KUALA LUMPUR 2012 WORLD GAS CONFERENCE

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"Gas: Sustaining Future Global Growth"

Technology Options and Economics for Unconventional Shale Gas and Gas Liquids Monetization

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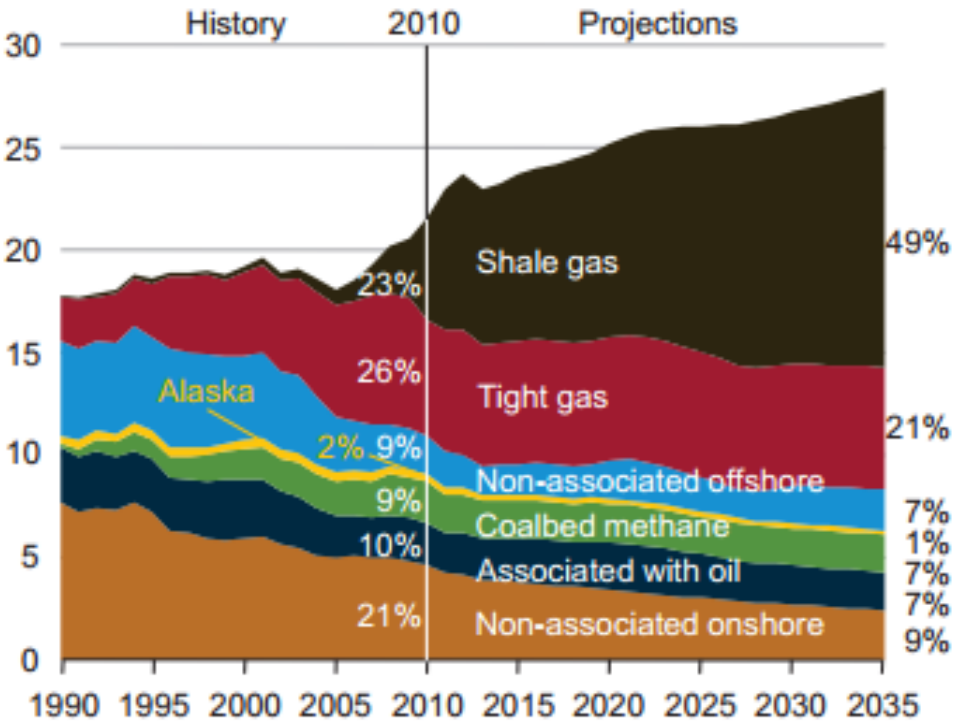
The Problem with Shale Gas

- U.S. gas resource base and domestic production has been declining for decades
  - Periodic price spikes and high volatility
- Enter the Dragon
  - Development of new technology for shale gas and other UCG
    - Fracking
    - Horizontal drilling
    - Multiple production zones
    - Multi-well pads
    - Progress on the learning curve
- Shale Gas fraction growing as total production grows
- Expected to grow from current 5 TCF to ~14 TCF by 2035 and 50% of gas.



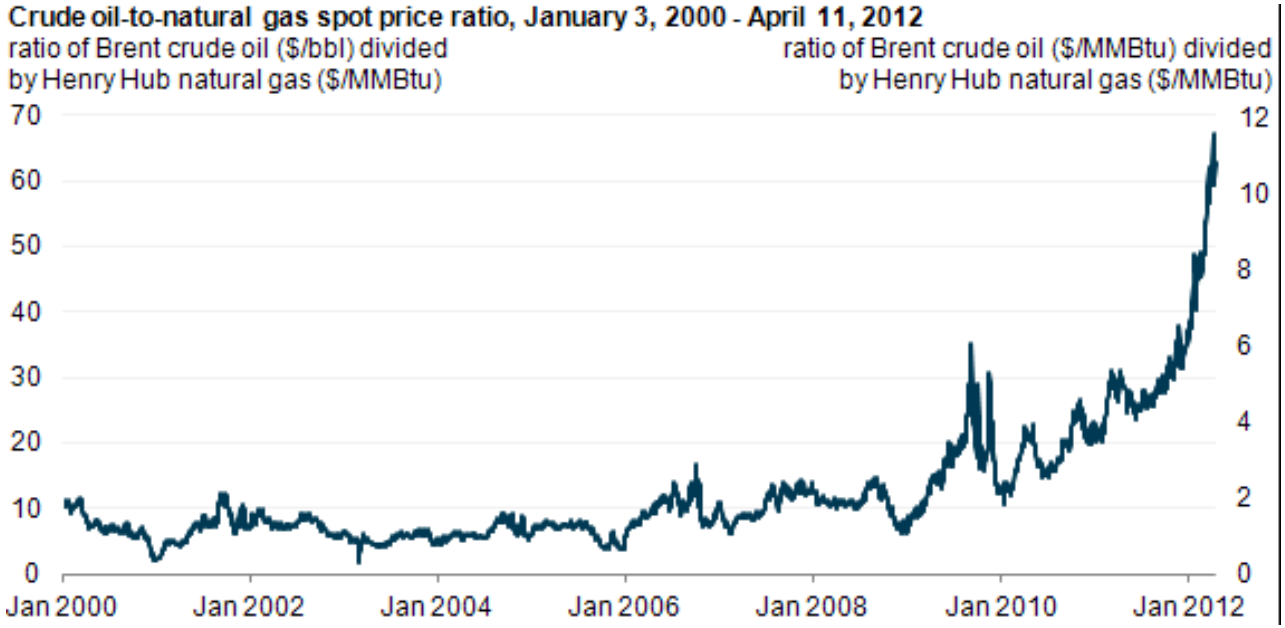
The Problem with Shale Gas

So what is the problem?

- Very large resource base
  - Technically recoverable resource (TRR) of shale gas for the United States is 482 trillion cubic feet (source: EIA 2012)
- Too many wells being drilled
- Uneconomic dry gas on “held by production” gas leases being produced
- High content of potentially profitable liquids in shale gas underwrites excess dry gas production
- Problem: Gas prices in free fall
  - Gas prices hits ten year lows in 1Q 2012

The problem with liquids

- Natural Gas Liquids, condensate, natural gasoline, is found in many of the U.S. production basins
  - Bakken, Marcellus, Eagle Ford…
- This is great news if you are the producer since liquids to gas price ratios are at historic highs



The problem with liquids

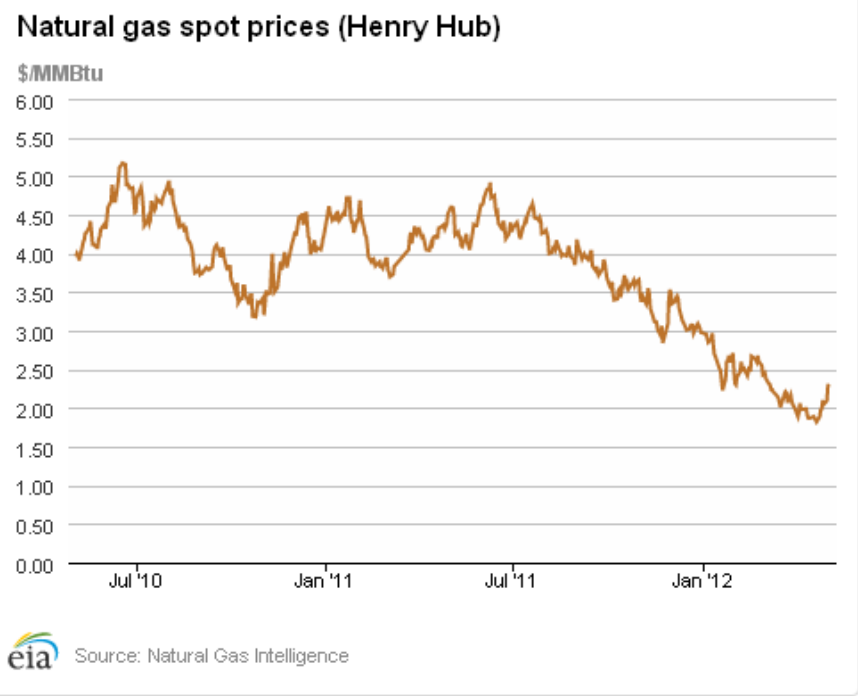
- Liquids need to be removed from the gas
  - Exceed Wobbe number and HHV specifications of transport pipelines
  - Are far more valuable sold as liquids
  - Increase pressure drop in pipelines
- Infrastructure to remove and transport the liquids not sufficient or did not even exist in some regions (Marcellus)
- Goal is to get the liquids to major hubs (Conway Kansas, Henry Hub, Texas, Sarnia, Ontario) for fractionation and transport to end customers
  - Ethane crackers
  - LPG/Propane distributors
  - Refineries
- In the early-going, it was sufficient to truck liquids out coupled with blending high ethane into other gas in the pipelines, along with moving up a few small refrigeration plants

Monetizing the liquids - infrastructure

- As the overall volume of gas and liquids production increased, massive infrastucture buildout was, and continues to be required
  - Liquids pipelines
  - NGL Extraction plants, mainly cryogenic expander plants
  - Fractionation capacity
  - Natural Gas pipelines, compressor stations
  - Storage (gas, but also liquids)
  - Roads, worker housing and facilities
- Blending of gas reaching limits
  - Ethane extraction needed to meet pipeline specifications
- Ethane crackers needed to handle the flood of ethane from Marcellus particularly
  - Proposed crackers in Texas and in Marcellus region, e.g., West Virginia announced
- Plans to ship ethane from Philadelphia (Mark West/Sunoco) via refitted ships

Monetizing the gas – falling gas prices

- Gas supply exceeding demand and ability to store and transport it
- While oil to gas price ratio remains high, natural gas will continue to be produced irrespective of demand
  - Producers of rich gas can give it away for free and still be profitable
  - Displaces imports from Canada and LNG imports
  - Excess supply causing natural gas prices to fall

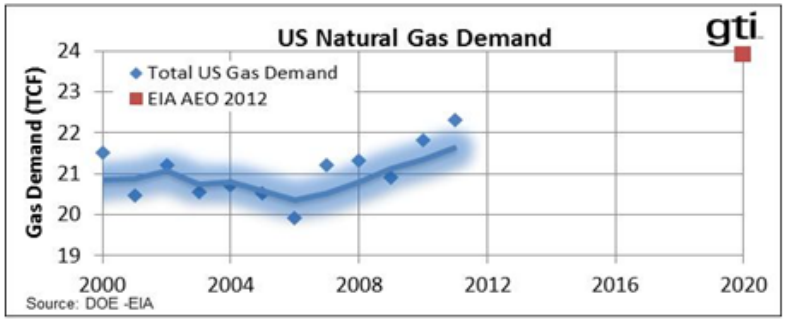


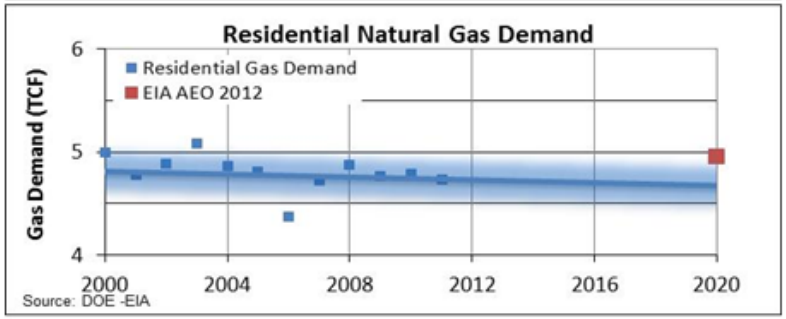
Monetizing the gas

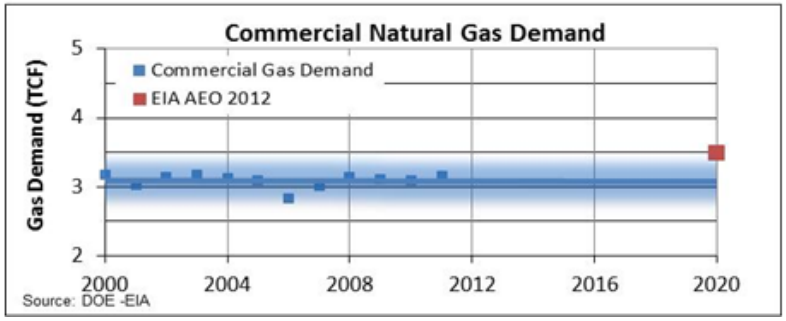
- Solution to the problem – basic economics
  - Increase demand for natural gas
  - Decrease supply of natural gas
- Demand Side
  - Low prices spur increased use
    - Fuel switching: displacing coal and oil in utility plants
    - Increased residential, commercial and industrial use
      - » Re-open shuttered chemical plants
      - » Build new fertilizer and chemical plants (e.g., methanol)
  - Build demand in new markets
    - Gas-fired electrical generation
      - » New units and increased utilization (dispatch) of existing units
    - NGV use
  - Exports (LNG mainly, but also as gas to Mexico and Canada)
  - GTL plants

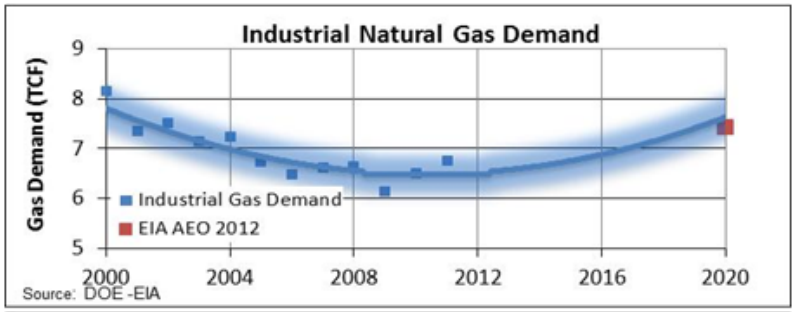
Monetizing the gas - increasing demand

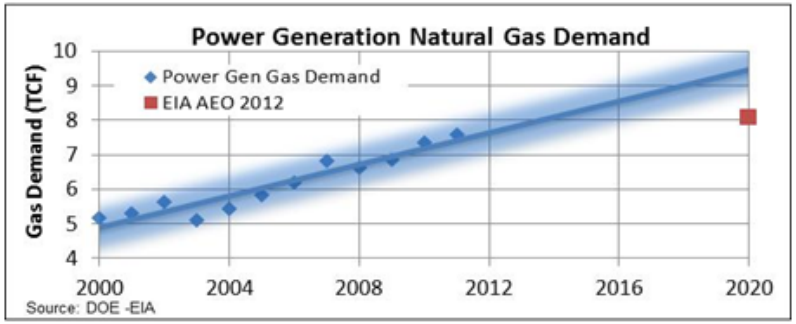
Growth in demand coming from electricity generation sector and industrial sector

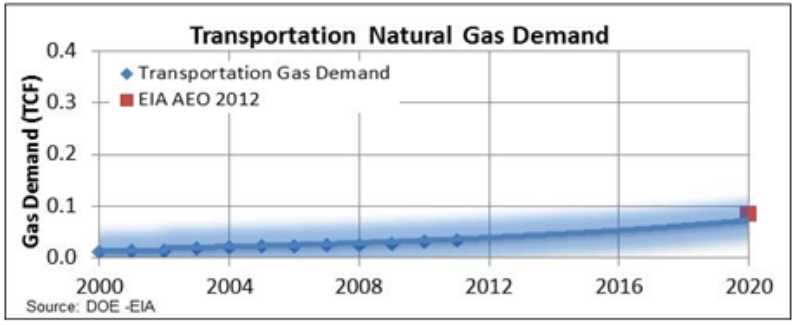












Monetizing the gas

- Supply Side
  - Shut-in uneconomic production
    - This is starting to happen as of April 2012
  - Reduced drilling in dry gas
    - Rigs migrating to oil plays
  - Lower prices for NGLs as a result of oversupply?
    - Liquids-focused production may reduce accordingly
  - Environmental objections surfacing to fracking may result in reduced access to resources and increased production costs
    - Onerous regulations and permitting processes
    - Outright bans on fracking
    - Litigation with “harmed” persons

Monetizing the gas – Technology Options

- Chemicals manufacture
- LNG
- GTL
- NGVs

Monetizing the gas – Chemicals

- Chemicals manufacture
  - Natural gas conversion to synthesis gas
  - Ammonia, Urea , Methanol and Hydrogen manufacture
    - Large enough markets to make a difference
    - Some mothballed plants might be reopened at moderate cost
    - Well established technology
      - » Steam reforming and catalytic converters
  - Specialty chemicals – markets too small to make much of a difference
  - Global competition from existing players
    - e.g., methanol from Trinidad
  - Volatile prices

Chemicals Manufacture (cont'd.)

- Recent Announcements indicate major companies think this approach is viable:

  - ExxonMobil is planning a multi-billion dollar petrochemical expansion at its facility in Baytown, Texas, which would include a new 1.5m tonne/year steam cracker, the company confirmed on Friday. Feeds two new 650,000 tonne/year high-performance polyethylene (PE) lines.
  - Prompted by cheap US natural gas, Celanese plans to spend $500m-1bn (€405-810m) either by expanding its large plant in Texas or by building a new unit in Louisiana, a spokeswoman said on Thursday. Texas-based Celanese's new chief executive, Mark Rohr, told a Dallas newspaper earlier this week that he would decide by the end of the year whether to expand a large plant near Houston or build a new unit at an unnamed site in Louisiana.
  - Dow Chemical plans to build a world-scale steam cracker in Freeport, Texas. Dow's plans call for the construction of a 1.5 million mt/year cracker at its sprawling Texas Operations complex some 60 miles south of Houston at a cost estimated at $1.7 billion.

Monetizing the gas – Technology Options

- LNG
  - Several LNG terminals in U.S. which can be repurposed for export
  - Very high demand for LNG and high prices
    - $16 /MMBTU
  - Shift away from nuclear and coal will increase demand in Europe
  - Preferred energy source in Asia
    - Exacerbated further by Fukushima

Monetizing the gas – Technology Options

- GTL
  - Considered proven technology
  - Makes commodity products such as diesel and naphtha with very large global markets
  - Not too expensive to transport
  - Large domestic market for products
  - Texas and Pennsylvania locations near shipping or refinery/distribution areas
  - Adequate supply of gas
    - Need ~8 TCF of gas over 20 years per 100,000 bbl GTL

Monetizing the gas – Technology Options

- GTL
  - Main questions are whether oil to gas ratio will hold up and how low, for how long will gas prices go
    - $1.00/Mcf gas needs only $40-50 $/bbl oil
  - LNG preferred to GTL when oil prices low and gas prices are high and vice versa
  - GTL preferred when long haul of product is involved
  - LNG will be exported but GTL may serve domestic market and displace oil
  - Cost of GTL plant somewhat uncertain
    - None built in U.S.
    - Pearl GTL large cost overruns – how representative of n^{th} plant?

Monetizing the gas – NGVs

- NGV Market
  - Compressed natural gas or LNG
    - 120,000 vehicles in U.S.
  - Technology well established
  - Poor market acceptance and penetration, except in fleet sector
  - Lack of ubiquitous fueling stations on major corridors
  - Major initiatives underway to improve availability

Natural Gas Vehicles

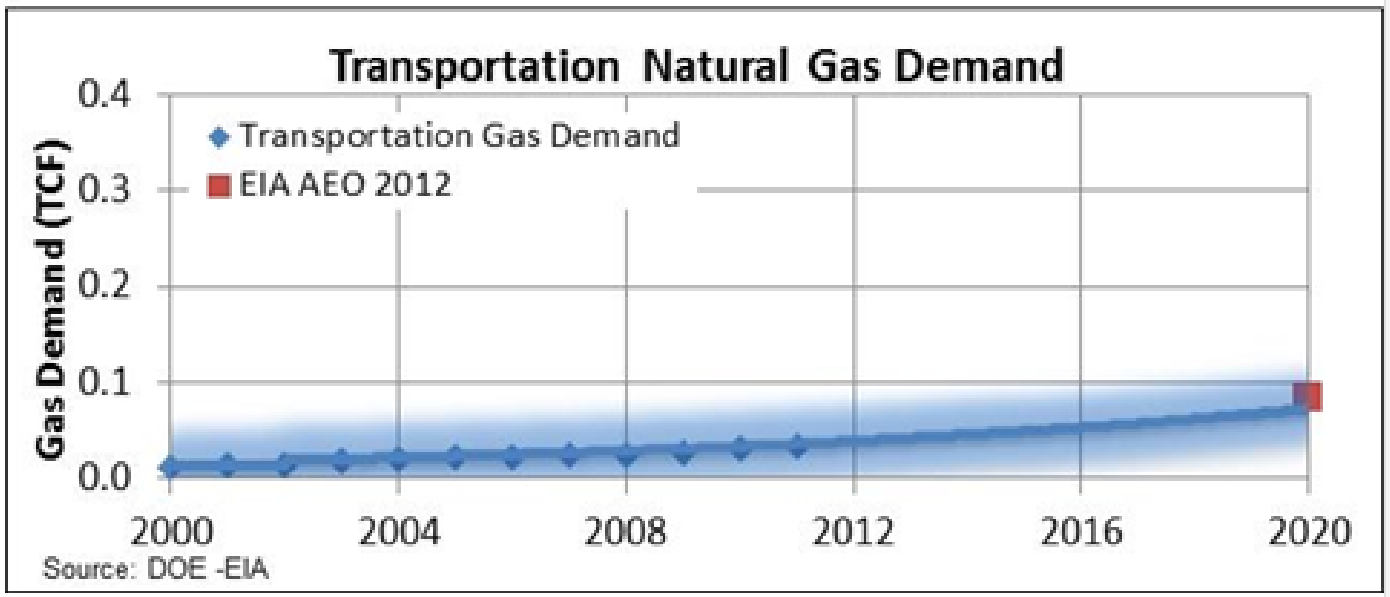
- Increasingly compelling economic case for NGVs in the US
  - Current CNG fuel prices are $1.50/gallon less than diesel or gasoline
  - Rapidly growing fleet interest
  - 1.5-3 year payback for high-fuel use heavy-duty vehicles
  - More vehicle product expected
  - Further cost reduction anticipated with volume

	Nationwide Average Price in Gasoline Gallon Equivalents
Gasoline	$3.37
Diesel	$3.46
CNG	$2.13

DOE Clean Cities; January, 2012 survey.

Monetizing the gas – NGVs

- Advantages are very low cost per mile driven, excellent environmental footprint
- Disadvantages in addition to availability of fuel stations are large loss of vehicle storage space, additional cost over gasoline/diesel vehicle, competition from electric and hybrid vehicles



Results and Conclusions

- The dynamics of natural gas production have radically shifted
- Existing situation is unstable with falling gas prices due to unrestrained production in rich plays. Shutting-in of production and migration of drilling activity to liquids rich plays
- Supply and Demand balance will have to establish a new equilibrium
- Key Driving forces are, on the demand side, increased natural gas consumption due to elasticity of demand for natural gas, and potentially the utilization of monetization technology options such as LNG (for export) and GTL
- Power generation is key demand variable, followed by industrial demand for chemicals, fertilizer and steel

Results and Conclusions

- Whether the situation is repeated elsewhere in the world remains to be seen
- Do rich plays exist in non U.S. shale gas?
- High oil to gas price ratios in U.S. are unique
- Infrastructure to utilize NGLs in huge quantities may not be feasible in other parts of the world