EMD Energy Economics and Technology Committee

2016 EMD Energy Economics and Technology Committee Annual Report

Jeremy Platt, Co-Chair, Consultant, Energy Research Management and Analysis – Palo Alto, California
Dieter Bieke, Co-Chair, Independent Consultant and oilfield services affiliation – Houston, Texas

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- **Nathan Schaffer,** Groppe, Long and Littell – Houston, Texas
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COMMITTEE ACTIVITIES

The principal activity during 2015-16 was preparation of the annual report by J. Platt, after monitoring developments in the U.S. and global oil and gas industry, the U.S. electric power industry, energy and metals commodity markets, environmental policies, a selection of oil and natural gas industry corporate investor presentations, and a selection of energy/environmental analyses from trade, government and academic organizations. We participated in several EMD leadership teleconferences.

EXECUTIVE SUMMARY

The annual report departed from its typical pattern this year, by compiling and documenting information on a single theme: the consumer's benefit of hydraulic fracturing across natural gas, oil and/or oil products and liquefied natural gas, both in the U.S. and globally. This was performed by comparing pre-shale era pricing to pricing in the year 2015, combined with production/consumption. We drew principally on recent data and notable reports from the U.S. Energy Information Administration, and in May and June 2016, reports and data published by the International Energy Agency, BP Statistical Energy Review, International Gas Union and Natural Gas Supply Association. The savings appear so large ($755 billion in 2015) that we offer it in the spirit of stimulating discussion, further analysis and perspectives on the implications.

STATUS OF ENERGY ECONOMICS AND TECHNOLOGY ACTIVITIES

Due to the single theme of the 2016 annual report, the Committee intends to follow up the report with inquiries by additional authors into additional topics in coming months. These include financial factors driving well/field evaluations, multi-commodity price cycles, hedging, and the withdrawal of half of Southern California's working gas storage capacity after the Aliso Canyon natural gas storage field leak.

Committee Review: Energy Economics and Technology 2015-2016
AAPG Energy Minerals Division
Jeremy Platt, Co-Chair

In last year's report, we outlined the principal role of hydraulic fracturing technologies, sometimes referred to as HVHF, high volume hydraulic fracturing.[1] Simply put, wild success in applying HVHF to natural gas shales (initially the Barnett Shale of Texas) led to an oversupply of natural gas and an ensuing, seemingly permanent price collapse ever since the end of 2008. With vastly higher revenues from oil during its recent $100/barrel era, producers applied these technologies to "wet" gas and shale oil formations (e.g. the Eagle Ford of Texas and the Bakken of North Dakota). Wild success, once again, led to an addition of some 3.8 million barrels per day of additional oil supply from the U.S. between 2011 and 2014, greatly reducing the U.S. appetite for oil imports and causing havoc in the global oil market – kicking off the oil price collapse toward the end of 2014, six years after the downward march had begun in natural gas prices. The Saudi Arabian response (announced November 2014) was to maintain "market share", which meant not to reduce its production. While analysts give much attention to surging production from various countries, such as Iraq and, prospectively, Iran, or to a weak global economy (and in the other direction, sabotage in Nigeria and wildfires in Canada), nothing compares in scale to the turnaround and injection of U.S. supplies owing to HVHF.

In this year's report, we examine just one issue of over-arching importance: a high-level (meaning simplified) sketch of *consumer's benefits* caused directly and indirectly by hydraulic fracturing. This is based on a price change (things getting cheaper) multiplied times amounts consumed, resulting in a measure of possible savings.[2] What's getting cheaper? Natural gas in the U.S.; electricity based on cheaper natural gas and even

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[1] This is a "lump sum" term for a host of enabling technologies, spanning horizontal refinement of chemical additives incl. use of food-grade materials, geophysical monitoring, multi-well pad drilling, water and other logistical management, and advances in geologic/ petro-physical interpretation and analysis.

[2] Technical comment on price elasticities: As will be seen, the "amounts consumed" in these calculations are based on actual 2015 consumption levels. These levels have indeed been higher (principally for U.S. electric sector natural gas use) than would have occurred under higher prices, leading to some overstatement of savings. The author appreciates this caution, raised by one of our reviewers Metin Celebi of The Brattle Group (July 8, 2016, personal communication). The cost changes, however, have been chosen conservatively, and other forces have influenced consumption (such as coal plant retirements in the case of natural gas). Full accounting for such price elasticities, regulatory and other factors across all hydrocarbons and in the global context of this paper would, in the author's opinion, lead to not only more-complicated and less-transparent calculations, but also to overly precise calculations. In some situations, demand is largely price-insensitive and moves more in response to weather than price (e.g. U.S. residential and commercial natural gas using sectors). We will examine explicitly the problems that occur when a change in a cost input is not matched by changes in retail prices (e.g., U.S. electricity prices). A similar camouflaging effect occurs in those international oil markets where retail prices are far more influenced by tax levels than underlying commodity prices, meaning effects of price elasticities are minimized. Moreover, 2015 is widely recognized as a year in which global economic stagnation depressed world oil demand – leading, if anything, to lower representative consumer savings than under more healthy global economic conditions.

electricity produced in some other way whose prices are linked to the costs of gas-fired generation; oil or oil products such as motor gasoline, diesel and jet fuel; the share of international natural gas shipments whose prices are linked to oil; and the share of liquefied natural gas whose prices are linked to oil.

These savings may not be fully transmitted to the final consumer from their measurement at the level of wholesale pricing (such as a Henry Hub price of natural gas or a West Texas Intermediate price of oil), due to such things as hedging (when a producer sells forward its output at higher prices) or due to a pent-up need to pay for other things in the "supply chain" such as modernizing/replacing parts of the natural gas pipeline distribution system. But arguably these delayed adjustments and investments ultimately accrue to the benefit of consumers. Consumer's savings are first estimated for the U.S. and second at a global level where lower oil and LNG prices greatly magnify impacts. Fracking's role as a catalyst to extraordinarily high and widespread consumer benefits is an untold consequence of the technology. Jumping ahead, the global benefit is on the order of **$775 billion** in 2015.

We are queuing up a number of additional topics for follow-on reporting, several of which are in preparation. This following is a list.

1. *Urengoy in Kansas*. A "thought exercise" -- imagining what these technologies might have meant to the U.S. energy economy had they come to fruition in the 1970s-80s, when oil price shocks and a super-cold winter stimulated policies for energy independence (oil) and prevented traditional electric utilities from constructing gas-fired electric generating plants. Imagine if the mega-natural gas fields of the Urals, kicked off by the discovery of Urengoy (estimated size: 350 trillion cubic feet, two-thirds produced to date), had been discovered in Kansas instead. By comparison, the probable and possible resources of the enormous Marcellus Shale are about 500 trillion cubic feet. It takes time to absorb what such an event might mean, including learning how big is the opportunity. The share of natural gas use in the Russian economy is anomalously high among major industrial nations. The push and pull over hydraulic fracturing gives an indication of the time it may take to absorb the implications of the U.S. new energy landscape.

2. A Plague of Commodity Price Cycles. Price collapses in oil and gas are not isolated events. Ongoing and severe price cycles have pummeled coal, iron ore, steel and other industrial metals, dry bulk shipping and the LNG carrier business. With somewhat different causes and timing from oil and gas, the pullback in China's headlong infrastructure building spree is a common theme. Among the most notable shocks are the 2015-2016 bankruptcies across the majority of U.S. coal producers.

3. Growth in Natural Gas Demand. When might demand bring some equilibrium/ higher prices to natural gas? All eyes are on LNG exports, the power sector and petrochemicals, but Mexico is leading the pack. We can examine what some have been saying, particularly such organizations as the U.S. Energy Information Administration, the first US LNG exporter Cheniere Energy, and the Natural Gas Supply Association. In some estimates, the fact that the power sector is lagging comes as a surprise and may remain one of the biggest question marks.

4. Window into Finance and Survival. The low price environment is having devastating effects on the oil and gas industries, causing unprecedented, multi-year cutbacks in capital expenditures and employment. The phrase “a high tide floats all ships” has occurred, in reverse, in the oil/gas price environment. This means companies, lenders, ratings agencies and securities regulators are giving close attention to every penny at the wellhead. The plan is to introduce the financial milestones that are redefining company fortunes. Examples of the recalculations of “wellhead economics” will be presented, illustrating at a first level the penalties of pricing at remote hubs (geographic “basis”), and the penalties from inadequate “takeaway capacity” (insufficient pipeline capacity to move production to market), costs of gathering systems and gas processing facilities, and other costs which erode and may extinguish profits at each wellhead. The changing economics are characterized by permanent elements (technology, efficiency) and unsustainable elements (underpriced well services, high-grading of drilling portfolios).

5. Hedging. Renegotiating how the gathering and processing costs are amortized and collected is just one of many strategies employed by producers to extend their survival. Courtesy of the American Gas Association, we expect to report systematic data on hedging practices. Hedging has limited allure in a high or rising price environment, but in some cases is considered a producer’s primary asset in today’s ultra-weak price environment.

6. A final topic on our wish list is the SoCalGas Aliso Canyon storage field, where a single well leak during the winter of 2015-16 disrupted a community and prompted the closure for an indeterminate period of time of 50% of working gas storage capacity serving southern California, including 16 or 17 natural gas-fired generating stations.
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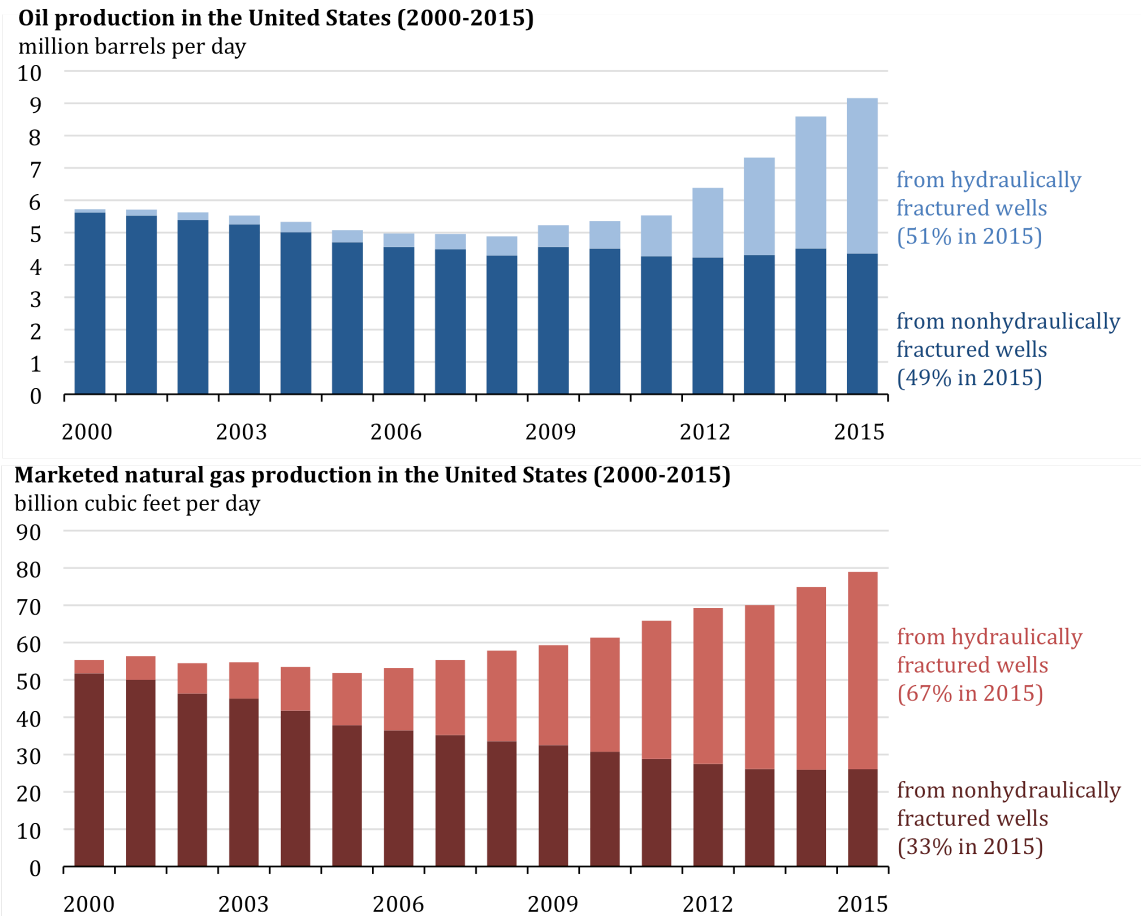
Consumer Benefits from Hydraulic Fracturing

The Setting: Quantities

In March and May of this year (2016) the US Energy Information Administration (EIA) issued two of its most important reports in years, each less than two pages long. They measure the technological revolution that has swept through the oil and gas industries. They are public documents, displayed on the single most prominent part of the EIA website, free and accessible to all, so it is all the more surprising that they have barely created a stir in US media or energy policy discussions. These reports are "Hydraulic fracturing accounts for about half of current U.S. crude oil production" (*Today in Energy*, March 15, 2016) and "Hydraulically fractured wells provide two-thirds of U.S. natural gas production" (*Today in Energy*, May 5, 2016). EIA's charts are reproduced here (Chart 1). The oil production low point was reached in 2008 (4.88 million barrels/day). Non-hydraulically fractured production had gradually declined to 4.29 million bbls/d, where it has remained with little change ever since, being 4.35 M bbls/d in 2015. 100% of the growth in oil production (from 4.88 to 9.16 million bbs/day) has been enabled by hydraulic fracturing.

Chart 1. Role of Hydraulic Fracturing in U.S. Oil and Natural Gas Production, 2000-2015 (EIA reports)



While the basic message is simple, the statistics on U.S. production can be confusing. For example, the sum of EIA's HF (4.88 M bbls/d) and non-HF columns (4.35), in 2015, is 9.16 M bbls/d. Accounting for "field" natural gas liquids production growth between 2014 and 2015 would drive the total liquids productions slightly higher (perhaps to 9.43 M bbls/d, per Jack Perrin, co-author of EIA's articles, personal communication, June 3, 2016). Elsewhere, EIA reports total field production of natural gas liquids as 3.27 mm bbls/d in 2015, having grown 83% from 1.78 mm bbls/d in 2008. Only by including field NGLs do EIA's crude production numbers come into close alignment with US production reported in BP's *Statistical Review of Energy*. From a technology perspective, the role of hydraulic fracturing is at least as great as EIA suggests, for crude, and greater still – probably 60% – when taking field natural gas liquids production into account.

Turning to natural gas, it is evident that growth from the first big shale, the Barnett in Texas, could not offset sharp declines in non-hydraulically fractured production. Technically the low point in total production was 2005 when production was sharply reduced by Hurricanes Katrina and Rita. Taking 2006 as a reference point, total production has grown 49% from 53.2 to 78.9 billion cubic feet per day (Bcf/d). Hydraulically fractured gas tripled, from 16.7 to 52.9 Bcf/d. Yet unlike oil, much of this growth displaced non-hydraulically fractured gas (which declined from 36.5 to 26.1 Bcf/d, a reduction of 10.4 Bcf/d or 29%).

One thing these reports do is show that hydraulic fracturing technology is not restricted to natural gas shales, nor to horizontal wells. We have emphasized the growth in production from gas shales for many years. Reaching 41.8 Bcf/d out of 74.2 Bcf/d (Lower 48 States dry gas production), shales claimed 56.9% of total production each of the last three months of 2015. The EIA reports show that even those numbers understate the importance of hydraulic fracturing technologies.

We will next turn to the economic impacts of all this oil and natural gas production. The landscape is strewn with winners and losers. The former include customers of all types, such as drivers, people heating their homes with natural gas – or oil, industries using NGLs as feedstocks, global customers of liquefied natural gas or LNG-based electricity (particularly Japan and other Asia-Pacific countries, but also Europe, Brazil during droughts that curtail hydroelectric power, and many other regions), global customers of heating oil (in the Northeast, U.S., and island economies still reliant on diesel steam electric generators including Hawaii, the US Virgin Islands, elsewhere in the Caribbean). For anyone who pays for electricity, basically everybody, wholesale prices have marched downhill in lockstep with natural gas' price collapse – but the benefits are more complicated to calculate because end-use customers typically do not pay wholesale prices. Then there are the losers during this prolonged period of rock-bottom prices (producers, drillers, oil field service companies, equipment suppliers, royalty owners and oil/gas states and tax jurisdictions). On either side, the gains and losses emanate in widening circles from those first, and directly, affected. With "fracking" getting such a bad name, the emphasis here is on the winners most directly affected from low, even if unsustainably low, prices.

Shale Era Natural Gas Savings – $ Billions per Year

A. U.S. Residential, Commercial and Industrial Sectors

To gauge consumer impacts related to natural gas, a before-and-after comparison could begin with the 5-year period 2003-2007 when yearly Henry Hub spot gas prices averaged $5.50-8.70/million Btu (mmBtu). This is the period of tightening supplies preceding the shale surge, when reliance on LNG imports appeared inevitable. It avoids the spectacular 2008 price spike. Turning to the period after the Great Recession, e.g. 2010-2014, the price hovered around $4.00, dipping far lower in 2012 and spiking during the extreme 2013-2014 winter dubbed the Polar Vortex. 2015 to the present (mid-2016) has experienced even lower prices, dropping from $3.00 to $2.00-$2.50. A fair estimate of the pre- and post-shale era price decline is about $3.00/mmBtu, and arguably even greater. U.S. consumption has grown steadily since 2010, from 22.1 Tcf (trillion cubic feet) to 25 Tcf (2015). To gauge the total savings for a single year (also the loss in producers' revenues), we can multiply the $3.00/mmBtu price drop by 25 Tcf consumption, which amounts to a lower annual cost (and revenue from a producer perspective) of **$75 billion**. Three dollars turns out to be a good ballpark estimate of before-and-after spot price changes. Closer analysis shows that average annual spot gas prices between 2004 and 2007 were $6.75/mmBtu. Between 2010 and 2015 the average was $3.64, a shale-gas driven difference of $3.11 ($3.20/mcf).

How do spot prices translate into savings actually realized by consumers? There is nothing simple or automatic about this translation, due to lags in ratemaking adjustments by natural gas and electric utilities and, as mentioned, effects of hedging programs protecting many producers from the full risk of falling prices for a short time, typically the "next year". Fortunately, the EIA provides data on prices paid by consumers (obtained via surveys) and on volumes of gas consumed. U.S. residential, commercial and industrial sectors consumed 4.6, 3.2 and 7.5 billion mcf in 2015. Annual average prices paid for gas delivered between the 2004-2007 and 2010-2015 periods changed from $12.57/mcf to $10.79 (residential), $11.03 to $8.56 (commercial) and $7.66 to $4.76 (industrial), a long-term reduction of $1.78, $2.47 and $2.91/mcf in these sectors. Multiplied by the billions of mcf (Trillion cf) consumed in each sector, the annual savings from lower natural gas prices by 2015 were approximately $8.2 billion (residential), $7.9 billion (commercial) and $21.8 billion dollars (industrial). The total savings for these three sectors was **$37.9 billion**, a little over half the $75 billion estimate based on changes in spot prices. It looks like something is missing.

The electric power sector makes up the difference. It has consumed 0.6 to 2.2 Tcf/year more gas than the industrial sector since 2010. Delivered natural gas prices to the power sector dropped from $7.25/mcf pre-shale to $4.46 post-shale. Coupled with the sector's record consumption of 9.7 billion mcf in 2015, its most recent savings amounted to $27 billion. The total across all four sectors, then, adds up to **$64.9 billion**, a number still shy, but close, to $75 billion. The largest variations are in annual prices, price-sensitive consumption for electric power, and weather-sensitive consumption in the residential sector. The $64.9 billion figure is based on the price drop experienced on average over six years. Much lower prices were actually paid in 2015. Calculating with those prices yields higher savings of $48.8 billion in the residential, commercial and industrial sectors, $37.5 billion in electric power, and **$86.3 billion** overall, over $10 billion higher than our simple spot price calculation. A full accounting is provided in Chart 2. It is interesting that the estimates based on retail sales are close to the $75 billion estimate based simply on total natural gas use and broad changes in the Henry Hub spot price.

Chart 2. Consumer Natural Gas Price, Use and Savings Pre- and Post-Shale Era (EIA Data)

Sector NG Delivered Prices

	Res $/mcf	Comml $/mcf	Ind $/mcf	El Pwr $/mcf
2004-2007 Ave.	$ 12.57	$ 11.03	$ 7.66	$ 7.25
2010	$ 11.39	$ 9.47	$ 5.49	$ 5.27
2011	$ 11.03	$ 8.91	$ 5.13	$ 4.89
2012	$ 10.65	$ 8.10	$ 3.88	$ 3.54
2013	$ 10.32	$ 8.08	$ 4.64	$ 4.49
2014	$ 10.97	$ 8.90	$ 5.55	$ 5.19
2015	$ 10.38	$ 7.89	$ 3.84	$ 3.37
2010-2015 Ave.	$ 10.79	$ 8.56	$ 4.76	$ 4.46

Sector Price Declines vs. 2004-2007 Average Prices $/mcf

2010	$ (1.18)	$ (1.56)	$ (2.17)	$ (1.98)
2011	$ (1.54)	$ (2.12)	$ (2.53)	$ (2.36)
2012	$ (1.92)	$ (2.93)	$ (3.78)	$ (3.71)
2013	$ (2.25)	$ (2.95)	$ (3.02)	$ (2.76)
2014	$ (1.60)	$ (2.13)	$ (2.11)	$ (2.06)
2015	$ (2.19)	$ (3.14)	$ (3.82)	$ (3.88)
2010-2015 Ave.	$ (1.78)	$ (2.47)	$ (2.91)	$ (2.79)

Sector NG Usage Billion mcf (trillion cf)

	Res Bmcf	Comml Bmcf	Ind Bmcf	El Pwr Bmcf	Total
2010	4.8	3.1	6.8	7.4	22.1
2011	4.7	3.2	7.0	7.6	22.4
2012	4.1	2.9	7.2	9.1	23.4
2013	4.9	3.3	7.4	8.2	23.8
2014	5.1	3.5	7.6	8.1	24.3
2015	4.6	3.2	7.5	9.7	25.0

Annual Savings in $ billions from Average Annual Price Declines

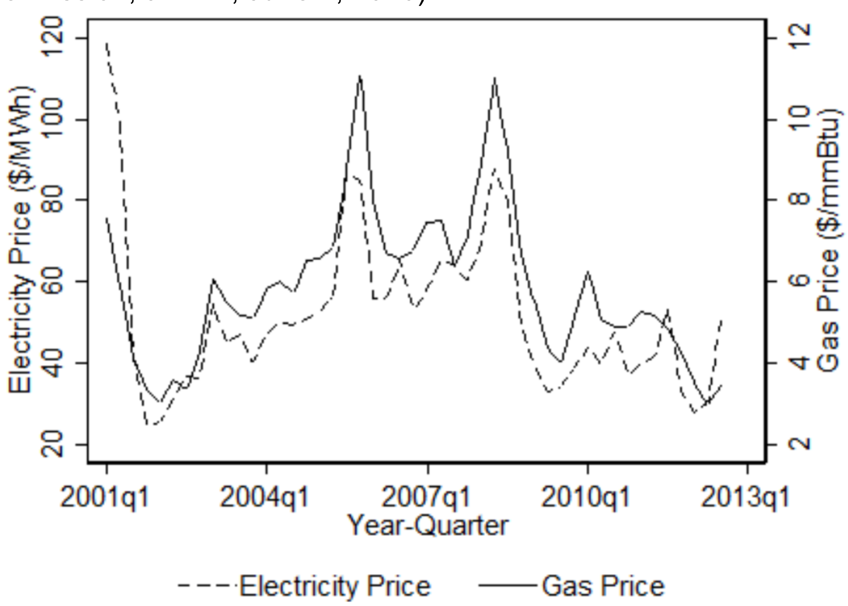
	Res $B	Comml $B	Ind $B	El Pwr $B	Total
2010	$ 5.6	$ 4.8	$ 14.8	$ 14.6	$ 39.9
2011	$ 7.2	$ 6.7	$ 17.7	$ 17.9	$ 49.5
2012	$ 7.9	$ 8.5	$ 27.3	$ 33.8	$ 77.5
2013	$ 11.0	$ 9.7	$ 22.4	$ 22.6	$ 65.7
2014	$ 8.1	$ 7.4	$ 16.1	$ 16.8	$ 48.4
2015	$ 10.1	$ 10.1	$ 28.7	$ 37.5	$ 86.3
2010-2015 Ave.	$ 8.3	$ 7.9	$ 21.2	$ 23.9	$ 61.2
2015 Savings based on 2015 Actual Use and 2010-2015 Average Prices					
	$ 8.2	$ 7.9	$ 21.8	$ 27.0	$ 64.9

B. U.S. Electric Power Sector

The electric sector presents special problems to estimating consumer benefits. We can readily envision residential, commercial and industrial entities as consumers, but the electric power sector is in an intermediate position between natural gas and the final consumers of electricity. The sector has enormous reach, affecting everyone who pays for electricity directly or as a cost embedded in something else, and it therefore greatly expands the universe of people affected by fundamental and sustained changes in natural gas prices. But it also brings complexity that obscures our ability to estimate how large is the leverage or multiplier on the savings of $27 billion or $37.5 billion described above.

At first, we might expect the connection between natural gas costs and consumers' electricity costs to be quite simple. There is ample public information on natural gas prices (e.g. EIA's reporting of delivered natural gas prices to utilities), but such a profusion of information on wholesale power prices in some regions, and little in others, that it is difficult to capture general trends. A unique nationwide multi-year perspective is that developed by researchers from Resources for the Future ("How Do Natural Gas Prices Affect Electricity Consumers and the Environment?" by Joshua Linn, Lucija Muehlenbachs, and Yushuang Wang, RFF Discussion Paper 14-19, July 2014). While they examined regional subsets, at the highest level of aggregation they averaged peak power price indices and assessments, reported by (and purchased from) Platts for 33 trading locations over most of the time period. This enabled their comparison to electric sector delivered natural gas prices (Chart 3).

Chart 3. U.S. Average Natural Gas and Peak Electricity Prices (RFF, used by permission, J. Linn, June 7, 2016)



As a general rule, the logic of why power prices might track natural gas prices is simple. It is based on the concept of "marginal" generation, or the cost of providing power by generating units called into service to meet the last increments, the last margin, of electricity demand at any moment. When electricity demand is low (off peak, at night and over weekends), other types of capacity is usually available to run on the margin, whereas during periods of high demand (peak, at breakfast, midday, when people return home from work, and during seasons when air conditioning or electric heating is needed), power prices need to be high enough to cover the cost of running gas generating units. This causes peak prices to align quite well with natural gas prices, but the concept is not as sharply defined in practice.

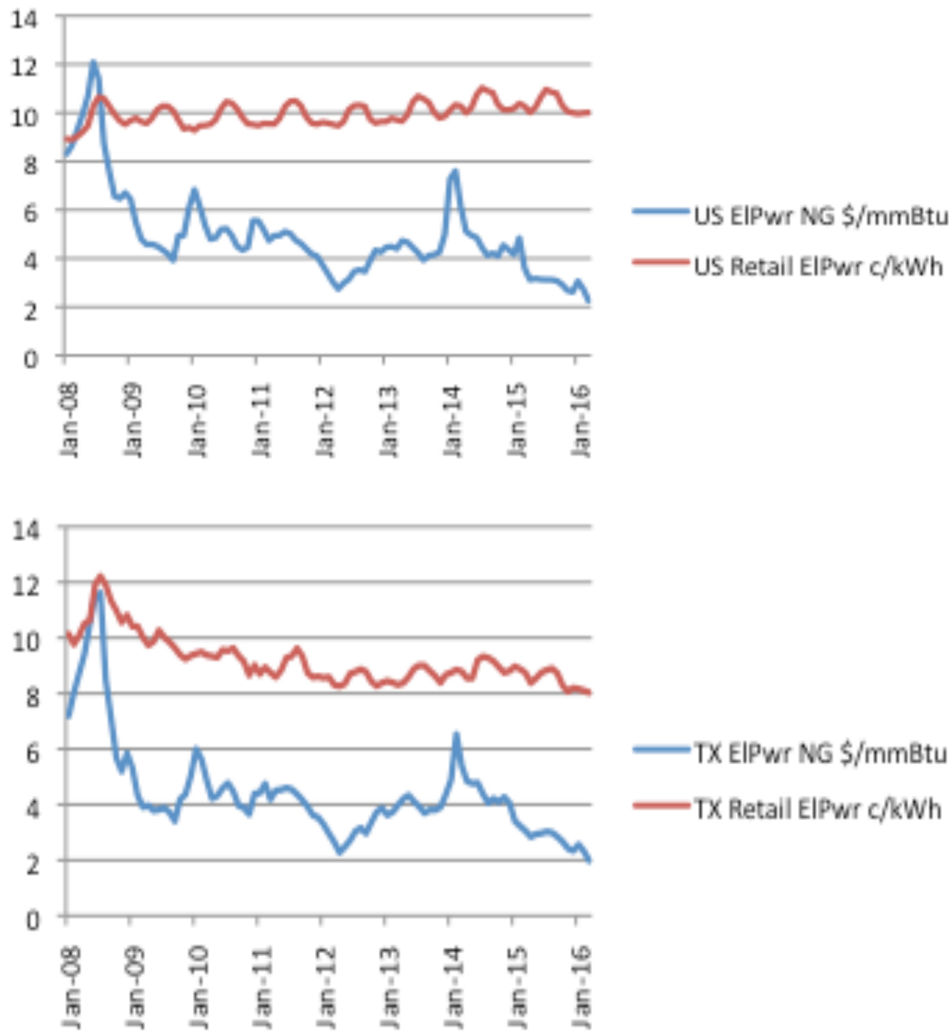
One example of this is the PJM Interconnection, the regional transmission organization which manages the electricity marketplace across Pennsylvania, New Jersey and Maryland. Because it is a large and diverse region, it is not unusual for coal units (in the western part) and gas units (in the eastern part) to serve as marginal units at the same time. In fact, this happens part of the time during nearly every hour of every day. Summing it all up, the PJM reports that gas generators were called upon to serve as marginal units 45% of the time during the first three months of 2016, compared to 33% the year before. Coal's role as marginal units dropped precipitously to 43% from 57% the year before, an impact from the 7,661 MW of coal generation capacity retired in 2015 (*2016 State of the Market Report for PJM*, May 12, 2016, by Monitoring Analytics LLC).

A final point of explanation, before turning to the electricity consumer, is the math of the natural gas – power price relationship. A calculation similar to the following is being made continuously by energy traders and by generators seeking to run during profitable hours. Multiply the heat rate of natural gas combustion turbines (about 8,000 Btu/kilowatt hour, kWh; this is the same as 8 million Btu/megawatt hour, MWh) by the delivered natural gas price (in an ultra-weak natural gas market, this may be $2.50-$3.00/mmBtu). This yields $20-24/megawatt hour. More efficient generators exist, but turning them on and off, and increasing and decreasing their output, keep them from achieving maximum efficiencies. A generator bidding to sell power would hope to obtain an additional $5.00/MWh to cover operating and maintenance expenses, not to mention any return on capital. In this example, if the actual power price was $24-28/MWh, then the difference between the power price and this generator fuel cost-to-power price calculation would be +$4.00/MWh. This difference is also called the "spark spread", the amount above the fuel calculation that can be realized in the market (See EIA, *Today in Energy*, An introduction to spark spreads, February 8, 2013.)

Have electricity consumers benefited from cheaper natural gas? I have found only one state where retail electricity prices declined significantly between the pre- and post-shale eras, Texas. Yet even here, there is not a direct line between cheaper natural gas and falling retail prices. Texas now has more wind generation than any other state. It has installed an impressive amount of wind capacity since 2000, with the bulk added during the shale era. At the end of 2007, its wind capacity stood at 4,784 megawatts (MW). Within a year, capacity had climbed to 8,005 MW. At the end of 2015, it had grown to 15,764 MW. This generation has a substantial effect on Texas power prices and obscures the effects of falling natural gas prices.

Natural gas costs to electric generators and retail prices of electricity have moved in opposite directions (Chart 4). The benefits of shale gas, multiplied through the electric sector, surely exist, but they are not reflected in obviously falling retail prices. Instead, they are reflected in avoiding what might have been. There has been stickiness to retail prices, such that falling costs in one area (natural gas supply expenses) have been more than offset by increasing costs in other areas. These other costs (costs of renewables, transmission lines and distribution systems, environmental control equipment, efficiency programs and the like) might have driven retail rates even higher if not for the effects of falling natural gas prices. A complete accounting of consumer benefits from falling natural gas prices translated into the power sector would have to quantify these impacts. My intuition is that the price multiplier of savings emanating from the power sector could be several times its reduced fuel expense alone. We will develop a back-of-the-envelope estimate, since we should not omit the electric sector's customers when estimating the most immediate savings from cheaper natural gas enabled by hydraulic fracturing.

Chart 4. Monthly Retail Electricity Prices to All Sectors and Delivered Costs of Natural Gas to Electric Utility Generators (EIA Data)



The estimation goes like this. Total annual electricity sales since 2010 have averaged a little over 3.7 billion megawatt hours (billion MWh) in the U.S. The electric power sector's reduction in natural gas prices, summarized in Chart 2, was $2.79/mcf on average (2010-2015) and $3.88/mcf in 2015. Let's take $3.00/mmBtu for illustration ($2.91/mcf). This cost multiplied times an assumed heat rate of 8 million Btu/MWh yields a pre- to post-shale cost savings $24/MWh. If natural gas sets marginal prices (at the wholesale level) every hour of every day in all regions, then we could multiply $24/MWh by 3.7 billion MWh to obtain the nationwide impact ($88.8 billion). This would overstate the impact -- we need to focus on the "on peak" prices that are most closely linked to gas-fired generation.

The peak period is typically categorized as 80 hours (five work days, 16 hours) out of 168 days per week, which is nearly 50% of the time. During the peak period, total generation may average 20% higher to as much as twice the level of a region's average off-peak requirements, depending on the region and the season. Overall, a reasonable estimate is that about 60% of all power production is "on peak". While it is generous to assume that all hours "on peak" are gas-linked, it is also conservative to assume that zero "off-peak" hours are gas-linked. Taking 60% of the sector's maximum $88.8 billion figure yields gas-driven savings in wholesale power markets of about **$53.3 billion**.

For a strict comparison with the electric sector natural gas cost savings given in Chart 2, we obtained direct $27 billion sector savings using a $2.79/mcf average post-shale price decline and $37.5 billion using the $3.88/mcf actual decline experienced in 2015. Expanding these savings through wholesale markets results in savings of **$48.1 to $67 billion**, a factor of 1.8 times larger than the sector's natural gas cost savings alone. This magnification of savings involves a series of assumptions which could be more, or less, aggressive. For example, if the heat rates of the marginal and thus least-efficient units required to meet load (electricity demand) were 10,000 Btu/kWh instead of 8,000 Btu/kWh, the savings would increase by 25% and the factor would climb from 1.8 to 2.2. In the opposite direction is generation that is less-closely linked to wholesale power markets and trading and which follow a cost-of-service model, such as municipal generating companies, electricity generation and transmission cooperatives, government generation entities (e.g. Tennessee Valley Authority or the Bonneville Power Administration), and even much of the southeast.

Chart 5. Wholesale Power Magnification of Electric Power Sector Natural Gas Savings

Electric Power Sector Natural Gas Savings
(based on 2015 usage)

$ Billions	Delivered NG Price Decline per mcf		per mmBtu
$37.5	$3.88	actual, 2015	*$3.77*
$27.0	$2.79	2010-2015 average	*$2.71*

presented in Chart 2

Economy-wide Electricity Consumption Savings

Delivered NG Price Decline per mmBtu	Heat Rate A mmBtu/MWh	Usage Billion MWh	NG Linkage Factor	Results $ Billions	Economy-wide Multiplier*
$3.77	8	3.7	0.6	**$67.0**	1.8
$2.71	8	3.7	0.6	**$48.1**	1.8
	Heat Rate B mmBtu/MWh				
$3.77	10	3.7	0.6	**$83.7**	2.2
$2.71	10	3.7	0.6	**$60.2**	2.2

* Multiplier is amount that economy-wide electric consumption savings are greater than electric power sector natural gas cost savings.

In conclusion, without resorting to the kind of sophisticated national economic modeling necessary to assess, for example, the impacts of LNG exports on the U.S. economy, GDP, employment etc., we can readily document first tier impacts of lower natural gas costs on its residential, commercial and industrial consumers. The largest impacts are in the costs of electricity generation, where a good argument can be made that savings to electricity consumers are about twice as large, owing to the ways that gas-fired units leverage wholesale power prices. Most of the benefits in this sector, however, are hidden at the retail level by offsetting increases in other rate categories

Looking ahead, years of declining natural gas costs and lower price volatility have reignited natural gas-based generation additions[3], providing the industry a necessary and attractive option for new capacity – often as a direct response to retirements of coal-fired power plants that are either already unprofitable or unable to support further investments in environmental control equipment. In some situations, this could evolve into reliability risks, such as the Public Utility Commission of Texas pointed out in its review of the proposed Clean Power Plan (Comments to the EPA, Appendix C, in PUCT Report to the 84th Legislature, *Scope of Competition in Electric Markets in Texas*, January 2015). Even some nuclear plants are at risk. These are some of the consequences within the power industry of living with success – low cost natural gas.

Coal-fired generation has been displaced at record levels, leading to record CO_2 reductions. Paradoxically, it is "fracking" which has enabled policymakers to promote measures to further decarbonize the electric sector with far less blowback than would ever have been possible without this option.

Shale Era Oil Savings – $ Billions Per Year

A. U.S. Oil Savings

Comparable to our first, ballpark estimate of consumer savings from low-cost natural gas, we can estimate what these might be for oil by multiplying the change in the oil price by the country's annual use. We can look back to as recently as 2014 for pre-shale era prices, as oil prices did not collapse sharply until near the end of the year. This choice may underestimate the savings slightly. The more important assumption is the logic – that increased U.S. oil production since about 2011 was the "straw the broke the camel's back", was the principal driver of the collapse in international oil prices, and remains the principal target of Saudi Arabia's policy announced in November 2014 to not-reduce production. We presented this logic in last year's report and believe it remains valid. Many other factors are at play and influence ups and downs in prices from day to day, but none are of the magnitude of U.S. production increases.

Chart 6 lays out the preliminary estimate. Average oil prices dropped $45.48/barrel between 2014 and 2015, a 48% decline. A comparable collapse is reported for changes in the costs of all net oil and oil product imports. Multiplying by total use (pegged to 2015),

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[3] See Exhibits 9 and A-4, in *Outlook for Natural Gas Demand for the Summer of 2016*, 2016 NGSA Summer Outlook (Natural Gas Supply Association), by Energy Ventures Analysis, Inc. Prepared May 26, 2016; posted by NGSA June 1, 2016. EVA projects natural gas combined cycle of capacity additions of 7,145 MW in 2016 and 12,289 MW in 2017. 2017 additions are over twice the average during the past ten years, a level not seen since the waning year of the great building boom in 2005.

savings amount to **$290 billion** per year. We labored over estimating savings of $65-75 billion, or more, triggered by natural gas. Oil savings appear to be four times as high.

Chart 6. Preliminary Estimate of Oil Savings

Consumer Savings Based on Crude Production, Imports, Dollars per Barrel

1. Oil Price Changes	WTI Spot (2015 Dollars, Ave.) $/barrel		Imported Oil/Products $/barrel	
Pre-Shale (2014)	$94.15		$90.57	
Post-Shale (2015)	$48.67		$46.42	
Oil Collapse Savings	**$45.48**	**per bbl**	**$44.15**	**per bbl**
	48%	decline	49%	decline

2. Ballpark Savings	Crude Oil Production and Imports mm bbl/day	savings/bbl	Millions savings/d	Billions savings/yr
Lower 48 States	8.94	$45.48	$407	$148
Alaska	0.50	$45.48	$23	$8
Net Imports incl Products*	8.32*	$44.15	$367	$134
Total	17.76		$797	**$290**

* Imports 6.88 mm bbl/d crude, 1.44 mm bbl/d products

The next step is to look at retail consumption and prices. Rather than examine every oil product, we will just summarize changes for motor gasoline, diesel fuel (also designated as Distillate No. 2, the bulk of which, shown here, is very low sulfur or less than 15 ppm), and jet fuel. Referring to Chart 7, fuel prices all declined about $1.00 per gallon. While they continued to drop in 2016 (EIA's Short Term Energy Outlook takes into account the bounce in oil prices through May 2016), it is an uncertain judgment call how much of the overall price declines during 2016, to mid-year, are explained by the U.S. oil production-driven price shock.

Total savings are $**221 billion** per year, led by the 9 million barrels per day of gasoline. Gasoline alone piles up savings of at least $350 million every day. Gasoline and diesel fuel savings clearly show up in the consumer's pocket book. Jet fuel savings are more like those in the electricity sector, where the final consumer is the buyer of the ticket and the fuel savings may be largely offset by other costs. $221 billion understates petroleum-related savings, since we restricted this analysis to the top 3 products. In round numbers, the sum of natural gas direct and electric-sector consumer savings and oil product savings – just in the United States – is in the neighborhood of **$300 billion per year**, most of which have been incurred since the beginning of 2015 due to the vastly greater financial impacts of hydraulic fracturing on the massive oil market than on the vital, but simply less financially-massive, natural gas market.

Chart 7. Oil Savings based on Retail Purchases of Principal Oil Products

Consumer Savings Based on Retail Costs and Quantities of Principal Petroleum Fuels

1. Product Price Changes	Gasoline	Diesel	Jet Fuel	
(EIA Retail Prices)	$/gallon	$/gallon	$/gallon	
Pre-Shale (2014)	$3.44	$3.83	$2.78	
Post-Shale (2015)	$2.52	$2.71	$1.62	
Oil Collapse Savings	$0.92	$1.12	$1.16	
@42 gal/bbl: $/barrel	**$38.64**	**$47.04**	**$48.72**	**per bbl**
Lower 2016 (STEO)	*$2.24/gal*	*$2.34/gal*	*$1.34/gal*	

2. Largest Product Quantities and Associated Savings (EIA Petroleum Products Supplied by Type)	2015 Supplies mm bbl/d	Millions savings/d	Billions savings/yr
Gasoline	9.2	$354	$129
Diesel (<15 ppm distillate)	3.8	$178	$65
Jet Fuel	1.5	$75	$27
		$607	**$221**

The flip side of this is lost income to the oil and natural gas industries. Over time, revenues will eventually track the decline in prices as hedges run their course. Returning to the figures cited earlier, the pre- and post-shale era "ballpark" estimates (based on production, not retail sales) are approximately $75 billion per year for natural gas plus $156 billion per year for U.S. and Alaskan oil, totaling $231 billion per year. Adding in crude plus product imports (Chart 6) increases these industries' revenue losses to **$365 billion** per year. The losses in imports would be borne by a mix of international and national (sovereign) oil companies. Many factors further complicate the industry impact. Prices at the wellhead are lower than at the primary trading hubs, Henry in Louisiana and Cushing in Oklahoma – the cost of remoteness. This could dampen the magnitude of the pre- and post-shale price collapse in selected regions (North Dakota, Pennsylvania). The EIA discontinued wellhead price reporting after 2012.

Massive losses have also been experienced in oil field services (drilling and completion), along the chain of midstream functions, and in a number of other ancillary activities. A further complication is just what is meant by the term "oil and gas industry". The U.S. industry is dominated by international oil companies and independents, but producer losses from U.S. imports of crude and oil products bring national oil companies (NOCs) into the calculation. Consumer benefits from imports are the same order of magnitude as from domestic production, but producer losses, to a large extent, are being "exported" to these NOCs. As noted initially, the aim of this discussion is to focus on the most direct consumer benefits related to hydraulic fracturing and ignore entirely the scale of producer losses, domestic or global, during the post-shale era price collapse.

B. Global Oil Savings

The price changes in world markets, triggered by the growth in US supplies, are about $45 per barrel between 2014 and 2015, very similar to the US experience. Brent crude dropped $46.56 between 2014 and 2015. Dubai Arabian Light dropped $45.87 (BP *2016 Statistical Review of World Energy*, June 2016). If our pre-shale era benchmark includes the $100-plus prices prior to 2014, back to 2011, the price drops have been even greater: $55.21/bbl for Brent crude, $53.25 for Dubai Arabian Light.

With global oil consumption standing at about 95 million barrels per day, and sticking with a $45/bbl price drop, apparent consumer savings are $4.3 billion per day or **$1.56 trillion** per year. The U.S. oil savings of $291 billion per year (crude plus imports estimate) or $221 billion per year (retail products estimate) appear paltry by comparison. But indiscriminate multiplication has problems. Much oil is consumed at lower, subsidized and not widely reported prices. And it is difficult to obtain a comprehensive set of changes retail prices to match to various oil products. This summary of well-documented global savings draws on the latest BP Statistical Review of World Energy and the International Energy Agency's (IEA) Oil Market Reports, issued monthly.

For a subset of 21 countries -- U.S. and Canada, 13 European countries, Israel, Australia/New Zealand, and Japan, South Korea and Taiwan – consumer savings total **$685 billion per year**. This estimate, shown in Chart 8, is based on a uniform $45 per barrel price decline. We prefer the precision of annual product savings at a retail level, if available.

Chart 8. Ballpark Estimate of Global Oil Consumer Savings for Well-Documented Countries

	BP Statistical Review 2016 2015 Consumption 1000s bbls/d	Savings at $45/bbl $ millions/d	Savings at $45/bbl $ billions/yr	**IEA** Diesel+Gasoline Retail Savings* $ billions/yr
N. Am excl Mex.				
US	19,396	872.8	318.6	302.0
Canada	2,322	104.5	38.1	25.1
Europe, subset				
Austria	263	11.8	4.3	
Belgium	661	29.7	10.9	
Denmark	165	7.4	2.7	
France	1,606	72.3	26.4	21.2
Germany	2,338	105.2	38.4	30.9
Ireland	143	6.4	2.3	
Italy	1,262	56.8	20.7	17.4
Netherlands	835	37.6	13.7	
Norway	234	10.5	3.8	
Spain	1,226	55.2	20.1	
Sweden	299	13.5	4.9	
Switzerland	228	10.3	3.7	
United Kingdom	1,559	70.2	25.6	18.6
Mideast, subset				
Israel	239	10.8	3.9	
Asia/Pacific, subset				
Australia	1,006	45.3	16.5	
Japan	4,150	186.8	68.2	36.5
New Zealand	159	7.2	2.6	
South Korea	2,575	115.9	42.3	
Taiwan	1,031	46.4	16.9	
Countries Total\1	41,697	1,876	**685**	**451.7**
less U.S.			**366**	

1/ Selected countries % of global consumption (95 mm bbls/d) is 43.9%.
Excluding U.S.'s 20.4% share, the remaining countries share is 23.5%.

*/ Diesel + gasoline savings: Based on IEA Ex-Tax price change, Aug 2014 to Dec 2015

Chart 9 presents the "ex-tax" gasoline and diesel prices compiled by the IEA for a handful of countries, including the U.S. We include the U.S. to corroborate the price trends from a different source. There is striking similarity in the commodity costs, whereas the European countries impose a wide range of taxes that may double or even triple the price to the consumer. The combined diesel and motor gasoline savings were included on Chart 8, last column.

The last column calculates for the two principal petroleum products motor gasoline and diesel the actual price changes reported by the IEA between the month of August 2014 and December 2015. This choice is illustrative, as many products with reported prices are excluded, such as naphtha and residual fuel oils, whose volumes outside the U.S. are about as large as gasoline and diesel. This gives further support to the general validity of making ballpark estimates of savings simply using total oil volumes and the major price indices.

Chart 9. Retail Oil Product Price Changes for Selected Countries (IEA)

Retail Savings Estimation -- Available IEA Subset of Countries
IEA Oil Market Reports: 2015 Demand, Aug 2014-Dec 2015 Prices

	Diesel 2015 Use mm bbls/d	Diesel Prices (Ex-Tax) Aug'14 $/l	Dec'15 $/l	Decline $/l	$/bbl	Diesel Savings $ B/yr
N. Am excl Mex.					~159 l/bbl	
US	3.98	0.884	0.474	0.410	65.18	**94.7**
Canada	0.31	0.900	0.515	0.385	61.21	**6.9**
Europe						
France	0.70	0.855	0.421	0.434	69.00	**17.6**
Germany	0.77	0.918	0.456	0.462	73.45	**20.6**
Italy	0.46	0.944	0.491	0.453	72.02	**12.1**
United Kingdom	0.50	0.894	0.482	0.412	65.50	**12.0**
Asia/Pacific						
Japan	0.43	1.008	0.556	0.452	71.86	**11.3**

	Gasoline 2015 Use mm bbls/d	Gasoline Prices (Ex-Tax) Aug'14 $/l	Dec'15 $/l	Decline $/l	$/bbl	Gasoline Savings $ B/yr
N. Am excl Mex.					~159 l/bbl	
US	9.16	0.809	0.419	0.390	62.0	**207.3**
Canada	0.82	0.842	0.461	0.381	60.6	**18.1**
Europe						
France	0.16	0.847	0.464	0.383	60.9	**3.6**
Germany	0.43	0.887	0.476	0.411	65.3	**10.3**
Italy	0.21	0.936	0.500	0.436	69.3	**5.3**
United Kingdom	0.29	0.830	0.433	0.397	63.1	**6.7**
Asia/Pacific						
Japan	0.91	0.972	0.495	0.477	75.8	**25.2**

C. Global Natural Gas Savings

Global natural gas savings are summarized here, still under the broad heading of "share era global oil savings", because it is the very recent collapse of oil prices and thus oil price-linked natural gas and liquefied natural gas prices (LNG) that can be attributed to some large extent to the surge in U.S. oil supplies. As mentioned, prices in 2014 and 2015 can serve as pre- and post-shale era prices, with greater price declines if we go back several years earlier. The surge was a catalyst to oil's initial downward trajectory.

Over time, diluting shale oil's (and hydraulic fracturing's) role in oil and LNG prices are additional influences – Saudi's market-share posture, weak European economic growth, China's slower growth, the strong U.S. dollar and other developments. With respect to LNG, the most important new development is growth in global liquefaction capacity (massive expansions from Australia and the U.S. in an overlapping time sequence through the end of the decade). Only the U.S. share is priced strictly apart from oil. A second development is vigorous effort to promote alternative pricing in Asia, with flexible destination clauses and creation of Asia-centered pricing hubs reflecting gas supply/demand conditions. The strength of oil price-linkage is a top strategic question, no one really has an answer. We can see, however, that over the past decade the total amount of natural gas and LNG consumption whose prices are linked to oil has remained quite steady, whereas the share of oil-linked volumes have remained quite steady.

The most comprehensive source of information about global transactions for natural gas/LNG is the series of reports by the International Gas Union, *Wholesale Gas Price Survey*. The 2016 Edition was released in May, subtitled *A Global Review of Price Formation Mechanisms 2005-2015*. We include selected statistics from this report and complementary statistics from the *BP Statistical Review of World Energy, June 2016*.

Sources of natural gas around the world are a combination of domestic production (73% of all gas), pipeline imports (18%) and LNG (19%). Chart 10 presents this breakdown plus the quantities within each of these segments that, as a result of the IGU's survey, are priced in close linkage to oil (IGU's term is Oil Price Escalation). While a small fraction of domestic production is linked to oil prices, almost 40% of pipeline imports and 70% of LNG is linked to oil prices.

Chart 10. Total Global Natural Gas Consumption and Oil Price Linkage

IGU Statistics on Natural Gas Consumption and Pricing (Wholesale Gas Price Survey)

	2015 World Consumption		Oil Price-Linked		
Segment	Bcm	% of World	Bcm	% of Segment	Principal Oil Price-Linked Regions
Domestic Prod'n	2,590	73%	193	7%	Asia: 109 Bcm, China-Pak. Thailand, Brazil.
Pipeline Imports	637	18%	244	38%	Europe: 114 Bcm. China, FSU, Asia-Pacific, Latin Am.
LNG	330	9%	227	69%	Asia-Pac: JKT. China India. Europe: Spain, Turkey, France, Italy.
	3,557	100%	664	19%	

Chart 11 translates these quantities into possible savings, a ballpark estimate, assuming all the oil price-linked volumes have experienced a $3.00/mcf savings. Choosing just the volumes of pipeline imports and LNG, the resulting total is **$50 billion** per year. This includes savings of about $5.8 billion associated with the net U.S.-Canada pipeline trade of over 5 Bcf/d. Despite that, this figure may underestimate the effect of falling oil prices.

Chart 11. Traded Natural Gas and LNG Preliminary Savings

Ballpark Savings - Oil-linked Volumes (IGU volumes)

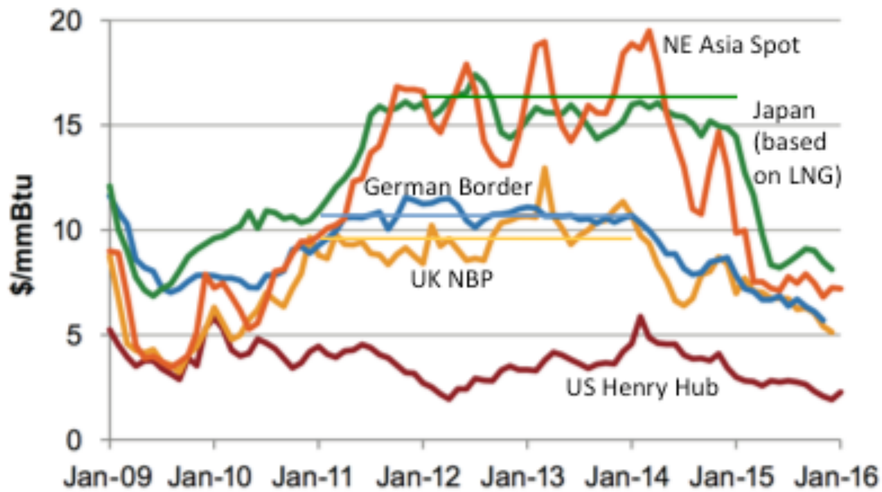
(2015)			Savings at $3/mcf
Segment	Bcm	Tcf	$B/yr
Pipeline Imports	244	8.6	25.8
LNG	227	8.0	24.0
	471	16.6	**49.9**
Excludes			
Domestic Prod'n	193	6.8	20.4

A higher price drop than $3.00/mcf was experienced in the Asia-Pacific region, especially Japan-South Korea-Taiwan (JKT), where average prices declined at least

$6.00/mmBtu and as much as $8.00/mmBtu during 2016. Too, the German border price is a factor in European natural gas imports, and it declined an average of $4.00/mmBtu. Spot LNG shipments are a very small part of total volumes but indicative of some of the lowest-priced bargains, such as $4.26/mmBtu in the Asia Pacific region seen in early 2016 (the ICIS East Asia Index).

Overall price trends for the major international natural gas indices are provided by IGU in Chart 12. This covers the period from January 2009, when the Great Recession was still deepening, to January 2016. Japan's prices tend to follow oil prices, with about a five month lag. The German Border price (eastern border with Russia) appears to have effectively converged with National Balancing Point prices.

Chart 12. IGU Gas Price Series
(used by permission, Mel Ydreos, June 11, 2016)



The three 3-years in length horizontal lines (Japan, German Border and UK NBP) are added for this discussion, superimposing the average price over some of the higher-cost pre-shale years as reported in BP's *Statistical Review.*

Chart 13 calculates the price drop for the various indices, and shows how those three pre-shale price benchmarks were derived.

Chart 13. IGU Gas Price Series

BP Statistical Review Price Series	$/mmBtu		
	LNG JAPAN cif*	German Border	UK NBP
2011	14.73	10.49	9.04
2012	16.75	10.93	9.46
2013	16.17	10.72	10.64
2014	16.33	9.11	8.25
Ave (Boxes)	**16.42**	**10.71**	**9.71**
2015	10.31	6.61	6.53
Decline	**6.11**	**4.10**	**3.18**
Energy Equiv $/bbl (at 5.8 mmBtu/bbl)	35.42	23.80	18.46
Last half 2015	~8.50	~6.50	~6.50
Max Decline	**8.00**	**4.00**	**3.00**

* cif: cost, isurance and freight (i.e. delivered at port of entry

The final step is to take a finer-grained look at price declines for a handful of well-documented gas-importing countries. These are countries in Europe for pipeline flows and in both Europe and the Asia Pacific region for LNG imports. These are not exhaustive tallies, but they tell a compelling story. We compare this subset of savings to the very rough "ballpark" estimate in Chart 11.

BP's pipeline trade statistics are summarized in Chart 14. The total trade is larger than IGU's, Chart 10, resulting in part from including all trades not just "net" trades between countries (i.e. 704.1 Bcm vs. 637 Bcm). Savings for nine European countries are calculated based on the approximate mix of NBP-priced and German Border-price gas, the latter assumed to represent Federation imports. Total savings are $**30 billion per year**, incurred in 2015. Turkey is considered a major European consumer but excluded because of uncertainty over pricing.

BP's LNG trade statistics are summarized in Chart 15. Total savings are about **$52 billion per year**, half of that incurred by Japan alone ($25 billion), a number that could jump to $33 billion if average $6.00/mcf savings are sustained at the recent higher level of $8/mcf. China and India add about $11 billion per year to the LNG total. We excluded China from the prior pipeline trade total over uncertainty about pricing of its imports from Turkmenistan.

Combining pipeline imports and LNG, the total well-documented savings is (for a subset of countries) **$82 billion per year**. It is actually similar to the ballpark estimate (Chart 11) using IGU data on oil-linked trading volumes, if we were to increase the LNG price savings to $6/mcf or more from the $3 assumption. U.S. savings are additive to this number.

Chart 14. Pipeline Natural Gas Trade and Savings, Selected European Countries (BP Statistical Review 2016)

Pipeline Trade (Excludes Domestically Produced/Consumed Nat Gas)

2015 Natural Gas Trade (BP Statistical Review)	Bcm	Tcf	Bcf/d	Savings at $3.00/mcf $ billions/yr
All Movements	704.1	24.9	68.1	**74.6**

(Trade-related maximum. Incl. Ru Fed'n to Turkey, Bolivia to Brazil, Turkmenistan to China, as well as US to Canada and Mexico, Canada to US, etc.)

Selected Countries	Bcm	Tcf	Bcf/d	Savings $/mcf est.	Savings $ billions/yr
Austria	6.0	0.2	0.6	$ 4.00	$ 0.85
Belgium	23.7	0.8	2.3	$ 3.50	$ 2.93
France	35.9	1.3	3.5	$ 3.35	$ 4.25
Germany	104.0	3.7	10.1	$ 3.50	$ 12.85
Ireland	4.4	0.2	0.4	$ 3.00	$ 0.47
Italy	5.2	0.2	0.5	$ 3.65	$ 0.67
Netherlands	30.2	1.1	2.9	$ 3.00	$ 3.20
Spain	15.2	0.5	1.5	$ 3.00	$ 1.61
United Kingdom	29.0	1.0	2.8	$ 3.00	$ 3.07
	253.6	9.0	24.5		**$ 29.88**

* Savings: $3/mcf German Border price, $4/mcf NBP price, or a mix.

Chart 15. LNG Trade, Selected European and Asian Countries (BP Statistical Review 2016)

Liquefied Natural Gas

2015 LNG Trade (BP 2016 Statistical Review)	Bcm	Tcf	Bcf/d	Savings at $3/mcf $ billions/yr
All Movements	338.3	11.9	32.7	$ 35.83
Asia Pacific, Largest Consumers				JKT $-6/mcf
Japan	118.0	4.2	11.4	$ 24.99
South Korea	43.7	1.5	4.2	$ 9.26
Taiwan	18.7	0.7	1.8	$ 3.96
China	26.2	0.9	2.5	$ 5.55
India	21.7	0.8	2.1	$ 4.60
Selected European Countries				NBP $-3/mcf
Belgium	3.8	0.1	0.4	$ 0.40
France	6.6	0.2	0.6	$ 0.70
Italy	6.0	0.2	0.6	$ 0.64
Spain	13.1	0.5	1.3	$ 1.39
United Kingdom	12.8	0.5	1.2	$ 1.36
				$ 52.83

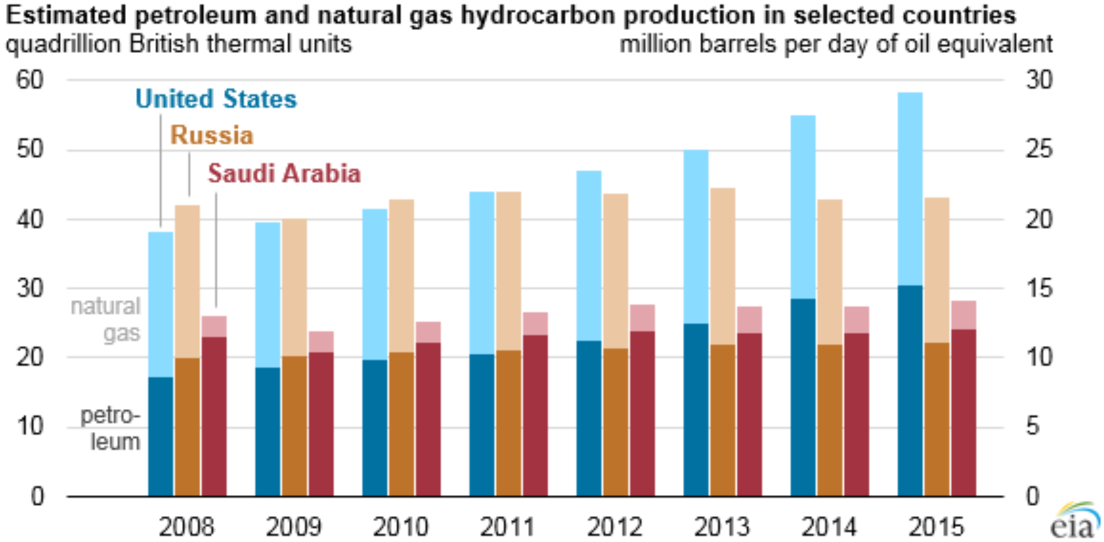
*JKT = Japan, South Korea, Taiwan

D. US and Global Total Shale-Related Oil, Natural Gas and LNG Savings

The figures add up roughly as follows: (1) US natural gas, residential-commercial-industrial sectors, **$37.9** B/yr (Ch. 2), electric sector **$48.1** B/yr (Ch. 5), (2) US gasoline, diesel and jet fuel, **$221** B/yr (Ch. 7), (3) global oil, less U.S., principally Canada, Europe, major Asia Pacific countries excl. China and India, **$366** B/yr (Ch. 8), (4) global natural gas, less U.S. – centered on European pipeline trade, **$30** B/yr (Ch. 14) and (5) LNG, principally top five Asia Pacific countries, thus incl. China and India, **$52** B/yr (Ch. 15). **Total: $755 billion per year** – quite a testament to the consumer benefits of hydraulic fracturing.

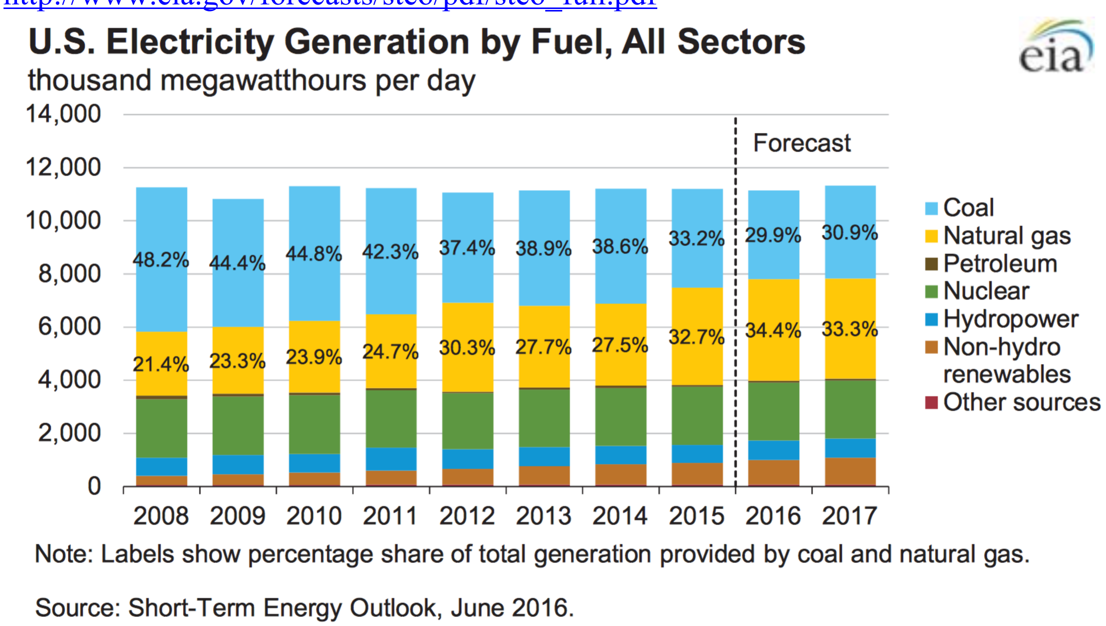
APPENDIX Charts: Food for Thought

1. U.S. Oil and Gas Resurgence at a Global Scale
http://www.eia.gov/todayinenergy/images/2016.05.23/main.png



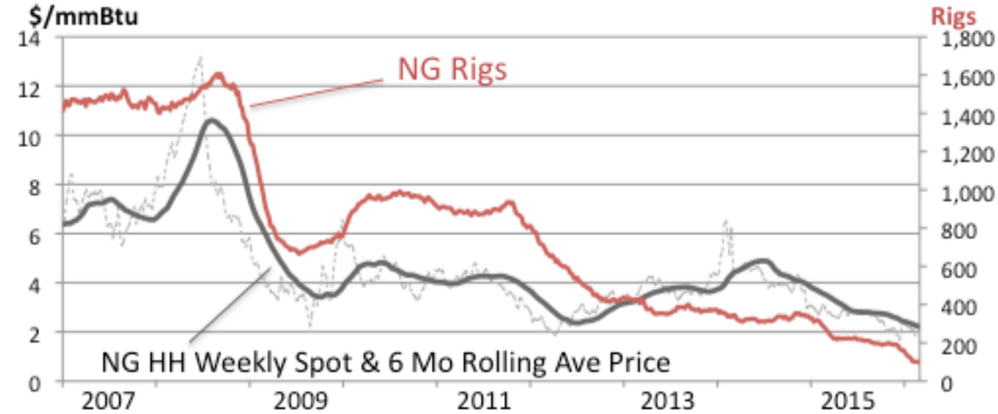
Source: EIA *Today in Energy*, May 23, 2016, by Linda Doman
This chart illustrates the "shale effect" in US oil and natural gas production compared to the former top producers, Russia (natural gas) and Saudi Arabia (oil).

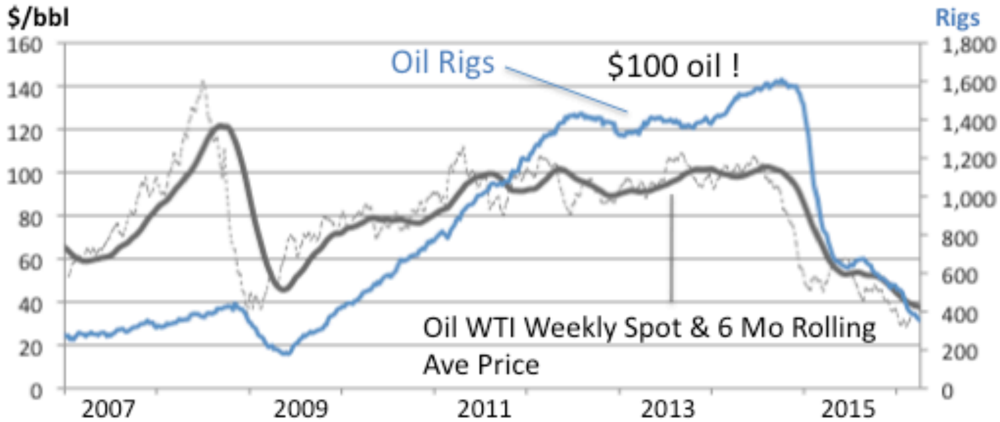
2. U.S. Electricity Generation, Natural Gas Exceeding Coal
EIA Short Term Energy Forecast, June 2016
http://www.eia.gov/forecasts/steo/pdf/steo_full.pdf



Natural gas-fired generation first overtook coal for a full month in April, 2015.

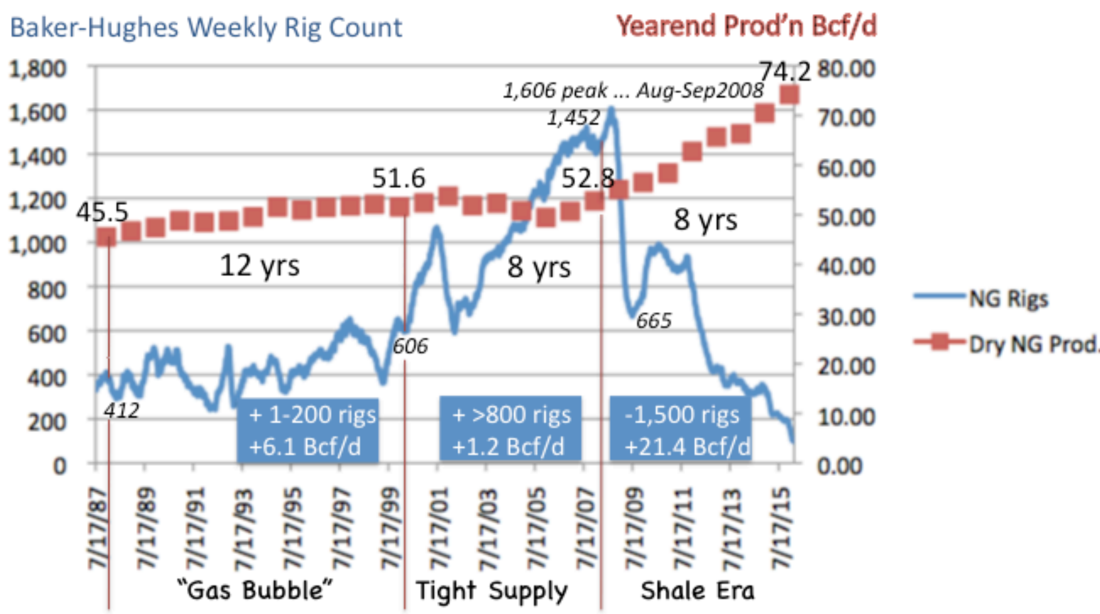
3. U.S. Oil and Gas Drilling and Prices





Oil supported activity after the first natural gas price collapse.

4. Eras of U.S. Natural Gas Production and Price



Latest era: production defies drilling cuts. Prior: massive effort, no gain.

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