Oil Basics and The Limits to Economic Growth

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Oil Dominates World Primary Energy Consumption 2015

<table>
<thead>
<tr>
<th>Energy Source</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil</td>
<td>33%</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>24%</td>
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<tr>
<td>Coal</td>
<td>29%</td>
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<tr>
<td>Nuclear</td>
<td>4%</td>
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<tr>
<td>Hydro</td>
<td>7%</td>
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<tr>
<td>Renewable Energy</td>
<td>3%</td>
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</tbody>
</table>

- Fossil energy—oil, coal and natural gas—dominate world primary energy (86%).
- Oil dominates fossil energy (38%).
- Renewable energy is 3% of primary energy.
- The world will continue to depend on oil and other fossil energy for some time regardless of climate concerns and advances in renewable technology.

Source: BP & Labyrinth Consulting Services, Inc.
What Is Oil?

• An organic compound of hydrogen and carbon.
• It is a naturally occurring substance that has been abundant and relatively cheap for the last 150 years.
• It is called crude oil if it is dark and viscous with an API gravity < 35 (SG oil/SG water)
• It is called condensate if it is clear and volatile with an API gravity >35.
• Oil is stored in rocks below the earth’s surface and is produced by drilling wells.
How Oil Is Formed

- Oil is formed from the remains of organic matter from plants and animals that lived in the ocean millions of years ago.
- Phytoplankton (algae) and other microscopic animals are the major sources of commercial oil.
- Organic matter was buried under sediment brought from nearby shorelines.
- It can’t decay too much—it must keep its carbon.
How Oil Is Formed

- Organic matter and sediments accumulate in marine basins that subside over geologic time to form depositional basins.
- Heat and pressure from burial transformed the organic matter into thermally mature organic matter (kerogen) and eventually, into oil.
- Most of the maturation process occurs between 50 to 100 degrees C.
- At higher temperatures the hydrocarbon converts to methane gas.
The Total Petroleum System

Elements
- Source Rock
- Migration Route
- Reservoir Rock
- Seal Rock
- Trap

Processes
- Preservation
- Generation
- Migration
- Accumulation

• The total petroleum system consists of all the elements and processes from source rock deposition to oil accumulation.
• Oil is generated in the source rock.
• It is expelled by expansion and migrates vertically along fracture systems and faults.
• After encountering a reservoir or carrier bed with porosity and permeability, it migrates laterally until it is trapped.
• Each element of the petroleum system can be evaluated qualitatively to determine project risk.
The Total Petroleum System

- Oil in the reservoir rock migrates upward by buoyancy above ground water.
- Migration stops when a barrier or trap is encountered.
- This can be an anticlinal or buoyancy trap, a fault trap or a natural stratigraphic trap.
- The vertical component of the accumulation is called a seal.
- Fluids segregate in the accumulation according to buoyancy.
- Oil is lighter than water and gas is lighter than oil.
- Anticlinal or structural traps are the most common for conventional oil accumulations.
How Oil Is Stored and Moves Through Rocks

- Reservoir rocks consist of matrix grains and pore space.
- Fluid resides in the pore spaces and can move if the pores are well connected.
- Although it may not seem logical that fluid can move through a rock, it is important to consider the considerable pressure at depth.
- Average pressures are about 0.5 psi/ft so at 10,000 ft., pressures may be 5000 psi.
- This is approximately the force needed to put the space shuttle into orbit.
Depletion: Much Reservoir Energy Comes From Dissolved Gas

• When a well is opened, it is a pressure sink—an escape path for high pressured fluids in the reservoir.
• Gas dissolved in the oil expands to several hundred times its reservoir volume pushing the liquids up the well bore.
• This means that maximum drive pressure exists at the moment the well is first opened and decreases thereafter.
• Once most of the dissolved gas has been produced, the reservoir pressure approaches zero and production stops.
• This is called depletion.
• Solution gas reservoirs typically recover between 5 and 25% of original oil in place and 60 to 80% original gas in place.
• Fields have geographic limits based on the extent of the trap.
• Field production will increase until all locations are drilled and then production will decline.
Conventional Oil and Tight Oil

- Conventional oil plays involve drilling reservoir rocks with vertical wells.
- After all the commercially attractive conventional fields in the U.S. were discovered and were in depletion, unconventional plays were the only option.
- Tight oil plays (fracking) involve drilling the source rock with horizontal wells.
- Tight oil horizontal wells cost 2-3 times more to drill and complete than conventional vertical wells.
- There is considerable fanfare about the new volumes of oil but little discussion about the cost of the technology and its effect on the price of oil.
Deep Water and Oil Sand Plays

- Unconventional plays include tight oil, deep water and oil sand plays.
- Deep-water plays involve conventional reservoirs but in thousands of feet of water, reliance of unconventional technology, great cost and risk.
- Oil sands are basically a mining operation.
The observation of Peak Oil: once conventional production peaks, supply will become increasingly dependent on more expensive, lower quality sources of oil.

...Like shale, deep-water, and tar sands.

It looks like Peak Oil is batting 1000!

Many people mis-understand and think that Peak Oil means that we are running out of oil.

That is wrong. Peak oil is about running out of affordable oil.
Where Is The Remaining Oil?

Who has the oil?

- Nearly half of the world’s proven reserves are in the Middle East.
- Only 14% are in North America.
- U.S. imports have declined since the advent of unconventional oil.
- The U.S. still imports 52% of its crude oil (7.9 million barrels per day 2016 average).
- That means that the U.S. will become increasingly dependent on foreign oil.
- The hype about energy independence is absurd.
The Difference Between Oil and Liquids

- Crude oil represents about 80% of what is often called “oil.”
- The rest of what are called “liquids” are a combination of other things some of which do not even come from petroleum.
- The biggest component is natural gas liquids—compounds like ethane, butane and propane—that come from processing natural gas. They contain ~65% of the energy content of crude oil and ~45% of the value but are counted as barrels.
- Biofuels come from plant material like corn and sugar cane that is processed into flammable alcohols like the ethanol and is added to gasoline.
- Refinery gain is the volumetric increase that results from refining crude oil into products that have a lower specific gravity.
Conventional and Unconventional Oil

- Conventional oil represents about 85% of total production today.
- EIA forecasts that heavy oil will remain about 3% of total production while tight oil will double from about 5% to 10% of world production by 2040.
- Despite increases in unconventional and NGL production, the overall percentage of conventional oil is forecast to remain fairly constant at about 85% for the next 25 years.
- The uncertainty in these forecasts is that world liquids production will increase from 93.5 mmbpd in 2016 to 118 mmbpd in 2040.
- If not, the percentage of unconventional oil and NGLs will be higher.
Conflicting Views of The Future of Oil Supply and Demand

- Mainstream oil production forecasts make a demand assumption: if you build it, they will come.
- If demand is there, supply will come.
- This model has no relation to supply but assumes that high prices will result in any level of production needed.
- The problem—other than the obvious supply component—is that this same assumption has resulted in both oil bubbles in which high prices crippled the world economy...and demand destruction prolonged the supply for awhile.
- The great fear among demand-side advocates is that peak demand is around the corner.
- More pessimistic Peak Oil forecasts also have been consistently wrong.
- The bottom line: all forecasts are wrong but mainstream forecasts are disconnected with economic reality. Peak Oil forecasts under-estimate the role of monetary policy and capital markets to subsidize supply.
- The world after the 2008 Financial Collapse is different and must be considered in any forecast.
Net Energy & Energy Density

- Not all energy sources are equal.
- Promoters of alternative energy sources emphasize cost competitiveness but other factors are important: net energy, energy density, carbon intensity, intermittency and breadth of use.
- Net energy: how much energy goes into getting energy out.
- Oil and coal win on net energy but unconventional oil has lower net energy and coal has high carbon intensity.
- Renewable energy wins on carbon intensity but lose on intermittency, energy density and breadth of use particularly for transport.
- Energy transitions are complex, costly and take decades.
• The oil shocks of the 1970s and early 1980s brought high oil prices that led to massive investment in oil exploration and production.
• That resulted in major discoveries in the North Sea, Mexico and Siberia that greatly over-supplied the market.
• High oil prices caused demand destruction and over-supply that burst the oil bubble. Oil prices did not recover for almost 25 years.
• Oil supply flattened after 2005 and prices increased leading to renewed E&P over-investment.
• Debt-fueled economic expansion in China and zero-interest rates after the 2008 Financial Collapse resulted in the 2nd oil bubble.
• This time, over-supply was caused by expensive unconventional oil and the bubble burst in mid-2014.
Economic Growth and The Real Cost of Oil

- U.S. GDP increases when oil prices are low and is flat when oil prices are high.
- 1986-2004 was a time of great expansion of the American economy.
- The average real price of oil since 2005 is 2.5 times higher than in the period 1986-2004. This reflects the increased cost of technology for unconventional oil.
- Even at today’s depressed oil prices, the real price of oil—$48 per barrel—is 40% higher than the in 1986-2004 of $34 per barrel.
- Economists and politicians cannot understand why the economy won’t grow but never consider the underlying cost of energy.
Why is Oil Such A Big Deal?

- Energy is the economy and oil is the master energy resource.
- The global economy requires massive surplus energy to extract natural resources, move them to be manufactured into products and transport them to be sold around the world.
- That global economy developed when oil prices averaged $34 per barrel.
- When oil prices increased to more than $85 per barrel after 2005, economic growth could not continue.
- No business can withstand a 2.5-fold increase in underlying cost and make a profit.
- Although oil prices are lower since the price collapse in 2014, they are still 40% higher than in the 1990s.
- The average break-even price for OPEC, tight oil, oil sands and deep-water plays is $82 per barrel. That means that production costs have not decreased and that oil is being produced well below its replacement cost.
- Economic growth is unlikely at these underlying energy costs.

Projected 2016 Break-Even Oil Prices for OPEC* & Unconventional Plays

Source: IMF, Rystad Energy, Suncor, Cenovus, COS & Labyrinth Consulting Services, Inc.

*IMF estimate that includes revenue to balance fiscal budgets of OPEC countries

Average Break-Even Price
Today is $82/Barrel
Concluding Observations

• Energy is the economy and oil is the master energy resource.
• Oil will continue to dominate the world energy landscape for decades because no other energy source can meet global needs.
• Unconventional oil does not offer a meaningful long-range alternative.
• While increased use of renewable energy is inevitable and desirable, it is not a satisfactory substitute for oil.
• A transition away from an oil-weighted energy supply will be complex, costly and lengthy despite supporting arguments or preferences.
• There is no clear way forward that includes sustaining current levels of energy use.
• The best path forward is to stop looking for improbable solutions that allow us to live like energy is still cheap, and find ways to live better with less.