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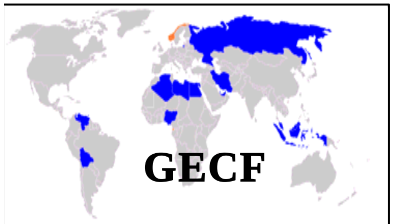
Recent Developments in Global Gas Markets



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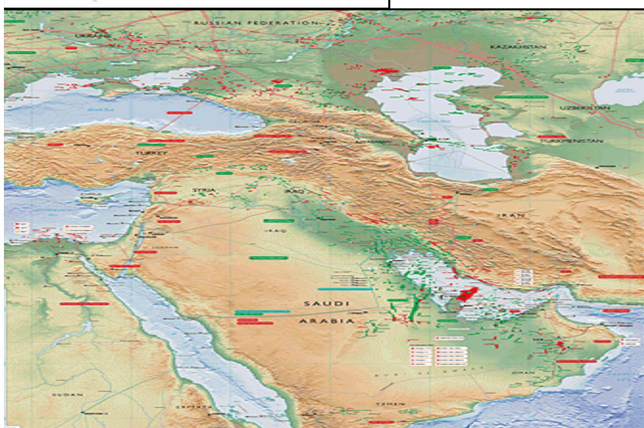

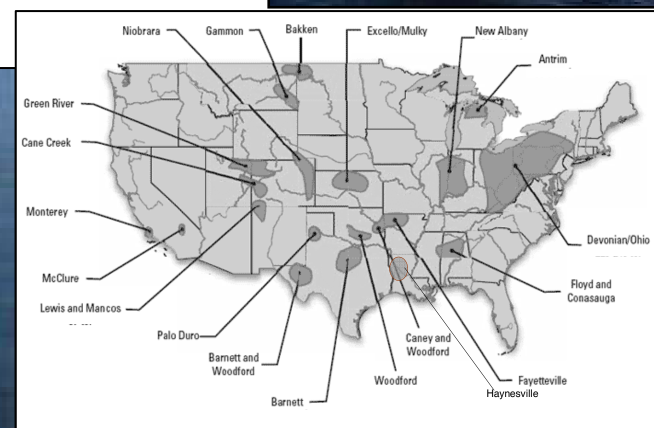

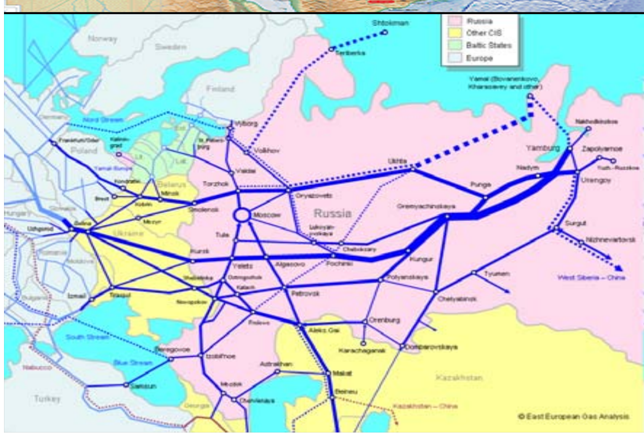

The Emergence of a Global Gas Market

- As recently as a decade ago most natural gas was traded in distinct, segmented markets. This has changed because of…
  - … higher prices
  - … declining supplies in mature markets
  - … cost reductions in transport
  - … rapidly increasing demand
- Demand trends have been driven by…
  - … environmental pressures
  - … cost reductions (i.e. – combined-cycle technology)
  - … gas-fired capacity expansion in power sector encouraged by expectations of low gas prices
  - … deregulation
- Supply is…
  - … maturing in traditional end-use markets
  - … being increasingly comprised of non-conventional sources
  - … increasingly going to come from areas associated with an abundance of oil internationally

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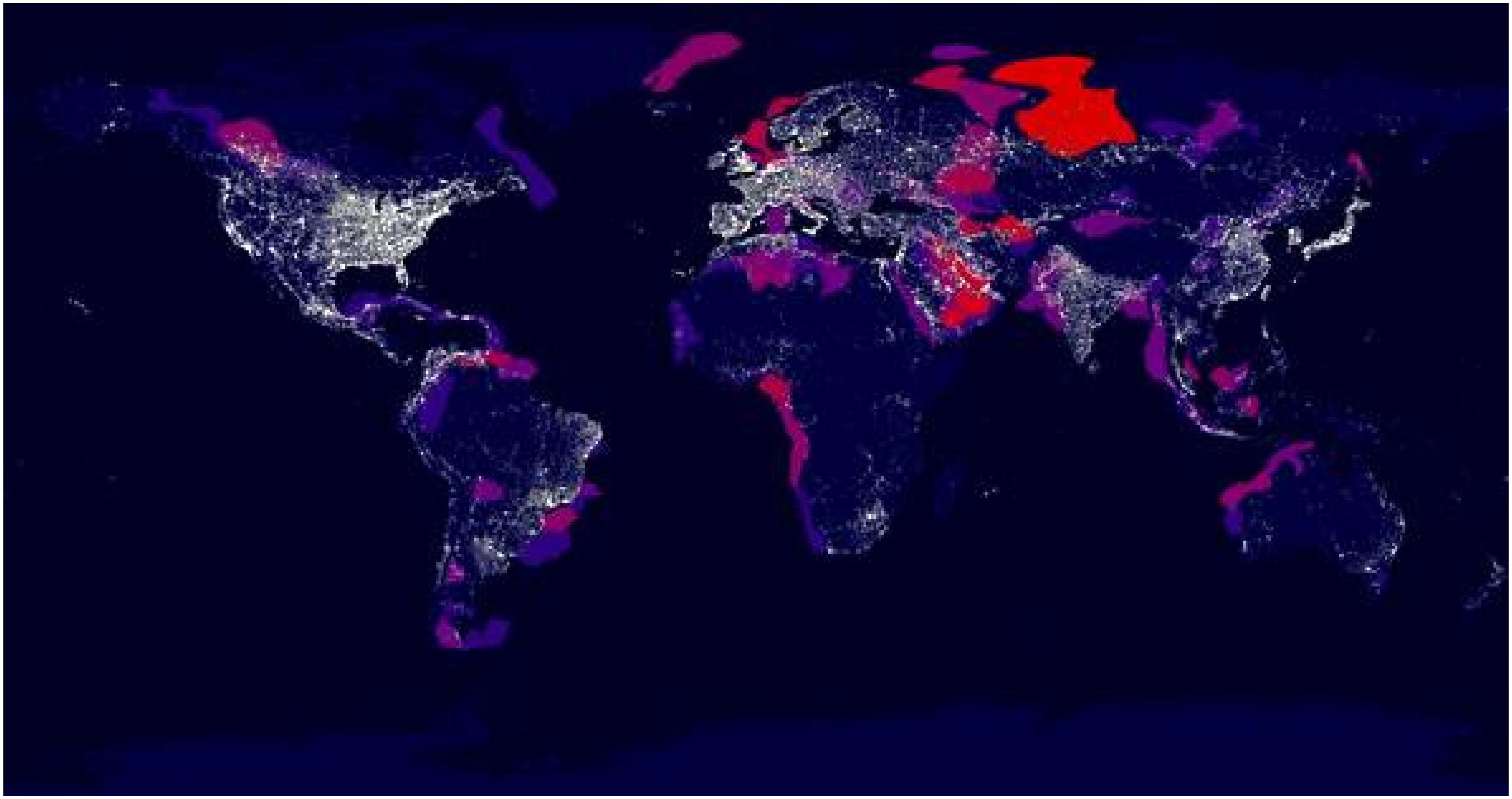
The world and *conventional* gas resources



- According to the USGS, conventional global gas supply potential is large, but located in regions remote from major demand centers.
- *Unconventional* resources and alternatives may act as a backstop.

The Rice World Gas Trade Model:
A Tool for Analysis

The RWGTM

- The Rice World Gas Trade Model (RWGTM) has been developed to examine potential futures for global natural gas, and to quantify the impacts of geopolitical influences on the development of a global natural gas market.
- The model predicts regional prices, regional supplies and demands and inter-regional flows.
- Regions are defined at the country and sub-country level, with extensive representation of transportation infrastructure
- The model is non-stochastic, but it allows analysis of many different scenarios. Geopolitical influences can alter otherwise economic outcomes
- The model is constructed using the *MarketBuilder* software from Altos
  - Dynamic spatial general equilibrium linked through time by Hotelling-type optimization of resource extraction
  - Capacity expansion is determined by current *and* future prices along with capital costs of expansion, operating and maintenance costs of new and existing capacity, and revenues resulting from future outputs and prices.

The RWGTM (cont.)

- Demand
  - Over 290 regions.
    - North America (Residential, Commercial, Industrial, Power Gen)
    - Rest of World (Power Gen, Direct Use, EOR)
  - Population growth taken from the UN median case projection to 2050.
  - Economic growth is based on conditional convergence.
  - Energy intensity falls as income rises (see Medlock and Soligo, *EJ* 2001)
  - The natural gas share of total energy increases with income, reflecting natural gas as a premium fuel, but declines with relative price increases.
    - Price elasticity is decreasing in the natural gas share of TPES. This captures rigidities associated with capital deployment.
- Supply
  - Over 120 regions
  - Natural gas resources are represented in three categories
    - proved reserves (updated 2006 Oil & Gas Journal estimates)
    - (GTK) growth in known reserves (P-50 USGS estimates and NPC estimates)
    - (YTF) undiscovered resource (P-50 USGS estimates and NPC estimates)
  - Long run costs increase with depletion.

The RWGTM (cont.)

- Reserves are not the best indicator of a region's supply potential – they are not even an economic measure of potential. We focus on *resource*, recognizing that *technically* recoverable resources may become *economically* recoverable as price rises going forward. This captures the effect of higher prices on E&D activity.
- Global undiscovered technically recoverable resources
  - 5,336 tcf (YTF) + 3,660 tcf (GTK) = 8,996 tcf
    - Unconventional data is limited
      - Some information about location of potential resources but less about size;
      - Detailed data available for North America and Australia;
      - Limited data available for China and India – focused mostly on CBM
- The 9:1 rule… unconventional resources dwarf conventional, but cost more
- Russia has a prominent position in the natural gas market… Russian development will have an impact on future gas developments
  - Russia has 27% of stated global gas *reserves* (1,680 tcf of 6,254 tcf)
  - Russia has 17% (1,168 tcf (YTF) + 339 tcf (GTK)) of the mean estimate of technically recoverable undiscovered global natural gas *resource*.

The RWGTM (cont.)

- Required return on investment varies by region and type of project (using ICRG and World Bank data)
- Detailed transportation network
  - Pipelines aggregated into corridors where appropriate.
  - Capital costs based on analysis of over 100 pipeline projects relating project cost to various factors.
  - Tariffs based on posted data, where available, and rate-of-return recovery.
  - LNG is represented as a hub-and-spoke network, reflecting the assumption that capacity swaps will occur when profitable.
  - LNG shipping rates based on lease rates and voyage time.
- For all capital investments in both the upstream and midstream, we allow for existing and potential pipeline links, then "let the model decide" optimal current and future capacity utilization.
- **For detailed information please see Peter Hartley and Kenneth B Medlock III, "The Baker Institute World Gas Trade Model" in *The Geopolitics of Natural Gas*, ed. Jaffe, Amy, David Victor and Mark Hayes, Cambridge University Press (2006).**

The Emergence of LNG

US LNG Import Capacity

- Capacity is growing rapidly, and will reach 20-25% of annual demand by 2010.
- Low utilization will persist, but the capacity represents a real option for LNG marketers.

Terminal	Capacity (bcfd)
Operational	
Everett, Massachusetts	1.035
Cove Point, Maryland	1.800
Elba Island, Georgia	1.200
Lake Charles, Louisiana	2.100
Gulf Gateway Energy Bridge, Gulf of Mexico	0.500
Northeast Gateway, Offshore Boston	0.800
Freeport, Texas	1.500
Sabine, Louisiana	2.600
Under Construction	
Hackberry, Louisiana	1.800
Sabine, Texas	2.000
Pascagoula, Mississippi	1.500
Elba Island, Georgia	0.900
Sabine, Louisiana	1.400
Offshore Boston, Massachusetts	0.400
Total Regasification Capacity	**19.535**

Source: Federal Energy Regulatory Commission (http://www.ferc.gov/industries/lng.asp)

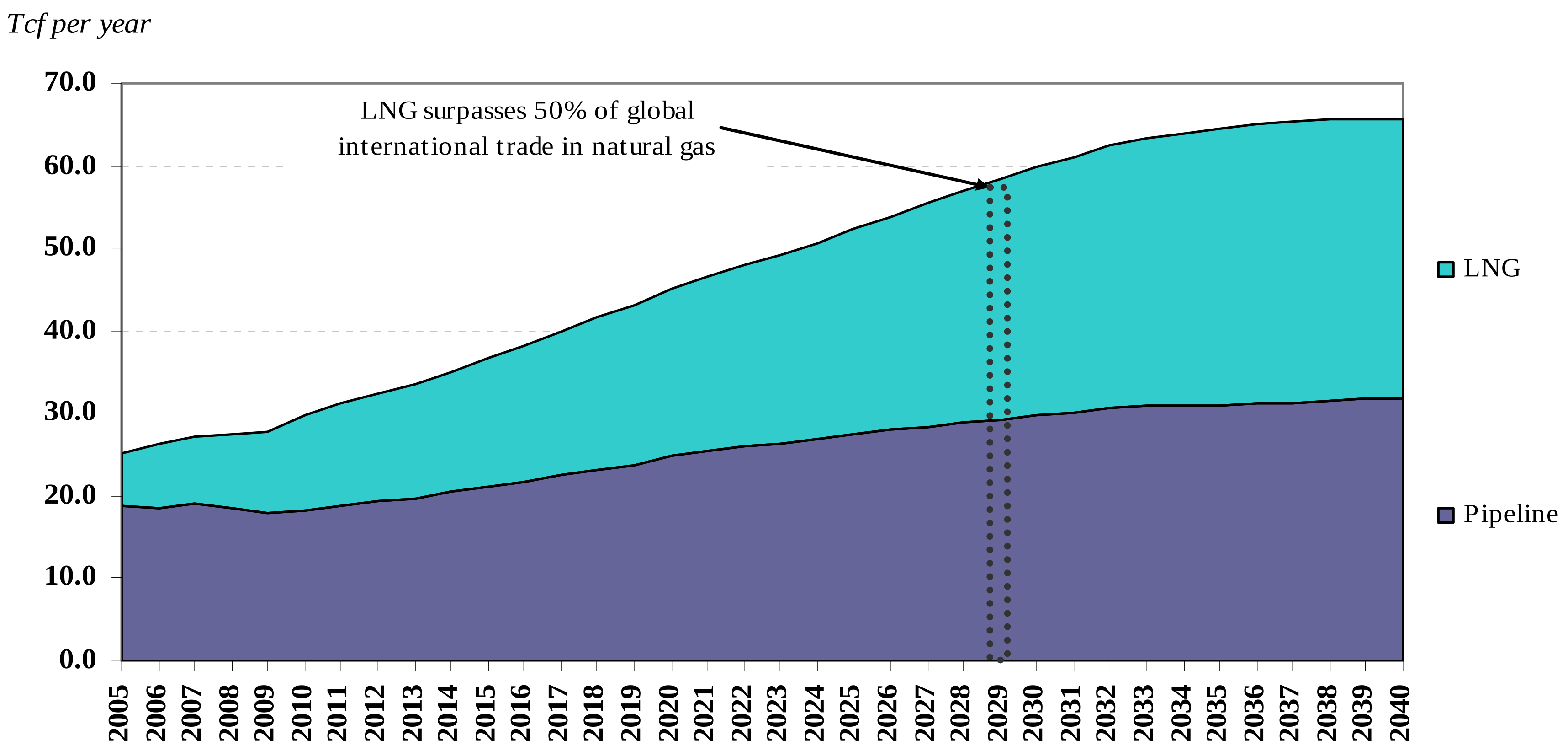
European LNG Import Capacity

- Capacity in 2009 will be 28% of annual demand, and it could be as high as 40% of annual demand by 2011.
- There is an additional 180 bcm of import capacity that has received approval or is in the approval process.
- LNG will be relatively cheap in the short term due to high supply, low demand, and new shale resources in the US.

Terminal	Location	Country	Current Capacity (Bcm/yr)	Current Capacity (bcf/d)	Initial Start-up
Existing					
Fluxys LNG	Zeebrugge	Belgium	9.1	0.8805	1987
Fos Sur Mer	Fos sur Mer, Marseille	France	4.5	0.4354	1972
Montoir De Bretagne	Montoir-de-Bretagne, Nantes	France	10	0.9675	1982
Revithoussa	Revithoussa, Athens	Greece	4.5	0.4354	2000
GNL Italia	Panigaglia	Italy	3.5	0.3386	1971
Sines LNG	Sines	Portugal	5.2	0.5031	2003
Barcelona	Barcelona	Spain	14.45	1.3981	1969
Bilbao	Bilbao	Spain	8	0.7740	2003
Cartegena	Cartagena	Spain	10.5	1.0159	1989
El Ferrol LNG	Murgados	Spain	3.6	0.3483	2007
Huelva	Huelva	Spain	11.83	1.1446	1988
Saggas	Sagunto, Valencia	Spain	6.57	0.6357	2006
Aliaga	Aliaga	Turkey	6	0.5805	2006
Marmara Ereglesi	Marmara Ereglisi	Turkey	5.2	0.5031	1992
Grain LNG	Isle of Grain, Kent	UK	13	1.2578	2005
Teeside Gasport	Teesside	UK	4.13	0.4000	2006
Total			***120.08***	***11.62***	
Under Construction					
Fos Cavou	Fos Cavaou	France	8.25	0.7982	2009
OLT Offshore LNG Toscana	Offshore Port of Livorno	Italy	4.7	0.4547	2011
Terminale LNG Adriatico	Offshore Rovigo	Italy	8	0.7740	2009
Dutch Gate Terminal	Rotterdam	Netherlands	12	1.1610	2011
Dragon LNG	Waterston, Milford Haven, Wales	UK	6	0.5805	2009
South Hook LNG	South Hook, Milford Haven, Wales	UK	10.5	1.0159	2009
Total			***49.45***	***4.78***	

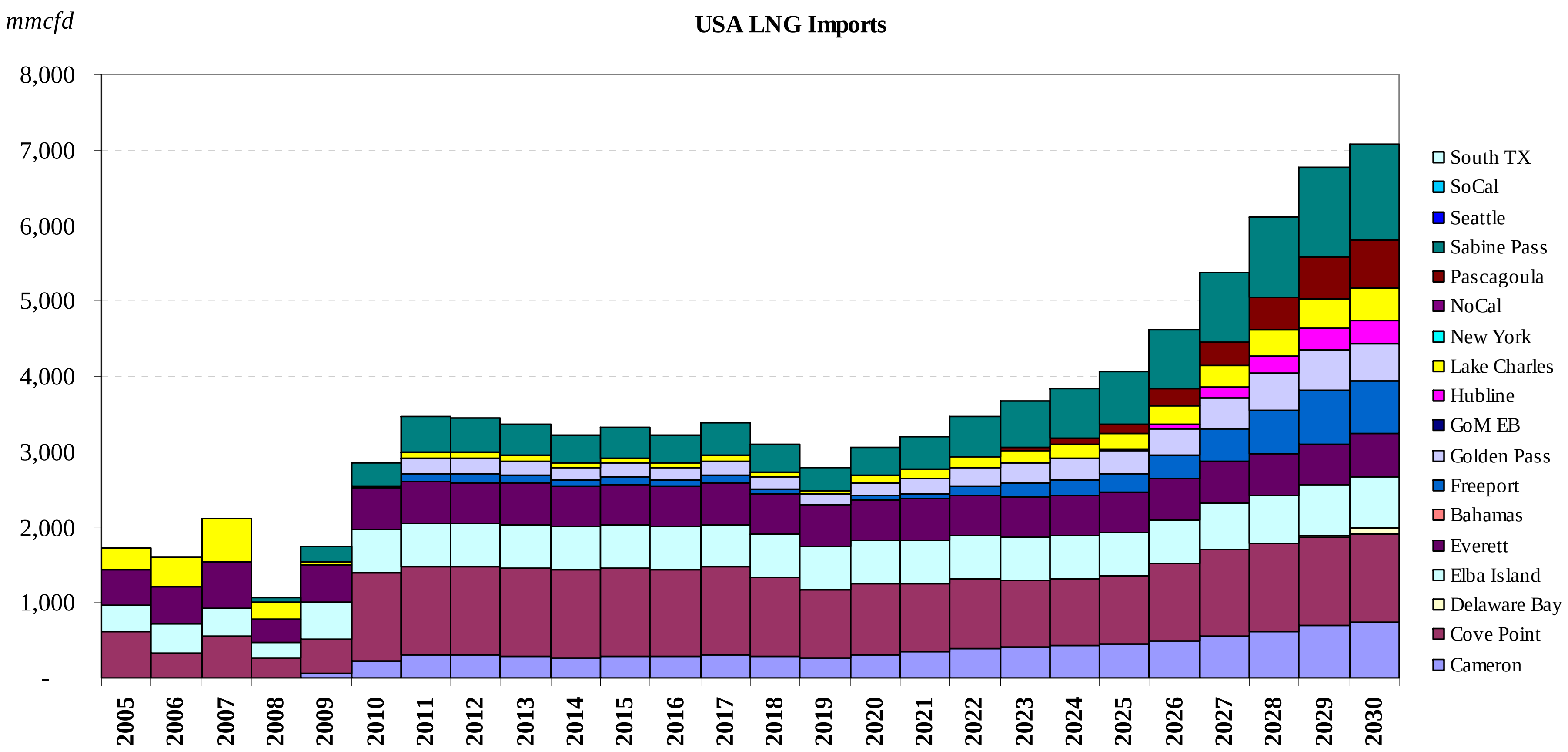
Global Gas Trade: LNG vs. Pipeline

- LNG growth is strong, reaching about 50% of total international natural gas trade by the late 2020s.
  - This date moves under different scenarios, but the pace of growth in LNG is generally stronger than pipeline trade.



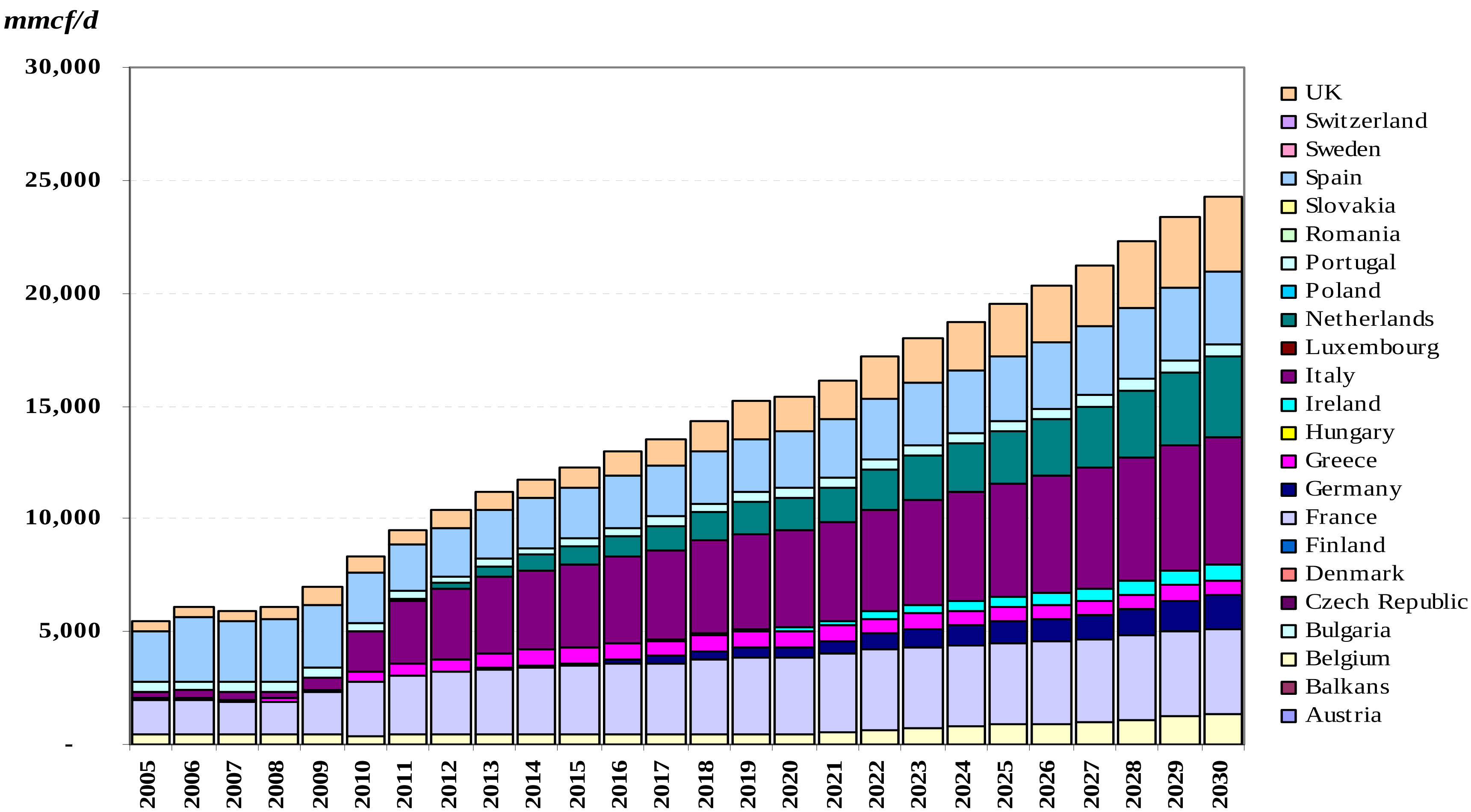
RWGTM: LNG Imports to the US

- Growth out of 2008 but stagnant from 2011-early 2020s. Low annual load factors on LNG regas facilities.



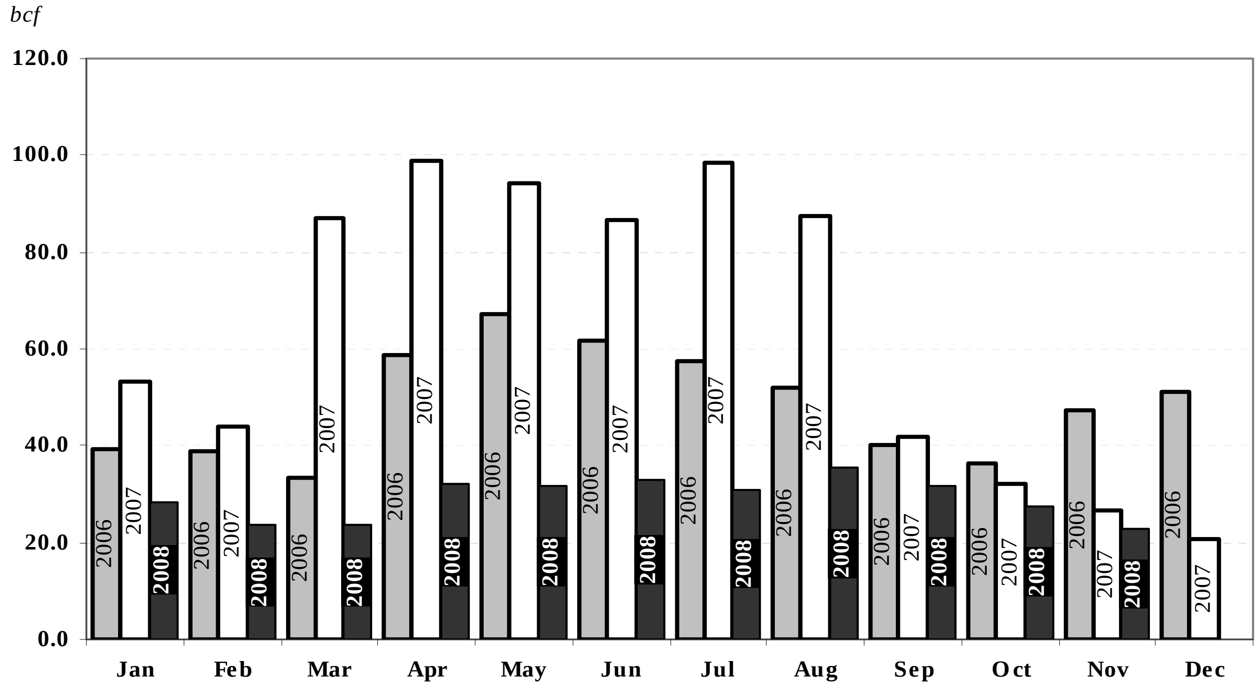
RWGTM: LNG Imports to Europe

- Growth steady going forward. Decent load factors on LNG regas facilities.



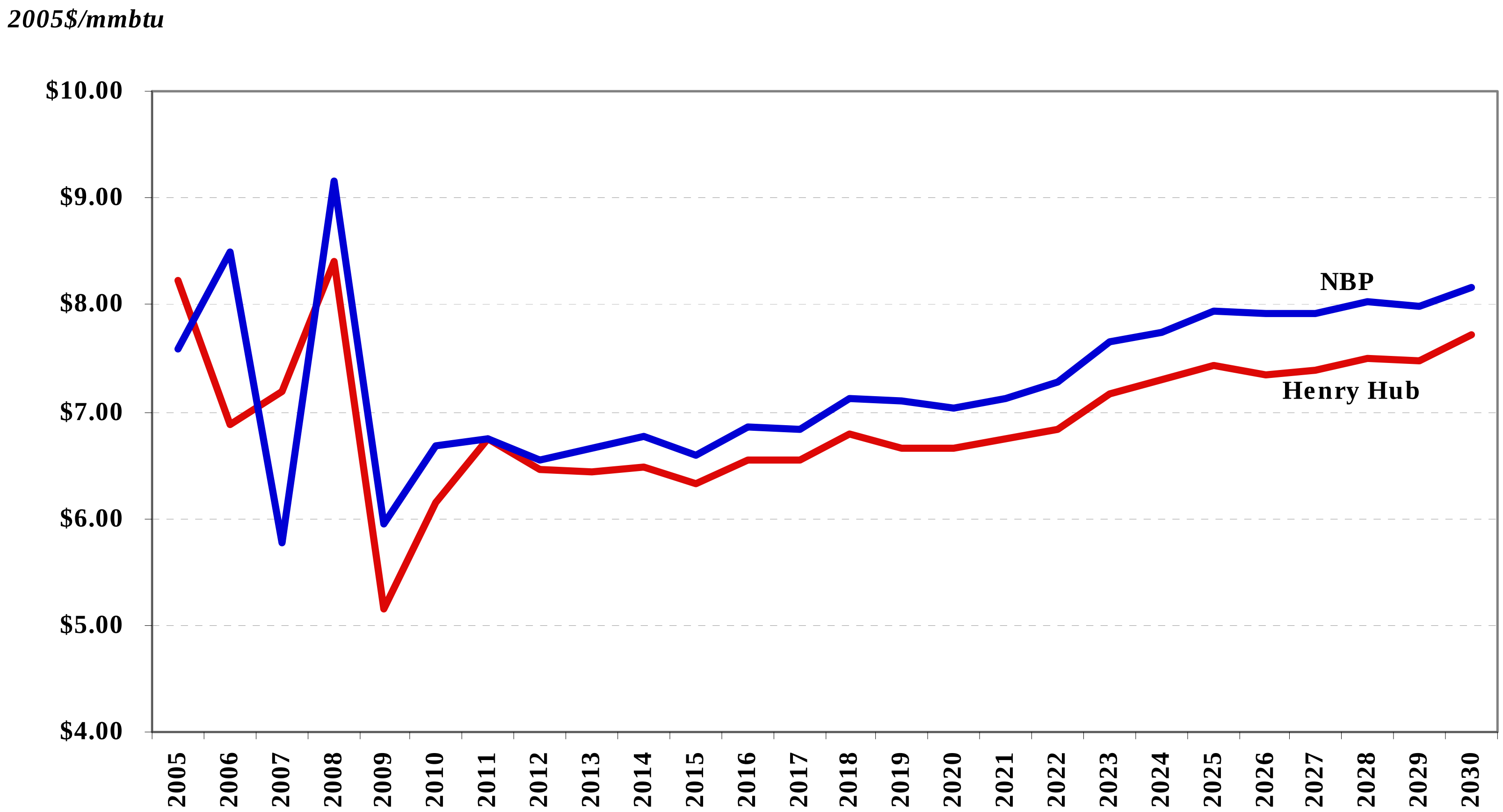
LNG Imports to the US: Seasonal Flows and Atlantic Basin Balancing

- The next three to five years will be interesting…
- LNG deliveries to the US have shown a seasonal pattern in the past. In particular, when markets in Europe cannot absorb supplies, they tend to be delivered to the US, which has ample storage capacity – hints at seasonal arbitrage.
- 2008 was an aberration due to demand in Asia. Reactivation of nukes in Japan likely to exacerbate the seasonal trends. 2009 has been slightly stronger than 2006.



RWGTM: Selected Regional Natural Gas Prices

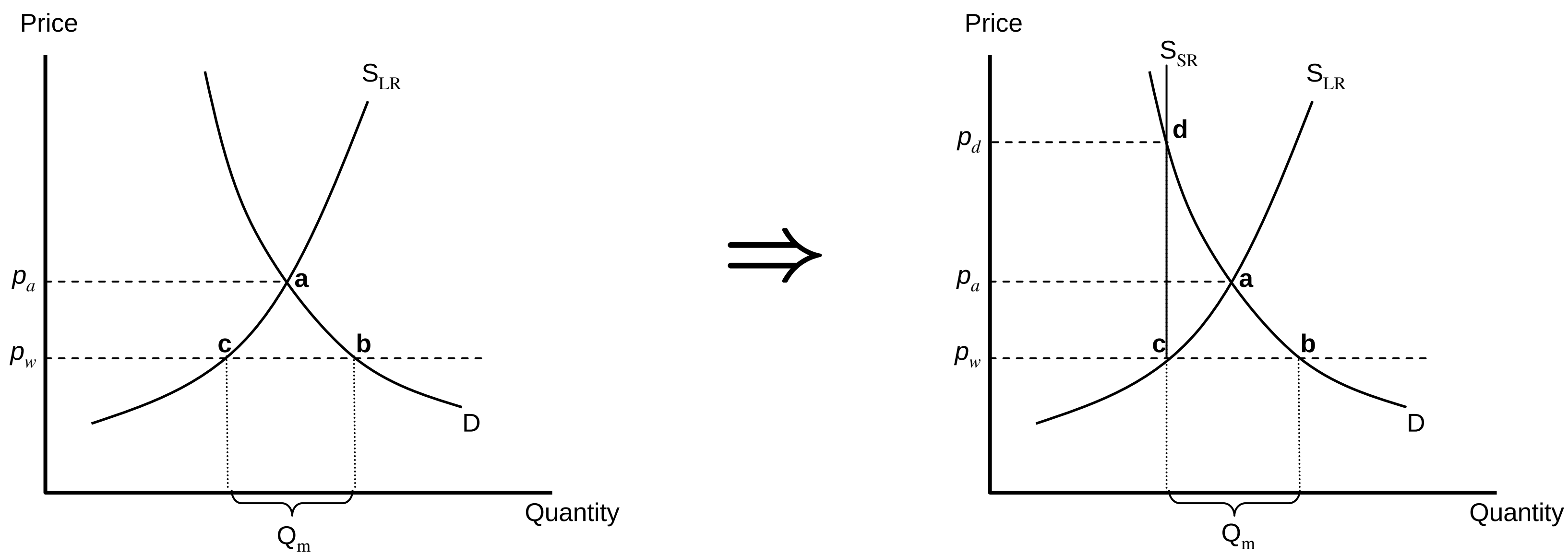
- Increased trade leads to price differentials that reflect transport differentials
- Longer term prices at Henry Hub (averages)
  - 2010-2020: $ 6.52 2021-2030: $ 7.29



"Energy Security" A Driver of Policy

An Energy Security Framework

- There are gains from trade, given as Δabc. But, there are potential losses as well.
  - Consider the extreme case of a complete disruption. The welfare loss is Δbcd
- Since $\Delta bcd > \Delta abc$, why do we trade?
  - A disruption occurs with probability ρ. We will trade as long as $(1-\rho)\Delta abc \geq \rho\Delta bcd + \pi$ where π is an energy security premium, or the amount we are willing to pay to minimize either ρ or Δbcd.
  - Note $\rho \to 0$ implies $\Delta abc \geq \pi$ meaning we would be willing to give up the gains to eliminate costs.
- This where policy plays a role… The energy security premium, for example, could be funds directed at R&D in efficiency and alternative energy sources (shift D in), policies supporting exploration such as royalty relief (shift S out), military presence in exporting regions (reduce ρ), and foreign policy that is preferential to key trading partners (reduce ρ).



What Does the Future Hold?

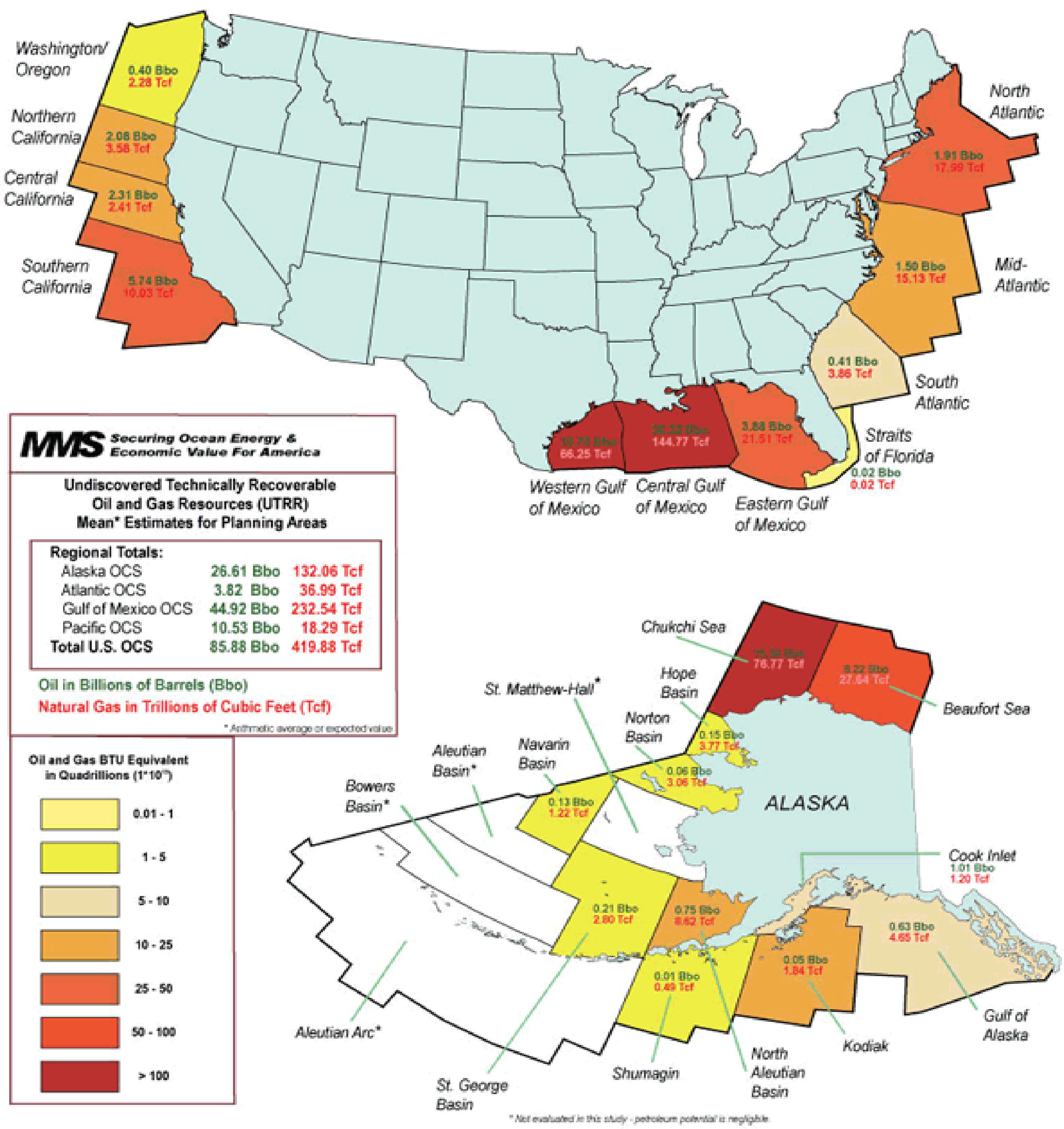
Factors that will effect market developments: Commerce and Technology

- Shale gas has emerged and is here to stay.
  - Technical breakthroughs continue, thus driving down cost
- Hydromethanation… Great Point Energy just signed a 15 year deal to provide Dow Chemical with natural gas via gasification technology
- Renewable technologies have received massive amounts of funding…
  - Reminiscent of the late 1970s-early 1980s.
  - If prices fall, this funding could begin to diminish unless real commercial progress is demonstrated.
- Efficiency improving technologies
  - Smart meters
  - Internal combustion engine technologies
  - Brake energy capture technologies in heavy vehicles
- Fuel substitution
  - Natural gas for transportation
  - Electricity for transportation

Factors that will effect market developments: Policy

- Climate and energy come next, but the order depends on price.
- "Green" technology will see increased investment and likely deployment… is it perhaps the next bubble.
  - Green jobs… how real are they?
    - The case in Spain (see Gabriel Calzada Álvarez (2009) "Study of the Effects on Employment of Public Aid to Renewable Energy Sources" at the Universidad Rey Juan Carlos)
    - "For every 4 jobs created, 9 were lost"
- Drilling offshore – the "state's prerogative"
- Efficiency, efficiency, efficiency – the 1980s all over again?
- Ethanol – obstacles despite Obama's support, unless some environmental and technological hurdles can be overcome – supports gas demand
- Clean coal? An obvious solution, especially given US endowment – hampers gas demand
- Cap-and-trade will likely happen, largely because politicians don't like "tax".
- Will the price cycle repeat?
  - Capacity investments matter!
  - The role of technology, both in the upstream and in end-use, is critical.

Assessment of Undiscovered Technically Recoverable Oil and Gas Resources of the Nation's Outer Continental Shelf, 2006



Access restrictions: A new call or greater awareness?

- Access restrictions have been lamented in NPC literature for well over a decade
- Lower48 OCS effected resource (mean est.)
  - 18 billion bbl oil
  - 76 tcf natural gas

Natural Gas impacted by restrictions

Planning Region/Basin		Resource Off-limits (Tcf)
Rocky Mountains	Montana	9.4
	Wyoming Thrust Belt	0.8
	Green River	39.5
	Powder River	6.0
	Uinta-Piceance	8.4
	San Juan	5.3
Total Lower 48 (incl. OCS)		**146.8**
Alaska	ANWR	8.6
	North Aleutian Basin	8.6
Total		**164.0**

Data Sources: NPC2003 Supply Task Group Report, MMS, Hartley and Medlock (2007)

The "offshore drilling" debate

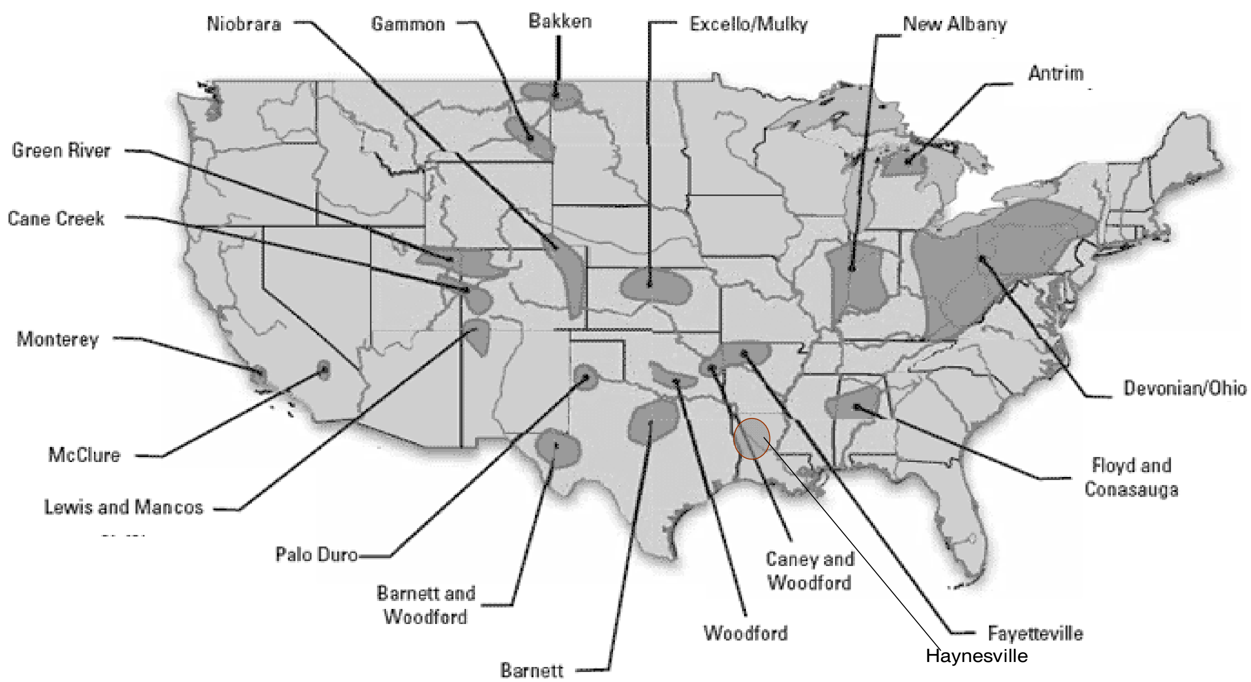
- Common objections to lifting the moratorium are:
  - (1) Don't use all acreage in areas with access
  - (2) Not that much oil anyway
  - (3) Shortage of equipment and personnel
  - (4) Impact is in the distant future and, according to EIA, not substantial
  - (5) Offshore drilling is environmentally detrimental
  - (6) Does not help to eliminate our addiction to oil
- Are these good arguments?
  - (1) Prospect size and promise. Acreage number often cited is not correct. No objection to "use it or lose it", but...
    - it could result in lower lease revenues and lower production
    - leased acreage provides an option to respond to changing conditions.
  - (2) Assessments are filled with uncertainty… there could be more, or there could be less. If there is nothing there, no drilling will occur anyway.
  - (3) Short run phenomena
  - (4) Expectations and modeling
  - (5) Only 0.001% of all oil drilled in the OCS has been spilled (NAS)
  - (6) Could serve as a bridge to the future, if policy is done right
- **The debate ignores natural gas potential.** This will be ever more important as we move into the future!

The "Pickens' Plan": A role for gas and wind

- Goal is to "reduce foreign oil dependence by harnessing domestic energy alternatives, and buy us time to develop even greater new technologies."
- This is to be accomplished (in 10 years!) by
  - Displacing natural gas in power generation with wind
  - Displacing oil in transportation with natural gas
- The plan requires
  - Massive investment in electricity transmission
  - Large scale deployment of wind turbines
  - Rapid adoption of natural gas fueled vehicles
- Is this the most efficient use of capital and domestic resources?
  - Idea of facilitating energy independence is timely.
  - An overhaul of the electricity distribution network has additional benefits, even if wind is not deployed at the scale required.
  - Costs are very large.
  - Efficient electricity storage is needed… this does not necessarily favor wind.
  - Will consumers really buy NGVs? Will station owners install NG facilities?
  - Why not plug-in hybrids, using natural gas to generate power?
- What about transportation fuel taxes?

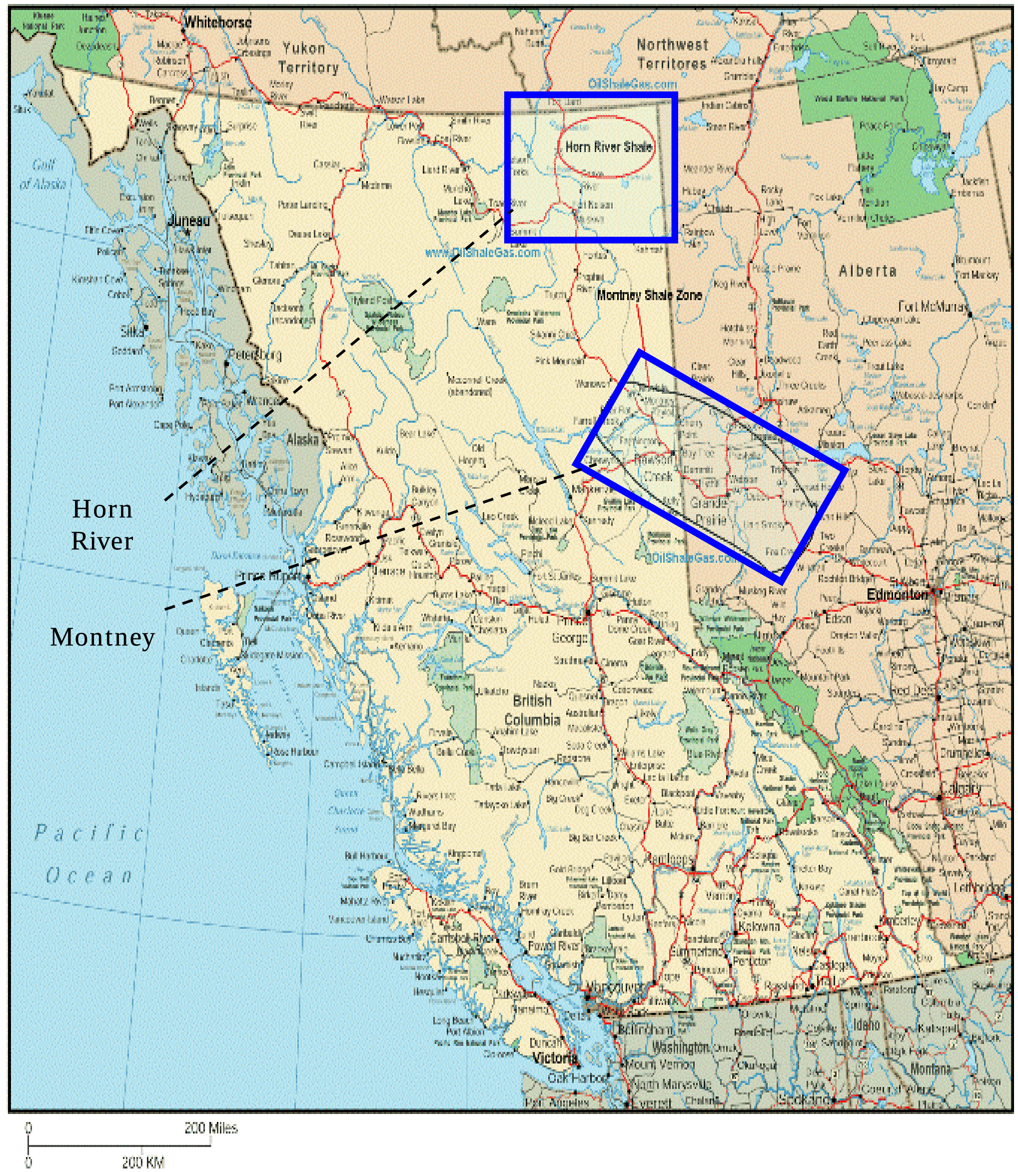
Developments in Shale Gas

- Very active area of exploration and development
  - NCI assessment indicates 275-840 tcf of technically recoverable shale gas
    - Differences driven primarily by producer reports for the Haynesville and Marcellus.
    - Even low end is higher than EIA's 125 tcf (AEO2008) or the 131 tcf cited by PGC (2006)
    - *Do not* include Canada (Montney, Horn River).
    - These are *technically* recoverable estimates. Costs may be an impediment.
      - Breakeven estimated at roughly $7/mcf in most plays. Favors Appalachian developments.
  - Other studies are ongoing.



Developments in Shale Gas (cont.)

- Shale plays in Canada are also being developed.
- Most active areas are in the Horn River and Montney plays in BC and Alberta.
- Supply potential in BC, in particular, has pushed the idea of LNG exports targeting the Asian market
  - Asia is a premium market.
  - Competing projects include pipelines from Russia and the Caspian States, as well as LNG from other locales.
- BC is a basis disadvantaged market, but selling to Asia could provide much more value to developers.
- Utica Shale in Quebec has been compared to the Barnett in Texas, and price is even more favorable.



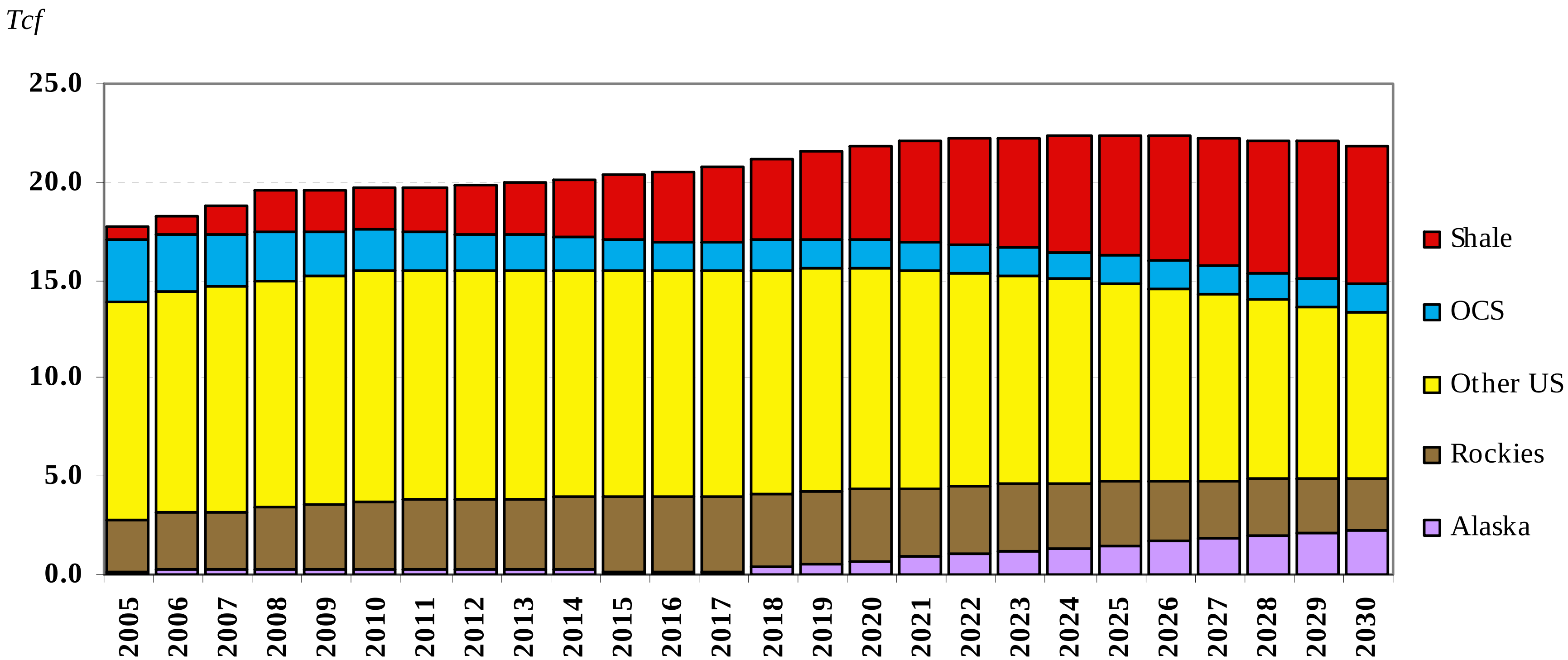
Shale Gas Assessment in the RWGTM

- Technically Recoverable Assessment in RWGTM
- Economically Recoverable Assessment is smaller
  - Development costs based on the breakeven economics from various consultants
- Assessed volumes could be much larger. As activity progresses, the assessments change.
- Technology is also a major X-factor that wuill change both the technically recoverable and economically recoverable assessments.

	Shale Play	Basin	Mean technically recoverable gas
US	**Antrim**	Michigan Basin	13.2
	Devonian/Ohio	Appalachian Basin	79.6
	Marcellus	Appalachian Basin	44.2
	New Albany	Illinois Basin	3.8
	Floyd/Chatanooga	Black Warrior Basin	2.1
	Haynesville	Gulf Coast Onshore	34.0
	Fayetteville	Arkoma Basin	26.0
	Woodford Arkoma	Arkoma Basin	8.0
	Caney and Woodford	Arkoma Basin	No Data
	Woodford Ardmore	Ardmore Basin	4.2
	Barnett	Fort Worth Basin	26.2
	Barnett and Woodford	Permian Basin	35.4
	Palo Duro	Palo Duro Basin	4.7
	Lewis	San Juan Basin	10.2
	Cane Creek	Paradox Basin	No Data
	Excello/Mulky	Cherokee Platform	No Data
	Bakken	Williston Basin	1.8
	Gammon	Williston Basin	No Data
	Niobrara (incl. Wattenburg)	Denver Basin	1.3
	Hilliard/Baxter/Mancos	SW Wyoming	11.8
	Lewis	SW Wyoming	13.5
	Mowry	SW Wyoming	8.5
	Monterrey/McClure	San Joaquin Basin	No Data
Canada	**Horn River**	WCSB	49.0
	Montney	WCSB	14.0
	Utica	Quebec	8.0
	Total Shale Gas Assessment		**355.3**

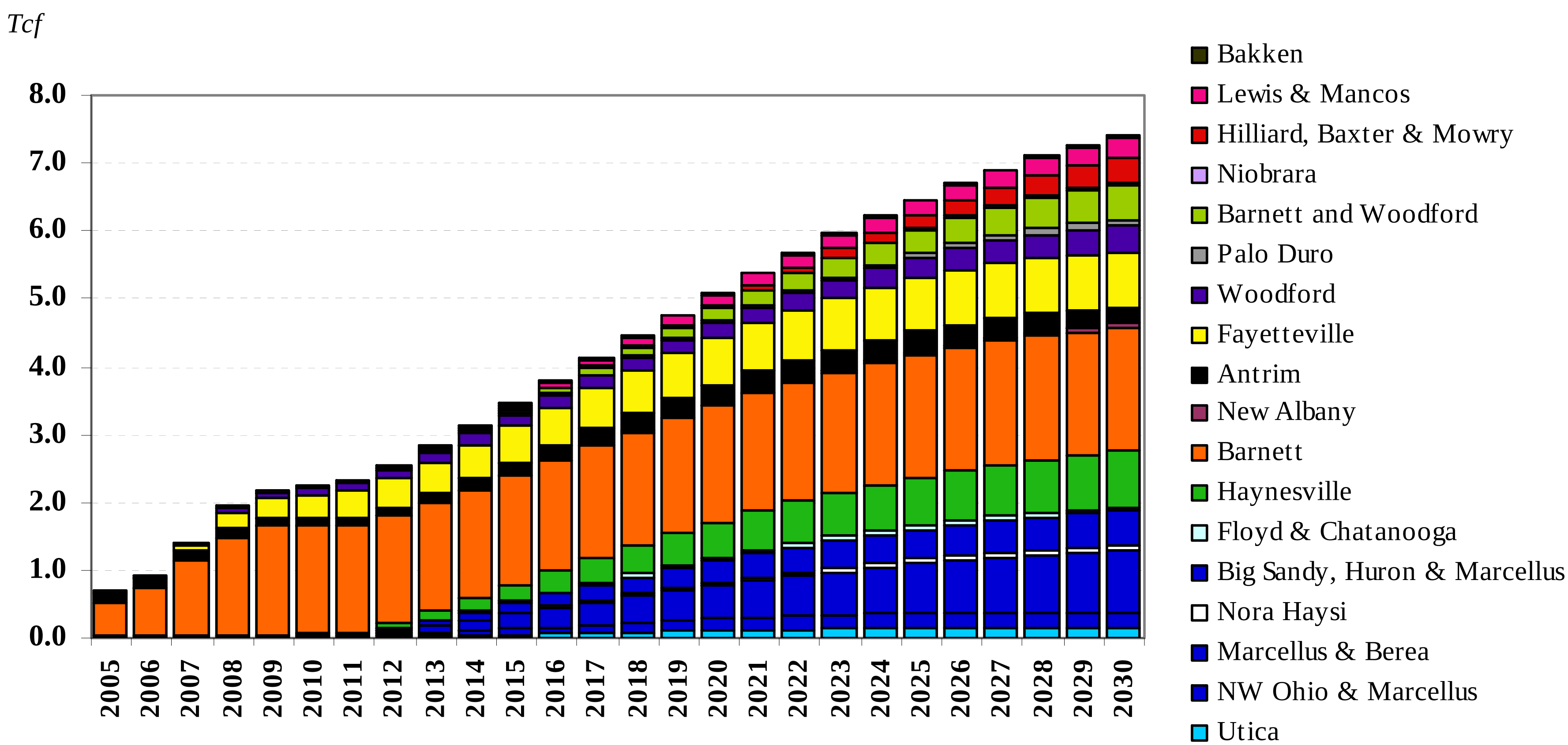
RWGTM: U.S. Supply

- Growth in U.S. production comes from expansion in shale basins.
- Steady declines in OCS and other regions.
- Medium term growth in Rockies.
- Alaska PL develops early 2020s.



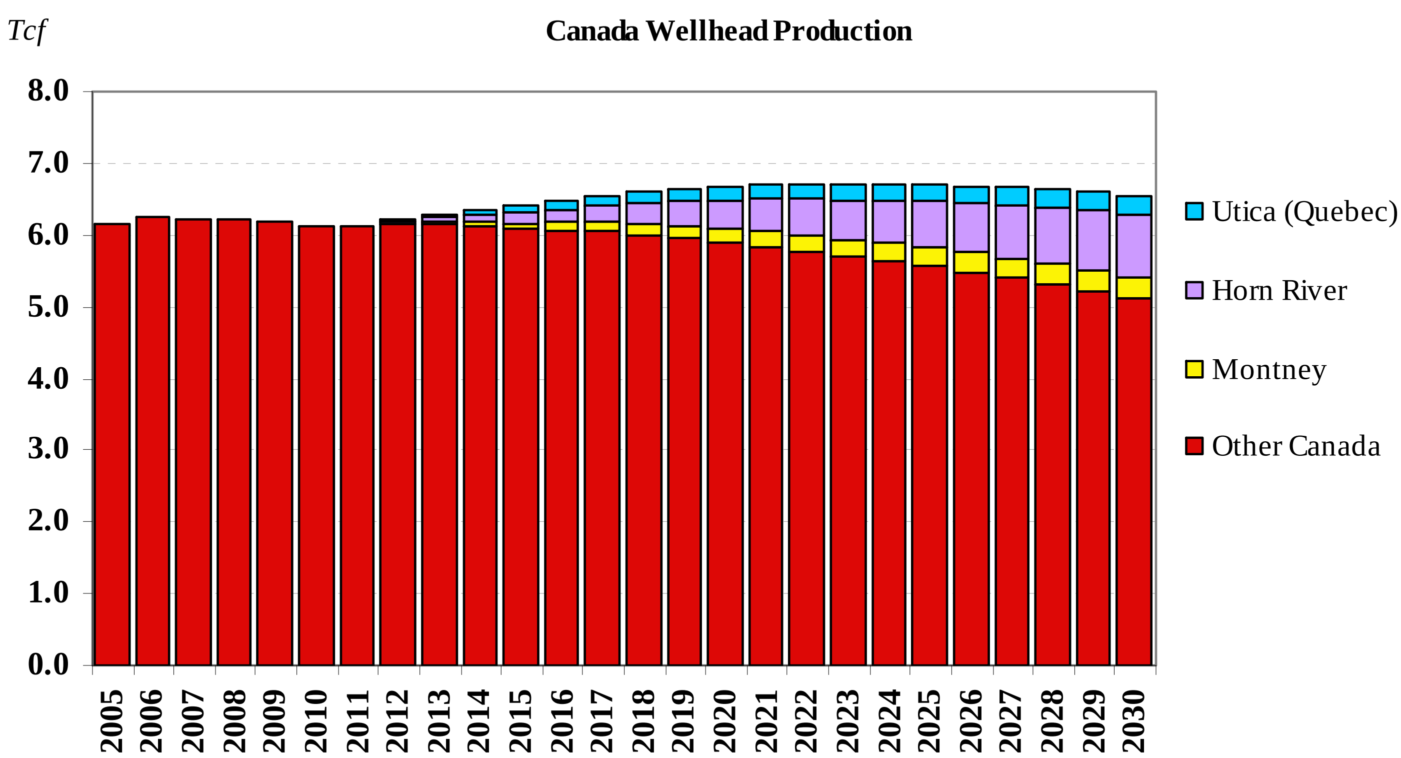
RWGTM: U.S. Supply (cont.)

- Strongest shale production is in Barnett.
- There is strong growth in the Marcellus, Fayetteville, and Haynesville shales in particular, with modest growth in several others.



RWGTM: Canadian Supply

- Growth in Canadian production comes largely from British Columbia in the Horn River Shale. However, the growth does not support LNG exports.
- Overall, shale production in Canada offsets decline in other regions and supports expanded tar sands production.



Geopolitical Risks

NOCs: Are they "efficient" firms?

- Non-commercial objectives influence the ability of national oil companies to function as many of the international integrated oil companies.
  - The word "efficient" should be used with care. NOCs may be "economically efficient" in the sense that they are maximizing some objective. However, the NOC likely faces a different objective than an IOC.
  - Theoretical modeling indicates these objectives indeed skew the firm's observed behavior away from the unimpeded outcome (Hartley/Medlock, "A Model of the Operation and Development of a National Oil Company," *Energy Economics*, 30(5)).
- Empirical analysis investigating the relative revenue efficiency of NOCs and IOCs. The results are robust to methodology
  - Stochastic Frontier Analysis (SFA)
  - Data Envelopment Analysis (DEA)
- Explaining the observed inefficiency:
  - Vertical integration
  - Share of government ownership, employment practice, domestic fuel subsidies
- Implication: higher prices are needed to maintain a given supply, much less grow production.

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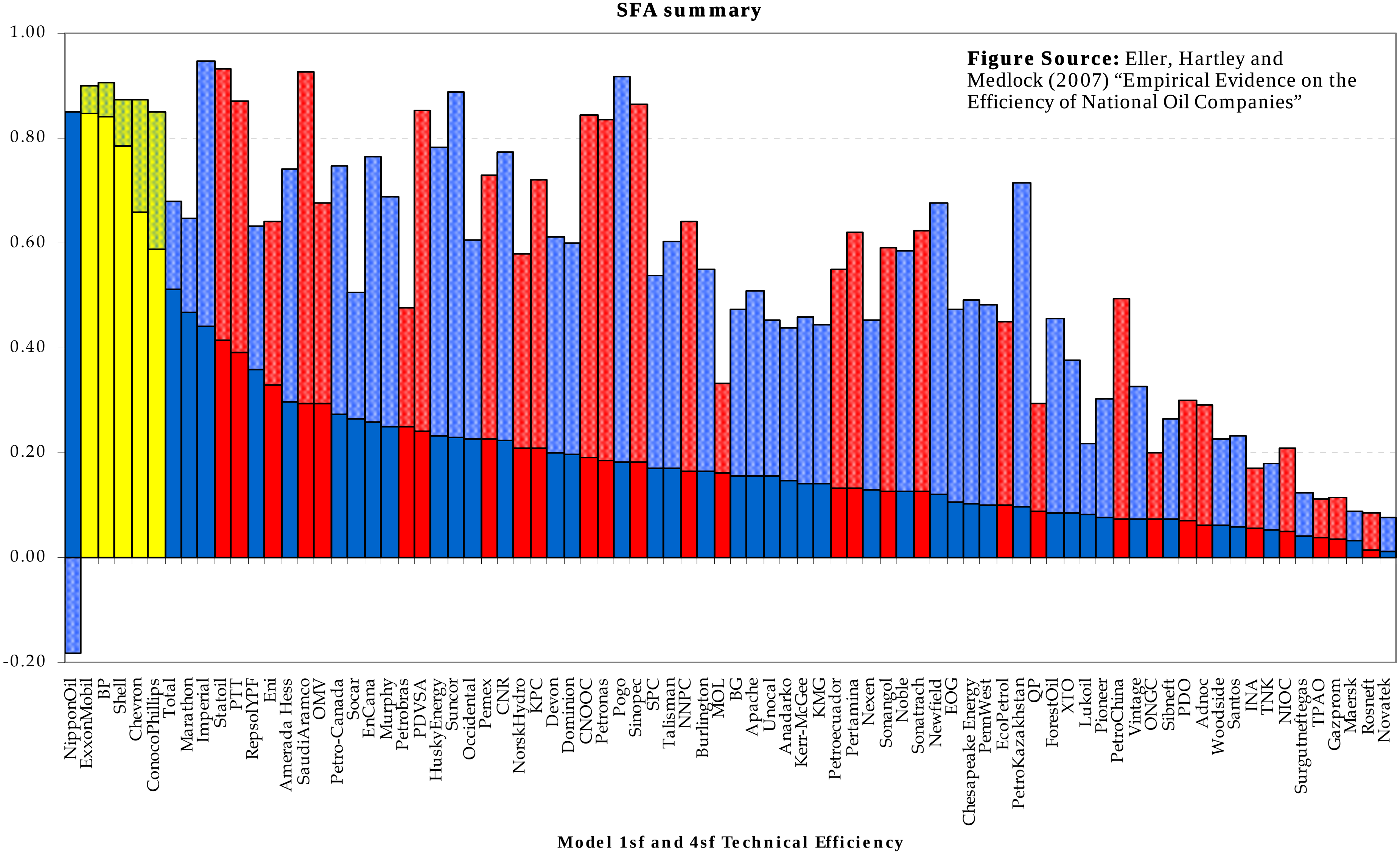
NOCs: Relative revenue efficiency



Areas to Watch

- Asia
  - Tensions with North Korea will prohibit the development of infrastructure. This will ultimately raise prices, particularly in South Korea, but also in China.
    - RWGTM Case
  - Chinese demand is expanding rapidly, commensurate with its pace of economic development. This creates competition for scarce resources with other large consuming nations.
    - Domestic pricing policies
    - RWGTM Case
  - India and Pakistan have an expanding need for energy due to economic growth and population growth.
    - The most economic source of supply is Iran, but this is at odds with the politics in the U.S. Short of choking these economies, something must give.
    - RWGTM Case

Areas to Watch (cont.)

- Iran
  - According to the USGS, Iran holds the second largest natural gas resource potential in the world. According to the OGJ, Iran also holds the second largest oil reserves (not including non-conventional oil). However, much of that resource may never reach major markets due to sanctions.
  - Possibility of fugitive resource conflicts with Qatar.
  - If any war breaks out, it could create choke points for the flow of oil and gas (Strait of Hormuz), particularly if Iran is involved.
  - Domestic pricing policies
- Russia
  - Disputes over rents to transit countries (Ukraine/Belarus) could limit European willingness to rely on Russian pipeline supplies
  - Russian handling of Western interests in existing projects could jeopardize future capital flows.
  - Moves to block Caspian developments through first mover advantage could hold those resources captive to Russian pipeline infrastructure.
    - RWGTM Case
  - Domestic pricing policies

Areas to Watch (cont.)

- West Africa
  - Civil strife can disrupt supplies (in fact it has). In a tight market, this has significant implications.
- South America
  - Brazilian finds could be very important
  - Venezuela holds a large potential, but nationalism and provocation of the U.S. will likely limit the availability of those supplies.
  - Bolivia has resource, but it is far from markets. Nationalization will likely do more harm than benefit by discouraging capital inflow.
    - RWGTM Case
- North America
  - Policy may push LNG reliance
    - Environmental objections keep resource untapped – OCS, Rockies, Gulf of Mexico, ANWR.
      - RWGTM Case
    - Tax proposals
  - "Rent" negotiations continue to push Arctic gas infrastructure development into the future.

Concluding Remarks

Concluding remarks

- Geography and geology indicate a likely concentration of supplies in the future. This brings geopolitics to the forefront.
- Energy security concerns about heavy reliance on Russian supplies that must transit multiple borders prior to reaching the end-user could push more rapid development of LNG and/or adoption of alternatives to gas. Modeling suggests this is, in fact, an economic outcome, barring constraints on other developments.
  - Demand growth in Russia, supply deficits in "end-of-pipe" markets makes other supplies preferable to meet demand in Europe.
- European security can be enhanced through open access capacity rights. This could abate the need for some LNG import capacity
- One possible constraint for consideration results from a fact of geology, which foretells of a concentration of supplies. Is there potential for a "Gas-OPEC"?

Concluding remarks (cont.)

- There are potential unintended consequences of CO2 regulations, which are not necessarily in-line with goals of achieving energy security as it makes demand very inelastic. It does however encourage developments in alternatives, but these may take time.
  - Hartley and Medlock (2008), “Two sides of the same coin?”
- Proactive policies (rather than reactive) can be engaged to mitigate risks. Countries where coal reserves are large are most likely to seek coal-based gas import mitigation strategies. The US is home to roughly 27% of the world’s proven coal reserves, Russia 16%, China 12%, India 8%.
  - Europe benefits from clean coal even if it is not widely deployed in Europe.
- Prices will be linked through global arbitrage. Trade need not actually occur, just need the ability to trade – LNG provides this capability.
- For at least the near term: there is ample gas available. But, this could turn rather quickly if timely investments are not made.

Comments/Questions