What is Shale Gas?

• Characteristics of Shale Gas
  – Natural gas trapped in shale formations;
  – The shale acts as the source and the reservoir for the natural gas;
  – It is of pipeline quality when produced;
  – Horizontal drilling and “fracking” have increased flow rates tremendously and opened up previous uneconomic plays;
  – Current shale gas reserves in the US have a R/P ratio of over 100 years;
  – Environmental concerns such as water contamination from fracking fluids have led to increased scrutiny which will likely add to costs via regulations, but not stop shale gas production.
Shale Gas Horizontal Drilling
US Gas Revolution: Implications for Global LNG

Barne:
- Production 2010: 1.828 tcf (around 28% of total Texas production).

Unconventional gas production (shale gas plus CBM): roughly 36% of US total gas production in 2011; shale gas accounts for around 3/4 of unconventional gas production.

Marcellus Shale:
- Strong potential and lower costs
- BUT faces topography, infrastructure, and regulatory bottlenecks.

Barnett production 2010: 1.828 tcf (around 28% of total Texas production).

Woodford
- Fayetteville
- Haynesville-Bossier

Unconventional gas production (shale gas plus CBM): roughly 36% of US total gas production in 2011; shale gas accounts for around 3/4 of unconventional gas production.
Breakdown of US Gas Supply

Source: EIA AEO2012 (early release)
From Buyer to Seller: The Americas as a Major LNG Export Province?

- North Slope (Valdez) LNG; Kenai LNG
  
- Kitimat LNG; BC LNG; Shell LNG
  
- Freeport, Sabine, Lake Charles, etc.
  
- Peru LNG
  
- Delta-Caribe Oriental LNG
  
- Brazil - deepwater sub-salt LNG
  
- Cove Point LNG

- Amount of LNG export capacity
- Existing LNG import terminal
- LNG import terminal under construction
- Planned LNG import terminal
- Existing LNG export terminal
- Planned LNG export terminal

23.0 mmtpa; 1.4 mmtpa
10 mmtpa; 1.8 mmtpa; 14 mmtpa
4.5 mmtpa
8 mmtpa
90 mmtpa
14.1 mmtpa
3.5 mmtpa
The shale-gas boom in the US has driven prices down sharply, from nearly $9/mmBTU in 2008 to $4/mmBTU in 2011. (In recent weeks, the price has dropped as low as $2/mmBTU).

US and UK prices are expected to rise, but still to stay well below the prices of LNG in Asia.

Asian LNG prices are mainly liked to the price of oil. In the US, the oil-gas pricing link has been largely broken, and the connection is fragile in NW Europe as well.
Gas in Power Generation

- Gas was always popular in the US for peaking power, but it has become an important baseload fuel in the US as well.

- Gas has obvious environmental benefits, but an important driver has been the increase in use of Combined Cycle Gas Turbines (CCGT). These units have efficiencies of 52-60% (as compared to existing steam boiler efficiencies of about 31%).

- CCGTs use a cleaner fuel, and also use less fuel per kWh (heat rates of around 6,500 or better).
Price Competitiveness in Power Generation

<table>
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<tr>
<th>Gas Fuel Price Savings, cents/kWh</th>
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| ![Graph showing price savings for different fuel options.](image)

- If local LSFO prices rise to an average of $149/b by the middle of the decade, then gas delivered on Oahu is competitive up to $24/mmBTU—even in an existing steam plant.

- If gas is employed in a CCGT, it offers significant fuel-cost savings over LSFO even at $30/mmBTU delivered gas prices.
Offshore Regasification
Import Infrastructure

- LNG offers significant price savings over LSFO even if the delivered price is similar to those seen in Asia—the most expensive market.

- Japan, Korea, Taiwan, China, and other LNG importers already have LNG import terminals in place, of course. Developing port infrastructure and regasification facilities can be a daunting and time-consuming prospect.

- Fortunately, in recent years many utilities have found themselves needing to move into LNG imports on smaller scales and in short time frames. The technology for solving these problems is now well-developed.
Offshore Regasification

• **Ships as Floating Storage Units (FSUs)**
  – Ships are moored at a berth
  – LNG is transferred into the FSU from the ships that transport it from the liquefaction plant
  – The LNG is delivered to onshore regasifiers

• **Regas Vessel**
  – Ships with onboard regasifiers connect to a floating buoy and are equipped with a submerged turret loading system. The buoy is connected to a pipeline to shore (“Energy Bridge”).
  – Some RVs now operate as FSRUs

• **Floating Storage Regasification Units (FSRUs)**
  – Ships with onboard regasifiers are permanently moored alongside a berth either in a port or offshore
  – Ships transport the LNG from the liquefaction plant and transfer the cargo either across the berth or by ship-to-ship transfer
Why Offshore Regasification?

• Low initial capital cost ($100 million to $250 million) versus $500 million to $1 billion for an onshore terminal.

• FSUs and FSRUs can be built in 12 months compared to 5 years for an onshore terminal (as the majority of the construction activity will take place offsite).

• Offshore terminals avoid significant environmental impact (e.g., permanent fill of coastal wetlands, dredging impacts, safety concerns raised by local residents, etc.).

• More flexibility on location and faster to approve/permit and install

• Well suited to seasonal markets since it may be possible to find alternative employment for the vessel when gas demand is low.

• Puerto Rico (similar power fuel and demand profile to Hawaii) looking at offshore terminal; Aguirre GasPort
  – Started process in early 2012 looking to be online in 2014
  – Will convert all oil-fired capacity (1,500 MW) to use natural gas.
Mid Scale FSRU Solution For Hawaii

- A 500 MW of CCGT power generation on Oahu would require roughly 500 ktpa of LNG (i.e. 3,140 m³ or 1,380 tonnes per day)

- This falls into the Mid-scale LNG infrastructure category:

- Mid-scale LNG shipping is as old as LNG technology itself!
  - First LNG shipment was on a 5,000 m³ vessel
  - Old ships of ~35,000 m³ still serve Mediterranean terminals

- Some 100,000 m³ of LNG per month could be shipped to Hawaii on a mid-scale LNG career (25,000 m³), assuming 4 deliveries per month.
What is needed and where FSRU is located?

The necessary infrastructure could include:

- The location depends on whether environmental and met-ocean conditions will allow a jetty moored system or if the FSRU needs to be located offshore!

Offshore:

- The offshore design allow a flexible site selection with no direct onshore impact (safety/visual/noise/environmental), however the mooring system and FSRU should withstand extreme weather conditions – i.e hurricanes

Jetty Moored (close to the power plant in sheltered marine conditions):

- Simple barge design with utilities provided from shore and minimum accommodation lowering Capex and Opex
The infrastructure could be in place by 2015!

- Based on estimates from a mid-scale project developer, such system could be in constructed in 2-3 years.
- The shipping and FSRU operation costs would be $4-5 per mmbtu!
- The assumptions would be:
  - Long term contractual commitment (i.e. 20-25 year contract)
  - 500 ktpa jetty moored FSRU design
  - Quarterly payment, commencing with operations (i.e. no payments during construction)
  - No upfront payment
  - Shipping between British Columbia (Kitimat) and Oahu (Alternative loading can be done in Alaska under the same cost configuration due to the same distance of both LNG suppliers)
LNG for Hawaii

• Although it might seem like a longer-term option, offshore regasification is very much a near-term option.

• LNG supplies are also available in any time frame—but at the moment it is a seller’s market.

• It is not out of the question to supply LNG to Oahu by the middle of the decade—perhaps in time to deal with new environmental standards—but it would require quick action.

• Figuring out how to stage the onshore aspects of rolling LNG into the system would require careful thought. If the initial substitution is into steam plants, then when subsequent CCGT capacity is built it will free up gas for other uses (perhaps additional fuel switching; perhaps for neighbor islands).