Conference on World Affairs
University of Colorado, Boulder

Whither the Oil Market

Bill Reinert and Jan F Kreider
Advanced Technology Group,
Toyota Motor Sales, USA, INC
April 11, 2012
Oil Prices Strongly Influenced by Excess Capacity

Source: Neftex (Dr. Peter Wells)
A CLOSER LOOK
Issues and constraints in capacity expansion – decision making is slow

<table>
<thead>
<tr>
<th>-ve</th>
<th>+ve</th>
</tr>
</thead>
<tbody>
<tr>
<td>National heritage</td>
<td>Spare capacity competition (Iran vs Saudi Arabia)</td>
</tr>
<tr>
<td>Timing of investment</td>
<td>Concern about demand destruction and loss of market</td>
</tr>
<tr>
<td>High prices – why expand to reduce prices?</td>
<td>Concern about value of investments in US and Europe</td>
</tr>
<tr>
<td>Politics – Iran, Iraq, Venezuela, Nigeria, Kuwait</td>
<td>(Kuwait, Qatar, UAE, Saudi Arabia - $1,500 billion invested)</td>
</tr>
<tr>
<td>Capability and openness</td>
<td></td>
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<tr>
<td>Old fields/reserves</td>
<td></td>
</tr>
</tbody>
</table>
Balance of main factors affecting spare capacity and oil price

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Iran – sanctions and embargoes, war
Iraq – failed state
Libya – militias out of control
Leadership changes in Iran, Saudi Arabia and Venezuela
Civil strife in Angola, Nigeria, Equatorial Guinea
Fast decline in non-OPEC conventional production

+ve

Iraq – “stabilised” politics and production rising
Libya – “stabilised politics” and production restored
Brazil – sub salt (after 2016)
Angola – sub salt (after 2020)
Kazakhstan – Kashagan production (after 2016)
NGLs – rising especially with shale gas
Biofuels – rising as Brazil imports to USA
Shale oil – rising but only in USA to 2020
Canadian tar sands – Keystone XL built in 2013
China and India – demand growth eases
OECD – oil intensity falls faster than forecast under price pressure
Oil discoveries, giant and non-giant fields, United States

- Non giant fields
- Giant fields
- Average field size non giant fields
- Percent fields >100 million b
- Total number of fields discovered

- 1940: Non giant fields (277.0), Giant fields (846.4), Average field size non giant fields (1,123.5)
- 1950: Non giant fields (277.0), Giant fields (846.4), Average field size non giant fields (1,123.5)
- 1960: Non giant fields (277.0), Giant fields (846.4), Average field size non giant fields (1,123.5)
- 1970: Non giant fields (277.0), Giant fields (846.4), Average field size non giant fields (1,123.5)
- 1980: Non giant fields (277.0), Giant fields (846.4), Average field size non giant fields (1,123.5)
- 1990: Non giant fields (277.0), Giant fields (846.4), Average field size non giant fields (1,123.5)
- 2000: Non giant fields (277.0), Giant fields (846.4), Average field size non giant fields (1,123.5)
- 2010: Non giant fields (277.0), Giant fields (846.4), Average field size non giant fields (1,123.5)
Exploration success, giant and non-giant fields, total world
OPEC – issue is not reserves but maximum sustainable rate and pace of getting there

Maximum production capacity determined by maximum production from primary and secondary recovery from existing producing fields

EOR, development of discovered fields and exploration extend plateau

(EXCEPTIONS:- Nigeria, Libya, Algeria)

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OPEC – Forecast Production Capacity

Raw historical data and most primary and secondary recovery reserves from IHS and forecast from Neftex

Includes data provided by Petroconsultants S.A. (data copyright 2008 Petroconsultants S.A.)
Above or below ground risks?

- **Geological constraints**
  - **Low**
  - **High**

- **Political constraints**
  - **Low**
  - **High**

- **“Below ground”**
  - USA
  - ROW
  - FSU
  - Libya
  - Algeria
  - Qatar

- **“Above ground”**
  - Saudi Arabia
  - UAE
  - Kuwait
  - Nigeria
  - Iran
  - Venezuela
  - Iraq

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“Non-crude oil” liquids

- Oil shale
- Other liquids
- Biofuels
- Coal-to-Liquids
- Gas-to-Liquids
- Canadian tar sands
- NGLs

© Peter R.A. Wells
Peak liquids production: 98-105 million b/d between 2017 and 2023

- **CERA Asian Phoenix (2006)** 121 million b/d
- **IEA Ref. Case (2007)** 116 million b/d

Spare capacity

- OPEC crude oil
- Non-OPEC crude oil
- Canadian tar sands
- NGLs
- GTL
- CTL
- Biofuels
- Shale oil

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<table>
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<tr>
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<tbody>
<tr>
<td>Demand</td>
<td>87.4</td>
<td>89.1</td>
<td>90.1</td>
<td>91.3</td>
<td>92.5</td>
<td>93.4</td>
<td>94.4</td>
<td>95.4</td>
<td>96.4</td>
<td>97.4</td>
<td>98.4</td>
</tr>
<tr>
<td>Spare capacity</td>
<td>4.8</td>
<td>4.0</td>
<td>2.9</td>
<td>4.4</td>
<td>5.4</td>
<td>6.1</td>
<td>6.5</td>
<td>6.7</td>
<td>6.1</td>
<td>5.9</td>
<td>5.3</td>
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<tr>
<td>Comfort index</td>
<td>1.7</td>
<td>0.9</td>
<td>-0.3</td>
<td>1.2</td>
<td>2.2</td>
<td>2.9</td>
<td>3.2</td>
<td>3.4</td>
<td>2.8</td>
<td>2.6</td>
<td>2.0</td>
</tr>
</tbody>
</table>

**Significant supply increments**

| Non-OPEC         | 41.5  | 40.9  | 40.8  | 41.1  | 41.3  | 41.5  | 41.3  | 41.2  | 40.2  | 39.8  | 39.2  |
| OPEC10           | 26.3  | 27.4  | 28.3  | 29.5  | 29.8  | 30.0  | 30.5  | 31.1  | 32.2  | 33.1  | 34.0  |
| Iraq             | 1.8   | 2.6   | 3.5   | 3.7   | 3.7   | 3.7   | 3.7   | 3.7   | 3.9   | 4.1   | 4.4   |
| NGLs             | 11.1  | 11.5  | 11.6  | 11.9  | 12.1  | 12.3  | 12.5  | 12.6  | 12.9  | 13.0  | 13.3  |
| Canadian tar sands| 1.5   | 1.6   | 1.8   | 1.9   | 2.1   | 2.2   | 2.4   | 2.5   | 2.7   | 2.8   | 3.0   |
| Shale oil        | 0.3   | 0.5   | 0.6   | 0.8   | 0.9   | 1.0   | 1.2   | 1.3   | 1.5   | 1.6   | 1.7   |
| Biofuels         | 2.2   | 2.3   | 2.5   | 2.6   | 2.7   | 2.8   | 2.9   | 3.0   | 3.2   | 3.3   | 3.4   |

So where are we headed from here?
Mitigation - Substitution within the crude oil system

- Liquid fuels are uniquely efficient for transportation – high energy per volume
- 75% of crude oil consumed in the USA is used for transportation (motor gasoline, jet fuel and diesel)
  - 25% is 5 million b/d!
- Only ~60% crude oil worldwide used for transportation
  - 40% is 25 million b/d - mainly heavy end of the barrel used for space heating, industry and power generation
- Scope for substituting gas and nuclear in power generation and natural gas liquids in industrial uses
- Major investment in refining and refining technology and access to cheap, clean hydrogen – nuclear power for hydrogen and process energy
Mitigation - Natural gas will outlast liquids

…Compressed natural gas (CNG)

Natural gas
Mitigation - substitutions... electricity replaces gasoline (plug ins, hydrogen fuel cells) – nuclear!

Global Warming

- Gas from Russia
- Gas-to-liquids
- Coal-to-liquids
- Shale oil

Security of Supply

- Solar-wind-tidal
- Behaviour
- Plug-ins
- Hybrids
- Diesel
- Sugar cane ethanol
- Clean coal power
- Canadian tar sands
- EU biodiesel
- Corn ethanol
Tar sands area in Canada
The process starts with clearing the forest, 1 acre/hour. The trees are sent to be used for pulp or in this case, just stacked and burned.
Next, the strip mining starts. These are the biggest strip mines in the world. The haulers below have a capacity of 300 tons each.
The mining operation runs 24 hours each day, 365 days each year
The tar sands are then sent to the refinery for processing. The emissions are tremendous.
They hang like an overcast over the entire region
Water from nearby rivers is heated to produce steam which removes the tar from the sand. In the process the water becomes polluted with heavy metals and oil.
You need to see the scale to believe it. The earthen dam on the left is over 300 feet high. Originally it was designed to be 30 feet. The river immediately adjacent runs to the arctic.
This is the inflow into one of the holding ponds. Ponds really doesn’t describe them as there is no known way to decontaminate this water.
Real GDP, oil consumption and oil prices

Source: Peter Wells
Decreasing Benefit of Increasing Fuel Economy. It’s All About Fuel Consumption

Source: Idaho National Labs
PHEV Evaluation
# Finding replacements part 1

<table>
<thead>
<tr>
<th>Fuel source</th>
<th>Transportation energy displacement</th>
<th>Acres$^b$</th>
<th>Fraction of U.S. cropland</th>
<th>gallons of fuel per acre</th>
<th>MMBTU$^e$ of fuel per acre</th>
<th>Water use (gallons)</th>
<th>Energy ratio</th>
<th>CO$_2$ emissions$^a$</th>
<th>BTU input per BTU of fuel</th>
<th>lb per MMBTU of fuel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional gasoline</td>
<td>0-100%</td>
<td>a few thousand</td>
<td>very low</td>
<td>-</td>
<td>-</td>
<td>5</td>
<td>45</td>
<td>0.05</td>
<td>175</td>
<td></td>
</tr>
<tr>
<td>Conventional diesel</td>
<td>0-100%</td>
<td>a few thousand</td>
<td>very low</td>
<td>-</td>
<td>-</td>
<td>10</td>
<td>80</td>
<td>0.08</td>
<td>175</td>
<td></td>
</tr>
<tr>
<td>Coal-to-liquid</td>
<td>10%</td>
<td>4,100</td>
<td>very low</td>
<td>~4.4 M</td>
<td>~500,000</td>
<td>3</td>
<td>24</td>
<td>~0.5</td>
<td>~380</td>
<td></td>
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<tr>
<td></td>
<td>25%</td>
<td>10,300</td>
<td>very low</td>
<td>~20 M</td>
<td>~65,000</td>
<td>~6</td>
<td>~45</td>
<td>~0.1$^d$</td>
<td>~240</td>
<td></td>
</tr>
<tr>
<td></td>
<td>50%</td>
<td>20,600</td>
<td>very low</td>
<td>~3 M</td>
<td>~350,000</td>
<td>~5</td>
<td>~38</td>
<td>~0.25</td>
<td>~180</td>
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<tr>
<td>CNG</td>
<td>0-100%</td>
<td>a few thousand</td>
<td>very low</td>
<td>-</td>
<td>-</td>
<td>n/a</td>
<td>~10$^d$</td>
<td>~0.1$^d$</td>
<td>~150</td>
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<tr>
<td>Heavy crude</td>
<td>0-100%</td>
<td>a few thousand</td>
<td>very low</td>
<td>-</td>
<td>-</td>
<td>~10</td>
<td>~80</td>
<td>~0.25</td>
<td>~200</td>
<td></td>
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<tr>
<td>In situ oil shale</td>
<td>10%</td>
<td>7,500$^c$</td>
<td>very low</td>
<td>~3 M</td>
<td>~350,000</td>
<td>~5</td>
<td>~38</td>
<td>~0.25</td>
<td>~180</td>
<td></td>
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<tr>
<td></td>
<td>25%</td>
<td>19,000$^c$</td>
<td>very low</td>
<td>~20 M</td>
<td>~65,000</td>
<td>~6</td>
<td>~45</td>
<td>~0.15</td>
<td>~240</td>
<td></td>
</tr>
<tr>
<td></td>
<td>50%</td>
<td>37,000$^c$</td>
<td>very low</td>
<td>~20 M</td>
<td>~65,000</td>
<td>~6</td>
<td>~45</td>
<td>~0.15</td>
<td>~240</td>
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<tr>
<td>Tar sands</td>
<td>10%</td>
<td>48,000$^c$</td>
<td>low</td>
<td>~3 M</td>
<td>~350,000</td>
<td>~5</td>
<td>~38</td>
<td>~0.25</td>
<td>~180</td>
<td></td>
</tr>
<tr>
<td></td>
<td>25%</td>
<td>120,000$^c$</td>
<td>low</td>
<td>~3 M</td>
<td>~350,000</td>
<td>~5</td>
<td>~38</td>
<td>~0.25</td>
<td>~180</td>
<td></td>
</tr>
<tr>
<td></td>
<td>50%</td>
<td>240,000$^c$</td>
<td>low</td>
<td>~3 M</td>
<td>~350,000</td>
<td>~5</td>
<td>~38</td>
<td>~0.25</td>
<td>~180</td>
<td></td>
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Source: Kreider and Associates
Finding replacements part 2

<table>
<thead>
<tr>
<th>Fuel source</th>
<th>Transportation energy displacement</th>
<th>Land use</th>
<th>Water use (gallons)</th>
<th>Energy ratio</th>
<th>CO₂ emissions a</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional gasoline</td>
<td>0-100%</td>
<td>a few thousand</td>
<td>very low</td>
<td>5</td>
<td>45</td>
</tr>
<tr>
<td>Conventional diesel</td>
<td>0-100%</td>
<td>a few thousand</td>
<td>very low</td>
<td>10</td>
<td>80</td>
</tr>
<tr>
<td>Corn-based ethanol</td>
<td>10%</td>
<td>65 M</td>
<td>20%</td>
<td>28</td>
<td>170</td>
</tr>
<tr>
<td></td>
<td>25%</td>
<td>160 M</td>
<td>51%</td>
<td>28</td>
<td>180</td>
</tr>
<tr>
<td></td>
<td>50%</td>
<td>337 M</td>
<td>103%</td>
<td>28</td>
<td>220</td>
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<tr>
<td>Cellulosic ethanol</td>
<td>10%</td>
<td>46 M</td>
<td>15%</td>
<td>39</td>
<td>146</td>
</tr>
<tr>
<td></td>
<td>25%</td>
<td>112 M</td>
<td>35%</td>
<td>39</td>
<td>146</td>
</tr>
<tr>
<td></td>
<td>50%</td>
<td>228 M</td>
<td>72%</td>
<td>39</td>
<td>149</td>
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<tr>
<td>Soybean biodiesel fuel</td>
<td>10%</td>
<td>253 M</td>
<td>80%</td>
<td>7</td>
<td>900</td>
</tr>
<tr>
<td></td>
<td>25%</td>
<td>380 M</td>
<td>120%</td>
<td>7</td>
<td>900</td>
</tr>
<tr>
<td></td>
<td>50%</td>
<td>1.2 B</td>
<td>390%</td>
<td>7</td>
<td>900</td>
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<tr>
<td>Algalculture</td>
<td>10%</td>
<td>2.5 M</td>
<td>&lt; 1%</td>
<td>800</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>25%</td>
<td>6.5 M</td>
<td>2%</td>
<td>800</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>50%</td>
<td>13 M</td>
<td>4 %</td>
<td>800</td>
<td>50</td>
</tr>
<tr>
<td>MSW-based ethanol</td>
<td>0-100%</td>
<td>tens of thousands</td>
<td>very low</td>
<td>5</td>
<td>65</td>
</tr>
</tbody>
</table>

Source: Kreider and Associates
Future Engines Require Future Fuels

- Diesels & ICEs are unlikely to become a single technology
- New engines will require new fuels, all synthetic
In review

- As a percentage of disposable income, gasoline is actually more affordable today than in the ‘80s.
- Gasoline prices are a witches’ brew of taxes, local standards, refinery capacity, geography and yes, the cost of oil.
- Oil prices today are not driven by supplies. We have plenty of supply, the market can barely absorb more capacity. The price driver is spare capacity.
- All things being equal (no black swan event) spare capacity will increase and oil prices will moderate by next year.
- Conceptually, Peak Oil, is not an accurate description.
- Eventually production will level and decrease, additional capacity will result from demand destruction “nega-barrels”
- Liquid fuels and advanced are likely to dominate the landscape for decades to come.
THANK YOU FOR YOUR KIND ATTENTION
Algae Uses Existing Infrastructure And Minimal Land

No changes to current infrastructure needed

Less than 10% of corn ethanol land mass requirement

Source: Sapphire Energy

Note: Calculated on a BTU basis. Assumes all algae is used to produce diesel and all cellulosic processes produce ethanol.
CA Air Resources Board, GREET model, 2009; Walters, Yang, “Corn stover removed without compromising soil quality”, Dept. Agronomy & Horticulture, UNL; Vinod Khosla
## Comparison of Vehicle Powertrain Technologies

<table>
<thead>
<tr>
<th></th>
<th>CO2 equiv</th>
<th>SOx</th>
<th>NOx</th>
<th>Hg</th>
<th>MMBTU</th>
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<tr>
<td></td>
<td>lb</td>
<td>lb</td>
<td>lb</td>
<td>lb</td>
<td></td>
</tr>
<tr>
<td>Gasoline (30mpg Sentra)</td>
<td>140,000</td>
<td>150</td>
<td>160</td>
<td>0.00084</td>
<td>721</td>
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<tr>
<td>EV-40 (Current US Grid)</td>
<td>110,000</td>
<td>430</td>
<td>210</td>
<td>0.00190</td>
<td>339</td>
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<tr>
<td>PHEV-20 (Reduced Volt)</td>
<td>100,000</td>
<td>270</td>
<td>160</td>
<td>0.00120</td>
<td>409</td>
</tr>
<tr>
<td>HEV (2010 Prius)</td>
<td>97,000</td>
<td>140</td>
<td>120</td>
<td>0.00071</td>
<td>472</td>
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<tr>
<td>Fuel Cell (70mi/kg)</td>
<td>76,000</td>
<td>4,100</td>
<td>53</td>
<td>0.00047</td>
<td>626</td>
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### Comparison of Vehicle Powertrain Technologies

<table>
<thead>
<tr>
<th></th>
<th>FC</th>
<th>HEV</th>
<th>PHEV-20</th>
<th>EV-40</th>
<th>Gas</th>
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<tbody>
<tr>
<td><strong>Material production</strong></td>
<td>17%</td>
<td>17%</td>
<td>20%</td>
<td>25%</td>
<td>11%</td>
</tr>
<tr>
<td><strong>Vehicle assembly</strong></td>
<td>3%</td>
<td>3%</td>
<td>4%</td>
<td>5%</td>
<td>2%</td>
</tr>
<tr>
<td><strong>Fuel production / transport</strong></td>
<td>10%</td>
<td>10%</td>
<td>9%</td>
<td>5%</td>
<td>12%</td>
</tr>
<tr>
<td><strong>Vehicle operation</strong></td>
<td>63%</td>
<td>63%</td>
<td>59%</td>
<td>54%</td>
<td>71%</td>
</tr>
<tr>
<td><strong>Vehicle maintenance</strong></td>
<td>3%</td>
<td>3%</td>
<td>3%</td>
<td>4%</td>
<td>2%</td>
</tr>
<tr>
<td><strong>Vehicle disposal</strong></td>
<td>4%</td>
<td>4%</td>
<td>5%</td>
<td>7%</td>
<td>3%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>
“What the Market will Bear”

2008 Midsize Car Prices

Mass Market

Prius

Prius PHV

Source: PIN
The Obama administration has made EVs an agenda item...

Energy Plan from Campaign - Key Points

- Put 1 million plug-in hybrid and/or electric vehicles on the road by 2015
- Ensure 10% of energy comes from renewable sources by 2012 and 25% by 2025
- Implement economy-wide cap-and-trade program to reduce greenhouse gas emissions 80% from 1990 levels by 2050

Progress vs. Campaign Promises

- Congress passed energy legislation in 2009 to reduce U.S. emissions below 2005 levels (Senate has not voted on legislation)
  - 17% reduction by 2020
  - 83% reduction by 2050
- American Recovery and Reinvestment Act included $2.4 billion in funding for battery development and electric vehicle component
...backed by significant financial commitments

Advanced Tech Vehicles Manufacturing Loan Program
Measured in USD Millions

American Reinvestment & Recovery Act Awards
Measured in USD Millions

Source: U.S. Department of Energy
However, past presidential agenda items such as solar power have struggled once funding was cut.

Estimated Department of Energy Solar Funding
Measured in 2007 Dollars
- Photovoltaic
- Concentration

1977 - 1979: President Carter makes multiple speeches touting solar power and installs panels on roof of White House

President Reagan cuts funding for solar development

Summary

- Apply existing technologies in new ways
  - Most of the technologies mentioned already exist, just not yet in the mobility space
- For now smaller battery approaches are more cost effective
  - Implies multiple charge periods throughout the day
- At the end of the day, customer is king
  - All solutions must solve customers problems without creating new ones
  - Charging solutions to manage the grid may be at odds with customer expectations.