Unconventional Fuels and The “Shale Revolution” Myths and Realities

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Points to be covered:

- The ENERGY SUSTAINABILITY DILEMMA

-Unconventional Fuels, the SHALE REVOLUTION and CONVENTIONAL WISDOM

-SHALE GAS and TIGHT OIL – A look at the fundamentals with examples from major U.S. Plays and a look at LNG export plans in Canada

- IMPLICATIONS for long term energy sustainability
World Primary Energy Consumption*: 1965-2011

By Region

- Asia Pacific
- Africa
- Middle East
- Former Soviet Union
- Europe
- S. & Cent. America
- North America

By Fuel

- Hydro
- Nuclear
- Coal
- Gas
- Oil

227% increase in World Consumption 1965-2011; 2011 increase = 2.5%

Highest growth in 2011 = Asia Pacific 5.4%; Highest Fossil Fuel Growth = Coal 5.4%

*Excludes traditional biomass

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World Per Capita Annual Primary Energy Consumption by Fuel 1850-2011

- **Oil**: 89% Non-Renewable, +809%
- **Gas**:
- **Coal**:
- **Wood**:
- **Hydro**

World Population, Per Capita and Total Energy Consumption, 1850-2011, as a Percentage of 2011 Levels

Population

Per Capita Consumption

Total Consumption

5.5 times

9.1 times

50 times

89% Non-Renewable
World Population, Per Capita and Total Energy Consumption, 1850-2035, as a Percentage of 2011 Levels

Population

Per Capita Consumption

Total Consumption

% of 2011 Population

% of 2011 Per Capita Consumption

% of 2011 Total Consumption

Year

Year

Year

6.8 times 1850
2011 +24%

10.2 times 1850
2011 +13%

70 times 1850
2011 + 44%

88% Non-Renewable


(data from Arnulf Grubler, 1998; 

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Global Primary Energy Consumption by Source in 2011
A Comparison to Total Non-Hydro Renewable* Energy

Total Energy by Source
12275 MTOE

Renewable Energy by Source
195 MTOE

- Biomass-electric
- Wind
- Solar
- Geothermal

Percent of Total Consumption

<table>
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<tr>
<th>Year</th>
<th>Biomass</th>
<th>Wind</th>
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<th>Geothermal</th>
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*excluding biomass burned for non-electric uses

(data from BP Statistical Review of World Energy, 2012)

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Cumulative Consumption of Fossil Fuels Since 1850 through Yearend 2011

90% of Fossil Fuels have been consumed Since 1938

50% of Fossil Fuels have been consumed Since 1986

3083 Billion barrels Oil Equivalent

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Projected Consumption of Fossil Fuels Through 2035 as a Percentage of Yearend 2011 Cumulative Consumption

Cumulative % Consumed since 1850

- Gas
- Oil
- Coal

Relative to 2011


© Hughes GSR Inc, 2013

Projected Consumption of Fossil Fuels Through 2035 as a Percentage of Yearend 2011 Cumulative Consumption

CONSUMED to Date
3082 Billion Barrels Oil Equivalent

NEEDED
71% more or an Additional 2190 Billion Barrels Oil Equivalent to Cover Next 24 years

Oil Equivalent

5272 Billion barrels
There is a Great Inequity in Energy Consumption Worldwide

Per Capita Energy Consumption by Country and Region, 2010

22% of World Population
(1.5 Billion People)

78% of World Population
(5.4 Billion People)

OECD four times
Non-OECD
18% of population

Non-OECD
82% of population

© Hughes GSR Inc, 2011

(B.P. Statistical Review of World Energy, 2011; U.S. Census Bureau, 2011)
There is a Great Inequity in Energy Consumption Worldwide

Per Capita OIL Consumption by Country and Region

© Hughes GSR Inc, 2011

(B.P. Statistical Review of World Energy, 2011; U.S. Census Bureau, 2011)
EIA World Oil Production Estimates from 2000 through 2011 compared to Actual Production

Million Barrels per Day

Year

Net Energy Available for Useful Work versus Energy Return on Investment

- Energy Yield %
- Energy Input %

- Old conventional oil (100:1)
- New conventional oil
- Mineable Tar sands
- In Situ Tar sands
- Biodiesel from Soybeans
- Ethanol from Corn

Energy Returned for Useful Work

Energy Invested

Percentage of Total Energy Expended vs. Energy Return on Investment Ratio
In Situ Oil and Gas Resources versus Supply

Conventional vs. Unconventional

Increasing Effort (Energy IN Vs Energy OUT)
Decreasing Concentration

>90% of World’s Production

Price/Technological Limit to access

Extra-Heavy Oil
Shale Oil
Tar Sands
Oil Shale
Gas to Liquids
Coal to Liquids

Tight Gas
Coalbed Methane
Shale Gas
In Situ Coal Gasification
Gas Hydrates

In Situ Resources
Wabiskaw-McMurray Tar Sand Deposit

Bitumen pay thickness (m)
- 70 - 100
- 60 - 70
- 50 - 60
- 40 - 50
- 30 - 40
- 20 - 30
- 10 - 20
- 1.5 - 10

30 miles
Forecasts of Oil Sands Bitumen Production from Alberta ERCB 2005-2012 and NEB 2011 for period 2005-2021

Average Growth Rate During Boom Years of the Last Decade
Statoil Shelves Canadian Oil-Sands Project, Citing Costs and Access

Total shelves $11-billion Alberta oil sands mine

CARRIE TAIT
CALGARY — The Globe and Mail
Published Thursday, May 29 2014, 3:49 PM EDT
Last updated Friday, May 30 2014, 6:09 AM EDT

Alberta’s oil sands among riskiest energy plays in the world, report says
U.S. Oil Shale Deposits Allegedly 4.2 Trillion bbls In Situ
Maximum production 18,400 barrels per day in 1980 (.02% of world petroleum liquids consumption)
Methane Hydrate Resource Pyramid Illustrating the Rock Types with the Most Potential at Top

- Arctic sands
- Marine sands
- Non-sandstone marine reservoirs, including fractured fine-grained
- Vent site related massive hydrate
- Marine fine-grained
Median Estimate of World In Situ Methane Hydrate Resources (Total = 43,311 tcf)

- U.S.A.: 7013
- Canada: 2228
- Former Soviet Union: 3829
- North Africa: 218
- East Africa: 1827
- West & Central Africa: 3181
- South Africa: 3139
- Latin America & Caribbean: 4940
- Southern Ocean: 3589
- Arctic Ocean: 6621
- Central & East Europe: 13
- West Europe: 1425
- Other Asia Pacific: 1654
- Oceania: 811
- Japan: 212
- South Asia: 557
- India: 933
- East Asia: 371
- China: 177
- Middle East: 573
Other Unconventional Sources

• **Coalbed Methane** – Some production but restricted to limited economic basins – San Juan (first), Powder River, Black Warrior, Horseshoe Canyon (Canada) and other minor producers.

• **Underground coal gasification** – Very limited production – mainly Uzbekistan.

• **Coal-to-liquids** – Very limited and forecasts are being reduced.

• **Gas-to-liquids** – Very limited with no scaleup in forecasts.

• **Enhanced oil recovery** – has been done for decades but is a cleanup operation, with low rates – not a significant new high-rate source.
Which Brings Us to “The Shale Revolution”
The Shale Revolution

- Began with the application of high-volume, multi-stage, hydraulic-fracturing of shale for gas in the Barnett Field of eastern Texas.

- Now accounts for 42% of U.S. gas production.

- The technology was first applied to oil extraction in the Bakken Field of Montana and North Dakota.

- Allowed a 50% increase in U.S. oil production since 2005, reversing the long standing decline from peak U.S. production in 1970.

- Nearly 35% of upstream investment in lower 48 exploration and development in 2013 was applied to the Bakken and Eagle Ford tight oil plays.
Conventional Wisdom

- The United States is on the verge of Energy Independence thanks to the “SHALE REVOLUTION”.
- Shale Gas production will continue to grow for the foreseeable future (2040 at least) and prices will remain below $5.00/mcf for the next 10 years and below $6.00/mcf until 2030.
- Shale Gas can replace very substantial amounts of oil for transport and coal for electricity generation.
- The way is clear for U.S. LNG exports to monetize the shale bounty. Large scale LNG exports of shale gas from Canada will provide a bonanza.
- Tight Oil will allow U.S. production to exceed that of Saudi Arabia and U.S. imports will shrink to zero.

- **Shale Gas**: (25% of 2040 Production)
  - 67% increase in production by 2040

Other Sources:
- **LNG Imports**
- **Canada Imports**
- **Alaska**
- **Coalbed Methane**
- **Tight Gas**
- **Associated**
- **Conventional**
- **Offshore**

**U.S. domestic consumption**

**Exports** (15% of Production)

Data from EIA Annual Energy Outlook 2014, Tables 13 and 14, [http://www.eia.gov/forecasts/aeo/er/excel/yearbyyear.xlsx](http://www.eia.gov/forecasts/aeo/er/excel/yearbyyear.xlsx)

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U.S. Shale Gas Production Estimates by Play – June 2014

Top 2 Plays = 51% of Total
Top 5 Plays = 82% of Total

Marcellus, Barnett, Eagle Ford, Haynesville, Fayetteville, Woodford, Bakken, Antrim, Rest of US

(data from EIA current to June 2014)
The Shale Play Life Cycle

- Discovery followed by leasing frenzy.

- Drilling boom follows to meet “held-by-production” lease requirements.

- Sweet spots identified, targeted and drilled off.

- Gas production rises rapidly and is maintained for cash-flow despite potentially uneconomic full-cycle costs.

- Sweet spots become saturated and well quality and field production decline.

- Plays like the Haynesville become middle aged after just five years.
Barnett Gas Production and Number of Producing Wells, 2000-2014

- Gas Production (Billion cubic feet per day)
- Number of Wells

Peak December 2011
Production Down 18%

© Hughes GSR Inc, 2014
(data from Drillinginfo, August, 2014, three month trailing moving average)
Barnett Gas Production by Well Type, 2000-2014

- Peak December 2011
- Production Down 18%
- Modern Fracking Begins

(data from Drillinginfo, August, 2014, three month trailing moving average)
Barnett Average Gas Well Decline Curve

First Year = 56%
Second Year = 30%
Third Year = 22%
Fourth Year = 24%

3-Year Decline = 76%

Gas Production (Thousand cubic feet /day)

Months on Production

(data from Drillinginfo, February, 2014)
Barnett Field Decline – Gas Production from all Wells Drilled Prior to 2012

First Year Field Decline = 27%

© Hughes GSR Inc, 2014
(data from Drillinginfo, February, 2014)
Average First Six Month Production (Thousand cubic feet/day)

**Barnett Well Productivity – Average Production Rate over First Six Months, 2009-2013**

Peak well productivity 2011

Down 17% from 2011 peak

(data from Drillinginfo, February, 2014)
Barnett Cumulative Gas Production By County

Cumulative Production (Trillion cubic feet)

- **Tarrant County**: Peak 2012 Down 20%
- **Johnson County**: Peak 2009 Down 43%
- **Denton County**: Peak 2012 Down 16%
- **Wise County**: Peak 2013 Down 7.5%
- **Parker County**: Peak 2008 Down 18%
- **Other 19 Counties**: Peak 2012 Down 5.6%

Total Recovery to Date = 15.6 Tcf

Top County = 32% of production
Top 2 counties = 56% of production
Top 5 counties = 92% of production

(data from Drillinginfo, August, 2014)
Barnett Average Well Decline Curves by County

Average 3-Year Decline = 76%

© Hughes GSR Inc, 2014
Barnett Gas Production Forecast in various Drilling Rate Scenarios through 2040

Peak 2012 Without Quintupling Drilling

Peak 2016 if Drilling rate Quintuples

Recovery to date 15.6 tcf
Ultimate Recovery 35-47 tcf by 2040

Gas Production (Billion cubic feet per day)

Number of Producing Wells

© Hughes GSR Inc, 2014
(data from Drillinginfo, August, 2014,
Haynesville Gas Production and Number of Producing Wells, 2007-2014

Peak January 2012
Production Down 46%

© Hughes GSR Inc, 2014
(data from Drillinginfo, August, 2014, three month trailing moving average)
Type Gas Well Decline Curves for Top Five Shale Gas Plays Constituting 74% of Shale Gas Production

3-Year Decline
- Haynesville = 89%
- Marcellus = 79%
- Barnett = 79%
- Fayetteville = 80%
- Woodford = 77%

Average 3-Year Decline = 84%

(data from Drillinginfo, March, 2013)
Overall Field Decline for Top Five Shale Gas Plays based on Production Decline from pre-2012 Wells

Field Decline (per year)

- Haynesville = 47%
- Marcellus = 29%
- Barnett = 28%
- Fayetteville = 35%
- Woodford = 28%

Average Field Decline = 37%
U.S. Shale Gas Production by Play, 2000-2014

5 Legacy Plays Collectively Peaked in August 2012 and are now down 21%

Current Production
Top 2 Plays = 48%
Top 5 Plays = 78%

Marcellus
Eagle Ford
Bakken
Utica
Rest of US
Antrim
Woodford
Fayetteville
Barnett
Haynesville

© Hughes GSR Inc, 2014
(data from EIA Natural Gas Weekly Update, September 24, 2014)
Most Likely Drilling Rate Gas Production from Major Shale Plays through 2040

- Plays in this Report
  - Recovered to date: 47.5 tcf
  - Recovery 2014-2040: 244.2 tcf

- EIA other plays
  - Forecast 2014-2040: 50.8 tcf

- EIA Forecast is an Additional 135.8 tcf by 2040 from Plays in this Report

- EIA AEO2014 additional for report plays

- EIA AEO2014 forecast for report plays

- EIA All shale plays Weekly Update

- EIA AEO2014 Forecast for All Plays

Peak 2016

(data from Drillinginfo, September, 2014, © Hughes GSR Inc, 2014)
Wood Mackenzie 2014 Projection of U.S. Shale Oil, 2010-2030

Potential upside to US tight oil production

Production (0,000 b/d)

Source: Wood Mackenzie
U.S. Crude Oil Production Projection by Source and Region 2010-2040 (EIA 2014 Reference Case)

- Alaska
- Onshore EOR
- Onshore Shale/Tight Oil
- Lower-48 Onshore Conventional
- Lower-48 Offshore

Peak Production 2019

© Hughes GSR Inc, 2014

(data from EIA Annual Energy Outlook 2013)
U.S. Tight Oil Production Estimates by Play – May 2014

Top 2 Plays = 62% of Total
Top 5 Plays = 84% of Total

Permian Basin Plays (TX & NM)

© Hughes GSR Inc, 2014
(data from EIA current to May 2014)
Bakken Oil and Gas Production in North Dakota and Montana and Number of Producing Wells, 2003-2014

© Hughes GSR Inc, 2014
(data from Drillinginfo, September 2014, three month trailing moving average)
Bakken Average Oil Well Decline Curve

First Year = 72%
Second Year = 34%
Third Year = 22%
Fourth Year = 17%

3-Year Decline = 85%

Oil Production (Barrels per day)

© Hughes GSR Inc, 2014
(data from Drillinginfo, April, 2014)
Bakken Field Decline – Oil Production from all Horizontal Wells Drilled Prior to 2013

First Year Field Decline = 45%

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(data from Drillinginfo, April, 2014)
Bakken Horizontal Well Productivity – Average Production Rate over First Twelve Months, 2009-2013

Average First Twelve Month Production (Barrels/day)

Year

2009 2010 2011 2012 2013

Up 3% from 2011

Bakken Average
Bakken Sweet Spot Well Pattern through March-2014

© Hughes GSR Inc, 2014

(data from Drillinginfo, March, 2014)
Bakken Cumulative Oil Production By County June 2014

Total Recovery = 1.16 billion barrels

Top 2 counties = 51% of production
Top 4 counties = 79% of production

Past Peak
Growing

Peak 2013 Down 8%
Peak 2006 Down 81%

Cumulative Production (Million Barrels)

County

Mountrail
2030 Wells

McKenzie
2063 Wells

Dunn
1378 Wells

Williams
1394 Wells

Divide
542 Wells

Richland
611 Wells

Other 9 Counties
763 Wells

Vertical Wells
444 Wells

© Hughes GSR Inc, 2014
(data from Drillinginfo, September, 2014)
Bakken Average Oil Well Decline Curves by County

- Mountrail County
- McKenzie County
- Dunn County
- Williams County
- Richland County
- Divide County
- Richland County
- Other 9 Counties

Average 3-Year Decline = 85%

© Hughes GSR Inc, 2014
(data from Drillinginfo, April, 2014)
Bakken Oil Production Risked Forecast in various Drilling Rate Scenarios through 2040 assuming 3 wells/section

- Peak 2015 with gradual drilling decline
- Peak 2016 with 50% drilling rate increase

Recovery to date 1.16 Bbbl
Ultimate Recovery 6.6-7.3 Bbbl by 2040

© Hughes GSR Inc, 2014
(data from Drillinginfo, September, 2014)
Eagle Ford Play Wells by Initial Productivity (highest month production)
Eagle Ford Oil and Gas Production and Number of Producing Wells, 2007-2014

- **Gas Production**
- **Oil Production**
- **Number of Wells**

(data from Drillinginfo, September 2014, three month trailing moving average)
Eagle Ford Liquids Production Forecast in various Drilling Rate Scenarios through 2040 assuming 6 wells/section

Peak 2018 if Drilling rate Grows 13%

Peak 2017 With gradual Drilling Decline

Recovery to date .9 Bbbl Ultimate Recovery 8.9-9.9 Bbbl by 2040

© Hughes GSR Inc, 2014 (data from Drillinginfo, September, 2014,)
Eagle Ford Oil, Gas and Condensate Production through 2040 assuming 6 wells/section Risked at 80%

- Gas Portion
- Condensate Portion
- Oil Portion
- Cumulative wells

Liquids Recovery to date: 0.9 Bbbl
Ultimate Recovery: 7.8 Bbbl by 2040
- 6.2 Bbbls of Oil
- 1.6 Bbbls Condensate

Plus 37.1 Tcf of Gas

Peak 2017
With gradual Drilling Decline
From 3550 wells/yr to 2000 wells/yr

© Hughes GSR Inc, 2014
(data from Drillinginfo, October, 2014)
Bakken and Eagle Ford “Most Likely” Projections versus EIA AEO 2014 Tight Oil Production Forecast

Other Plays
- 29.9 Bbbls 2012-2040

Eagle Ford
- 7.6 Bbbls 2012-2040

Bakken
- 6.1 Bbbls 2012-2040

© Hughes GSR Inc, 2014

(EIA Annual Energy Outlook 2014 Final Release, September, 2014)
Shale Reality Check?

Shale Drillers Feast on Junk Debt to Stay on Treadmill
(Asjylyn Loder, Bloomberg, April 30, 2014)

“There’s a lot of Kool-Aid that’s being drunk now by investors,”
“People lose their discipline. They stop doing the math.
They stop doing the accounting.
They’re just dreaming the dream,
and that’s what’s happening with the shale boom.”

“It’s a perfect set-up for investors to lose a lot of money,”
Gramatovich said. “The model is unsustainable.”
2013 Free Cash Flow and CAPEX for Shale Drillers

(data courtesy of Deborah Rogers, April, 2014)
Free Cash Flow and CAPEX for Shale Drillers, 2010-2013

$235 Billion CAPEX and $81 Billion in Negative Cash Flow over 2010-2013

(data courtesy of Deborah Rogers, April, 2014)
Shale Takeaways

• High field decline rates mandate sustained high levels of drilling to maintain production.

• Shale gas production from seven plays constituting 88% of production is likely to peak in 2015-2018 timeframe, depending on drilling rates.

• Tight oil production from the top two plays constituting 62% of production is likely to peak in 2016-2017 timeframe.

• Increasing drilling rates significantly over current levels will increase immediate supply and peak production levels and will move peak forward but results in steeper declines after peak – basically making the supply situation worse post-peak.

• High quality shale plays are not ubiquitous:
  • 86% of shale gas production comes from 6 of 30 plays.
  • 62% of tight oil production comes from 2 of 21 plays.
Summary and Implications

- Unconventional fuels will be important but are not scalable to offset declining conventional supplies in the long term.

- The Shale Revolution has been a “game-changer” in that it has temporarily reversed decline in supplies from conventional sources. Long term sustainability is questionable and environmental impacts are a major concern.

- Almost all eggs are in the shale basket as a hope in meeting U.S. energy supply growth projections from oil and gas. In Canada both shale gas and oil sands exports are a focus.

- U.S. “Energy Independence” with the forecast energy trajectory is highly unlikely, barring a radical reduction in consumption.

- Unconventional fuels have provided a temporary respite from declining oil and gas production but should not be viewed as a panacea for increasing energy consumption – and exporting the bounty - rather they should be used as an opportunity to create the infrastructure needed for a lower energy throughput to maximize long term energy security.