CARBON MANAGEMENT TECHNOLOGY CONFERENCE

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The Energy Gap – How CO_2 Tertiary Oil Recovery will mark its place in the 21st Century

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Abstract

The Economic Sustainability of the 21st Century is based largely on how well Mankind can best fill its World Oil Energy needs. Back in 2005, the World was consuming around 80 million barrels of oil a day. Today, that number has risen to 86.8 million barrels a day. Based on straight line projections, the World would require between 160 million barrels a day and 200 million barrels a day in the year 2100 to support an ever increasing population growth.

In 2005, the World thought we were running out of oil. What we learned is that Peak Oil is a function of how fast we can keep up with technology to help "Fill" the "Energy Gap" that exists between Consumption and Energy Supply.

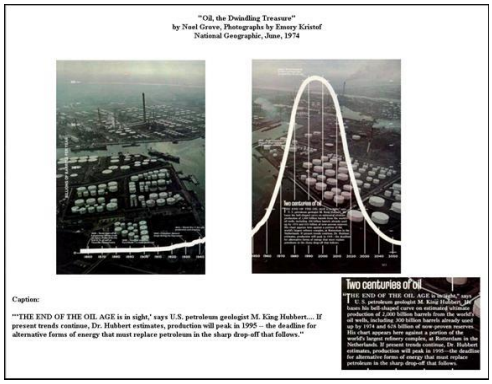
For the World to maintain Economic Sustainability in the 21st Century and lower our CO_2 impact on the Planet, we must at some point transition ourselves between a Hydro-Carbon Based Economy to a Hydrogen Based Economy without sacrificing all of what we have accomplished as a society to date. The Hydrogen Economy currently contains Wind, Solar, and Nuclear (Fission) that by themselves will add to the curve, but will still be small in comparison to our total energy needs. In addition, Hydrogen Power along with Nuclear (Fusion) are only in their infant stages of development and will not see any impact until the technology can compete economically with conventional sources of power.

To achieve Economic Sustainability requires filling the total area under the curve all the way through the 21st Century. "Gap Fillers" such as Conventional Oil Recovery (Primary, Secondary, and Tertiary) along with Unconventional Methods (Shale Oil and Shale Gas) will help fill our energy needs in the 21st Century.

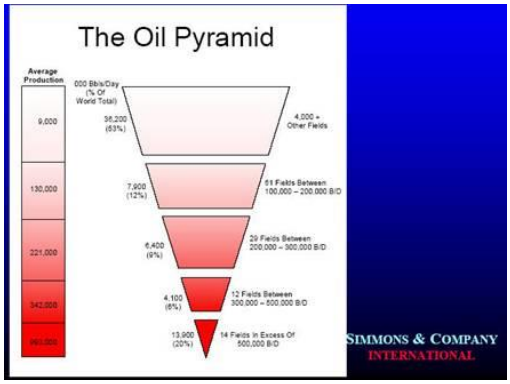
The question becomes "How will CO_2 for Enhanced Oil Recovery mark its place in the 21st Century?"

Peak Oil in 2005 – Fact or Fiction

M. King Hubbert was a distinguished scientist who published on many aspects of petroleum geology. In 1974, he predicted World Oil Supply would Peak around 1995 after he had successfully demonstrated he could predict the Continental USA Oil Production would Peak in 1970, in which it did, in a prediction he made in the 1950's. His methods still hold true today.



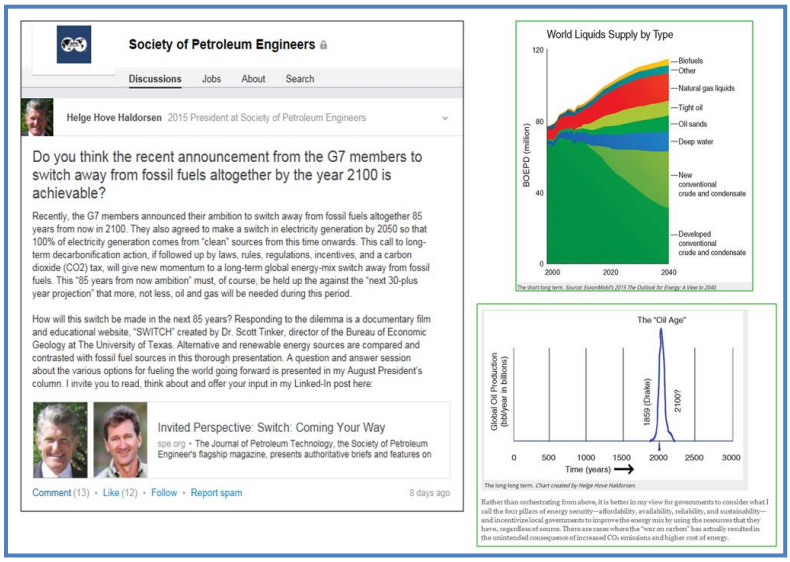
1974



2005

In 2005, Mathew Simmons, a respected Consultant in Houston, wrote the Book "Twilight in the Desert" which challenges whether or not Saudi Arabia can meet today's World Oil Demand. The World's Top 14 fields supply 20% of the World's Current Oil Producing Capacity. All these fields are 60 years or older and based on historical basin performance, are expected to decline sharply.

In 2015, Helge Hove Haldorsen, President of SPE, along with Scott Tinker, announced the G7 members' ambition is to "Switch" from a "Hydro-carbon" based economy to a total "Hydrogen" based economy within the next 85 years (2100).



http://www.switchenergyproject.com/

What that means is an end to the "Hydro-carbon" Revolution that has spurred both Domestic and International Economic Sustainability for over a hundred and fifty years.

The Energy Gap – Future Economic Sustainability through CO_2 Injection in Enhanced Oil Recovery Projects

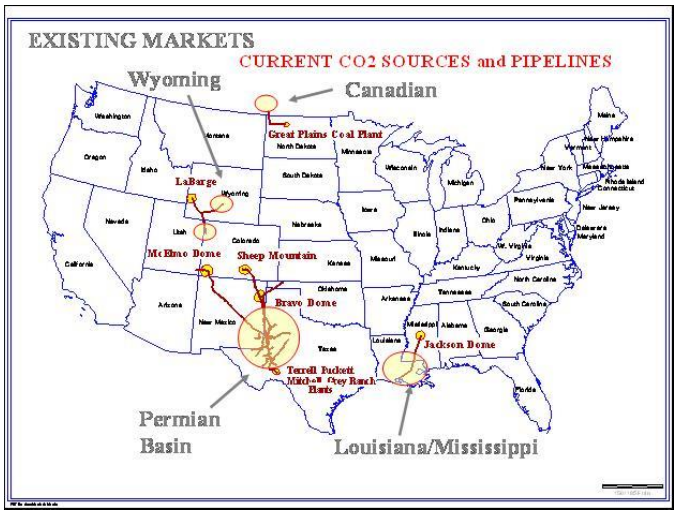
The objective of this paper is to present "The Energy Gap – Future Economic Sustainability through CO_2 Injection in Enhanced Oil Recovery (EOR) Projects". The paper addresses the current World Status Quo in regards to Future Oil Recovery and how Anthropogenic CO_2 from IGCC Plants, Refineries, and other plants will be used to fill the "Energy Gap" that exists between oil depletion of our current Hydrocarbon Economy and full implementation of the future Hydrogen Economy. New Technologies are currently being developed to fill this gap such as gas-to-liquids and Clean Coal Technology such as IGCC (Integrated Gasification Combined Cycle). IGCC technology converts biomass (Coal, Petroleum Coke, etc.) to a gaseous state whereby the gas can be reformed into various components, creating a variety of different products. Electricity has been the central driver for economic purposes. However, Ammonia and Urea can be output for the creation of fertilizer. The IGCC plant also outputs a high quality CO_2 stream at high pressure, which makes the CO_2 economically attractive when compared to Post-combustion CO_2 extraction stack gas processes. The availability of CO_2 at high pressure can "Revitalize the Oil Industry" in many Mature Basins around the World. Hydrogen is also output. In the future, the Hydrogen from these plants will provide the necessary fuel to drive the World from coal producing basins for the next thousand years.

Most countries in the World recognize CO_2 is a major contributing factor to Global Warming. In addition, most countries in the World also recognize we are running out of light oil and expect Saudi Arabia and other major Middle East countries to supply the World with enough oil to meet our needs until the Hydrogen Economy can take over. In 2005, the World contained approximately 1,106 BBO (Billion Barrels of Crude Oil) as reported by the BP Statistical Annual Review, World Oil, and Oil & Gas Journal. Of this total, two-thirds of the World's Proved Oil Reserves lie in the Middle East. In 2005, the World consumed around 80 MMBOPD (Million Barrels of Crude Oil a day) of which 10 MMBOPD was supplied by Saudi Arabia. Today, the World consumes around 86 MMBOPD (Million Barrels of Crude Oil a day). To maintain market share, Saudi Arabia increased oil production in 2014 to 11.5 MMBOPD, bringing oil price down to historically low levels less than $50.00 per barrel. The Saudis have also provided predictions for a sustained 10 MMBOPD or 12 MMBOPD case for years to come. However, as current World Oil Demand increases to 100 MMBOPD by 2030, the question becomes "How long can the current low oil prices be sustained?" And, "At what oil price will CO_2 for Enhanced Oil Projects and CO_2 for Sequestration Projects be profitable?" And, from competing technologies for funding, "At what Oil Price will "Horizontal Fracture Drilling and Heavy Oil Extraction Recovery Techniques come back to market?" In 2005, the World was concerned with the question of "Peak Oil" and its impact on global oil supply. Today, in the "New Millennium" the question becomes "What new technology will fill the energy gap? And, "What place will CO_2 for Enhanced Oil Recovery and CO_2 for Sequestration have to help fill the energy gap?"

During the past 43 years, CO_2 flood technology for enhanced oil projects evolved from a partially understood process filled with uncertainties to a process based on proven technology and experience. Many questions involved with CO_2 flooding have been thoroughly analyzed and answered. This knowledge is currently being used by a limited number of companies that actually know how to design, implement, and manage a CO_2 flood for long term profit. The purpose of this report is to help disseminate this knowledge to operating companies interested in EOR flooding or to CO_2 Sequestration Communities interested in storing CO_2 in EOR projects.

The Old Millennium - Enhanced Oil Recovery

With more than forty-three years of successful Enhanced Oil Recovery (EOR) Projects in the Permian Basin, Rocky Mountains, and Louisiana, Carbon Dioxide (CO_2) Flooding is a proven method for recovering oil not recoverable by either Primary or Secondary Recovery Methods. In the **Previous Millennium**, CO_2 was produced from Natural CO_2 Source Fields located in Colorado, Wyoming, New Mexico, and Louisiana and delivered to oil fields with over 4,500 miles of pipeline infra-structure. Today, the Permian Basin produces over 900,000 BOPD, of which 237,000 BOPD is a direct result of CO_2 Injection. Since 1972, over 1.1 Billion Barrels of Tertiary Oil have been recovered with CO_2 Injection.

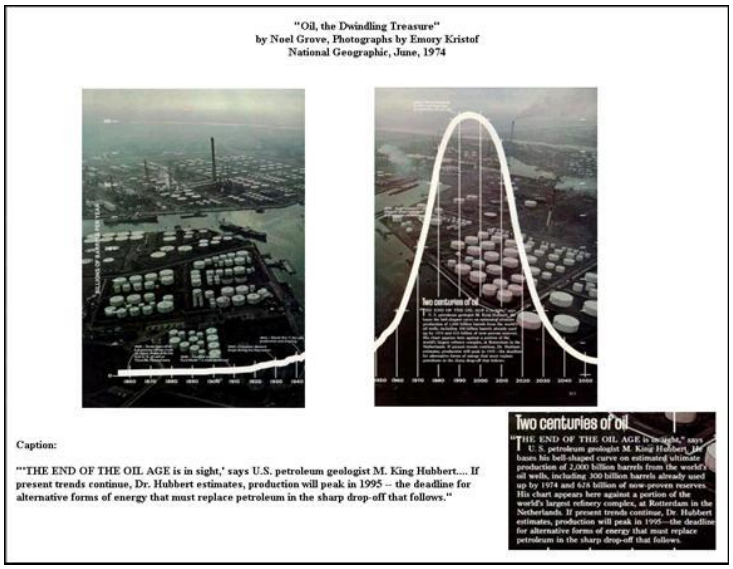


The New Millennium - Enhanced Oil Recovery and CO_2 Sequestration

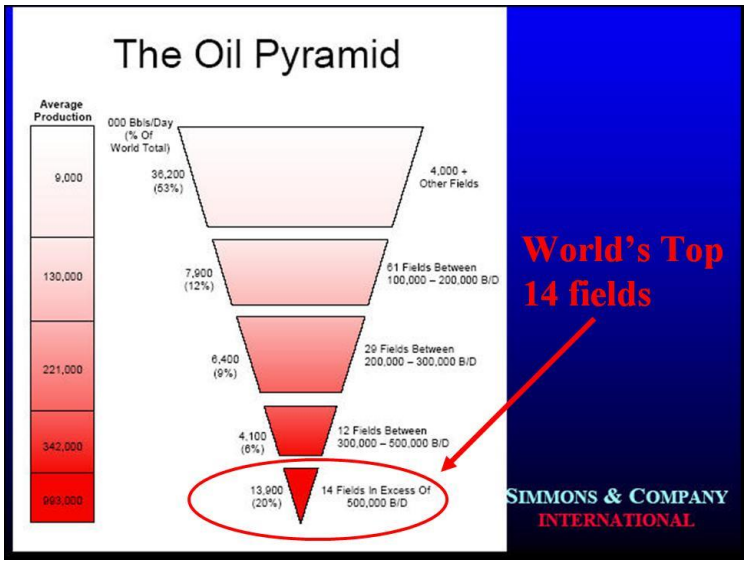
In the "**New Millennium**" CO_2 produced from IGCC Plants, Post Combustion, Oxy-fuel Plants, and other CO_2 Industrial Sources will provide the oil we so desperately need in tomorrow's hungry Energy Environment. The availability of CO_2 from these plants will provide the ability to "Revitalize" the Oil Industry in many Mature Oil Basins in the United States and throughout the World. Tertiary Oil Recovery using CO_2 will be used to recover an additional 10% to 26% of the Original Oil-in-Place, not recoverable with any other type of Oil Recovery Mechanism.

World Oil Reserve Determination

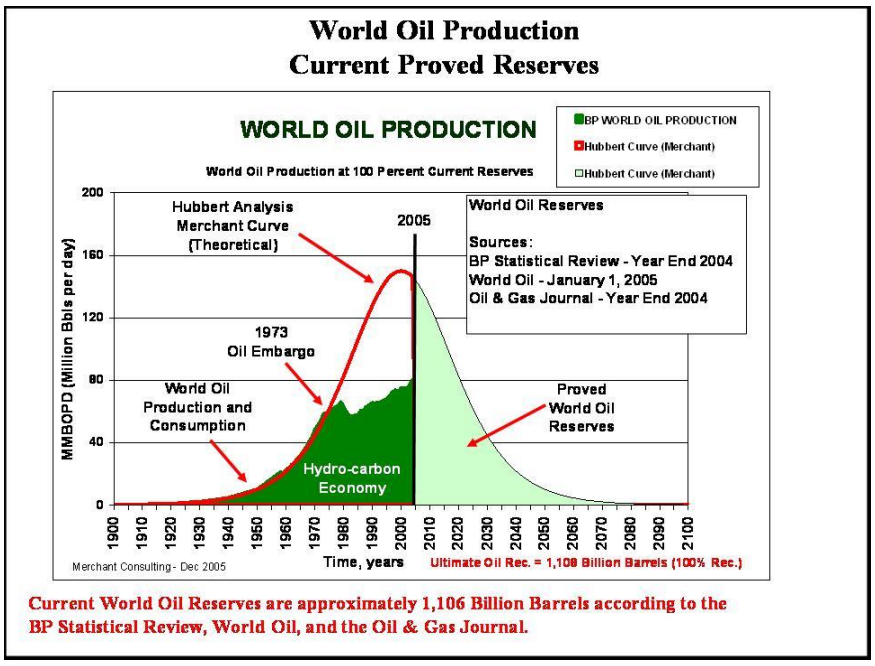
M. King Hubbert was a distinguished scientist who published on many aspects of petroleum geology. In 1974, he predicted World Oil Supply would Peak around 1995 after he had successfully demonstrated he could predict the Continental USA Oil Production would Peak in 1970, in which it did, in a prediction he made in the 1950's. His methods still hold true today.



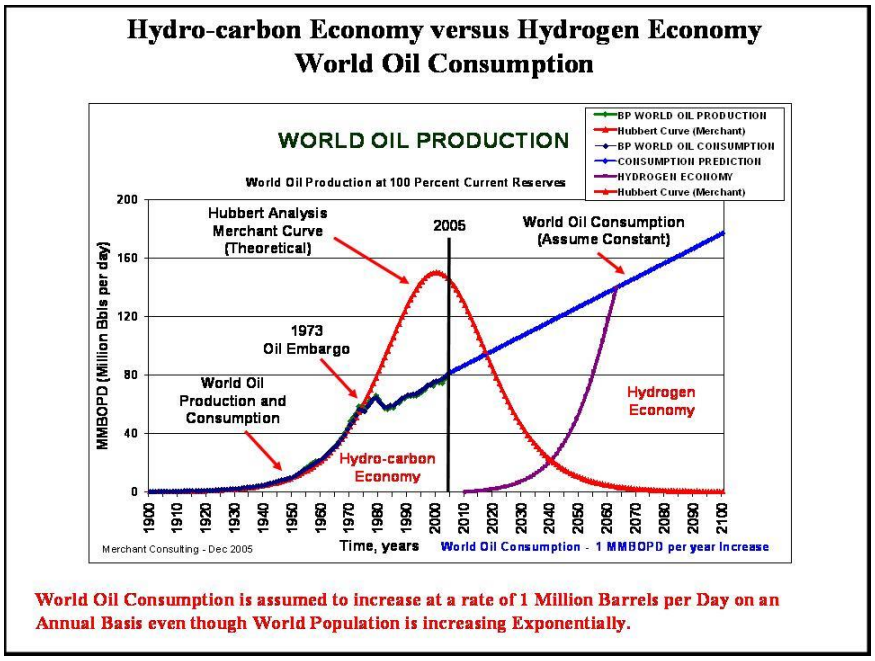
In 2005, Mathew Simmons, a respected Consultant in Houston, wrote the Book "Twilight in the Desert" which challenges whether or not Saudi Arabia can meet today's World Oil Demand. The World's Top 14 fields supply 20% of the World's Current Oil Producing Capacity. Based on historical basin performance, all these fields are expected to decline sharply.



The Top 14 fields (500,000+ BOPD) in the World produce 20% of the Worlds Current Oil Producing Capacity. These fields are 60 years or older. No new Giant Oil fields have been found in over 30 years. New Discoveries today are much smaller in size and rate when compared to these Giants.
A Hubbert Curve (Merchant) was developed based on historical World oil production and current proved reserves. Current World Oil Reserves at the end of December 2004 were approximately 1,106 Billion Barrels according to the BP Statistical Review, World Oil, and the Oil & Gas Journal.



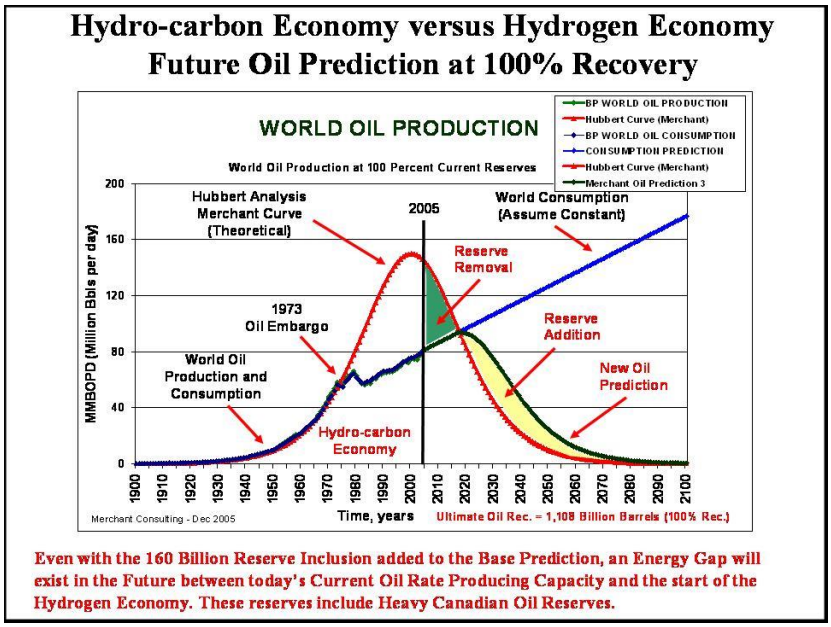
In 2004, Middle East Reserves represented 734 Billion Barrels of the total 1,106 Billion Barrels or 66 % of Total World Oil Reserves.

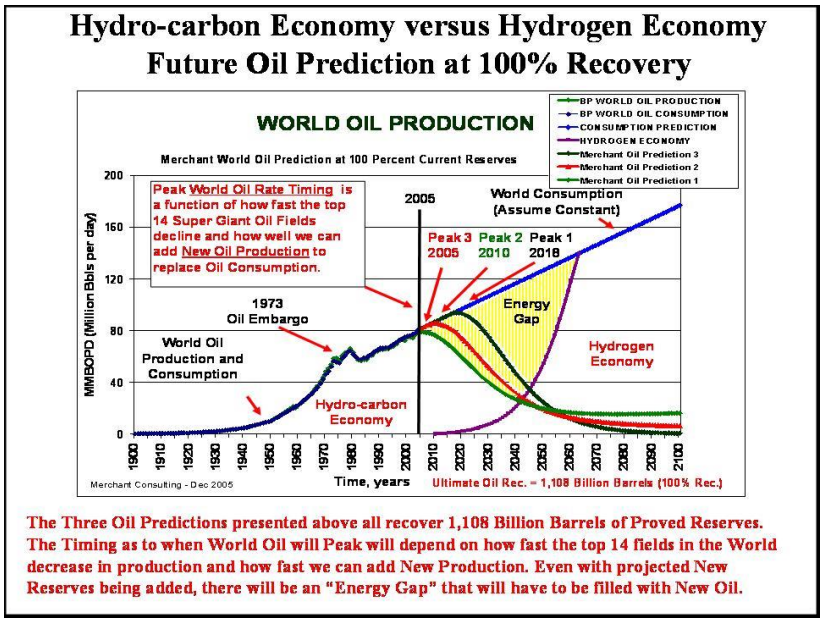


World Oil Consumption (Blue Curve) will continue to increase. Here we assume the Oil Rate Consumption will grow at a constant rate of 1 Million BOPD per year even though population is growing exponentially. After 10 years of history, the Oil Consumption Rate was 86 MMOBPD in 2014, which is still on trend with the original 2005 prediction. The Hydrogen Economy will have to grow quickly in order to fill the Energy Gap as oil rate falls in future years unless suitable alternative sources are found.

World Oil Rate Prediction

The ability to predict future World Oil Rate Performance depends on many factors, the first factor being the amount of oil remaining to be produced. Proved Oil Reserves by definition are estimated quantities that analysis of geologic and engineering data demonstrates with reasonable certainty are recoverable under existing economic and operating conditions. With the inclusion of Saudi Arabian Reserves, the World certainly contains a sufficient supply of oil reserves. Therefore, the World doesn't have a RESERVE SUPPLY problem. The second controlling factor is World Oil Producing Rate. The World's current Producing Oil Rate Capacity is controlled by the top producing fields in the World, along with new oil recovery technologies. To date, Oil Supply has been able to meet all our Consumption needs, new discoveries and technology was found to help fill the gap. A graph showing how the prediction was adjusted is shown below. Each of the three predictions is tied to current World Oil Reserves of 1,106 MMBO.

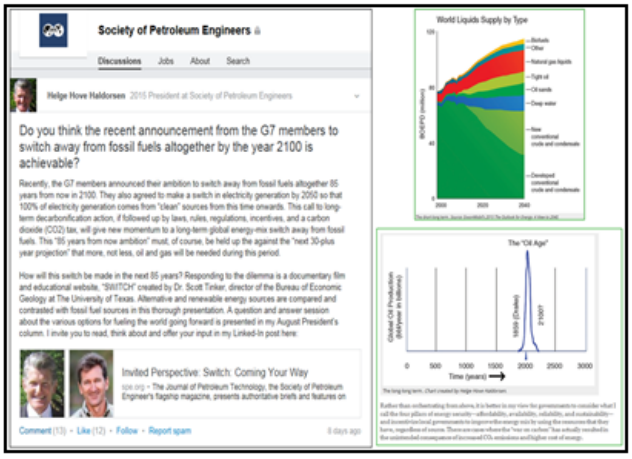




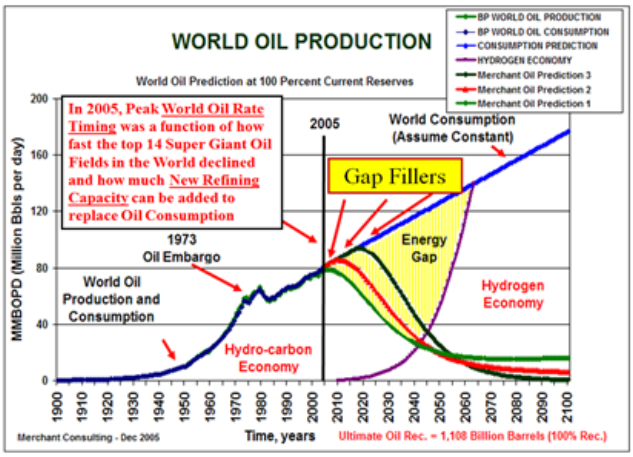
Where in the 21st Century will CO_2 for Tertiary Oil Recovery fit-in?
The Energy Gap:

For the World to maintain Economic Sustainability in the 21st Century and lower our CO_2 impact on the Planet, we must at some point transition ourselves between a Hydro-Carbon Based Economy to a Hydrogen Based Economy without sacrificing all of what we have accomplished as a society to date. The Hydrogen Economy currently contains Wind, Solar, and Nuclear (Fission) that by themselves will add to the curve, but will still be small in comparison to our total energy needs. In addition, Hydrogen Power along with Nuclear (Fusion) are only in their infant stages of development and will not see any impact until the technology can compete economically with conventional sources of power.

Merchant Consulting – "The Energy Gap – How CO_2 Tertiary Recovery will mark its place in the 21st Century"



Helge Hove Haldorsen and Scott Tinker – 2015 (Switch)



Hydrogen Economy – "Clean Air Environment"

1. Wind Power
2. Solar Power
3. Nuclear (Fission)
4. Nuclear (Fusion)
5. Hydrogen Power (Hydrogen Cars and Hydrogen Fuel Cells)
6. Tertiary CO_2 – EOR and CO_2 Sequestration
7. Mass Transportation (Automobiles poor means to move people)
8. Clean Coal Gasification (Pre-Post Combustion, Oxy-fuel)
9. Clean Natural Gas – (Conventional and Un-Conventional)
10. Biomass – Balance with Mother Nature
11. Nano Tech
12. Algae (Clean Fuels)

Gap Fillers

1. Primary Oil Recovery
2. Secondary Oil Recovery
3. Tertiary CO_2 - Conventional Tertiary Oil Recovery
4. Tertiary CO_2 - Residual Oil Zone (ROZ)
5. Tertiary CO_2 – Heavy Oil (14+ API)
6. Offshore – Shallow and Deep Water
7. Natural Gas (Conventional Reservoirs)
8. Liquefied Natural Gas (LNG)
9. Shale Oil (Wolfcamp, Eagle Ford, Bakken, Others)
10. Shale Gas (Marcellus, Barnett, Eagle Ford)
11. Coal to Gas, Coal to Liquids
12. Steam, Thermal, and MEOR (Bacteria)

To achieve Economic Sustainability requires filling the total area under the curve all the way through the 21st century. "Gap Fillers" such as Conventional Oil Recovery (Primary, Secondary, and Tertiary) along with Unconventional Methods (Shale Oil and Shale Gas) will help fill our energy needs in the 21st Century.

BP Statistical Review - 2015

The BP Statistical Review for Total Proved Reserves in 2015 demonstrates how the "Energy Gap" theory works when New Technologies are added to help "Fill the Gap". The report provides a basic understanding of how New Technologies including CO_2 for Enhanced Oil Recovery will mark its place in the 21st Century. Here, current high oil prices over the past ten years advanced Heavy Oil Sands development and Horizontal Frack Drilling. The result was an improvement in total proved reserves.

BP 2015 Statistical Review

Oil: Total proved reserves

	at end 1994	at end 2004	Inc/Dec over 1994 at end 2004	at end 2014	Inc/Dec over 2004 at end 2014	Share of total	R/P ratio	
	Thousand million barrels	Thousand million barrels	Thousand million barrels	Thousand million barrels	Thousand million barrels			
Total World	**1118.0**	**1366.2**		**1700.1**		**100.0%**	**52.5**	
Venezuela	64.9	79.7	22.9%	298.3	274.2%	17.5%	100.0	Orinoco Belt/Heavy Oil
Saudi Arabia	261.4	264.3	1.1%	267.0	1.0%	15.7%	63.6	
Canada	48.1	179.6	273.0%	172.9	-3.7%	10.2%	100.0	Canadian Oil Sands
Iran	94.3	132.7	40.8%	157.8	18.9%	9.3%	100.0	
Iraq	100.0	115.0	15.0%	150.0	30.4%	8.8%	100.0	
Russian Federation	115.1	105.5	-8.4%	103.2	-2.2%	6.1%	26.1	
Kuwait	96.5	101.5	5.2%	101.5	0.0%	6.0%	89.0	
United Arab Emirates	98.1	97.8	-0.3%	97.8	0.0%	5.8%	72.2	
United States	29.6	29.3	-1.1%	48.5	65.4%	2.9%	11.4	Horizontal Fracking
Libya	22.8	39.1	71.6%	48.4	23.6%	2.8%	100.0	
Nigeria	21.0	35.9	70.9%	37.1	3.3%	2.2%	43.0	
Kazakhstan	5.3	9.0	69.2%	30.0	233.3%	1.8%	48.3	
Qatar	3.5	26.9	667.6%	25.7	-4.3%	1.5%	35.5	
China	16.3	15.5	-4.5%	18.5	19.0%	1.1%	11.9	
Brazil	5.4	11.2	109.2%	16.2	43.7%	1.0%	18.9	
Angola	3.0	9.0	204.8%	12.7	40.2%	0.7%	20.3	
Algeria	10.0	11.8	18.2%	12.2	3.4%	0.7%	21.9	
Mexico	49.8	14.8	-70.3%	11.1	-25.2%	0.7%	10.9	
Ecuador	3.5	5.1	44.9%	8.0	58.1%	0.5%	39.4	
Azerbaijan	1.2	7.0	505.0%	7.0	0.0%	0.4%	22.6	
Norway	9.7	9.7	0.2%	6.5	-32.7%	0.4%	9.5	
India	5.8	5.6	-4.2%	5.7	3.2%	0.3%	17.6	
Oman	5.1	5.6	9.3%	5.2	-7.6%	0.3%	15.0	
Australia	3.8	3.9	1.9%	4.0	2.4%	0.2%	24.3	
Malaysia	5.2	5.2	-0.8%	3.8	-27.3%	0.2%	15.4	
Indonesia	5.0	4.3	-13.7%	3.7	-14.1%	0.2%	11.9	
Colombia	3.1	1.5	-52.9%	2.4	65.5%	0.1%	6.8	
Argentina	2.3	2.5	10.0%	2.3	-6.1%	0.1%	10.1	
Other Europe & Eurasia	2.3	2.2	-1.5%	2.0	-11.7%	0.1%	14.0	
Other S. & Cent. America	1.0	1.5	53.3%	0.5	-64.3%	*	9.6	

Gap Fillers

Note:

1. **Canadian Heavy Oil Sands Development Increase**
2. **Venezuelian Orinoco Heavy Oil Increase**
3. **United States Horizontal Fracking Increase**

Acknowledgements

I would like to express my gratitude to the members of the Carbon Management Technology Conference (CMTC) for allowing me the opportunity to be part of this CO_2 Conference. I would especially like to thank George Koperna of Advanced Resources International for his support in making this effort possible.

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