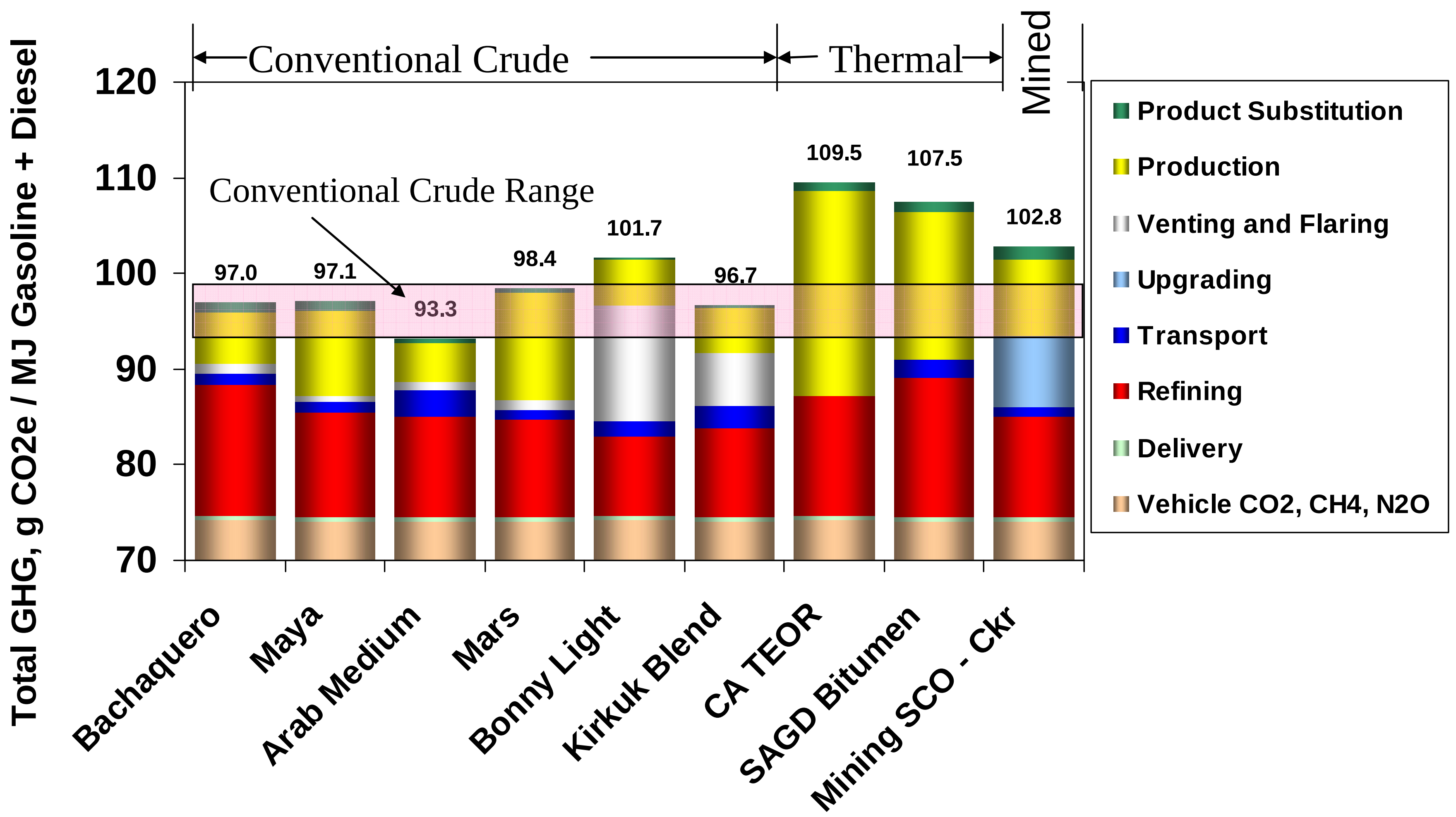
- Track utilities to intermediate products in each step of refining
- Ensures that products "pay" their fair share of GHG emissions
- Carbon intensity (CI) depends on processing intensity

Product GHG from Refining



Crude: Arab Medium
Refinery: High conversion

Concept 5 – CI of Transport Fuel from Heavy Crude Oils are within 10% - 12% of Those from Conventional Crude Oils



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Observations from 2009 Study

- Rigorous and detailed Life Cycle analysis provides a better understanding of differences between crude oils
- GHG burden for bitumen derived transport fuels is smaller than shown in previous studies
- Life Cycle GHG emissions between bitumen and some conventional crudes overlap
- Continuing effort to reduce GHG burden of bitumen production and refining

Agenda

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- New developments
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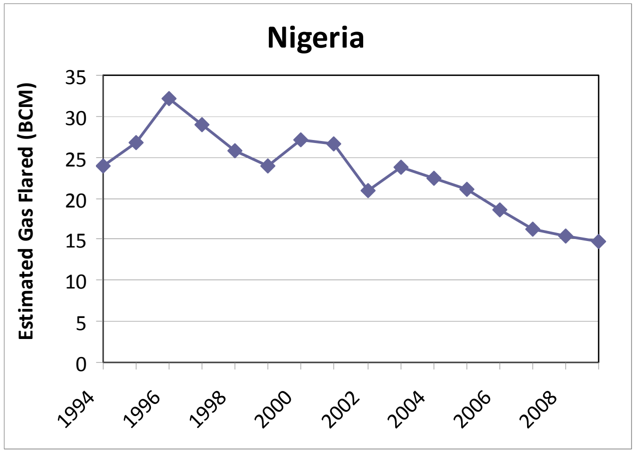
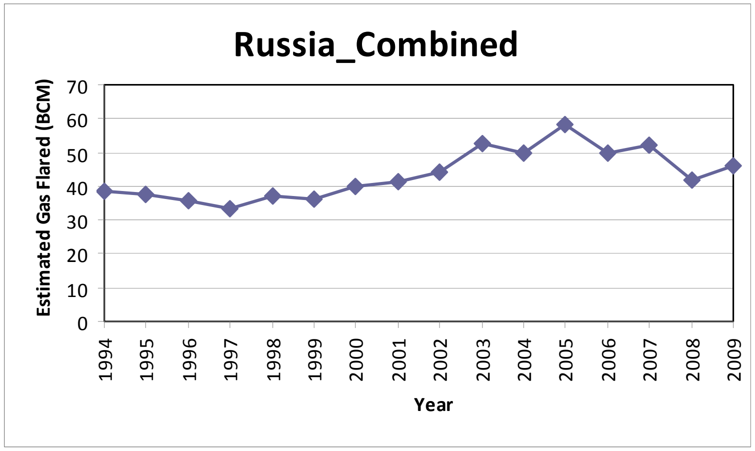
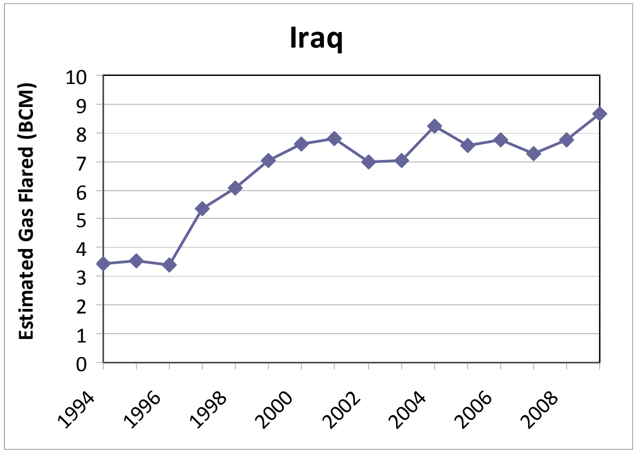
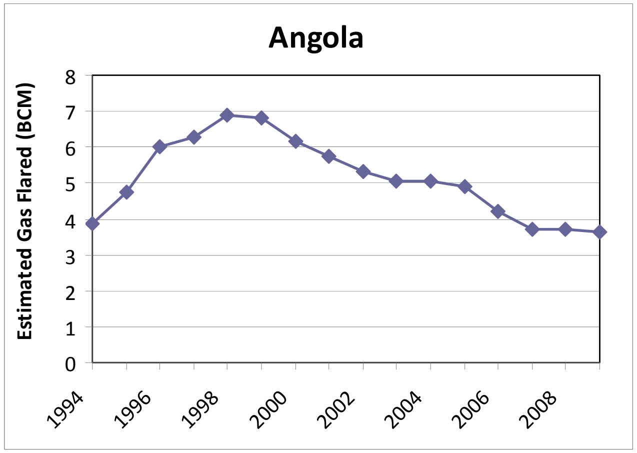
  - Advancements in bitumen production technology
  - EU crude oil pathway LCA

Flaring Trend is Downward - But Not Everywhere









Convert flaring to CO_2e, and Divide by crude production to get flaring in terms of CO_2e/MJ of Crude

NOAA - http://www.ngdc.noaa.gov/dmsp/interest/flare_docs/

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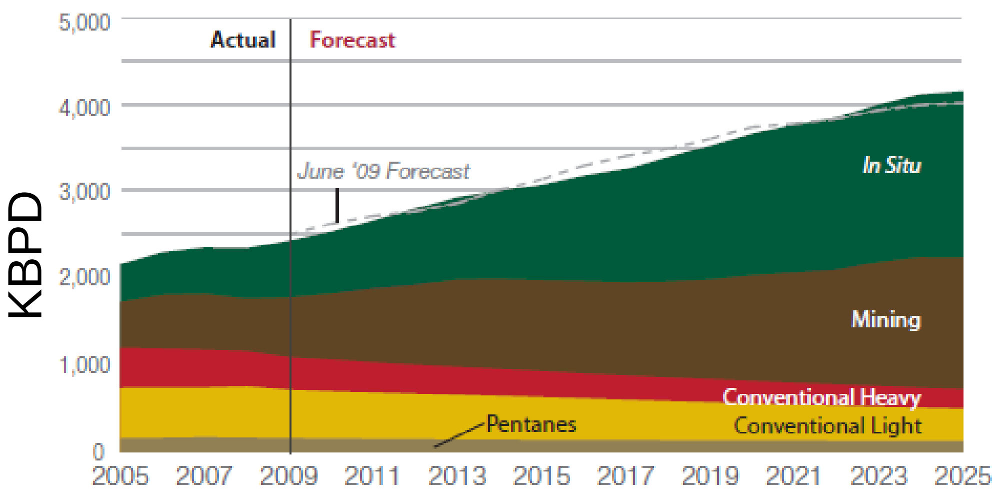
Canadian Bitumen Forecast

Growth Case - Western Canada Oil Sands & Conventional Production



- Forecast to exceed 3.5 MM BPD in 2025
- Bitumen production methods continually improving

CAPP – Canadian Association of Petroleum Producers – June 2010

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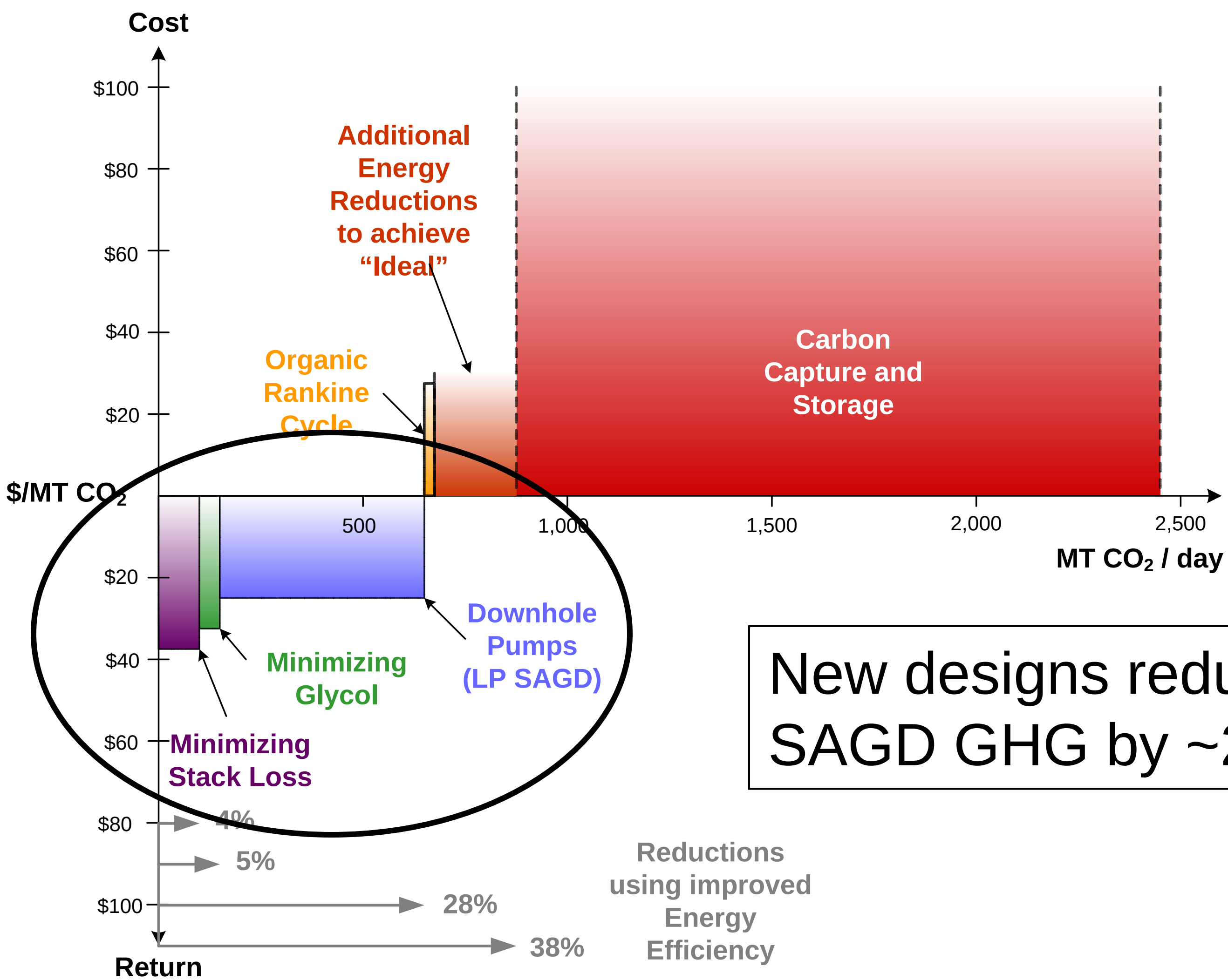
Improvements in Bitumen Production

- SAGD
  - Better heat integration reduces energy use
  - Fast SAGD makes better use of heat injected into reservoir
  - Improved lift technology – use of mechanical lift instead of gas lift
  - Better reservoir pressure management
  - Use of solvents reduces steam required
  - Improved recovery with polymer flooding
  - Water reduction and reuse reducing environmental burden
- Mining
  - Paraffin froth treatment at mine removes significant carbon resid which improves refining yield and reduces energy and GHG
  - Mature fine tailings recovery is reducing tailing ponds

Continued Development Driving Down GHG from SAGD



New designs reduce SAGD GHG by ~20-25%

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Commercial SAGD Production with < 3 SOR Demonstrated

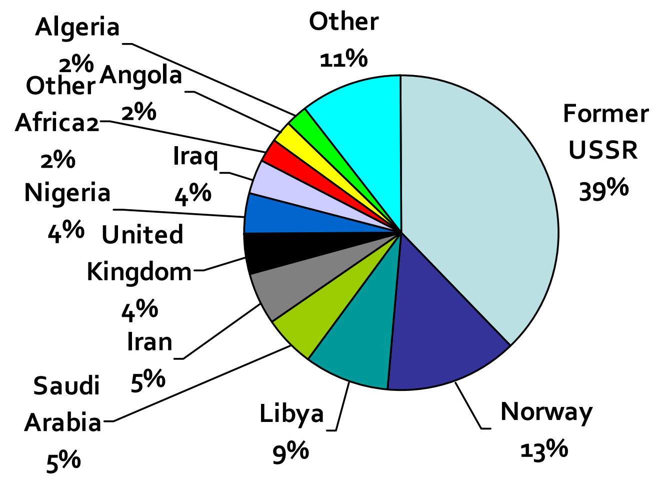
	After 9 Months of Operation		In 2010
Project	Date	SOR	SOR
Foster Creek	1998	4.0	2.5
Surmont Pilot	1998	5.2	3.5
MacKay	2003	3.4	2.5
Christina Lake	2003	2.8	2.0
Long Lake	2003	11.4	6.9
Firebag	2004	7.3	3.3

- SOR depends on reservoir conditions, good design and operation
- SOR below 3 have been demonstrated in commercial practice
- Reducing SOR from 4 to 2 cuts GHG in half

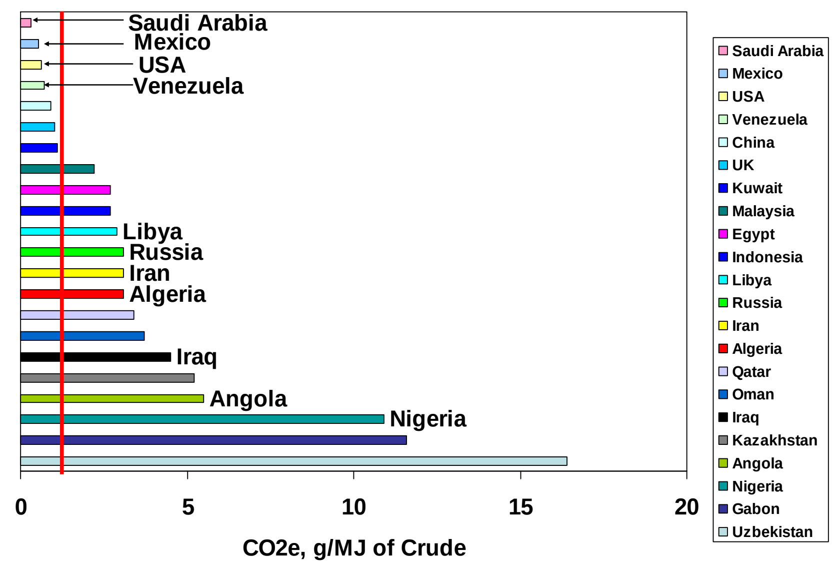
What Next

- ~50% of EU crude supply is from regions defined by California Air Resources Board as being high carbon intensity regions
- Forthcoming LCA study for Alberta Energy to provide a transparent view of bitumen and other crudes in an EU context
  - Define crude oil production GHG for typical crudes including flaring
  - Define refining GHG using EU refining configurations
  - Define oil transport and product distribution to the EU
  - Use EU vehicle emissions
- Goal – similar detail and transparency as 2009 AI-EES LCA study

EU Crude Supply in 2009



Gas Flaring in Crude Production



Thank You