Energy Independence for North America - Transition to the Hydrogen Economy

Dr. James J. Eberhardt, Chief Scientist
FreedomCAR and Vehicle Technologies Program
Energy Efficiency and Renewable Energy
U.S. Department of Energy

2003 Diesel Engine Emissions Reduction
(DEER) Conference
Newport, RI
August 24-28, 2003

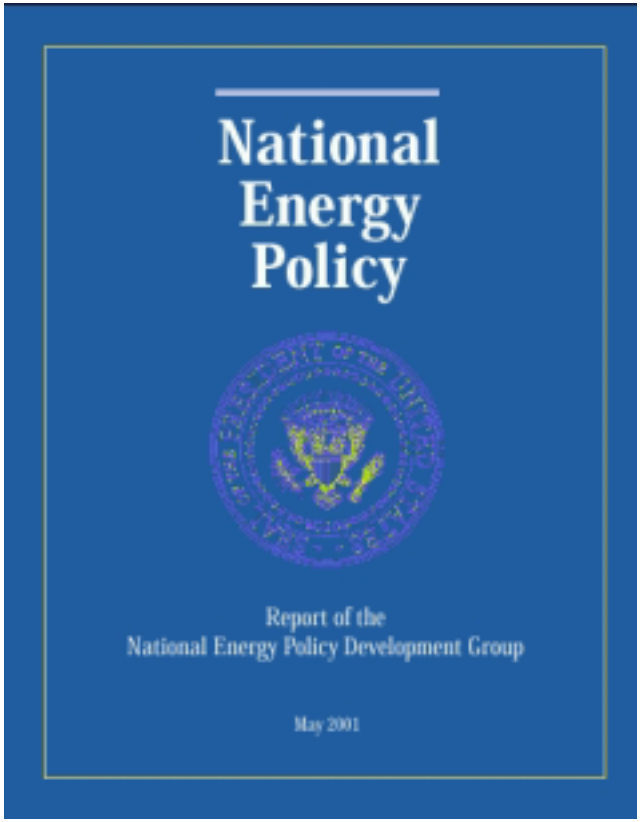
Outline

- Pathways to Energy Security
- Transportation Energy Demand Reduction
- Energy Resources from More Secure North American Sources
- Foundation for Transition to Hydrogen

Pathways to Transportation Energy Security

- Transportation energy demand reduction (through improved energy efficiency, e.g., via dieselization and/or hybridization);
- Greater use of non-conventional resources
  - heavy oils;
  - oil sands;
  - shale oil;
  - biorenewables;
  - GTL/Fischer-Tropsch
- Transition to the hydrogen economy.

The President's National Energy Policy



Using Energy Wisely – *Increasing Energy Conservation and Efficiency*

"The NEPD Group recommends that the President direct the Secretary of Energy to establish a national priority for improving energy efficiency."

Increased Fuel Efficiency from Vehicle Propulsion System

Now

- Direct Injection Diesel
- Gasoline Direct Injection
- Gasoline-Hybrid

Near Future

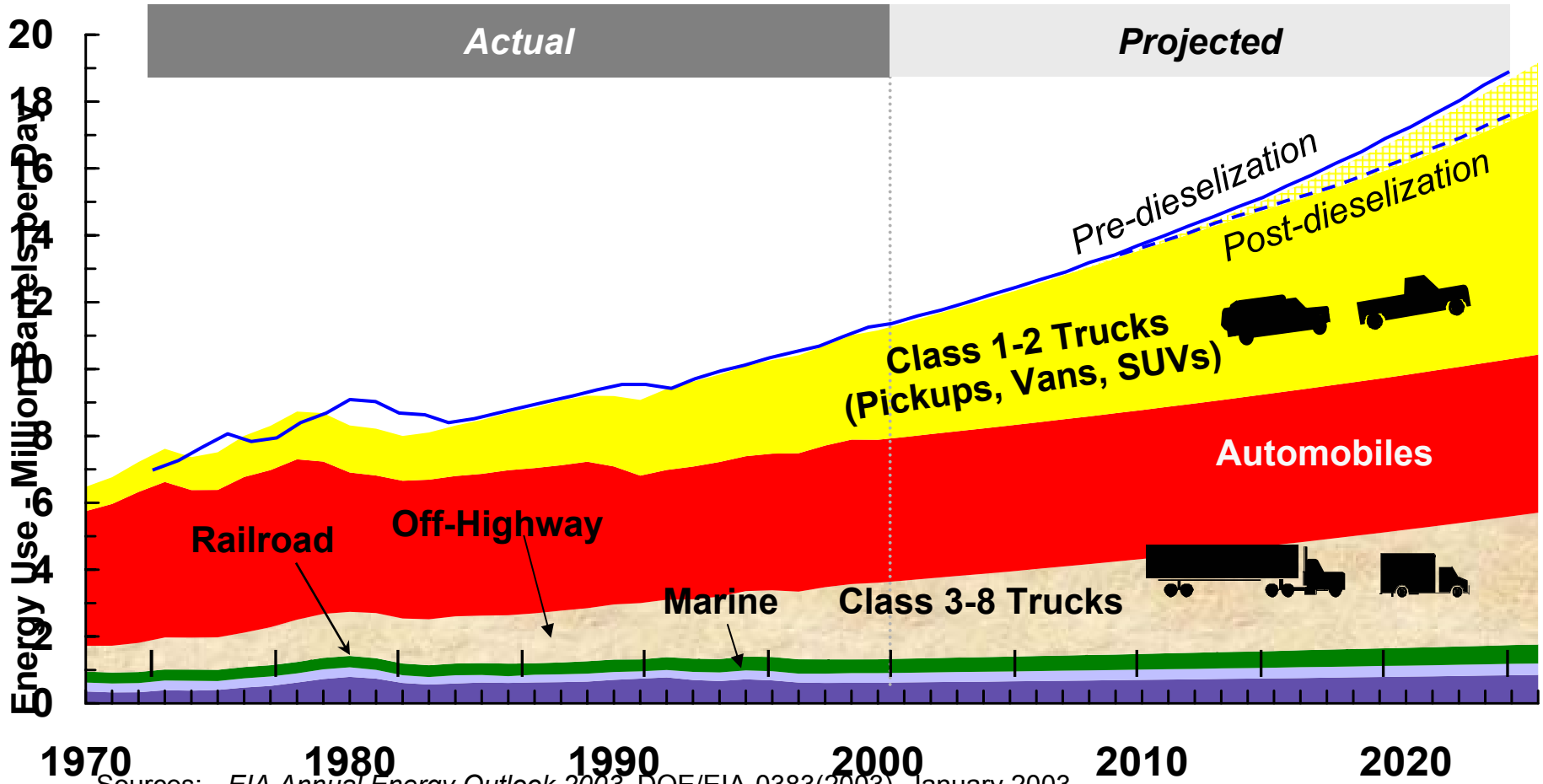
- DI Diesel-Hybrid
- Homogeneous Charge Compression Ignition
- Low-Temperature Combustion

Far Future

- Hydrogen Combustion Engines
- Hydrogen Fuel Cells

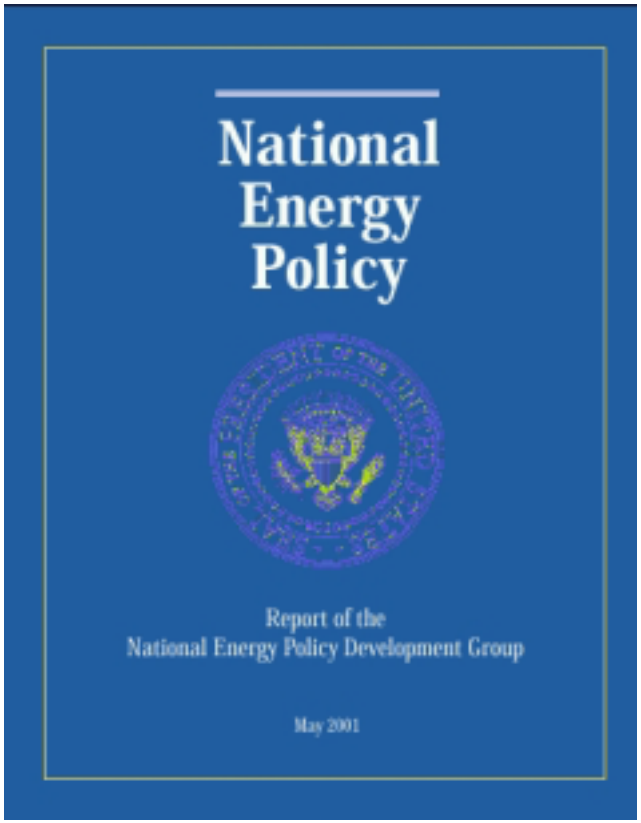
Dieselization of Light Trucks

Significant Potential Impact on Light Truck Fuel Use



Sources: *EIA Annual Energy Outlook 2003*, DOE/EIA-0383(2003), January 2003
Transportation Energy Data Book: Edition 22, ORNL-6967, September 2002
Market Data Book, Automotive News, May 2000.

The President's National Energy Policy



Strengthening Global Alliances – *Enhancing National Energy Security and International Relationships*

"Estimates of Canada's recoverable heavy oil sands reserves are substantial… Their continued development can be a pillar of sustained North American energy and economic security."

"The NEPD Group recommends that the President direct the Secretaries of State, Commerce, and Energy to engage in a dialogue through the North American Energy Working Group to develop closer energy integration among Canada, Mexico, and the United States and identify areas of cooperation, fully consistent with the countries' respective sovereignties." NEP p. 8-9.

Oil Sands

A Major New Hydrocarbon Resource

"You will observe with concern how long a useful truth may be known and exist, before it is generally received and practiced on." -- Benjamin Franklin

U.S. Imports of Crude Oil & Refined Products (2002)

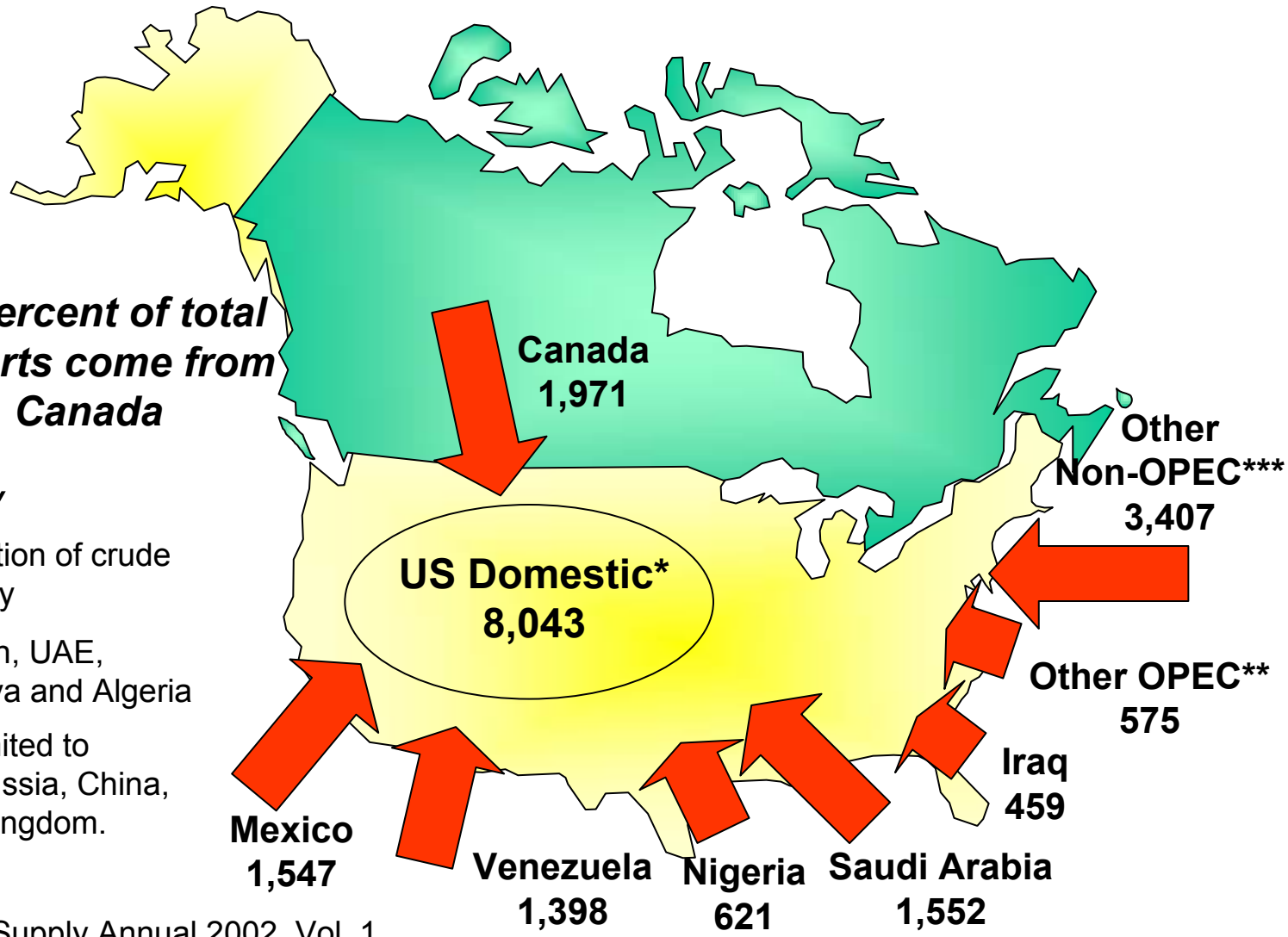
17 percent of total imports come from Canada

Thousands of barrels per day

*includes field production of crude oil plus Alaskan supply

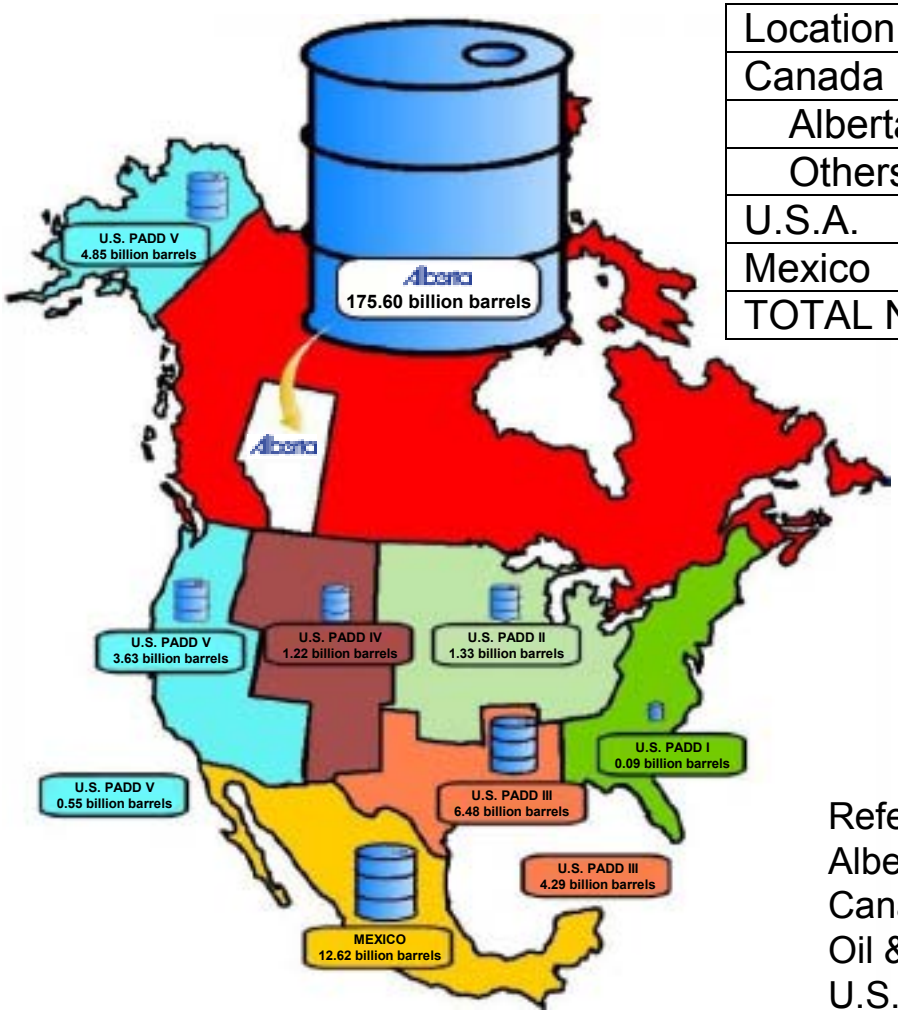
**includes Kuwait, Iran, UAE, Indonesia, Qatar, Libya and Algeria

***includes but not limited to Angola, Colombia, Russia, China, Norway and United Kingdom.



Source: EIA Petroleum Supply Annual 2002, Vol. 1

North American Oil Reserves (2002)

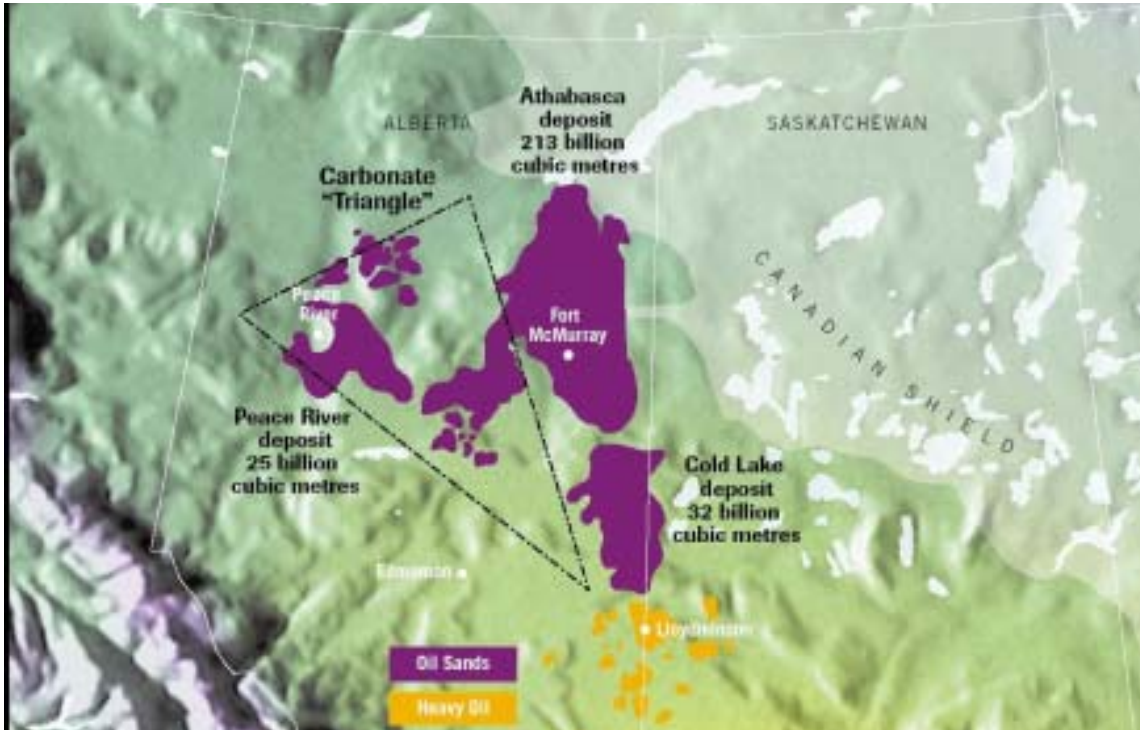


Location	Billion Barrels	Reference
Canada	178.31	
Alberta	*175.60*	EUB
Others	*2.71*	CAPP
U.S.A.	22.45	EIA
Mexico	12.62	OGJ
TOTAL North America	213.40	

References:
Alberta Energy and Utilities Board (EUB)
Canadian Association of Petroleum Producers (CAPP)
Oil & Gas Journal (OGJ)
U.S. Energy Information Administration (EIA)

Canada's Oil Sands Resources Stagger The Imagination

World's largest single hydrocarbon resource



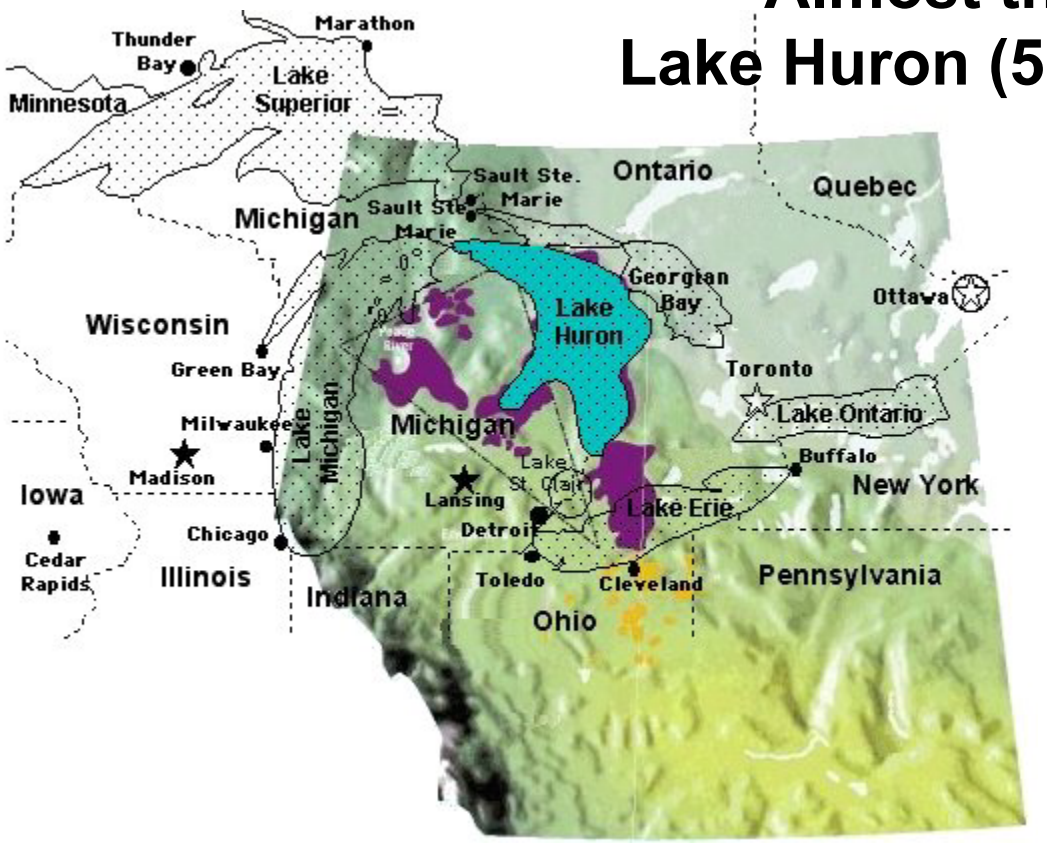
- 400 billion m^3 of bitumen (2.5 trillion barrels of oil) in Canada's oil sands
- 48 billion m^3 (300 billion barrels of oil) or 12 percent of the resource considered "recoverable" with today's technology

- Global oil demand for next 100 years could be met if all of Canada's bitumen could be recovered and refined

Data Source: *Canada's Oil Sands and Heavy Oil,* Petroleum Communication Foundation, April 2002 (originally from *Alberta Oil Sands Technology Research Authority*)

The Athabasca Oil Sands Deposit

Almost the Size of Lake Huron (58,880 sq. km.)



The world's largest "oil spill"!!!

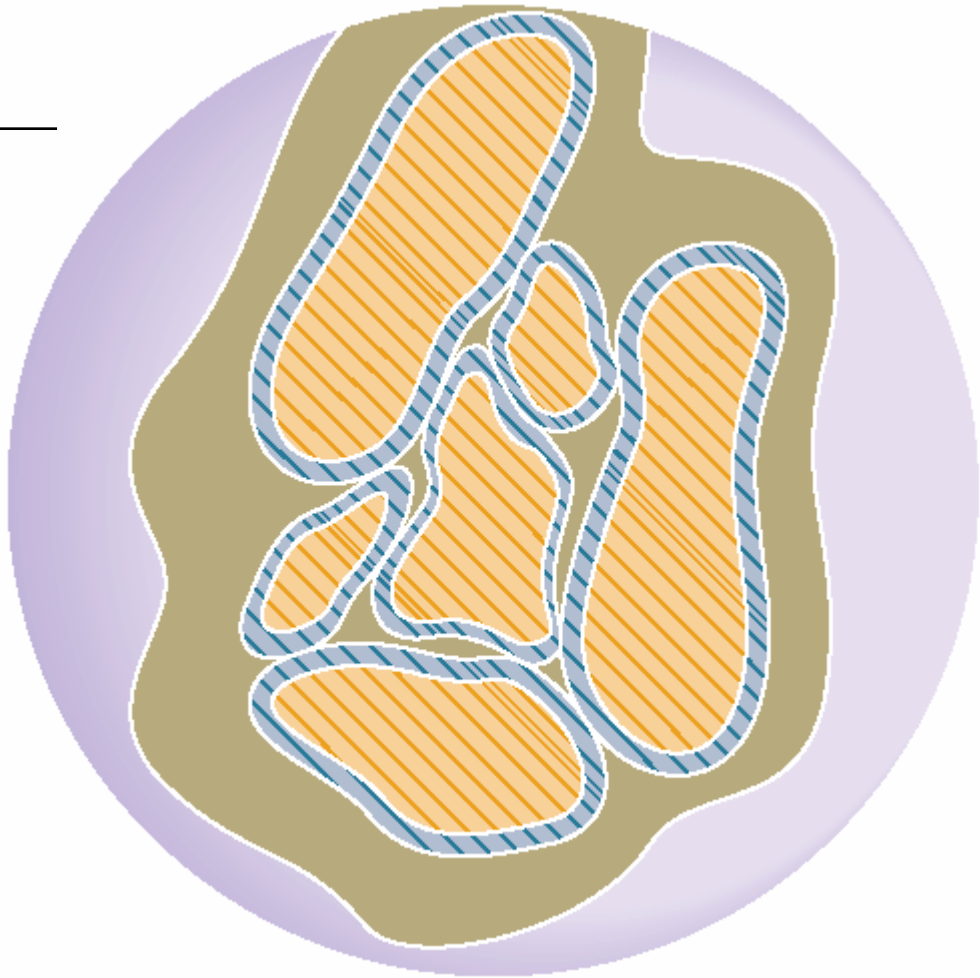
What Are Oil Sands?

Composition	
sand and clay	70 – 80 %
water	< 10 %
bitumen	0 - 18%

Water Layer

Sand particle

Bitumen film



Sources: "*Canada's Oil Sands and Heavy Oil,"* Petroleum Communication Foundation, April 2000.

What Is Bitumen?

- Has been described as ***hydrogen-deficient oil***.
- Composed of two major fractions
  - ~ 85 percent maltenes
  - ~ 15 percent asphaltenes
- Maltene fraction dissolves in “pentanes” (natural gas liquids)
- Asphaltene is insoluble in “pentanes”

What Is Bitumen?

- Bitumen contains extremely large hydrocarbon molecules
  - Diesel oil – $C_{20\text{-}30}H_{62}$
  - Bitumen – can be as high as $C_{2,000}$
- To be used, it needs to be upgraded
  - by "coking" (removing some of the carbon)
  - By "***hydrogenation***" or "***hydrocracking***" (***adding hydrogen***)

Bitumen from Oil Sands

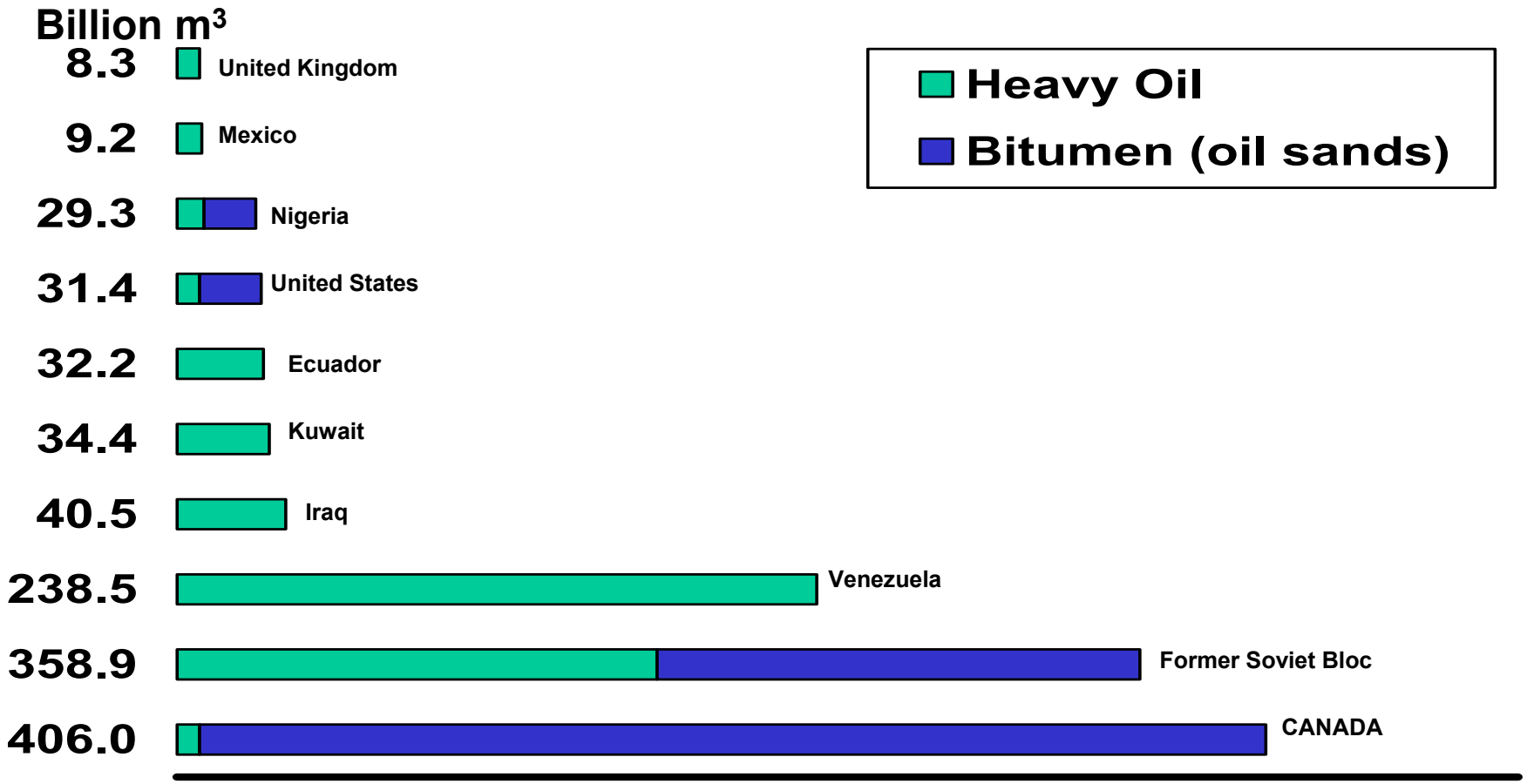
U.S. Definition

High viscosity

- 10,000 cP at reservoir conditions (water = 1.00 cP)
- must be “mined” to be produced

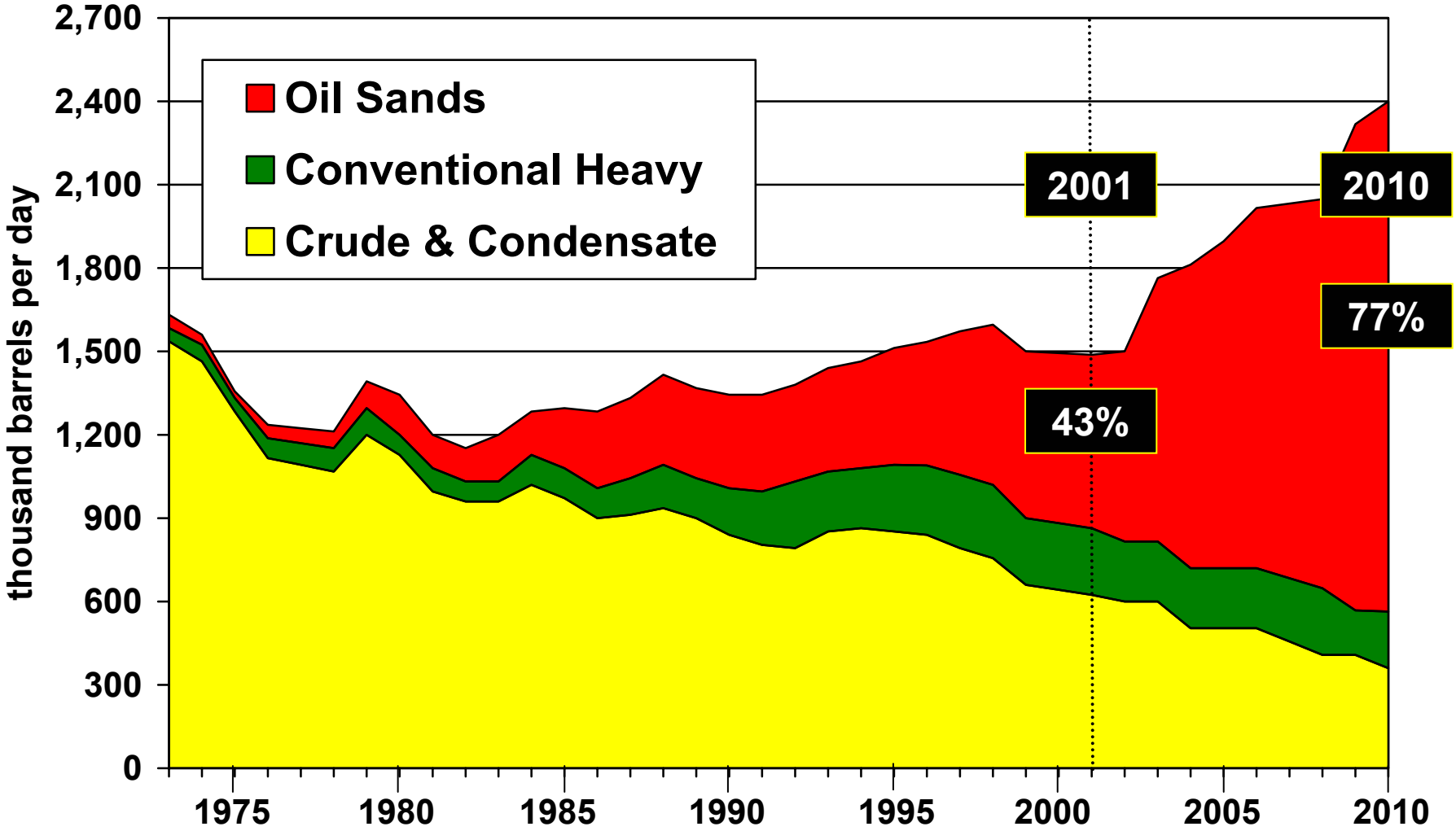
photo credit - Syncrude

World Heavy Oil and Bitumen Resources



Source: *Canada's Oil Sands and Heavy Oil*, Petroleum Communication Foundation
Original Source: *Alberta Oil Sands Technology Research Authority*
1 m3 (oil sands) ~ 6.8 barrels of bitumen

Trend of Oil Production in Alberta, Canada



Source: "*Focus on Canadian Oil Sands,*" Non Conventional Oil Conference, Nov. 25, 2002

Companies Involved in Alberta's Oil Sands In-Situ Projects

2000 (Can$17B invested to date)

- Imperial
- AEC
- CNRL
- Shell
- PanCdn
- Numac
- Northstar
- Murphy

2006 (Can$56B projects planned to be invested)

- Imperial
- Encana
- CNRL
- Shell
- Suncor
- PetroCanada
- Northstar
- Murphy
- JACOS
- Deer Creek
- OPTI
- BlackRock
- Conoco
- Husky
- TotalFINAElf

Not an all inclusive list

Source: *Focus on Canadian Oil Sands,* Alberta Department of Energy, presented at the IEA Non-Conventional Oil Conference, Nov. 25, 2002

What's Old? - $20 per barrel

Bucketwheel Loaders

Source: Syncrude.com

Draglines

Source: Syncrude.com

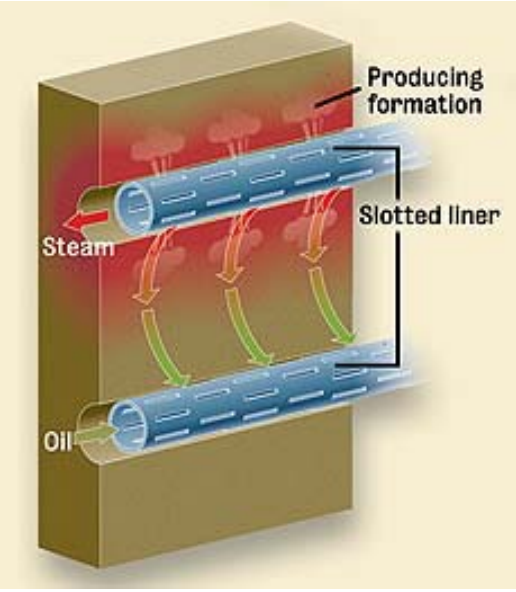
What's New? - $16 - $12 per barrel

Steam Shovels and 350-Ton Trucks

Source: Syncrude.com

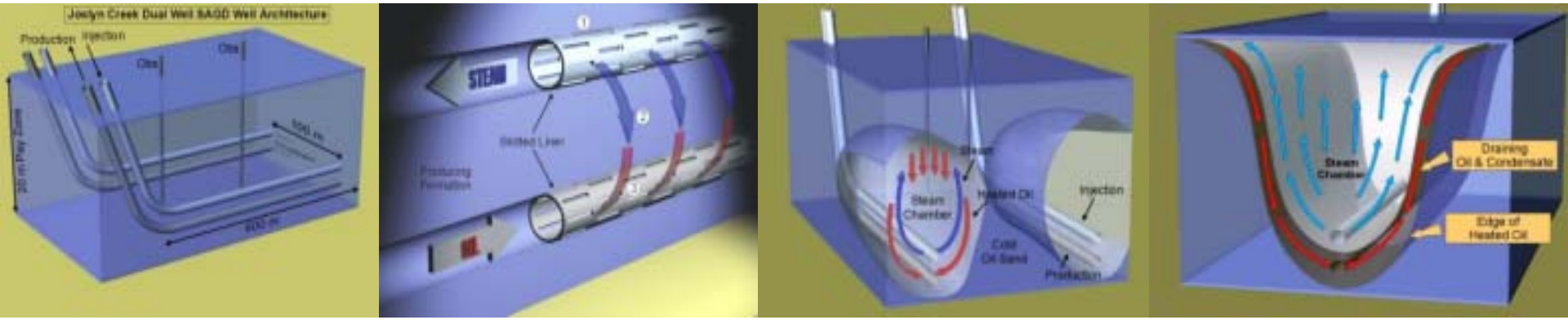
What's Newest? - $9 - $6 per barrel

Steam Assisted Gravity Drainage (SAGD)



Source: McGraw Hill Construction (enr.com)

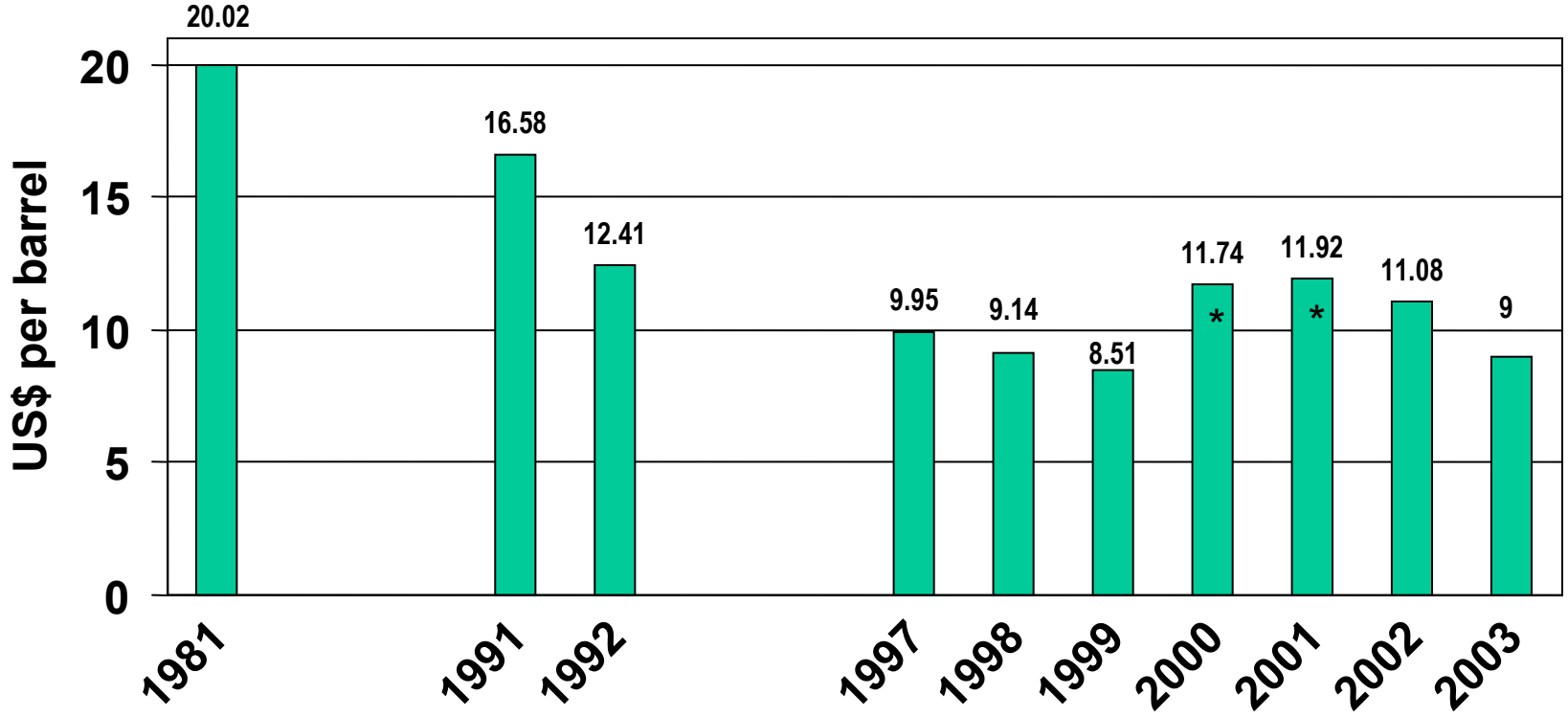
Source: Alberta Department of Energy (energy.gov.ab.ca)



Source: Deer Creek Energy (deercreekenergy.com)

Syncrude from Oil Sands Is Getting Cost-Competitive with Conventional Crude Oil

New Extraction Technologies and Virtually No Exploration Cost for Syncrude



* Major increase in cost due to lower than forecast production and much higher energy costs (natural gas).

Muskeg River Mine and Extraction Plant

Source: *Western Oil Sands*, Annual Report 2001.

Muskeg River Mine – Located on a 121-sq. km. area estimated to contain 1.7 billion barrels of bitumen reserves

Muskeg River Mine and Extraction Plant

Source: *Western Oil Sands*, Annual Report 2001.

Scotford Upgrader

Source: *Western Oil Sands*, Annual Report 2001.

Scotford Upgrader

Source: *Western Oil Sands*, Annual Report 2001.

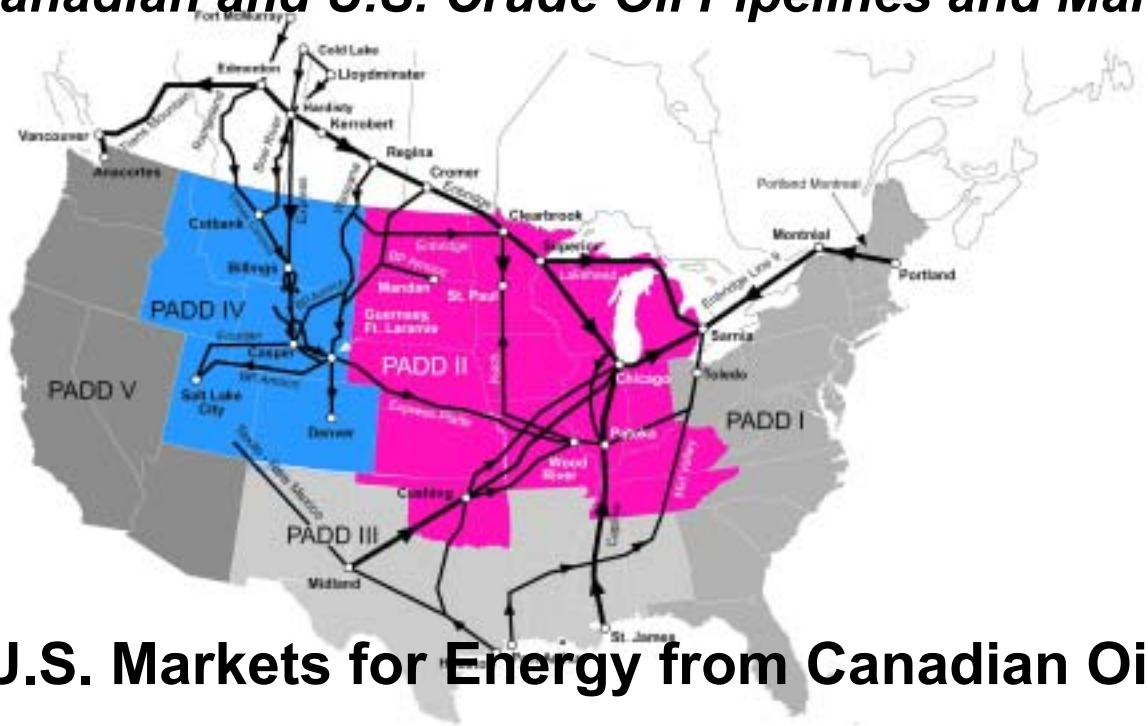
Scotford Upgrader

- Key design characteristic:
  - coupling of hydro-conversion and hydro-treating components of the light carbon fining upgrading technology.
- Other advantages
  - sharing of utilities and services between the upgrader and the adjacent refinery.

Source: *Western Oil Sands*, Annual Report 2001.

Infrastructure In Place for Closer Energy Integration

Major Canadian and U.S. Crude Oil Pipelines and Markets



Potential U.S. Markets for Energy from Canadian Oil Sands

- Additional trunkline expected to serve PADD*s II and IV based on estimated increased production of synthetic crude and bitumen over next 15 years.
- Additional market in PADD V (mainly WA) as ANS** supplies decline.

Source: *Canada's Oil Sands: A Supply and Market Outlook to 2012*, October 2000

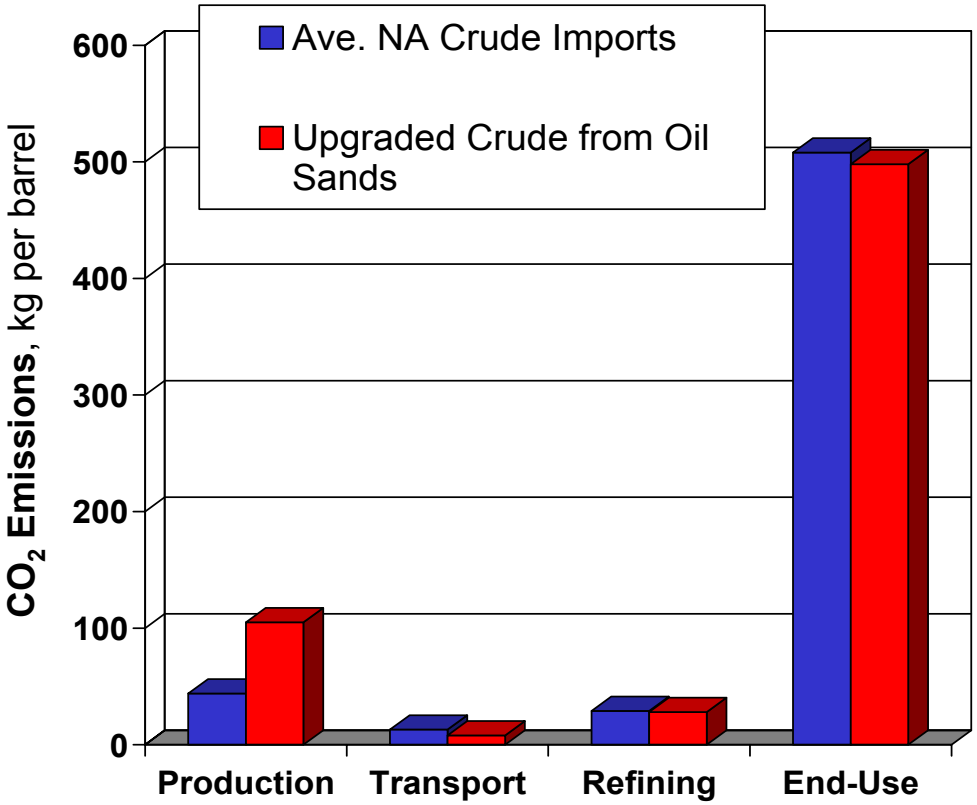
*Petroleum Administration for Defence Districts

**Alaska North Slope

Life-Cycle CO_2 Emissions

Conventional Process of Bitumen Production and Upgrading to Syncrude Using Natural Gas as the Hydrogen Source

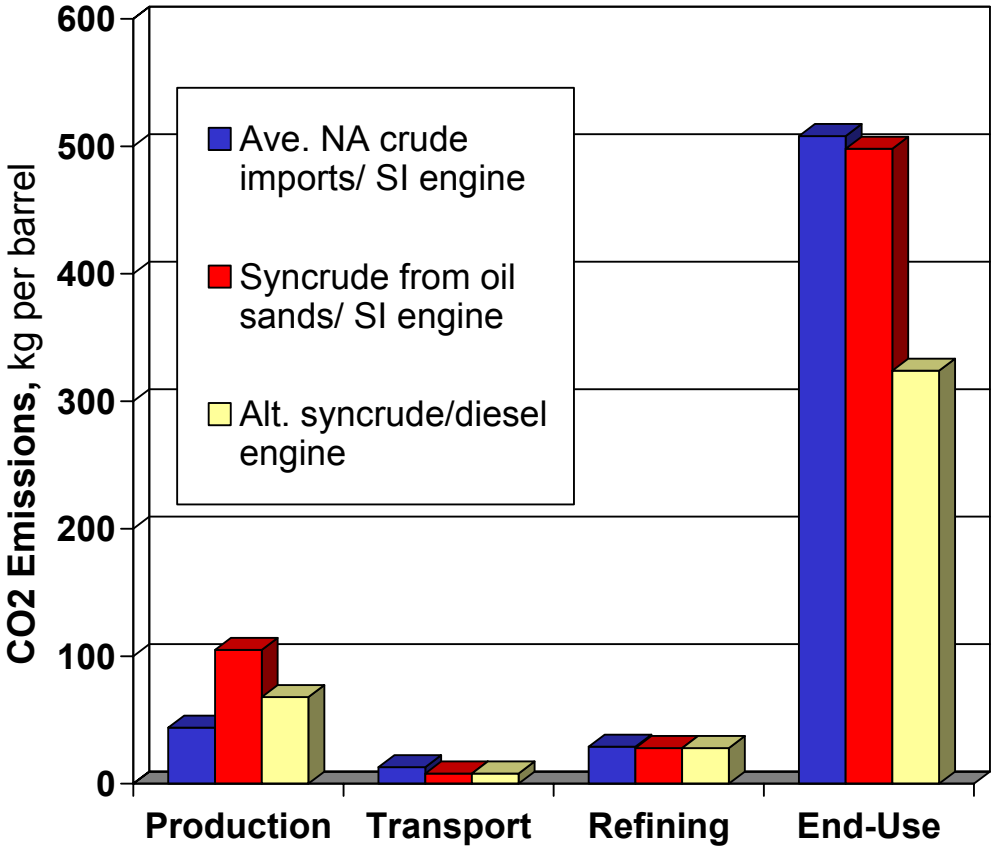
- Overall, total life-cycle CO_2 emissions, including end use (transportation sector), are 7.6% higher than average imported crude.
- This reinforces the importance of ***increasing end-use efficiency***.



Source: Petroleum Communication Foundation

Life-Cycle CO_2 Emissions – Alternative Scenario

- Alternatively:
  - 35% less GHG emissions compared to conventional process (using H_2 produced via electrolysis for upgrading of bitumen);
  - 35% less GHG using diesel engines in lieu of gasoline engines
- Overall, total life cycle GHG emissions, including consumption, are 28% lower than average imported crude.



Foundation for Transition to Hydrogen (?)

- Oil sands (bitumen) have been described as hydrogen-deficient petroleum.
- Bitumen requires hydrogen in substantial amounts (1,500 scf per barrel) to “upgrade” and remove sulfur compounds.
- As the oil sands are exploited in ever growing quantities, ***more hydrogen*** will be required to be generated and delivered, thereby stimulating the development of a hydrogen infrastructure.

Bottom Line:
Large quantities of hydrogen are needed to upgrade bitumen to syncrude.

Transition To A Hydrogen Economy

What Would It Take?

Estimated Electric Energy Need via Electrolysis/Hydrogen/Fuel Cell Route

2025 Scenario

Light-Duty Vehicle Energy Needs ~ 13.37 MMBOE per Day

Electricity to Produce Hydrogen for all Light-Duty Vehicles ~ 1,300 GW

Nearly 1,500 Additional GW Nuclear Plants (88% capacity factor)

OR 3.7 Million 1MW Windturbines (35% capacity factor)

**MMBOE – Million Barrels of Oil Equivalent; FC eff. = 2x ICE eff.*
Hydrogen Data Source: Eliasson, Baldur and Bossel, Ulf "The Future of the Hydrogen Economy: Bright or Bleak"

Transition to the Hydrogen Economy

Transportation Energy via Oil Sands Route

At 2MMBOE per Day Syncrude Production

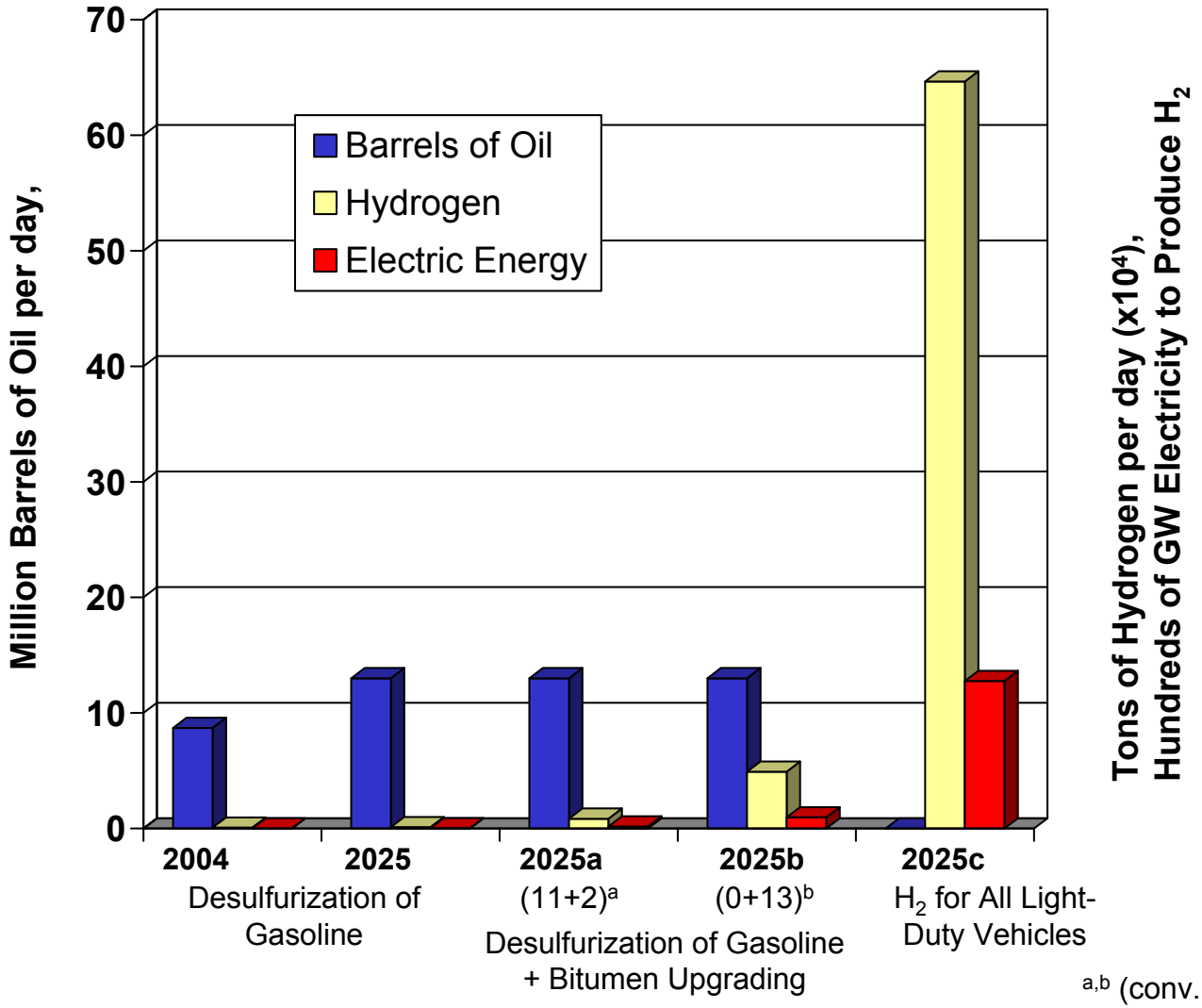
Electricity to produce Hydrogen for upgrading bitumen ~ 15.1 GW

Need about 17 GW Nuclear Plants (88% CF)

OR 43 Thousand 1MW Windturbines (35% CF)

**(Hydrogen for Upgrading ~ 1,500SCF per bbl bitumen)*

Transition to Hydrogen



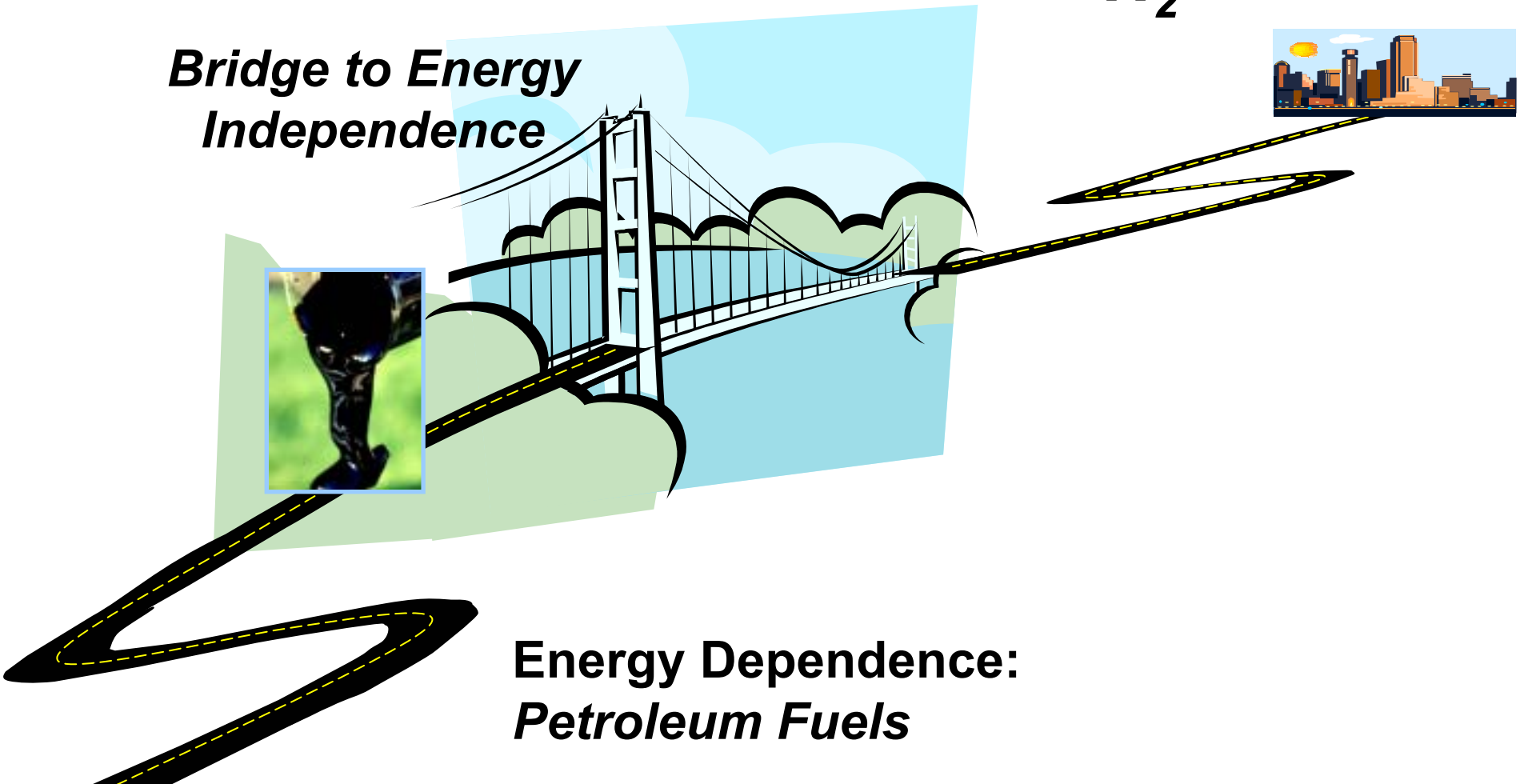
a,b (conv. crude+syncrude)

The Path To The Hydrogen Economy Will Likely Be the "Asphaltene Highway"

Energy Independence

H_2

Bridge to Energy Independence



Energy Dependence:
Petroleum Fuels

Summary

- The NEP supports improving energy efficiency as well as collaborating with North American countries for regional energy security.
- Hybridization and DI-dieselization promise to moderate the rate of increase in demand.
- Dieselization of the light truck fleet will have a significant impact on total U.S. fuel consumption.
- Engines operating in new combustion regimes promise even higher efficiency and lower emissions.
- There is a vast North American resource of new non-petroleum hydrocarbon fuels for combustion engines.
- The increasing hydrogen requirements for removing sulfur from petroleum fuels plus “upgrading” bitumen (oil sands) and heavy oils will serve to stimulate the development of a hydrogen infrastructure for transportation vehicles.