Natural Gas
“Infrastructure as Momentum”

Dr. Fred Beach
Energy Institute
The University of Texas at Austin
Fossil Fuels Supply 87% of All Energy Consumption in the World

World primary energy consumption grew by 2.5% in 2011, less than half the growth rate experienced in 2010 but close to the historical average. Growth decelerated for all regions and for all fuels. Oil remains the world's leading fuel, accounting for 33.1% of global energy consumption, but this figure is the lowest share on record. Coal's market share of 30.3% was the highest since 1969.
Global Consumption Trends 2011

• Energy Consumption, +2.5%
  OEDC, Down
  Non-OEDC, Up

• Oil Consumption, +0.7%
  OEDC, -1.2%
  Non-OEDC, +2.8%

• Natural Gas Consumption, +2.2%
  EU, -9.9%
  China, +21.5%

• Coal Consumption, +5.4%
  OEDC, -1.1%
  Non-OEDC, +8.4%
<table>
<thead>
<tr>
<th>Rank</th>
<th>Name</th>
<th>Energy</th>
<th>Country</th>
<th>Cost ($ Billion)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Three Gorges Dam</td>
<td>Hydro</td>
<td>China</td>
<td>$28</td>
</tr>
<tr>
<td>9</td>
<td>Gladstone (Santos, Petronas, Total)</td>
<td>Gas</td>
<td>Australia</td>
<td>$30</td>
</tr>
<tr>
<td>8</td>
<td>Kearl (Imperial &amp; Exxon Mobile)</td>
<td>Oil</td>
<td>Canada</td>
<td>$33</td>
</tr>
<tr>
<td>7</td>
<td>Queensland Curtis (BP)</td>
<td>Gas</td>
<td>Australia</td>
<td>$34</td>
</tr>
<tr>
<td>6</td>
<td>Wheatstone (Chevron, Apache, TEPCO,</td>
<td>Gas</td>
<td>Australia</td>
<td>$35</td>
</tr>
<tr>
<td></td>
<td>Kuwait Foreign Petroleum)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Australia Pacific (Origin, ConPhil, Sinopec)</td>
<td>Gas</td>
<td>Australia</td>
<td>$37</td>
</tr>
<tr>
<td>4</td>
<td>Bovanenkovskoye (Gazprom)</td>
<td>Gas</td>
<td>Russia</td>
<td>$41</td>
</tr>
<tr>
<td>3</td>
<td>Ichthys (Inpex &amp; Total)</td>
<td>Gas</td>
<td>Australia</td>
<td>$43</td>
</tr>
<tr>
<td>2</td>
<td>Gorgon (Chevron, Exxon &amp; Shell)</td>
<td>Gas</td>
<td>Australia</td>
<td>$57</td>
</tr>
<tr>
<td>1</td>
<td>Kashagan (KazMunayGas, ENI, Shell, Exxon, Total, ConPhil, INPEX)</td>
<td>Oil</td>
<td>Kazakhstan</td>
<td>$116</td>
</tr>
</tbody>
</table>
Figure 4. Total U.S. natural gas production, consumption, and net imports, 1990-2035 (trillion cubic feet)

- **Consumption**
- **Domestic production**
- **Net imports, 2010** 11%
- **Net exports, 2035** 5%

Henry Hub spot market natural gas prices (2010 dollars per million Btu)

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IGERT, Iowa State
July 18, 2013
U.S. Energy Independence Trend

US for 2012 (Quads)
Consumption = 95
Production = 80
Imports = 15.8%
2013 (to date) 12.9%
“Physical Trends Have Momentum”
Eagle Ford Oil, Gas, & Liquids Production
Texas Rig Count Feb 2013

- **Granite Wash Formation**: 47 rigs
- **Barnett Shale**: 34 rigs
- **Haynesville/Bossier Shale**: 21 rigs
- **Permian Basin**: 403 rigs
- **Eagle Ford Shale**: 235 rigs

Rig count as of Feb. 15. Approximate areas of fields shown.
Sources: Railroad Commission of Texas; Baker Hughes Rig Count
Mike Fisher / San Antonio Express-News
U.S. Energy Use

Estimated U.S. Energy Use in 2009: ~94.6 Quads

- Solar: 0.11
- Nuclear: 8.35
- Hydro: 2.68
- Wind: 0.70
- Geothermal: 0.37
- Natural Gas: 23.37
- Coal: 19.76
- Biomass: 3.88
- Petroleum: 35.27

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## Natural Gas Demand Growth Potential

### Demand options | Example users | Potential impact (Bcf/day)
--- | --- | ---
Transportation | CNG/LNG transportation | 0.92
Generate | Power plants | 5
Export | LNG | 5.4
Convert | F-T liquids/methanol/DME | 1.3
Refine | NSPS-compliant process fuel | 2
Manufacture | Process fuel or feedstock | 2.16

Incremental demand: 17.1 Bcf/day by 2018 (13 Bcf/day beyond current power fuel switching)

Total consumption: 73.1 Bcf/day by 2018

Source: Project on Realizing the Potential of Unconventional Gas, Workshop #3: Policy Pathway Forward, December 13, 2012, CSIS.

Note: CNG = compressed natural gas; LNG = liquefied natural gas; F-T = Fischer-Tropsch; DME = dimethyl ether; NSPS = New Source Performance Standards; Bcf = billion cubic feet.

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2012 US Consumption was 69.7 Bcf/day
U.S. Ground Transportation Fuel Market

Average Retail Fuel Prices in the U.S.

Dollars per GGE

Date


Gasoline
E85
CNG
Propane
Diesel
B20
B2/B5
B99/B100
Gas Cost Versus GGE Cost

CNG Sales Profitability

On January 20, 2012 the NYMEX spot price for natural gas closed at $2.26/MMBtu, the lowest point in a decade. These low commodity prices are a boon for CNG retail profit margins.

Pump price of $1.99/gge

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<th>COST</th>
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<td>Maintenance per GGE</td>
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<tr>
<td>Federal and State Taxes</td>
<td>$0.25</td>
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<tr>
<td>Fuel Card Fees per GGE</td>
<td>$0.05</td>
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<td>Retailer Profit Margin</td>
<td>$0.75</td>
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<td>CNG at the Pump</td>
<td>$1.99</td>
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Pump price of $2.45/gge

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Transportation
Transportation

Coast-to-Coast and Border-to-Border LNG Truck Fueling
The Honda Civic GX is the only Natural Gas LDV for Sale in the U.S.

- Cleaner air at tailpipe than coming in the vents
- Extensive residential fueling infrastructure
  - fill up with home compressor
  - (~$4000)

$25,190

[Image: Honda Civic GX]

[Image: Fueling station]

[Image: Honda Civic GX fuel cap]
Why Not NatGas PHEVs?

• There are 78 million single family homes in the US
• 99.99% have electricity service
• 50 million have natural gas service
• That is a lot of fueling stations…..But
• NFPA is Working to Ban Natural Gas Home Refueling Through Building Code Restrictions
Power Generation

Combined Cycle Natural Gas Plants Have High Efficiency
50%-60% versus ~30% National Power Plant Average
Are We Building a Less Resilient Generation Portfolio?
Fuel Switching in Electricity Generation

U.S. Electricity Generation by Fuel, All Sectors

(thousand megawatt-hours per day)

- Coal
- Natural gas
- Petroleum
- Nuclear
- Hydropower
- Renewables
- Other sources

Forecast

Note: Labels show percentage share of total generation provided by coal and natural gas.

Source: Short-Term Energy Outlook, January 2012
Pipeline Network
LNG Market

World LNG Estimated May 2013 Landed Prices

Altamira $4.42
Lake Charles $3.79
Cove Point $4.16
Spain $11.78
Belgium $10.08
UK $10.17
India $14.40
Korea $14.95
Japan $14.55
Bahia Blanca $16.41
Rio de Janeiro $15.11
China $14.55

Export

Qmax LNG Tankers, 5.7 Bcf capacity (9.4 Mcf Liquid)
Q-max Ships are Market Tailored

Qmax Ships are tailored for the Arabian Gulf and Australia to Asia Market
LNG Export Terminals

LNG Terminals Can Cost Several Billion $ to Construct
**LNG Export Terminals**

**Proposed/Potential**

**Import Terminal**
- PROPOSED TO FERC
  - 1. Robbinston, ME: 0.5 Bcfd (Kestrel Energy - Downeast LNG)
  - 2. Astoria, OR: 1.5 Bcfd (Oregon LNG)
  - 3. Corpus Christi, TX: 0.4 Bcfd (Cheniere – Corpus Christi LNG)

**Export Terminal**
- PROPOSED TO FERC
  - 4. Offshore New York: 0.4 Bcfd (Liberty Natural Gas)
  - 5. Freeport, TX: 1.8 Bcfd (Freeport LNG Dev/Freeport LNG Expansion/FLNG Liquefaction)*
  - 6. Corpus Christi, TX: 2.1 Bcfd (Cheniere – Corpus Christi LNG)*
  - 7. Coos Bay, OR: 0.9 Bcfd (Jordan Cove Energy Project)
  - 8. Lake Charles, LA: 2.4 Bcfd (Southern Union - Trunkline LNG)
  - 9. Hackberry, LA: 1.7 Bcfd (Sempra – Cameron LNG)*
  - 10. Cove Point, MD: 0.82 Bcfd (Dominion – Cove Point LNG)*
  - 11. Astoria, OR: 1.30 Bcfd (Oregon LNG)
  - 12. Lavaca Bay, TX: 1.38 Bcfd (Excelerate Liquefaction)
  - 13. Elba Island, GA: 0.35 Bcfd (Southern LNG Company)
  - 14. Sabine Pass, LA: 1.3 Bcfd (Sabine Pass Liquefaction)
  - 15. Lake Charles, LA: 1.07 Bcfd (Magnolia LNG)
  - 16. Plaquemines Parish, LA: 1.07 Bcfd (CE FLNG)

**PROPOSED CANADIAN SITES IDENTIFIED BY PROJECT SPONSORS**
- 17. Kitimat, BC: 0.7 Bcfd (Apache Canada Ltd.)
- 18. Douglas Island, BC: 0.25 Bcfd (BC LNG Export Cooperative)

**U.S. – MARAD/OA/USCG**
- 25. Gulf of Mexico: 3.22 Bcfd (Main Pass - Freeport-McMoRan)

**Potential Canadian SITES IDENTIFIED BY PROJECT SPONSORS**
- 26. Prince Rupert Island, BC: 1.0 Bcfd (Shell Canada)
- 27. Goldboro, NS: 0.67 Bcfd (Pieridae Energy Canada)
- 28. Kitimat, BC: 2.0 Bcfd (LNG Canada)

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**Office of Energy Projects**

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Natural Gas
IGERT, Iowa State
July 18, 2013
So What is the US Policy for NatGas?

- NatGas for Transportation?
- NatGas for Electricity Generation?
- NatGas for Export?
- NatGas for Economic (Manufacturing) Advantage?
- NatGas for Carbon Reduction?
- NatGas for Energy Transition (A Bridge to …)?
- NatGas for Revenue Generation?
Governing Federal Statutes

- National Environmental Policy Act (NEPA) Requires EIA on Federal lands
- Clean Air Act (CAA) Requires Permitting for Drilling and Production
- Clean Water Act (CWA) Regulates Surface Water Discharge of All Liquids Related to Drilling and Production
- Safe Drinking Water Act (SDWA) Regulates Underground Injection of Waste Fluids
- Emergency Planning and Right-to-Know Act (EPCRA) Requires Emergency Plans and Notification Procedures
- Endangered Species Act (ESA)
- Toxic Substances Control Act (TSCA) Regulates Manufacturing and Use of Certain Chemicals
- Resource Conservation and Recovery Act (RCRA) and Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Regulates the Handling of Drilling Waste
### Fugitive Methane Emissions

Table 2: Fugitive methane emissions associated with development of natural gas from conventional wells and from shale formations (expressed as the percentage of methane produced over the lifecycle of a well)

<table>
<thead>
<tr>
<th>Event</th>
<th>Conventional gas</th>
<th>Shale gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emissions during well completion</td>
<td>0.01%</td>
<td>1.9%</td>
</tr>
<tr>
<td>Routine venting and equipment leaks at well site</td>
<td>0.3 to 1.9%</td>
<td>0.3 to 1.9%</td>
</tr>
<tr>
<td>Emissions during liquid unloading</td>
<td>0 to 0.26%</td>
<td>0 to 0.26%</td>
</tr>
<tr>
<td>Emissions during gas processing</td>
<td>0 to 0.19%</td>
<td>0 to 0.19%</td>
</tr>
<tr>
<td>Emissions during transport, storage, and distribution</td>
<td>1.4 to 3.6%</td>
<td>1.4 to 3.6%</td>
</tr>
<tr>
<td>Total emissions</td>
<td>1.7 to 6.0%</td>
<td>3.6 to 7.9%</td>
</tr>
</tbody>
</table>

See text for derivation of estimates and supporting information

Howarth, Santoro, & Ingraffea, “Methane and greenhouse-gas footprint of natural gas from shale formations” Climate Change, June 2011
Laredo Petroleum’s Cline Shale Play

- Repeatable horizontal resource play in the Cline Shale
- Laredo has been drilling and gathering data on Cline Shale since 2008
- 26 horizontal wells drilled and completed in the Cline Shale, a baseline of historical well performance
- Cline Shale has been identified across Laredo’s entire Permian acreage position
- Laredo has gathered extensive petrophysical data on the Cline Shale that is currently proprietary

943 Horizontal Cline Shale Identified Potential Locations

- Laredo Cline hz well (26)
- LPI acreage
- Early stage exploration
- Early stage development
- Late stage exploration
- Cline whole core
But It’s Not Just Laredo

- Current target intervals include Vertical Wolfberry, Horizontal Wolfcamp Shale (Upper, Middle, Lower) and Horizontal Cline Shale
- Interest in over 300 sections with ~135,000 net acres concentrated in Glasscock and Reagan Counties
- ~96% average working interest

Legend:
- Laredo
- Pioneer
- Apache
- Devon
- Exco
- Petrohawk / BHP
- EOG
- Approach
- COP
- El Paso
- Range
As a Saudi oil minister once said, "Shale and renewable energy are not mutually exclusive, with some countries being blessed with resources in both..."
Bakken Shale
Export

Qmax LNG Tankers, 5.7 Bcf capacity (9.4 Mcf Liquid)