

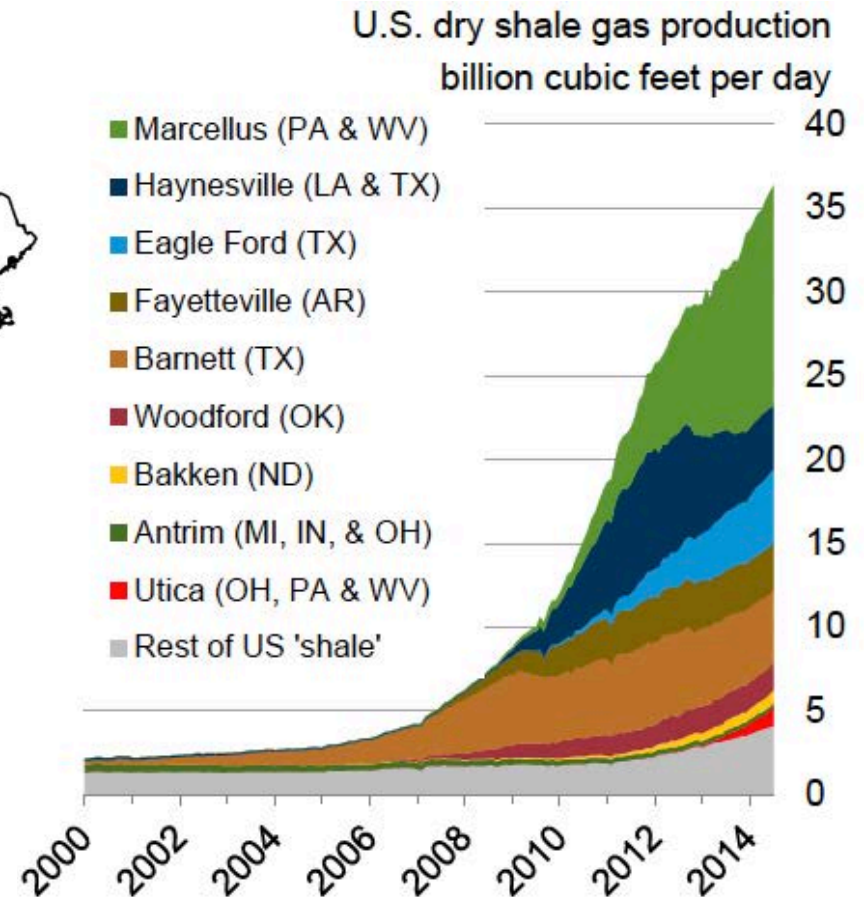
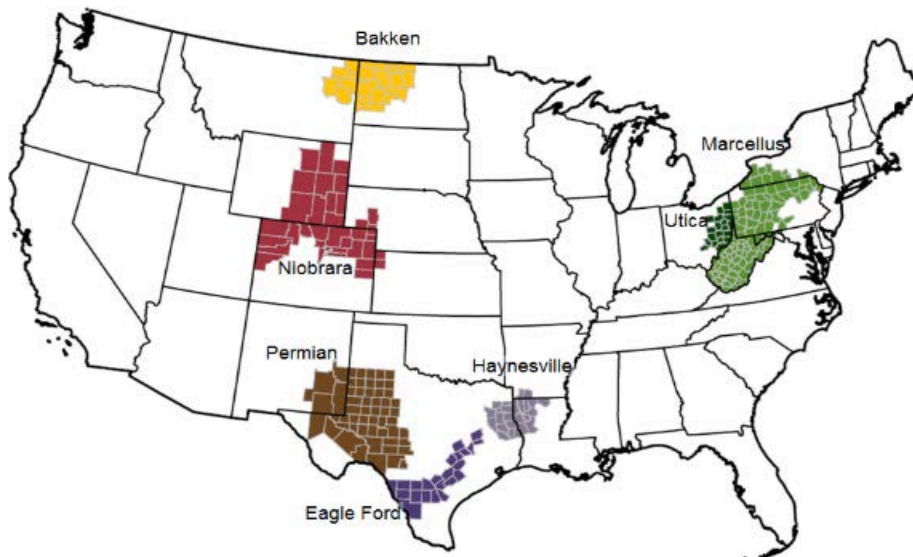


US Shale Gas Revolution—Economic, Commercial and Environmental/ Carbon Implications

**Benjamin Schlesinger and Associates, LLC
3 Bethesda Metro Center, Suite 700
Bethesda, Maryland 20814**

**5th UNECE Gas Centre Industry Forum
Outlook for the Long Term Contracts in a Globalizing Market
Palais des Nations, Geneva – 19 January 2015**

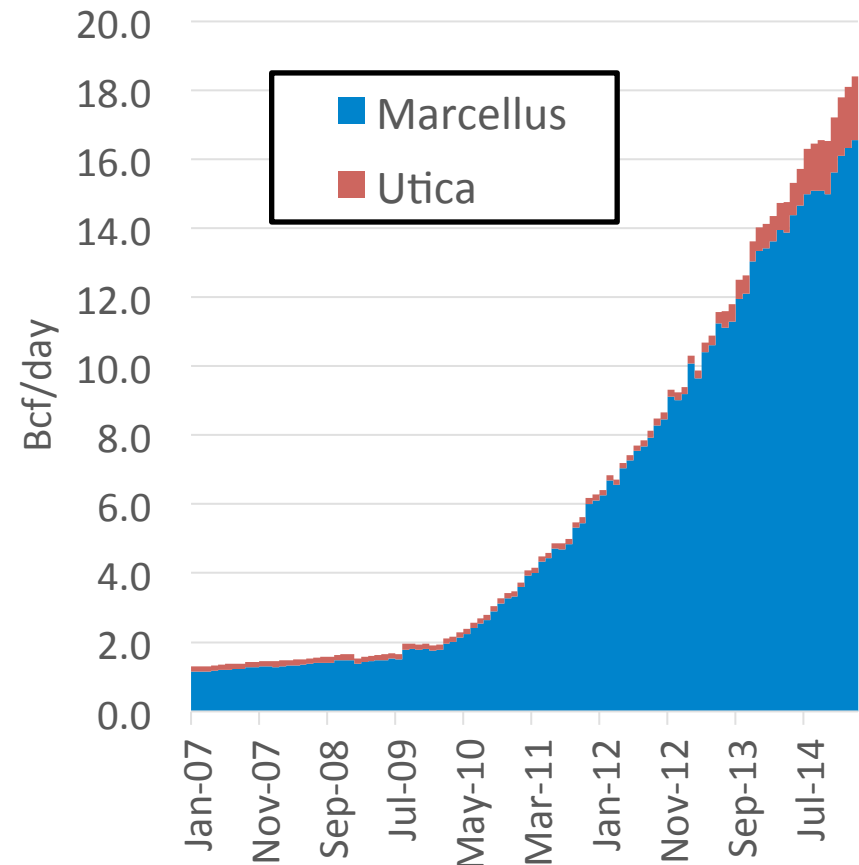
Shale gas production has swamped North American markets, changing pipeline flows.



Source: EIA Administrator Adam Sieminski, 9/22/2014; from state administrative data collected by DrillingInfo Inc. Data are through July 2014 and represent EIA's official tight oil & shale gas estimates, but are not survey data. State abbreviations indicate primary state(s).

Increasingly productive Marcellus/Utica shales “suddenly” supply 24% US market.

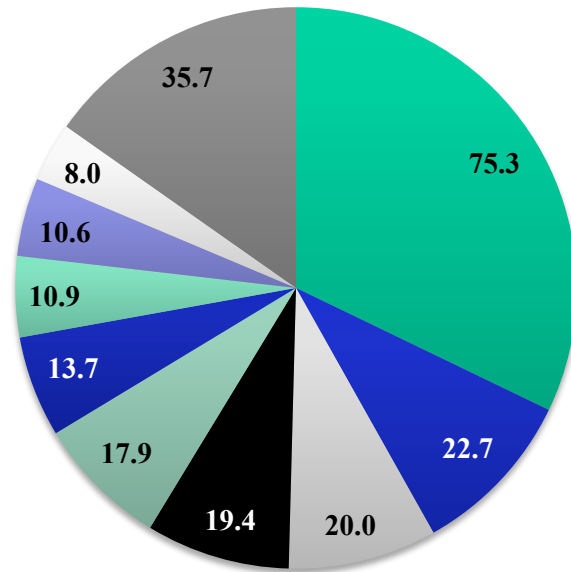
Natural Gas Supplies (Dry)	Potential Production, Bcm	Est. Recoverable, Tcm
Yamal	310-350	16.7
Bovanenkovo (alone)	220	4.9
Marcellus/Utica	190 (February 2015)	12.8
Qatar	159 (2013)	25.1



Source: EIA, Drilling Productivity Report, January 12, 2015; resource data from <http://www.eia.gov/analysis/studies/usshalegas/> (Northeast excl. Antrim); Yamal data from Gazprom, <http://www.gazprom.com/about/production/projects/mega-yamal/>, incl. explored and provisionally estimated; Qatar data from EIA, BP statistical review.

The US Energy Dept. has approved enough LNG exports to place US first, globally.

2013 LNG Exports, Mtpa



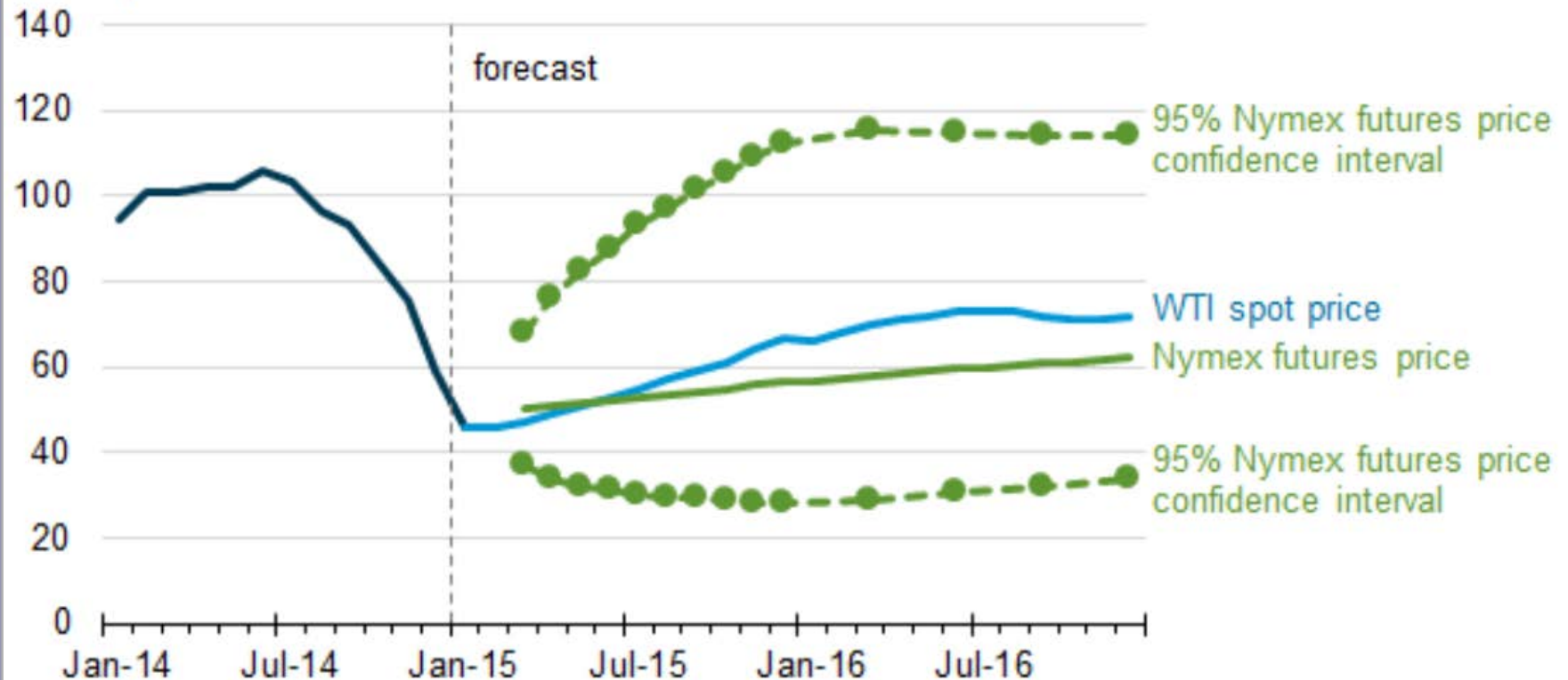
- Qatar
- Australia
- Indonesia
- Algeria
- Oman
- Malaysia
- Nigeria
- Trinidad & Tobago
- Russian Federation
- Others

Issue: How high will US LNG export volumes actually get?

- DOE has now approved about 85 mtpa of exports to non-FTA countries and South Korea.
- Deprived of grounds for rejection by its own studies, DOE recently announced suspension of further LNG export approvals to projects that have not been granted facilities certification from the FERC.
- FERC is likely to approve environmentally acceptable projects for which bone fide sponsors will assume commercial risk.
- The market, not the regulators, will decide: Global markets, with low oil-indexed prices, may reduce US LNG exports well below approved levels.

But market expectations of oil price uncertainty have increased in recent months.

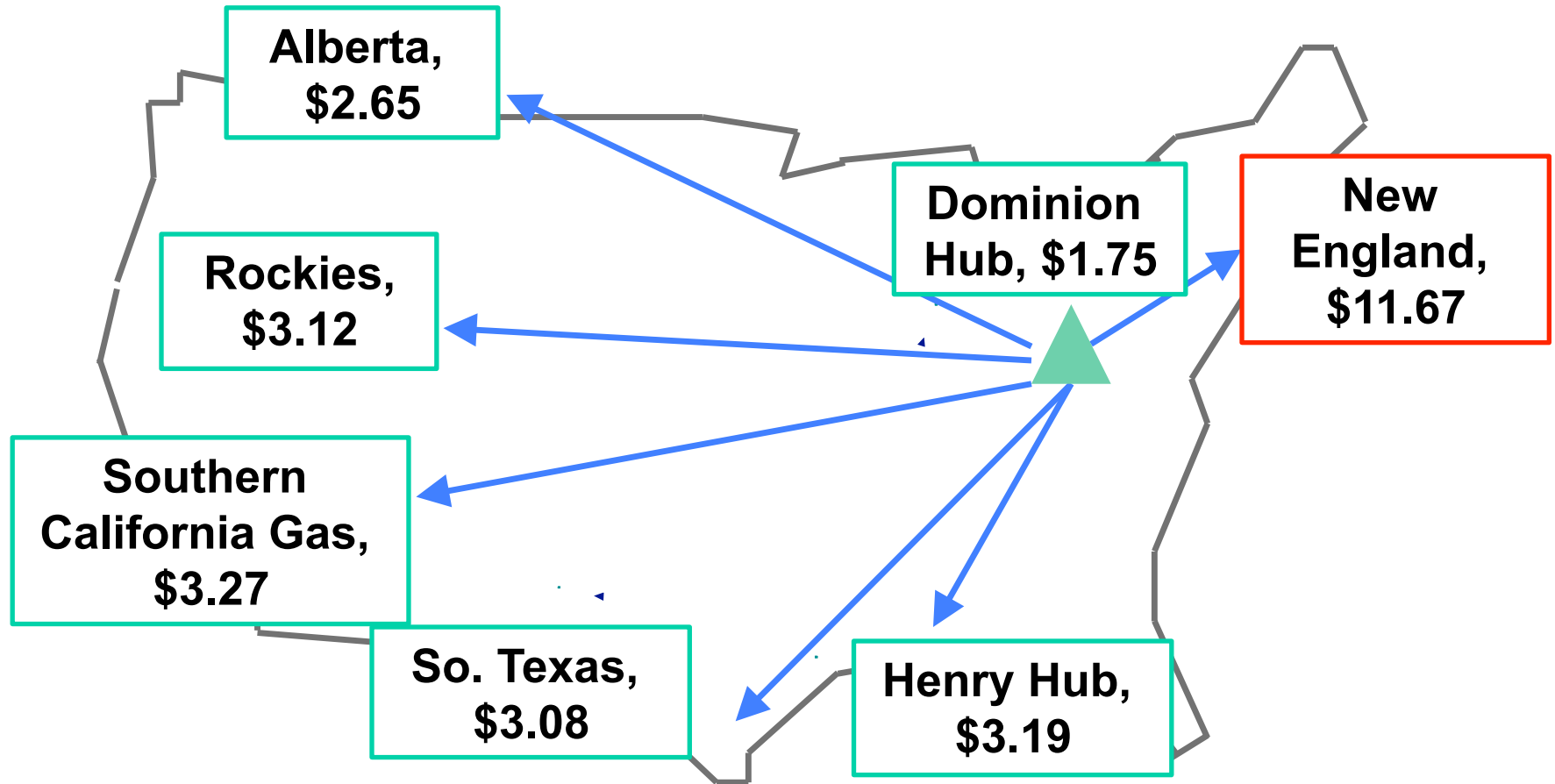
West Texas Intermediate (WTI) crude oil price
dollars per barrel



Source: U.S. Energy Information Administration, *Short-Term Energy Outlook*, January 2015

Note: Confidence interval derived from options market information for the five trading days ending Jan. 8, 2015. Intervals not calculated for months with sparse trading in near-the-money options contracts.

Shale gas has cratered North American gas prices in most regions.



Source: BSA 2015, from Platts Inside FERC's Gas Market Report, January 1, 2015 Spot Gas Prices; Dominion refers to Dominion Appalachia (South Point), New England refers to Tennessee Gas Pipeline, Zone 6..

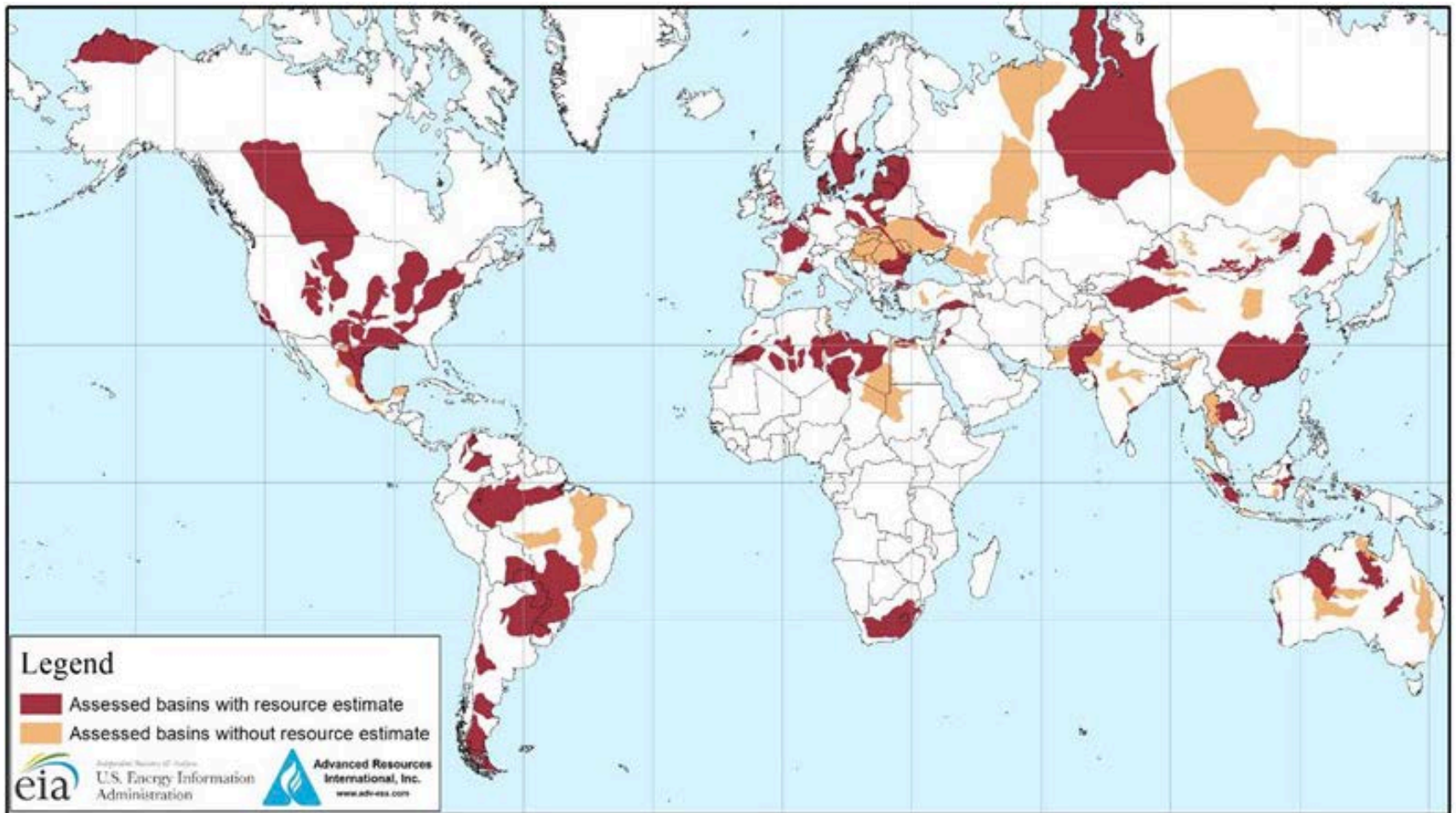
Great environmental & carbon advantages of natural gas include shale gas.

- ◆ US Environmental Protection Agency (EPA) investigations show groundwater contamination usually pre-exists fracking.
- ◆ Over 500 drillers report fluids on Frac-Focus, as required by top producing states.
- ◆ Replacing old coal boilers with new gas CCGT reduces CO₂ emissions by 63-72%.
- ◆ Environmental Defense Fund (EDF) studies show initial fears of high methane leakage rates (from over-flights) greatly overstated.
- ◆ Obama Administration and producing states are adopting “green completions” regulations based on EDF-Univ. of Texas studies.



Hydraulic Fracturing Job Circa 1950

Global shale gas development potential is estimated to exceed 200 Tcm.



Source: United States basins from U.S. Energy Information Administration and United States Geological Survey; other basins from ARI based on data from various published studies.



Benjamin Schlesinger and Associates, LLC

The Bethesda Gateway

3 Bethesda Metro Center, Suite 700

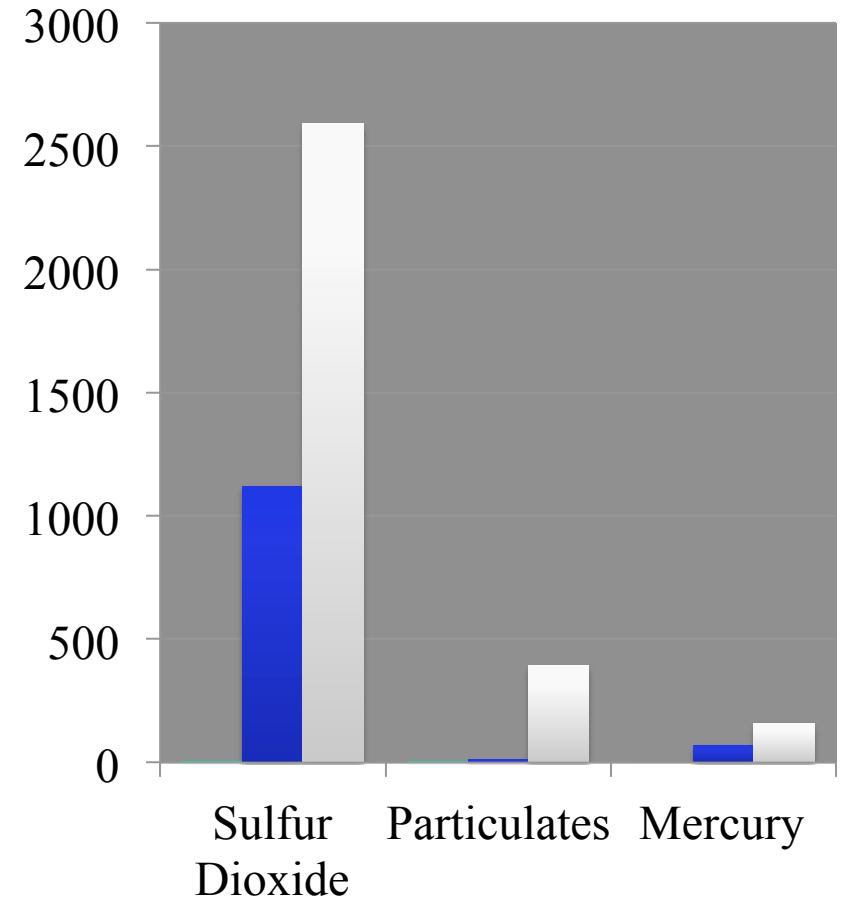
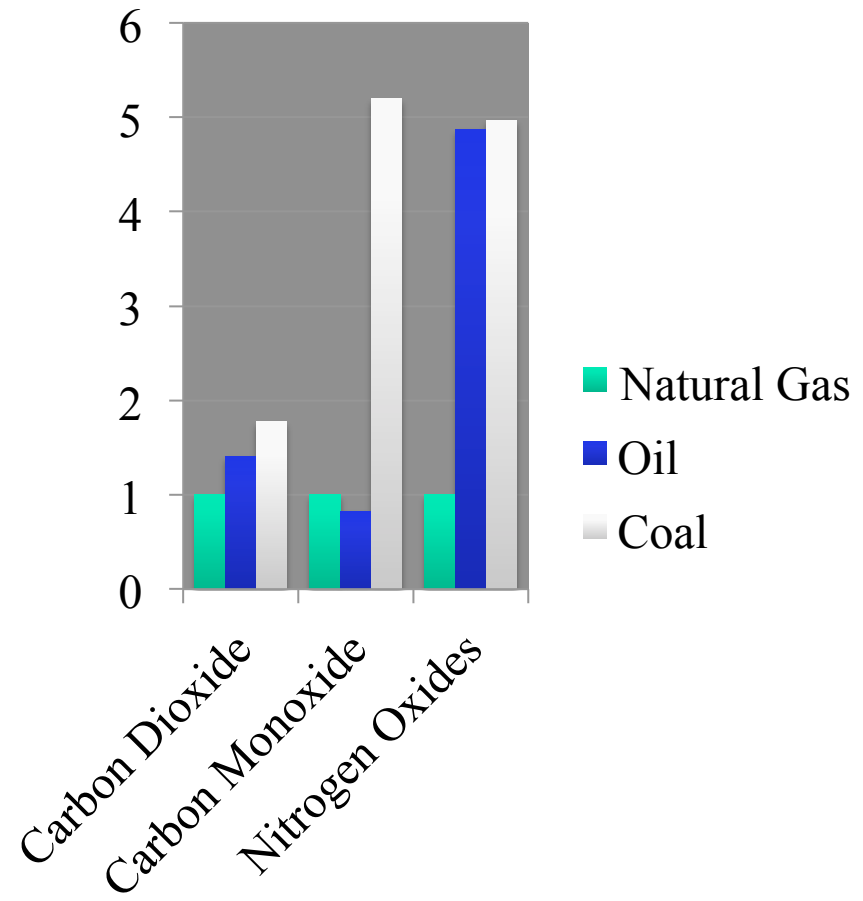
Bethesda, MD 20814

Phone: (301) 951-7266 Fax: (301) 951-3381

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Extra Slides

Natural gas burns 2x up to 2,590x cleaner than coal, and cleaner than oil as well.



Over 500 drillers report fluids on Frac-Focus, as required by all top producing states.

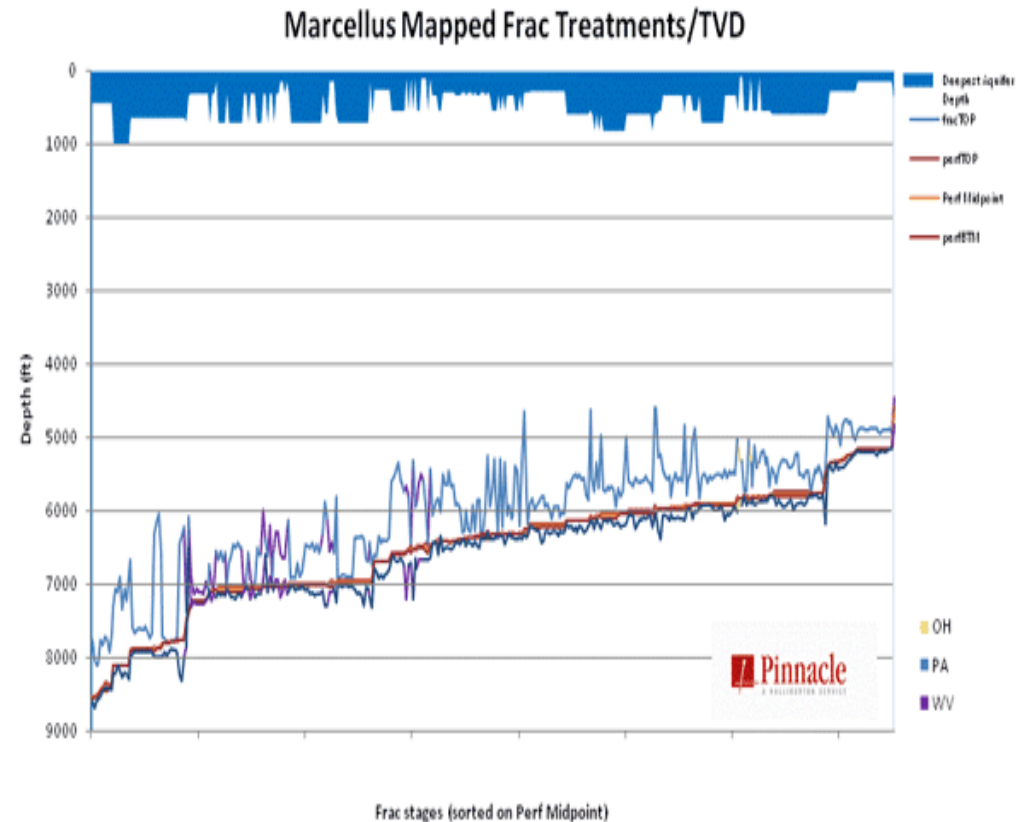


Hydraulic Fracturing Job Circa 1950

- ◆ First hydraulic fracturing in the 1940s.
- ◆ Since then, the process has become routine, used on **over 1 million producing wells**.
- ◆ As the technology continues to develop and improve, operators now fracture as many as 35,000 wells of all types (vertical and horizontal, oil and natural gas) each year.
- ◆ 55,978 well sites report fluid contents to FracFocus.

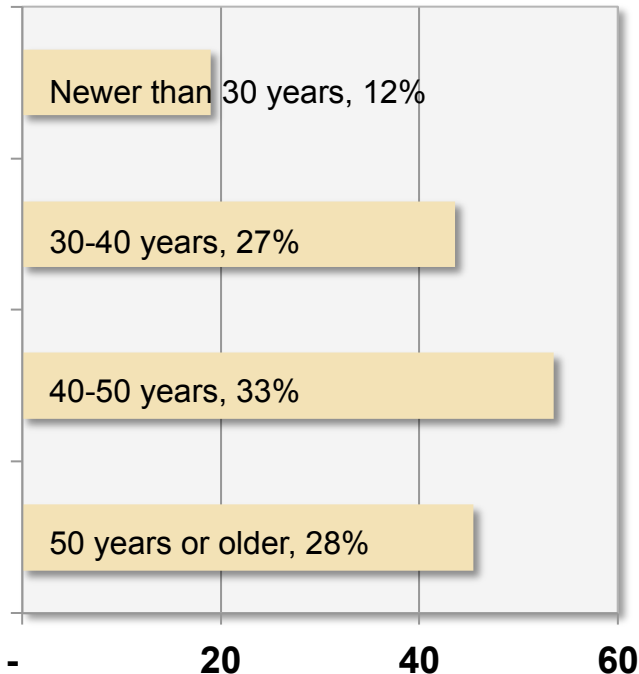
EPA investigations show nearly all groundwater contamination pre-exists fracking.

- ◆ Shale seams co-located with conventional gas, but lie far below groundwater tables.
- ◆ Shell, Range Resources and other drillers are recycling return waters in TX, PA.
- ◆ Drillers in arid regions are increasingly using waterless and air fracking systems.
- ◆ State environmental laws and the CWA prevent dumping of return wastes.
- ◆ What pathways are left?
Operator error! Well bores?

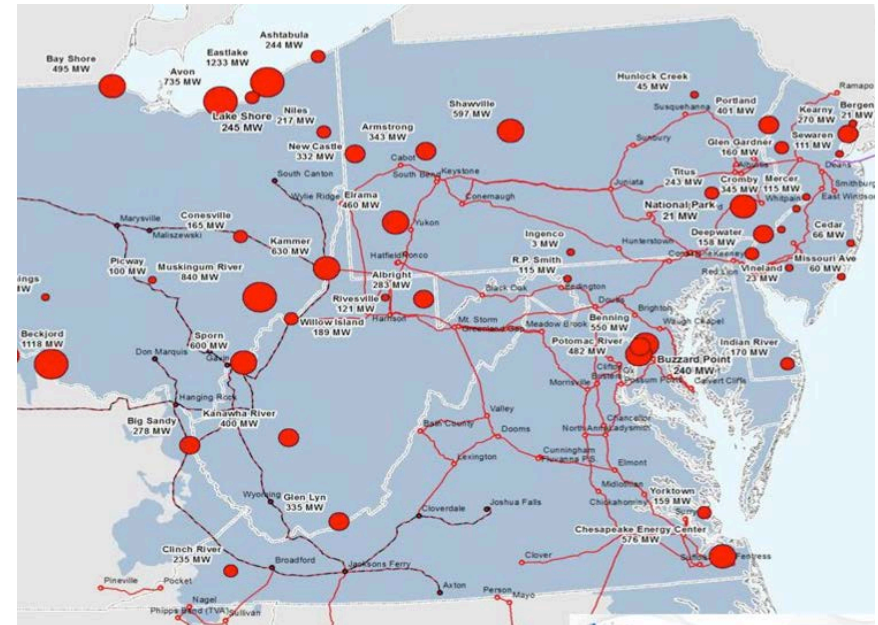


Some near-term surplus gas is replacing coal in aging power plants.

Coal-Fired Plants, MW



Retiring Coal-Fired Plants



Demand for gas pipeline and storage capacity is intensifying.

The good news: Replacing old coal with new gas reduces CO₂ emissions by 63-72%.

	Average Age of Plants at Retirement	No. of Plants Retired in Each Year	Total Net Summer Capacity, GW	CO ₂ Reduction Replacing Bituminous Coal with Gas
2009	50	12	0.5	67.7%
2010	54	35	1.5	69.4%
2011	62	31	2.5	63.3%
2012	56	57	8.9	63.9%
2013	55	14	2.1	71.7%
2014	57	34	4.7	64.4%
2015	57	61	9.9	63.1%

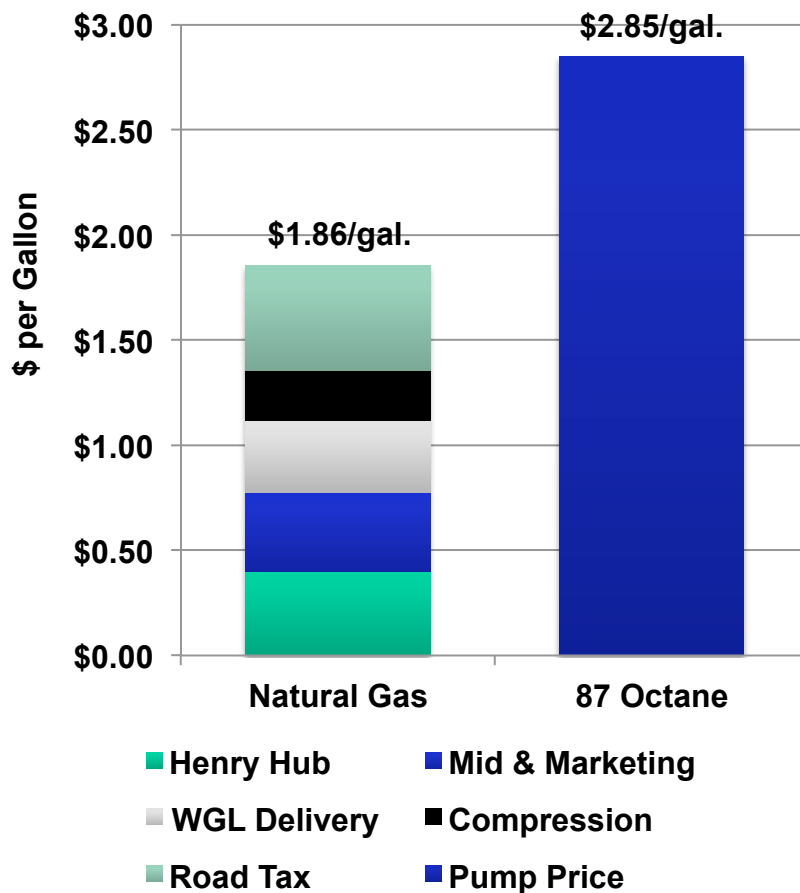
- ◆ GHG reduction due to:
 - Chemical advantage: Gas burning emits 46% less CO₂ than coal.
 - Efficiency advantage of new gas CCGTs versus old coal boilers: 55-60% vs. 31-33%.
 - Carbon emissions savings from fuel cycle as well.
- ◆ Other criteria air emissions reduced/prevented, especially sulfur, particulates, oxidants.
- ◆ But the “low-hanging fruit” might all be picked by 2020.

Natural gas (CNG and LNG) has begun to find markets trucking, rail and ships.



But natural gas demand in vehicles will take decades to evolve in the US.

Issue: Why doesn't America have 20 million NGVs by now?



- ◆ Economics have been highly favorable for 3 decades!
- ◆ Natural gas is best used in large vehicles, high-mileage fleets:
 - Municipal trucks, buses
 - UPS, Dulles Flyer
 - Forklifts, compressors
- ◆ Lower mileage personal vehicles are headed toward electricity:
 - \$4 pipeline gas vs. \$26 gasoline, both per MMBtu
 - 61% efficient CCCTs vs. 26% efficient piston engines
 - No wonder electricity = 79 c/gal!

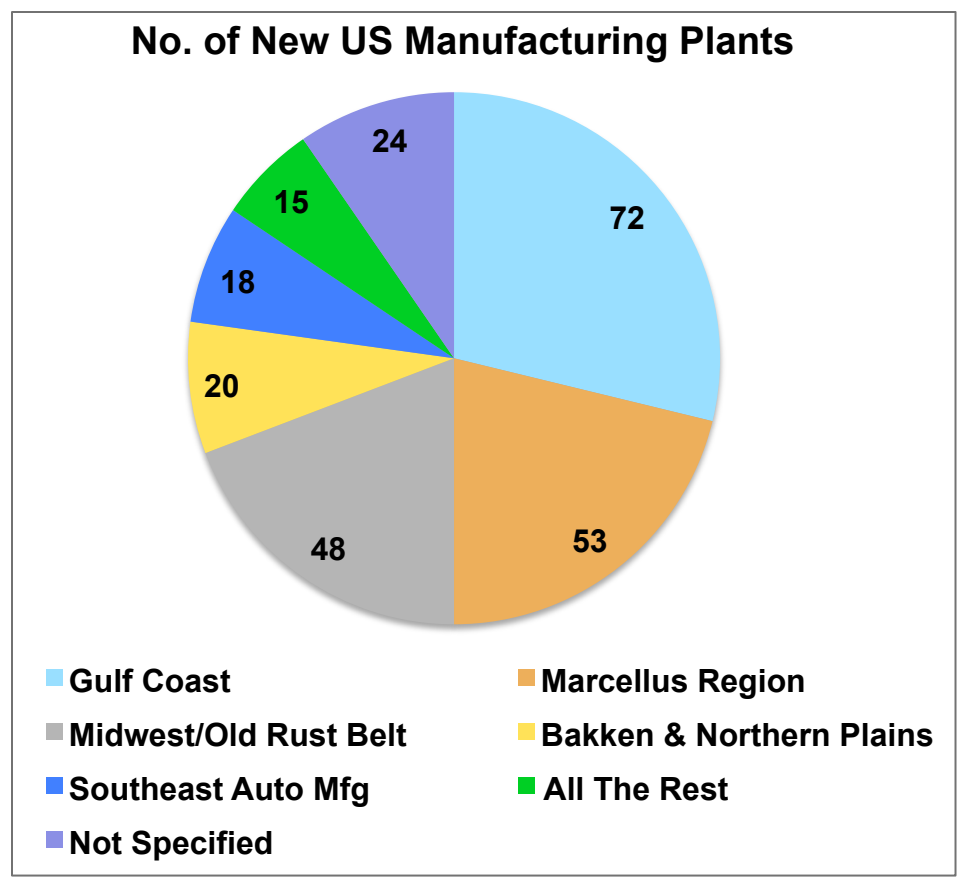
Gas-fired electricity means battery EVs are, in effect, just very high-efficiency NGVs.



- ◆ Production of methanol and gasoline from natural gas (GTL) will also become options, as price differentials remains favorable.

Global firms plan to spend more than \$110 billion on new US gas-based industries.

- ◆ 175 new manufacturing plants in development:
 - Chemicals & petrochemicals
 - Fertilizers
 - Steel & aluminum
 - Tires, plastics
 - Gas to liquids
- ◆ Most sited near shales (see count of # plants at right).
- ◆ Increased gas demand will range from 2.1-3.2 Bcf/day by 2025.



Newer LNG delivery concepts can deliver surplus shale gas to under-served areas.

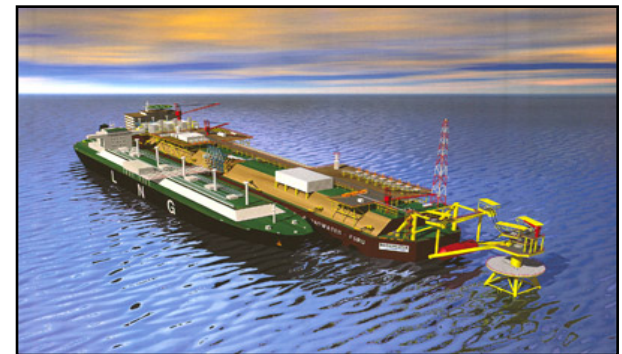


Moored Buoy System with pipeline to shore

- Special ships moor to buoy
- Regasification done on board the ship
- Ship departs once LNG regasified

Floating Storage and Regasification Unit

- Terminal is a specially designed moored vessel
- LNG storage and regasification done on board
- Natural gas piped to shore



Gravity Based Structure

- Terminal is submerged concrete structure
- LNG storage and regasification done on terminal
 - Natural gas piped to shore