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That's why UH is the Energy University.

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Selected from nine colleges across campus, the Fellows work in collaboration with UH Energy and the Energy Advisory Board to shape the conversation on energy at UH and beyond. The Fellows serve a term of one full academic year and contribute to an online blog forum hosted by UH Energy and Forbes.

FACULTY CONTRIBUTORS

MARCO AVENDANO

Petroleum Engineering Senior, University of Houston

STEPHANIE COATES

UH Energy, University of Houston

JACINTA CONRAD

Associate Professor, Chemical and Biomolecular Engineering, Cullen College of Engineering

HEATHER DOMJAN

Interim Executive Director, University of Houston STEM Center

EMRAN EL-BADAWI

Program Director and Associate Professor of Middle Eastern Studies, College of Liberal Arts and Social Sciences

VIKRAM ENJAM

MBA Candidate, C.T. Bauer College of Business

BILL GILMER

Director, Institute for Regional Forecasting, C.T. Bauer College of Business

REBECCA GOLDEN-TIMSAR

Associate Director, Global Energy, Development & Sustainability (GEDS)

ED HIRS

Lecturer, Department of Economics, College of Liberal Arts and Social Sciences

RYAN KENNEDY

Associate Professor, Political Science, College of Liberal Arts and Social Sciences

RAMANAN KRISHNAMOORTI

Chief Energy Officer, University of Houston

WILLIAM MALONEY

Director, Trident Energy; Energy Advisor, Warburg Pincus; and Energy Advisory Board Member

TOM MITRO

Co-Director, Global Energy, Development, and Sustainability (GEDS), College of Liberal Arts and Social Sciences

DAVID RAINBOW

Assistant Professor, Honors College

LATHA RAMCHAND

Dean, C.T. Bauer College of Business

EARL J. RITCHIE

Lecturer, Department of Construction Management, College of Technology

CHRIS ROSS

Executive Professor, C.T. Bauer College of Business

ROBERT TALBOT

Director, Institute for Climate and Atmospheric Science (ICAS), Earth and Atmospheric Sciences

GINA S. WARREN

George Butler Research Professor of Law, UH Law Center

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WHEN AMBITION EXCEEDS MEANS: INCENTIVES AND THE LIMITS TO MLP GROWTH

CHRIS ROSS

Executive Professor, C.T. Bauer College of Business

VIKRAM ENJAM

MBA Candidate, C.T. Bauer College of Business

Midstream master limited partnerships, or MLPs, rode the boom in oil prices, offering investors low risk and tax advantages with slow but steadily increasing distributions. That growth stalled with the 2015 price collapse, and a recent study has offered some lessons on how this unique form of publicly traded company can best be structured to ensure long-term success.

The initial growth was mainly inorganic, as MLPs acquired midstream assets divested by the major oil companies. The shale revolution opened new growth opportunities to “replumb” oil and gas supply chains by connecting growing oil and gas production to established demand centers. This building boom for pipelines and other midstream infrastructure allowed MLPs to boost their distributions to investors.

Plunging prices in 2015 acted as a stress test on this more expansive value proposition. Companies with gas processing assets structured as “percent of proceeds” contracts suffered from the shrinking spread between oil and natural gas prices. Low prices raised questions about whether oil and gas production growth could be sustained, possibly leading to fewer “replumbing” opportunities.

That prompted a series of transactions as MLPs were acquired, merged or changed from master limited partnerships to C-Corp structures.

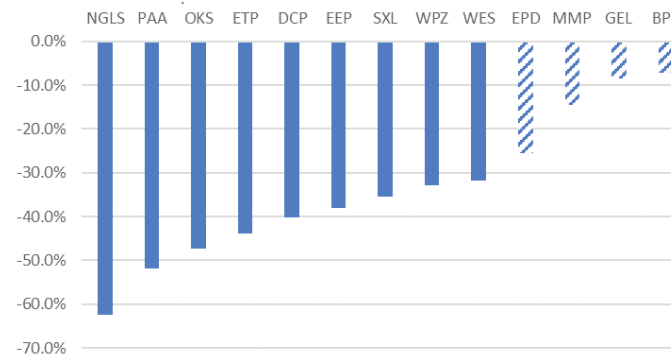
- MarkWest was acquired by Marathon Petroleum’s MLP (MPLX July 2015)
- Targa Resources Corp (TRGP) bought back all units of its MLP (NGLS, November 2015)
- Kinder Morgan (KMI) absorbed its MLP affiliates (KMP and EPB August, 2015)
- Sunoco Logistics LP was folded into its Energy Transfer GP (ETP April 2017, following an earlier merger between Regency and ETP)
- ONEOK, Inc. (OPE) acquired all the units of its MLP (OKS June 2017)

At the University of Houston’s Bauer College of Business, we were interested in what caused these transactions and what was different about the companies that were acquired compared to those that remained in the MLP structure.

A student research project examined the 2014 and 2015 financial results of a set of MLPs. Our study of 13 master limited partnerships over the period of dramatically dropping commodity prices offered some lessons about which corporate structures seemed best fitted for different corporate strategies.

We found the companies studied all lost unit-holder value, with the weakest performer, Targa, losing over 60% of its total unit-holder value (TUR) from the end of 2014 to end 2015, while the company with the least erosion in value, Magellan, lost just 10% (Figure 1). It is also noteworthy that three of the four worst-performing MLPs were among those involved in transactions that changed their corporate status.

Figure 1: MLP TUR (End 2014-15)



Source: S&P Capital IQ and UH Bauer Research

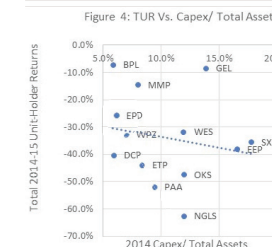
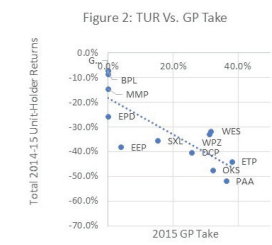
We also collected financial data from 2014 and 2015 to see whether financial performance might account for the relative loss of total unit-holder returns. Our set of MLPs included nine (solid bars) which had a general partner awarded incentive distribution rights (IDRs) under the partnership agreement, designed to encourage the general partner to grow distributions to all invested partners, and four (striped bars) that had no incentive distribution obligations.

Specifically, we looked at the following:

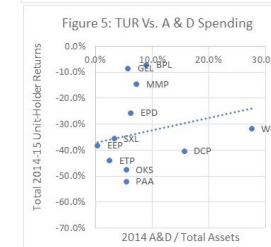
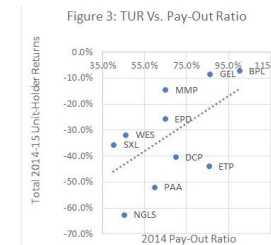
- “GP Take” at end 2015, calculated by Alerian as the proportion of total distributions at the end of 2015 paid to the general partner, including IDRs.
- 2014 pay-out ratio calculated as total distributions paid/distributable cash flow to see whether high pay-out of cash flow in 2014 was linked to high or low total unit-holder returns in 2015.
- Capital spending/total assets to see whether erosion of total unit-holder returns in 2015 was linked to high or low capital spending on organic growth during 2014.
- Net acquisition and divestiture expenditures to see whether they were viewed differently from capital spending.

Our analysis highlights two main findings:

1. MLPs where the general partner held incentive distribution rights fared worse than those that had previously bought out the general partner’s IDRs. Clearly, the unit-holder performance of MLPs without the incentive distribution obligations was more resilient to the stress test than those with these obligations. Figure 2 captures the inverse relation between total unit-holder returns and the general partner’s take of the cash flows which include the incentive payments.



Source: S&P Capital IQ and UH Bauer Research



2. Investors preferred MLPs that distributed most of their distributable cash flow (Figure 3). We found that higher capital spending (Figure 4), if anything, was associated with lower total unit-holder returns. By contrast, inorganic growth, which can more easily be dialed down, was viewed more positively, especially for MLPs with incentive distribution obligations (Figure 5).

We interpret these results to mean that the stress test of 2015 favored MLPs that distributed most of their cash and had the lowest “GP Take.” Investors in these MLPs disliked organic growth, as captured in higher levels of capital expenditures. However, they were tolerant of acquisitions when the General Partner was

financially strong and could drop down assets to the MLP (Western Gas, DCP), enabling growth in distributions.

Looking forward, incentive distribution rights are a problem. They can become a choke point during times of stress, similar to a debt obligation. They raise the cost of capital and make it harder for firms to distribute cash to limited partner investors who provide capital in the first place. It is expensive for the MLP to buy out these rights from the general partner, and the MLP may have difficulty raising capital in a relatively thin market for MLP units.

Magellan (2009), Enterprise and Buckeye (2010) made their moves at a time when values were more modest. Since then, of the five transactions mentioned earlier, three (Kinder Morgan, Targa and ONEOK) had their C-Corp general partner purchase its publicly owned MLP units, and two were mergers among MLPs (ETP and SXL; MPLX and MWE).

Other midstream companies have partially waived their IDRs. Energy Transfer Partners has set an explicit schedule of its incentive waivers as part of its merger with Sunoco, moving value from the general partner to the limited partners:

Existing IDR Waivers

(in thousands)	Existing ETP IDR Reduction	Existing SXL IDR Reduction	Total IDR Reduction
December 31, 2016	\$137,500	\$7,500	\$145,000
March 31, 2017	\$149,500	\$7,500	\$157,000
June 30, 2017	\$154,500	\$7,500	\$162,000
September 30, 2017	\$155,750	\$7,500	\$163,250
December 31, 2017	\$165,750	\$7,500	\$173,250
2018	\$138,000	\$15,000	\$153,000
2019	\$128,000	--	\$128,000
Total Through 2019	\$1,029,000	\$52,500	\$1,081,500

Source: S&P Capital IQ and UH Bauer Research

According to its 10K filing for 2016, ONEOK GP also waived some earned increases in general partner receipts of IDRs. This became moot after the parent company’s acquisition of all MLP units held by the public, thus becoming another C-Corp midstream growth company.

Since we completed our analysis, Andeavor Logistics (ANDX, formerly Tesoro Logistics) has merged its MLPs, and the merged MLP has bought out the general partner incentive distribution rights. The press release claimed this transformation “positions Andeavor Logistics as a growth-oriented, full-service and diversified midstream company with at least \$1 billion of annual growth investments,” with the growth presumably originated largely by its oil refining parent Andeavor.

In light of our analysis and the trends discussed, it seems that one category of midstream companies with organic growth ambitions such as Energy Transfer Partners and Plains All American Pipeline are finding it difficult to make the traditional structure of MLPs with incentive distribution rights obligations work. These companies should probably follow the footsteps of Kinder Morgan, Targa and ONEOK, and restructure as a C-Corp entity for reasons shared by ONEOK in its press release:

“We have performed well in a tough environment; however, this transaction positions ONEOK for continued success through expected:

- Improved access to broader capital markets to fund future growth opportunities;
- Strong dividend coverage over the long term;
- Lower cost of funding with the elimination of incentive distribution rights; and
- No cash income taxes through at least 2021.”

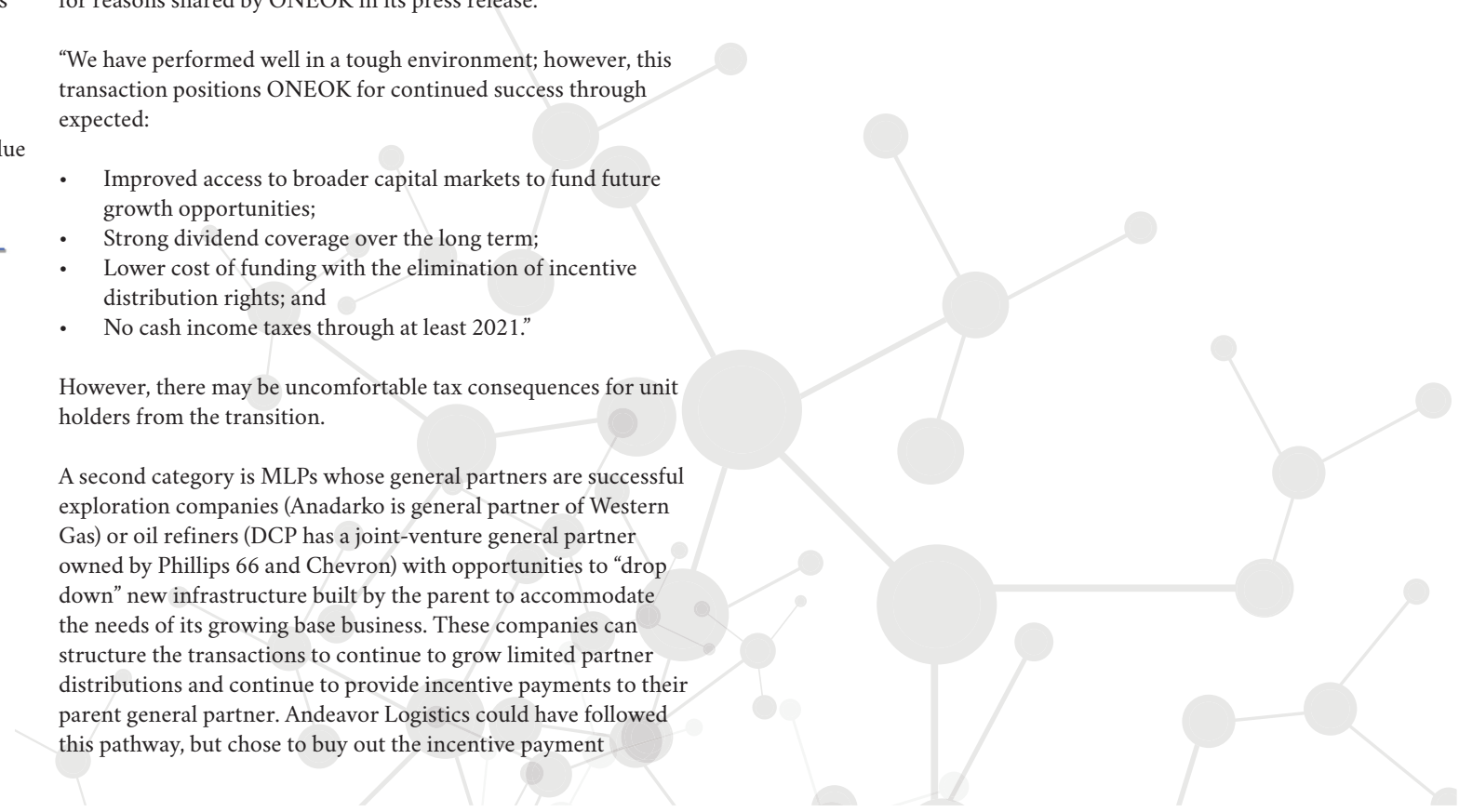
However, there may be uncomfortable tax consequences for unit holders from the transition.

A second category is MLPs whose general partners are successful exploration companies (Anadarko is general partner of Western Gas) or oil refiners (DCP has a joint-venture general partner owned by Phillips 66 and Chevron) with opportunities to “drop down” new infrastructure built by the parent to accommodate the needs of its growing base business. These companies can structure the transactions to continue to grow limited partner distributions and continue to provide incentive payments to their parent general partner. Andeavor Logistics could have followed this pathway, but chose to buy out the incentive payment

obligations and facilitate an eventual transformation into a third category when the parent’s growth funnel is exhausted.

The third category is made up of traditional MLPs with no incentive distribution obligations, which should be conservative in their growth ambitions and limit capital spending.

The MLP structure works well for low-risk fee-based steady cash flow businesses where growth is slow and steady. This structure is not suited for high growth, high risk businesses unless backed by a complementary general partner providing financial strength and “drop down” growth opportunities. ■



AFTER HARVEY, ATTENTION TURNS TO HOUSTON'S PETROCHEMICAL INFRASTRUCTURE

RAMANAN KRISHNAMOORTI

Chief Energy Officer, University of Houston

The rains and flooding of Hurricane Harvey have been devastating, dropping an average of more than 24 inches on the Houston region and flooding huge portions of the city. Now, with the storm moving east, attention has switched to the region's infrastructure. While much of the public's immediate concerns are the aging dams on the west side of Houston, a second and equally important challenge is brewing on the east side of Houston.

Houston's ship channel and the surrounding area along the Gulf coast represents about 40% of U.S. petrochemical manufacturing, and as Harvey moves off the Texas coast, the challenges are just beginning in terms of the refineries, chemicals and plastics manufacturers, and these go beyond the direct economic impact of any shutdown or supply chain bottlenecks. The chemical industry has worked hard to modernize the refining and manufacturing infrastructure over the last several decades, and that has accelerated in recent years with the changing feedstock brought by the shale and unconventional renaissance in Texas.

That's good, but it may not have been enough.

Modern refineries, chemicals manufacturing and plastics production are designed to work like well-oiled, continuously operated machines, and most of the time, they perform remarkably well, running safely in an increasingly regulated and controlled environment. But this well-oiled machinery came to a grinding halt before Harvey struck, and as the true impact of the hurricane has begun to ripple through the industry, the challenge we face now is one of safety and ensuring no further public harm.

Already, some of the impact is becoming clear. Since Friday, there have been numerous news stories on the roof collapse at ExxonMobil's facility in Baytown, the shelter-in-place in the Ship Channel city of La Porte following a pipeline leak, and the loss of refrigeration and back-up units at the Arkema facility in Crosby, all on the east side of Houston. The Crosby facility produces organic peroxides, used in the manufacturing of plastics such as polyethylene and PVC, that if not cooled could result in a fire or an explosion. By late Wednesday, company officials were acknowledging the risk, saying the water and lack of electricity offered few alternatives. It is critical that these challenges be immediately neutralized – not an easy task but critical to ensure the well-being of a large number of Houstonians. The industry along with federal and state agencies, are hard at work doing just that.

Ultimately, these problems – even the most serious problems – will be solved, and the Gulf coast may even see an economic boom of sorts as construction projects and repairs, at the plants and in the wider region, get underway. Solving the immediate challenges isn't the only task, however. We also need to take a more serious look at how we handle the operations and, more importantly, redundancies and shutdown procedures for many of the highly concentrated chemicals, refining and plastics manufacturing that happen in the Houston area. The Chemical Safety Board and various academic and non-academic organizations, including the Mary Kay O'Connor Process Safety Center at Texas A&M University, have focused on identifying best practices and are helping implement them with the chemical industry. A strategic and sustained focus is needed.

Harvey was a wakeup call, reminding us that it is time to take a more serious look to ensure the safety of the petrochemical industry and the public at large, just as the nuclear power industry has done in reaction to the Fukushima disaster. This should not become the clarion call for a move of the chemicals industry out of Houston or the larger Gulf Coast. Nor should it be used for a broader call to phase out fossil fuels.

Perhaps the biggest takeaway message is this: unlike what happened following the Fukushima disaster, let's avoid another knee-jerk reaction that ignores and even negates the many positive and significant improvements that have come about in the petrochemical industry and its impact on human prosperity. Instead, we need to use the examples of what went wrong during Harvey to build on past improvements and prepare the petrochemical industry for the future. ■

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HOW AMERICAN FRACKING RAN OPEC'S OIL RECOVERY OFF THE RAILS

BILL GILMER

Director, Institute for Regional Forecasting, C.T. Bauer College of Business

Last fall, it seemed the end of the global oil glut was already at hand, when optimism soared after OPEC's commitment to speed the process by limiting production. Oil prices were expected to quickly move to \$55 and \$60 per barrel, and then continue climbing in 2017. The rig count rose, and jobs began to return throughout the oil patch.

But it has since become another false start for oil markets. Oil prices remain mired between \$45 and \$50 per barrel, and price expectations – measured by the futures market for West Texas Intermediate – have fallen back to levels well below those that prevailed before the OPEC accord. The domestic rig count has peaked for now, and the big investment houses forecast a decline in domestic drilling through the second half of this year.

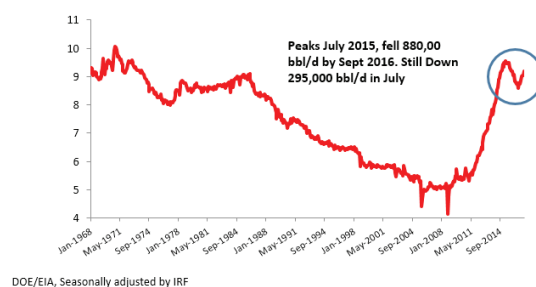
What happened? American fracking ran the recovery off the rails. A competitive industry that – in principle – should move oil output and price to stable long-run levels, fracking is once more living too high on large subsidies to its capital base and operating costs. This leaves oil markets locked in a destructive cycle that has again reached the stage of over-production and depressed price. It has brought us to the brink of yet another pull-back in U.S. drilling activity, and another round of financial stress for many producers.

What happened to \$60 Oil?

The revolution brought by American fracking is a technical marvel, but it also leaves the industry largely responsible for the 2014 oil bust. Figure 1 shows how horizontal drilling and hydraulic fracturing reversed 40 years of declining U.S. oil

production, adding just over four million barrels per day (b/d) of new production between 2011 and 2014. This was the only source of new non-OPEC oil during this period, and flooded into a market that had averaged annual growth of only 1.3 million b/d over the previous 20 years.

Figure 1: U.S. Shale Reversed 40 Years Of Declining Oil Production (million barrels/day, s.a.)



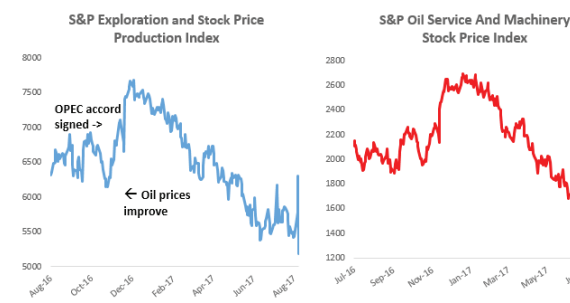
Source: DOE/EIA

The economics of the shale revolution set it well apart from conventional oil exploration and production. In contrast to the oligopolistic markets of Shell, Exxon, and the giant national oil companies, fracking looks and behaves more like a competitive industry: numerous small firms, low barriers to entry, and production that can be quickly ramped up or down in as price changes. Unlike conventional oil, there is no significant exploration risk, making output relatively certain, and working more like an assembly line. Given these properties, if the long-run equilibrium oil price is \$60 per barrel – something that both the petroleum and financial engineers tell us – then producer behavior should move supply and demand into balance near that level.

The trigger for the 2014 collapse in oil prices was OPEC's declaration that it would no longer act as swing producer, i.e., no longer withdraw oil from world markets to support price. OPEC handed that job on to American fracking, but the industry has proved messy and undisciplined in the process. U.S. production fell slowly and by nearly 900,000 b/d in response to low oil prices, but then began to rise again in late 2016. Based on drilling already performed, it should return to near record-high levels by year-end. New production was partly triggered by OPEC's renewed efforts to rebalance oil markets last November, and partly by perverse incentives enjoyed by the fracking industry.

What went haywire here? One answer seems to be too much cheap money. Producers have been outspending cash flows again, just as they did before the oil bust, facilitated by private equity and high-yield funds that have put few limits on available cash. Instead of paying attention to profits over the oil-price cycle, producers built their oil reserves and production, hoping to impress equity markets. (See Figure 2)

Figure 2: If Oil Producers Are Chasing Equity Gains ... It Isn't Working for Them or their Suppliers



Source: S&P Dow Jones Indices

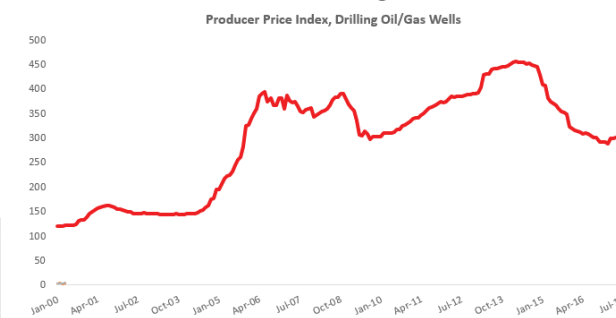
The result was to push the rig count up quickly, and expand collective production to unsustainable levels. If the goal was quick gains in the stock market, the strategy has failed, with producer stock values down by over 30 percent since December. The strategy has also failed their suppliers, the oil service and machinery companies, who have experienced even bigger stock-price declines.

Bringing Fracking to Heel?

What brings these producers back into line? First, they have to be frozen out of capital markets again, as they were during the early stages of the oil bust, when many of these same companies were working their way through bankruptcy. Second, oil service and machinery costs need to rise to reflect the total cost of exploration and production, including capital costs. With wide-spread over-capacity in the industry, many oil service and machinery companies have been pricing to cover little more than operating costs, just hoping to keep the doors open until better times.

Figure 3 shows a December 2014/December 2016 decline in drilling costs of 31.9%, with little recovery in recent months. The increase in the rig count has not yet been big enough to tighten capacity and improve pricing. Recent earnings reports from the giant service companies like Schlumberger and Halliburton claim to achieve better pricing, but the rest of the supplier base remains quite depressed. These low prices are an implicit subsidy to producers, and the other vehicle to enable over-production of oil.

Figure 3: Cost of Drilling and Oil Services Remains Depressed Despite the Rise in the Rig Count



Source: Bureau Labor of Statistics

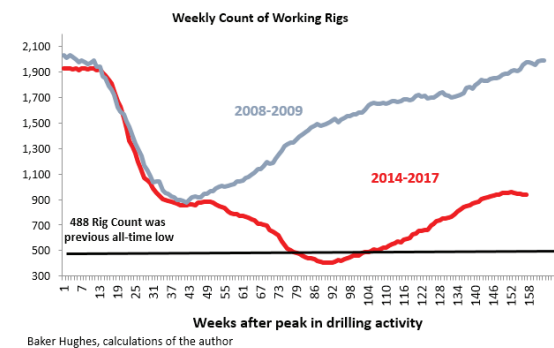
Reversal in Drilling? Here we go again!

Figure 4 shows the Baker Hughes rig count over the course of this downturn, and compares it to the last cycle in 2008-09. You see an earlier attempted recovery at week 40 of the 2014-16 decline, aborted by the return of Iran's oil to market; at week 90, the rig count falls to the lowest level ever measured by Baker Hughes.

Drilling activity rose steadily after June 2016, reaching a peak of 958 rigs in late July, a level that was not quite half of the 2014 peak.

As this is written, oil prices are still mired near \$45 per barrel, the rig count has fallen or stayed flat for 6 of the last 7 weeks, and the major investment houses predict a continued decline in drilling through the rest of this year. Raymond James, for example, forecasts 850 rigs working by early 2018, when drilling activity will pick up again, according to the Oil and Gas Journal. If nothing changes, American fracking begins another destructive cycle in 2018. ■

Figure 4: Drilling Peaking Again after Rising to Only 958 Rigs?



Source: Baker Hughes, Calculations of the Author

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CONSUMER PROTECTION CONCERNS AS BIG TECH ENTERS THE ENERGY MARKETS

GINA S. WARREN

George Butler Research Professor of Law, UH Law Center

Imagine a situation where technology companies have the motive, means and opportunity to supply energy with one click. It may not be too far-fetched, and already some of the ramifications for utilities and consumers are becoming clear.

Private tech companies like Apple and Google have emerged onto the energy landscape, a shift that could have a significant impact on the existing energy delivery system. In June 2016, Apple Energy received federal approval to sell wholesale electricity into the national grid. Prior to that, Google Energy received approval to do the same. Globally we are seeing more private businesses, especially Fortune 500 companies, generating their own electricity, investing in renewable energy facilities and voluntarily purchasing renewable energy credits to cover their carbon footprints.

While multiple reasons have factored into this shift, one reason may be that utilities are unable to supply the amount of renewable energy now in demand by large businesses, and those businesses are working to meet the market demands of millennials who are seeking sustainable products.

According to a 2015 market study conducted by Morgan Stanley, millennials – and especially female millennials – care significantly more about sustainability than previous generations. With a whopping 84% of millennial investors identifying sustainability as an important factor when making living and investment decisions, private businesses are taking note.

Apple, Google and 70 more of the world's most influential companies have joined RE100, a collaborative of businesses

who are committed to only using electricity generated from renewable sources and to increasing the demand for and access to renewable energy around the globe. While they each have varying goals, these companies have all made commitments to become 100% renewable by a certain date, with nearly half using some form of on-site power generation. According to a 2016 RE report, most companies do not want to become energy providers, but “the lack of responsiveness from utilities in some regions has forced them to do exactly this.” Unless the power sector can find “more proactive and creative solutions,” it may be the wave of the future.

The energy delivery landscape will continue to change as more and more businesses self-generate. This change can be positive in that we are adding much needed renewable energy. As the negative impacts of climate change accelerate around the globe, the goal of decreasing reliance on fossil fuels is certainly an important one. It is a time of opportunity for collaboration between utilities and businesses that would allow companies to access the renewable energy they demand and utilities to avoid lost profits and stranded investments.

One concern, however, is the private disruption of what has historically been a highly regulated public service industry, potentially resulting in a slippery slope of market power and a loosening of consumer protection.

Safeguarding consumer protections will be key. As large multinational corporations seek to sell electricity, the Federal Energy Regulatory Commission (FERC), the agency in charge of regulating wholesale energy sales, will need to implement more protective measures to ensure consumers are charged reasonable

and nondiscriminatory rates for electricity and energy products. Under FERC's current rule, these large corporations are allowed to use market-based rates and are given a lot of leeway in setting customer rates for electricity or energy products, so long as they do not own or control more than a certain amount of electricity within any given region. This is called the horizontal market power rule. The rule was intended to promote competition and entry into the market by small utilities and independent power producers. Large utilities holding horizontal market power do not qualify but instead are subject to more stringent regulation by FERC so as to ensure their rates are fair, reasonable and non-discriminatory.

FERC's regulatory test for market power never contemplated large corporations, such as Apple or Google, that hold monopolistic market power in their own industries using this test to escape regulatory oversight in wholesale sales of electricity – a public good.

One way to potentially address this issue is for FERC to redefine its market power definition to include market power in any industry, regardless of whether it is a FERC-regulated industry. FERC has the exclusive authority to regulate wholesale sales of electricity and an obligation to ensure that customers are protected and not manipulated by those sales. It may establish whatever rule is appropriate in order to carry out this congressional mandate. In doing so, FERC should consider all relevant factors, such as whether the applicant holds market power in another industry that could allow it to manipulate the energy industry and its consumers.

FERC has historically adapted to changing realities in the energy industry. It has adapted its approach to rate making and regulation on several occasions, and it can do so again. FERC is obligated under the Federal Power Act to take actions that would protect the public from unreasonable rates and discriminatory practices.

It should now take a more proactive role in regulating energy sales by multi-nationals – with the ability to reach millions with one click. ■

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RETHINKING CHEMICAL STORAGE: A WAKE-UP CALL FROM HARVEY

RAMANAN KRISHNAMOORTI

Chief Energy Officer, University of Houston

Hurricane Harvey, and especially the flooding along the Gulf Coast that accompanied the storm, offered a litmus test for the safety of the nation's petrochemical and refining industry. With a few notable exceptions, the plants passed.

Investments in plant and equipment safety appear to be paying off. Storage, transportation and other supply chain issues need similar attention. The substantial economic and environmental impact Harvey imposed on the industry is a stark illustration of that.

The Federal Reserve Bank has noted that the hurricane and flooding affected about 30% of refining and petrochemical production in the U.S. That followed similar disruptions to petrochemical production from recent hurricanes and weather events, including hurricanes Katrina (2005) and Ike (2008).

During Harvey, production facilities, including refineries and chemical plants, and the raw material supply chain – from tankers at ports, offshore and onshore production wells – were systematically shut down and process safety barriers implemented. No significant production mishaps were reported.

Impressively, no significant safety-related issues were reported when many of these systems came back online, either.

The soft underbelly of the chemical and petrochemical industry along the Gulf Coast turned out to be the storage of raw materials, intermediates and refined products, not the process of refining or chemical manufacturing or their startup or shutdown processes.

Petrochemical storage facilities continue to be vulnerable during natural disasters, risking releases which can damage the environment and impact public safety.

The most recent example happened when Harvey-related flooding swamped the Arkema Inc. facility in Crosby, Texas, about 30 miles from downtown Houston. That triggered the ignition of highly energetic organic peroxides when the plant's emergency power system failed to maintain the refrigeration required to keep the chemicals stable.

Similarly, the gasoline tank leak by Magellan Midstream spilled nearly 11,000 barrels of gasoline, a fraction of which entered the Houston Ship Channel. During Katrina in 2005, more than 190,000 barrels of oil were spilled into the ground and waterways in what has been labeled the "worst onshore oil spill disaster" in the U.S.

Chemical storage and weather-related disasters are not restricted to the Gulf Coast. While hurricanes and flooding pose risks along the Gulf, facilities in the Midwest, for example, are vulnerable to earthquakes and tornadoes.

There is a clear and pressing need to address combinations of active and passive barriers to improve the safety of stored chemicals, from feedstock and intermediates to value-added products including gasoline and jet fuel.

That must include both technological innovation and new ways of thinking about the petrochemical infrastructure in the Gulf of Mexico, including reconfiguring supply chain systems using modern chemical and digital methods to lower the risk from natural

disasters to both the environment and to people. Such technologies and operational changes will have clear implications for storage of chemicals near large urban regions along the east and west coasts, as well as in the Midwest.

Similar technological and digital improvements, along with the push to raise operational standards, have led to demonstrable improvements in both the safety and environmental records of the exploration, production and manufacturing sectors of the energy industry.

But as the Arkema explosions and less dramatic accidents during and in the aftermath of Harvey demonstrated, there is more work to do.

As a first step in this process, it is critical to develop a prioritized list of storage and supply chain challenges that require both active and passive barriers to mitigate vulnerable inventories of hazardous petrochemicals, lowering the risk of similar accidents in the future. Industry, along with state and federal regulators working with academic experts, need to develop this list based on a realistic determination of risk, including well-considered worst case scenarios.

Technological and business practice solutions to lower the risk faced by both storage and the supply chain can then be applied by focusing on several specific possibilities:

- Using innovations in digital data collection, data analytics and supply-chain optimization to lower the risk of storing hazardous petrochemicals.
- Using process synthesis and intensification and micro process engineering tools to develop in-situ generation of high-toxicity and energetic chemicals to avoid storage of such specialized intermediate toxic chemicals.
- Developing storage solutions that include numbering-up through modularization instead of volumetric scale-up of storage units.

We must systematically develop and deploy technologies to ensure the integrity of the entire supply chain of petrochemical products, irrespective of geography and the specific threats faced. This will build the public's confidence that the industry's growth and continued operations are in the best interest of society. ■

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METHANE IS A POWERFUL GREENHOUSE GAS, BUT WHERE DOES IT COME FROM?

ROBERT TALBOT

Director of Institute for Climate and Atmospheric Science (ICAS), University of Houston

Carbon dioxide, or CO₂, gets all the attention when people talk about global warming, but it's far from the only greenhouse gas we should be thinking about. Methane (CH₄) – like carbon dioxide, a gas emitted by both natural and man-made sources – is starting to draw more attention, too.

Methane has a global warming potential of 28 over a 100-year time frame, a measure developed to reflect how much heat it traps in the atmosphere, meaning a ton of methane will absorb 28 times as much thermal energy as a ton of carbon dioxide. That makes it a very important greenhouse gas, much more powerful than carbon dioxide. Methane comes from natural sources, such as wetlands and animal digestion, along with thermogenic sources, including oil and gas production. Natural gas is approximately 90% methane.

Recent analysis indicates that additional sources of atmospheric methane should be considered, as well.

While methane is just starting to gain public attention, scientists have been studying it for decades. The National Oceanic and Atmospheric Administration started measuring methane in the Earth's atmosphere at its global monitoring sites, such as atop Mauna Loa in Hawaii, in the early 1980s. Throughout the '80s, methane levels showed a steady increase of 1% to 2% per year, dropping to around 1% per year in the '90s.

It held steady from 2000 until 2007, when the rate of increase abruptly began to rise again, which continues today. (Figure 1) These changes have been challenging for scientists to explain quantitatively and to attribute explicitly to varying sources.

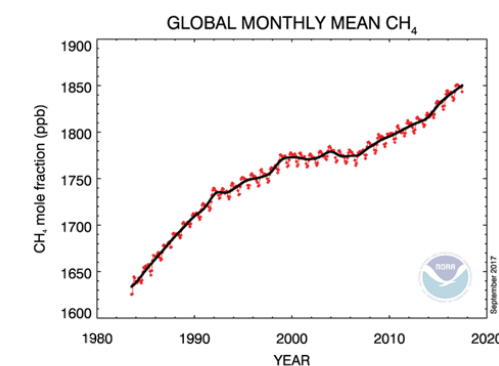


Figure 1. Increase in global CH₄ mixing ratios (concentration units in ppb) in the Earth's atmosphere since the early 1980's. ([NOAA Global Monitoring Division](#).)

Source: NOAA Global Monitoring Division

Recently there has been a flurry of activity to quantify fugitive methane emissions from oil and gas production sites. Indeed, I was a participant in the Barnett Shale Coordinated Campaign in 2013. Using our mobile laboratory, we visited 152 facilities and found that instead of well sites, the largest emissions occurred from compressor stations and chemical processing plants. Other studies have investigated distribution systems and other components of the delivery system. All were found to be leaking methane to some degree. Could the recent 10-year increase in global methane be related to oil and gas production?

The answer appears to be probably not.

A paper published in Science magazine last year showed that the dominant source of ¹³C (carbon-13) in methane was shifting on a global basis. Carbon-13 is useful in that it can distinguish different sources of methane from one another. For example, isotopic analysis suggests a new trend away from oil and gas sources in the 21st century and indicates that global agriculture may be responsible for the recent increase in atmospheric methane.

This directly contradicts emission inventories and points out the growing problem of controlling methane emissions while still feeding an increasing human population - truly a delicate balance to manage responsibly.

A second scenario that has been suggested to account for increasing global methane is increasing production of biogenic (bacterial) methane in tropical areas. Under global warming, these areas are receiving more rainfall, which increases the size of flooded areas. This may, in turn, enhance the biogenic production of methane.

However, it appears that increasing agriculture and human population is a more likely scenario. That's consistent with the isotopic data analysis.

The situation should become clearer in the future as more data is collected. Stay tuned. ■

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ELIMINATING THE CLEAN POWER PLAN IS A STEP IN THE WRONG DIRECTION

ROBERT TALBOT

Director, Institute for Climate and Atmospheric Science (ICAS), Earth and Atmospheric Sciences

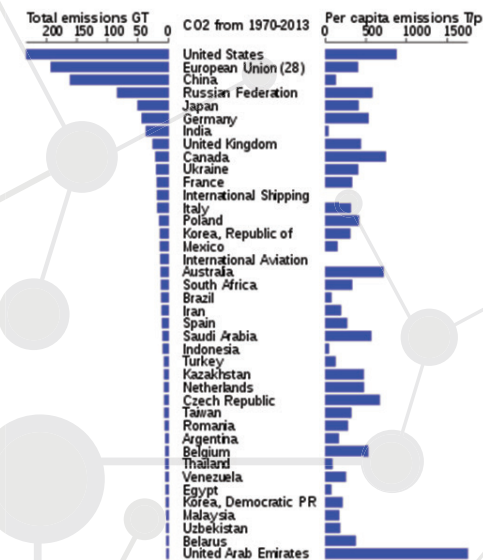
The Trump administration formally proposed Tuesday to scrap the Obama administration's signature climate change rule for power plants. The plan was meant to curb emissions of carbon dioxide from coal- and natural-gas-fired power plants, which are responsible for about one-third of the U.S.'s carbon dioxide emissions.

Carbon dioxide is the primary greenhouse gas in the Earth's atmosphere, causing global warming. Today, China is the largest emitter of carbon dioxide, but the U.S. is the clear leader in cumulative emissions over the past several decades (Figure 1).

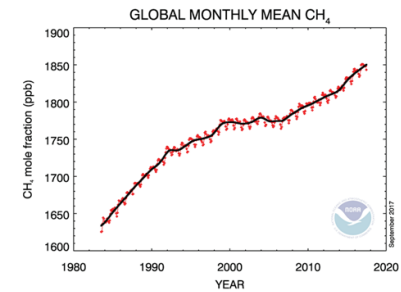
When the Clean Power Plan was unveiled in 2015, it had a goal of cutting power industry emissions by 32%. Many states were already shifting away from coal for economic reasons. This reversal could slow the transition.

Environmental Protection Agency (EPA) chief Scott Pruitt signed the notice Tuesday, arguing that former President Barack Obama's 2015 rule, dubbed the Clean Power Plan, exceeds the agency's authority under the Clean Air Act. Environmentalists and Democrats have pledged to fight the rollback. Environmental groups and some states plan to challenge the new plan based on scientific and economic grounds.

The scientific evidence of the need to continue to curb emissions is overwhelming. The last two years have seen the largest increase of carbon dioxide in the Earth's atmosphere - more than 3 ppm (parts per million) per year based on National Oceanic and Atmospheric Administration's data from Mauna Loa (Figure 2).



Source: Joint Resource Centre



Source: NOAA Global Monitoring Division

This is no time to allow uncontrolled emissions of carbon dioxide to continue in the U.S. A number of factors combine to create damaging storms, but rising amounts of greenhouse gases in Earth's atmosphere is leading to rising temperatures, which may be fueling outbreaks of extreme weather.

The planet's atmosphere and oceans are warming at an unprecedented rate, and devastating storms such as Harvey and Irma are becoming more frequent, with record amounts of precipitation due to increasing oceanic and atmospheric temperatures.

This is all causing increased stress on the human population. Why follow a path of legal legislation that will just enhance and aggravate these issues?

Despite the fact that the U.S. backed out of the Paris agreement, the U.S. can lead the world by following prudent actions. Limiting emissions of carbon dioxide by coal-fired power plants is just one of them. ■

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SABOTAGING ENERGY AND PEACE: TRUMP MOVES TO UNDERMINE IRAN NUCLEAR DEAL

DR. EMRAN EL-BADAWI

Program Director and Associate Professor of Middle Eastern Studies, University of Houston

Is sabotaging international agreements the “art of the deal?”

Last week, U.S. President Donald Trump announced he would not “recertify” the Iran Nuclear Deal — fancy lingo for the U.S. government undercutting an international contract. Trump further designated Iran's Revolutionary Guard a “terrorist” group and authorized new sanctions against them. Somewhere in the middle of this, the U.S. Congress is to decide the fate of the now-damaged deal with Iran.

The Joint Comprehensive Plan of Action (JCPOA) is an Obama era policy limiting Iran's nuclear program from ever including nuclear weapons, in exchange for much needed sanctions relief. Since the deal first took effect in July 2015, Iran has kept its end of the bargain and complied with the terms. One year into the deal, in 2016, analysts at the Brookings Institution concluded the JCPOA to be a “net positive” among supporters or a “new normal” compromise among detractors.

Even today Iran is “compliant.” Who says so? As late as last month, the U.S. Department of State (DOS) and the International Atomic Energy Agency (IAEA), among numerous other government or regulatory bodies, agree.

So why is Trump appearing to dump this deal? Since his presidential campaign began in 2015, Trump has reviled former President Barack Obama's diplomacy with Iran and that nation's growing power in the Middle East, including mutual animosity with Israel and funding of militant groups in neighboring countries. His latest policy against Iran comes in the context of

“Protecting the Nation from Foreign Terrorist Entry into the United States,” the enhanced vetting proposal issued March 6. The law makes it virtually impossible for foreigners from Iran and a handful of other nations to enter the U.S.

Those of us who study the Middle East have seen this move before. This is not simply a campaign promise. Trump's undermining of the JCPOA deliberately sabotages new energy projects and foments old wars in the Middle East.

Restricting European and Asian Energy Business

Outside the dysfunction and xenophobia of Washington, D.C. much of the world has started doing business with Iran. In July, French Total SA and China National Petroleum Corporation (CNPC) signed a \$5 billion agreement to develop some of the world's largest natural gas fields, located in Iran. China recently opened up a \$10 billion line of credit for Iran. What is more, throughout 2015-2016 China, which relies heavily on importing Middle Eastern oil, has moved swiftly to import more oil from Iran and less from its rival Saudi Arabia. Iranian oil production has boomed from about 1.3 million barrels a day in early 2016 — before sanctions were effectively lifted — to 2.3 million barrels in the fourth quarter of the 2017 fiscal year. That is more than three times U.S. oil exports.

Moreover, a consortium of over 30 oil and gas giants and service providers have been “qualified” to do business in Iran since sanctions were lifted between 2015-2016. Oil companies include Royal Dutch Shell Plc, Italy's Eni SpA and Russia's Rosneft Oil. Service providers include Schlumberger, among others.

Is it any surprise that European leaders condemn Trump's undermining of the Iran Nuclear Deal? Of course not. Nor is it any surprise that China is against Trump's actions involving a deal 13 years in the making. Might the Americans and Saudis be troubled by Iran's newfound economic success in the oil and gas markets?

Iranian oil has not flowed into American ports for 40 years. Furthermore, no American oil and gas companies or service providers have been doing business in Iran since sanctions spiked in 2011. How could they do business there when Washington flip-flops between war and diplomacy with the third largest OPEC member?

Perhaps mixed signals from Washington turned off Iranian interest in business with the Americans. Wrong, and quite the contrary. In 2016 Iranian Oil Minister Bijan Zanganeh announced, "we welcome the presence of American oil companies in Iran...we will definitely prepare the grounds for the presence of American oil companies in Iran." The Trump administration appears to be single handedly calling the shots on American business with Iran.

In other words, the policy appears to be don't do business with Iran; if anything reclaim global market share through undercutting Iranian oil exports.

This is precisely what U.S. Secretary of Energy Rick Perry has been doing in India throughout 2017. India has typically been supplied by Iranian oil exports. Trump is working to change this and assert American oil dominance in India. Asserting U.S. dominance and clawing back market share are not appropriate demands while cutting out a nation — Iran — with whom the U.S. had a binding international agreement, JCPOA. U.S. Interior Secretary Ryan Zinke justified this behavior earlier this month by blaming Iran for —what else? — "terrorism."

Undermining the Iran Nuclear Deal is more than bad for business. It sends a message to potential partners in the Middle East that the Americans don't play fair. They cannot be trusted to keep their word. It sends a message to commercial and political allies in Europe and Asia that their economic interests are against

ours. To complete the logic of the Trump doctrine, "America first"... everyone else last.

The Invisible Hand Is Gone; the Oil Curse Returns

Ten months into his presidency, Trump's greatest contribution to "Middle East peace" has been undermining the Iran Nuclear Deal. This contribution is, unfortunately, a step backwards. It means moving once again towards war and renewed instability in the Middle East. Tehran feels betrayed by Trump, and justifiably so. However, the director of the National American Iranian Council (NIAC), Trita Parsi, is correct in calling the Trump presidency a "gift to the [Iranian] hard-liners." This is as true for Iran as it is for North Korea, where Trump is sparring with Supreme Leader Kim Jong Un over a possible nuclear conflict in East Asia.

In the case of Iran, Trump's disregard for diplomacy and his explicit desire to step up to foreign military strikes has a long history in the Middle East. The U.S. has been making war intermittently with Iran's neighbors — Iraq and Afghanistan — for about four decades. American wars helped birth Al-Qaeda, the so-called Islamic State (ISIS) and increase global terrorism. During this time Iran has stayed remarkably stable — and defiant. With each American blunder in the region, Iran has filled one power vacuum after another. This is especially the case after the Second Gulf War in 2003 and following the Arab Uprisings (or "Arab Spring") in 2011. Iran's influence in Shia-controlled Iran, Syria, Lebanon and north Yemen is now a fact. Along with Iranian influence comes Russian dominance, especially in Syria where the Trump Administration's merciless bombing campaign against both militants and civilians there and in Iraq throughout 2017 have only renewed accusations of yet another U.S. president committing war crimes.

The ground continues to shift in the Middle East. Within the past year the Saudis and Israelis have both received U.S. President Donald Trump, as well as made visits to Russian President Vladimir Putin in Moscow. The fate of the region is being shaped behind the scenes. To say this differently: Syria, Iraq and Iran are accessible through military might or economic sanctions, whichever serves foreign interests.

In this context, "refusing to recertify" the JCPOA has an entirely different meaning. It demonstrates a loss of trust after more than a decade of hard fought diplomacy. It represents a plunge back into the dark ages. I describe the time when Iran secretly developed highly enriched uranium (perhaps for a bomb) and the U.S. and Israel were accused of acting together to assassinate Iranian nuclear scientists. The dark storm clouds have already gathered over the region as Iran's two arch-enemies — Israel and Saudi Arabia — now celebrate the damaged JCPOA.

Like a shrewd (even reckless) businessman, Trump is determined to dismantle international diplomacy and grip U.S. energy and strategic interests forcibly through the language of war. In economic terms, the "invisible hand" does not truly control the global oil and gas market. That control belongs to the series of wars, failed states and broken promises characterized by the "oil curse."

The Economic Importance of Iran

Iran sits on the fourth largest proven oil reserves and second largest proved natural gas reserves in the world. However, it also has an active, storied nuclear energy program stretching back to the 1970s, i.e. before the days of the Islamic Republic. Iran is also home to a thriving and diversified alternative energy portfolio, including solar, wind and geothermal energy. Iran's "renewable energy boom" runs parallel to innovative water solutions being implemented. And again its partners on this front include foreign investors and companies from Norway, China, South Korea and others.

Over the past two years Iran has re-forged its economic and political relationship with European, Russian and Asian partners. Therefore its progressive energy and water agenda are attractive to foreign investors and trusted by a growing number of foreign governments. Iran is simply too important economically to ignore. The choice, therefore, is either to partner with Iran on economic terms as most of the world has done — as former U.S. President Barack Obama did — or to fester through decades of failed U.S. foreign policy, further destabilizing the region and the world.

Sanctions against Iran have not worked in the past, and they won't work now. There is a good chance Europe and Asia will continue to do business with Iran, leaving the U.S. with no option but the 'war

card.' This is all to say nothing about future vacillations in the price of oil, changes in energy security or decline of American supremacy in the Middle East and the incremental rise of Russian-Chinese power instead. Those are subjects for another day.

The coming days will truly decide the fate of the Iran Nuclear Deal, and just how much damage Trump has precipitated. ■

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LEAVING EITI WILL BE A BLOW TO U.S. LEADERSHIP AND SUSTAINABLE GLOBAL ENERGY EFFORT

TOM MITRO

Co-Director, Global Energy, Development & Sustainability,
College of Liberal Arts and Social Science

The Extractive Industries Transparency Initiative has little impact on the U.S. domestic oil and gas industry but has been transformative in some parts of the world. So why did the U.S. pull out?

Last week, the U.S. government officially withdrew its membership from the Extractive Industries Transparency Initiative (EITI). On the surface, this sounds like another of the Trump administration's efforts to disentangle the U.S. from costly "bad deals" made through "big government overreach" in trade treaties, climate change agreements, or military and economic assistance whose benefits may not be worth the tradeoffs in costs, troops and economic growth. But that is not the case with EITI.

EITI is a voluntary coalition of 53 countries and more than 80 large corporations (including ExxonMobil and Chevron) plus more than 30 civil society groups and international organizations (like the World Bank) committed to adhering to standards to increase transparency around payments made to governments in oil, gas and mining activities. EITI was designed to serve in lieu of government-imposed requirements. In fact, the American Petroleum Industry successfully argued that by virtue of its member companies' active participation in EITI, the disclosure requirements mandated by the Dodd-Frank Act were not necessary.

EITI participation carries very little cost, no real downside risk and the potential for great benefits. It has virtually no impact on the operations or profitability of the U.S. domestic oil and gas industry. But not participating in EITI has the potential to

destroy U.S. international credibility and leadership on a range of issues.

More on these points later, but a simple example might help explain what EITI is all about. Suppose you make \$1,000 per month in rent payments (\$12,000 for the year) to your landlord, but your landlord tells you and the IRS that he received only \$10,000. Wouldn't it be worth keeping clear track and regularly comparing the amount of rent paid and received so that you can make sure you don't overpay on your rent and that the government receives the correct amount in taxes? EITI standards reflect the exact same principle – in this case, the oil, gas and mining companies voluntarily commit to track and disclose the amount of royalties and taxes they pay to various governments, and in turn each participating government agrees to disclose what it has received from the companies. It's actually quite simple. Why is this so important?

In the U.S., the rights to oil and gas can be owned by individuals, states, tribes or the federal government. These various mineral rights owners receive royalties from the companies that produce the oil and gas. In addition, most state governments are paid "severance" or production taxes based on the value of that production. Such a variety of individuals and government entities benefiting directly from oil and gas production ends up providing a strong degree of checks and balances that ensure that financial benefits are in line with agreements and the law.

But in virtually all other countries in the world, the rights to oil and gas are owned exclusively by the national government, so 100% of these payments are funneled to a single central government entity. Consequently, in the absence of strong democratic countervailing

checks and balances, the central government and individual officials grow to be much more powerful, which creates a greater potential for abuse of that power, conflicts of interest and corruption.

One proven way to protect against misuse of those funds is by greater public disclosure and transparency with respect to what was produced and the financial benefits that were derived by the government. Not only does this help reduce corruption, but it helps citizens independently assess whether funds were spent and allocated wisely and equitably – an essential element for any democracy.

Numerous studies have demonstrated that oil and gas and mining have led not to greater prosperity but have instead resulted in less diversified economies, boom and bust cycles, and greater regional and ethnic strife. One of the factors leading to those results has been the corruption that often accompanies the large flows of funds into centralized coffers, which is often enabled by governments and companies agreeing to restrict public information of the amounts involved. Referring to conflicts in Iraq, Syria, Nigeria, South Sudan, Ukraine and the East and South China Seas, Michael Klare, professor of peace and world security studies at Hampshire College, has summed it up: "It would be easy to attribute all this to age-old hatreds, as suggested by many analysts; but while such hostilities do help drive these conflicts, they are fueled by a most modern impulse as well: the desire to control valuable oil and natural gas assets. Make no mistake about it: These are 21st-century energy wars."

The Extractive Industries Transparency Initiative began in 2003 when members established the first set of principles; and the number of member countries and organizations has grown substantially along with refinement in the standards and disclosures that members pledge to follow. Many member countries long had poor track records for corruption. In order to comply with EITI standards they had to collect and publish detailed data on the moneys received from oil and gas and mining. Member oil and mining companies also began to publish what they paid to those governments as a means of comparing and verifying. Compliance with these mutually agreed standards have made it much more difficult for corruption and its attendant impacts to thrive in many parts of the world.

If reducing corruption contributes to reducing conflict over energy, why wouldn't the U.S. government and businesses prefer to hire a hundred extra accountants whose impact on reducing corruption and conflict might reduce the need for deploying and potentially endangering hundreds of U.S. troops? Of course, the choices and consequences are not quite as simple as that. So what did the U.S. consider in making its decision to withdraw?

The coordinating U.S. agency, the Department of the Interior, suggested that EITI disclosures might violate business confidentiality and that some outlying U.S. companies were unwilling to participate. Most feel these issues can be overcome, especially if participants can better understand the public support for doing so and the greater benefits.

Corruption within the U.S. domestic oil and gas industry has not been seen as a significant risk, so U.S. participation in EITI can be viewed as more of an international leadership question rather than necessarily addressing a problem within the U.S. The Office of the Attorney General states, "The U.S. Government has long had a management system featuring numerous controls and protections to oversee natural resource extraction, which helps reduce the risk of corruption." But illustrating the point using a simple example, if you constantly admonish your friends and family for not eating their broccoli while at the same time munching away on a candy bar, then your views on nutrition lose believability. And this quickly erodes the credibility of your counsel and advice on other topics in this example, such as financial matters or family and neighborhood conflicts.

Finding a way to actively participate in anti-corruption initiatives can highlight the U.S. example for the rest of the world and at the same time be good for business. A coalition of ninety-plus institutional investors and pension funds have proactively endorsed the EITI approach as being good for encouraging investment in the oil and gas and mining sectors. So, by withdrawing from EITI the U.S. has yielded an opportunity for influence and leadership in this and other arenas. Now is the time before it's too late for the U.S. to re-establish a form of leadership and influence that requires no troops, no financial aid, and no sacrifice of economic growth – in short, "an unbelievably good deal". ■

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ROBIN HOOD RIDES AGAIN: LIFTING THE ELECTRIC VEHICLE TAX CREDIT

CHRIS ROSS

Executive Professor, C.T. Bauer College of Business

The recently issued House GOP tax overhaul bill proposes to eliminate the \$7,500 federal tax credit for battery electric vehicle (BEV) purchases. This subsidy was introduced in 2012 and applies only to the first 200,000 BEVs sold by each manufacturer.

A smaller tax rebate has been available for plug-in hybrid electric vehicles, or PHEVs, since 2016. In California, BEV manufacturers can also benefit from sales of clean air credits through the sale of zero emission vehicles, funded by manufacturers who sell the internal combustion engine vehicles that most people choose to drive.

These tax credits and other benefits are generally intended to reduce greenhouse gases and on-road emissions of toxic pollutants in urban areas. There is a widespread belief that BEVs represent the future and will steadily displace internal-combustion-powered vehicles in the global vehicle fleet.

BEV advocates worry that cutting the subsidies will slow the growth of electric vehicles. But the reality is more complex.

As important as tax rebates in promoting BEVs is the aggressive Corporate Average Fuel Efficiency (CAFE) standards imposed by the Obama administration in 2012 as a measure to “reduce our dependence on foreign oil,” as well as reduce emissions. This will require manufacturers’ sales of cars and light trucks to average 54.5 mpg in model year 2025, up from a mandated 35.5 mpg for model year 2017. The standards and their penalties are under review by the Trump administration, and in July 2017 the National Highway Traffic Safety Administration (NHTSA) of the Department of Transportation filed in the Federal Register:

“NHTSA seeks comment on whether and how to amend the civil penalty rate for violations of Corporate Average Fuel Economy (CAFE) standards. NHTSA initially raised the civil penalty rate for CAFE standard violations for inflation in 2016, but upon further consideration, NHTSA believes that obtaining additional public input on how to proceed with CAFE civil penalties in the future will be helpful.”

There is a lot to like about BEVs. Neighbors of mine both recently retired after long careers as engineers for major oil companies and immediately acquired a Tesla Model S. They are enraptured with its design, extraordinary torque and technological sophistication. Doubtless, the tax credit helped them decide; there is gratification beyond economics in receiving money from, rather than sending it to, the IRS. But the Tesla Model S probably would have competed well with conventional vehicles in the luxury car niche even without the tax credit.

The tax credit is more important outside the luxury niche, but the CAFE standards may be more important still. A Bloomberg report estimated that GM was selling its Bolt BEV at a loss of \$8,000 or \$9,000 per vehicle, presumably hoping to recover the costs through lower penalties from failing to meet increasingly stringent CAFE standards. In this case the costs are being borne ultimately by GM’s shareholders. If the CAFE standards are relaxed and penalties reduced, GM may have to answer questions from shareholders on whether this was a wise use of resources.

The answer will probably be yes, on the grounds that battery costs are declining such that the BEV niche may expand beyond the luxury sector.

Nevertheless, there remain barriers to BEV penetration rates:

- **Range anxiety:** The Chevy Bolt takes about 10 hours to fully recharge from empty to its full range of 238 miles at a home 24 Volt/32 Amp charging unit in your garage; there are a limited number of publicly available DC power fast-charging stations to top up. This suggests that the Bolt would be best suited for commuting or short trips, which limits its functionality.
- **Full cycle cost:** The Bolt received very positive reviews but remains expensive for a small hatchback when fully equipped, relative to its internal combustion engine competitors. It would be economically more attractive if gasoline prices increase while the price of natural gas – which in many areas is the marginal source of the electricity that powers these vehicles -- stays low. Thus, BEVs will be most competitive where gasoline is highly taxed and power is relatively inexpensive.
- **Social costs:** Cobalt, which is required to stabilize lithium ion batteries, is largely found in parts of the Congo renowned for human rights violations and abusive workforce practices.
- **Battery recycling:** As BEVs penetrate the vehicle fleet and batteries wear out, a new industry will be required to recycle the spent batteries and separate the component materials.

These barriers will put brakes on the penetration rate of BEVs. There will doubtless be an angry response to the GOP proposal, but its effect will be minimal. Tesla will likely reach the 200,000 battery electric vehicle mark in early 2018, followed quickly by GM and Nissan, so killing the rebate this year will only slightly advance the schedule for eliminating the tax credit.

There is also an issue of equity. The \$7,500 tax rebate is most valuable to high income people, but it is paid for by the rest of us in a reverse Robin Hood move of robbing the poor to give to the rich. Eliminating it will rob the rich of this perk, and the money saved can be put to more fruitful and equitable uses.

Hopefully the administration will seek out other situations that are regressive, where high-cost energy solutions favored by the rich are paid for by spreading the costs over rich and poor alike. ■

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IS THIS A NORMAL BUSINESS CYCLE, OR ARE WE SEEING STRUCTURAL CHANGES TO THE ENERGY BUSINESS?

WILLIAM MALONEY

Director, Trident Energy; Energy Advisor, Warburg Pincus; and Energy Advisory Board Member

There are many aspects of what we are experiencing today in energy markets that can lead you to believe we are simply in another commodity cycle. In years past we have seen the low-cost producers maintain production to capture market share. We have also seen production cuts aimed at balancing supply and demand. Today we are approaching a delicate supply-and-demand balance. We see oil prices firming as a result.

However, I do not believe this is the entire story. My view is that there are four factors impacting the energy business that will lead to long-term structural change. They are:

1. Changing of the guard - We are witnessing a change in the type of individual running some of the largest energy companies. ExxonMobil, Chevron, Shell, Total and Statoil are all currently or about to be run by people who have significant downstream experience. Why is that important? The downstream sector of the energy business (refining, chemicals and marketing) has had to live with thin margins forever. So the focus on cost cutting and a relentless drive for improvement has always been part of downstream's DNA. Now the same drive to control costs and improve profitability will be happening across all sectors within these companies – upstream, downstream and new energy.

2. Costs - We have experienced a large reduction in the cost of doing business especially in the upstream sector. Service companies are hurting and struggle to make a profit at current commodity prices. As supply and demand comes into balance and prices firm we will likely see some increase in costs. However, an argument can also be made that a significant percentage, perhaps up to 50% of the cost reductions we have

witnessed are both structural and sustainable. Many publicly traded companies are disclosing how they are now profitable at \$50 a barrel. They have made changes to their businesses in the form of greater efficiency, fewer staff and the application of technology. In my view, there is no going back. Having worked hard to make these changes, companies are not likely to abandon all the good work they have done.

3. Climate - Many oil and gas companies are working toward producing cleaner and greener energy. Many states in the U.S. and countries outside the U.S. are demanding a stoppage or significant reduction to flaring. Companies are spending more money on various forms of clean and renewable energy. Looking toward the future we can already see that power generation, heating in buildings and passenger cars are all changing and will result in less carbon usage in decades to come. We are clearly on a long journey, which will result in the world changing to a lower carbon society.

4. Financial markets - We have just finished third quarter earnings reporting. The financial markets are pushing companies for even more capital discipline and even further improvements on returns. Some companies are almost bragging about their ability to lower costs and be robust at current commodity prices. Right now only the best projects, especially offshore oil and gas, are being funded. Non-core or non-competitive assets in company portfolios are being sold to others that can see better profitability. No longer are the headlines being about growth in reserves. Rather the conversation is all about the growth in profits.

These four factors will have a large impact on the energy business going forward and will lead to some structural change. Recently

I was talking about this on a radio program and the interviewer asked, "What about the state run companies? Will they be doing what you describe as well?" My answer was first, we are all aware that Saudi Aramco is getting ready for an initial public offering (IPO). When that happens, Saudi Aramco will be subject to the same pressure from financial markets that I have mentioned. In addition to that, if any company, be they public, private or state run, can increase profitability, bring down costs and produce cleaner energy, it is a win for all concerned. So my view is that state controlled companies have as much to gain as public companies in running their businesses as efficiently as possible.

I would like to mention one more thing. The structural changes outlined above will not circumvent commodity cycles. Companies have adjusted to a low price environment by cutting costs, lowering capital expenditures, deferring projects, layoffs and some have even cut their dividend. There will come a time where this underinvestment will manifest in a supply shortage. As a world, we use over 30 billion barrels of oil a year. We are currently not replacing the reserves we produce by a wide margin. Additionally, oil fields naturally decline at 5% each year, although I continue to marvel at how advances in technology enable the industry to slow that decline.

In any case, at some point in the next decade we could very well see a supply shortage due to the massive underinvestment we are witnessing at the moment. Related to this, some believe that shale in the U.S. can come to the rescue. I would not count on that. Today the onshore U.S. produces approximately 8% of total world oil production. It is hard to visualize a world where shale can take the place of a large portion of today's conventional oil production.

In closing, many people ask me what the future will look like, especially for jobs in the energy industry. Bringing reliable energy to the world's population will always be a priority for any energy company. The fundamentals of science and engineering will never go away. They are the foundation of the energy business. Technology will improve and as it does, it will only enhance our ability to safely and efficiently bring energy to the world. So my view is that while today things may look tough for employment in energy, the future is bright. The world needs energy and it needs smart dedicated men and women to deliver that energy. ■

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WHAT HARVEY TAUGHT US: LESSONS FROM THE ENERGY INDUSTRY

LATHA RAMCHAND

Dean, C.T. Bauer College of Business

RAMANAN KRISHNAMOORTI

Chief Energy Officer, University of Houston

The last week of August 2017 will remain etched in Houston's memory for a long time to come. The week started with a total solar eclipse that captured the nation's imagination. Then, Harvey made landfall on Aug. 25.

Dumping more than 51 inches of rain in some areas, Harvey gave new meaning to flooding. Damaging more than 148,000 single family homes, 163,000 apartments and more than 500,000 vehicles, Harvey also is responsible for 88 fatalities.

The storm's impact on the energy supply chain was significant, too. Airports, roads and freight were affected, including about 10% of the nation's trucking business. Harvey shut down 22% of nation's refining capacity, 25% of oil production in the Gulf of Mexico and half of both the production of organic chemical and plastics resin and of natural gas in the Eagle Ford. Fuel shortages (perceived or real) hit Houston, Austin and Dallas.

So how did the industry deal with the disaster? We interviewed key decision-makers from a dozen companies to find out what they had learned from the past and what should be changed before future storms. And we asked their thoughts on remaining and growing their organizations along the Gulf Coast, a geographic region prone to severe weather.

This wasn't the industry's first test, although past emergency management plans mostly addressed hurricane-force winds and storm surge. Massive rain and inland flooding on the scale witnessed during Harvey was unprecedented. In addition to facilities and operations, approximately 10% of industry

personnel were impacted, as was access to offices, and industrial sites. In short mobility was curtailed for 7 days for over six million people. Harvey was unique.

After Superstorm Sandy, the Department of Energy (DOE) requested the National Petroleum Council (NPC) to study emergency preparedness, which led to a series of recommendations. These revolved around coordinating industry efforts with those of federal, state and local agencies to make sure emergency management plans reflect energy system interdependencies in responding to regional and national disruption.

The American Petroleum Institute has protocols for members to use during emergencies while maintaining compliance with antitrust laws that limit information-sharing across companies. During emergencies, the electric power utilities operate under rules set by the Federal Energy Regulatory Commission and in the state of Texas by ERCOT, which operates most of the state's electric grid. In addition, in Texas the Fuel Team, a state level coordinating council, brings together industry and the public sector to help coordinate relief efforts, including the ports, Federal Emergency Management Agency, the Department of Public Safety, Department of Transportation, health care and local emergency management officials.

While the framework for disaster planning was in place, Harvey tested its effectiveness.

Our interviews with 15 C-level executives from 12 energy firms offer insight into what went well and what did not. The companies – which included large integrated oil and gas firms, oilfield

equipment suppliers, specialty chemicals manufacturers and power companies – have market capitalization ranging from \$30 billion to \$355 billion.

Here is what we learned.

Every firm had a risk mitigation plan in place. Whether it was part of a crisis management plan or a business continuity plan, the components were somewhat similar and included defining and preparing differently for different levels of risk, implementing annual drills involving hundreds of managers and employees, creating coordination channels across functional areas and with the teams on site (incident management teams), and covering the spectrum of preparedness from the strategic to the tactical.

Everyone agreed that experience with prior hurricanes Katrina, Ike, Sandy and Gustav, helped fine-tune their plans. Working with regulators helped reduce supply-chain bottlenecks in stranded areas primarily through waivers. DOE and the U.S. Energy Information Administration provided daily guidance reports.

Unlike storm surges associated with previous natural disasters, Harvey-related flooding impacted operations and entire communities. Many firms relocated their decision-makers and supply chain liaisons, leaving ride-out teams onsite. In some cases they worked with weather experts and meteorologists, relocating leadership teams prior to Harvey's landfall.

Most respondents said having a designated individual (not the CEO) who could direct resources and manage the emergency response team ensured efficiency and safety. Organizationally, the process worked via decentralized teams that reported to senior leadership and in some cases to 'country' chairs who communicated frequently.

In addition to reaching out to customers and employees, public affairs teams reached out to the media and external groups.

All executives we spoke with described efforts to provide accommodation, transportation and emergency financial assistance, including interest-free loans to affected employees. "Mucking" crews helped employees and the community in the clean-up process. In the weekends that followed, it was not unusual to see

teams wearing company/organization branded T shirts arrive to help communities and neighborhoods across the region.

In many cases, company ride-out and volunteer teams wound up helping both their own employees and other residents. This was perhaps the most commonly cited "learning" from the disaster. Natural disasters result in damage to communities and to the extent that businesses were actively helping their customers and employees, they also deployed relief efforts to aid the community. That included donations of gasoline and diesel, air lifting people from stranded areas, providing food and water to residents where the firms had operations and direct financial assistance to charity organizations that operated in the community.

What went better than expected:

1. Communications - The variety of platforms used to communicate with employees and customers was critical. Emails, phone trees, daily summary text messages, call in numbers, emergency alerts, text blasting, intranet communications and social media channels all helped management stay in touch with employees. Social media platforms including Facebook, Twitter and Yammer connected employees who wanted to volunteer with those who needed assistance.
2. Technology – Modern technology clearly helped, from using drones to monitor facilities and operations to services like the Power Alert Service offered by CenterPoint Energy, which sent customers notifications of power outages on a timely basis. Agile deployment of technologies such as remote connectivity allowed for business continuity.
3. Preparation – The multiple sets of training and simulations along with "hardening" of critical assets led to a swift recovery of much of the upstream, refining and downstream chemicals industry. Many companies contracted with hotels and conference facilities outside of Houston to maintain business continuity and leveraged IT solutions to ensure a smooth work flow.
4. Agile decision-making – Communications between industry and regulators enhanced the effectiveness of the response. Examples include access to the Strategic Petroleum Reserve, waivers allowing

refiners and blenders to adopt winter gasoline standards rather than summer standards. Similarly, in response to hurricanes Harvey and Irma, the Federal government waived the Jones Act on Sept. 8th, allowing for a more effective emergency supply chain of fuel and refined products.

5. Employee care – Companies offered several initiatives to help employees, including interest-free loans, paid days off, paid volunteer days, charitable giving by employees to fellow-employees, per-diem payments for temporary accommodations, extension of emergency benefits and corporate contracting of “mucking crew” and cleaning services. Employees were given flexibility to work from remote locations and/or from home.

6. Leadership – Daily check-ins at the highest levels and the ability to listen in on conversations without actively participating at lower levels helped leaders function as ‘guides on the side’. One CEO alluded to his efforts to not interrupt crisis managers, instead communicating with his direct reports by text message if necessary, enabling decentralized ownership of the risk management process. The ability to listen to all levels of the organization, not just the direct reports, was considered valuable and used strategically to manage disaster response.

What could be improved:

- More preplanning and flexibility in travel plans to help move people as plans and potential impact projections change.
- The magnitude of disruption associated with Harvey was unique and affected the supply chain of gasoline, jet fuel and diesel in Texas. State and local leadership dealt with industry disruption even as they responded to life safety and humanitarian crises in three locations – Corpus Christi, Houston and Beaumont in succession. In contrast, the Governor’s Office in Florida coordinated all supply chain activities before, during and after Hurricane Irma. One possible mechanism for Texas or other state and local agencies in a similar challenge would be to coordinate with industry associations such as the American Petroleum Institute, the Texas Oil and Gas Association and the American Fuel and Petrochemical Manufacturers, creating

coordination groups comprised of industry and non-governmental organizations. While there was coordination with the local and state officials, a broader coordination group that uses modern communication tools would result in real time appraisal and awareness of the collective status of the industry. This would need to be done within the guidelines set by antitrust regulations.

- A small fraction of petroleum and chemical storage was affected by the massive rain and inland flooding, with spills and leaks reported, some with significant life-safety risks. Revisiting design guidelines, examining retrofits and increasing smart sensors and analytics are being examined to improve the vital components of this supply chain.

Overall, our analysis suggests the industry has well-defined risk management and mitigation plans in place. At the same time, given the nature of the crisis which temporarily shut down the entire region and impacted employees personally and professionally, the management plans were only as good as the communications systems used to share them. While decisions could be made by centralized leadership teams, the efficacy of communications channels and agility in decision making were crucial to the success and rapidity of the recovery. Harvey spoke loud and clear that private and public partnerships can and must work together to deal with disasters that have broad impact.

Finally, while extreme events prompt consideration of location risk, almost all respondents agreed the industry has developed better tools to manage the risks associated with extreme weather. Balancing those risks against the advantages of the Houston region – capital on the ground via already hardened sites, an established supply chain and support infrastructure, including ports and terminals, a knowledgeable work force, improving weather prediction services, innovations in communications platforms and improved coordination systems that bring together public and private agencies during times of natural disasters – as Houstonians, we were very happy with what we heard.

Moving energy facilities away from the Gulf Coast is not a consideration, Harvey or not. ■

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RADIOACTIVE WASTE AND THE HIDDEN COSTS OF THE COLD WAR

DAVID RAINBOW

Assistant Professor, Honors College

Hanford, a dusty decommissioned plutonium production site in eastern Washington state, is one of the most polluted places in the country. The disaster is part of the inheritance of the Cold War.

A few months ago, a 110-meter-long tunnel collapsed at the site, exposing an old rail line and eight rail cars filled with contaminated radioactive equipment. This open wound in the landscape, which was quickly covered over again, is a tiny part of an environmental and human health catastrophe that steadily unfolded there over four decades of plutonium production. Big Cold War fears justified big risks. Big, secretive, nuclear-sized risks.

Hanford and other toxic reminders of the Cold War should serve as a cautionary tale to those who have a say in mitigating geopolitical tensions today, as well as to those who promote nuclear energy as an environmentally sustainable source of electricity. The energy debate must balance the downside – not just the risk of a nuclear meltdown but also the lack of a permanent repository for the still-dangerous spent fuel rods – with the environmental benefits of a source of electricity that produces no greenhouse gases. People on both sides of the issue have a vested interest in how the current geopolitical tussling over nuclear weapons plays out.

These days, fear of other countries is big again. North Korea’s nuclear detonations and intercontinental ballistic missile launches – the most recent just days ago – are explicit threats to the U.S. For his part, President Trump has responded with threats (and mockery) of his own, promising to reign down

“fire and fury” on North Korea if Kim Jong Un follows through on his threats.

On the campaign trail last year, Trump called for the U.S. to “greatly strengthen and expand its nuclear capability.” Recent reports (which Trump denies) that the President has called for increasing our nuclear arsenal by 10 times are in line with this campaign pledge. According to the reports, Trump wants to return to the peak nuclear production of the 1960s, the height of the Cold War. While Trump’s statements on nuclear weapons have been inconsistent, the overall picture has been clear and in line with his general chest-thumping approach to foreign policy: We will do and say what we want. None of this rhetoric is conducive to making the world safer from nuclear weapons.

The saga of Russia’s connection to Trump’s presidential campaign continues, too. Again this past week we learned more about conversations between Trump’s people and the Russians during the election. Here it’s been the left that has most often drawn upon rhetoric to characterize Russia’s meddling – or “The Plot Against America” – that harks back to the conflicts of the last century. Secret plots, missile tests, Russian spies, insinuations of treason, radioactive materials. Put these together with the deep disagreements between the U.S. and Russia over the ongoing conflicts around the globe (Syria, Ukraine, and the significant military exercises conducted along NATO’s eastern border), and we are back, it seems, to the bad old days of the Cold War. Even if, as we all hope, the “new Cold War” never gets hot, escalating tensions can have seriously harmful effects at home. The radioactive cave-in at the Hanford site earlier this year should serve as a reminder of that.

Nuclear refinement at Hanford began as a part of the Manhattan Project during World War II, the highly secretive plan to develop a nuclear bomb.

Initially, the drive to mobilize for war justified substantial costs, among them significant damage to human and environmental health in the U.S. resulting from the nuclear program. Hanford was integral to the program: its plutonium fell on Nagasaki. But after the end of the war, the scale of production at the site increased to a fevered pitch thanks to the ensuing competition for global influence between the U.S. and the Soviet Union that became the Cold War.

Our gargantuan stockpiles of nuclear arms demanded gargantuan quantities of plutonium. Forty-five years of work at Hanford – from 1943 to 1987 – yielded 20 million uranium metal plugs used to generate 110,000 tons of fuel. The process also generated 53 million gallons of radioactive waste, now stored in 177 underground tanks at the facility, and created 450 billion gallons of irradiated waste water that was discharged onto “soil disposal sites,” meaning it went into the ground. Some of the irradiated discharge simply ran back to where it had originally been taken from, the nearby Columbia River. The Office of Environmental Management at the Department of Energy is currently overseeing a cleanup project involving 11,000 people. It is expected to take several decades and cost around \$100 billion.

Kate Brown’s award-winning book, “Plutopia: Nuclear Families, Atomic Cities, and the Great Soviet and American Plutonium Disasters,” is a history of the Hanford plant and its Soviet doppelgänger, a plant in the Ural Mountains called Maiak. Brown points out that over the course of a few decades, the two nuclear sites spewed two times the radiation emitted in the Chernobyl explosion. Yet few Americans at the time, even those involved in plutonium production, realized this was going on or how dangerous it was.

Naturally, the hidden nature of the project meant that information was hard to come by. As Brown shows, even the experts, managers and scientists involved directly in overseeing the production process knew little about the seriousness of the risk. Doctors studying the effects of radiation on people didn’t

have access to the research related to environmental pollution. Scientists studying fish die-offs had no way of connecting their findings to the deteriorating immune systems of humans in the same areas. Most poignantly, researchers measuring the effectiveness of nuclear bombs on the enemy did not communicate with researchers measuring the threat of nuclear bombs on the workers making them. Consequences for the workers were grave. Hanford and Maiak’s hidden mega-pollution was collateral damage in the fight to win the Cold War. Russia, like the U.S., is still living with the damage, and trying to bury it, too.

Within two days of the tunnel collapse at the Hanford site this past May, workers filled the breach with 53 truckloads of dirt and narrowly avoided a radiological event. However, these eight railcars are hardly the only waste left behind in the U.S. from our cold conflict with the Soviet Union, in which our willingness to risk human and environmental health was proportionate to our fears. It’s going to be a while before it’s all cleaned up. In the meantime, hopefully our leaders will work to keep the new Cold War from getting any worse. ■

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BIG SPORTS EVENTS HAVE BIG ENVIRONMENTAL FOOTPRINTS. COULD SOCIAL LICENSES TO OPERATE HELP?

GINA S. WARREN

George Butler Research Professor of Law, UH Law Center

Minneapolis will host the 2018 National Football League (NFL) Super Bowl in February. Pyeongchang, South Korea will host the 2018 Winter Olympics that month, followed next summer by the FIFA World Cup in Ekaterinburg, Russia. A growing number of mega sporting events promise fame and fortune to the host cities, with the lure of funding for new infrastructure and community projects and a boost in tourism for the event and beyond.

Just as the athletes compete in their sport’s biggest showcase, cities dream of urban revitalization, an improved economy and a better quality of life for residents. Past experience has shown, however, that host cities do not always reap social and economic benefits from these events. Instead, these major sporting events generate significant unforeseen – or at least unaccounted for – environmental consequences.

The environmental consequences involve everything from building new stadiums, hotels, parking lots and other infrastructure to handling the sanitation from all those new toilets. The use of “social licenses” – a practice adapted from mining and energy industries working in developing nations – could help.

Carbon emissions that contribute to climate change are a significant factor. While some organizers tout policies for offsetting carbon emissions generated by an event, this is little comfort in a time when the world needs to reduce carbon emissions, not just offset extra carbon generated by an event. Further, those offsets do not account for the heaps of trash and food waste, energy consumption to power the stadium or water consumption for toilets and to irrigate the fields and nearby

areas. It is separate from the consumption, pollution and waste of constructing new buildings, parking lots, apartments and other structures. One research study conducted by professors at Cardiff University in the United Kingdom looked at different models to assess the ecological footprints of a major event – the Football Association Challenge Cup Final (English domestic football). The impact elements included travel, food and water, infrastructure and waste.

The study found that the average attendee generates a footprint seven times greater than someone going about normal, everyday activity. Increased travel by event visitors accounted for the biggest part of this significant increase. The consumption of food and drink, and the energy and resources required to produce that food and drink, makes up the next largest part of the footprint.

The study apportioned a very small footprint to the stadium itself (here the Millennium Stadium in Cardiff, Wales), in part because the footprint was amortized over a 100-year life span. This is a very optimistic view. Instead, it is more likely that the stadium will become obsolete within a few decades, as new technologies are introduced, new urban development occurs and cities offer lavish facilities to lure teams looking for a new home. NFL stadiums in the United States, for example, have a median age of 31 years before they are replaced. In any event, it is difficult to assess the global environmental and economic impact of these events, let alone to try to create a strategy to address them.

Lastly, the ambition of hosting a mega sporting event tends to encourage cities to relax their rules for urban development and restructuring. This may be because of the short timeframe for

hosting the event, or it may be that cities receive significant internal and external pressure to satisfy their obligations for the event.

In the run up to the 2014 World Cup and the 2016 Olympics in Brazil, for example, politicians in Rio de Janeiro executed “flash-votes” that allowed the Legislative Assembly to push through emergency bills to (1) lift the ban on alcohol at stadiums; and (2) annul the laws that protect historical architecture and patrimony of certain existing stadiums. These emergency bills were approved without the usual mandatory public debate, resulting in the demolition of two historical structures - the Sambodromo and Maracana Stadiums – and their replacement with a new stadium. This not only reflects a disregard for community involvement, it is also disconcerting because much of the cost for these events is borne by public funding. In the United States, for example, sports stadiums have historically been funded through publicly subsidized financial mechanisms including general sales taxes. In Australia, much of the \$30 million annual cost of holding the Formula 1 Grand Prix comes from public funds. Further adding insult to injury is the fact that most local residents cannot afford to attend these mega events, which are targeted toward the elite foreign traveler.

Little legal framework exists to regulate these transient pop-up cities created by mega sporting events. While there are a handful of United Nations treaties on sports, mostly recognizing the general right to participate in and have access to sporting and recreational events, no international treaty addresses the social, economic and environmental externalities. The closest is Agenda 21, adopted by United Nations (UN) member nations in 1992. At the 1992 Rio Earth Summit, many UN member states committed to environmental sustainability in economic development generally and adopted Agenda 21 as the framework for fulfilling this obligation. Agenda 21 is non-binding and voluntary but encourages all organizations - governmental and non-governmental, international, regional and local - to prepare their own version based on the framework provided. While it does not specifically address sporting events, the International Olympic Committee (IOC), working with United Nations Environment Programme, adopted its own Agenda 21 in 1999, following the general framework of the Rio Agenda 21 and providing a plan to

improve socioeconomic conditions, conserve and manage resources and strengthen the role of major groups in each Olympic host country.

Agenda 21 provides a potential framework for sustainable development generally, but it does little to address the unique temporary nature of mega sporting events, and if the 2016 Olympics were any indication of its effectiveness, it falls well short of ensuring sustainable practices. Further, other than the IOC, it does not appear to have been adopted by any other major sporting organization.

With more sporting events on the horizon than ever before, it is time to more holistically address the pollution, waste, greenhouse gases and other negative consequences. Agreements between host city and event organizer often ignore key issues, and host cities are sometimes concerned that organizers will simply go on to the next city if they push too hard on specific terms.

So what might work? One possibility is the use of social licenses, a concept that originated with mining and energy industries operating in developing nations. After unbridled environmental damage – and the ensuing reputational hits – during the 1990s, the World Bank encouraged the industry to use social licenses. These social licenses, which are essentially ongoing agreements with local governments and other stakeholders to indicate local acceptance of a project, helped identify and address concerns about the environmental and human cost of the transitory mining and drilling activities.

Over the last few decades, societies around the globe have begun to shift to a more informed and involved form of decision-making, with an eye toward sustainable practices. Social licenses are part of that, legitimizing stakeholder decisions and providing a framework for managing expectations. The use of social licenses for mega sporting events could benefit all parties and allow for a fair allocation of the benefits and costs associated with the event. Some of the key elements of a social license that could apply include full disclosure and transparency of process; making environmental, social, and economic information available in the local language; early and meaningful community involvement in decision-making; a commitment to sustainable energy

and environmental sensitivity, and longevity of community investments.

Although there is no silver bullet to prevent the negative side effects of these mega sporting events, implementing a social license to operate mechanism could at the very least allow communities to identify and meaningful analyze the costs and benefits associated with hosting the event early in the process. ■

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ANOTHER OPEC PROMISE: FOOL ME TWICE, SHAME ON ME

BILL GILMER

Director, Institute for Regional Forecasting, C.T. Bauer College of Business

OPEC is back again, with an extension of its November 2016 accord that – subject to review – will extend its existing production quotas through 2018. The oil market responded by pushing oil prices up quickly and sharply to near \$60 at year end.

This comes after OPEC promised to crush American fracking in November 2014, although to no significant effect if measured by current levels of U.S. oil production. Then OPEC returned to the oil market as swing producer in November 2016, claiming it was taking back control of oil prices and was committed to “do whatever it takes” to raise oil prices in 2017.

We saw West Texas Intermediate sitting at \$45 per barrel by June and through the summer. With this latest November 2017 meeting, why does the market believe OPEC can support higher oil prices this year? Their members need the money, after all, to run their kingdoms and socialist governments. And maybe there are reasons to think it could happen: stronger global demand, the return of political risk to oil markets, or a newfound, profit-oriented discipline in the U.S. fracking industry.

But more likely, the competitive behavior of the U.S. fracking industry that ruined OPEC’s plans in 2017 is still in play and will quickly pull prices down in 2018. By mid-2018, many analysts, forecasting models and international agencies may find that they bought into another tall tale from OPEC. Fooled again? Shame on them.

Whatever It Takes ...

My September blog post described how OPEC’s 2016 agreement

failed, largely due to American fracking. The U.S. fracking industry has changed the face of domestic oil production. This is not the Seven Sisters anymore but many small, competitive oil producers and a low bar to entry, with companies needing only capital, some geology, leases and a service contract to drill. Exploration risk is gone, and increased production is virtually assured once you drill.

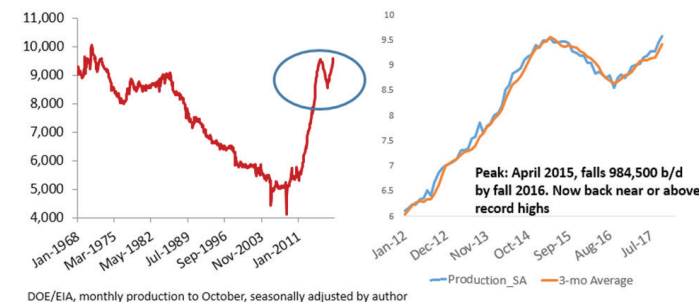
Despite the smoke and mirrors from the fracking industry, the petroleum engineer and the financial analyst will tell you that the long-run, capital-recovery price of oil from fracking or tar sands is \$60-\$65 per barrel. However, the industry is heavily subsidized right now, allowing it to operate well below this long-run marginal cost. Capital subsidies come from a world awash in cheap money, and specifically in 2017 from private equity and high-yield markets. Operating subsidies come from depressed oil service and machinery industries, discounting work to keep the doors open while the rig count lingers at less than half its previous peak.

These subsidies are a powerful incentive to overproduce. In 2017, the fracking industry tried to use these subsidies to build production quickly, impress the stock market with a growing asset base and cash in through higher equity values. This did not end well, with collective peak-to-trough losses in 2017 equity values of 32% for producers, and 43% oil service suppliers, according to the S&P indexes for Exploration and Production and Oil Services and Machinery.

How did this strategy fail? It might work for a few producers, but if everyone jumps in the game, the only important effect is that U.S. oil production rises sharply. Figure 1 shows the big turnaround in domestic oil production between 2011 and 2015, adding 4.1 million

barrels per day; this was followed by a fracking bust loss of nearly a million barrels per day by late 2016. But then production turns back up and begins to grow quickly again in October 2016, not coincidentally timed with OPEC’s 2016 promise of higher prices.

Figure 1: U.S. Fracking Responds to OPEC Price Incentives: Now Near All-Time High Levels of Production in late 2017 (million barrels/day, s.a.)



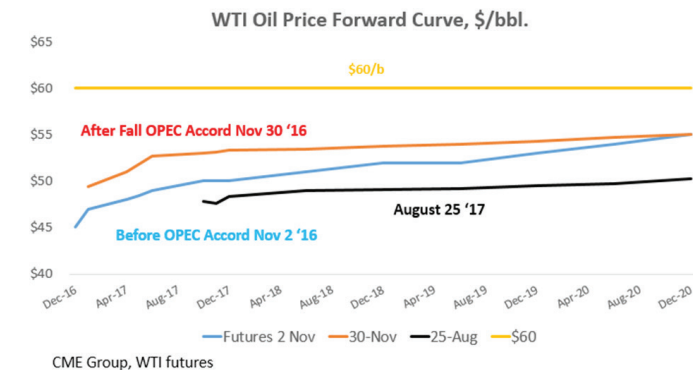
Source: DOE/EIA

Part of the 2016 turnaround in the rig count and the stabilizing of U.S. production was just West Texas Intermediate price returning from \$30 to near \$45 per barrel. But when OPEC announced its return as swing producer in late 2016, it raised price expectations and gave further momentum to oil prices and drilling.

Figure 2 shows the forward curve for WTI futures prices just before and just after the OPEC agreement was signed, with price expectations moving from \$45 to near \$55 per barrel. However, it also shows that by summer, any OPEC optimism had completely washed out of the market.

Where did the optimism go? Look back at Figure 1, where U.S. production begins to climb quickly in October 2016 and has continued to climb through the latest available data, in October 2017. By October, these seasonally-adjusted values are just above peak 2015 levels, and OPEC’s best efforts to squeeze out the high-cost producer seem to have backfired on them. It is hard to see how higher prices will cure their whack-a-mole fracking problem.

Figure 2: OPEC Optimism Came and Went in 2017 After OPEC Says: “Whatever It Takes ...”



Source: CME Group

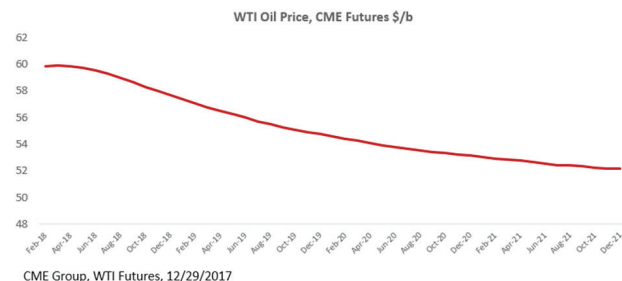
How Is 2018 Different?

Several factors might justify current higher oil prices: a stronger global economy, growing political risk, and a new-found discipline in the U.S. fracking industry. The first two are true, but probably not the key to an oil market recovery. The competitive, many player structure of the fracking industry makes the last option – producer discipline – very unlikely.

The current forward curve for WTI prices (Figure 3) shows lack of conviction about the durability of current higher prices, casting doubt on whether any fundamental market rebalancing is even in play here. Price starts 2018 at \$58 per barrel, and ends the year near \$57. But then the near term tightness disappears, and WTI is \$54 at the end of 2019, and \$52 by year-end 2020.

Regarding stronger global growth, it is without doubt a plus for higher oil prices. The global oil market has historically seen annual growth of 1.4 million barrels a day for decades, and this rate has continued from 2014 to the present. The fundamentals of the latest downturn in oil prices have not been about global demand, but about a glut of production from Texas and North Dakota. This overproduction remains the problem OPEC needs to fix.

Figure 3: Near-Term Tightness Disappears in WTI Forward Curve



Source: CME Group

We recently have seen the emergence of significant political and other risks that provide an upside to oil prices that has been missing for several years: major pipeline disruptions, rebel attacks and militant unions in Nigeria, the Kurdish threat in Iraq, and an ongoing financial and political crisis in Venezuela. The return of symmetric risk -- high and low -- is said to support higher prices.

But specific threats come and go. I am sure I could quickly think of 100 low-probability events where any one could have a big effect on the oil market. If each had a 1% likelihood in 2018, it means there is a 63% chance at least one of them will happen. And if I thought up 500 events, there is a 99% chance that at least one will happen. The risk is always there, specific disruptive events usually blindside analysts and forecasters and thinking up two or three front-burner issues will not cure this problem.

Finally, the fracking industry is said to have foresworn chasing equity gains at the expense of long-term profits. No more leveraging themselves and outspending their cash flows to impress the stock market. Newfound discipline is now the industry watchword after getting burned badly in 2017. What makes this unlikely is the many small firms now in the oil production business, combined with the basic DNA of any competitive industry. Think of it as a cartel with dozens of members instead of OPEC's current 14, and you get the idea how strong the incentives will be to forego discipline, i.e., cheat.

Suppose only 5% of U.S. producers cheat in early 2018, and as a result, they win some nice equity gains in the stock market. The other 95% will quickly pile in behind them. Stockholders and investors will turn on laggard managements, asking why they weren't in the early 5%. More drilling ensues, production rises, OPEC's price gains disappear, and oil prices remain capped at a low level. Low prices persist until next November, when OPEC will probably give it another try. ■

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BACK TO THE BASICS: EVOLUTION OF THE MIDSTREAM SECTOR

CHRIS ROSS

Executive Professor, C.T. Bauer College of Business

Midstream Master Limited Partnerships (MLPs) were created as tax efficient entities to own and operate energy infrastructure assets and distribute most of their cash flow to their general and limited partners. Early MLPs in the 1980s were run conservatively, minimizing capital expenditures to maximize distributions.

Following the lead of Kinder Morgan and Enterprise Products, MLPs transformed themselves in the 2000s by adding a growth component to their investor value proposition, initially inorganically through acquisitions and later organically. New opportunities emerged to "replumb" the nation's gathering and pipeline infrastructure as shale oil and gas developments needed to be connected to traditional markets.

And the MLP structure continues to evolve in response to changing conditions in the field and on Wall Street. Today's midstream ventures face fierce competition, the new GOP-led tax plan will lessen some of the tax advantages and a shift in ownership from the original founders to traditional investment managers has brought new perspectives on how shareholder value can be created within the sector.

As part of a series of shareholder value research classes, students of the C.T. Bauer College of Business at the University of Houston found that from 2003-2013, MLPs provided exceptional returns to their unit holders, with the Alerian MLP Index advancing at twice the rate of the S&P 500 Index. The drivers of this appeared to be strong growth in revenues, with less significance given to returns on assets. The class found market values were consistent with an assumption that past growth in

distributions per share would continue indefinitely, regardless of the ability of the MLP to deliver sufficient cash to sustain the distribution growth.

In late 2014, global oil prices collapsed, and midstream companies' valuations followed soon after (Figure 1). As described in an earlier blog focused on the period 2014-15, this provided a stress test for the sector and revealed that MLPs with higher general partner (GP) take through normal and incentive distribution rights suffered higher value erosion. We questioned the viability of incentive distribution rights in an environment that may be less supportive of aggressive growth strategies.

Figure 1: Alerian MLP and S&P WTI Indices



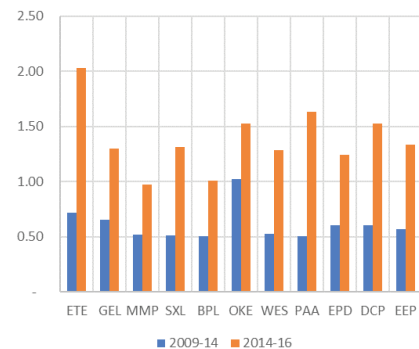
Source: Provided by Author

A new class of 12 students researched the midstream sector during the Fall 2017 semester to try to understand the drivers of the midstream devaluation and the implications for the future of the midstream sector. The 2017 class found a very different business environment to that of our earlier class.

The midstream sector had become about twice as risky in the period 2014-16 as it was in 2009-14 (Figure 2). The higher beta stemmed from a variety of factors:

- Lower distribution growth rates after several companies made reductions in 2014-16.
- Uncertainty on the corporate structure best suited to the needs of the next five years.
- Increased competitive intensity for new projects and acquisitions, with attendant risks of capital indiscipline.
- Uncertainty on how changes in tax policy might affect MLPs' historical tax advantage over C-Corporations.
- Change in ownership structure, bringing in new investors with different value expectations requiring new value propositions from MLP management teams.

Figure 2: Midstream Beta: Two Time Periods



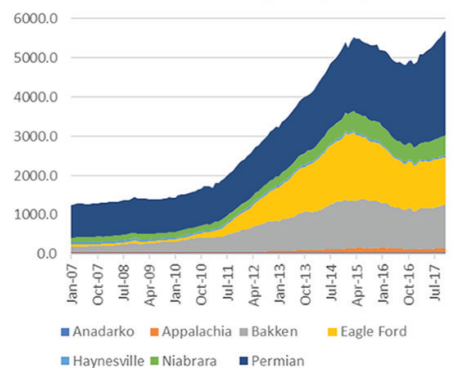
Source: Provided by Author

Reduced "Re-plumbing" Opportunities

Oil prices have now recovered from the extreme lows of 2016, and drilling has picked up. But not every field offers equal opportunity.

Production growth for oil is largely in the Permian Basin (Figure 3), where numerous pipeline projects are planned to expand capacity and lessen the impact of geographic basin differentials; production growth seems to have plateaued in the Eagle Ford, Bakken, SCOOP and STACK plays in Oklahoma and from Colorado Niobrara formations, limiting demand for new infrastructure projects there.

Figure 3: Oil Production from Major Shale Regions (kbd)



Source: Provided by Author

Natural gas growth is largely in the Marcellus and Utica formations of Appalachia, where new infrastructure projects are virulently contested by environmental activists. Growth from the Haynesville in Louisiana requires modest new pipeline investments to connect to LNG projects on the Gulf Coast. Many of the most important infrastructure projects have been completed or are under construction, and midstream investors may question future growth prospects.

Increased Competitive Intensity

In addition to diminished investment opportunities, growth opportunities are fiercely contested by mature midstream companies and a relatively new set of companies whose primary business is upstream or downstream. These companies include most of the independent refiners, including Phillips 66, Valero Energy Corp., Andeavor Logistics LP, Holly Energy Partners and Marathon Oil, and some domestic exploration and production companies, including Western Gas Partners (Anadarko), EQT Corporation, Antero Midstream Partners and Shell Oil. In the past, these integrated companies were sources of growth investments for MLPs as they divested underutilized legacy midstream infrastructure and outsourced major midstream projects.

Both groups of midstream companies provided similar returns to unit holders, but integrated companies have a head start on sourcing new projects to meet the future needs of the parent company.

Tax and Monetary Policy

MLPs have historically held a substantial tax advantage over traditional midstream firms due to favorable treatment of depreciation and, as a partnership, avoidance of double taxation incurred by C-Corps. The new GOP tax plan lowers the corporate tax rate and reduces the cost of double taxation, lowering the MLP advantage.

The Federal Reserve plans to continue to raise interest rates, which will increase the cost of capital and reduce the value of future cash flows. How long-term interest rates will respond is uncertain, but falling rates in the 1990s and 2000s provided powerful tailwinds increasing the value of all fixed income securities, including MLPs. Rising interest rates would provide headwinds to value creation in fixed interest securities, including MLPs.

Change in Ownership Structure

All the studied companies raised new equity capital to fund growth between 2011 and 2016 by selling new units primarily to traditional investment managers such as Vanguard, Tortoise Capital, Fidelity

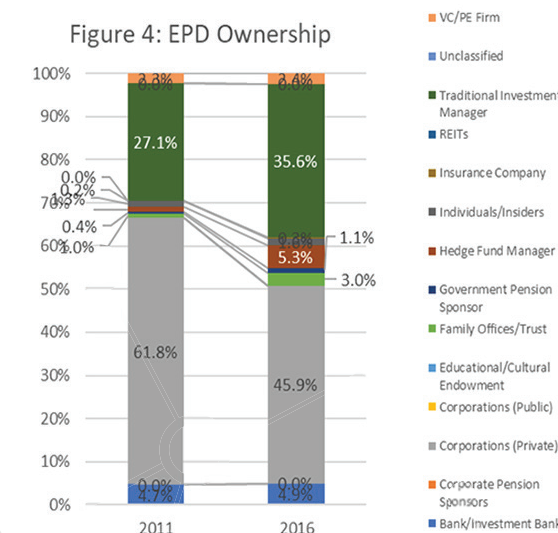
and major bank investment funds. A few companies sustained their 2011 ownership shares (Table 1). Most MLPs and former MLPs such as Kinder Morgan Inc. ended 2016 with a majority of their units owned by traditional investment managers (Figure 4).

Table 1: Change in Ownership Patterns 2011-16

1. Relatively Stable	2. GP Share Diluted	3. GP Sells Down	4. VC, Insiders Sell Down
Magellan	Enterprise Products	Energy Transfer Partners	Kinder Morgan Inc
Dominion Midstream	Boardwalk	DCP Midstream	Genesis
Antero Midstream	TC Pipelines	EQT Midstream	Targa
Andeavor Logistics	Holly Energy Partners		Energy Transfer Equity
	Williams Partners		Enbridge Partners
	Western Gas		Calumet
	Shell		Buckeye

Source: Provided by Author

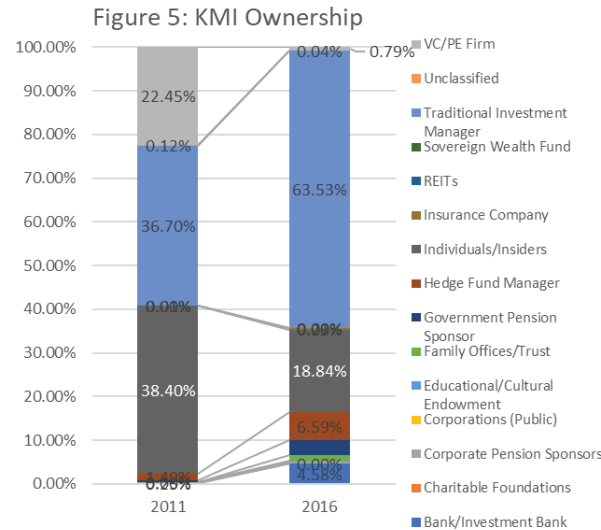
Figure 4: EPD Ownership



Source: Provided by Author

In a second group of companies, the general partner, or GP, maintained its ownership position but did not participate in new offerings so their ownership position was diluted (Enterprise Products does not have a GP, but Duncan family interests provide a stable, though eroding ownership foundation (Figure 4)).

In a third group, the GP sold down its position to traditional investment managers, presumably to raise cash. The fourth group of companies underwent radical changes, in which individuals/insiders, venture capital and private equity investors reduced their holdings and sold to traditional investment managers. Kinder Morgan, Inc. is an example (Figure 5).



Source: Provided by Author

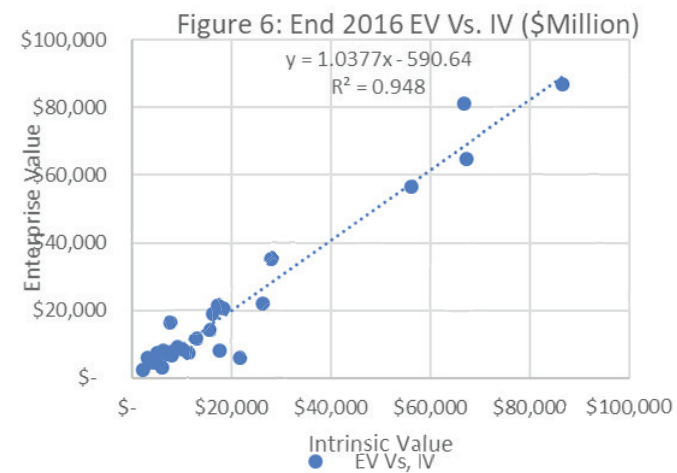
Hedge funds have also shown an interest in the midstream sector. Companies with more than 10% ownership by hedge funds at the end of 2016 were Holly (13%), Targa (11%), ETP (10%), EQM (10%). Eleven other companies studied had hedge fund ownership above 5%. Due to the short-term intent of many hedge funds, this may be a harbinger of future instability.

Looking Forward

It seems that the business outlook for the midstream sector is settling into a period when investor confidence has been sapped by failed expectations of distribution growth, lower growth opportunities, high competitive intensity driving down returns, along with uncertainty on appropriate corporate structure and whether the MLP tax advantage will be weakened. There are also questions about whether management and investor groups are aligned on the proper value proposition.

These uncertainties influenced enterprise values at the end of 2016, and the class developed a series of valuation models for 20 companies. They were based on the premise that capital spending would drive growth in cash flows and would earn a 10% discounted cash flow return over 20 years; 2017 cash flow would be increased as a result of investments in the prior three years and 2017 capital spending would consume 70% of cash flow from operations with the remainder available for distributions.

This process was repeated for five years, then terminal value was calculated using the perpetual growth methodology assuming 4.2% per year growth rate for each company. These models estimated the intrinsic value for each company at the end of 2016, which matched market based enterprise value quite well (Figure 6). The correlation was much better than we had found in a similar study in 2013, when growth in distributions seemed the predominant driver of value.



Source: Provided by Author

This analysis suggests midstream companies should return to the basics of creating value growth by investing in profitable new midstream projects but focus less on high growth in distributions. Successful companies will present a clear investor value proposition, clearly defining targets for growth, profitability and risk, backed up by a credible strategic plan to deliver financial goals aligned with the portfolio needs of their investors.

They will probably eliminate Incentive Distribution Rights in exchange for a one-time payment to lower the MLP cost of capital and remain competitive in bidding for acquisitions or major projects. They will work hard to exceed expectations and develop exceptional capabilities in:

- Operations excellence, to minimize the risk of incidents that increase beta and cost of capital and tarnish the reputation of the whole sector;
- Mastery of the regulatory process to minimize regulatory delays;
- Business development to maintain a strong funnel of potential projects;
- Partnership to combine projects with rivals and avoid overcapacity;
- Negotiation, to assure that tariffs will provide a satisfactory internal rate of return;
- Project management, including deep social management skills.

In a mature industry sector with fewer growth opportunities, consolidation should be expected as the strong devour their weaker rivals. However, our belief is that most acquisitions are fully priced, present significant post-merger integration challenges, and add little value. Management teams should remain skeptical as bankers promote seemingly compelling M&A opportunities. They should dive deep in due diligence to pursue only those potential transactions that enable tangible synergy cost reductions or unlock hidden value in growth opportunities unrecognized or not realizable by the target. ■

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DEFUNDING THE CHEMICAL SAFETY BOARD IS A BAD IDEA AND LIKELY TO INCREASE CHEMICAL DISASTERS

JACINTA CONRAD

Associate Professor of Chemical and Biomolecular Engineering, Cullen College of Engineering

The two explosions in Crosby, Texas, on August 29 weren't loud or massive – just gentle pops of sound. Even such small pops, however, were sufficient to disperse chemicals involved in the manufacture of organic peroxides into the air. First responders at the scene reported respiratory irritation and fell ill after breathing the smoke undefined seen at the perimeter of the plant site.

The explosion at the Arkema plant in Crosby was a result of flooding caused by Hurricane Harvey, one of the costliest hurricanes to hit the mainland United States. The plant lost electricity early in the storm, leading to the shutdown of refrigeration systems. After backup power generators also failed, volatile peroxides – used in the creation of plastics for a wide range of consumer products – heated up and became combustible. Result: explosions. Over several days, 500,000 pounds of organic peroxides in nine trailers burned at the plant.

Hurricane Harvey hit Houston hard last year, and the Arkema explosion was only one incident. While much of the world's attention was focused on the breathtaking rescues carried out by first responders and volunteers, chemical engineers in and near Texas also thought – with great concern – of the many chemical plants located around Houston. Were plants and facilities designed to handle challenges posed by severe flooding? Were necessary safety processes in place to ensure that operations could be safely halted?

Other recent high-profile incidents in Texas – most prominently, the explosion at the West Fertilizer Company in 2013, which caused 15 deaths and over 260 injuries – have reinforced the

idea that safety must be a central focus of the chemical industry. Competition, however, makes it difficult to share best practices across companies. In addition, changes to improve safety are often reactive – made in response to catastrophic incidents such as those at the Arkema or West Fertilizer plants and focused on minimizing consequences after damage.

The U. S. Chemical Safety Board (USCSB) has a critical role to play in surmounting these challenges. Inspired by its vision of “a nation safe from chemical disasters,” the USCSB investigates industrial accidents involving chemicals that are focused on identifying the root cause. Its board members, who have significant experience and expertise in one or more of chemistry, engineering and hazard management, use the information collected from the investigations to make safety recommendations designed to reduce the risk or consequences of accidents. Importantly, the nonpartisan USCSB does not regulate or fund chemical safety. Instead, the Chemical Safety Board acts as an independent, objective party in assessing chemical accidents and recommending better practices.

Thus it functions analogously to the National Transportation Safety Board (NTSB), which investigates accidents in transportation. The NTSB does not regulate or fund transportation. Nonetheless, its recommendations have greatly improved transportation safety over its 51 years – including from anti-collision technologies in aviation and rail to airbag and brake light improvements on automobiles. These advances have saved lives by identifying ways to make industry better.

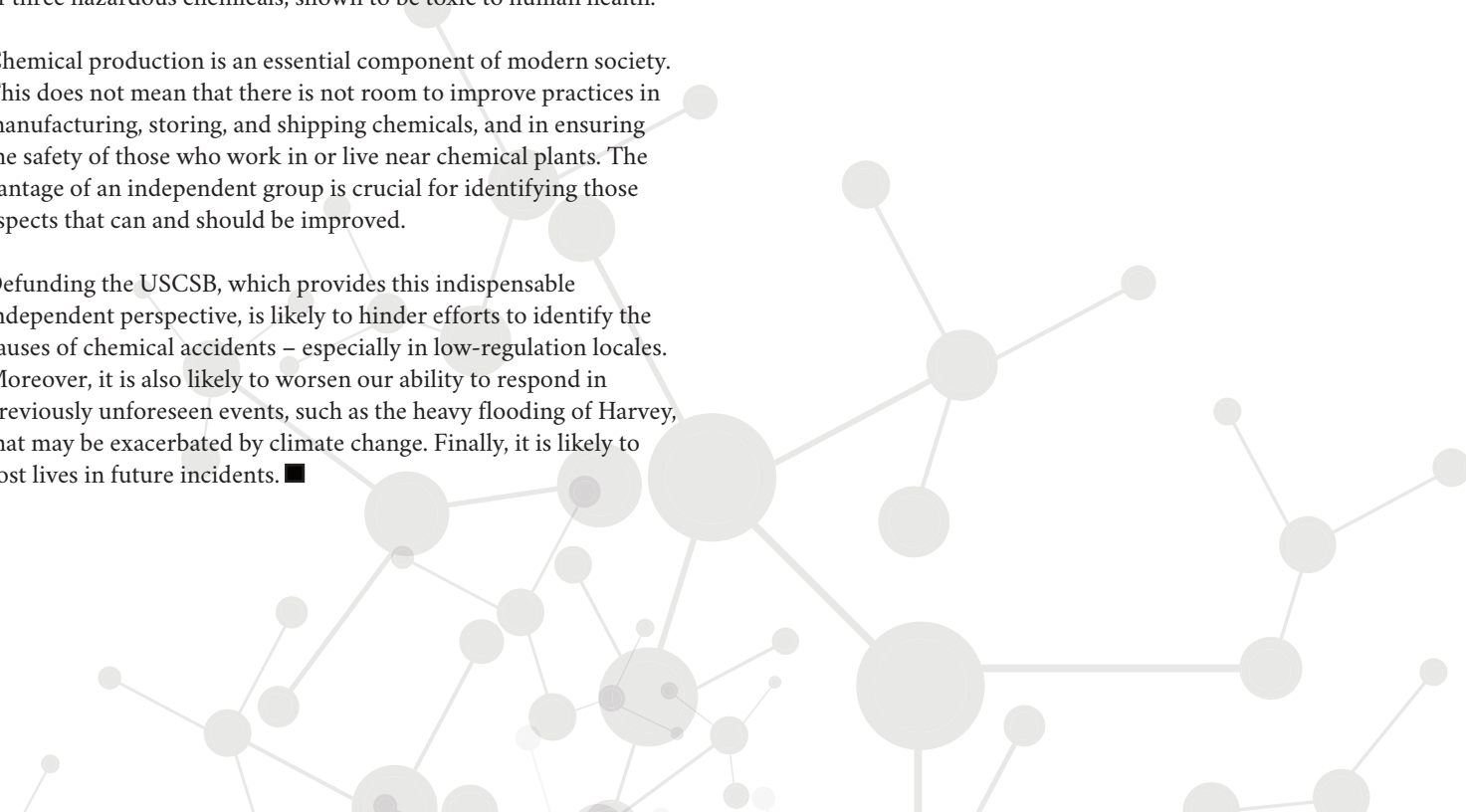
The history of the USCSB is shorter – it was started in 1998 – but it has still played an important role in improving safety in

the chemical industry. As one example, its 19 recommendations after the West Fertilizer explosion and fire have already led to improvements in hazardous materials training for firefighters across multiple delivery platforms. Likewise, its 26 recommendations after the explosion at BP America's Texas City refinery in 2005 led to changes in practices sanctioned by key professional organizations and spurred the development of two new performance indicator standards for process safety by the American National Standards Institute. The Chemical Safety Board's investigation into the Arkema incident is ongoing.

Unfortunately, the 2019 budget proposed by the Trump administration zeros out funding for the USCSB. Its requested fiscal-year funding, \$12 million, is modest for a government agency. Likewise, the 2018 budget also proposed to defund the USCSB. This sustained effort reflects an ongoing de-emphasis on chemical safety – as a second example, Environmental Protection Agency Administrator Scott Pruitt has indefinitely delayed bans on the use of three hazardous chemicals, shown to be toxic to human health.

Chemical production is an essential component of modern society. This does not mean that there is not room to improve practices in manufacturing, storing, and shipping chemicals, and in ensuring the safety of those who work in or live near chemical plants. The vantage of an independent group is crucial for identifying those aspects that can and should be improved.

Defunding the USCSB, which provides this indispensable independent perspective, is likely to hinder efforts to identify the causes of chemical accidents – especially in low-regulation locales. Moreover, it is also likely to worsen our ability to respond in previously unforeseen events, such as the heavy flooding of Harvey, that may be exacerbated by climate change. Finally, it is likely to cost lives in future incidents. ■



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A NEW GENERATION GETS AN UP-CLOSE LOOK AT THE OIL AND GAS INDUSTRY

MARCO AVENDANO

Petroleum Engineering Senior, University of Houston

NAPE claims to be the upstream industry's largest marketplace. A few days at the 2018 NAPE Summit earlier this month – the 25th anniversary of the event – suggests that is true.

Attracting over 12,275 oil and gas professionals from all over the world, the summit offered countless opportunities for networking and business deals. The organization's website describes the event as "the oil and gas industry's marketplace for the buying, selling, trading and producing properties."

And the action on the summit floor at Houston's George R. Brown Convention Center certainly seemed to bear that out.

We were invited to be part of this gathering of leaders in the energy industry – four students from the University of Houston's student-run Energy Coalition and one from the student chapter of the American Association of Drilling Engineers, sponsored by Quorum Software, which works with more than 85% of companies in the oil and gas industry.

What we saw gave us a first-hand view of NAPE and its main attractions – exhibits, prospect review, live demonstrations and company presentations.

The summit concluded with an energy market outlook presented by Ryan Sitton of the Texas Railroad Commission, which regulates oil and gas activity in Texas. His bullish forecast ignored concerns about peak demand to predict rising U.S. production to meet growing demand from China, India and other countries.

Strong future growth is important for students planning to enter

the industry. But what else did NAPE offer to students?

The conference kicked off with a job fair, which gave us the chance to interact with professionals from major companies across the industry spectrum, including Chevron, Concho Resources, Oasis Petroleum, IHS Markit and DrillingInfo. The next day we attended the main attraction of the summit, the exhibit. These events included booths of major oil and gas players, as well as Prospect Previews that were showcased all day in the NAPE theaters and live demonstrations in the exhibit floor.

When NAPE claims to be "the largest organization of its kind," we saw why: An oil and gas firm from Peru, a Forbes 500 operator, a major exploration company from Canada and a two-person operation from Texas, all in the same place.

But what really caught our attention – we all are thinking about graduation – was the overall excitement and enthusiasm we saw for the young upcoming generation of students. While anyone studying in an energy-related discipline has heard of the Crew Change, commodity prices have been depressed for most of our college years.

What we heard – including from Olivier Thierry, chief marketing officer of our sponsor, Quorum Software – left us fired up.

Everyone we spoke with emphasized the significance of young professionals to the industry. Thierry emphasized the importance of adapting to new trends not only in the industry, but also in the overall job market. That, he said, can only be achieved with the help of new generations.

Likewise, Aisha Ghuman, marketing director at Quorum, stressed the importance of millennials in the development of all companies.

We also had the chance to interact with other undergraduates from colleges across the country, and we connected over our respective energy initiatives. These interactions and conversations reminded us of the privilege we have in attending a university located in the energy capital of the world. It also strengthened the meaning of UH Energy and the Energy Coalition, which represents more than 5,000 undergraduate and graduate students at UH from a variety of disciplines.

At NAPE, we knew we would encounter multiple opportunities to interact with industry leaders, and in order to make the most of this experience we had to be well prepared.

And we were. We had researched the latest trends and developments in the energy industry in order to better understand and explore the main topics during the exhibit. These trends can especially be exemplified by Quorum Software, who are making big strides in digital transformation. The companies that were present reflected on how the industry is picking up and were there to buy and sell assets. The development of unconventional shale plays as well as new and improved fracturing technologies, in addition to increased renewables, complimented for a great exhibit. We also had researched companies registered for the exhibit and the job fair, allowing us to make the most of our time with industry professionals.

Attending NAPE was a remarkable experience and a unique moment in our college careers, allowing us to network with fellow students, industry leaders and politicians. We now have a better understanding of current trends in the industry and where it is heading.

Our next stop will be the transition to the professional world. ■

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COUNT ON SEA LEVELS TO KEEP RISING FOR A LONG TIME

ROBERT TALBOT

Director, Institute for Climate and Atmospheric Science (ICAS), Earth and Atmospheric Sciences

The world's oceans have been warming for decades. Increasing water temperatures – driven by higher emissions from a variety of greenhouse gases – have caused the oceans to thermally expand. Glaciers and other previously frozen areas are melting, aggravating and accelerating the rise of the ocean surface.

Fossil fuels are a key contributor to the warming, but they are not the only one.

Scientists now track ice across the Arctic and Antarctica, and what they are finding isn't encouraging. Last year was the warmest year ever recorded for the global oceans, a phenomenon linked to a number of potential problems, including damage to important habitats such as coral reefs and risks for certain animal populations. In addition, the Arctic Ocean is expected to be ice-free during the summer within the next 20 years. Rising sea levels are among the most visible signs of climate change, as well as one that will have a dramatic impact on humans.

And it's happening faster along the Gulf Coast – home not only to the nation's fourth-largest city, Houston, but also home to much of the nation's critical energy infrastructure – than anywhere else in the United States, between 5 millimeters and 10 millimeters per year.

Eventually, cities such as Galveston will be underwater, and the rising waters also will impact the Port of Houston's operations in coming decades. This is the largest U.S. port in terms of tonnage handled each year, and the amount is increasing due to enhanced Panama Canal ship traffic.

The same thing is happening along the Florida Keys, where areas are already flooded today. Hurricane Irma facilitated the erosion of beaches and other low-lying areas. Today residents are driving to the local grocery store with many inches of seawater on the roadways in many locations, and although efforts to raise the roads are underway, it won't be cheap.

All of this is just the tip of the iceberg. The worst is yet to come. And the economic impact on the United States could be dramatic. The causes are complex. That means the solutions – and the timeline for any possible recovery – are complex, too.

Fossil fuels are a major contributor to the problem. Carbon dioxide and other greenhouse gases are being added to Earth's atmosphere at alarming rates as the world continues to burn crude oil, coal and natural gas. Indeed, the annual increase in carbon dioxide is at its highest rate ever. That has pushed the Earth out of radiative equilibrium – ideally, the heat coming to Earth from the sun is equal to the amount of heat that returns to space. Because carbon dioxide and other greenhouse gases trap some of the heat that is trying to escape our atmosphere, the radiative equilibrium is out of balance.

But the causes go beyond fossil fuels. Global agriculture is also a growing problematic source of methane and nitrous oxide, two powerful greenhouse gases. The ever-expanding population of Earth will not stop, and these people need to be fed.

And not all greenhouse gases are equal. Methane, for example, is a more potent greenhouse gas than carbon dioxide, but it also degrades in the atmosphere within a decade or so. Cutting methane emissions would, therefore, show results relatively quickly.

Carbon dioxide and nitrous oxide are different, and their warming effects will remain intact for future generations. This is because they are essentially chemically unreactive in the troposphere, or the lowest part of Earth's atmosphere, where we live. Moreover, carbon dioxide is most soluble in cold oceanic waters, which are diminishing. Warmer ocean waters means the oceans can absorb less carbon dioxide.

Estimates of this are highly uncertain, but the full warming effect of an emission may not be felt for several decades, if not centuries.

What does this all mean?

Sea levels will likely continue to rise for many centuries into the future. Don't get wet. ■

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DON'T LIKE TRADE DEFICITS? THEN SAY HELLO TO ECONOMIC RECESSION!

ED HIRS

Lecturer, Department of Economics, College of Liberal Arts and Social Sciences

Trade deficits keep your mortgage rates low. Trade deficits help you buy your cars. Trade deficits pushed the U.S. stock and bond markets higher until the recent call for increased tariffs on aluminum and steel slammed markets.

The Trump administration claims that these tariffs are to protect American jobs and to benefit national security. This is backwards. Our trading partners are our leading investors, and trade deficits keep the U.S. out of war.

The world economy is a network of flows — capital, goods and services going from one trading partner to another to another. Disrupting these flows will have consequences that many Americans do not readily see.

In 2017 the U.S. trade deficit was \$566 billion, which means that we spent more on foreign goods and services than our trading partners spent with us. It also means that we can afford to make the purchases. But where did that \$566 billion in dollars go once it was abroad? The answer is that for it to be valuable to the recipient — think China, Russia, South Korea and other large trading partners — those dollars were exchanged for other currencies. Larger trade deficits mean more dollars abroad, which will drive down the value of the dollar making our goods more competitive abroad.

If left alone over time, trade deficits can be self-correcting as the value of the dollar falls. But our trading partners and currency traders do not want to hold a depreciating asset. They ultimately exchange these dollars by purchasing U.S. real estate, stocks and bonds.

The U.S. Treasury estimates that foreign investors hold more than \$18.4 trillion in U.S. stocks and bonds alone.

The world's largest issuer of securities is the United States, and we will soon have \$21 trillion in debt outstanding. As of November 2017, our trading partners held \$6.3 trillion of that debt. Without our trading partners supporting federal deficit spending, interest rates and the cost of borrowing in the U.S. will rise. Sales of homes and cars will plummet as interest rates rise across the board.

If the foreign investors exit U.S. stocks and bonds, the additional carnage will be legion as all asset prices will begin to fall. Imagine the Dow Jones Industrial Average falling below 10,000.

No one argues that the U.S. has a level playing field with our trading partners. Incremental gains from renegotiated trade deals can be realized and can be pursued. But the broad, sweeping unilateral imposition of tariffs by the U.S. will hurt us even more than it will hurt our trading partners.

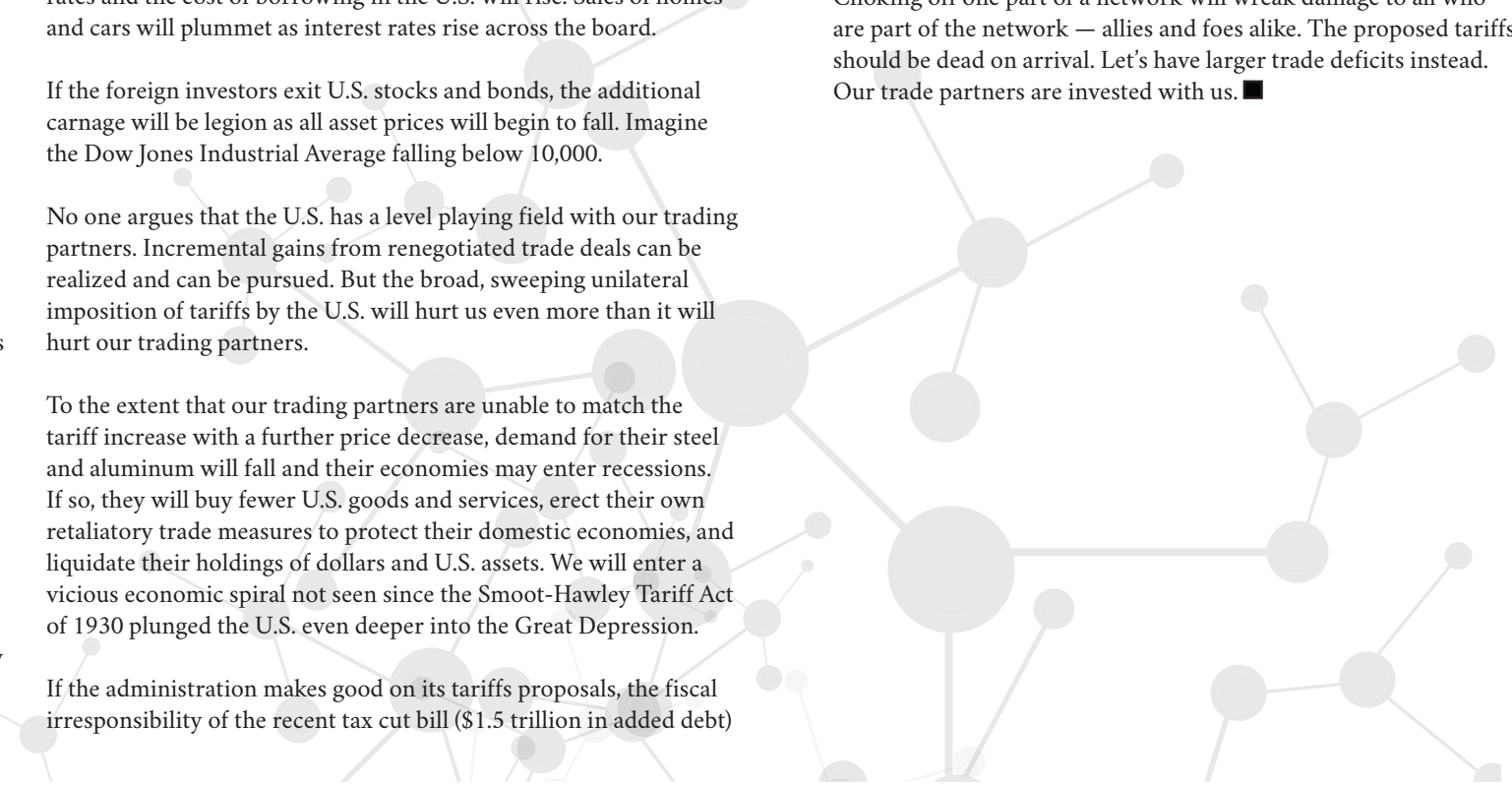
To the extent that our trading partners are unable to match the tariff increase with a further price decrease, demand for their steel and aluminum will fall and their economies may enter recessions. If so, they will buy fewer U.S. goods and services, erect their own retaliatory trade measures to protect their domestic economies, and liquidate their holdings of dollars and U.S. assets. We will enter a vicious economic spiral not seen since the Smoot-Hawley Tariff Act of 1930 plunged the U.S. even deeper into the Great Depression.

If the administration makes good on its tariffs proposals, the fiscal irresponsibility of the recent tax cut bill (\$1.5 trillion in added debt)

and the recent spending bill (which added \$500 billion more in debt) will come home to roost during the current administration with increased interest rates, increased unemployment and a staggering recession.

The administration argues that the new proposed tariffs are also for national security. Strategically speaking, which one of our trading partners would attack the U.S. while owning trillions of dollars of U.S. real estate, stocks and bonds? That these partners have found investment opportunities in the U.S. that dominate what they could earn in their own economies means that they are invested in the future of America. Even if we pick one aggressor who is not invested in U.S., its trading partners certainly are. It is a networked world economy. Having more foreign investments in the U.S. should lessen the risks of war.

The administration's cable news presentations of soup cans do not change economic history and cannot change economic realities. Choking off one part of a network will wreak damage to all who are part of the network — allies and foes alike. The proposed tariffs should be dead on arrival. Let's have larger trade deficits instead. Our trade partners are invested with us. ■



PLASTICS RECYCLING: COULD THE FUTURE BE IN INDIA?

RAMANAN KRISHNAMOORTI

Chief Energy Officer, University of Houston

On a recent visit to India, I made two striking observations: First, in the smaller cities and on national highways, plastic bags were everywhere. Plastic pollution was rampant. Second, even as the Indian government's pro-growth policy calls for the increased use of plastics – plastics are, in effect, a proxy for economic growth – the country's plastics recycling industry is booming, spread across an informal amalgam of street pickers, small start-ups and non-governmental entities focused on the secondary use economy.

India isn't alone in its efforts to deal with plastic waste. About 75 percent of plastic waste in the U.S. ends up in landfills, and less than 10% is successfully recycled. (Most of the rest is combusted for energy.)

Plastics are lightweight, versatile and durable but in spite of their ubiquitous presence and critical role in many of our technological advancements – from automobiles and computers to replacement heart valves – they are now seen as a challenge to animals, marine life and future generations of humans.

Recent reports of plastics and microplastics pollution in every remote corner of the oceans has raised public awareness of the challenges posed by our increased use of synthetic plastics. In some cases this has raised the call for more biodegradable plastics to replace synthetic plastics. However, a UN report in 2016 indicated that biodegradable plastics are not the panacea for the marine challenge of plastic litter in the ocean. Even so, biodegradable plastics and those that are easier to recycle or repurpose will be important for reducing other waste streams, and science has responded.

A number of researchers are working on the problem. From the other end, a growing number of cities in the U.S. and Europe have banned single-use plastic bags. India, too, is struggling to deal with these ubiquitous carry-alls.

Some cities and regions of India have banned these ultra-thin bags – which are made of polyethylene, a non-biodegradable petrochemical product – and metropolitan areas and both some state and the national governments are focused on the difficult task of enforcing the bans.

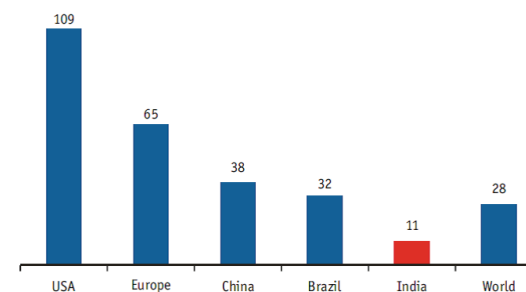
India's informal plastics recycling economy has instead focused on the more lucrative water and shampoo bottles, which are easier to gather and process and are far more lucrative than the lightweight bags. But the country also has spawned some of the most creative thinking about how to deal with this thorny issue.

And all of those efforts come amidst a government push to actually increase the amount of plastics in Indian society.

The average Indian uses approximately 25 pounds of plastics each year, about a tenth of what an average American uses. The Indian government has set the goal of doubling the per capita plastics consumption by 2022, presumably a surrogate measure for economic advancement and increased advanced manufacturing.

More plastic represents more wealth.

Figure 1 Per capita plastic products consumption (Kg/person)



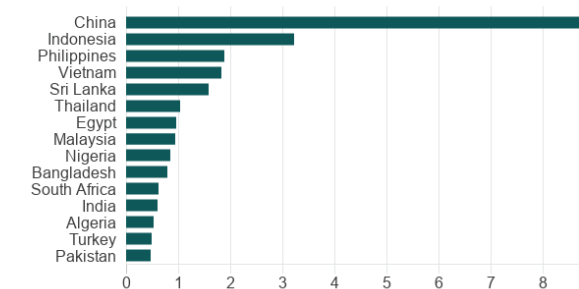
Source: AIPMA and Plastindia, TATA Strategic Analysis

Recent estimates predict a 10% compound annual growth rate (CAGR) in plastics consumption over the next five years, reflecting a similar growth in the preceding five years. On the other, the local governments are responding to public outrage, including with the banning of plastic bags including ultra-thin bags of polyethylene and Styrofoam-based products. The national government is also considering banning polyvinyl chloride, or PVC, a plastic used in infrastructure building that, when improperly disposed of, leads to the release of toxic compounds into the environment.

That's just one example of why India has long been called the land of contradictions. The country's love-hate relationship with all things plastics is no different.

Which countries produce the most plastic waste?

Top 15 countries worldwide that mismanaged plastic waste in 2010 (million metric tonnes)



Source: sciencemag.org

The street picker-based recycling economy, along with the various bans, have ensured India's continued efforts in battling plastic pollution. At the other end of the spectrum, the country is home to some of the most innovative thinking about plastics recycling. Clearly the economic and developmental goals of India, if not the world, require a fresh approach to changing the story of plastics.

That approach might be found here. Banyan Nation, a plastics recycling start-up from the Indian city of Hyderabad, stunned the world by winning the Dell People's Choice Award for Circular Economy Entrepreneur as part of the Circulars Awards at the World Economic Forum in Davos.

The five-year-old company is known for its work with Tata Motors in recycling automotive bumpers and for working with the French cosmetics company L'Oréal to recycle shampoo bottles. But its true innovation lies in its efforts to address the three key challenges in plastics recycling in countries like India – addressing the "last-mile" of the waste through a digital network; developing a strategy for cleaning and sorting the plastic waste economically to ensure creation of a secondary-use pellet that was comparable to primary plastic; and lastly partnership with large state-wide entities and multi-national corporations towards the waste-to-product recycling for e-waste, automobile parts and consumer products packaging.

Such a systems level approach is perhaps the only way we are going to address the challenge of plastics pollution and ensure their continued use to fuel life-changing innovation across the world. ■

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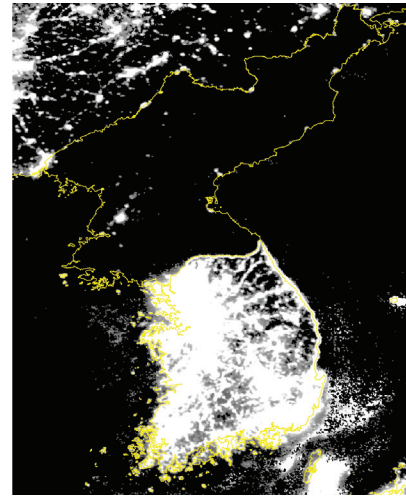
EYES IN THE SKY OFFER A DRAMATIC PICTURE OF ENERGY USE

RYAN KENNEDY

Associate Professor, Political Science, College of Liberal Arts and Social Sciences

Some readers will remember the dramatic change that took place with computer access in the 1980s and 1990s. Computers were once large machines, which took entire rooms to themselves and were only available to major corporations, government organizations and universities. This changed dramatically in the 1980s with the introduction of the personal computer. Much smaller machines, still capable of doing advanced computations with what, for the time, was amazing speed.

Today we may be experiencing a similar revolution, but this time with satellites, and this revolution will have important implications for the energy industry. Two interrelated trends are driving this. First, governments and corporations are opening up the data collected from their satellites for public use. One of the most popular examples of this is the Night Lights dataset, provided by the National Oceanic and Atmospheric Administration (NOAA). Originally used to detect cloud cover for military usage, NOAA now makes available a global map of the world as it is lit at night – producing dramatic illustrations of global energy usage, like the map of North and South Korea below.



Source: Provided by Author

The second trend has the potential to be even more disruptive. Much as the microprocessor allowed access to computers for the masses, the development of picosatellites – small, low-cost satellites that could be used for a variety of purposes – have the potential to do the same for satellites. Planet, for example, is a private company that utilizes a chain of satellites constantly orbiting the earth to collect high-resolution pictures of the planet at all times. From this information, they design computer algorithms to monitor supply chains, natural disasters and a variety of other metrics that may interest other companies. Everyone from NASA to SpaceX is now trying to encourage the development and deployment of smaller and smaller satellites that can do everything from monitoring pollution to creating an artificial meteor shower.

The explosion of satellite data has large potential impacts on research and policy in the energy arena. Eugenie Dugoua at Columbia University, Johannes Urpelainen at Johns Hopkins University's School of Advanced International Studies and I approached a specific application of this satellite data in our forthcoming article in the International Journal of Remote Sensing. We used the data from the Night Lights dataset to explore the extent to which it could be used to track electrification patterns among villages in rural India. This was the largest attempt to validate the data on a sub-national level, and our results suggested satellite data could be used with reasonable success to track the progress of rural electrification throughout India.

This suggests policymakers can use such data to gain nearer-real-time monitoring of the progress of their policies, without having to wait for the next census.

There were, however, some caveats. First, we noticed that the capability of the satellite data to capture the development of rural electrification was conditioned on the methods used for analysis. In particular, the performance depended greatly on how good the available geographic information was for the actual shape of the village. Second, we noted that the capability of the satellite data to detect electrification was conditioned on the steadiness of the regional electricity supply. This suggests satellite data works better in areas that are more developed and have access to high quality connections. Finally, even though some scholars have used Night Lights to detect the level of economic development for regions, we find that it is not a very strong indicator in rural India, where the government has made a strong push to electrify poorer villages.

All of these findings suggest some areas about which policymakers and corporations need to be aware for the upcoming satellite revolution. While satellite data can do a lot for us, the ability to develop good proxies for events on the ground still depends on our ability to directly capture the relevant comparison information. Satellite data may not replace traditional monitoring, but it will likely provide a way to get data more quickly and cheaply between traditional data gathering periods.

It also provides a warning about the limitations of satellite data collection. Careful validation is crucial for understanding what the

satellites are actually capturing with their images and making sure the data means what we think it does.

Much like the hype about “Big Data,” managers should beware of latching onto this data before its utility has been established.

We must also be aware of the context around the data collected. As we found, policies intended to electrify poorer villages undermined the ability for us to use the satellite data for measuring economic wellbeing, since some villages gained electricity access exactly because they were underprivileged. As with any data source, we need to have a clear understanding of the process that generates the data we observe.

We are moving into a potentially revolutionary era when it comes to the accessibility of data from satellites. With careful study and evaluation, this data can greatly assist corporations and governments as we attempt to pursue policy goals and monitor how our world works. ■

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AMNESTY AND NEW VIOLENCE IN THE NIGER DELTA

REBECCA GOLDEN-TIMSAR

Associate Director, Global Energy, Development & Sustainability (GEDS)

Hoping to quell a violent insurgency aimed at the Nigerian government and the oil industry in the Niger Delta, the Nigerian presidency implemented an unconditional amnesty in 2009, offering a clean slate to militants whose demands for resource control, environmental justice and sustainable socioeconomic development had resulted in massive regional disruption.

I have been conducting research in the Niger Delta for the past 20 years, and my latest trip there in early 2018 found ample evidence that the amnesty hasn't worked as planned. The negotiated amnesty and resulting fragile peace are primed for collapse, while crime and oil theft remain serious problems.

Then-President Umaru Musa Yar'Adua introduced the Presidential Amnesty Program, (PAP) or the Niger Delta Amnesty Program (NDAP), as a disarmament, demobilization and reintegration program to answer to the increasing violence throughout the prior decade, which intensified after Ogoni environmental rights' activist Ken Saro Wiwa was executed by a military tribunal in 1995.

The amnesty was originally designed to last only five years, but it remains in effect.

In the 18 months leading up to the 2009 amnesty deal, world crude oil prices topped \$145 per barrel while the insurgency compromised Nigeria's production capacity by 900,000 barrels per day (about 30% in 2007), which dramatically impacted the national treasury. Although the amnesty precipitated a cessation of hostilities against the federal government and the oil industry, the results are fraught with the makings of new violence.

Approximately 30,000 people in the Niger Delta enrolled in the PAP as ex-militants. However, only 2,700 weapons were surrendered. Some militants, fearing the program and its potential repercussions, abstained from participating. I found three potentially explosive problems with the amnesty as it relates directly to reintegration of ex-combatants: reinforcement of militant hierarchies and commodification of violence; substitution of militancy for criminality and ongoing communal tensions; and professionalization of illegal oil lifting of Nigeria's current production.

Reinforcement of militant structures and organizations

Under the agreement, former combatants were promised monthly stipends and job training. But the payment system is hampered with challenges. The extended duration of the payments – almost 10 years – and the methods by which they are distributed reinforce militant hierarchies rather than dismantling them and helping to reintegrate the former militants into society. At the outset, the federal government of Nigeria reportedly made lump sum payments to ex-commanders, who were charged with distributing the cash to their ex-combatants. This system was challenged in 2015 by mid-level commanders claiming corruption in the payment system and in the granting of large pipeline security contracts to top commanders, with little trickle-down effect.

A new system was devised to directly deposit the payments to the former combatants' bank accounts. But this was also challenged by the ex-militants, who accused commanders and the banks charged with the distribution of collusion and shortchanging payments. The lump sum cash payment system was resumed in 2017.

This is problematic on several levels. First, paying ex-commanders directly maintains fighting organizations and power structures. The continued amnesty payments reinforce patronage networks. They also create vehicles for political power and political violence for the 2019 presidential elections.

Finally, the stipends have morphed into a cash-for-peace system that is not sustainable, turning violence into a commodity.

Exchanging militancy for criminal behavior and community tensions

The top-down cash distribution creates and re-creates potential rivalries through discretionary and often opaque cash disbursements. By bolstering ex-commanders' control, the former fighting organizations are re-created and able to leverage their power over the government.

This has resulted in fresh threats and eventual attacks on the military, oil installations and hostage taking, with direct consequences on oil production at a time when lower oil prices have already affected Nigerian coffers.

When stipends were not paid for several months in 2016, ex-combatants quickly slipped into old patterns of resistance as 'new' groups that emerged. The Niger Delta Avengers, Red Scorpions and the Niger Delta Greenland Justice Movement all rose in 2016, attacking the Forcados pipeline installations in the western Niger Delta, causing national production to plummet to a 30-year low at 1.1 million barrels per day. After payments in arrears were made, these groups fell somewhat silent again.

Further, because of the relatively significant amount of monthly individual stipend, ex-combatants are discouraged from getting a job, which even for professionals, generally pays less than the amnesty stipend of 65,000 Naira per month, equivalent to about \$180 in U.S. dollars. An average schoolteacher in Nigeria earns 18,000 Naira, or about \$50. The sizeable stipends, coupled with limited access to and availability of skills training under the amnesty agreement, the lack of fundamental improvements in regional socioeconomic development and increasing small arms circulation, only serve to sustain the fighting frameworks and

capabilities to strike. Consequently, concepts of the marginalized warrior identity, fundamental to the protracted violence, are also sustained. Because there haven't been sufficient sustained reintegration efforts in the way of training and job creation, there is an increasing perception of criminality in the Niger Delta, and particularly in the oil capital, Port Harcourt. Reports of the kidnapping of prominent locals and their family members abound, as do reports of increased armed robbery. Additionally, former combatants continue to turn to gang (known as cults or campus cult organizations) membership, creating altered if not new layers of communal rivalries as these gangs battle for turf.

Further, the amnesty program's lack of full participation from some commanders and their militants, along with the limited surrendering of weapons, generates additional communal rivalries and violent clashes, both between and within militant and gang hierarchies.

Illegal oil lifting

Finally, illegal oil lifting (known as bunkering) has been increasingly professionalized and militarized: there are organized underground labor unions for both crude and refined products; there are well-defined levels of investment for buy-in for the lifting and marine transport activities from the pipeline tappers, pumpers and speedboat drivers to offshore tankers, captains and document forgers; there are set payoff calculations for the players including the Nigerian military's joint task force; and security details for each phase of the operation. Current bunkering estimates range from 10% to 15%, or a minimum of 200,000 barrels per day (roughly the total production of Trinidad) out of the official production rate of just over 2 million barrels per day in early 2018.

Despite the decreased hostilities ushered in by the amnesty, Niger Deltans report that since the inception of the amnesty, the federal government's military presence has broadened rather than diminished. They blame the military and the politicians that control it for the majority of the bunkering activities and for generating the conditions for the current reciprocal racketeering. The outcome of the military presence, the ongoing militant hierarchies and poverty serve to maintain a social disorder and a security economy-potent ingredients for petrol violence anew. ■

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RENEWABLE ENERGY SUBSIDIES – YES OR NO?

WILLIAM MALONEY

Director, Trident Energy; Energy Advisor, Warburg Pincus; and Energy Advisory Board Member

A panel of experts convened in front of a live audience at the University of Houston recently to discuss one of the key energy issues of our time – should government subsidies for renewable energy continue?

It's not a simple question, and finding the right answer requires an understanding of global needs and policies, as well as some hard decisions.

Today 80% of the energy we use globally is sourced from hydrocarbons (oil, natural gas and coal), and 20% comes from renewables and nuclear. There are many hypotheses about the future energy mix. One possibility is that in 2040, 60% of the world's energy will come from hydrocarbons, with natural gas making up the largest percentage of that, while 40% will come from renewables and nuclear, with most of that in the form of wind and solar energy.

In 2017 in the United States, wind and solar represented almost half of new electricity generation capacity.

Meanwhile, total energy usage is predicted to rise between 25% and 35% by 2040 due to increasing population and higher global GDP. So the projections are that in the future, we will use more energy, and a larger share of that energy will be from renewable sources. We are already seeing an increase in the usage of renewables, especially to generate electricity.

What about energy subsidies? If you look at the top six countries that subsidize energy, the total spent on subsidies is greater than \$40 billion each year.

In the U.S. alone in 2016, \$18.4 billion was spent on energy subsidies; \$11 billion of that went to renewable energy and \$3 billion to energy efficiency.

I served as moderator for the panel discussion that night in Houston, as speakers considered subsidies in the context of everything from the free market to health impacts related to fossil fuels. The speakers included Katie Tubb, policy analyst for Energy and Environmental Issues in the Thomas A. Roe Institute for Economic Policy Studies at the Heritage Foundation; Richard Heinberg, senior fellow at the Post Carbon Institute in Oregon; Michael Skelly, founder and president of Clean Line Energy; and Dev Millstein, a research scientist at the Lawrence Berkeley National Laboratory.

A study by the University of Texas projected that U.S. energy subsidies per megawatt hour in 2019 would be \$0.5 for coal, \$1- \$2 for oil and natural gas, \$15- \$57 for wind and \$43- \$320 for solar. Many of the renewable energy subsidies come in the form of a Production Tax Credit (PTC) of 2.3 cents per kilowatt hour. Wholesale prices for electricity in 2017 were between approximately 2.9 cents to 5.6 cents per kilowatt hour. Therefore the wind production tax credit covers 30% to 60% of wholesale electricity prices.

What have those subsidies accomplished? One thing subsidies have done is help bring down the cost curve for wind and solar energy. Today we see dramatically lower costs for both wind and solar. Without subsidies going forward, Skelly believes costs for both wind and solar will be about 3.0 cents per kilowatt hour in the U.S.

But adoption varies across the states. The Texas model of wide-open energy markets since 1999 has led to an integrated marketplace where solar, especially, and natural gas seamlessly provide energy to all Texans. Costs for wind and solar are coming down, and they are competing with traditional forms of energy.

Given that, should subsidies continue? First we need to explore another side to this discussion, and that centers around environmental, social and health factors.

Many believe climate change is one of the most important challenges to humanity this century and that governments have the moral responsibility to provide subsidies for renewable energy in order to increase the rate at which the world transitions to a lower carbon society.

Millstein, the Berkeley National Lab researcher, has tried to quantify the impact of pollution from carbon sources of energy. Basically, he has reported, more pollution equals more deaths – his research found that 7,000 deaths could have been avoided over a 10-year period through the increased use of wind and solar.

Millstein looked at this another way using data from 2015. His conclusion was that each kilowatt hour of wind generated 7.3 cents worth of air quality and climate benefits. Further, each kilowatt hour of solar generated 4.0 cents of air quality and climate benefits.

I think there are large uncertainties in these estimates, but at least it is a way of trying to quantify the impact. Therefore, given the production tax credit is 2.3 cents per kilowatt hour, should we keep subsidies going because of the implied benefits? A long-used policy idea says that if you want to slow or stop the use of something, simply put a tax on it. You can look to cigarettes as an example. Well, what about carbon? If you concur with Millstein that there is a direct link between pollution and health risks, why not put a tax on carbon?

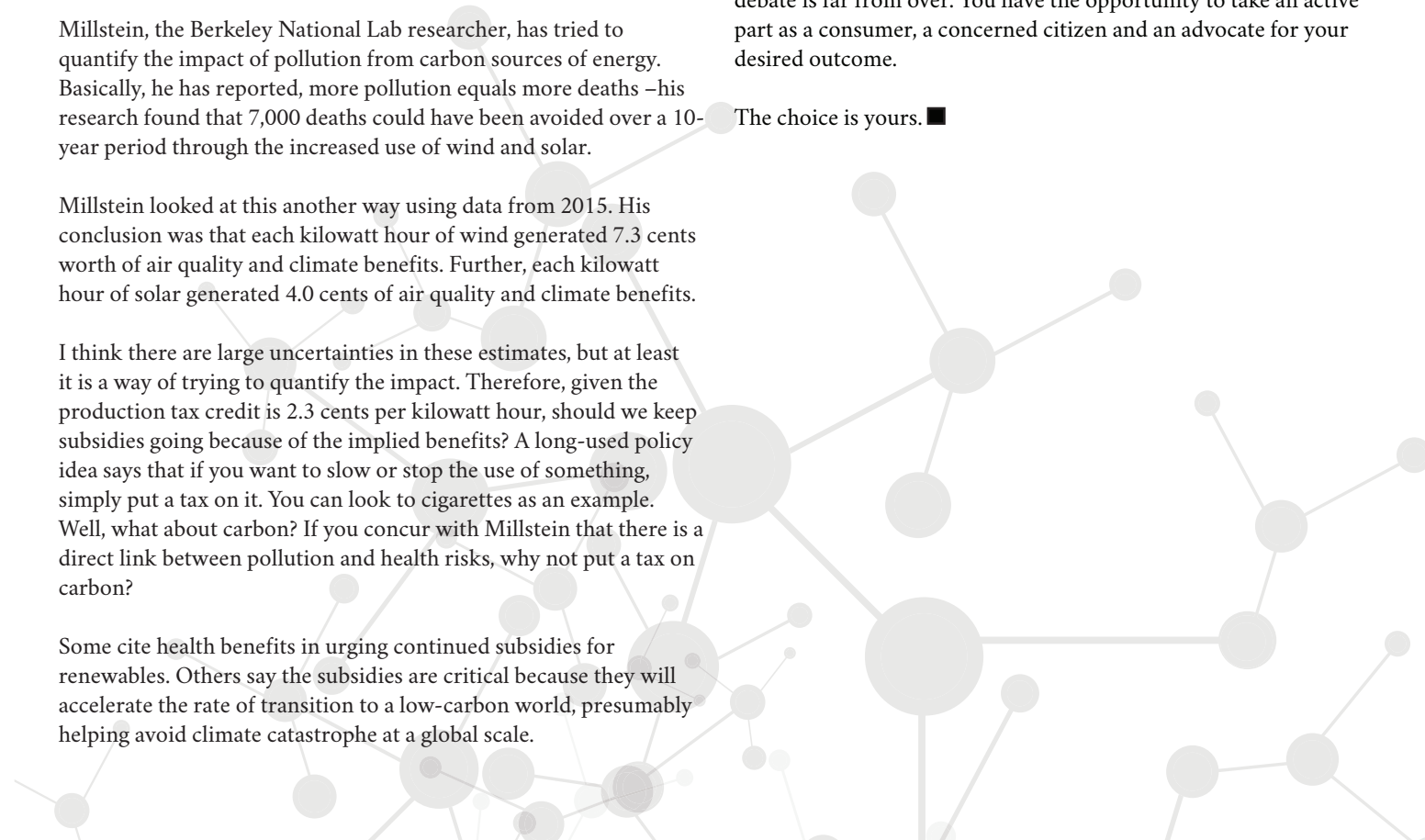
Some cite health benefits in urging continued subsidies for renewables. Others say the subsidies are critical because they will accelerate the rate of transition to a low-carbon world, presumably helping avoid climate catastrophe at a global scale.

But others say, No. Get rid of subsidies. They argue the costs of wind and solar have been reduced to a point where they are competitive with traditional sources of energy, at least for electricity, so let the markets rule.

Panelists beyond Millstein provided data and their own views on the subject of renewable subsidies. (You can watch a video of the discussion here.) What is your view? No matter what side of this discussion you find yourself on, it is important to be informed, seek multiple opinions, search for facts and be an active citizen in this debate. Hopefully this panel discussion helped in that regard.

Today around the world energy systems are becoming more and more distributed giving each of us as consumers more power. As a collective body can we impact change around the world? This debate is far from over. You have the opportunity to take an active part as a consumer, a concerned citizen and an advocate for your desired outcome.

The choice is yours. ■



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FEWER PROTECTIONS FOR ABANDONED OFFSHORE OIL PRODUCTION PLATFORMS WILL BE RISKY

TOM MITRO

Co-Director, Global Energy, Development and Sustainability (GEDS)

The oil and gas industry is all about managing big risks – dry holes, wildly fluctuating oil prices and cost overruns. Oil companies and investors bear the brunt or enjoy the benefits of their decisions when those risks go badly or go well.

But one risk more directly affects the public: the risk of leaks and explosions. The Trump Administration's Interior Department recently overturned and weakened existing rules that required companies producing offshore to provide formal financial assurances that they will appropriately decommission and abandon their offshore structures and restore the area once production ends.

That is out of step with the rest of the world. And it could lead to serious trouble.

Following sound decommissioning and abandonment practices means that companies must plug the wellbores, “tie-off” wellheads, drain pipelines and storage tanks of toxic chemicals or petroleum products, and partially or fully dismantle the production platforms and clear them from shipping lanes. Otherwise, the abandoned facilities are at greater risk of leaks, explosions and shipping accidents. Consequently, bodies such as the International Maritime Organization and the U.N. Law of the Sea have established standards and guidelines for how such work should be carried out.

The problem is that the costs of this clean-up work are incurred after production and revenue have ceased – no funds are available to pay for it at that time.

The overturned U.S. Department of Interior regulations (NTL No 2008-N07) required companies to provide clear financial assurance that funds would be provided for this work by posting a financial bond, taking out an insurance policy, issuing a third-party guarantee or arranging a letter of credit with a financial institution that the government could call on if the company did not follow through. There was very little leeway in these requirements.

Why was this even necessary you might ask? We tend to think of oil companies as financial behemoths with annual revenues greater than the GDPs of most countries. But most of the well-known, financially secure oil majors end up selling off their aging properties to small independents who are specialists in cheaply extracting the last bit of oil from the reservoirs. These smaller operators do not have deep pockets and often carry heavy debt loads; because of their more precarious financial conditions, they are at a much higher risk (there is that “risk” word again) of renegeing on their obligations, including the obligation to properly decommission and abandon their aged facilities.

Were the previous requirements just another example of government overreach that damaged U.S. competitiveness in petroleum as claimed by Interior Secretary Ryan Zinke? Based on commercial considerations and international comparisons, the answer would appear to be, No.

Whenever large oil companies sell off their declining properties, they agree on a sales price that roughly compensates them for the remaining net value they are giving up. The final price negotiated is full discounted/reduced to account for the expected future costs of restoration and abandonment. In other words, the small

independents acquired the declining properties at a discount for that very reason so they would have fully anticipated and been already “compensated” via a lower purchase price, in exchange for bearing future decommissioning costs.

Standard global government regulations and agreements require companies to provide some financial assurances that cover the cost of abandonment of their properties. The exact nature of the arrangements varies; most methods entail some degree of judgement and valuation of the remaining reserves.

In Angola for example, where I was involved in negotiating many of the details, government rules go beyond a bond or insurance policy and require that companies pre-fund decommissioning costs in cash over time into a trust account.

In the United Kingdom, the government has the power to block the sale of an offshore property if the buyer does not put in place adequate decommissioning security. The U.K. government also can, in certain circumstances, hold financially accountable companies that no longer hold an interest in the property if their successors default. From personal experience, decommissioning funding obligations are a critical part of the negotiation of any sale of assets in the North Sea.

The State of Texas Railroad Commission, as the oil industry regulator for state coastal waters, requires financial securities be posted under its Rule §3.78.

And since 1977 the Securities and Exchange Commission has required oil companies to record and disclose in public financial reporting their estimated pro rata liability for future decommissioning and abandonment costs. (I was a part of the original implementation design team for a major oil company at that time.) As one example, Chevron had by the end of 2016 recorded a \$14 billion liability for its share of such costs globally. Decommissioning is a significant obligation, widely recognized around the world as requiring advance financial assurances and disclosures. The previous U.S. rules were in line with worldwide practice.

The new regulations (NTL No. 2016-N01) do away with the rigid requirements and in their place grant the Interior Department's Bureau of Ocean Energy Management (BOEM) significant discretion as to whether security is required and if so, how much, based on fairly subjective criteria such as the company's trade references and projected business stability, past financial health, projections of future cash flow and past reliability.

On the surface, this sounds like a pragmatic and flexible business approach. But the reality is that oil markets change quickly and what may look like a financially sound company in a time of high prices can quickly become one in immediate danger of default within a few months of a price downturn. These new rules will place the BOEM regional director in the untenable position of having to immediately impose sweeping additional financial security requirements at the very time when companies are most likely to be abandoning uneconomic properties and can least afford the decommissioning.

This is kind of like waiting until you have become terminally ill to take out medical and life insurance. The increased discretion will place tremendous political pressure on the BOEM to grant waivers and exceptions – a potentially dangerous and reckless approach.

So why do the smaller companies object? Larger, more financially secure companies enjoy higher credit ratings (BBB to A) that permit them to provide a parent company guarantee or obtain credit assurance from an independent financial institution at relatively low cost. But many of the smaller independents operate with much greater debt relative to the value of their assets and have only a handful of income-producing properties to buffer the impact of large obligations.

A financial institution will charge bigger fees to guarantee the obligations of those deemed to be riskier. Lower-rated B companies' obligations are characterized by ratings agency Standard & Poor's (S&P) as being “more vulnerable to nonpayment, but the obligor currently has the capacity to meet its financial commitment.” S&P goes on to caution that for these companies, “adverse business, financial, or economic conditions will likely impair the capacity or willingness to meet its financial commitments on the obligation.”

Based on historical data compiled by S&P, 20% of all companies rated B will end up defaulting on their obligations within five years. Of those rated slightly worse, at CCC, approximately 40% will default within five years. And in 2016, according to S&P, low oil prices meant the overall oil industry rate of default had increased substantially, to four times its historical average and roughly seven times the general corporate default average. As oil prices drop, past company financial performance, the general standard that BOEM would likely utilize, loses reliability as a predictor of future default risk in the oil industry.

The waters off the U.S. coast are not private property that can be controlled and preserved by individual owners, whose best interests are served by safely dismantling oil equipment after production ends to avoiding leaks and damages to their own property. The waters within U.S. maritime borders represent a public resource requiring public oversight.

The question becomes, is the U.S. government and public willing to accept the risk that 20%-40% of financially vulnerable smaller oil companies are likely to default on their obligations to safely decommission and abandon the platforms and pipelines that they operate in public waters in the Gulf of Mexico? Loosening these financial security requirements may end up doing just that. ■

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PRICES ARE UP, BUT CHALLENGES REMAIN FOR OIL AND GAS COMPANIES

CHRIS ROSS

Executive Professor, C.T. Bauer College of Business

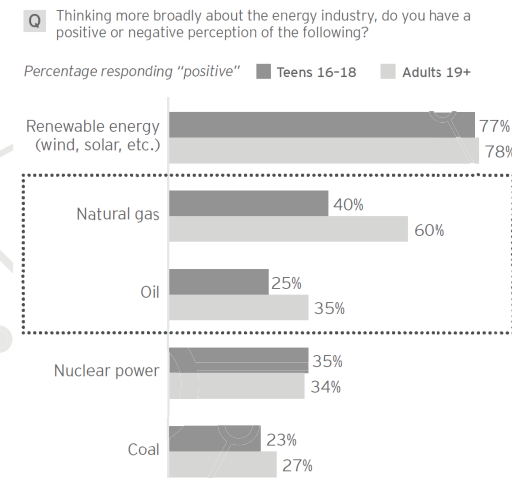
The oil and gas industry appears to have weathered the storm of the 2015 price collapse and has responded with considerable accomplishments. In November 2017, domestic crude oil production reached its highest level in U.S. history. International trade in crude oil and petroleum products is booming with exports of 6.6 million and imports of 10.3 million barrels per day in January 2018. New discoveries of substantial international offshore oil fields are being made.

The U.S. is now a net exporter of natural gas, and more natural gas liquefaction plants are planned and under construction. Oil at around \$60 per barrel and gas prices below \$3 per million But are affordable.

Yet the industry faces considerable headwinds from external challenges to its future. They include:

- Continued negative public perceptions of the industry have been exacerbated by fears of its contributions to greenhouse gas emissions and global warming. Natural gas is less unpopular than oil, according to research conducted by EY, but renewables are overwhelmingly preferred by adults and teens alike.
- The emergence of battery electric vehicles (BEVs) as viable, albeit expensive competitors to internal combustion engines has been abetted by remarkable improvements in battery performance. Batteries could also resolve issues deriving from the intermittency of wind and solar power generation.
- Decarbonization policies – either mandates and subsidies for renewables, cap-and-trade or a carbon tax -- could help close the gap between the cost of renewable power and the cost of power from natural gas.
- Geopolitics seem unusually fragile today, and wars are raging close to major oil and gas resources.
- Though some oil companies are hoping for stronger prices, there is a genuine risk that another oil crisis might initiate a “three strikes and you’re out” cycle, as high oil prices spur increased investment and innovation in batteries and renewables.

Oil and gas compared with other sectors



Source: Provided by Author

Negative perceptions lead to legal challenges. States, cities and investor groups are suing large oil companies for marketing products that, when burned, release greenhouse gases with potential adverse consequences to their citizens. Environmental non-governmental organizations have expanded their missions from “beyond coal” to “beyond fossil fuels,” and are organizing to impede infrastructure projects with the intent to limit oil and gas producers’ access to markets. Politicians curry favor by withholding required permits.

End Use Technologies, particularly in battery science, have allowed Tesla and conventional auto manufacturers to develop battery electric vehicles that match or exceed the performance and customer satisfaction of vehicles with internal combustion engines. Battery electric vehicles have zero emissions while driving and can help limit smog formation in cities. Norway and the Netherlands plan to phase out registration of all fossil fuel powered automobiles by 2025. The UK and France plan to halt sales of new oil-fueled cars by 2040. Tesla provided an enormous battery power pack to South Australia to complement intermittent solar power and match the load curve. China is considering when to ban the production and sale of oil-fueled cars by an unspecified date and intends to be the global leader in producing batteries and battery electric vehicles.

Decarbonization policies include mandates and subsidies for renewables as well as cap-and-trade regimes. The latest advance toward a global approach to reduce greenhouse gas emissions was the 2016 Paris Agreement negotiated under the United Nations Framework Convention on Climate Change, whose aim is to “strengthen the global response to the threat of climate change by keeping a global temperature rise this century well below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius.”

Additionally, the agreement aims to strengthen the ability of countries to deal with the impacts of climate change. It requires all parties to put forward their best efforts through “nationally determined contributions” (NDCs) and to strengthen these efforts in the years ahead. This includes requirements that all parties report regularly on their emissions and on their implementation

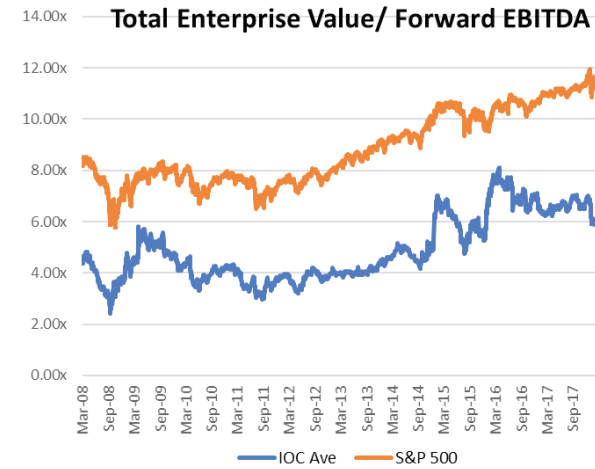
efforts. 175 countries ratified the agreement, though many of them committed to goals that were relatively easy to accomplish. The U.S. committed to stretch goals but has withdrawn from the agreement.

Geopolitics appear particularly fragile as the U.S. seems to have abdicated the “Pax Americana” role that has helped stabilize international relations since 1945. In the absence of this stabilizing force, two dystopias appear to have filled the vacuum:

- Russia, Iran and the Middle East seem to have adopted the mores of continuous border skirmishes laid out by George Orwell in his iconic novel
- China resembles more a society where loss of freedom and individuality is deemed a small price to pay for stability, as in Aldous Huxley’s novel Brave New World.

Neither of these dystopias are likely to appeal to citizens in the way that the capitalist democracy model adopted by members of the Organisation for Economic Cooperation and Development after the Second World War became aspirational for developing countries. However, both dystopias appeal to putative dictators, and they are extending their reach into resource rich failed states: China through its “one belt, one road” initiative to restore the ancient Silk Road trading route and control the South China Sea as well as infrastructure investments in Venezuela and Africa; Russia by threatening its “near abroad” (newly independent republics which emerged after the dissolution of the Soviet Union) and, with Iran, gaining control of Syria and Lebanon. Russia’s ability to sustain border skirmishes would be lessened by low oil and gas prices; China’s anxiety over energy supply security would be mitigated by ample supplies and low prices.

Three Strikes in baseball and you are out. A third oil price run-up as in the 1970s and the 2000s could transform the oil industry’s headwinds into a full gale, amplifying negative perceptions of the oil industry, encouraging development of substitutes for oil, solidifying international commitments to decarbonization and exacerbating competition for control of resources.



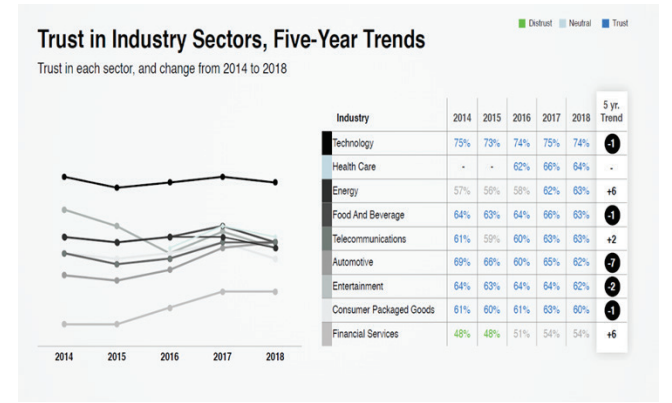
Source: Provided by Author

The Market Speaks

This all sounds bleak and there are certainly risks to oil companies’ future ability to create value for investors. But are they really more severe than in previous times? Is the current conventional wisdom of decarbonization by forcing the adoption of renewable energy a sound economic solution? Will oil and gas companies become obsolete?

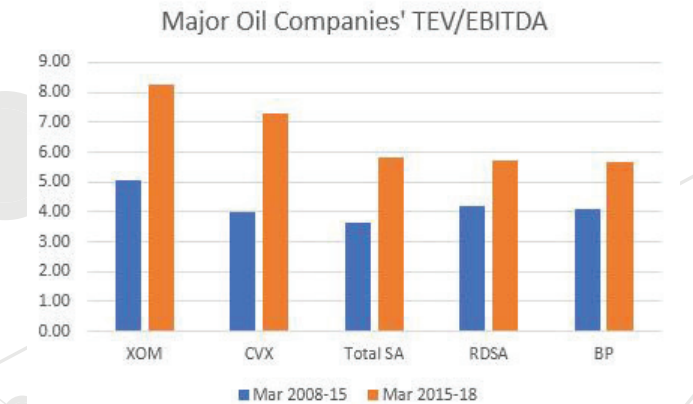
The stock market would appear to say no. The average ratio for the Supermajors (XOM, CVX, RDSA, BP and Total SA) of Total Enterprise Value (TEV) to forward EBITDA, or earnings before interest, taxes, depreciation and amortization, remains below that of the S&P 500 but appears to have found a range higher than most of the period 2008-14, when oil prices were high, implying that the market sees greater potential today for growth or lower risk for the Supermajors. Could it be that they are already taking steps to increase growth and mitigate risks to their future prosperity?

The 2018 Adelman Trust Barometer shows that trust in the energy sector in aggregate has climbed steadily since 2014. This could be because respondents are pleased by growth in renewables but could also reflect satisfaction with lower oil prices from 2015 through 2017 and Supermajors’ acceptance that climate change is happening and greater willingness to debate economic responses.



Source: Provided by Author

All the Supermajors are considering strategic options for scenarios in which battery technology continues to advance and improve the economic competitiveness of battery electric vehicles. Some are making investments in wind and solar power generation. Royal Dutch Shell has gone further than most by investing in electric vehicle recharging facilities and in purposefully shifting its upstream portfolio towards low-carbon natural gas. However, the European majors lag the U.S. majors in TEV/EBITDA suggesting that they face more serious risks than the U.S. majors or that investors are not ready for oil companies to pivot from oil to gas and renewables.



Source: Provided by Author

All the majors recognize that high oil prices would accelerate battery electric penetration of the transportation sector and that ample supplies will lead to lower prices and more economic evolutionary rather than economically disruptive revolutionary change in the transportation sector.

Most of the Supermajors favor a revenue-neutral global tax on greenhouse gas emissions to provide an incentive towards decarbonization, with a border adjustment so that manufacturers aren't encouraged to move their factories to high carbon-emitting countries. Several companies have worked with the Environmental Defense Fund to better understand sources of emissions and develop commitments and a plan to reduce fugitive methane emissions.

Willingness to seek common ground between oil and gas companies and environmental groups in these polarized times could improve public perceptions of the energy sector.

Major oil and gas companies are stressing capital discipline but continue to make impressive new discoveries of substantial offshore oil resources; onshore, they are harnessing the power of big data analytics to increase productivity of wells and personnel and contribute to global supply adequacy with stable oil and gas prices as they did from 1945 (when the U.S. was last the largest international oil producer) through 1970 (when OPEC started flexing its muscles). The industry is vigorously defending legal suits alleging foreknowledge of global warming causes and consequences, is making cautious moves in the renewable power sector and is contributing to the conversation on how to incent decarbonization. If they are successful in developing ample oil supplies, resulting moderate prices should lead to a less favorable cost-benefit equation for the expansionist powers.

By taking these actions and communicating more effectively the value of its work, companies will be better aligned with consumer preferences, may strengthen public trust, realize yet higher TEV/EBITDA ratios and increase shareholder value. ■

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CALLING GENERATION Z: THE ENERGY INDUSTRY REACHES OUT TO ITS FUTURE WORKFORCE

HEATHER DOMJAN

Interim Executive Director, University of Houston STEM Center

The energy industry is engaged in a tug of war – it sees itself as playing a crucial role in helping mankind, while many Americans possess a deep-seated mistrust of oil and gas companies. That's especially true of today's school-age students.

According to Gallup, almost half of Americans (47%) had a negative view of the oil and gas industry in 2015, while just more than one-third (34%) viewed the industry positively. By 2017, the gap had narrowed, but negative opinions still topped positive ratings by 2%.

Public opinion has dampened energy companies' ability to overcome misconceptions and differences in opinion. And young people may be their toughest audience, at a time when the industry is facing a growing demand for new workers.

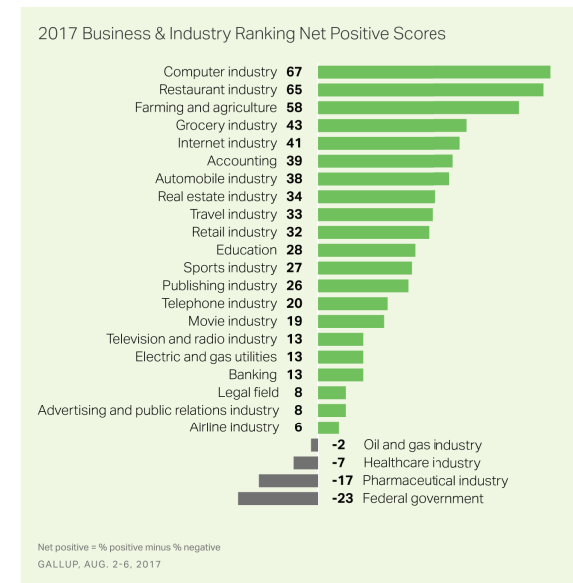
Generation Z's Perception:

Here's the storyline for America's youth:

- Coal was the fuel for their grandparent's lifetime
- Oil and gas was for their parent's generation, and
- Renewable energy is the future.

This should be a wake-up call for the industry, which must make members of Generation Z – definitions vary, but generally those between 2 and 19 – a priority, as these individuals have the ability to shape the future of energy through innovation. The complexity of this task becomes clear when you realize this generation may hold beliefs that are not necessarily substantiated by facts, contributing to the divide between supporters of the oil and natural gas industries and those whose concerns about climate change and the production of fossil fuels push them toward renewable energy.

EY last year surveyed U.S. consumers and energy industry executives about current perceptions of the industry with striking results, especially among teens. Generation Z described the industry as a "problem causer, rather than a problem solver." More than half of teens – 56% -- said the industry isn't worth the damage it causes to the environment.

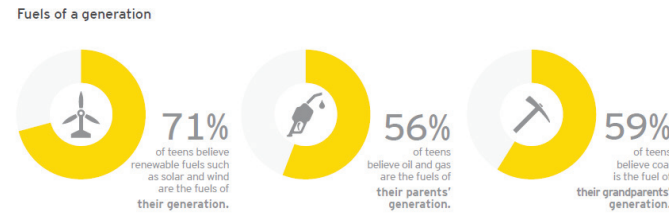


Source: Gallup

Media coverage of oil spills and other accidents become ingrained in the minds of these young people and, over time, they have developed a one-sided mindset.

Teens are digital natives and when only 44% deem the energy industry a leader in technology and 41% consider it “innovative,” clearly there is a disconnect. Only 45% of teens surveyed said the industry is trustworthy.

It is difficult to overcome these negative images, especially when only 35% of teens believe your industry will be important for another century.



Source: Provided by Author

This disdain may originate from embedded misconceptions developed through exposure to various media. Young people want to find solutions to climate change, display responsibility through “green” actions and showcase their consumer power by using the premise of renewable initiatives to speak to government and industry regulations.

But these young people can miss the nuances of an argument. For example, teens often fail to note that although renewable energy is considered “clean” because solar and wind power don’t themselves generate greenhouse gases, it has other drawbacks, including that it is a variable source of energy, available only when the sun shines and the wind blows. Therefore renewable energy currently is usually supplemented with fossil fuels to meet consumer demands.

The insights from the EY survey should capture the industry’s attention, especially considering they are already up against the wall of time, with one-third of the energy workforce at retirement age.

So how can industry overturn this perceptual tide among young people? It has begun to fight back.

Energy Industry Response:

Investing in K-16 students – that is, those from kindergarten through higher education – is vital, but how can oil and gas companies obtain a return on their investment when identifying what action best works can take months or even years?

Even with so many education programs encouraged and funded, in part, by the industry, Generation Z remains skeptical. Time is of the essence for industry to re-evaluate its stance within K-16 education and make a calculated effort to ensure students are exposed to valid points on both sides of the discussion to debunk any falsifications. The industry must step up its efforts to collaborate with educational experts to forge a united front that ensures the message of transformative energy is appropriately delivered.

Social interaction will be key, too, recognizing that Generation Z will be tomorrow’s decision makers about critical energy issues. Students are exposed to many opinions as they surf the web’s turbulent waves, and if the energy industry is to get buy-in, it must continue to be visible. There are options. A massive career awareness media campaign highlighting the variety of jobs within the industry could expose students to the possibilities. When was the last time you saw a commercial about careers in the energy industry?

Oil and gas companies are investing both money and manpower in America’s youth, but will the effort be enough to overcome the views Generation Z currently holds? Oil and gas companies invest in initiatives such as STEM programs and competitions that emphasize science, technology, engineering and math skills, diversity outreach, educator support, career awareness campaigns and community engagement. In Houston, home to dozens of both majors and independent energy firms, and elsewhere, company employees are encouraged to volunteer with schools as mentors and guest speakers. Only time will tell; however, energy industry executives must remain in the game so college-bound students will consider the industry with confidence. ■

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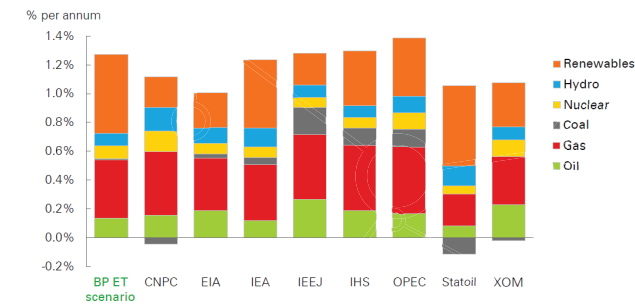
THE COMING DIGITAL REVOLUTION IN ENERGY: PEOPLE, TECHNOLOGY AND DATA

RAMANAN KRISHNAMOORTI

Chief Energy Officer, University of Houston

The data are indisputable: The world will need between 25% and 35% more energy in a little over two decades, primarily due to increased global population and affluence, especially in the non-OECD countries. The increased demand will come in spite of increased efficiency (that is, increased energy intensity per dollar of GDP). Shifts to non-fossil based renewables and other sustainable forms of energy are accelerating, but considering price structure, required capital investments and infrastructure adaptation, fossil energy sources (coal, oil and gas) will continue to grow in absolute terms. And this is borne out in all of the scenarios developed by various global agencies and energy companies.

Figure 1: Contributions to growth of energy consumption, 2016-2040



Source: BP

The energy industry broadly is a technology industry. Reductions in cost of solar and wind derived energy have plummeted in the last decade because of the rapid adoption of technological innovations. The fossil fuel industry, and especially oil and gas, are strongly reliant on technology. The shale phenomenon in the Permian, the Bakken, the Marcellus, the Eagle Ford and elsewhere in the United States is clear evidence of that, allowing those sources to maintain market share. But what the various scenarios don’t capture are the ways in which artificial intelligence and data science have and will continue to transform the energy industry.

Also left unsaid is how we will prepare our future workforce – the schoolchildren of today and tomorrow – to use and advance those tools. Data-driven technological innovations are going to require a different approach and necessitate a re-think on how we develop our workforce.

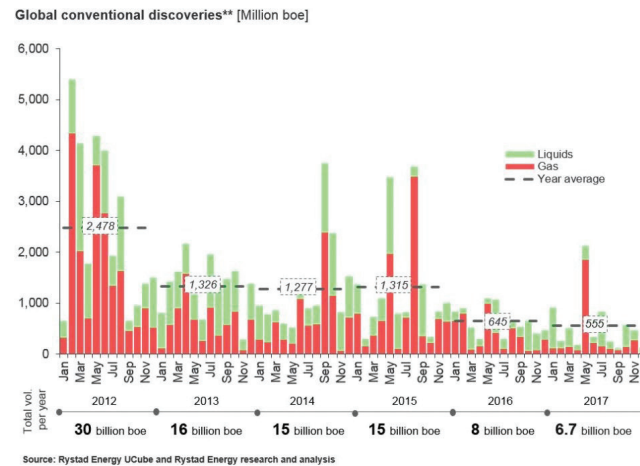
Much of the increased supply of oil and gas in the United States over the last decade, and a significant cause of the overall lowering of the global price of oil, is due to the increased production from unconventional shales in the U.S. These have been largely accomplished by the adoption of key technologies that have leveraged such paradigm shifters as horizontal drilling and hydraulic fracturing. The average cost to lift oil in the U.S. has dropped over 30%.

This focus on technology will grow in the coming decade. First has been the decline in new discoveries for oil over the last decade (Rystad Energy, Figure 2). The last time the reserve replacement ratio (ratio of new reserves to production) reached 100% was 2006. Therefore, in order to achieve the expected energy production

based on demand, which is remarkably similar no matter what particular outlook scenario you consider (Figure 1), the supply will have to come from much more complicated reservoirs, including tight oil and oil sands, and from remote and harsh locations, such as deepwater (Figure 3).

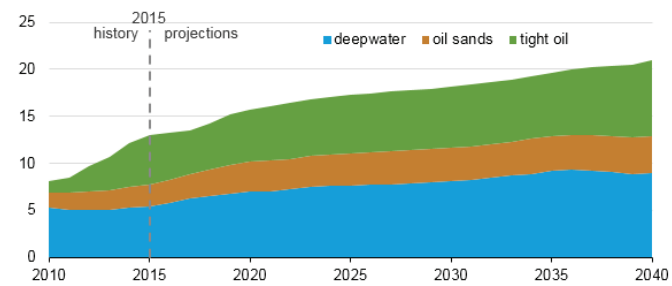
Technology and data science-derived technologies are likely to shape that future.

Figure 2:



Source: Rystad Energy UCube and Rystad Energy Research Analysis

Figure 3: World Oil Production from Oil Sands, Tight Oil, and Offshore Deepwater



Source: U.S. Energy Information Administration

Three key enablers make this the right time to consider the data science-driven transformation of the oil and gas industry.

First is the explosion and socialization of computational power that has continued to progress over the last decade at an unanticipated pace. Second is the confluence of big data sources that are transported and stored – these include the maturing area of “internet of things” (IOT), advancing robotics and process automation, and nascent technologies such as computer vision and speech recognition.

Lastly, the key tools to automate the conversion of big data to smart data including machine learning and cognitive computing are finding broad applicability. New tools such as deep learning, cognitive engagement, augmented and virtual reality are rapidly evolving and will continue to shape the data-driven transformation. Augmented and virtual reality are beginning to be deployed in the training and simulation of safety and hazard training for offshore platforms. Deep learning algorithms are being used to provide automated seismic interpretation and sweet-spot identification.

The increased adoption of data sciences is driven by the need to:

- Automate business processes, thereby improving functionality and increasing efficiency,
- Improve business and technical decision making by deploying and socializing data driven decision making, and
- Improve customer and employee engagement.

And contrary to popular belief, this isn't a way to reduce the engagement of people in growing the business.

While the biggest challenges that have been discussed across a broad range of media platforms address the notion of “intelligence explosion” or conferring machines with more cognitive intelligence than most humans, I strongly believe more pragmatic issues challenge the broad adoption of data sciences in the energy industry. The most important challenge is that of an educated and appropriately trained workforce, far exceeding

practical issues such as standardization, security, reliability, ethics and regulations, although those also certainly need to be addressed.

The glib answer to increase and skill-up the workforce is to address the issue of educating all school-going students with key fundamentals in computer science to complement the 3R's or to encourage programming “boot camps” to retrofit data-related expertise. These are necessary and have already started happening across our educational systems. However, for this transformation to achieve broad societal goals, we need to address data science education broadly across the entire educational system.

One issue is the need to increase diversity – it is stunning to recognize that today women represent just one-sixth of undergraduate computer science majors. That's down from the early 1980s, when 1 in 3 enrollees in computer science were women! Similarly, the participation of Hispanics and African Americans in STEM-related programs are alarmingly low and has not substantially improved over the last two decades. In order to address the strong demand of highly educated individuals in the energy industry, it is increasingly clear that this diverse demographic must be enthused to pursue careers in the energy industry.

For STEM-related higher education, the paradigm must shift to one that encourages collaboration, teamwork and uncertainty and embraces fuzzy complexities rather than the traditional values of competition: individual-focused, single-number answers and strict assumptions. These changes reinforce the role of multidisciplinary problem solving based on critical thinking and effective communication, embodied in the liberal arts and social sciences education for the last 500 years, to address some of the most important real-world challenges facing data sciences and energy.

We have the tools and the intelligence to adapt our education system for the new era of data-driven technologies and artificial intelligence. The next step, which we must take both to meet the energy demands of the future and broader societal needs, will be finding the will to insist that happens. ■

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LNG PROJECTS HAVE STALLED. A NEW BUSINESS MODEL COULD HELP

CHRIS ROSS

Executive Professor, C.T. Bauer College of Business

Liquefied natural gas (LNG) developers and natural gas producers have depended on third parties to create demand for their product. In recent years, LNG market prices have dropped in response to a surge in supplies and roughly two million tons of LNG contracts are set to expire in the next 10 years. Promising new LNG projects cannot be financed and have stalled.

Developers need to do more to encourage end users – including industrial users and electric generation facilities – to switch from diesel and other liquid fuels to LNG. A new business model could help. We propose a broad collaborative, including natural gas producers, pipeline companies, Engineering, Procurement and Construction (EPC) companies, equipment manufacturers and end users to accelerate market growth.

The International Energy Agency predicts that global oil use will decline as it is replaced by natural gas and renewables. The collaboration we are proposing could accelerate the switch.

A Little Background

Early LNG developments in the 1970s were driven by oil companies that had the misfortune to discover natural gas distant from gas markets. The discovery would have been stranded but for the advent of integrated LNG developments to liquefy, transport and regasify the gas for use in power plants and local distribution. Although LNG was more expensive than oil, utilities in Japan and Europe were prepared to sign long term, take-or-pay contracts because of natural gas' low emissions and enhanced energy security through the interdependence of buyer and seller and diversification from oil.

U.S. utilities signed similar deals with Sonatrach, the Algerian national oil company, but reneged when domestic production and pipeline companies were deregulated from 1978 through 1985 and advances in 3D seismic technologies opened the Gulf of Mexico shelf as a prolific hydrocarbons resource. A natural gas oversupply "bubble" caused prices to decline below the contractual costs of LNG, and a long arbitration process resulted in settlement agreements. Regasification plants were built, but essentially no LNG was delivered until the bubble deflated after 2000.

Meanwhile, successful lobbying encouraged new domestic natural gas demand, notably through cogeneration facilities that provided steam to industrial customers and sold surplus electricity into the grid at "avoided cost" that would have been incurred from a new power generator.

It is time to shake the dust off that playbook.

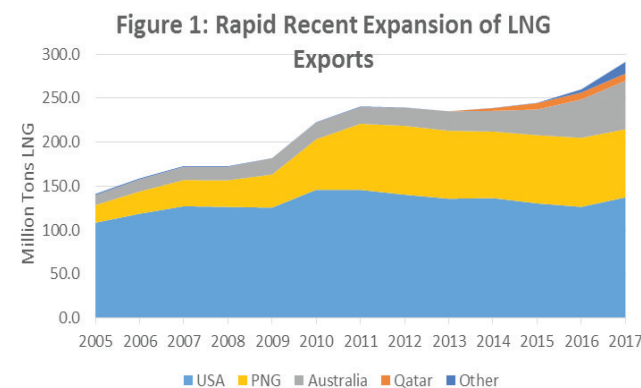
Recent LNG Contracting Evolution

Those early LNG sales contracts were all point-to-point, stressing the interdependence of buyer and seller. Cracks in the global contracting regime began to emerge in 1995 with Atlantic LNG's waiver of destination restrictions. From its web site: "Atlantic was often described as "The Trinidad Model", which referred to the unique partnership between four energy majors and the Government of Trinidad and Tobago to form an LNG company. The model was unique too in its objective to target two dedicated primary markets at that time: the US East Coast and Spain, capitalizing on Trinidad and Tobago's geographic proximity to these markets and therefore competitive delivery costs."

To further that goal, Atlantic successfully lowered the construction cost of its liquefaction plant below previous international LNG projects.

Fifteen years later, the majors led by ExxonMobil doubled the size of single liquefaction trains and the size of the LNG carriers as they invested in massive Qatargas LNG projects commissioned in 1998 through 2011. LNG supplies surged, and the global contracting regime could have come under extreme pressure (Figure 1).

However, on March 11, 2011, a massive earthquake offshore Japan caused a tsunami which killed thousands and inundated the Fukushima Daiichi nuclear power plant. Failure of back-up systems resulted in a meltdown and release of radiation. Most nuclear power plants in Japan were shut down in reaction and fossil fuel power generation plants had to fill the supply gap; demand for LNG escalated and fortunately major new Qatar LNG plants were able to supply it.



Source: Poten & Partners

A robust spot market soon emerged to provide incremental LNG supply to Japan beyond that assured under previously executed long term contracts. LNG prices rose to support new LNG plants in Australia to address growing Asian demand.

At the same time global LNG suppliers were realizing premium prices for their spot sales, U.S. natural gas prices were under tremendous downward pressure in the face of the oversupply of unconventional gas.

The coupling of these premium LNG prices and the glut of U.S. gas combined to provide the economic incentive for the U.S. to evolve from LNG importer to exporter, adding to LNG capacity being built in Australia and Papua New Guinea (Figure 1).

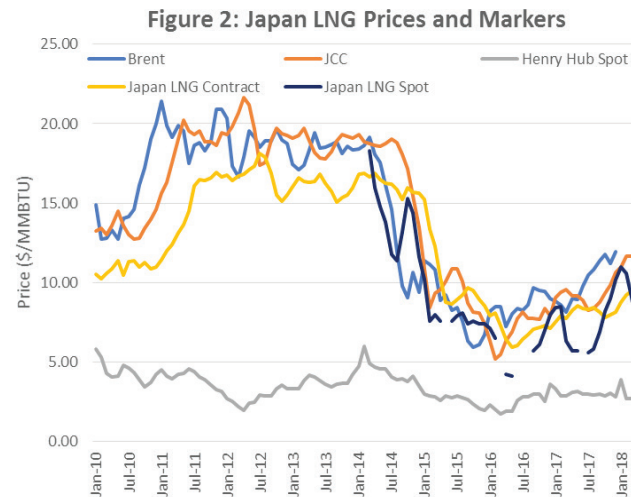
Cheniere was first and pioneered a new tolling contracting model to support financing its Sabine Pass natural gas liquefaction complex. Under this model, buyers would acquire U.S. natural gas at spot market prices and make long term take-or-pay commitments to liquefy their gas in Cheniere's facilities. Buyers took the risk that the delivered cost of LNG would be lower than it would be under a traditional oil-indexed contracting regime.

Table 1: Traditional and New LNG Contracting Models

	International	North America
Natural Gas Supply	Integrated with field production	Purchased at market prices
Liquefaction Cost	Passed through by seller to buyer	Long term tolling fee charged to buyer
Transportation	Dedicated tanker fleet	Buyer's responsibility
Marketing/ Pricing	Point-to-point long term S-Curve	Cost Recovery
Price risk	Passed to end user	Buyer's responsibility

Today we have two competing contracting models (Table 1): the traditional model still used for integrated LNG projects from reservoir through end user, with prices indexed to oil prices, coexisting with the new tolling model seen in the wave of U.S. liquefaction projects. This should provide arbitrage opportunities for global LNG traders, while LNG project developers will see enhanced spot liquidity as they optimize not only the rights they retained to process uncontracted volumes from the new projects but also those volumes from contracts which are soon to expire.

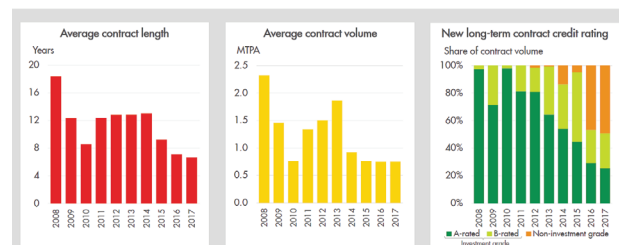
The problem with spot markets for a capital-intensive commodity such as LNG is that variable operating costs are low, especially for the traditional integrated field to liquefaction facilities. It costs very little to produce incremental volumes at the field especially if condensate is a co-product. Any price above these costs will contribute positively to cash flow and the economic incentive will favor running the liquefaction complex at full utilization. The consequence was illustrated by the collapse of spot Japanese LNG prices in advance of crude oil in 2014 (Figure 2).



Source: Poten & Partners

The market rebalanced in 2016 and 2017, but contracts were shorter term and covered lower volume, with prices influenced by local alternatives and less creditworthy buyers than in the past (Figure 3). New importing countries Egypt, Pakistan, Jordan, Jamaica and Colombia were added in 2016, showing newly price-elastic demand segments benefiting from pre-existing infrastructure but contributing to lower overall credit risk. Buyers have become more sophisticated and are putting together portfolios of contract supplies with different tenors and pricing but will soon need new downstream infrastructure to accommodate higher export volumes.

Figure 3: Deteriorating Contract Quality in 2016-17
LNG BUYERS SIGNING SHORTER AND SMALLER CONTRACTS



Source: Moody & Fitch

Australian supplies continue to expand, the U.S. is emerging as a major LNG supplier and Qatar has promised to increase its LNG production 30% by 2020. Natural gas discoveries in the Levant Basin have the potential to supply Egypt, Jordan and Israel, displacing LNG imports in the next few years.

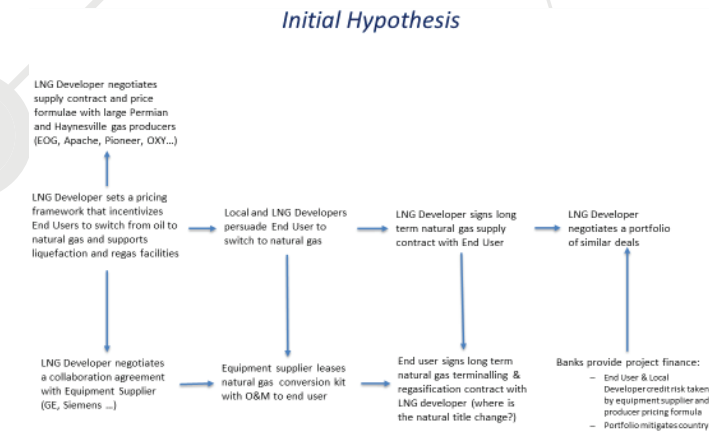
China and India both suffer from appalling air quality and benefit from switching from coal to natural gas in power generation. However, coal extraction is a major employer in both countries, and there are political risks in switching too fast. China and India will want to negotiate low prices based on coal economics; in the medium term the industry must find innovative ways to expand global LNG demand by providing end users with incentives to encourage a switch from oil to LNG.

Absent long-term contracts with high credit counterparties, it has become almost impossible for an independent LNG developer to finance the huge capital investment required for a new project, and major oil companies are demonstrating capital discipline. Domestic natural gas producers will struggle to find markets and prices will remain depressed as associated gas production increases. Project developers are trying different business models but fail to engage with end-users, hoping that low LNG prices alone will stimulate demand. A more detailed discussion of new business models is found in the full paper. Opening a new market segment has the potential to smooth the typical bust and boom commodity price cycle.

Proposed Collaborative

With a plentiful supply, barriers to continued growth in demand and reluctance by traditional buyers to commit to long-term contracts required to finance needed infrastructure, new projects will be stranded. We propose a new model (Figure 4) that may be difficult to negotiate but would spread the risk among entities which in aggregate should have sufficient credit to support project finance.

Figure 4: Schematic of Hypothetical Collaboration Relationships



Source: Bauer College of Business

In our view, natural gas producers are the primary medium-term beneficiaries of expanding the global LNG market by encouraging fuel switching from diesel to natural gas. By securing new markets on long-term contracts, producers will eliminate the need to sell at sometimes distressed spot prices and will strengthen the overall market by increasing global demand. End users should also reap strong benefits of improved air quality, lower carbon emissions and lower costs.

- Natural gas producers should be prepared to commit a proportion of their production to long-term reserve-backed contracts with emerging LNG markets at prices related to the oil products that are being substituted.
- End users and their stakeholders should benefit from lower costs and improved air quality by switching from diesel fuel to regasified LNG.
- Providers of equipment needed for the switch from oil to LNG should be prepared to lease the equipment and provide ongoing maintenance at fair prices, rather than trying to sell the units at prices that the end user would find difficult to finance.

- A shipping agreement for small used LNG tankers should be negotiable at favorable rates.
- A liquefaction agreement could be negotiated with “ceiling and floor” features that allows the developer low returns on investment when netback prices to the producer are below Henry Hub spot rates but delivers superior returns when netback prices are above spot prices.
- The “fixed price” construction agreement with the EPC contractor could also provide upside when netback prices are favorable.
- By repeating the same model to various end users in various countries, country risk can be reduced.

This arrangement should spur expanded LNG demand from end users who might not otherwise switch from oil and aggregate credit strength to allow project financing and FID (Final Investment Decision) of the fuel switching and liquefaction construction projects.

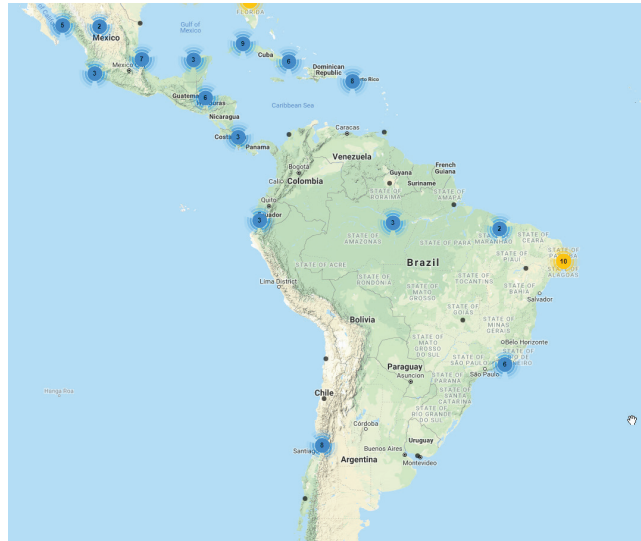
The primary economic driver is the current and expected future gap between oil and natural gas prices. Google has recently compiled a database of power plants, listing nearly 3,000 globally (other than China) that rely primarily on oil as fuel.

The natural targets for switching to LNG may be in South and Central America (Figure 5) where there are close to 100 oil-fired power plants greater than 80 MW in capacity. The IEA estimates worldwide oil use for power generation in 2016 at 275 million tons of oil equivalent (over 5 million barrels per day) so the potential market is large.

The natural targets for switching to LNG may be in South and Central America (Figure 5) where there are close to 100 oil-fired power plants greater than 80 MW in capacity. The IEA estimates worldwide oil use for power generation in 2016 at 275 million tons of oil equivalent (over 5 million barrels per day) so the potential market is large. Perhaps over time, LNG penetration may happen organically, but it is important to recognize the high inertia for change. The schematic we propose will be difficult to negotiate,

but the alternative absent a catalyst to overcome inertia is a bust period of low LNG capacity growth as good project ideas are stranded, coupled with depressed U.S. natural gas prices. LNG supplies will then fail to meet demand growth ultimately leading to a commodity boom with higher LNG (but not domestic natural gas) prices leading to stifled global LNG demand growth and frustrating low cost domestic natural gas producers.

Figure 5: South and Central Americas Power Plants Using Oil as Primary Fuel (Top Capacity Quartile)



Source: Provided by Author

It's an appropriate time to look for innovative ways to accelerate creditworthy LNG demand growth in the medium term. Our hope is that this article will stimulate some productive conversations. ■

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TRUMP'S ENERGY POLICY: BOON FOR THE OIL INDUSTRY OR NON-EVENT?

EARL J. RITCHIE

Lecturer, Department of Construction Management, College of Technology

The rhetoric of the Trump administration is certainly pro-oil industry. This can be seen in the recent National Security Strategy and the President's remarks at the Unleashing American Energy Event on June 29. However, there have been opinions that the Trump administration's actions have had and will have at best a minor effect, with some authors saying the policies "will provide marginal support for increased growth of oil and gas output" and "Trump's energy plan isn't a game-changer."

To assess the effect of the administration's policies, one must weigh the impact of numerous individual actions, for example, executive orders, legislation and changes in regulatory practices. I find it convenient to look at these as grouped into three categories: actions specifically targeting the industry, environmental regulations that affect industry demand or costs, and general actions that nonetheless have a significant effect on oil and gas. The latter include lower corporate taxes, tariffs and withdrawal from the Iran nuclear deal.

Actions specifically targeting the oil and gas industry

These numerous actions are almost all positive for the industry. They include opening additional lands for leasing, reduction in Outer Continental Shelf royalties, expediting environmental review of the Dakota Access and Keystone XL pipelines and rollbacks of Obama era fracking and methane emissions rules. These actions benefit and are welcomed by the oil industry, however, the majority of the new acreage is not economically attractive with current oil and gas prices, and the prospectiveness of the Gulf of Mexico shelf is limited even with lower royalty payments.

Easing the rules and expediting regulatory procedures are certainly benefits. As the articles cited above point out, these effects are small compared to the effects of improvements in technology and higher oil and gas prices.

In addition to their practical and monetary effect, Trump's positive view has raised the spirit of many in the industry.

Environmental regulations that affect industry demand or costs

The Trump administration has made elimination of "burdensome" regulations a priority. To date, they have proposed to roll back approximately 70 environmental regulations. Two of these, the Clean Power Plan and review of automotive fuel economy (CAFE) standards, have received particular attention with regard to the oil and gas industry. As I pointed out in an earlier post, the Clean Power Plan has a negligible effect on oil and a minor effect on natural gas. Renewable energy subsidies, which have not been cut, are more important.

A rollback of CAFE standards would hypothetically help the industry by increasing gasoline consumption. In practice, the effect would probably be negligible. State regulations, consumer demands for more efficient vehicles and the growth in electric vehicles will likely keep fuel efficiency on the same path. Car sharing may reduce miles driven.

President Trump also touts cost savings from deregulation. This is difficult to quantify. Environmental spending by oil companies is shown in a Reuters article to be about 2% of gross revenue.

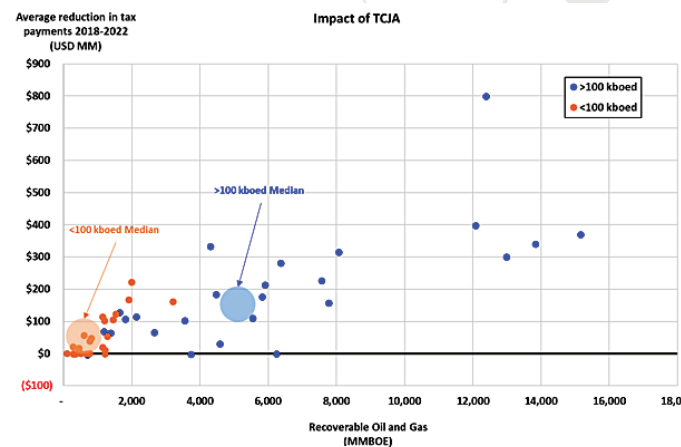
Because the Trump administration's actual and proposed changes are only a fraction of federal environmental regulations, and because regulations in states and other countries remain, the overall reduction in environmental spending will be small. There will be benefits from faster approvals.

Other actions having an effect on oil and gas

Some of the most significant effects on the industry are a byproduct of actions taken for other purposes. These actions include the tax bill, trade policy and withdrawal from the Iran nuclear deal.

The Tax Cut and Jobs Act is often described as a giveaway to the oil industry. In the aggregate, the revisions reduce taxes on the industry. After all, reducing taxes is the purpose of the bill. However, the provisions are not uniformly favorable.

The effect on individual companies varies tremendously, depending upon financial structure, degree of international concentration, industry sector, existing tax situation and other factors. Some "win bigly." Some have little benefit or even see a tax increase in the near term. The graph below from a Rystad Energy analysis of a group of U.S. shale producers provides an estimated magnitude and variation.



Source: Modified from Rystad Energy

Rystad estimates the annual cash flow benefit to the shale drillers, which currently produce about half of U.S. oil, to be about \$5 billion per year. This sounds like a lot, but it is about the same as a \$3 per barrel increase in the oil price.

Similarly, headlines proclaiming the tax bill to be a bonanza for big oil ignore unfavorable provisions in the bill. The overall effect is more modest.

Trump's restrictions on trade, particularly the steel tariff and NAFTA renegotiation, are expected to hurt the industry. The effects cannot be quantified since these are works in progress.

The U.S. withdrawal from the Iran nuclear deal is expected to raise oil prices. Goldman Sachs has been quoted as estimating the increase to be between \$3.50 and \$7 per barrel. This may be more important than any other measure the administration has taken.

The bottom line

The Trump administration's actions are a combination of positives and negatives. Many are proposed but not implemented; some are challenged by lawsuits. The effects on individual companies differ. Assessing the net effect requires assumptions piled on assumptions. The most significant effects on the industry are likely to be unintended consequences of actions taken for other purposes.

It is a fair guess that the net effect is moderately positive. This is welcomed by the industry and certainly more favorable than the actions proposed by Democratic presidential candidate Hillary Clinton during the election campaign.

However, the effect is small compared to the effect of improvements in technology, oil and gas prices and reduction in the cost of operation. The current revival of industry activity is focused almost entirely in the shale plays and results from improvements in technology combined with higher prices. ■

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WHAT HAPPENED TO THE IPO MARKET FOR OIL AND GAS INDEPENDENTS?

ED HIRS

Lecturer, Department of Economics, College of Liberal Arts and Social Sciences

There is no IPO market for oil and gas independents today. Why is this? Because the market value of publicly traded shale companies today is less than the cost of replacing the leaseholds, seismic, reserves and drilling inventory that make up their assets. Consequently, cash-rich companies and private equity managers have acquired or merged publicly held companies into their portfolio companies to acquire assets more cheaply.

When will the market again favor private equity managers' favored strategy of privately acquiring assets and then exiting to an overvalued public market? Simple: when market values exceed replacement costs. To understand when that might happen, let's take a quick look at the fundamentals driving today's market. After that we'll look at some time-honored ways to view risk and reward.

The supply of public equities in oil and gas is disproportionately smaller than the use and the value of oil and gas in the national economy. "Market allocations" for oil and gas are underweighted now in the public equities market. Until there is a flow back into public equities, independents and their investors must rely upon excellent science to discover the next low-cost play, to drive down current drilling and operating expenses, and maintain positive cash flow. It will happen.

Consumers are short oil and gas for the rest of this year, next year and the years afterward, no matter how much they plan to use. Threats of supply shortfalls lead to remarkable inflows of capital, price increases in the futures markets, surging equity prices, and overweighting of oil and gas equities in the portfolios of institutional investors. Always.

The current price elasticity of demand for oil is negative 0.04. This means that a relatively small change in world supply changes the price (in the opposite direction) by 25%.

This lack of elasticity is what Saudi Arabia used to take aim at U.S. shale drillers in 2014, resulting in a catastrophic loss of capital, 330-plus bankruptcies, 250,000 direct jobs lost and more than \$200 billion in lost annual GDP. This lack of elasticity also means that despite current sentiment that the world has plenty of oil and gas and that peak demand is only a few years away, OPEC has succeeded in withdrawing sufficient oil supplies to drive up the price from \$40 per barrel to more than \$60.

Note that "Peak Oil" supply has always been a quaint fiction — especially so in the price regulated U.S. market in which the notion was advanced. Increased demand and higher prices will draw out more supply, putting upward pressure on prices. The 2009 Energy Journal paper "Depletion and the Future Availability of Petroleum Resources" lays out the supply availability of oil, gas and gas liquids as the real price increases and allows for economic production.

The biennial study of the Potential Gas Committee details that gas resources will last well beyond several lifetimes. The marginal cost of producing natural gas from the Barnett and Haynesville shales was about \$1 per Mcf in 2011. That number has only decreased as technology has improved by leaps and bounds.

According to recent data, private equity sponsors have stakes in 350 portfolio companies to which \$200 billion of equity has been added since 2014.

Much of this funding went to shore up expensive shale and offshore investments that were bleeding cash at \$40 per barrel oil.

These ideas are not new. Time honored analysis.

- In a 1931 article, Stanford University professor Harold Hotelling detailed conditions under which the owner of a limited amount of natural resources would be indifferent between current production and future production if the forecast price increase of the resource was equal to the rate of interest. Known U.S. shale plays offer the certainty of hydrocarbons — essentially, storage in place — the commercial production of which is entirely dependent upon the current gross margin.

Barring supply manipulations elsewhere in the world, investors today in the U.S. domestic shale plays face the prospect of bringing oil to market when the long run prospects for price exceeding marginal costs are not good and, in fact, while the prospect of price increasing at a rate greater than the rate of interest is decidedly negative.

- Yale University professor William Nordhaus forecast in 1979 that the real price of crude oil would increase at the rate of real economic growth. Discounting short run manipulations by OPEC, misguided political responses and reactions by producers and consumers adjusting to these divergences, the real price of crude has indeed increased at the rate of real economic growth for the past 40 years. The manipulations and reactions have provided the volatility needed for smart active investors to realize outsized returns.
- One's level of success depends on what others do. Think John Nash of "A Beautiful Mind" and his paper "Non-Cooperative Games." OPEC remains the "swing" producer in the global oil market. The U.S. shale plays have improved their costs, but one cannot characterize these high cost producers as "swing" producers because they do not have the incentives or abilities to increase or decrease production at will.

In recent decades, OPEC works backward to assign quotas based on their assessment of world demand and non-OPEC production. OPEC's quotas were designed to provide an intersection of supply and demand at a forecast price. OPEC often got it right, but when it failed to respond rapidly to China's 2008 increased demand (necessary to replace coal to clean up the air before the Beijing Olympics), OPEC inadvertently created a new competitor; the U.S. shale plays. By 2013, it was obvious that the U.S. shale plays had encroached on OPEC market share and that OPEC would employ another Nash response, predatory pricing.

- Martin Shubik is a titan of game theory and value investing, and in his Dollar Auction paper, he describes a game that investors must avoid. The auction is for a dollar bill. It is won by the high bidder, but the second-place bidder must also pay out his bid while gaining nothing. The Dollar Auction describes perfectly what happens when nations go to war; the winner survives (sometimes barely) and the loser is wiped out.

For some investors, the game also describes the challenge faced when too much money chases too few assets. Investors can find themselves upside down or bidding more than one dollar to win the asset, just to stay in the game.

- The shale drillers that survived \$40 oil are those who followed the dictum of Michael Porter's book "Competitive Strategy" — be the lowest cost producers. For commodities, it is the only strategy that succeeds over the long run.

Private Equity Game

Private equity sponsors have become larger and larger over the past 20 years. Portfolio companies backed by hundreds of millions of dollars are rarely allowed to make money on new discoveries and new drilling. Nowadays, they are kept on short leashes and directed to infill drilling of known shale plays that commonly have inbound costs of \$30,000 to \$40,000 per acre. Ouch! These numbers are reflected in the publicly traded companies adjacent to the private companies in the shale plays.

Here, we see that the efficient market hypothesis and Stephen Ross' Arbitrage Price Model begin to work against outside returns for the shale play companies and especially against those that have to pay a premium price for entry. In this instance, the sponsor may be better served by making a long-only bet on NYMEX and avoiding the liabilities of owning an operating company.

The time horizons of sponsors do not match those of their pension fund and endowment investors. Institutional investors typically invest in oil and gas as a hedge against increasing energy prices and for diversification. Private equity sponsors have shorter horizons (generally not more than seven years for a fund) and, consequently, their portfolio companies have shorter time horizons. With cycles and manipulations by OPEC occurring over years and even decades, there is often a mismatch of timing among capital providers and their investments.

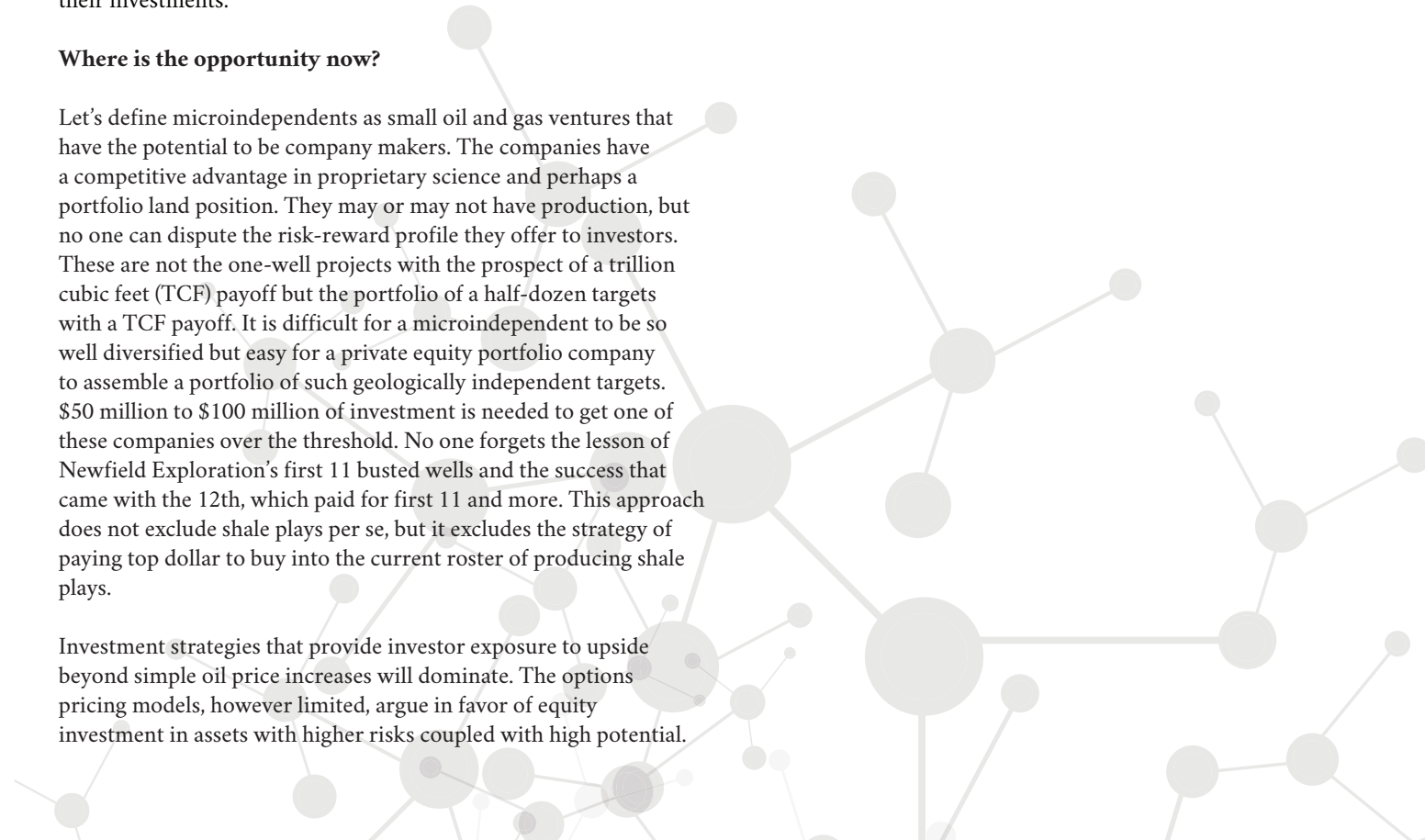
Where is the opportunity now?

Let's define microindependents as small oil and gas ventures that have the potential to be company makers. The companies have a competitive advantage in proprietary science and perhaps a portfolio land position. They may or may not have production, but no one can dispute the risk-reward profile they offer to investors. These are not the one-well projects with the prospect of a trillion cubic feet (TCF) payoff but the portfolio of a half-dozen targets with a TCF payoff. It is difficult for a microindependent to be so well diversified but easy for a private equity portfolio company to assemble a portfolio of such geologically independent targets. \$50 million to \$100 million of investment is needed to get one of these companies over the threshold. No one forgets the lesson of Newfield Exploration's first 11 busted wells and the success that came with the 12th, which paid for first 11 and more. This approach does not exclude shale plays per se, but it excludes the strategy of paying top dollar to buy into the current roster of producing shale plays.

Investment strategies that provide investor exposure to upside beyond simple oil price increases will dominate. The options pricing models, however limited, argue in favor of equity investment in assets with higher risks coupled with high potential.

See, for example, the Cox, Ross, Rubenstein model or Stanford professor Myron Scholes' recent work that directs investment managers to move away from "average" or "The Black Swan" by Nassim Nicholas Taleb of New York University.

Profitably selling oil and gas is the first exit. Fundamentals and risk analysis never go out of style. ■



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IS THE IPCC WRONG ABOUT SEA LEVEL RISE?

EARL J. RITCHIE

Lecturer, Department of Construction Management, College of Technology

The dangers and costs associated with future sea level rise have been heavily publicized. Computer visualizations of future flooding show the inundation of low-lying areas, including disappearance of many low-lying islands.

The most commonly quoted sea level rise predictions are those of the IPCC's Climate Change report. Their median projection for all scenarios except RCP8.5, the worst of their four scenarios, is about a half meter by 2100. Even in the worst case, there is a 95% probability that sea level rise will be less than one meter by 2100.

Recently, a number of articles have speculated these estimates are too conservative, with arguments of twice as much rise or more. These differences of opinion are primarily based on how fast the West Antarctic and Greenland ice sheets will melt. Although there are indications rise may be faster than the IPCC's projections, the evidence remains inconclusive.

Differences of this magnitude are not just of academic interest. The impact of sea level rise of 2 meters is significantly greater than a half meter. Therefore, the choice of projection will have great influence on actions to deal with rise.

A bit of science background

The two influences likely to have significant effect on sea level in the next few decades are thermal expansion of the ocean and ice melt. There are additional contributions locally from winds, ocean currents, salinity and other minor factors.

In this article, it is impossible to capture all the alternative

theories, opinions and nuances that appear in the thousands of scientific articles on this subject. As an example, the rate of sea level rise attributed to thermal expansion after 1993 quoted in a National Academies of Science report is from 0.7 millimeters to 1.6 millimeters per year, a 2:1 range. The high-end number is from the IPCC.

The largest differences are in the rate of ice sheet melt. The range of 2002 to 2008 rates attributed to ice sheets in the National Academies of Science report is from 0.23 to 0.68, a 3:1 ratio. The National Snow and Ice Data Center says, "Although thermal expansion has been projected to contribute the most to sea level rise, the potential of large contributions from the Antarctic Ice Sheet has added significant uncertainty to predictions."

There is nothing sinister about disagreement in estimates of sea level rise. It is a complex issue. Scientific disagreements result from different analysis methods, assumptions, portion of the sea analyzed and time interval. Nonetheless, it is important to recognize there is no one answer.

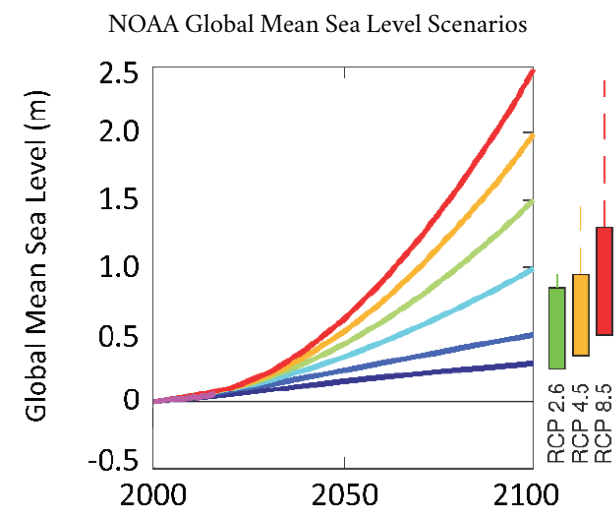
The faster melt argument

The greatest differences in rise predictions result from assumptions of how fast the Greenland and Antarctic ice sheets will melt. This is partially related to predictions of future temperatures, but in the near term, it is more due to the mechanics of melting.

Concern over faster rise from ice sheet collapse dates back at least 50 years. The mechanics of ice sheet loss remain the subject of scientific debate.

Most of the recent articles describing possible faster rise are based on a 2016 paper by DeConto and Pollard, predicting sea level rise by 2100 could be twice as much as the IPCC projections. The paper was reported by CarbonBrief.org to have had more coverage in the news than any other climate change paper.

A 2017 NOAA report offered the scenarios shown below, with sea level rise ranging from 0.3 m to 2.5 m by 2100. The colored bars represent IPCC 90% probability, with DeConto and Pollard additions as dashed lines.

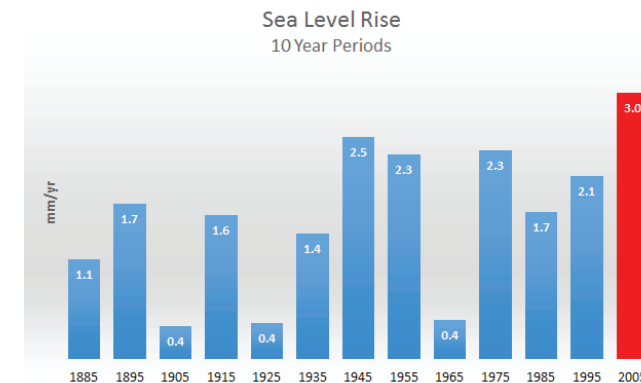


Source: Modified from Sweet, et al. 2017

The higher scenarios are given very low probability in this report. Rise greater than 1 meter is given less than a 1% probability under RCP4.5 and less than 2% under RCP8.5. A UK Government Office for Science report, which specifically considered the DeConto and Pollard model, said rapid Antarctic sea ice loss this century is "highly unlikely."

The measured rate argument

The empirical evidence for faster rise is illustrated in the graph below. Data from tide gauges is shown in blue. The last bar, in red, is from satellite altimetry. This is one of several published reconstructions. The rate is variable but generally rising.



Source: Data from Church and White, 2011

Sea level reconstructions require corrections and assumptions. There is considerable debate in the scientific community about tide gauge correction methods and other adjustments, resulting in differences between published curves. Satellite altimetry, available since 1993, also requires correction. Corrections by Watson, et al. decrease the rate to 2.6mm per year. A NOAA estimate places it at 3.4.

Acceleration in the rate does not mean the IPCC projections are too low since the IPCC anticipates an increasing rate. A widely quoted 2018 paper by Nerem, et al. says, their estimated acceleration "agrees well with climate model projections."

In addition, projections of continuing increases in the rise rate cannot be reliably made from the short interval of the recent increase. Hansen, et al., who have one of the more aggressive predictions of possible rise say, "We conclude that empirical data are too brief to imply a characteristic time for ice sheet mass loss."

Comparison to past warm periods

Estimates of future warming and sea level rise are often made by analogy to warm periods in the geologic past. Favorites are the Paleocene-Eocene Thermal Maximum because of its fast rise rate, the Pliocene because CO₂ concentration was similar to today, and the last interglacial period because the most accurate data is available on it.

Sea level at these times is believed to have been much higher than any of the projections for this century presented here. They may be good indicators of ultimate sea level rise being at least several meters over a period of centuries, but not for rise in the near future.

Past geologic periods are imperfect models because conditions at these times were not identical to today, knowledge of past conditions has a wide range of error, and most sea level and temperature correlations from those periods reflect equilibrium conditions, whereas the current period is in transition. Haywood, et al. concluded there were no satisfactory geologic analogues.

Adjusting for differences between the analogues and the current situation is done by calibrating mathematical climate models to the analogues. The Hansen, et al. and DeConto and Pollard papers are calibrated to the last interglacial period, and the last interglacial period and Pliocene, respectively. Climate models have their own uncertainties, which are well described elsewhere.

Local variations

In addition to the global changes, local factors have significant influence. These factors include the minor sea level effects mentioned above and tectonic effects, that is, whether the land is locally rising or falling.

For example, median projected rise for 2100 in the NOAA report is about 1m at New York City and 1.25m at Galveston, Texas. Juneau, Alaska sees a 0.9-meter fall due to high local uplift. The IPCC estimates about 30% of global coastlines will experience change greater or less than the global mean change.

Discussion

There is general agreement in the scientific community that the range of possible longer-term sea level rise is great. Over the next several centuries, the world faces the possibility of several meters of sea level rise, even runaway warming. That is not the subject here. This is a discussion of what is likely in this century.

Continued rise is locked in due to temperature changes that have already occurred. No reductions in greenhouse gas emissions will prevent sea level rise in the near term.

The foregoing has demonstrated that rise greater than 1 meter in this century is highly unlikely. However, greater rise is possible. Considerable scientific effort is currently being devoted to whether faster ice melt is happening. The University of Houston is participating in one such study focused on West Antarctica.

Regardless of whether such faster or greater rise occurs, adaptation to higher sea level will be necessary. The UK report cited above mentions risk to residences, businesses, hospitals, roads, railroads, power plants and virtually all infrastructure near the coast. As with most reports of this type, it has few specific recommendations.

Measures to deal with rise have begun in a few areas, but preparations to date fall far short of what will be necessary. Often, willingness to spend is low until significant damage has already occurred. One of the most extensive programs is in Miami Beach, which has already experienced tidal flooding.

These decisions involve the complicated interplay of public opinion, governmental processes and available financing. A report of a Working Group of the California Ocean Protection Council Science Advisory Team calls these “challenging planning and decision processes” using “uncertain sea-level rise projections.” There is no simple answer. ■

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WHAT'S IN THE AIR? WE NEED A COMPREHENSIVE APPROACH TO MANAGING POLLUTION

STEPHANIE COATES

UH Energy, University of Houston

When a waterway is deemed too heavily polluted, there is a federal protocol that state and local authorities can follow to measure pollutants, evaluate and enforce cleanup of the waterway. When air becomes too heavily polluted in an environmental “hotspot,” there is no similar mechanism.

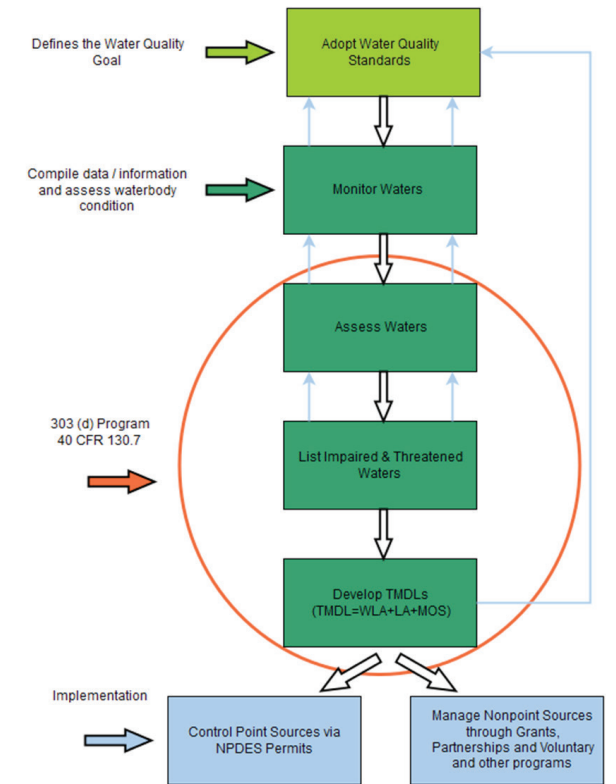
And people living in these hotspots too often pay the price.

It's essential to regulate air pollution, not only for the sake of clean air but also for the health of communities living nearest the highest concentrations. We already have a model for how to do that in the Clean Water Act.

Under the Clean Water Act, if a state identifies a waterway that is “impaired,” or in danger of not meeting water quality standards, the state is supposed to calculate the pollution affecting the waterway and determine a plan, or Total Maximum Daily Load (TMDL), to reduce the pollution to levels that meet water quality standards. Part of the plan includes identifying the sources of pollution and, determining how to allocate responsibility among the various sources for reducing the pollutants to an overall acceptable level.

The plan is implemented and the waterway is then reassessed.

As the graphic demonstrates, states are constantly reevaluating and updating their plans throughout this process and moving their waterways toward meeting cleaner standards.



Source: EPA

WLA is the sum of wasteload allocations (point sources), LA is the sum of load allocations (nonpoint sources and background) and MOS is the margin of safety.

A key feature of this process is that if a body of water is threatened by more than one pollutant, TMDLs account for the heavier cumulative load posed by multiple pollutants, then permits for sources of pollution are issued through the Environmental Protection Agency's National Pollutant Discharge Elimination System, or NPDES program.

There isn't a comparable plan for air pollution.

The EPA sets limits for six pollutants, including carbon monoxide and lead, but what if an area is already exposed to several pollutants and a company there is seeking a permit for another? Or if an area experiences emissions of a chemical not on the EPA list?

Since there is nothing like a Total Maximum Daily Load for air pollutants – which would set overall levels allowed, adjusting for how many types of pollution are found in one geographic area – communities in “hotspots” are pitted against individual emitters and have to fight each new pollutant one at a time, without federal support. The situation is exacerbated by the lack of a flexible process for evaluating and lowering those pollutants.

Public health is potentially at risk. As an example of how this is playing out, consider the permit fight between Valero Refining – Texas, LP, and the community of Manchester, the southeast Houston neighborhood where the refinery is located.

The Texas Commission on Environmental Quality (TCEQ) in June held a public meeting to take comments on a permit Valero requested to authorize already existing emissions of hydrogen cyanide from the Fluid Catalytic Cracking (FCC) Unit. Emissions of hydrogen cyanide (HCN) have been occurring since the cracking unit was deployed, but Valero was not previously required to track them. However, the EPA recently started requiring testing for HCN, meaning the company needed an addendum to its existing permit for other types of emissions at the site.

According to the notice published by TCEQ, after reviewing the technical aspects of the amendment, the agency's executive director “made a preliminary decision to issue the permit because

it meets all rules and regulations.” The executive director of TCEQ appeared to see it as a straightforward issue and granted preliminary approval.

But to the citizens testifying at the public meeting, the permit feels like another nail in the coffin.

The town of Manchester, zip code 77012, straddles Interstate-10 and sits in a fork of Buffalo Bayou at the Houston Ship Channel – the interstate and ship channel are both heavily trafficked. Other prominent features of the immediate neighborhood include a fertilizer plant, two recycling facilities, two refineries including Valero, and the Union Pacific train yard. A number of chemical plants sit within a three-mile radius.

The University of Texas School of Public Health found a possible link between cancer risk in the area and the air pollutants. In 2016, the Union of Concerned Scientists concluded similarly and also noted that the risk of respiratory hazards is 24 percent greater in Manchester than in more affluent parts of Houston.

At the public meeting with representatives from TCEQ, residents reported health-related issues, including frequent nosebleeds, asthma and headaches. Without regulations on total air quality, it was easy for TCEQ to dismiss the complaints. It is not the hydrogen cyanide alone that causes all the noted health problems, but that was the only issue being considered.

HCN is a neurotoxin, and at high concentrations causes death. Lower chronic exposure can cause headaches, weakness, nausea and enlarged thyroid, but HCN is also lighter than air. That means when it's released from the refinery, it usually rises rapidly and since it is being emitted from a tall stack, it will be able to disperse into the atmosphere to break down (albeit slowly). At that point, most people would not consider it a health risk.

In July 2017, TCEQ wrote an interoffice memo regarding the health effects from the emissions related to the new permit. It concludes that they “do not anticipate any short- or long-term adverse health effects to occur among the general public as a result of exposure to the proposed emissions from this facility.”

However, this memo intended to attest to the health risk does not examine the already existing total accumulation of emissions, nor how allowing the HCN emissions impacts the risk. It does not consider the possibility of potential leaks or other unplanned emissions, or potential explosions.

Without an overarching federal rule requiring it to do so, TCEQ, although it could do otherwise, grants permit requests for each individual chemical emitted at each individual facility instead of considering the overall impact of adding hydrogen cyanide to the pollution mix over Manchester.

In this permit fight, Valero is not to be seen as an enemy or villain – many Manchester residents work at the refinery, which by at least some accounts has been a good and responsive neighbor.

In fact, we can't blame any individual refinery, especially since emissions only come as a by-product of supplying the gas, chemicals and other valuable consumer products we all demand.

The cumulative risk – not only the air quality risk posed by total pollutants, but also the health risk from pollutants in an area already made vulnerable by the fact that so many residents are poor, members of a minority ethnic or racial group and speak limited English – should be considered when permitting an additional facility or more emissions. We have a system for reporting air pollution emissions through the Toxic Release Inventory, for example, but after we collect and report the data, we don't do enough to ensure the safety of affected communities. As it is now, health risk is only assessed as individual chemicals newly become regulated, as in the case of HCN; even then, the assessment is incomplete since it does not address total ambient air quality.

Limiting the overall load of air pollutants is a better way to address hotspots and is already working well under the Clean Water Act.

Residents haven't given up the fight against allowing hydrogen cyanide emissions at the Valero refinery, but the odds aren't in their favor. Until Manchester and similar communities have a better way to deal with the source of public health problems, they will need to keep fighting, one chemical at a time. ■

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HOW HOUSTON SURVIVED THE GREAT OIL BUST OF 2015-16

BILL GILMER

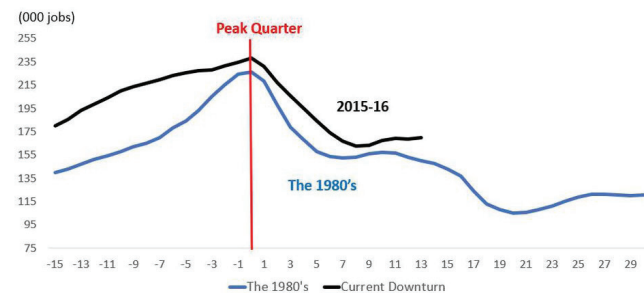
Director of Institute for Regional Forecasting, C.T. Bauer College of Business

In November 2014, OPEC announced it would no longer serve as swing producer in world oil markets, triggering what would arguably become the worst downturn in the history of American oil. Based on the rate of decline of the rig count, the number of rigs left working at the worst of it, the lost oil jobs or the fall in capital expenditure, the 2015-16 oil downturn rivaled or exceeded that of the 1980s.

However, the story for Houston's economy was very different. Between 1982 and 1986, for example, Houston suffered its worst recession ever, losing 211,000 jobs or about one job in 12. In contrast, 2015-16 brought the local metro area a loss of only 4,300 jobs overall, or about 0.1% of payroll employment, making it the mildest of any oil-related downturn in local history.

This improved performance was not because Houston was somehow immune to the oil price collapse. Before 2014, the city was riding a huge boom in oil-related activity, and its abrupt end spelled the loss of 74,200 local oil-related jobs over the following two years. Figure 1 shows that at the cyclical peak in both 1982 and 2014, Houston had a similar number of oil-related jobs, and as losses mounted, both cycles followed a very similar path.

Figure 1: The Fall in Houston's Oil Jobs in 2015-16 Closely Follows an Earlier Path from the 1980s



Source: Bureau of Labor Statistics

Offsetting Losses to Oil

There were probably three key factors that helped Houston's economy offset the 2015-16 losses in the oil sector: continued growth of the U.S. economy, sustained momentum from a decade of boom-time growth, and a huge petrochemical construction boom driven by low natural gas prices. This combination added up to just enough to offset a serious setback in oil employment.

- The most important factor was that the U.S. economy performed well, growing moderately but steadily after 2012. This growth supported Houston's many companies that are unrelated to oil but which sell into national and global markets. Local examples would be United Airlines, AIG, Sysco, Men's Warehouse and Waste Management. This contrasts with the 1980s downturn, for example, which began with the long and deep 1982 U.S. recession.

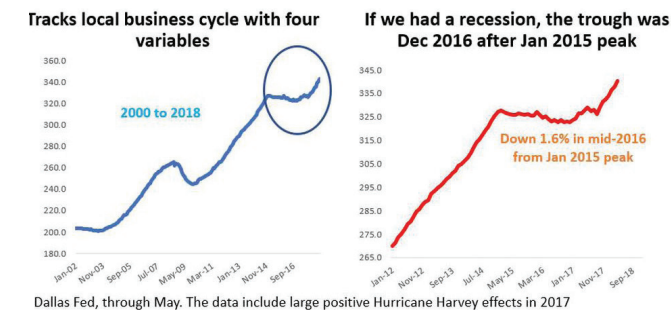
- Houston had built up tremendous economic momentum from the oil-boom years. Between December 2003 and December 2014, Houston added 696,000 new jobs or enough new jobs to match the total employment of major metro areas like Jacksonville, Salt Lake City or Richmond. By 2014, Houston was still seriously pressed to finish building the equivalent of a major new metro area in a short period of time, and just because the price of oil fell, the city had not nearly caught up on much-needed roads, schools, hospitals, shopping centers, banks and restaurants. Growth in these secondary sectors continued at boom-time rates in 2015 and slowed only slightly in 2016.

- Finally, low natural gas prices came to Houston's rescue. High oil and natural gas prices drive high levels of activity in exploration, drilling and production, and this same activity contracts if prices fall. However, for Houston's Ship Channel complex of refineries and petrochemical plants, low energy prices bring good news in the form of reduced feedstock costs and higher profit margins. In this particular case, a sharp fall in natural gas prices after 2012, to levels below \$4 per thousand cubic feet, kicked off a massive \$50 billion construction boom. Centered in East Houston and along the Ship Channel, it was primarily a petrochemical and plastic boom, with some help from LNG exports and refining. The construction peaked in 2015-16 and has been winding down quickly since then.

How did all this add up for Houston's economy? The Federal Reserve Bank of Dallas publishes a business cycle index for Houston that is specifically designed to track the local business cycle. The index includes four variables: payroll employment, the unemployment rate, real wages, and real retail sales (Figure 2).

From 2001-03, for example, the index says that the U.S. tech bust pushed Houston into its mildest recession since 1972, a 2.5% decline measured peak to trough. In 2008-09, the Great Recession saw Houston's index fall much further, to 7.9%. If we had included the 1982-86 period in the chart, it would have shown a local economic collapse of 18.0%.

Figure 2: If 2015-16 Brought a Recession to Houston It Was the Mildest Since 1970



Source: Dallas Fed

In 2015-16, it remains a close call as to whether Houston had a recession or not. The index fell only 1.6% over the period, less than the 2.5% of the "mildest-ever" recession of the Tech Bust period. Some economists define a recession as two consecutive quarters of decline, and Houston's index fell for each of the last three quarters of 2016. But the combined fall was less than 1%, with most of it concentrated in the second quarter of the year. If we choose to call 2015-16 a recession, it is now Houston's shallowest since 1972.

Is Houston's Business Cycle Now Weaned from Oil?

If 2015-16 brought a serious oil downturn but only limited damage to the local economy, has Houston been weaned from oil and its business cycle tamed? Unfortunately, it is not that simple. It should first be noted that the Houston/oil nexus definitely got a bad rap from events of the 1980s. The 1982 bust was never just about oil prices and has never served as a guide to the city's future. Oil was an important ingredient, but the '80s came with a major U.S. recession, badly misguided federal energy policies and a real estate and banking bust of epic proportions. Fortunately, most of these mistakes won't or can't easily be repeated.

Some claim that Houston's 2015-16 performance was the result of Houston diversifying away from oil, leaving the local economy less susceptible to the oil-price cycle. We can't make any comparison of today's local economy to the 1980s, because the government's industrial classification system changed completely after 1990. But since 1990, there is no evidence of a long-term structural shift in

Houston that indicates less dependence on oil markets.

Houston did well because the oil and natural gas markets have been decoupled and the boom in chemicals manufacturing (the other part of the energy industry) was largely the driver of the market in Houston.

Most of the credit for Houston's relative stability in 2015-16 must go to the positive performance of the U.S. economy. Before 2014, every local recession was first brought on by a setback to the U.S. or global economy, quickly followed by a decline in demand for oil. The 2015-16 oil price collapse was different: it was initiated by an oversupply of global oil from new U.S. fracking technology, and lower oil prices simply stimulated the U.S. economy to roll right on. The more typical one-two blow of recession followed by oil-price collapse can still be brutal in Houston, as we have seen as recently as the 2008-09 downturn led by the Great Recession. This combination will likely be seen in Houston again and again – as long as the business cycle persists, and as long as Houston's economy and oil markets remain thoroughly intermingled. ■

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HOW MUCH SEA LEVEL RISE IS ACTUALLY LOCKED IN?

EARL J. RITCHIE

Lecturer, Department of Construction Management, College of Technology

One frequently sees articles claiming a certain amount of global warming or sea level rise is inevitable based on the amount of CO₂ already in the atmosphere. Locked-in warming is commonly estimated to be 1.5 degrees C (2.7° F) above preindustrial levels, about a one-half degree above the current temperature. This is the aspirational target of the 2015 Paris Agreement of the United Nations Framework Convention on Climate Change.

Although there may be some rhetorical benefit in this number, it understates the actual amount of committed warming and sea level rise predicted by mainstream climate change theory. The IPCC says, "Stopping emissions today is a scenario that is not plausible." Therefore, we will inevitably have higher CO₂ concentration than the present, greater warming and more sea level rise.

Under the lowest of the IPCC's four scenarios, RCP2.6, peak temperature rise of 2 degrees C will be reached before 2100, and sea level rise will be less than about a half meter. However, due to lag effects in ocean warming and ice melt, sea level will continue to rise for centuries. Rise can theoretically be reduced by negative carbon emissions or geoengineering.

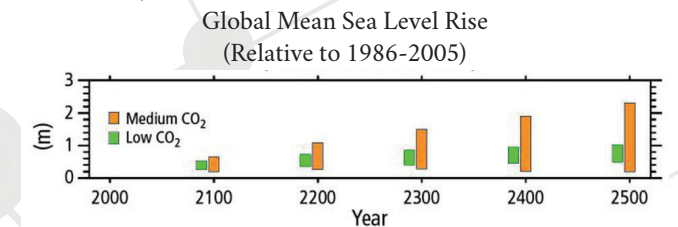
The Best-Case Scenario

If one accepts "locked-in" as actually involving some amount of future emissions, the door is opened to the numerous speculations about what is achievable and what will actually happen. RCP2.6 requires very rapid CO₂ reduction and, ultimately, negative emissions. There is considerable question,

even as expressed by the original authors, whether these reductions can be realized. Assuming the IPCC's models are correct and RCP2.6 is achievable, one might say locked-in warming is the 2 degree primary target of the Paris Agreement, approximately 1 degree higher than today.

What Happens After 2100

The IPCC projects temperatures to decline slowly after 2100 under RCP2.6 and rise slowly under RCP4.5, the second most favorable scenario. However, due to lag, sea level continues to rise under all scenarios. The graph below shows sea level projections to 2500 for scenarios roughly equivalent to RCP2.6 (low CO₂) and RCP4.5 (medium CO₂).



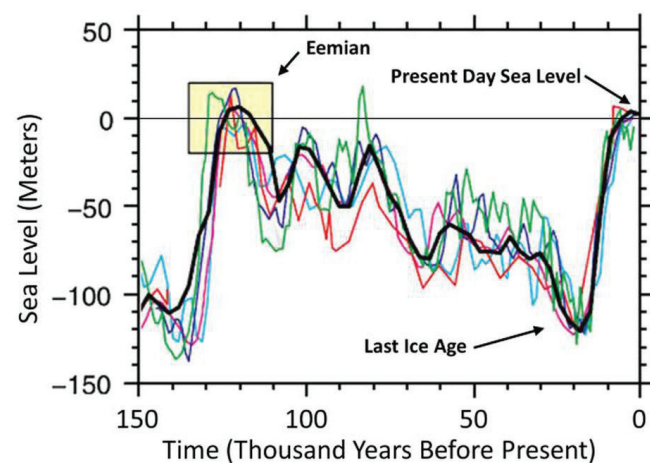
Source: Modified from IPCC Climate Change 2014

The maximum rise of about 2 meters (7 feet) in these scenarios is quite moderate compared to what could happen. The IPCC's range for "multi-millennial" commitment is 3 to 13 meters (10 to 36 feet) for warming of 2 degrees C. There is ongoing debate in the scientific community about melting thresholds and rates. As discussed in a recent post, several recent articles have predicted faster rise in this century. Differences of opinion over short-term rise, to 2100, are primarily a question of how fast the Antarctic

and Greenland ice sheets will melt. Longer-term rise is a question of how much of the sheets will melt.

Comparison to Past Warm Periods

Although I am somewhat skeptical of the ability of current climate models to predict melt rates, an independent estimate of long-term sea level rise can be made by analogy to earlier warm periods. The argument is shown in the graph below, with the different colored lines representing sea level reconstruction by different researchers.



Source: Modified from Siddall, et al.

In this case, the comparison is to the last interglacial period, known as the Eemian or MIS 5e, about 125,000 years ago.

Temperature in the Eemian is estimated to have been about 1 degree C higher than today and maximum sea level about 5 meters higher. The analogy argument is that peak temperature expected in the near future will be similar to the Eemian maximum; therefore, we can expect ultimate sea level rise to be similar.

Unfortunately, there are two reasons why the value of this comparison is limited. First, there is considerable disagreement about the actual temperature and sea level during the Eemian.

The temperature difference is commonly quoted as 1 degree to 2 degrees C; however, estimates range from negligible to “several degrees.” Similarly, sea level has been estimated to have been 3 to 10 meters higher, with estimates around 5 to 6 meters most common.

Second, conditions during the Eemian are not similar to the present. Solar heating was higher, and CO₂ was lower.

The Eemian and other warm periods are not great analogs. But they do indicate a high probability of substantial sea level rise over the longer term for temperatures that are already locked in.

How High Will the Water Get?

Kopp, et al. say, “future sea-level rise remains an arena of deep uncertainty.” The range of projected sea level is very wide, and it depends upon how far into the future you project.

The main cause of variation is the amount of melt of Greenland and Antarctic ice sheets. It’s estimated that complete melt of the ice sheets would raise sea level by about 66 meters (217 feet). Since only a small fraction of the sheets melted in the Eemian, projected rise at 2 degrees will be much less.

Levermann, et al. modeled sea level rise 2000 years into the future at 1 degree and 2 degrees above pre-industrial levels, bracketing the Paris Agreement goals. Their median estimates are 2.3 meters at 1 degree and 4.8 meters at 2 degrees. Not too much should be made of the specific numbers, because the model range is large (1 to 4.9 and 2.6 to 9.8, respectively), and other articles have different projections.

It is fair to say ultimate sea level rise could be in the range of 3 to 10 meters (10 to 33 feet). The difference in rise predicted between different models is small for the next two or three decades so there will be little evidence in the near term pointing toward a clearer estimate.

If you can reverse it, is it locked in?

Both warming and sea level rise can theoretically be halted or

reversed by geoengineering methods: removing carbon dioxide to reduce the greenhouse effect (carbon dioxide removal, CDR) or reflecting sunlight (solar radiation management, SRM). There are dozens of proposed methods of each. Some are pretty innocuous, such as growing more forest to remove carbon dioxide and having more white roofs to reflect sunlight. Others, such as fertilizing the ocean to encourage algae or phytoplankton growth, have side effects and could get out of control.

At present, they are considered by most to be impractical, too expensive or too dangerous. Keller, et al. say, “At present, there is little consensus on the impacts and efficacy of the 60 different types of proposed CDR.” This is also true of solar radiation management, about which there is considerable concern about adverse effects. In any case, it is unlikely these methods will be implemented on a significant scale for at least two or three decades.

Why Should We Care?

It’s hard to get people concerned about possible events hundreds, or even thousands, of years in the future. James Hansen says, “nobody cares about matters 1,000 years in the future.” However, these are serious matters. Sea level rise of several meters has significant implications for displacement of populations, damage to infrastructure and loss of land.

Several visualizations available online show the effect of even modest sea level rise. The photo below is a NOAA simulation of 1-meter (4 foot) rise at Galveston, TX. We are very likely facing amounts of sea level rise with serious consequences even at temperatures we have already reached.



Source: NOAA

What is to Be Done

Significant sea level rise is unavoidable. Adaptation will be necessary.

The uncertain rate of sea level rise makes planning difficult. A 2015 report by the New Zealand Parliamentary Commissioner for the Environment discusses the choice of time horizons. They describe that a 50-year planning horizon may be sufficient for projects with a short intended life and a 100-year planning horizon may not be enough for those with a long life. Their recommendation is to use a timeframe “appropriate for different types of development.”

What is necessary or feasible will vary by location. Levees, tidal barriers, seawalls and elevating infrastructure may be possible. It would make sense not to allow new development in low-lying areas. Adaptation methods are extensively discussed in the IPCC Fifth Assessment Working Group II Report. ■



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