The Shift from the Static Hydrocarbon Model (Hubbert) to a Dynamic Model:
Re-Evaluating the Hubbert Curve and the Global Petroleum Revolution: A New Era*

Thomas Ahlbrandt¹

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Abstract

Why have the predicted global oil and natural gas shortages and demise of civilization by 2010 related to these vanishing supplies not occurred? The static view has created a pessimistic outlook based on historical perspective, such as the Hubbert curve analysis, which results in the inescapable and inevitable depletion that will result in catastrophic consequences for civilization. A new paradigm, a dynamic or petroleum system view, demonstrates a different and more optimistic hydrocarbon scenario. Evidence for this new view was initially demonstrated for natural gas. Natural gas was thought to be in critical shortage a decade ago, but is now plentiful in the U.S. and globally, so much so that gas prices are falling and the debate currently centers around a 100- or 200-year supply? This can be explained by a global revolution in petroleum and engineering sciences to explain a new paradigm which has completely altered how and where we find and develop petroleum. Most hydrocarbons (75% or more) have remained in the source rock (where thermally mature), yet developing them relies on new technologies not available until the last decade. The conventional (or static) approach to exploration is rapidly changing to the dynamic (petroleum system) approach, and this transformation is the most profound shift in the petroleum business in a century. Molecular-level studies of petroleum now abound, requiring wholly new techniques and evaluation parameters to determine economic viability. This in turn requires new research and educational pathways, and conversely some geosciences research areas will likely atrophy in the light of a new set of paradigms. This revolution has now extended to unconventional (also called resource) plays which are economically preferable to natural gas resource plays in the current market. The significance of an oil resource play is the Devonian Bakken play in the Williston Basin which in the past five years has catapulted the basin from the 98th ranked oil province in the world to 25th (and soon to 13th). Are we really in the sunset of the petroleum age or a new era?
Selected References


Charpentier, J.-C., 2005, four main objectives for the future of chemical and process engineering mainly concerned by the science and technologies of new materials production: Chemical Engineering Journal, v. 107, p. 3-17.


Thomasson, M.R., 2000, Petroleum geology; is there a future?: AAPG Explorer, v. 21/5, p. 3, 6, 9-10.

The Shift from the Static Hydrocarbon Model (Hubbert) to A Dynamic Model:
Re-Evaluating the Hubbert Curve and the Global Petroleum Revolution: A New Era

AAPG 31st Annual Leadership Days
August 13, 2011
Tulsa Geological Society
February 7, 2012

Thomas Ahlbrandt

Thanks to Pete McCabe; Pete Stark IHS; APEX Engineering
The Petroleum Revolution:

- The Static View—some history
- The Dynamic View—we are witnessing the paradigm shift from rocks to petroleum
- Demand constraints (OPEC got it right)
- Shift to unconventional natural gas and now oil resource plays
- All conventional petroleum systems have large unconventional for BCGA and BCOA—shortage of these professionals—requires new skills, training and technology
- Are we really running out of petroleum?
The Static View:

- Rock focused and Static (Plays)
- Technology is Reservoir focused
- Hydrocarbon composition in reservoirs is static; prediction of petroleum is commonly unexpected
- Reservoirs are on structure; off structure is less favorable
- Unconventional resources are curious developments but far less significant than conventional resources
- Source rocks are largely the expended remnants of an existing play
- Inescapable Conclusion That We are Near the End of Hydrocarbon Era
The Coming Oil Crisis?

“...the peak of production will soon be passed—possibly within three years—Dave White, Chief Geologist, USGS, 1919

“the peak of production will be reached in 1989, Campbell, 1989; prior to 2000”—Campbell, 1994; Duncan, 1997; “in 2004”—Campbell, 1997; “in 2010”, Campbell, 2000--subsequently very dire consequences—most people die, we return to caves-- “Olduvai Theory”
The Rise and Fall of the Hubbert Curve: Its Origins and Current Perceptions

Peter J. McCabe
Technocracy

A self-sufficient North American state
Abolish political system.
State run by scientists and engineers.
Abolish money – institute a system of energy unit certificates.
Abolish unemployment.
Abolish liberal arts education.

Statistical trends can be used to scientifically anticipate the future needs of society.
Those technocrats you've heard so much about are right here at the Morrison Hotel today. Howard Scott (left) is the kingpin; Dorothy Crozier is secretary, and M. King Hubbert is assistant director. (Chicago American photo.)
THEORETICAL CURVES SHOWING RELATION BETWEEN PRODUCTION, MAN-HOURS PER UNIT, AND TOTAL MAN-HOURS, FOR U.S.
While we do not know exactly how much oil remains undiscovered, we do know that it is a limited supply…Furthermore, the easy discoveries have already been made and only the difficult ones remain.”

It is certain that the production of oil will reach one or more peaks and finally decline.

The time of this decline in the United States is somewhat uncertain, yet it seems doubtful that it can be postponed any later than 1950.”

M. King Hubbert, 1938
Hubbert’s World Oil Supply Views Through Time

1,250 BBO
Hubbert, 1956

1,350 BBO—2,100 BBO
Hubbert, 1969
Predictions Based on the Static View

**Expert Estimates of World Ultimate Oil Recovery**

- **Fig. 1**
- **This study**
- **Oil company**
- **Other expert**

**Conventional Oil Only**

- Ignores: "Unconventional" enhanced recovery
- Tar sands
- Oil shales
- Gas liquefaction advances

**Giant Discoveries 400 Fields >0.5 BBO**

- **Fig. 3**
- **Trend**

**Trend heralds end of giant discoveries**

- 50% of all discovered to date came from GIANIT FIELDS

---

**Crude Oil Price 1987 $**

- **World War II**
- **End of 7 Sister Control**
- **Opec control**
- **Increase in perception of reserves, falling non Middle-East production, and falling exports, esp. USSR.**
- **Increasing probability**

**Campbell, 1989**

- **Projection of depletion of remaining oil at present rate**
- **Scale 10 BBC**
- **OIL PRODUCTION**
- **NORTH AMERICA**
- **USSR & OTHER COMMUNIST**
- **CHINA**
- **OTHER**
- **M. EAST**
- **SAUDI ARABIA**
- **IRAQ**
- **KUWAIT**
- **IRAN**
- **UK**
- **MEXICO**
- **KENYA**
- **SOUTH AFRICA**
- **50% of all discovered to date came from GIANIT FIELDS**

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**Current Production**
The Oil Crisis Causes the Decline of Many Things

Rock Music Quality vs. US Oil Production

- Songs in "Rolling Stone 500 Greatest Songs of All Time"
- US Crude Oil Field Production, Lower 48 States (1,000 barrels)

Rolling Stone Magazine, EIA, 2008
Hubbert’s U.S. Production Peaks

Oil (Lower 48)
- Actual Production
- Hubbert's 200 \times 10^9 \text{ BBL} oil Ultimate Production Curve
- Hubbert's 150 \times 10^9 \text{ BBL} oil Ultimate Production Curve

Gas (Lower 48)
- Actual Consumption
- Actual Production
- Hubbert's 1290 \times 10^{12} \text{ SCF} gas Ultimate Production Curve

Charpentier, 2005

2010 Production, EIA
U.S. Oil Production is Increasing
U.S. Gas Production is Increasing
2008 Data Show Problems with Previous Hubbert Curves for World Oil Producing Resource Now 2,860 Billion Barrels

Al-Husseini, 2009
2009 View - World Producing Resource

WORLD OIL PRODUCTION (Includes Condensates and NGL, BP, 2008)

- 1974 Iran Peak
- 1980-1986 Iran-Iraq War
- 2007 at 29.76 Gb/y (81.5 Mb/d)
- 2016 at 31.3 Gb/y (85.7 Mb/d)
- 2030 at 28.5 Gb/y (78.0 Mb/d)

Price of Oil (2007 Dollars)

Al-Husseini, 2009
Recognition of the Effects of Secondary Recovery

Logistic growth curves of cumulative production and their derivatives which give the rates of production

Hubbert, 1959

(a) single-cycle curve

(b) multiple-cycle curve
The Dynamic or System View:

- Fluid focused and unstable (dynamic) (Petroleum Systems)
- Basins are complex non-linear, dynamic systems trying to maintain equilibrium but are thrown in and out of thermodynamic and pressure equilibrium
- Petroleum is constantly in a state of flux in response to burial, uplift and is essentially responding to changing PVT conditions
- Source rocks are the critical element and are cyclic (rejuvenated) and may be the reservoir (self-containing)
- Unconventional and conventional petroleum are linked; very large resources actually “kitchen” related, off structures
- Systems have life cycles — young, middle-aged and old, which link conventional and unconventional resources
**PRODUCTION**

Hubbert Curve—peak production marks midpoint of depletion

- **TIME**
- **50%**

**PLATEAU CONCEPT**

- Reserve Growth
- Additions to inventory as needed, through investment
- Slow Decline

- **Initial Development**
  - 3-5 Years

- 20-25%

- **Plateau Production**
  - 6-10 Years or Longer
    - E.G. North Sea
    - PV ~ 20-25 Years

- **Depletion**

Ahlbrandt, 2005
Global Resource Estimates from Total Petroleum Systems

Thomas S. Ahlbrandt, Ronald R. Charpentier, T.R. Klett, James W. Schmoker, Christopher J. Schenk and Gregory F. Ulmishek
Comparison of World Oil and Natural Gas Resource Endowment Estimates

Ahlbrandt et al., 2005

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**Trillion Barrels of Oil (TBO) or equivalent (TBOE)**

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<tr>
<th>Year</th>
<th>Source</th>
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* gas estimates

(H) - high estimate

(L) - low estimate

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Ahlbrandt et al., 2005

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**USGS, 2000**
Oil Reserve Additions: Reserve Growth vs. Undiscovered

New-field discoveries
Reserve growth of discovered fields

Klett et al., 2005
Natural Gas Reserve Additions: Reserve Growth vs. Undiscovered

Klett et al., 2005
Annotated

- Tupi: 6B
- Jupiter: 4B
- Iara: 3.5B
- Guara: 1B
- Azulao: 1B
- Nanpu: 1.7B
- Longgang: 1.5B
- Yoloten-Osman: 24 B
- Kish 2: 6B
- Umm Niqa: 2B
- Sefid Zakur: 1.5B
- Arabiya: 1B
- Bakken: 4B+
- DW Wilcox: > 3 B
- Shale gas: ~ 130B?
- 5,000 MMboe
- 1,000 MMboe
- 500 MMboe
- 100 MMboe

IHS 2009

140 BBO Discovered in Last Decade—Not Yet Producing

- Tupi 6525
- Jupiter 4147
- Iara 3500
- Guara 1083
- Azulao 1167
- DW Wilcox 3 -15 Bboe
- Nanpu 1748
- Longgang 1416
- Kish 2 6180
- Umm Niqa 2119
- Sefid Zakur 1489
- Arabiya 1168
- Yoloten-Osman 180 Tcf 2008!

Shale gas ~ 775 TCF?

IHS 2009
World Oil Reserves at New High
U.S. Oil Production is Increasing
~44 Year Supply at current consumption

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<th>Percent of world total</th>
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<td>259.9</td>
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<td>World Total</td>
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Source: Oil & Gas Journal.
World Gas Reserves at New High
~53 Year Supply at Current Consumption

Sources: International Petroleum Encyclopedia and Oil & Gas Journal.

Source: Oil & Gas Journal.
What Is Happening Now?
The Inversion of the Hydrocarbon Resource Pyramid

Conventional

Unconventional

Increasing Technological Capability

(After Thomasson, 2000)
U.S. Natural Gas Predictions in 2001

29.5 TCF Discovered in 2008 - EIA
20.5 TCF Used 2008
Natural Gas Imports & Exports, 2001 (BCF)

Japan: 66

Trinidad and Tobago: 98

Algeria: 65

Australia: 2

LNG

LNG

Nigeria: 38

Oman: 12

Qatar: 23

Trinidad and Tobago: 98

DOE, 2002
Shale gas and Alaska production offset declines in supply to meet consumption growth and lower import needs.

Source: Annual Energy Outlook 2010
The Perception Change in One Year—2009 to 2010

EIA, 2011
Global Gas Resources
Conventional & Unconventional

Conventional Gas Resources Compared with Potential Resources of Continuous-Type Gas Deposits

- **Cumulative Production**
- **Remaining Recoverable**

**In Place “Estimates”**

- **16,000 tcf**
- **9,250 tcf**
- **7,000 tcf**

**Trillion Standard Cubic Feet**

- **Conventional (“Discrete”) Gas**
- **Coal-bed Gas**
- **“Tight” Sand / Basin-Centre Gas**
- **Shale Gas**
- **Gas Hydrates**

- Resource growth and yet-to-find: 43%
- Remained discovered: 57%

Assumes 10% RF for countries for which only in place resource estimates available

Assumes 2% RF for oceanic and 5% RF for permafrost resources

Kawata SPE 68755

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Hart's DUG, April 8, 2009
Resource Plays Turn From Gas to Oil

- Resource plays are widely distributed; i.e., many jobs and political support
- Gas abundance (reserves per year 4 times oil adds) now disrupts LNG and long distance markets—the debate is now over a 100 or 200 year U.S. supply
- Three times the number of gas wells are being drilled in the U.S. compared to oil—the gas revolution has been occurring over the last decade
- Gas prices fall dramatically as gas supply increases ($11 to $4/Mcf or lower)
- On a BTU basis, oil is now worth about several times more than gas and this is causing an expansion of oil resource plays (Bakken, Eagle Ford, Niobrara, Monterey)
Shale Oil Historical Back Drop

- Same concept as Shale Gas except the organic material is only partially cooked
- Same drilling and completion concept
  Rubblize the rock to increase rock volume connected to the wellbore
  Very low permeability can be produced economically
- 75% of generated oil is still located in the source rock

EOG, 2009
A Prospective Depletion Curve for the World's Conventional and Non-Conventional Oil to 2080

Odell, 1998
The Williston Basin was 98th Oil Province in the World, Now it is the 50th (in 5 years) due to the Bakken Oil Resource Play and is estimated to go to 1 million barrels of oil per day soon, 25th or better in the world.
2008
500-750 Bopd
2009
1500-3000 Bopd
2010
4000-5000+ Bopd

APEX Engineering, 2010
New Technologies Bring Change

- Drilling and Completion Procedures
- Petroleum System Modeling The vocabulary and concepts have shifted to the source rocks—seems simple—it is not
  - Reservoir Scales (nanodarcies vs. millidarcies)
  - TOC’s, Brittleness (Poisson’s ratio, Young’s Modulus) much more laboratory focused, pressure regimes and identification
  - New training is required for modern resource plays
Conclusions

- We know and have successfully developed most technology for the Static Petroleum Resources
- We are just beginning to develop technology and get a glimpse of the Dynamic Petroleum System View
- Each view drives your effort where you explore, and the Paradigms of Petroleum one believes to be true
- Are we really at the end of petroleum in a static world or the beginning of a revolution into a dynamic system view first in natural gas and commencing in oil?

140 BBO found but not developed in last decade; World Oil and Gas Reserves at all time highs, U.S. production is rising

- The New Petroleum ERA began in earnest about 25 years ago for natural gas and about 5 years ago for oil and their effect is changing if not dominating the U.S. industry (e.g., Mesoproterozoic—1.4 Ga)
- Demand, price maintenance and qualified professionals are the primary concerns