Future Vision -- Cars, Engines, Fuels, and Mobile Emissions

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

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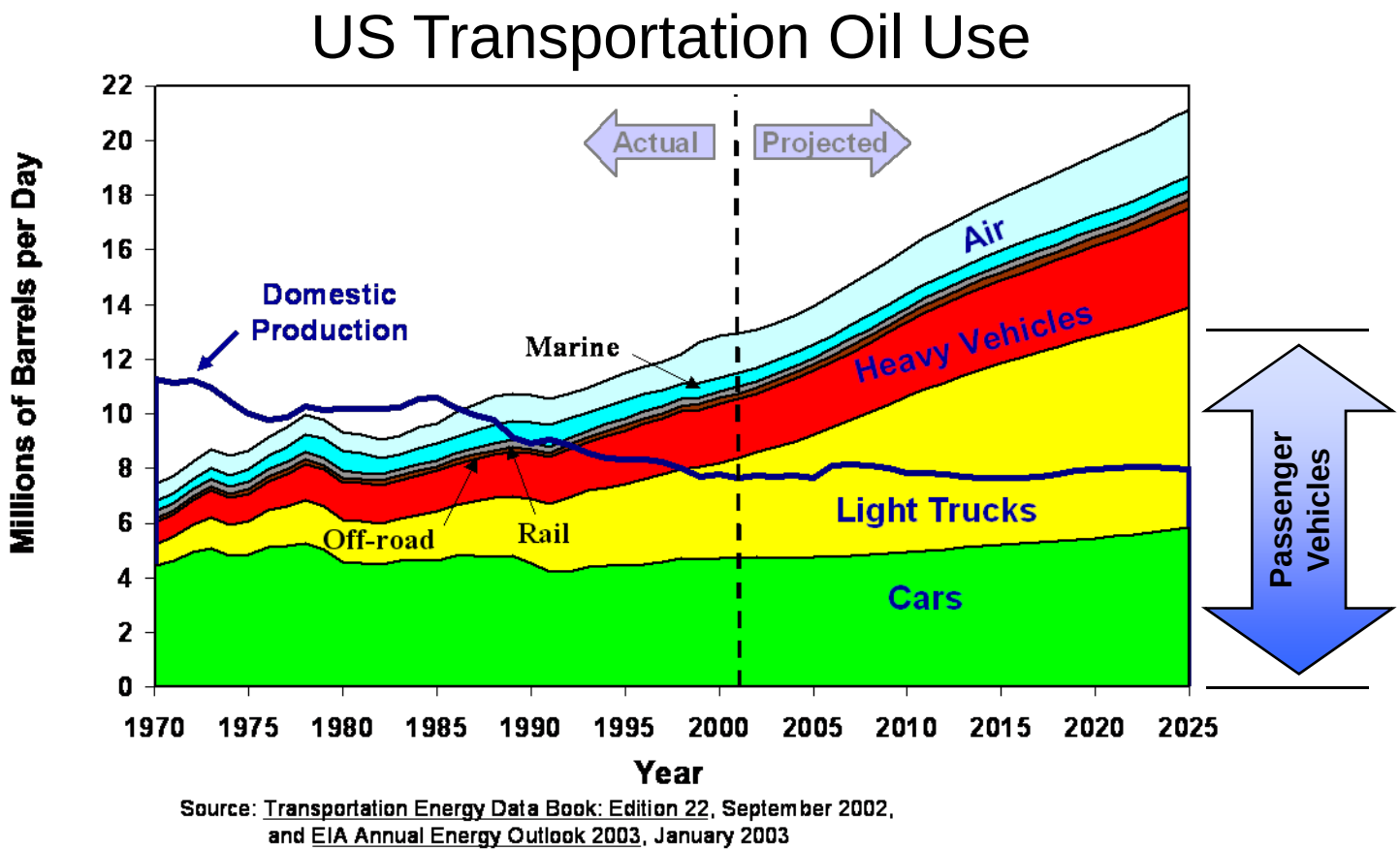
FCVT Program Mission

To develop more energy efficient and environmentally friendly highway transportation technologies that enable America to use less petroleum.
--EERE Strategic Plan, October 2002--

U.S. Energy Dependence is Driven By Transportation



Source: Transportation Energy Data Book: Edition 22, September 2002, and EIA Annual Energy Outlook 2003, January 2003

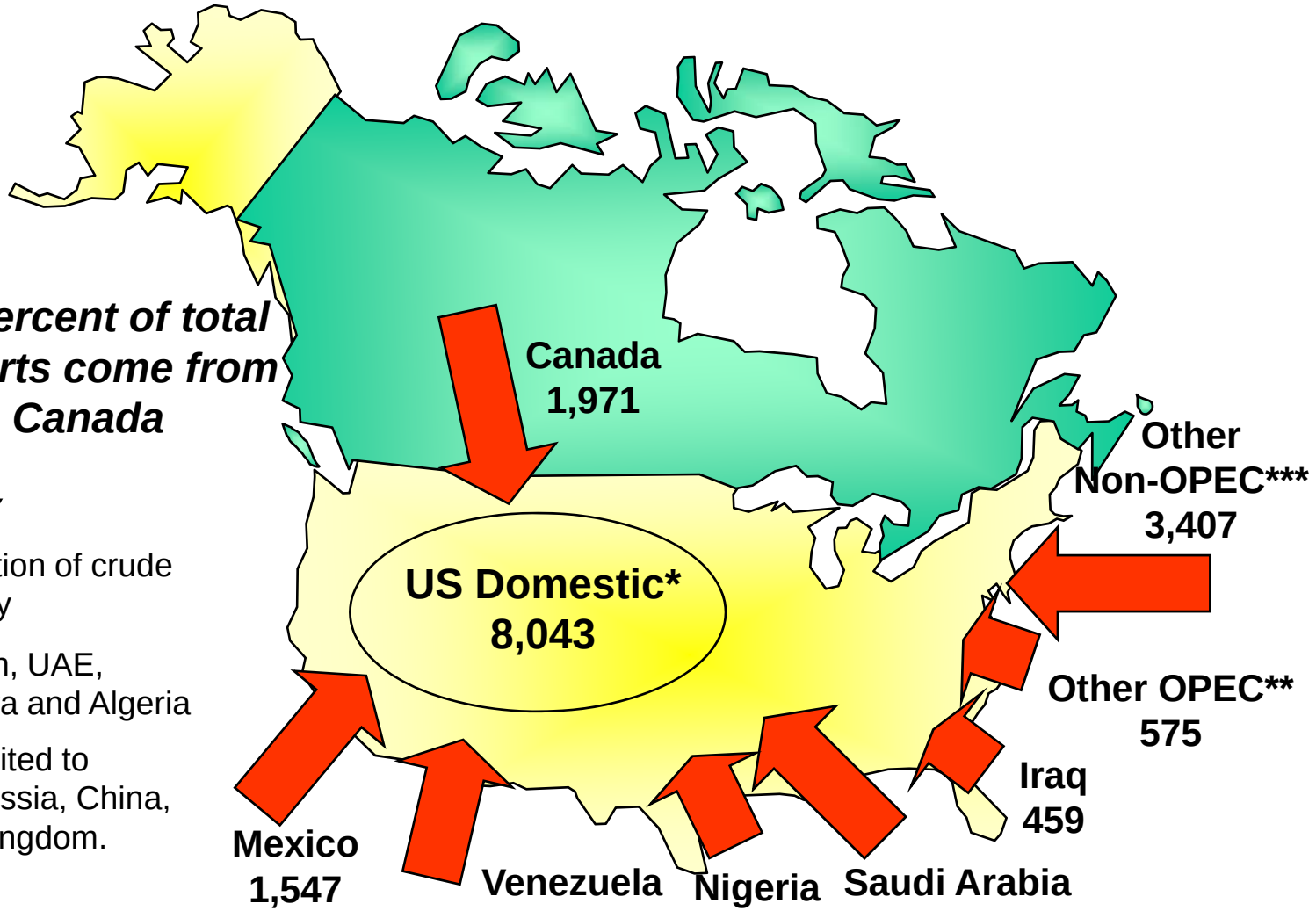
- Transportation accounts for 2/3 of the 20 million barrels of oil our nation uses each day.
- The U.S. imports 55% of its oil, expected to grow to 68% by 2025 under the status quo.
- Nearly all of our cars and trucks currently run on either gasoline or diesel fuel.

Energy Security Through Vehicle Technologies

The Ultimate Vision

Affordable, Full-Function Cars and Trucks
That are Less Dependent on Petroleum
and Free from Harmful Emissions
Without Sacrificing Mobility, Safety,
And Vehicle Choice

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



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

Cars of the Future

Near Term

Evolutionary

- Internal Combustion Engines/Hydrocarbon Fuels

Long Term

Revolutionary

- Hybrid Technologies
- Fuel Cells/Hydrogen
- Other?

Future Vision – Cars, Engines, Fuels, and Mobile Emissions

Near Term (next 10 years):

- Evolutionary Technology Vehicles
  - Limited lightweight materials substitution
  - Combustion engines utilizing hydrocarbon fuels
    - Lean combustion with improved catalytic aftertreatment
    - Variable valve timing
    - Variable compression ratio
    - “Cylinders-on-Demand”
  - Engine auxiliary electrification (e.g., water/fuel pumps)
  - Auxiliary load electrification (HVAC)
  - Auxiliary load reduction (insulation, window coatings)
  - Aerodynamics/rolling resistance reduction

Future Vision – Cars, Engines, Fuels, and Mobile Emissions

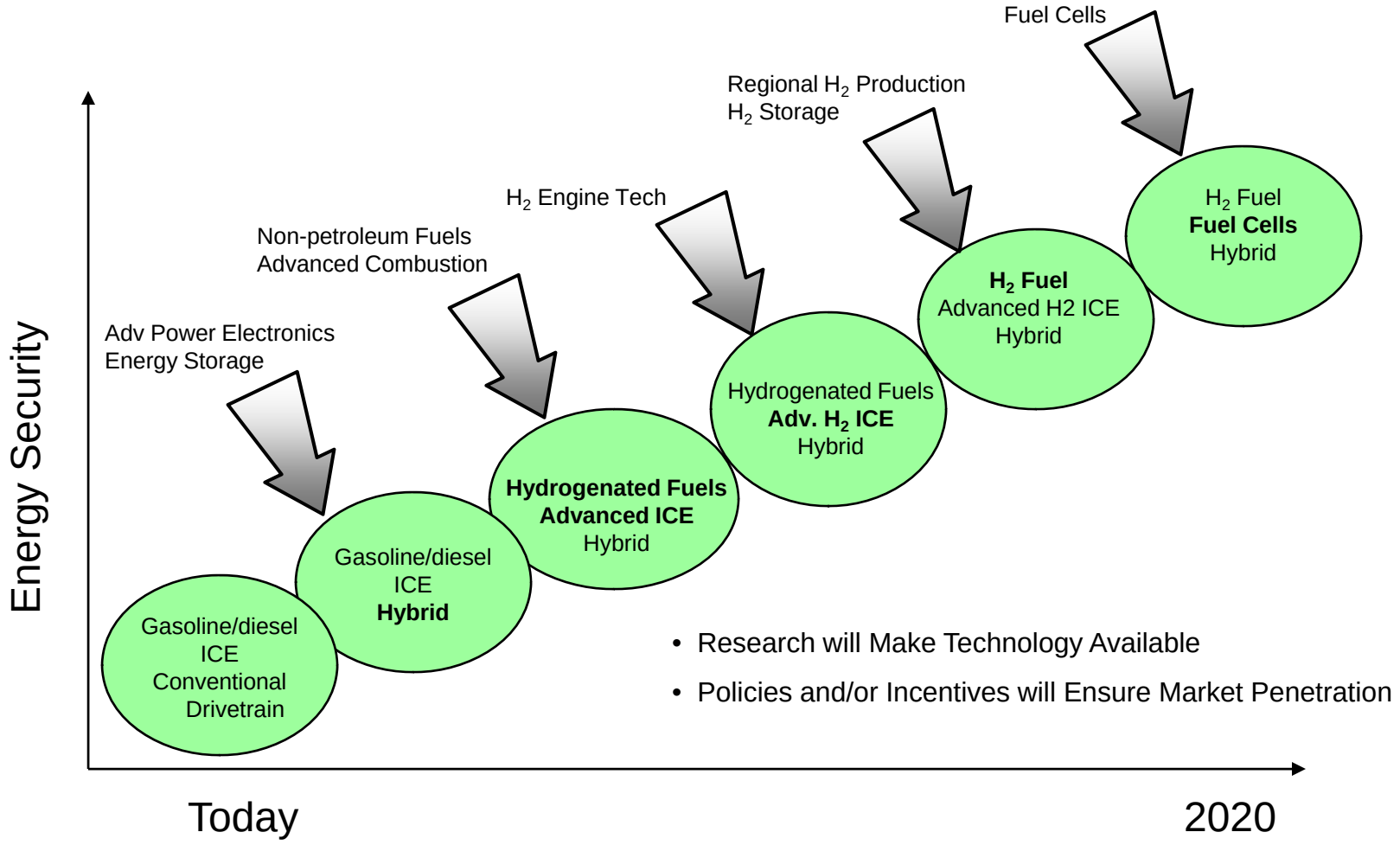
Intermediate to Long Term (2010 – 2025):

- Revolutionary Technology Vehicles
  - Lightweight materials gradually displace steel
  - Combustion engine hybrids
    - HCCI/LTC engines utilizing hydrocarbon fuels
  - Fuel cell hybrids enter the market
    - On-board H_2 storage – limited range vehicles early entry
    - On-board reforming of hydrocarbon or other liquid H_2-carrier – fully competitive vehicles

FreedomCAR's "Freedoms"

- Freedom from foreign petroleum dependence
- Freedom from pollutant and carbon dioxide emissions
- Freedom for Americans to drive where they want, when they want, in the vehicle of their choice
- Freedom to obtain fuel affordably and conveniently

FreedomCAR Pathway to Fuel Cell Vehicles and Hydrogen Economy



- Research will Make Technology Available
- Policies and/or Incentives will Ensure Market Penetration

Energy Sources

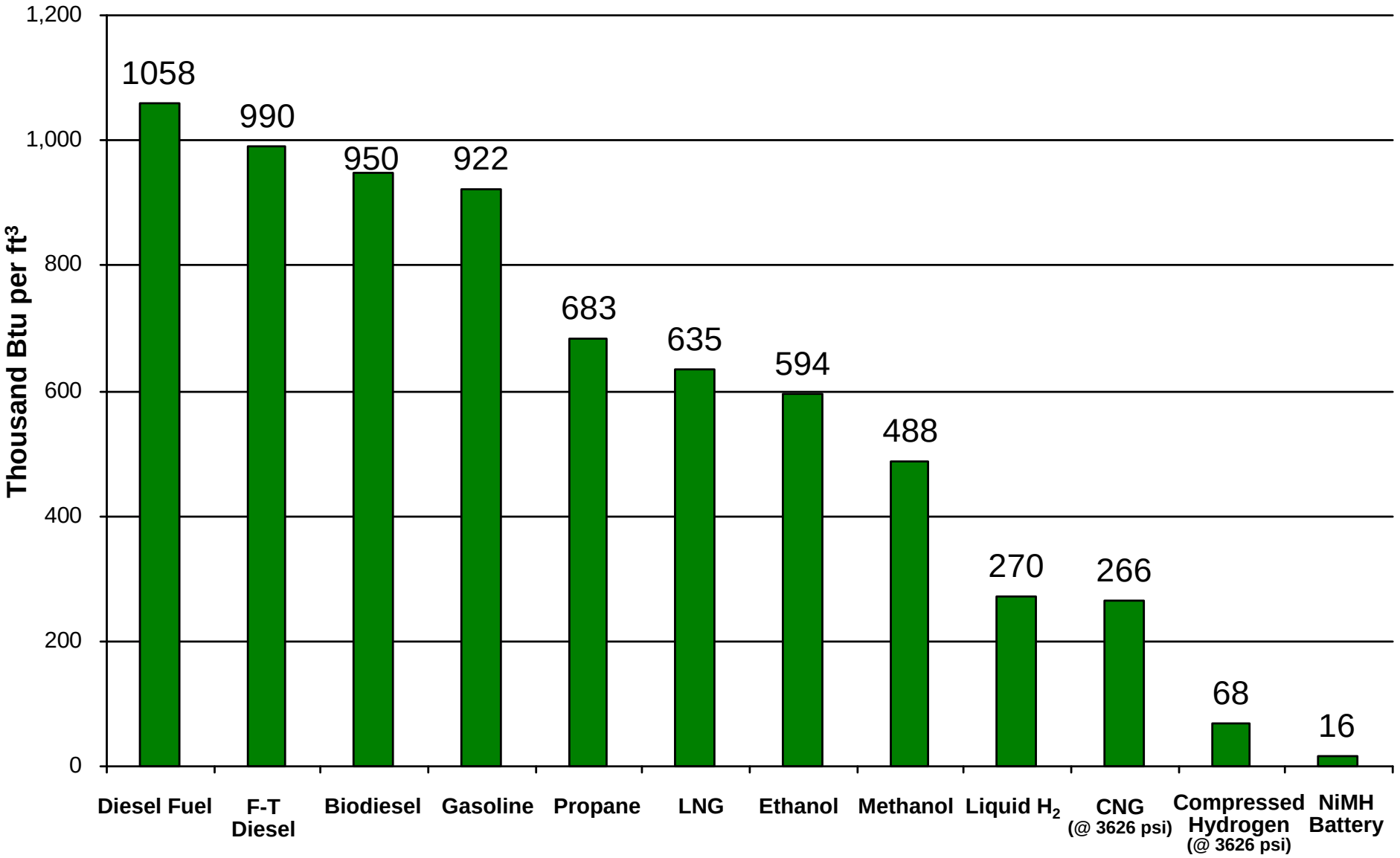
Fuels

- ***Hydrocarbons***
  - Coal
  - Natural Gas
  - Petroleum/heavy oils
  - Bitumen (oil sands)
  - Kerogen (shale oil)

Energy Carriers

- ***Electricity***
- ***Hydrogen***
- ***Chemicals (e.g., NH_3)***

Energy Density of Fuels



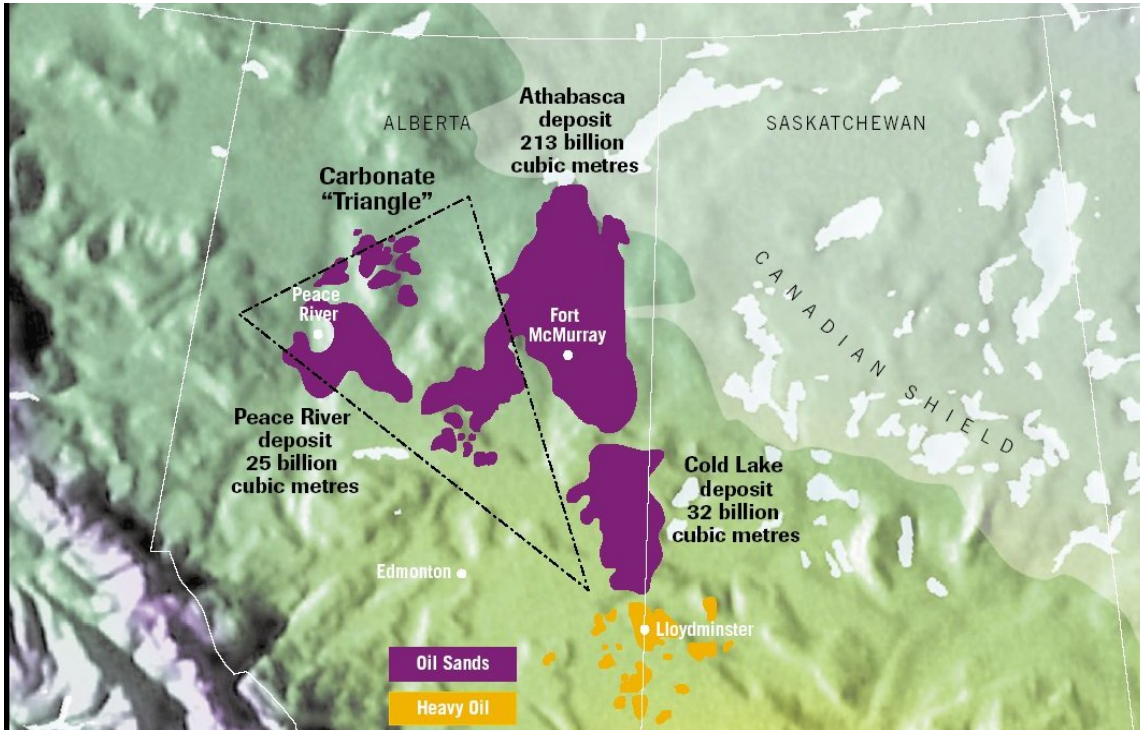
Oil Sands and U.S. Energy Security

"There is some very good news in our hemisphere, at least as far as Americans are concerned, and that is, that because of technologies – the Canadians have developed vast crude-oil resources … in what they call tar pits … That's good for our national security; it's good for our economy." – President George W. Bush, during a visit to Quebec in 2001.

Source: "Asleep at the Switch: Why America (But Not Canada) Failed to Set Up A Needed Synfuels Industry," *Time*, October 13, 2003, pp. 68-70.

Canada's Oil Sands Resources Stagger The Imagination

World's largest single hydrocarbon resource



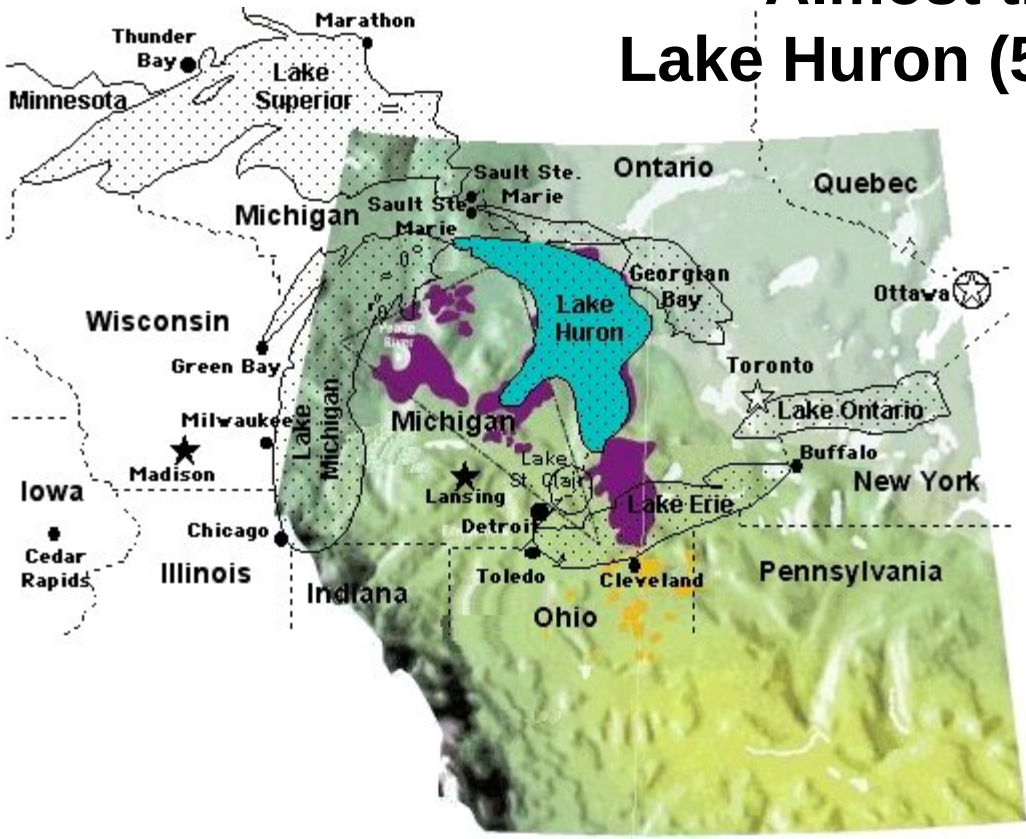
- 400 billion m^3 of bitumen (2.5 trillion barrels of oil) in Canada's oil sands
- 48 billion m^3 (300 billion barrels of oil) or 12 percent of the resource considered "recoverable" with today's technology

- 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"!!!

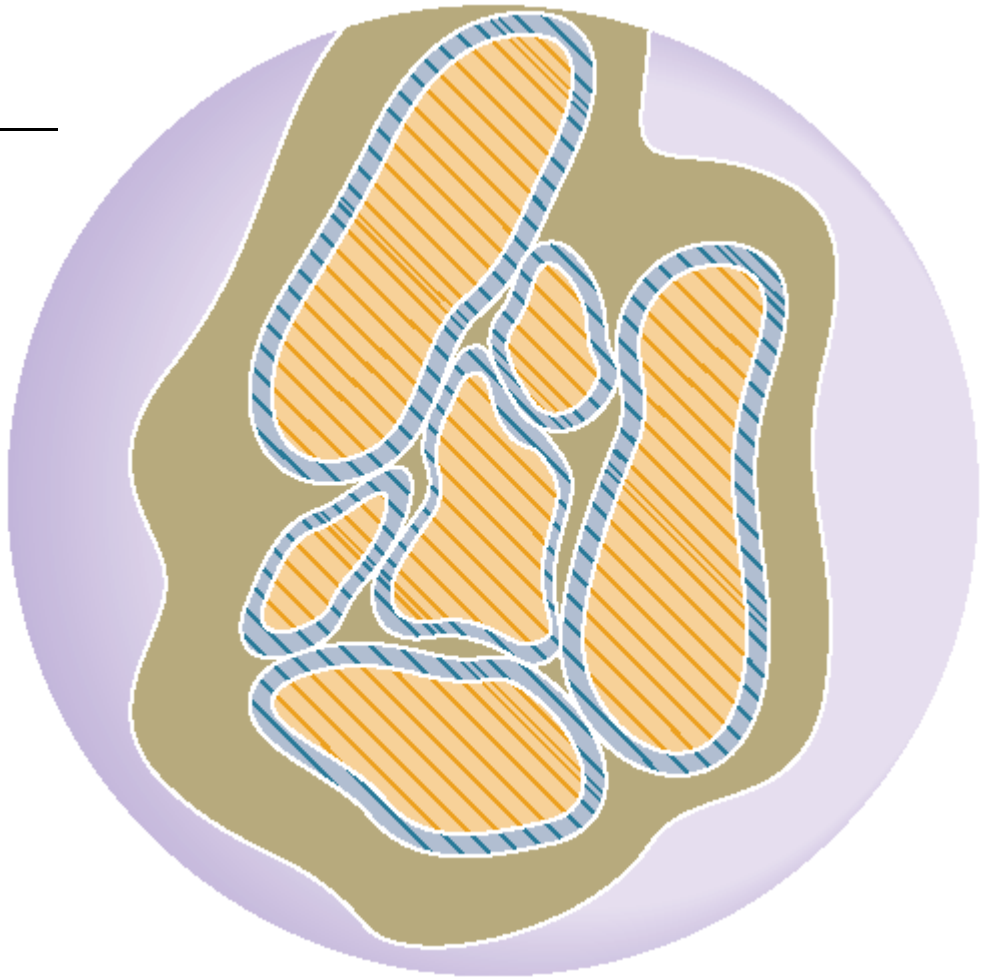
What Are Oil Sands?

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.

Bitumen from Oil Sands

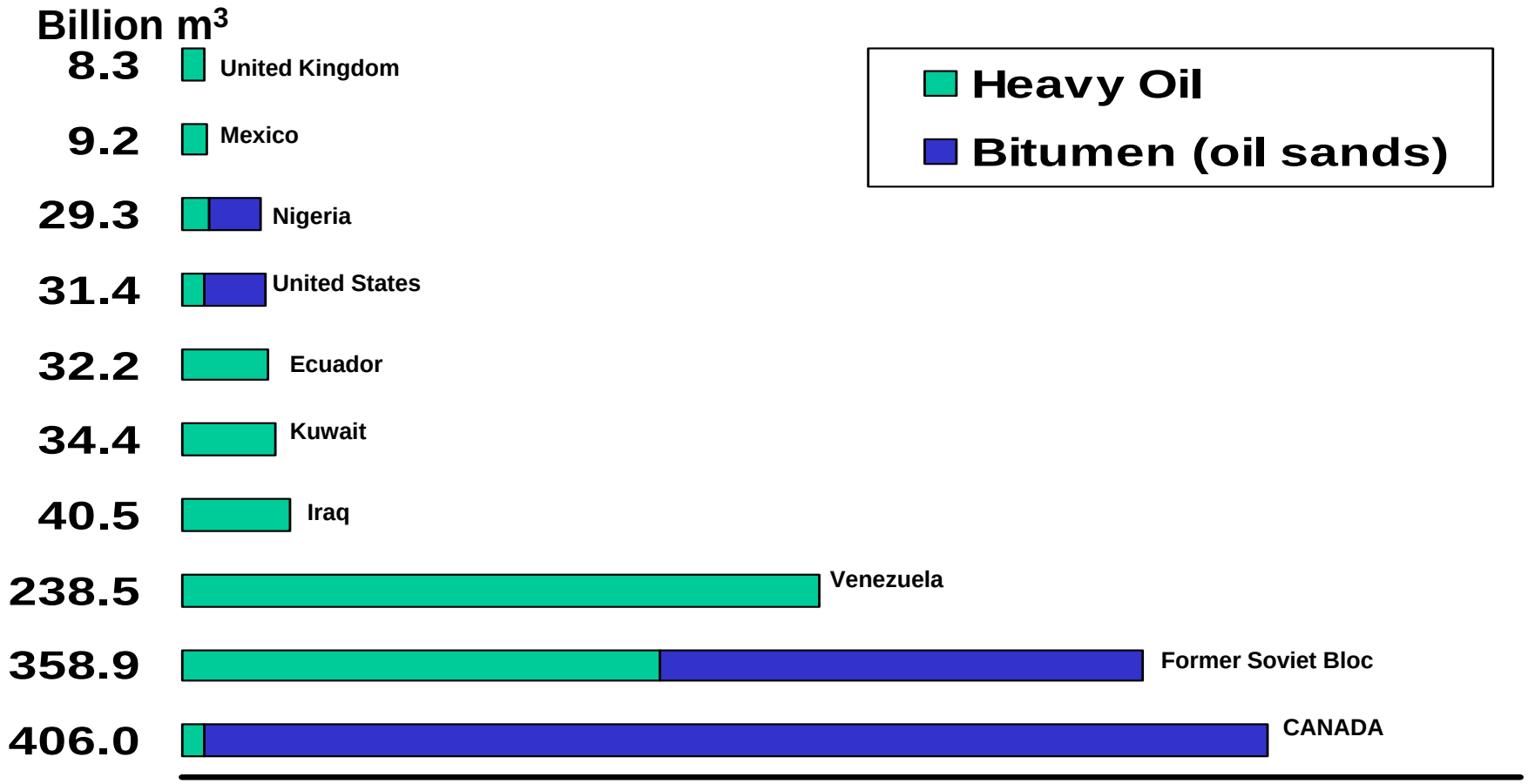
U.S. Definition

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



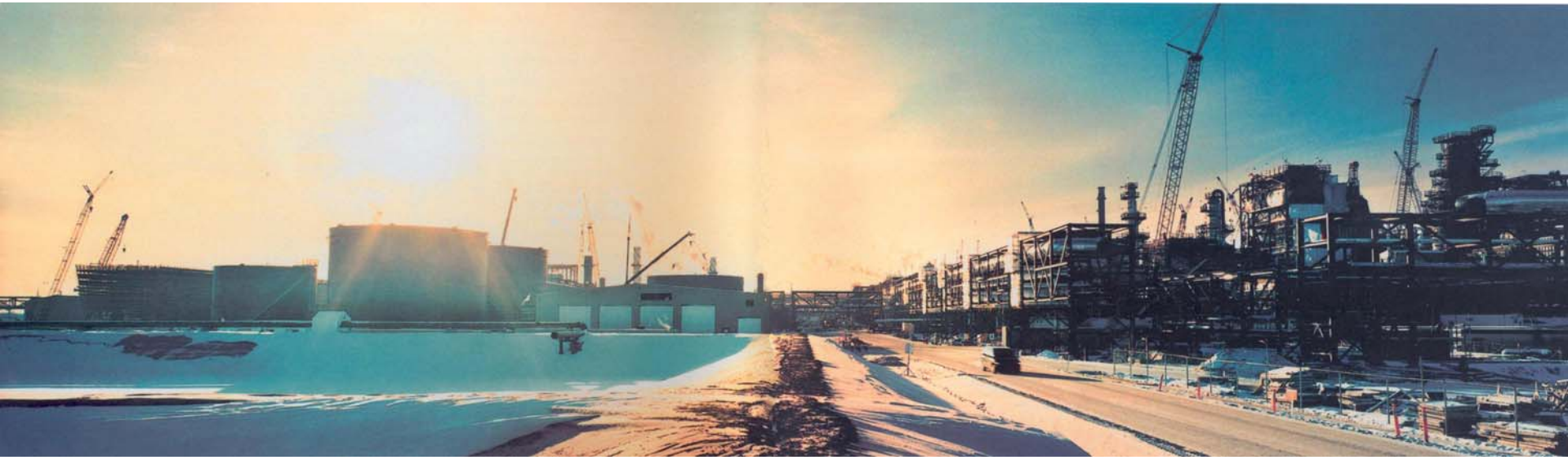
Source: *Canada's Oil Sands and Heavy Oil*, Petroleum Communication Foundation
Original Source: *Alberta Oil Sands Technology Research Authority*
1 m3 (oil sands) ~ 6.8 barrels of bitumen

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

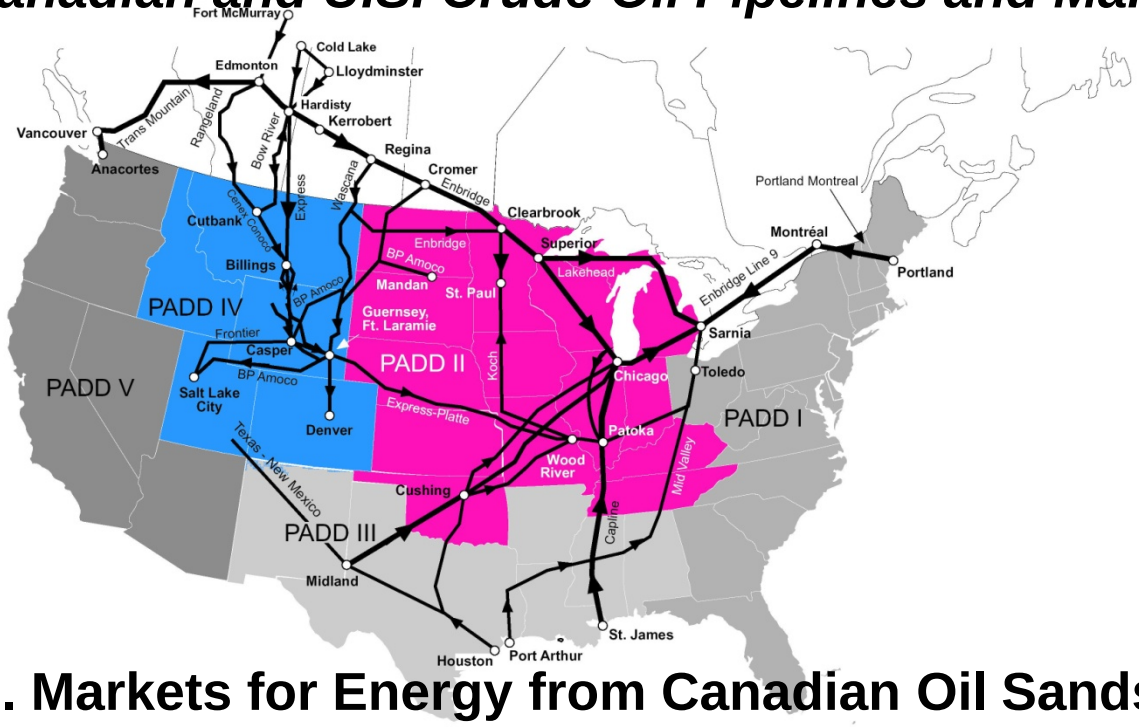
Scotford Upgrader



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

Transition To A Hydrogen Economy

What Would It Take?

Transition to Hydrogen Economy

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"

Large quantities (1,500 scf/barrel) of hydrogen are needed to upgrade bitumen to syncrude.

Transportation Energy via Oil Sands Route

At 2MMBOE per Day Syncrude Production

Electricity to produce Hydrogen
for upgrading bitumen ~ 15.1 GW

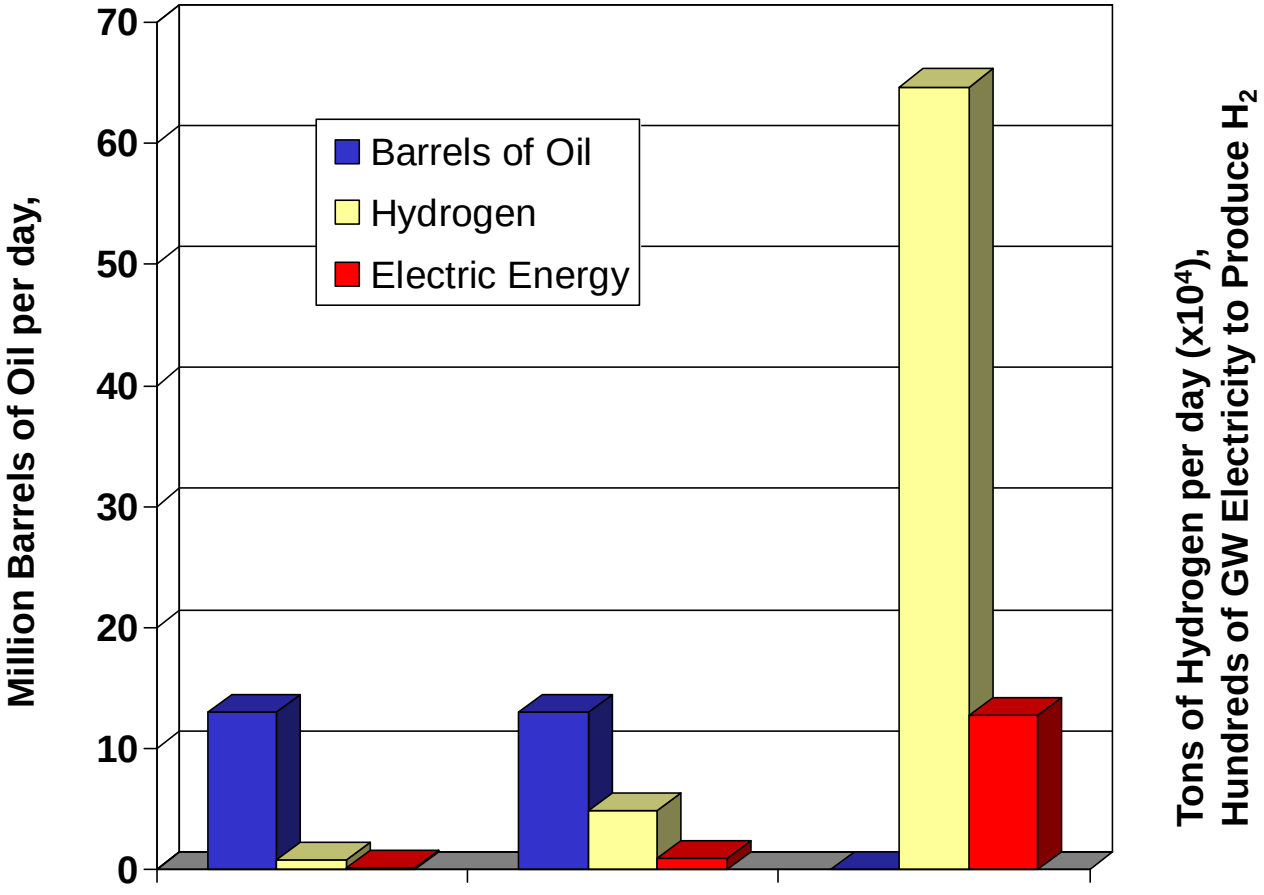
Need about 17 GW Nuclear Plants (88% capacity factor)

OR 43 Thousand 1MW Windturbines (35% capacity factor)

A likely alternative pathway to the required H_2 is gasification of asphaltenes from the bitumen with CO_2 sequestration.

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

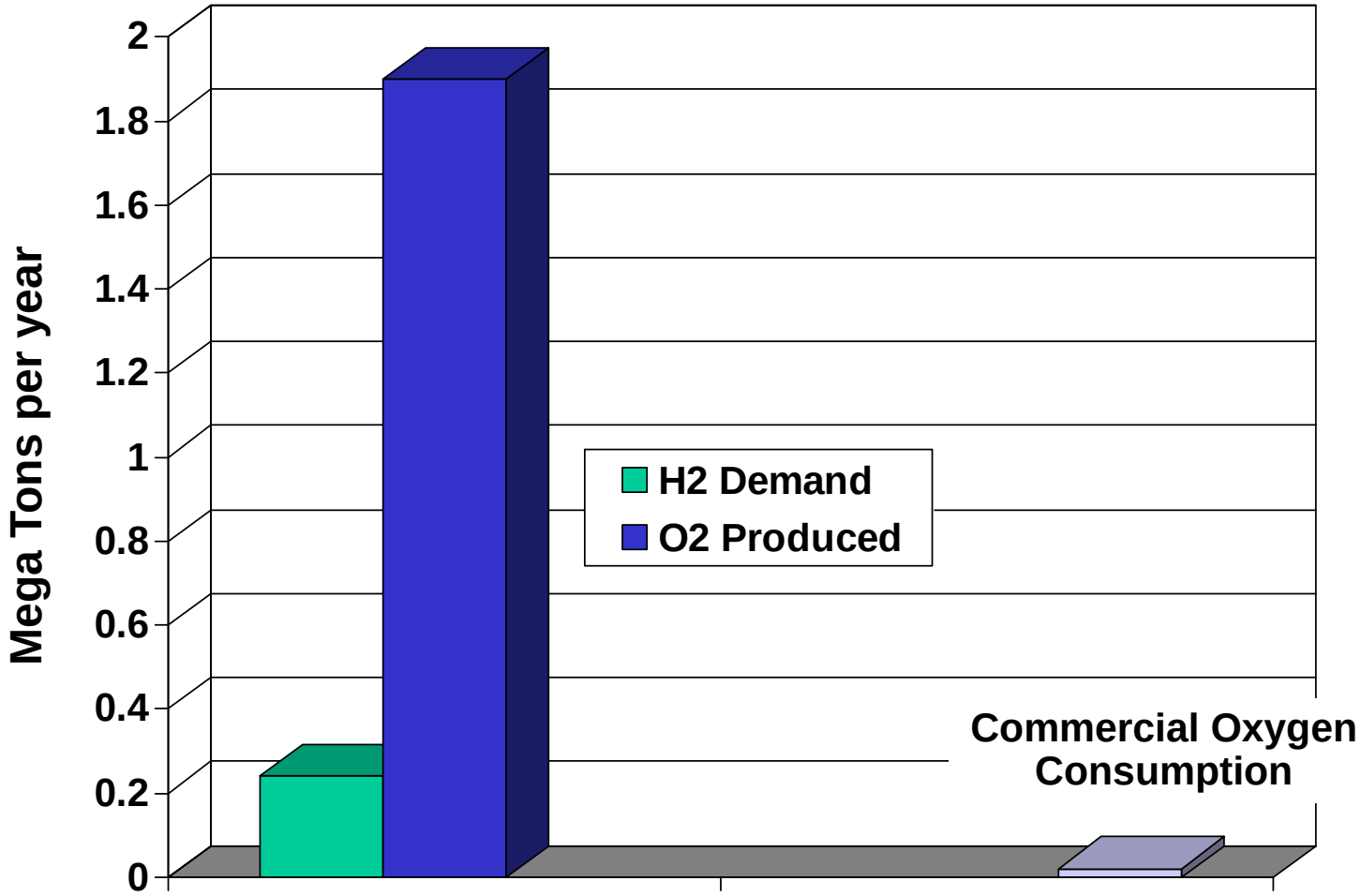
Transition to Hydrogen



[a,b] (conv. crude+syncrude)

Potential Environmental Problem

O_2 Co-Produced with H_2 (via Electrolysis) for Future LD Vehicles Far Exceeds Commercial O_2 Demand



Summary

Cars of the Future

Near Term (Next 10 years):

- Evolutionary Technology Vehicles will dominate the market.

Intermediate to Long Term (2010 – 2025):

- Revolutionary Technology Vehicles will gradually overtake and dominate the future light-duty vehicle market.