Peaking of World Oil Production:
The Mitigation Challenge

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Overview

- **Peaking** of world conventional oil production is **unavoidable**, but the **timing** is uncertain.

- **Mitigation** technologies are **available**.

- **Implementation** will be the challenge.

- **World oil consumption** is enormous so mitigation will be a **huge worldwide undertaking**.

There are no quick fixes.
Optimists: Not to worry

- We’ve heard this before.
- Geological problems are distant.
- There’s time enough for markets to work.
- We can muddle through.

Concernists: Worry!

- We know much more now.
- Geological limits are likely in 0-15 years.
- Effective action will take decades.
- Inaction will be catastrophic.

Oil & Futures Markets: Worry?

- Futures prices are very high.
- Something is different this time.

Wildcards: Worry?

- Terrorism
- Political instability
This Presentation

• Background Review
• Mitigation Options
• Three Scenarios
• Timing

At some point, world conventional oil production will no longer meet demand = OIL PEAKING

- **WHY?** Rapid depletion of a finite resource.
- **WHEN?** Uncertain - Soon? 10 years? Later?
- **WHY CAN’T THE PROBLEM BE FIXED QUICKLY?**
The scale of change is ENORMOUS

World oil consumption is over 3 million barrels per hour.

............. about 30 seconds to fill this room with oil........
Why will conventional oil production peak?

The world will peak. (All regions)
We’re finding much less than we’re consuming.

Trouble!
Fundamentals

Peaking is maximum production, not running out.

It’s a liquid fuels problem.
World Oil Consumption Follows & Fuels World Economic Growth

World GDP

Oil Demand = Oil Production
What’s likely to happen at peaking?

Oil Demand
(Healthy World Economy)

Supply cannot meet demand

Production reaches a maximum & then declines

1) Prices escalate
2) Shortages develop
3) Economic trouble
Learning from Two Oil Major Interruptions

• The 1973 & 1979 oil interruptions caused:
  + Inflation
  + Unemployment
  + Recession
  + High interest rates

• Both events were relatively brief.

• World oil peaking impacts could last more than a decade.

• The world has never faced a problem like oil peaking - The first forced energy transition.
## When?

No one knows for certain

<table>
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<th>Forecast</th>
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- **5 years**
- **5-15 years**
- **> 20 years**
The North American Natural Gas Error

  - National Petroleum Council - 1999
  - DOE EIA - 1999
  - Cambridge Energy Research Associates (CERA) - 2001

- Natural gas production is now flat / in decline.
  - Natural gas & oil geology have similarities.
  - What’s the RISK on oil?
Analysis of Three Mitigation Scenarios

Scenario I  -  No action until peaking occurs
Scenario II -  Mitigation started 10 years before peaking
Scenario III - Mitigation started 20 years before peaking

Assumptions:

» All mitigation initiated immediately

» Crash program implementation

Optimistic limiting case
Modelling Requires a Pattern for World Oil Growth, Decline, & Demand

Extrapolated Demand - Growing World Economy

Shortage

L 48 production pattern

Assumed:
- Demand @ 2%
- Oil Decline @ 2%
- Peak @ 100 MM bpd

(Not a prediction)

Leave the date for peaking open.
Rapid Oil Production Declines After World Oil Peaking Are Conceivable

EIA (Hakes, J.) .................................................. ~ 8%
Saudi Aramco (Al-Husseini, S)................. 3-5%
ExxonMobil.................................................... 4-6%
Schlumberger (Gould)........................................ 8%

Our model assumes 2%.
Higher declines make the mitigation problem worse.
Mitigation Options We Considered

- Vehicle fuel Efficiency
- Heavy oil / oil sands
- Coal Liquefaction
- Gas-To-Liquids (GTL)
- Enhanced Oil Recovery (EOR)

Why these? There’re ready for Implementation
High Prices & Advanced Technology?
Experience: U. S. Lower 48 Oil Production

Dramatic Improvement in Oil Field Technology

Help? - Yes
Reverse trends? - No
## Options Not Included in Our Analysis

<table>
<thead>
<tr>
<th>Option</th>
<th>Reasoning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nuclear</td>
<td></td>
</tr>
<tr>
<td>Wind</td>
<td>Electric / not LIQUID FUELS</td>
</tr>
<tr>
<td>Solar</td>
<td></td>
</tr>
<tr>
<td>Hydrogen</td>
<td>Neither ready nor economic</td>
</tr>
<tr>
<td>Biomass</td>
<td>Not economic</td>
</tr>
<tr>
<td>Shale Oil</td>
<td>Not commercial</td>
</tr>
</tbody>
</table>
### U.S. Transportation - 2003

<table>
<thead>
<tr>
<th></th>
<th>Autos</th>
<th>Light Trucks</th>
<th>Heavy Trucks</th>
<th>Airplanes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Share of transport fuel consumption</td>
<td>39%</td>
<td>28%</td>
<td>24%</td>
<td>9%</td>
</tr>
<tr>
<td>Fleet size - Millions</td>
<td>130</td>
<td>80</td>
<td>7</td>
<td>0.0085</td>
</tr>
<tr>
<td>New - Millions/Year</td>
<td>8.5</td>
<td>8.5</td>
<td>0.5</td>
<td>Small</td>
</tr>
<tr>
<td>Median life - Years</td>
<td>17</td>
<td>16</td>
<td>28</td>
<td>22</td>
</tr>
</tbody>
</table>

**Biggest, fastest savings**
VEHICLE FUEL EFFICIENCY

- Automobiles & light trucks (LDVs) are the largest liquid fuel consuming opportunity.
  - Diesel engines are up to 30% more efficient than gasoline engines.
  - Hybrids are 40% more efficient in small cars / 80% in medium cars.
  - Enhancements to existing technologies can also contribute.

Estimates based on 30%, then 50% improvements
GAS-TO-LIQUIDS

• Now commercial & could be significant
• Must compete with LNG
• Non-U.S. resource

Estimates based on 2x recent GTL projections
HEAVY OIL / OIL SANDS

- Canada + Venezuela: 3-4 trillion barrels
- ~600 billion barrels economic
- Only part clean fuels - Canada: 0.6 of 1.0 MM bpd
- Current plans - Canada: 3 MM bpd synthetic oil by 2030
- Large energy input required
- Oils harder to refine
- Significant environmental problems

Estimates based on 2-2.5x recent projections.
COAL-TO-LIQUIDS

- Now commercial / near-commercial.
- Cost: $30-35/bbl
- Huge coal resource in U.S., elsewhere
- Liquids don’t need refining

Assume five new 100,000 bpd production plants/year.
ENHANCED OIL RECOVERY

- EOR has been utilized for decades.
- It’s usually applied after primary and secondary recovery.
- It helps recover additional oil from reservoirs past peak production.

Production estimates paced by CO2 availability.
Wedges Used to Show Mitigation Effects

Impact Barrels/ Day

Prepare

Produce

Vehicle Fleet Fuel Saved

Actual

Wedge Approximation

Time - Years
### Wedge Estimates from Our Study

<table>
<thead>
<tr>
<th>Mitigation Option</th>
<th>Preparation Delay (Years)</th>
<th>Impact 10 Years Later (MM bpd)</th>
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<tbody>
<tr>
<td>Vehicle Efficiency</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Gas-To-Liquids</td>
<td>3</td>
<td>2</td>
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<td>Heavy Oils / Oil Sands</td>
<td>3</td>
<td>8</td>
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<tr>
<td>Coal Liquids</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Enhanced Oil Recovery</td>
<td>5</td>
<td>3</td>
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Sum of Wedges

- Delay, then rapid growth.
- Roughly 25 MM bpd after 15 years.
But In Our Model the World Shortage Would be 50 MM bpd, 15 years After Peaking

World modeled after the U.S. Lower 48 production pattern, 100 MM bpd at peak, & continuing demand associated with a growing world economy.
Apply the Wedges to World Demand & Production for the Three Scenarios
SCENARIO I: MITIGATION @ PEAKING

PRODUCTION (MM bpd)

YEARS BEFORE / AFTER OIL PEAK

Mitigation

Shortage
SCENARIO II: MITIGATION 10 YEARS BEFORE
SCENARIO II: MITIGATION 20 YEARS BEFORE

PRODUCTION
(MM bpd)

YEARS BEFORE / AFTER OIL PEAK

Oil Peaking
Further
Delayed

Start

Mitigation
SCENARIOS ANALYSIS CONCLUSIONS

Basis: Immediate crash program mitigation

I. Wait for peaking

II. Start 10 years early

III. Start 20 years early

Oil shortages largest, longest lasting

Delays peaking; still shortages

Avoids the problem; smooth transition
Forecasts of World Conventional Oil Production Peaking

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Trouble Free Scenario III
A Chinese View on Peak Oil

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

• no single “Magic Bullet” solution
• Deprivation, war
• Efficiency
• Transport mode shifts
• Pricing / taxes
• City design / lifestyle
• Other petroleum fuels
  gas, tar-sands
• Other fuels

Peak ~ 2012
Dealing with Uncertain Oil Reserves Estimates

**Most Agree**
World conventional oil reserves data are uncertain & often political. Truth will be known after the fact.

**Optimistic View**
Peaking is decades away & markets will manage.

**Concernist View**
Peaking may occur soon & result in long-lasting, large-scale economic damage.

**My Concern**
The downside of the optimists-being-wrong is dire, which heavily skews the RISK
Summary & Conclusions

- Oil peaking **timing is uncertain**.
  - It may be soon.
  - “Soon” is less than 20 years according to our analysis.

- Peaking = World’s first **forced energy transition**.

- It’s a **world liquid fuels problem**.

- A number of mitigation **technologies are ready**.

- With timely mitigation, **economic damage can be minimized**.