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On May 11, 2012, *The New York Times* published an editorial on making natural gas extraction technology "safer" for the neighbors and landowners where new wells are being drilled.[1] The editorial led with "There is little doubt that the [new shale] gas is plentiful and cleaner than coal [and] could help with the country's energy and climate problems."[2] Yet *The New York Times* editorial went on to ignore this economic gain, providing the limitation "unless the public can be sure that it will not pollute water supplies or the air."[3] This approach to new technology is in the tradition of cost-benefit analysis ("CBA"), as required for all federal regulation that certifies beneficial gains to the economy. When justifying acceptance of new energy technology, in most cases, the findings are that the benefits substantially exceed the cost, indeed by as much as is required to compensate those on whom the costs are imposed.

However, *The New York Times* editorial dispenses with the assessment of benefits. There is no mention of gains to industry from lower cost fuel and raw material supplies, of gains to home consumers from lower monthly heating, or of lower air conditioning and power costs as new shale gas expands supplies, decreasing prices delivered through the national large-scale pipeline network. Instead, the *Times* editorial focuses on contamination of groundwater, failure in the disposal of contaminated water used in the drilling process, failure to deal with

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1. Editorial, *To Make Fracturing Safer*, N.Y. TIMES, May 11, 2012, *available at* http://www.nytimes.com/2012/05/11/opinion/to-make-fracturing-safer.html?_r=0.
2. *Id.*
3. *Id.*

the chemicals used in the drilling process, and, last but not least, on air pollution from escaping methane (the natural gas itself).

The magnitude of these costs to the economy is not estimated nor are they compared to benefits. There are methods proposed for reducing costs, such as preventing any drilling where it is anticipated that costs could be imposed, or adding production taxes to pay for regulation that might prevent social costs.

The approach taken in this Article is to go beyond the complaints, however profuse and loud, and include those where the new gas wells caused spills, made excessive noise, and produced disagreeable odors. The authors attempt to assess the scale of benefits as well, including substantial front-end royalties paid to the landowners and increased amounts of lower cost energy resources for manufacturing, trade, and household consumption, as well as increased tax revenues of state and local governments generated from the sale of more shale gas. We have not been able to specify most of these gains, but we can find numbers for the order of magnitude of total quantities going to market.

I. THE CONCEPTS OF REVENUES AND COSTS IN SHALE WELL DRILLING

Initially, it is appropriate to ask whether there is more than local land, water, and air quality decay to be derived from drilling shale gas wells. In the most general sense, there must be gas-based product from which consumers derive benefits. The question then becomes whether the costs—both production and environmental—exceed the benefits from the purchase and sale and ultimate consumption of this new supply of natural gas.

The process of production, from the recent rapid spread of decades-old shale fracturing technology, is not different in kind from natural gas production methods developed over the last century for extracting gas from non-shale formations. Wells are drilled some distance underground and the vertical hole is encased by pipe and sealed with cement to produce gas under great temperature and pressure. The technology for shale formations uses pipes stretched horizontally from the base of the vertical pipe to inject liquids at high-pressure (water plus proppants and surfactants specific to the well) to fracture the shale formation, which allows the movement of additional methane, and any concomitant natural gas liquids and oil, to the base of the vertical pipe. Production costs incurred are very likely to be in the range of one dollar per thousand cubic feet (Mcf)[4] of gas produced plus or minus 50 cents depending upon specific drilling and pressure conditions.

Exhibit One shows these costs for five shale gas production companies for which there is information publicly available. In some instances, production cost outlays are less than amortization expenses or interest expenses on capital outlays. However, our estimate of marginal costs of $1.00 per Mcf is similar to those from company to company based on the operations of thousands of wells in various shale basins.

In 2010, the natural gas average sales price per company including all gains and losses on financial gas derivatives (dollars per Mcf) at the wellhead, regional pipeline market, and delivery point was between $4.64 and $5.57 per Mcf. Due to substantial differences in the locations of shale basins across the country and new wellhead production points, sales prices differed because of varied delivery costs into pipeline hubs. Prices also varied because of differences between short and long-term contracts and spot sales. Even so, one can make a judgment that in 2010, all natural gas together sold at a hypothetical central market for $5.00 per Mcf.[5] This is because natural gas from various sources is sold in a competitive market, both at the wellhead and in commodity exchanges, after incurring marginal costs of production of $1.00 per Mcf.[6]

4. "Mcf" denotes a unit of measurement commonly used to measure volume in the oil and gas industry for natural gas. 1 Mcf equals 1,000 cubic feet.

5. This includes both conventional vertical well gas and shale gas.

6. EIA has calculated the average U.S. Natural Gas Wellhead Price (Dollars per Thousand Cubic Feet) at $4.48 for 2010.

EXHIBIT ONE

	5 Company Weighted Average	Chesapeake Year End December 30,	Carrizo Nine Months Ended September 30,	Southwestern Energy Year End December 30,	Cabot Year End December 30,	WPX Energy Year End December 30,
	2010	2010	2010	2010	2010	2010
Natural Gas Average Sales Price* ($ per mcf)		**5.57**	**5.37**	**4.64**	**5.54**	**5.15**
Expenses ($ per mcf):						
Production expenses	0.99	0.86	0.70	0.83	1.09	1.45
Production taxes	0.18	0.15	0.18	0.11	0.29	0.27
General and administrative expenses	0.46	0.44	0.93	0.30	0.61	0.60
Natural gas and oil depreciation, depletion and amortization	0.66	1.35				
Impairment	0.00		0.10			
Depreciation and amortization of other assets	1.02	0.21	1.19	1.34	2.50	2.10
Interest expense	0.10	0.08	1.14		0.52	
Total Expenses	**3.41**	**3.09**	**4.25**	**2.58**	**5.01**	**4.42**
MC(1) = Production expenses + Production taxes ($/mcf)	***1.17***	***1.01***	***0.88***	***0.94***	***1.38***	***1.72***
Total Production (full year) - Gas Only (bcf)		924.9	35.8	403.6	125.5	403.9
Total "Net" Gas Production Wells (full year) - Gas Only		20600	251	2474	4613	7890
Average Production per Well (mmcf/well)	**72.12**	**44.9**	**142.7**	**163.1**	**27.2**	**51.2**

Source: Company Annual Reports,

The operating income margin of $4.00 would appear to be economic gain, but it is not what we mean by benefits.[7] As indicated in Exhibit One, general expenses, depreciation and amortization of assets, and interest expenses comprise parts of the total expenses that are in addition to marginal costs. If the representative company were to sustain its operations at current production rates, expenses making up an average total cost of $2.58 to $5.01 per Mcf would have to be included. The operating income margin (Price minus Average Total Cost) in the long run would have to exceed $2.48 per Mcf for Chesapeake and $0.53 per Mcf for Cabot. In the last year that prices were "normal," that is, relatively unaffected by the surge of new supplies from shale formations and reduced demand from mild winter weather, producer positive net returns ranged from $2.293 billion at Chesapeake to $66.515 million at Cabot.[8]

II. BENEFITS FOR USERS AND CONSUMERS FROM SHALE GAS

This net income from production accumulated by producers is hardly the amount of benefits of greatest interest. It is the consumers' gain from the gas that determines benefits, since consumers incur the environmental costs. Manufacturers of chemicals and materials, commercial, industrial, and household users of heating, air conditioning, and electricity, purchased more gas for less payment to realize these benefits. The traditional measure of such benefits, Consumer Surplus, is the "B" of CBA in our view, and equals the difference between what a consumer would pay rather than go without, the amount that they buy, and the amount they paid. In the traditional supply-demand diagram, demand is illustrated by a downward-sloping line stretching from a price at which zero units would be demanded down to the price at current consumption rates. The area above the current price, as illustrated in Exhibit Two, consists of a measure of such benefits, or Consumer Surplus. That is, the difference between an all-or-nothing offer to pay for the entire quantity and the amount actually paid at current price is the "benefit" from having the production available. With both linear supply and demand curves, the supply curve with a positive slope and the demand curve A to B with a negative slope, and equilibrium price where supply equals demand, then consumer surplus is illustrated by the triangle $(A - P)Q / 2$ for

7. The $4.00 operating income margin is found by subtracting $1.00 in marginal costs from $5.00 in operating revenues.

8. This number was estimated by multiplying the operating margin by annual gas production.

the volume **Q** taken at price **P**. This is the sum of the (vertical) amounts that consumers would pay—their total benefit minus actual market price paid.[9]

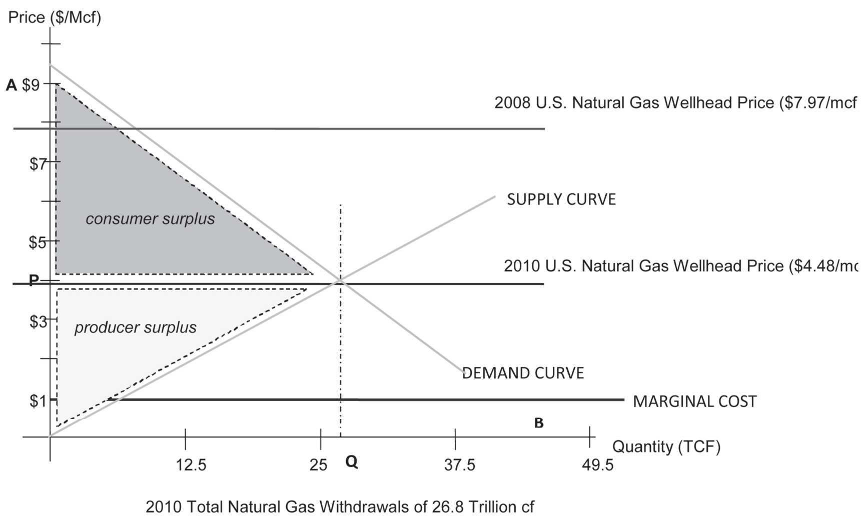

EXHIBIT TWO

Then what are the gains for consumers from the production distributed from its gas wells by Chesapeake, say, in 2010? To answer this question, we would have to know the slope of the demand curve facing Chesapeake at various locations. There is no such demand curve. In current markets, that slope is zero because with large numbers of other sources of both shale gas and conventional production gas in the same basins, any price specific to Chesapeake, net of transportation and other costs unique to Chesapeake's well, will be approximately the same as for any other producer.

But considering that each producer faces the same demand condition, the hypothetical demand is a pro-rata share of the basin demand and is downward sloping. The hypothetical demand curve at the well has the same slope at any price. The consumer surplus on Chesapeake's gas sales approximates $4.217 billion (924.9 million Mcf *($5.57–$1.01)/Mcf). In at least this one example, addressing consumer gains in one year for one company's production, the surplus of consumers is expected to exceed the producer's costs and gains by a factor of two.

9. *See* JACK HIRSHLIEFER, PRICE THEORY, 218–19 (3d ed. 1984).

III. BENEFITS FOR THE ECONOMY FOR ONE YEAR FROM SHALE GAS

There is some indication of very large gains for the economy from shale gas from comparing year-to-year total consumption. Within the triangle of consumer surplus, there is a rectangle of the difference in prices in successive years times the quantity of earlier years' sales. This is a conservative estimate of consumer surplus, since it takes no account of the increased consumption that occurs in response to price reduction. But since the elasticity of demand is quite low, that increase is small. The nominal price, that is, the Henry Hub spot price, in 2008 was $7.97 per Mcf and in 2011 was $3.95 per Mcf, making the difference in price over three successive years $4.02 per Mcf.[10] Gas production in 2008 was 25.6 Tcf, so the surplus to consumers by the price reduction from shale gas equaled $102.9 billion.

This very large amount of consumer gain—over $100 billion—from the new technology-induced price reduction in gas is the elephant in the room. It comprised a substantial majority of total expenditures on this fuel nationwide. In past years, those expenditures were limited by the higher costs of production of gas produced from vertical wells. These were in part producer surplus but most were the costs of sustaining well operations in the old technology. Even so, it is startling to acknowledge that consumer benefits from the technology of shale gas drilling and new gas production can be expected to exceed $100 billion per year, year-in and year-out, as long as present production rates are maintained.

IV. ECONOMY-WIDE COSTS OF SHALE WELL DRILLING

As we have indicated already in this assessment, there are adverse effects—costs against these benefits—on water, ground conditions, and air quality from shale fracking. To complete even the rough approximate, CBA requires these costs be estimated and subtracted from the $100 billion year-to-year consumer gains.

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10. *Natural Gas Prices Data Report*, U.S. ENERGY INFORMATION ADMINISTRATION, Jan. 7, 2013, http://www.eia.gov/dnav/ng/ng_pri_sum_dcu_nus_a.htm. Prices are quoted in dollars per Mcf, equivalent to dollar per mmBtu as recorded at the Henry Hub by the Energy Information Agency. CME Group settles its traded contracts for natural gas delivery at the Henry Hub in Louisiana where sixteen major pipelines meet. *See* U.S. Energy Information Administration, *What are Ccf, Mcf, Btu, and therms? How do I convert prices in Ccf and Mcf to Btus and therms?*, U.S. DEP'T OF ENERGY, http://www.eia.gov/tools/faqs/faq.cfm?id=45&t=8 (last visited Mar. 23, 2013); *see also Henry Hub Natural Gas*, CME GROUP, http://www.cmegroup.com/trading/energy/natural-gas/natural-gas_learn_more.html (last visited Mar. 23, 2013).

To undertake such an assessment of costs, we have reviewed current studies and reports on accidents, misuse of technology, and poor well design and installation. A 2011 report for the Secretary of Energy (hereinafter "Deutch Report") counted nineteen instances of problems with frackwater over the previous few years amid thousands of wells drilled.[11] The Deutch Report could not confirm any instances of groundwater contamination from fracking, but it found incidences of some remediated surface spills. The Oklahoma Corporations Commission, the regulatory authority for all oil and gas drilling in a state with more than 100,000 oil and gas wells hydraulically fractured, documented no incidents of groundwater contamination.[12] The Environmental Protection Agency has reported an instance of hydraulic fracturing contamination at two deep (more than 7,000 feet) water wells (in Wyoming) as a matter of concern (it is useful to note that many underground aquifers in Wyoming, as well as across the nation, are saltwater aquifers with heavily mineralized waters, which are unsuitable for agriculture, livestock, or human consumption without significant gains from purification).

At this stage, then, consider the known contamination that hypothetically could occur on a micro-scale: that of one well and one property owner. Would fracking impair the property owner's domestic water resources? What is the cleanup cost if a tanker truck turns over and spills the tank's contents in the rancher's pasture? In this instance, there is not likely to be impairment of a ranch's well water due to spatial and geologic separation of water resources. Nor would there be a case of intrusion of fracking liquids in the well water. Well water supplies are drawn from aquifers usually no more than 500 feet below the surface and generally well separated by much stratification of geologic formations from oil and gas resources at depths in excess of 4,000 feet or more. This makes contamination extremely unlikely. In addition, current state-by-state regulations require steel and cement sealed casing for oil and gas wells passing through the shallow aquifers. Furthermore, as a matter of course in the contracting

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11. *See* John Deutch et al., Secretary of Energy Advisory Board, *Shale Gas Production Ninety Day Report* (2011), *available at* http://www.shalegas.energy.gov/resources/081111_90_day_report.pdf. John Deutch chaired the Secretary of Energy Advisory Board. The Board also included Stephen Holditch (Professor at Texas A & M University), Fred Krupp (President of the Environmental Defense Fund), Kathleen McGinty (Managing Director of Weston Solutions), Susan Tierney (Managing Principal Analysis Group), and Mark Zoback (Professor at Stanford University).

12. Deroy Murdock, *The follies of frackophobes*, N.Y. POST (Jan. 20, 2013, 11:43 PM), http://newsle.com/article/0/57404079/.

process for drilling rights, private landowners can, and do, require even more safeguards.

However, there is always a potential for even the greatest of redundant safeguards to fail. Assuming that there is a failure during fracking or production, the well crew would be able to detect the failure by a loss of pressure and fluid return. Engineering calculations can be done to determine the fluid loss and the extent of the damage. Cleanup efforts would begin on the well, and the gas company would compensate the rancher by trucking in quantities of potable water for ongoing ranch operations. The cost of trucking in potable water can range from $0.50 per barrel to $2.00 per barrel. The damage costs would be determined by the number of barrels until either the aquifer self-cleans by its natural flow of water through the pores of the subsurface rock or the exploration company drills a new water well—ordinarily a task accomplished within weeks at a cost of less than $5,000.

But a 5,000 gallon tanker truck turning over in a rancher's pasture could mean a release of the whole 5,000 gallon load. Most of this would be water and sand, which could be eliminated with absorbents and shovels. In the Wyoming basins, the cost of removing contaminated water for either deep well disposal or remediation has been up to $3.00 per barrel. In Texas, the costs would be less. Depending on how porous the soil is in the yard, the wastes seep down into the earth. Once there, the concentrations in the soil determine the level of cleanup. Again, most of these are likely to be hydrocarbons, which may stay on the surface in thick masses or slowly leach into the soil, if they do not first evaporate and disperse into the air. Heavy metals, unless moved by the liquid portion of the waste or rainfall, are not likely to move deep into the soil. These contaminated soils can be scraped up and trucked offsite. A key factor is the distance of the remediation site to the landfill. A rough estimate is that 5,000 cubic yards of material disposed of at an offsite landfill at $500 per cubic yard, including onsite sampling, crew protection, transportation, and disposal comes to a total outlay of $2.5 million. This example, of course, may vary greatly due to site-specific conditions. However, based on our direct experience with environmental remediation efforts in oil and gas operations, it is clear that the cost of a discrete spill event would not impair the economic value of a drilling operation, especially if there is more than one oil and gas well on the rancher's land.

V. AN ECONOMY-WIDE ESTIMATE OF BENEFITS AND COSTS FROM SHALE GAS

How then do we extrapolate individual disaster scenarios across an entire industry to determine the social cost of possible contamination from fracking in order to deduct it from the consumer surplus of $100 billion for each year? We consider that the reported instances of contamination from fracking relate, at most, to an extremely limited minority over hundreds of thousands of wells. Assuming the worst—that the accidents occur in one year, that the cleanup requires a new water well at $5,000, and that one hundred spills occur at $2.5 million per spill given then that the industry drills 10,000 new wells per year, the cost of frackwater contamination is $250 million. Economic benefits, estimated in as limited methodology as is reasonable, exceed costs to the community by 400-to-1.

VI. CONSUMER SURPLUS DUE FROM REPLACING ONE BARREL OF CRUDE OIL WITH NEW SHALE GAS

In keeping with the national debate on the future of natural gas as a replacement for crude oil, we consider the consumer surplus of replacing one barrel of oil with its BTU equivalent of 6 Mcf of shale gas. We assume that the current price of oil is $100 per barrel. If we use the gas wellhead price of $5 per Mcf and multiply it by 6 to obtain a per barrel of oil equivalent of $30 of cost, the savings is $70 per barrel—a $30 barrel of oil equivalent. Therefore, the gain to consumers of replacing one barrel of oil with a natural gas fuel equivalent is approximately $70 per barrel. Current United States consumption of crude oil is approximately 15.0 million barrels per day. Replacing 1.0 million barrels per day of crude oil with the 6 billion cubic feet equivalent of natural gas would generate approximately $25.6 billion ($70/bbl*1 million bbls*365 days) in consumer surplus for the US economy over one year.

VII. CONCLUSION

Traditional cost-benefit analysis has not been applied to the shale gas industry prior to the analysis undertaken by the authors in this paper. The data from recorded and verified incidents of damage from shale gas development indicates an economic impact that is far less than that which is portrayed by the media. This information is contrasted with the benefit to consumers of at least $100 billion in 2010 due to the increased supplies of natural gas from shale. Even larger benefits have accrued to consumers due to natural gas prices averaging less than $4.00 per Mcf for 2011 and 2012. The potential for consumer savings due to a substitution from crude oil to natural gas can be in excess of $25 billion annually for the reduction in consumption of one million barrels of oil per day. The realized and potential benefits to the development of shale gas far exceed the reported and realized costs.