

AFTER PEAK OIL

**Beyond the Peak in World Oil Production
What are the Implications for Us?
What Can We Do?**

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**J.S. Wood Library
Saskatoon, Saskatchewan
June 11th, 2008**

**Saskatchewan Research Council
June 12th, 2008**

WHAT IS PEAK OIL?

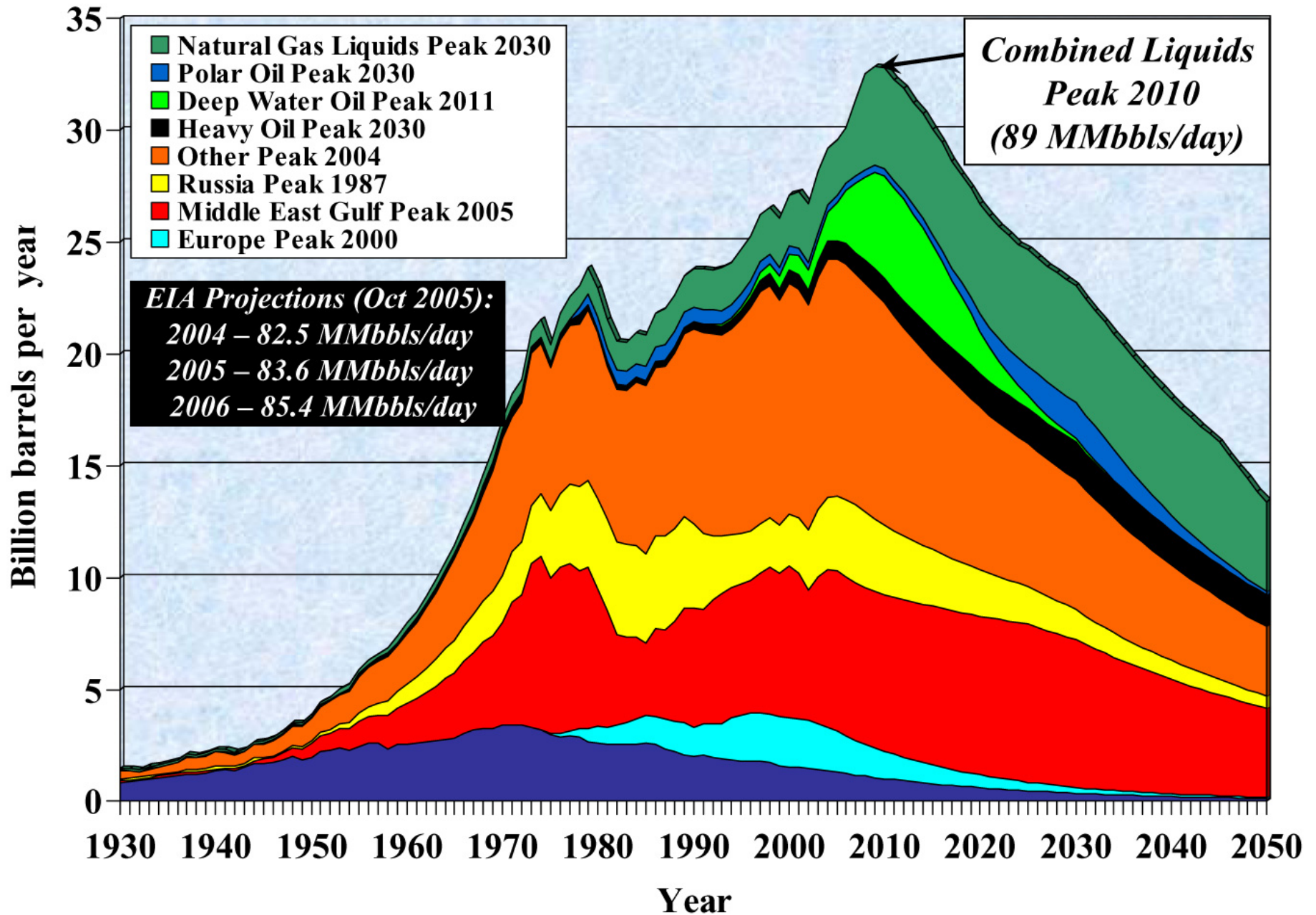
- Refers to the year that the total world oil production reaches its highest point and starts to decline
- Oil is 37% of all the energy used in the world
- Almost all the energy used in transportation

- **The peak in world oil production may be approaching rapidly.**

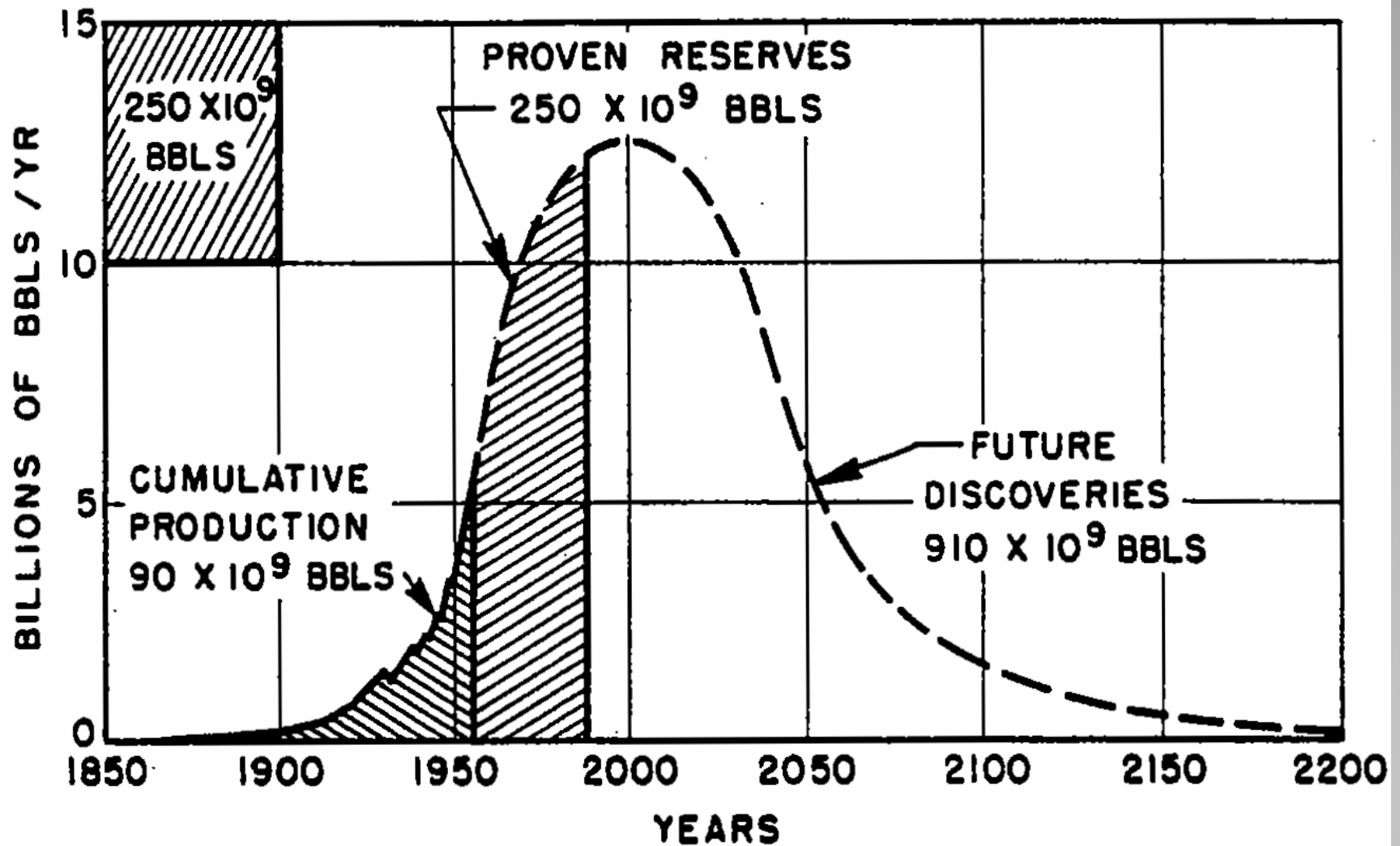
Editor of Petroleum Review (2005):

“Time is short and we are not even at the point where we admit we have a problem... The problem is the peak, which I think is 2008, is tomorrow in planning terms.”

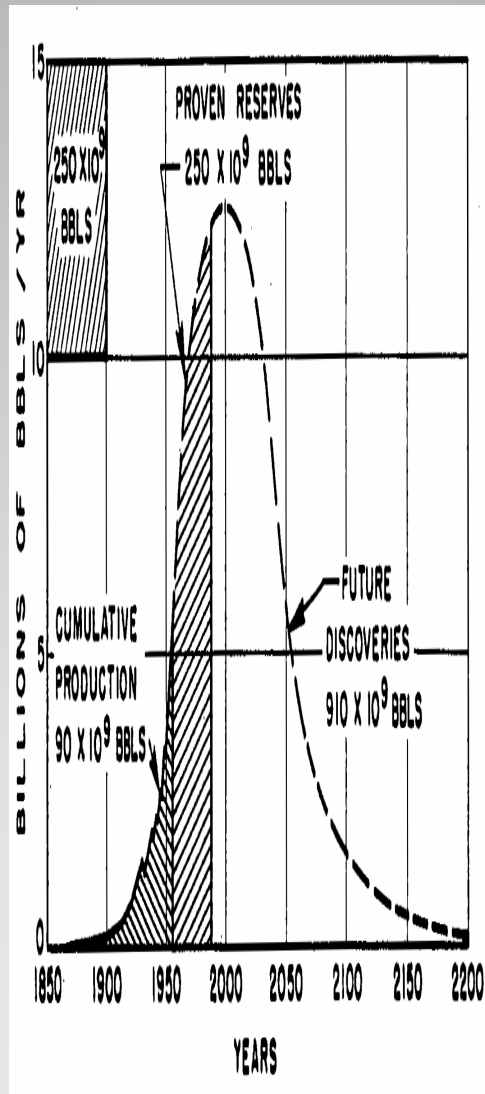
Campell's 2006 Hydrocarbon Liquids Production and Forecast 1930-2050



(C.J.Campbell, personal communication, September, 2006)



**1955 Prediction of World Peak Oil
by M. King Hubbert, Geologist at Shell Oil**



Hubbert's Pimple, or The Age of Petroleum

When is the estimated peak in world oil production?

**Based on four recent calculations:
2010 to 2015 including oil sands**

Reviewed by Hughes, 2006, 2008

Already seeing a big increase in crude oil prices

The United States Department of Energy disagrees:

Calculated a peak year for conventional oil = 2044 (optimistic about enhanced recovery)

For all oil, including massive development of Canadian oil sands and Orinoco (Venezuela) extra-heavy oil, peak year = 2065

Caruso, USDOE, 2005

This massive development of the Canadian oil sands (41 billion barrels/year in 2078) and Orinoco heavy oil, plus remaining production of conventional crude oil (enhanced recovery) =

**World total oil production
= 71 billion barrels per year, in 2065**

**Present production
= 31 billion barrels per year**

Caruso, USDOE, 2005

At 71 billion barrels per year:

**Greenhouse gas emissions:
Likely exceed amount of GHGs allowable for
all world activities in 2065 to avoid
dangerous global warming**

Accelerating demand for oil:

- **90% of the oil consumed by the human race has occurred since 1958**
- **50% of the oil consumed by the human race has occurred since 1984**

- **World production now is about 85 million barrels per day (WorldOil.com) or 31 billion barrels per year.**
- **OPEC provides 42% of production**
- **Russia provides 14% of production**
- **Rest of the world provides 44% of production**
- **Canadian production is about 3.3 million barrels/day or 1.2 billion bbl/year**

**J. David Hughes, Geological Survey of Canada, 2006
and WorldOil.com, 2008**

Where is the remaining oil?

Conventional oil: about 1 trillion barrels left

- **OPEC = 75.2%**
- **Russia and other members of the former Soviet Union = 10.2%**
- **Rest of the world = 14.6%**

Oil sands (Canada)

- **2.37 trillion barrels in-place**
- **1.42 trillion barrels recoverable**

Orinoco extra-heavy oil (Venezuela)

- **1.36 trillion barrels in-place**

Caruso, EIA, USDOE, 2005

Crash Program for Oil Sands Development:

- **Might produce 6 million barrels per day by 2038 (2.2 billion barrels/year)**
- **Has only a small effect on when peak oil occurs**
- **Loss in conventional oil production around the world much larger than increase in oil sands production**

Soderbergh, Robelius and Aleklett, 2006

- **Increase in oil sands production would have big negative environmental effects.**

Energy return on energy investment (EROEI)

- **Poorer for oil sands than heavy oil which is**
- **Poorer than conventional oil**

Other issues affect how much can be produced and how quickly:

- **natural gas supply for process heat and hydrogen**
- **water supply**
- **diluents to move viscous oil through pipelines**
- **capital availability**

Hughes, 2006, 2008

Other uses for oil:

World uses for crude oil (2004 data):

Transportation = 59% of oil

Gasoline 25%, 7.6 billion barrels/yr

Diesel fuel 27%, 8.2 billion barrels/yr

Jet fuel 6%, 1.8 billion barrels/yr

Heating (fuel oil) = 12%

Industrial products and asphalt = 17%

Canadian consumption of crude oil products (2005 data)

**Crude oil sent to refineries: 107 billion litres
(673 million barrels)**

Gasoline = 40.8 billion litres (36.1%)

Diesel fuel = 26.6 billion litres (23.5%)

Jet fuel = 6.8 billion litres (6.1%)

Industrial products = 10.7 billion litres (9.5%)

**Main industrial uses = petrochemical
feedstocks, asphalt and lubricating oils**

(Statistics Canada, 2005)

WHAT ABOUT NATURAL GAS?

World production estimate:

Campbell predicts:

- Conventional natural gas plateaus in 2025 - 2045
- Unconventional gas peaks in 2045

Campbell, quoted in Hughes, 2006

Canada:

**Natural gas peak, including coal bed methane
= about 2010 to 2015**

National Energy Board, 2003, quoted by Hughes, 2006

**Liquified natural gas from Russia and the
Middle East needed to meet possible demand**

**Loss of North American nitrogen fertilizer
production facilities starting to happen**

What about gas hydrates?

- Methane trapped by high pressures and low temperatures in a cage of water molecules
- Exists deep below the surface in frozen ground in the Arctic and off shore in the world oceans
- Total world resource is more than all the world's oil, conventional natural gas and coal combined
- Hard to recover until recently

Recent discovery by Canadian and Japanese scientists working in the Mackenzie Delta

- **reducing the pressure on the hydrate allows**
- **release and recovery of the methane**
- **rate similar to coal bed methane recovery**
- **takes much less energy to recover methane than using heat (not practical)**

O'Brien, Canadian Press, April 17, 2008

Using microbes under ground (*in situ*) to convert heavy oil and unrecoverable oil (by conventional methods) to methane

- **Recent discovery by Newcastle University and University of Calgary** (Jones et al., Nature 2007)
- **Field trials to start in Western Canada soon**

- **Inject naturally occurring microorganisms and nutrients into depleted heavy oil formation**
- **May be able to recover methane within a year**
- **In future may be able to recover hydrogen instead of methane and leave all the fossil carbon underground**

Both these new methods to recover/produce natural gas (methane) still release GHGs during combustion, but

- **less than oil or coal per unit energy produced**
- **could be important bridging energy sources during the switch to renewables such as wind and solar**

Dallimore, Geological Survey of Canada, 2008

WHAT ARE THE IMPLICATIONS FOR US?

- **big rapid increase in the price of crude oil**
- **big rapid increase in the price of gasoline and diesel fuel**
- **increase in the price of food (need oil to produce food)**

- **Surge in production of first generation biofuels made from grains and oilseeds: negative effects on food supply and price**
- **Increased interest in making oil from coal or shale: would increase GHGs a lot**
- **Transportation industry starting to move towards electricity to provide energy (e.g., plug in hybrid cars and light trucks)**

Cost of fuel and fertilizer to grow food:

Farm diesel fuel prices:

- **1999 = 31.7 ¢/litre**
- **2007 = 77.9 ¢/litre**
- **2008 = 104.9 ¢/litre**

Nitrogen fertilizer (made from natural gas):

Price of urea:

- **1999 = \$268/tonne**
- **2007 = \$591/tonne**
- **2008 = \$618/tonne**

Price of phosphorous fertilizer (12-52-0):

- **1999 = \$399/tonne**
- **2007 = \$617/tonne**
- **2008 = \$2111/tonne**

Not strong link to crude oil prices, but link to soaring world demand for fertilizer

(Western Producer, May 8, 2008)

WHAT CAN WE DO?

Energy needs to be thought of as a portfolio, as a package of resources – both supply and efficiency - that complement each other, rather than one big centralized resource...

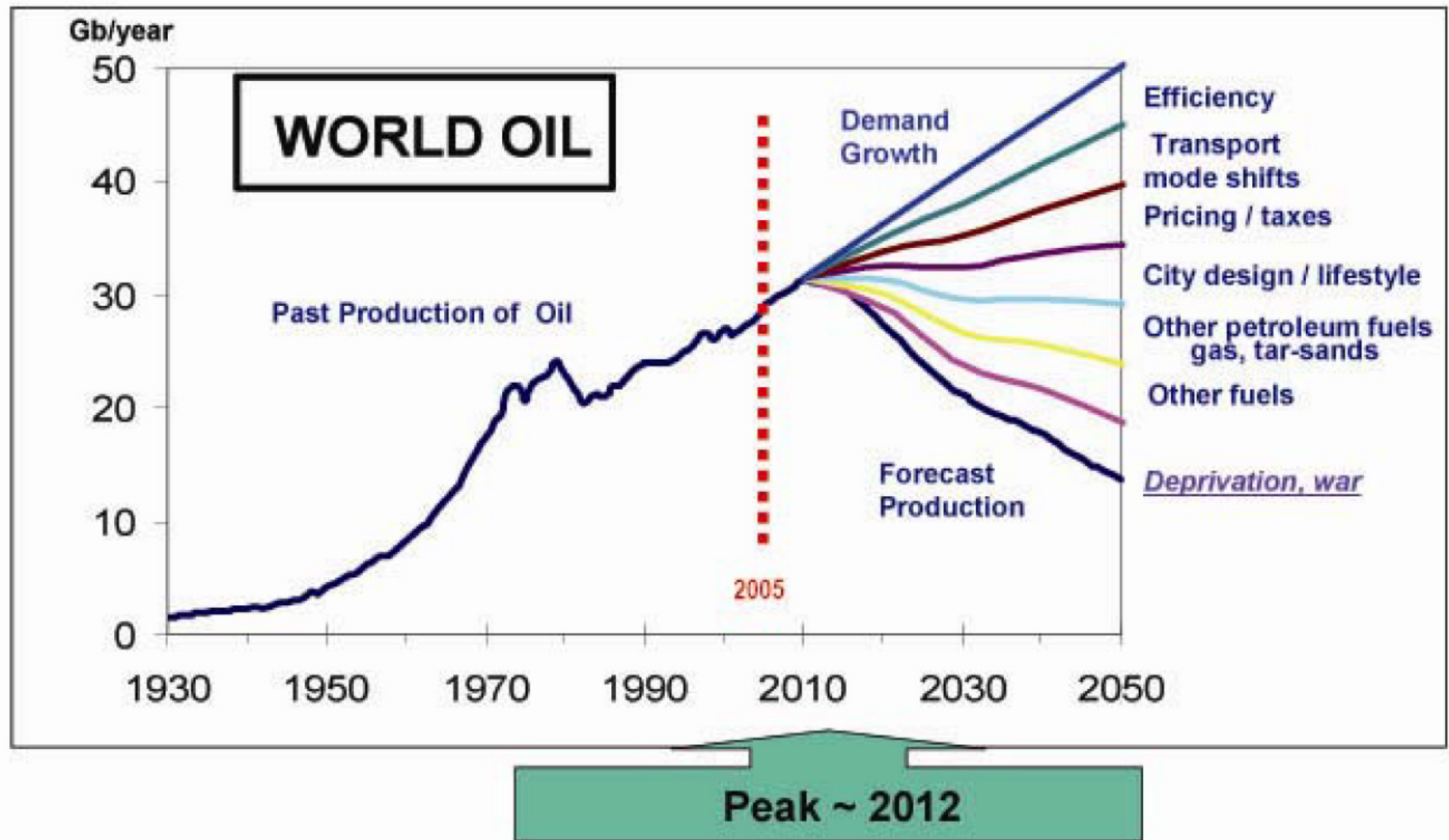
Create a diversified portfolio of resources that balance risk and return...

The big challenge is to fundamentally change the way energy planners, and our society in general, think about energy."

(Joel Swisher, RMI , 2007)

Hirsh et al, 2005

A Chinese View on Peak Oil



“The Chinese government is well aware of peak oil.”

Pang Xiongqi, China University of Petroleum in Beijing

(from Hirsh et al, 2005)



**A Net Zero Energy Duplex under Construction in Edmonton
(June 4, 2008)**

**Over the period of a year, the house will need no net energy.
Conservation (R56 walls, R100 attic, etc) and renewable
energy sources (passive solar, active solar thermal, and solar
photovoltaics) make it possible**



www.riverdalenetzero.ca

Immediate actions we can take to reduce petroleum consumption

Individuals, companies, cities and towns

Most actions are low cost or give a rapid payback on capital investment.

Some suggestions from the Government of B.C.

1. Regular tune up of the engine in your car, plus maintain proper tire pressure

- Saves 10% of fuel
- At \$1.00/litre = \$200/yr
- At \$1.50/litre = \$300/yr

2. Drive one day less per week

- \$228/yr @ \$1.00/litre
- \$342/yr @ \$1.50/litre

3. Walk to work

- \$192/yr @ \$1.00/litre
- \$288/yr @ \$1.50/litre

4. Switch to transit

Net savings = \$185 @ \$1.00/litre
 \$278 @ \$1.50/litre

5. When buying a new car, improve fuel efficiency from 12 L/100 km to 10 L/100 km

- Save \$400/yr @ \$1.00/litre
- In the future may be able to go from 12 L/100 km to 6 L/100 km; savings \$1800/yr @ \$1.50/litre

Extra costs for more fuel efficient vehicles?

B.C. Government Budget and Fiscal Plan – 2008/09 to 2010/11

Other ideas:

Use a bike to commute to work, shopping, etc.

Bike sales increasing in Saskatoon

Need more bike-friendly routes around the city

(Nickel, Star Phoenix, May 20, 2008)

Recommendations from the Saskatchewan Environmental Society

- **Bus**
- **Bike**
- **Walk**
- **Carpool**
- **Telecommute**
- **Buy high efficiency vehicle**
- **Plan trips to minimize driving**
- **Reduce speed:**
slowing from 120 km/h to 100 km/h saves up to 20% of fuel consumption

Suggestions from the American Council for an Energy Efficient Economy (ACEEE):

- **Avoid “jack rabbit” starts and aggressive driving**
- **Think ahead; don’t accelerate hard or brake hard**
- **Plan trips to avoid rush hour**
- **Combine trips**
- **Take a load off: carrying an extra 50 kg lowers fuel economy about 1%**

- **Follow the speed limit:**
120 km/h instead of 105 km/h lowers fuel economy by 10%
- **Keep tires properly inflated:**
3 psi under proper pressure lowers fuel economy by 1%
- **Buy low-rolling-resistance replacement tires**
can improve fuel efficiency by up to 4%
- **Companies may help with carpooling and other ways to reduce employees fuel consumption**

(www.greenercars.org)

WHAT ABOUT BIG TRUCKS?

Big improvements coming in fuel efficiency

Led by Wal-Mart with help from RMI

Wal-Mart redesigned their Class-8 truck fleet

- **Saved 25% on long-haul operations**
- **Plan in place to double fuel economy by 2015**
- **Net savings for Wal-Mart of \$494 million by 2020**
- **Even bigger savings look possible**

Fuel savings in big trucks result from a system approach to reducing final demand for fuel:

**2-6 % fuel savings by single different actions;
can be added together**

- 1. Aerodynamic bumper and tank skirts = 2%**
- 2. Tractor/trailer gap fairing = 2%**
- 3. Trailer base aerodynamics = 6%**
- 4. Trailer side skirts = 4%**
- 5. Low rolling resistance tires = 4-6%**
- 6. Auxiliary power unit = 8%**

Costs and GHG savings

Cheapest improvements

- **Cost \$12,546**
- **Improve fuel efficiency by 13%**
- **Save 23.3 tonnes of GHGs/truck year**

Full package of improvements

- **Cost \$33,589**
- **Improve fuel efficiency by 22%**
- **Save 39.2 tonnes of GHGs/truck year**

Need government support to put in place in a big way and quickly

Full package widely adopted would reduce fuel consumption by big trucks in Canada by 4.1 billion litres and reduce GHG emissions by 11,500,000 tonnes per year.

LONG TERM OUTLOOK FOR IMPROVING FUEL EFFICIENCY OF CARS AND LIGHT TRUCKS AND REDUCING OIL CONSUMPTION

Several trends emerging:

- **Reduce weight of vehicles**
- **System approach to energy savings**
- **More use of electricity as the energy source**

A system approach to reducing oil consumption for cars and light trucks:

Rocky Mountain Institute (RMI) and the Society of Automotive Engineers (SAE) have come to similar conclusions:

(Lovins, 2008; SAE, 2008)

- 1. Reduce fuel needs by more walking, biking, use of transit, design new subdivisions to reduce the need for cars (examples of Curitiba, Brazil; Portland, Oregon; Freiburg, Germany)**

- 2. Purchase a hybrid vehicle and drive it properly = double a conventional car's fuel efficiency.**

- 3. Make the hybrid ultralight and slippery = double the fuel efficiency of the hybrid.**

- 4. Fuel this vehicle with cellulosic ethanol (E85)
Cuts crude oil use per km another fourfold.
Now down to 1/16th of the current level.**

- Toyota Prius: First Built in 1997





**Chevrolet Volt
Extended Range Electric Vehicle
2010 Launch Date**

- 5. Make the vehicle a plug-in hybrid and cut oil by ½ again, down to 3% of original
Will need a renewable energy supply for the electricity**

- 6. With such a fuel efficient vehicle, could use renewable hydrogen and a fuel cell without high cost**

The change is starting:

Toyota has shown a 1/X concept carbon-fibre plastic composite car the size of a Prius but three times lighter and twice as fuel-efficient.

Needs only a small motor and 20 extra kg of batteries

Toray, the world's largest manufacturer of carbon fibre, has announced a \$300 million factory to make carbon-fibre plastic composite body panels, etc, for cars and light trucks.

BIG ISSUES:

How rapidly can these changes be made?

What is the role of more fuel efficient but non- hybrid vehicles?

What will be the cost and/or savings?

What incentives, taxes, policies will be needed to improve the rate and amount of change?

Are there issues of raw material supply?

Are there environmental costs?

Safety issues with lighter cars (looks to be solvable)

RENEWABLE ALTERNATIVES TO OIL

- **Biofuels**
- **Electricity from renewable sources to power plug-in hybrid vehicles or pure electric vehicles**
- **Hydrogen produced from renewable sources**
- **Must be integrated with greater energy efficiency in vehicles, more walking, more bicycling, more use of public transport to be sustainable**

BIOFUELS

- **Liquid biofuels such as ethanol, biodiesel, synthetic diesel fuel
(*e.g.*, Choren in Germany)**
- **Solid biofuels used to produce electricity to power plug-in hybrid vehicles (lower costs than producing liquid biofuels)**
- **Role of lignocellulosic liquid fuels and microalgae-based liquid biofuels**

Strategies to minimize conflict between fuel use of biomass and higher value uses:

Increase the energy efficiency of the transportation system first

1. Cascade biomass use from higher value use to fuel use:

- waste wood used to produce electricity to power plug in hybrid vehicles**
- co-products/waste streams from pulping of wood to produce fuel ethanol**
- biogas produced from manure and urban waste to power vehicles (Sweden example)**

2. Biomass production systems that produce food, feed and fuel together

Example: new agroforestry system in Niger

BIOFUELS

Three kinds of liquid biofuels:

1. First generation.

Ethanol:

- **made from grains such as corn and wheat**
- **fermentation produces ethanol and distiller's dried grains and solubles (animal feed)**

Biodiesel:

- **made from oil seeds such as canola or oil palm**
- **byproducts are oilseed meal (animal feed) and glycerol**

Big increase in production in third world countries and the USA

- **Conflicts with use of these crops for food**
- **Land use conflicts also**
- **Could be responsible for 10-30% of the rise in price of corn, rice and wheat**
- **Need a stop to further expansion of use of food for fuel and rapid development and implementation of sustainable alternatives**

Sustainable alternatives:

- 1. Greatly improved fuel efficiency**
- 2. Walk, bike, bus used more**
- 3. Second and third generation biofuels**
- 4. Electricity powered vehicles based on renewable electricity**

Second generation biofuels:

Based on lignocellulosic feedstocks such as MSW, black liquor from wood pulping, wood residues

Amounts potentially produced in Canada could be large: over 10 billion litres

Third generation biofuels:

Based on production of micro-algae (very high rates of photosynthesis)

Forest Biorefineries:

- **A way to revitalize the Canadian Forest Industry (Mabee, Gregge and Saddler, 2005; Saddler, 2007)**
- **Already being developed in Sweden (www.Processum.se)**
- **Refineries would produce biofuels, industrial products as well as pulp and paper**

Would be coupled with a new approach to sustainable forestry developed by Christian Messier, University of Quebec at Montreal.

Zone boreal forest areas for:

- parks (12+%)**
- ecosystem management (60%-80%)**
- traditional intensive forestry (5%-20%)**
- super-intensive forestry (1%-5%)**

Result:

➤ **More areas protected**

and

➤ **A net 40% gain in growth and yield**

➤ **Being tested in Quebec**

➤ **May also apply in tropical countries
(Messier has studies in Panama)**

Technologies for producing ethanol and other biofuels from forestry residues and MSW

Gasification route looks the most promising:

Wood, bark, MSW fraction:

- 1. Gasify (heat, steam) to produce a mixture of hydrogen + carbon monoxide (synthesis gas)**
- 2. Catalytically convert this to ethanol**

Examples of companies:

Nipawin Biomass Ethanol New Generation Co-operative Ltd.

- **Plans for a 100 million litre/yr ethanol plant**
- **Get 500 litre/tonne of bark or wood waste**
- **Potential for up to 10 other plants in Saskatchewan**

2. Enerkem (Quebec) (www.enerkem.com)

- building a 4 million litre/yr demo plant**
- could scale up to 50 million litres/yr**
- will use waste wood (urban wood) from Quebec cities**
- working with the City of Edmonton to produce fuel alcohol from sorted urban waste**
- process is scalable so can be used at fairly small resource sites**

3. Range Fuels (www.rangefuels.com)

- **similar gasification process to Nipawin and Enerkem**
- **modular technology which can be used on a relatively small scale**
- **flexible process which can use various feedstocks**

- **first commercial plant being built in Georgia.**
- **using forest residues as the feedstock**
- **initial scale is 76 million litres/year**
- **plan is to increase production to 379 million litres/year**
- **likely possible to use the ash as a fertilizer in the forest (Sweden has already shown this is possible)**

Next steps:

Start bringing in wind and solar-based electricity into the transportation energy mix

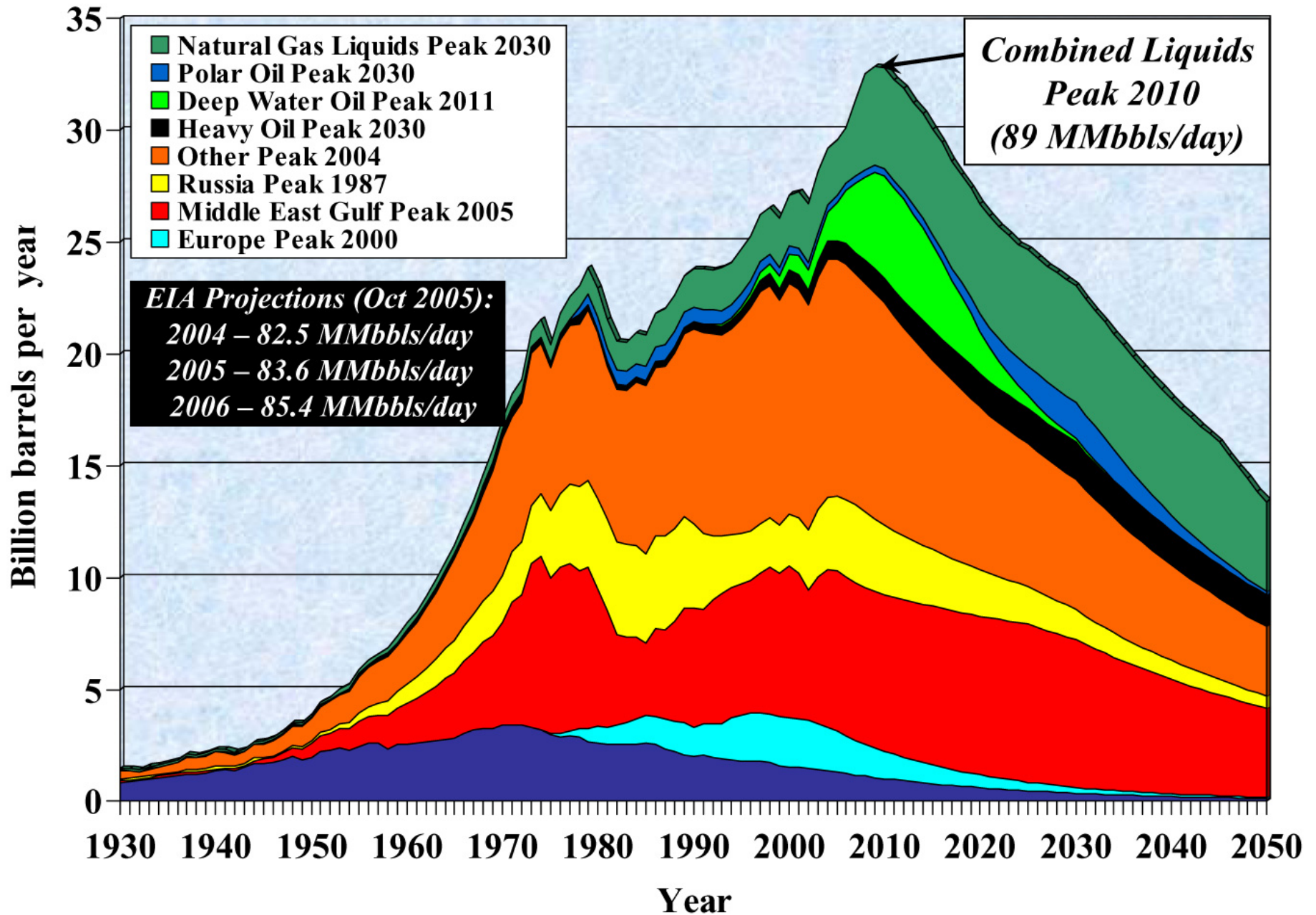
- **rapid developments occurring in wind and**
- **solar energy production and storage**
- **world wind energy and solar photovoltaic energy potential much higher than world electrical energy needs, at reasonable prices, although land requirement issues remain**

(deVries, van Vuuren and Hoogwijk, 2007)

Other steps and issues:

- **Taxes, feebates, support programs to encourage rapid development of the most promising new technologies (always evolving)**
- **Local organizations to share knowledge and experiences**
- **Start constructing local, regional and national plans and scenarios for the long term future, e.g. 2058**

Campell's 2006 Hydrocarbon Liquids Production and Forecast 1930-2050



(C.J. Campbell, personal communication, September, 2006)

Summary: To address peak oil

- First:
 - Reduce demand for oil dramatically by conservation, efficiency and land use planning
- Second:
 - Use alternative energy sources such as cellulosic based biofuels, and electricity from renewable sources such as wind, small hydro, forest/agricultural byproducts, and municipal solid waste