

2019-2020 | AN ONLINE ENERGY CONVERSATION

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FACULTY
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FELLOWS

UNIVERSITY of HOUSTON

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UH Energy is an umbrella for efforts across the University of Houston system to position the university as a strategic partner to the energy industry by producing trained workforce, strategic and technical leadership, research and development for needed innovations and new technologies.

That's why UH is the Energy University.

FACULTY ENERGY FELLOWS

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Selected from ten 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.

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Published September 19, 2019 on HoustonChronicle.com

IS THE CHEMICAL INDUSTRY SAFER AFTER HURRICANE HARVEY? DON'T BET ON IT (OPINION)

RAMANAN KRISHNAMOORTI

Chief Energy Officer, University of Houston

It has been two years since Hurricane Harvey and the explosions that rocked the Arkema plant in Crosby, and we are once again at the height of hurricane season. Just last spring, there were four substantial chemical fires in the Houston area within the space of five months.

What have regulators and the chemical industry done over the past two years to ensure we don't see a repeat of 2017? Considering the fires last spring, there is little visible evidence that we are ready for another Harvey.

We've been lucky, but recent satellite images of Hurricane Dorian are a reminder that we are unlikely to remain so forever. Legislators and industry have made efforts to address the risk, but there is little to show for it. As industry infrastructure is expanding rapidly along the Gulf Coast to serve growing production and exports, we can't afford to wait.

Last spring's fires at International Terminals Co., KMCO and two at ExxonMobil were different from what happened during and after Harvey, which exposed deficiencies in systems engineered to avoid just such chemical failures. But with 4,100 storage tanks along the Houston Ship Channel, according to research by one of my colleagues at the University of Houston, the performance and resilience of those tanks is of paramount importance.

A report by the PENTA Consortium LLC commissioned by Harris County earlier this year offered another metric: 110 chemical facilities in Harris County have hazardous chemical inventories in excess of 10 million pounds. More than 75,000 people live within half a mile of these facilities.

The Arkema plant offered a dramatic example of what can go wrong. When Harvey's floodwaters knocked out electrical power, chemicals that required freezing conditions to remain stable began to heat up, exploding on Aug. 31 and Sept. 1, 2017.

That wasn't all. According to the industry's own reporting to the state, 8.3 million pounds of un-permitted air pollution was released during and after Harvey due to electrical outages, unanticipated shutdowns, equipment malfunctions and the failure of storage tanks. More than 15 storage tanks holding crude oil, gasoline and other hydrocarbons and outfitted with floating roofs designed to rise and fall with the volume of their contents failed, resulting in 3.1 million pounds of pollutants released into the atmosphere.

There have been some efforts to address the problems. The state Senate Committee on Natural Resources and Economic Development submitted an interim report to the Texas Legislature last December and recommended retrofitting all existing external floating-roof tanks with geodesic dome covers. The Texas Commission on Environmental Quality estimated there are about 1,500 such tanks along a 50-mile stretch of the Gulf Coast, with retrofitting costs ranging from \$500,000 to \$1.6 million per tank. It said it doesn't have authority to require the change.

State Sens. Carol Alvarado D-Houston, and Nathan Johnson D-Dallas, filed Senate Bill 1446 earlier this year, addressing some of the challenges. The bill never made it out of committee.

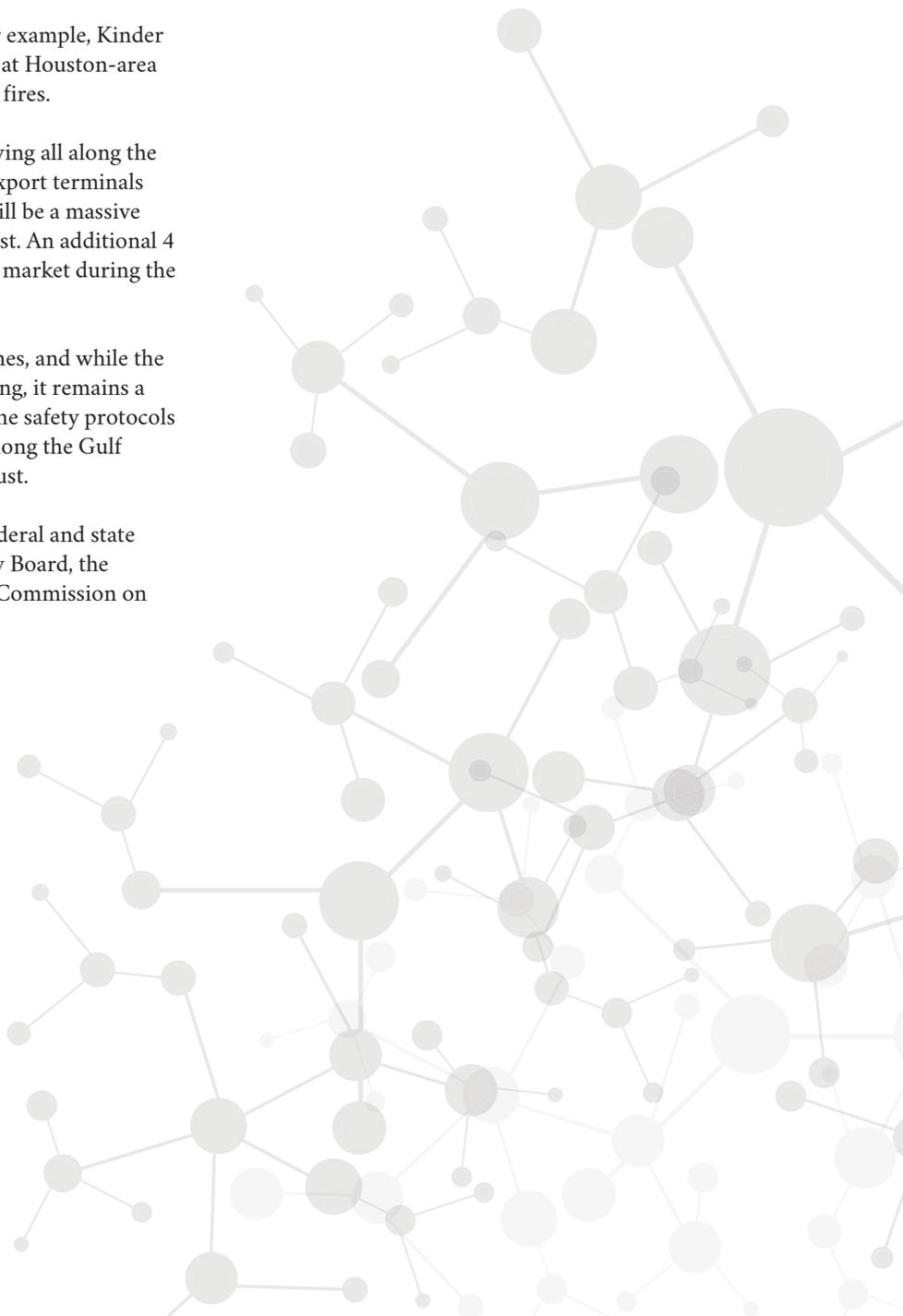
We know how to reduce the risks but plans to do so have not been implemented.

Industry is addressing some of the challenges. For example, Kinder Morgan is investing more than over \$170 million at Houston-area facilities to reduce the risk of spills, accidents and fires.

But there is much more to do, and the risk is growing all along the Texas coast. Chemical infrastructure and crude-export terminals are sprouting in Corpus Christi, meaning there will be a massive increase in chemical storage capacity near the coast. An additional 4 million barrels of crude oil per day will enter that market during the next three years.

We know the Texas coast is vulnerable to hurricanes, and while the track record for chemical storage may be improving, it remains a matter of serious public concern. Strengthening the safety protocols required of new chemical storage facilities built along the Gulf Coast would be a start toward regaining public trust.

A strong partnership between industry and the federal and state governments - perhaps led by the Chemical Safety Board, the Environmental Protection Agency and the Texas Commission on Environmental Quality — could make it happen.



Published September 20, 2019 on Forbes.com

THE FUTURE OF ELECTRIC VEHICLES: WILL U.S. MANUFACTURERS LEAD?

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National Drive Electric Week 2019 is underway in the United States, with organizers hoping to underpin the growth of electric vehicles and highlight the benefits of EV ownership. While the long-term impact on car manufacturing jobs appears murky, there is little doubt that there will be more market penetration of EVs in the next decade, especially with manufacturers such as Volkswagen, Mercedes-Benz, and Volvo setting phase out dates for internal combustion engine-only cars.

In the coming years, there is no logical reason why, if there is a two-car family, one of those cars should not be an EV. While the upfront costs of EVs are currently more than your middle or low-end car on the road, EVs cost significantly less in the long term. Prospective car buyers have to remember, with an EV, you do not have to pay for gas, change the oil, or even redo the transmission. When it comes to maintenance, you are really only paying for tires and possibly the a/c if it were to go out.

If EVs are less expensive than traditional cars in the long run, what is hindering their growth? It mostly comes down to range and hesitant car manufacturers. The largest current impediment to public perception of EVs is that of range. People want to be able to travel 500 miles without stopping, even though you couldn't do this with your traditional combustion engine car. Growth of the EV industry also depends on what manufacturers do—when they begin the wholesale transition to producing EVs. The EV industry is not so much demand driven but supply driven. One automobile manufacturer just has to take the risk of transitioning and thereby break the floodgate. It really just depends on a single strategic decision by one of the major automobile manufacturers.

As for another public perception issue, at least to those working in the automobile manufacturing industry, there is the concern that transitioning to EVs will cause many to lose their jobs. During the transition to EVs, there will be some job loss because there are simply fewer parts going into an EV. However, if U.S. manufacturers don't move fast enough, then they risk losing out to foreign manufacturers of EVs. Thus, if U.S. automobile manufacturers don't move at all, there is the risk that they will be at a severe disadvantage and miss out on what will likely be a major industry opportunity, which in the long term, could mean greater job loss.

When it comes to auto manufacturers and which ones will take that strategic step forward to be the lead innovators of EVs, it will probably be the ones you wouldn't expect right now. Ford, GE, Toyota, Volvo, Chrysler, and the other majors are all working on it and have for a long time. So far, there has been a lack of engineering progress and little movement on reducing the cost of manufacturing, battery pack notwithstanding. EVs are going to be an integral part of the future of transportation, and U.S. automobile manufacturers should take the strategic step forward to lead the transition by investing more in the technology behind EVs and figuring out how to reduce the cost of producing EVs. Only time will tell who will lead this movement. But one thing is certain: U.S. manufacturers do not want to drag their feet.

Published September 23, 2019 on Forbes.com

PAY NOW OR PAY LATER: THE CERTAIN COST OF CLIMATE CHANGE

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The UN Climate Summit 2019 got underway Monday, just in time for a populist groundswell in favor of climate action that cannot be ignored. Greta Thunberg has galvanized millions of our children. The climate strike and worldwide outcry over the burning of the Amazon's rainforests contrast with the Trump administration's move to relax automobile emission requirements and roll back methane emissions rules. Why this confusion?

The paths to reduce greenhouse gas emissions are well known. One question is how to implement them economically. The second question is whether a lower expenditure now can avoid a major planetary expenditure later—think World War III but with all nations fighting a common enemy, ourselves. Increasingly, industry and consumers in the U.S. and around the world are voting to reduce emissions to combat climate change. The primary approach is the reduction of fossil fuel combustion. The secondary approach is capturing fugitive CO₂ emissions or removing CO₂ from the atmosphere for long-term sequestration.

Cost of inaction

Since the early 1970s, the economic impacts of global warming have been analyzed and forecast. Each approach is informative. The late Harvard economist Martin Weitzman discussed the uncertain costs of irreversible environmental damage. To expand on MIT economist Robert Pindyck's use of Joni Mitchell's "Big Yellow Taxi:"

That you don't know what you've got 'til it's gone

They paved paradise
And put up a parking lot

The probabilistic odds of a certain outcome may be small, but the ultimate cost may be more than society can bear. In this sense, global warming falls into the same category as the preventable nuclear accidents of Fukushima and Chernobyl, except that the scale is larger than Hurricane Dorian's impact on the Bahamas or Hurricane Maria's impact on Puerto Rico.

Nobel winning economist William Nordhaus developed his Dynamic, Integrated Climate Economics ("DICE") model to consider the economic impacts of climate change and provide cost-benefit analyses of alternative policy decisions. The model is a very useful baseline tool for policymakers to attempt to forecast policy outcomes and in using the model, Professor Nordhaus has analyzed the costs of environmental damage and the ineffectiveness of international treaties and accords to reduce greenhouse gas emissions. He proposes a solution using a "Climate Club" to provide a mechanism for nations to work together. For those members of the club that do not adhere to an agreed greenhouse gas reduction target, the other members would impose a tariff on the offenders' exports. Professor Nordhaus estimates that a 3% tariff penalty would be the optimal charge that the world economies would accept while shouldering the internal costs necessary to reduce greenhouse gas emissions. The club would penalize free-riders.

Direct policy tools—cap-and-trade or carbon tax
Governments have implemented one of two schemes to provide market-based incentives to reduce carbon emissions.

Cap and Trade describes a policy that fixes an absolute limit on the emissions of carbon by point source. Those so regulated will gain credits for reducing carbon emissions below their caps and may trade these off to other regulated entities who exceed their carbon emissions cap. The intent is that a market-based price will provide incentives for at least some of the emitters to invest in new processes that reduce carbon emissions.

In practice, the scheme has a mixed track record. Because carbon emissions are directly related to economic activity, recessions can cause caps not to be binding upon the market and the value of the credits plummets to zero. Credit trading creates a cottage industry of intermediaries and speculators whose interests are not aligned with the goal of carbon reduction. Self-reporting of carbon emission and enforcement of the caps can confound market transparency. For these reasons, some economists and members of industry have settled upon a carbon tax as the appropriate policy tool.

Cap-and-trade failed to pass in the Democratic Congress in 2008 against the backdrop of the presidential campaign and the onset of the Great Recession. Multi-state initiatives instituted in the Northeast and in Western states appear to have at least accelerated the closure of some coal-fired electricity generation plants.

The alternative, a carbon tax, is a tax imposed upon the point source emitter. Taxes are generally easier to administer, collect and enforce than cap and trade schemes. The Climate Leadership Council's recently updated "Baker-Shultz Carbon Dividends Plan" is a revenue neutral plan that collects carbon taxes from industry and distributes the proceeds equally to citizens. This call for a carbon tax purports to be a zero sum game designed to encourage consumers to avoid carbon intensive fuels with the promised payoff of carbon taxes paid by other consumers who are not so able to change fuels. The plan appears not to consider the intra-U.S. localized impacts of plant closures, localized layoffs and anticipated rent-seeking behavior by consumers that also plagued the 2008 cap-and-trade bill. For example, carbon intensive manufacturing in Texas, Louisiana and Pennsylvania would transfer large amounts of money to consumer states. The manufacturing states would lose more in revenues than they gain

in carbon tax dividends.

Removing carbon directly from the atmosphere

Providing an economic incentive to reduce fossil fuel emissions via a carbon pricing mechanism is one way to go about the problem. A different tack will be to remove carbon directly from the atmosphere. These approaches have technological merit and the second-order impact of economic development. The Salk Institute's research is to increase and change agriculture by a globally modest amount such that plants and grasses capture more CO₂. Other innovators plan to tackle CO₂ directly by converting the carbon to ethanol and, essentially, creating a closed loop system with the carbon already present in the atmosphere.

Climate change does not discriminate. Few can forget that it was only when the ozone hole expanded over Kennebunkport, Maine, that President G. H. W. Bush was spurred to act against Freon and other chlorofluorocarbon gases. The event that causes U.S. policymakers to take positive action against rising greenhouse gases has not yet occurred. Still, a large, bipartisan majority of voters want action. We can decide which policy is best and most cost-effective now.



Published September 24, 2019 on Forbes.com

POLLUTANTS RELEASED DURING TROPICAL STORM IMELDA ARE A WAKE UP CALL FOR THE CHEMICALS INDUSTRY

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Over the last week, Tropical Depression Imelda dumped more than 40 inches of rain across the chemical corridor between Houston and Beaumont, causing at least five deaths and as much as \$8 billion in damage, most of it in Southeast Texas. Just a little over two years since Hurricane Harvey hit the region hard, leading to the explosions at the Arkema plant in Crosby northeast of Houston, we are once again reading reports of significant releases of chemicals related to this latest storm.

Early self-reporting indicates that tens of thousands of pounds of pollutants, including carcinogens such as butadiene and benzene, have been released into the air in Southeast Texas as a result of Imelda. The emissions were caused by a variety of things that tend to go wrong during these epic weather events – electrical outages, unanticipated shutdowns, equipment malfunctions and the failure of storage tanks. That’s much like what happened during and in the aftermath of Harvey.

In the wake of Harvey, the industry self-reported to the state of Texas that 8.3 million pounds of unpermitted air pollution was released from the region’s chemical plants. That’s in addition to the failure of more than 15 storage tanks with floating roofs, holding crude oil, gasoline and other hydrocarbons, failures that resulted in the release of 3.1 million pounds of pollutants into the atmosphere. The Environmental Integrity Project last year produced an extensive catalogue of air and water pollution caused by the storm.

Legislators and industry have made efforts to address the risks since Harvey, but there is little to show for it. As industry infrastructure is expanding rapidly along the Gulf Coast to serve growing oil and gas production and exports, we cannot afford to wait.

Harris County commissioned a report by the PENTA Consortium LLC earlier this year, which found that 110 chemical facilities in Harris County have hazardous chemical inventories of more than 10 million pounds. And these facilities are located within a half-mile of the homes of more than 75,000 people. But Harris County isn’t an isolated case. We anticipate a similar challenge in Corpus Christi on the Texas coast as that area prepares for substantial growth from the chemicals industry.

As mentioned, there have been efforts to address the problems, including the recommendation last December by a legislative committee to retrofit all external floating roof tanks with geodesic dome covers to reduce the risk of failure. There are about 1,500 such tanks along a 50-mile stretch of the Gulf Coast, with retrofitting costs ranging from \$500,000 to \$1.6 million per tank, according to the Texas Commission on Environmental Quality, or TCEQ. The state’s environmental agency has indicated it lacks the authority to enforce the change for both existing “brownfield” or new construction “greenfield” facilities.

Texas state senators Carol Alvarado and Nathan Johnson earlier this year filed a bill that would have empowered TCEQ and addressed some of the challenges in chemical storage. The bill died in committee.

We know how to reduce the risks of these potentially catastrophic failures, through such measures as requiring internal floating roofs for all new tank installations in locations that may be affected by a hurricane. Alternatively, we could also require floating roof tanks to be equipped with drain pipes large enough to handle most spills and leaks. Neither of these ideas have been implemented. With over 200 chemical facilities and 4,100 storage tanks along the 50 miles of the Houston Ship Channel, according to research by my colleagues at the University of Houston, the performance and resilience of those chemical facilities and storage tanks is of paramount importance.

The risk is growing all along the Texas coast and there is more to be done to ensure the safety of these facilities. Chemical infrastructure and crude export terminals are expanding in Corpus Christi and surrounding areas, meaning there will be a massive increase in chemical storage capacity near the southern Gulf coast over the next two to three years. An additional four million barrels of crude oil per day will enter that market over the next three years, and capacity building for processing and export of that crude along the coast of Corpus Christi remains the biggest bottleneck.

We know the Texas coast is vulnerable to tropical storms and hurricanes, and while the track record for chemical facilities and storage may be improving, it remains a matter of serious public concern, especially in light of the failures during Imelda.

Strengthening the safety protocols required of new refineries, chemical plants and chemical storage facilities built along the Gulf Coast would be a start toward regaining public trust. This cannot wait for the next Texas Legislative session to start the work.

Published September 26, 2019 on Forbes.com

FEDERAL CARBON PRICING IS CLOSER THAN YOU THINK

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The Climate Leadership Council this month released a revised carbon pricing plan that dropped its demand that any carbon taxing scheme also be accompanied with a pre-emption of legal nuisance claims against energy producers and users. I see this as an important development. Despite the impression that many have, carbon pricing seems poised to enter the mainstream political debate.

The Climate Leadership Council's announcement shows that many of the possible sticking points and side issues seem to be making way for a legitimate push for carbon pricing. Economists have long argued that the most efficient and effective way to lessen the impact of greenhouse gas emissions is to price them – forcing emitters to pay and paying those who pull the emissions out of the air. This creates the incentives which move the invisible hand of multiple entrepreneurs and investors towards the lowest cost reductions. Economy wide pricing can occur through taxes or through a cap and trade system. While there are differences between the two, both could provide the effective pricing system called for by economists.

Pricing of greenhouse gas emissions doesn't solve all of the issues surrounding climate impacts. By itself, it does nothing to compensate or assist those impacted by climate change, and it doesn't account for co-pollutants. But government pricing of pollution could only move the needle in the right direction, regardless of what other climate change policies, such as better renewable infrastructure, were in place. In addition to its support from the Republican-initiated Climate Leadership Council, it is supported by other conservative groups and Democratic policy makers as well. Though carbon pricing is not

mentioned in the Green New Deal, many of the leading candidates for the Democratic presidential nomination support it.

California has a well-functioning law that prices carbon, and CO₂ emissions are also priced in the electricity sector in the Northeast. But despite examples of functioning systems, near universal agreement that it is the most cost-effective solution to lower greenhouse gas emissions and increasing bipartisan support, it may seem we are no closer to carbon pricing at the federal level than we were after the collapse of the Waxman-Markey climate bill in 2010. To the astute observer, however, such pricing may be closer than appears. Perhaps most importantly, the major proposals have inoculated themselves against the claim that they are just another "tax" by suggesting any moneys collected be returned directly to the public on a per capita basis. Not only does this take the government spending issue off of the table, it also goes far in rebutting the charges that such emissions pricing will fall hard on those with low incomes. Low-income residents spend less on energy than higher income individuals and so on average should actually profit from a pricing system that returns money to the American public on a per capita basis.

Probably related to the coalescence around making carbon pricing revenue neutral, there is much more significant support from major Republican figures than there was in 2010, and the support keeps growing. While the biggest Republican supporters may be former public officials, the political case for Republicans to do something has also gotten stronger, as younger Republicans and conservatives see climate change as a central issue going forward.

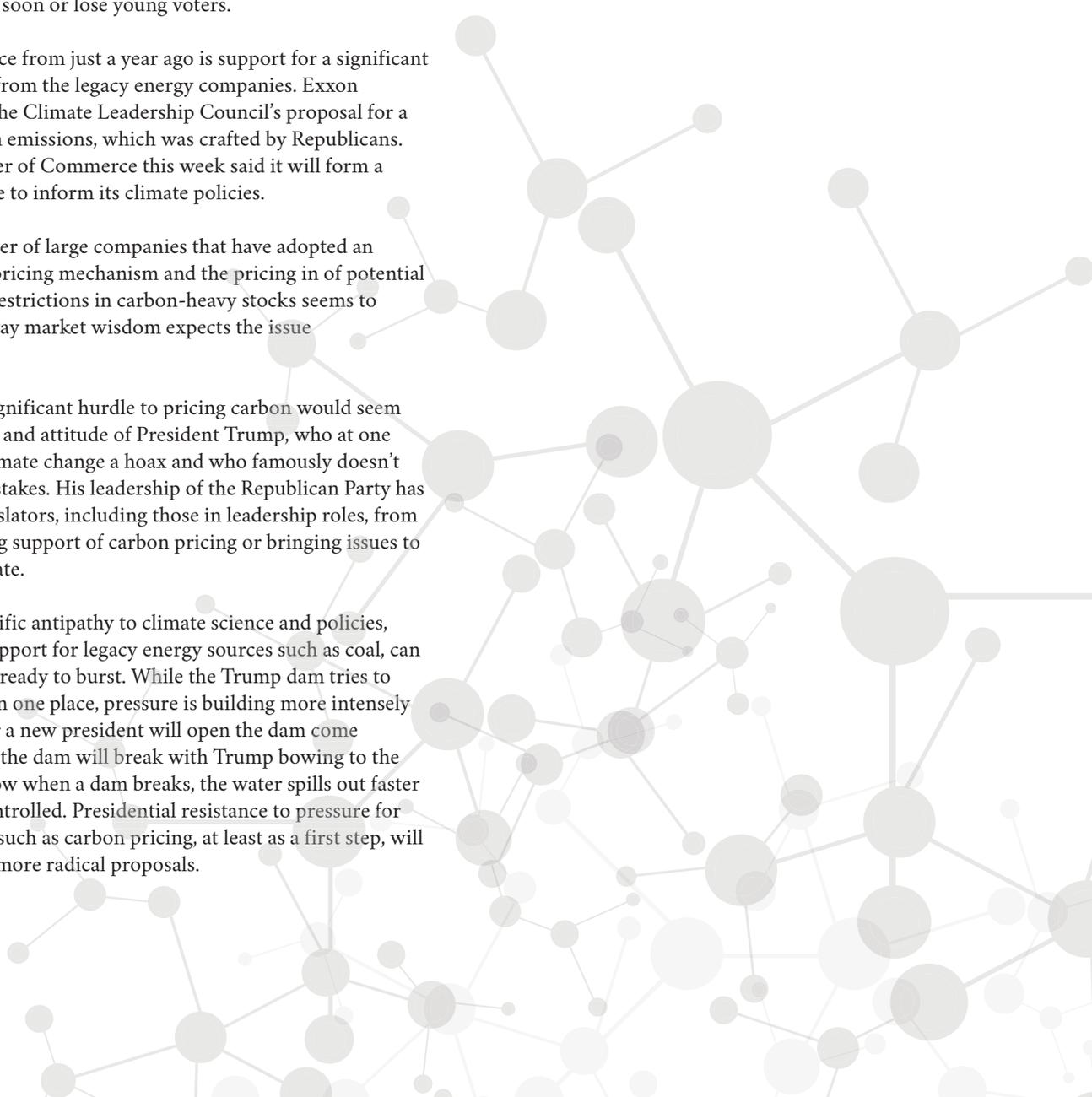
In fact Republican pollster Frank Luntz recently testified before Senate Democrats that he had been wrong to try to make climate a wedge political issue, and his message for Republicans is to address the issue soon or lose young voters.

Another difference from just a year ago is support for a significant price on carbon from the legacy energy companies. Exxon Mobil supports the Climate Leadership Council's proposal for a significant tax on emissions, which was crafted by Republicans. The U.S. Chamber of Commerce this week said it will form a climate task force to inform its climate policies.

Finally the number of large companies that have adopted an internal carbon pricing mechanism and the pricing in of potential greenhouse gas restrictions in carbon-heavy stocks seems to indicate which way market wisdom expects the issue to go.

The only truly significant hurdle to pricing carbon would seem to be the policies and attitude of President Trump, who at one time declared climate change a hoax and who famously doesn't admit to past mistakes. His leadership of the Republican Party has cowed many legislators, including those in leadership roles, from publicly declaring support of carbon pricing or bringing issues to the floor for debate.

But his very specific antipathy to climate science and policies, along with his support for legacy energy sources such as coal, can be seen as a dam ready to burst. While the Trump dam tries to hold the debate in one place, pressure is building more intensely for action. Either a new president will open the dam come January 2021, or the dam will break with Trump bowing to the pressure. We know when a dam breaks, the water spills out faster and can be uncontrolled. Presidential resistance to pressure for sensible policies such as carbon pricing, at least as a first step, will likely embolden more radical proposals.



Published September 30, 2019 on Forbes.com

POLITICIANS PROMISE QUICK CLIMATE ACTION. THAT'S NOT THE MOST EFFECTIVE SOLUTION. CARROTS VS. STICKS: WHAT WORKS TO ADDRESS CLIMATE CHANGE

JOHN HOFMEISTER

Founder and Chief Executive Officer, Citizens for Affordable Energy

The Current Reality:

As the Presidential campaigns evolve, candidates' promises on how they will address the future of energy will inevitably include their solutions for climate change. That articulation is expressed as their public policy mandates.

They will abbreviate complex issues and provide sound-bite solutions, regardless of the implications for our wider economic, social, political or cultural systems. The momentum of popularity and crowd applause, along with endorsements by narrow special interests and the potential campaign funding from both, will drive them to simplicity and clarity for the sake of convenience and communication, not explanation. Their comments about the current system are generally framed in pejoratives.

We hear rhetorical threats and promises: We have but 12 years to reverse course on energy to save the earth; I will ban fracking; the obscene profits of oil companies will pay for the pollution they've caused; fossil energy must remain where it is, in the ground; on Day One by executive order, I will do 'whatever it takes.' In short,

candidates are promising public policy mandates regardless of their personal knowledge or experience in energy or their willful lack of understanding of what they are promising.

Candidates are fundamentally misleading voters about climate change and potential solutions in order to win support. They are also pledging, perhaps without knowing it, economic harm and quality-of-life hardships on the very populations that can least afford to bear them. They discredit a century of sustained, dense, affordable energy supply to reconstruct the world's largest energy system. They promise to rapidly replace it with the uncertainties of the least dense, alternative and intermittent energy sources regardless of cost, disruption or inefficiency.

And yet climate change must be addressed if the nation will pass along to future generations as livable and productive and safe a world as past and current generations have enjoyed. There is consensus among scientists, environmentalists and energy companies, as well as a majority of the general population, that climate issues are the top public policy priority of our time. But we need to be rational, pragmatic and successful, not just promiscuously political, in order to solve the complex issues surrounding the future of energy and the environment. Public policy mandates made in the heat of campaign competition and

implemented when elected could lead to the worst, least successful and devastatingly harmful transformation imaginable.

Here's why:

The Risk:

Political fiats by politicians can destroy energy, but they can't produce it. The nation needs molecules and electrons to power the economy and the American way of life. These are the sources of all economic well-being in contemporary life.

Radical mandates will impoverish those closest to the poverty level, create massive unemployment and economic recession across the economy, deliver extraordinary increases in the costs of energy, and limit available supplies resulting in life-threatening outages, blackouts and fuel lines.

And what will those mandates do to solve climate change? Absolutely nothing. The United States acting unilaterally to restructure the energy we use, absent a coordinated and similar effort globally, cannot overcome the unremitting impacts of current energy supplies elsewhere. Political mandates destroy what they intend to achieve, as well as the careers of the political leaders making them.

Political time is defined as the time between the present and the next election. Like the fools' gold of crash diets, promises made in political time don't deliver. Candidates for office choose which policies to promote based on intent and expedience. Democracy has many attributes. Its rights and freedoms beat all other governance alternatives. It can also be messy, nasty, unpredictable and untruthful as the electoral process unfolds. And lying is not a crime.

But political-time promises damage the integrity of elections. And two years later we're right back at it, reversing course on the recent past, correcting the conditions the last candidates created. Government mandates cannot be the source of solutions to climate change.

Enablers and the Power of Markets:

In time, carrots win over sticks. Mandating the destruction of the

current energy system is the stick. Carrots will enable a complete energy transition over a realistic, adaptive timeframe, delivering permanent and lasting change. The power of markets to change behaviors and preferences, consumer choices and technological solutions is paramount. Such power overwhelms government. Witness the overtaking of communications and information management by the market preferences Silicon Valley has created. We are forever changed over the course of a few decades, not by political mandate but by the force of markets. We need to provide the enablers of energy change in order to create the market forces that will transition the current system to low- or no-carbon systems over the coming decades. Appropriate enablers will attract investors, innovators and entrepreneurs as well as current companies to pursue technologies that move us from the dominant fossil fuel energy system to low- and no-carbon energy. A price on carbon is the starting point. Additional incentives of tax policies, investment write-offs, government-assisted research and development, enabling regulations and fair market competition would add force and speed to the transformation.

It is inexcusable that political leaders have until now failed to enable a more rapid build out of new energy alternatives and redefined nuclear solutions to produce more zero-carbon energy. They have also not incentivized the re-use of the carbon dioxide waste stream to enable new products that prevent CO₂ release. Most significantly, they have done nothing to enable the direct removal of carbon from the atmosphere. Environmentalists, energy companies and citizens have been requesting help in all these areas for the better part of two decades.

In other words, the failure to create market enablers while we are fighting over government mandates have failed the nation's energy transition. Where is the shared responsibility and accountability for leadership? Energy is not provided by criminal technologies, practices, companies or people. It has been provided by hard working, intelligent, technically competent people and companies. Those people and companies enabled building the world's largest economy and highest quality-of-life on earth. Instead of mandating their demise, let's enable them and the nation's future to deliver a low- and no-carbon energy future.

Published on October 3, 2019 on Forbes.com

DEMAND RESPONSE: AN UNTAPPED ENERGY RESOURCE FOR THE GRID

ELIZABETH GEORGE

UH Energy Scholar

With increasingly hot summers, energy companies are having difficulty meeting demand, and the threat of blackouts looms ever closer. Energy companies and utility commissions are going to have to rethink how grid reliability is maintained in order to increase the available supply of electricity to meet growing demand. Demand response, a program that pays consumers to reduce their electricity usage at periods of peak demand, could help strengthen grid reliability and should be an integral part of this reframing.

In August, the Electric Reliability Council of Texas (ERCOT), the grid operator for much of Texas, reported a record high for energy demand due to the abnormally hot temperatures. ERCOT also reported a historically low reserve margin of 7.4% due to the retirement of several large generators.

A reserve margin is the anticipated availability of electricity compared to the predicted demand for electricity. When energy capacity or supply is not enough to meet demand, the electrical grid crashes, and people lose their access to electricity.

By paying consumers, like households and businesses of any size, to reduce energy consumption, generators and public utility commissions can effectively create a new energy source that has the added bonus of negative carbon emissions. Demand response participants are seen as generators, or producers of electricity, because by reducing energy consumption, they are effectively increasing the available supply of electricity.

There are currently several demand response products available in the ERCOT region, including programs administered by ERCOT and by utility companies. In 2017, peak demand was reduced by about 3.7% through utility-run demand response programs across the ERCOT grid, the largest amount achieved by any grid operator in the United States. However, demand response is still a largely untapped resource because not all utility companies have programs and the ERCOT programs are limited in scope. Thus, there is still ample room for demand response to grow.

For example, were the Public Utility Commission of Texas (PUCT) to require all utility companies to have demand response programs, peak demand would be reduced by significantly more than 3.7%.

In early 2013, the PUCT, which is charged with regulating ERCOT, requested comments from interested parties about the potential impact of demand response in the region served by ERCOT. There were over 65 submitted comments, and the majority of the interested parties expressed their desire for increased use of demand response as a tool in the ERCOT market for several notable reasons. For example, they said that because demand response is more diversely located geographically than generating plants, it can be tailored to achieve a specific amount of generation, with no negative environmental impacts.

The PUCT has yet to implement any of the recommendations arising from these comments.

There were several common suggestions that, if followed by the PUCT and ERCOT, would help increase grid reliability by fostering an electric market capable of supporting demand response.

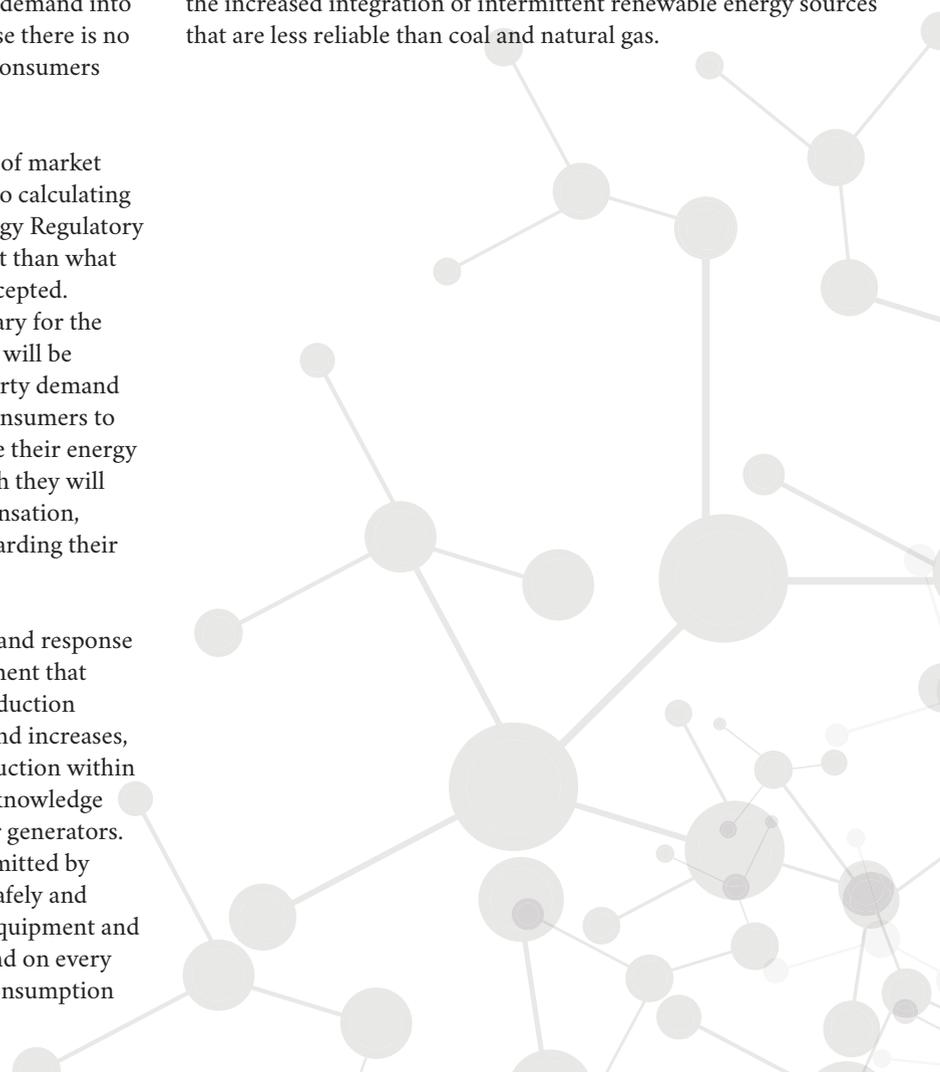
The Security Constrained Economic Dispatch (SCED) is the platform ERCOT uses to determine the most efficient distribution of all individual energy resources across the grid. Currently, participation on SCED is reserved to limited entities and does not allow customers wanting to engage in demand response to sign up on their own or with the help of a third-party services provider. Thus, demand response participation is severely hindered. In order to reverse this trend and promote demand response growth, the PUCT and ERCOT need to issue rules allowing third parties to sell the reduction of demand into SCED and to be paid for this transaction. Otherwise there is no great incentive to reduce energy consumption by consumers during extreme temperatures.

Additionally, the PUCT needs to decide what level of market inefficiency it is willing to tolerate when it comes to calculating demand response compensation. The Federal Energy Regulatory Commission (FERC) uses a method that is different than what the ERCOT Technical Advisory Committee has accepted. The PUCT has yet to address the issue. It is necessary for the PUCT to officially issue a set formula so that there will be market certainty as to how to compensate third-party demand response providers. In other words, in order for consumers to determine whether it is worth it for them to reduce their energy consumption, they need to know exactly how much they will get paid in return. Once a formula is set for compensation, consumers can make more informed decisions regarding their demand response participation.

Lastly, the chief technical barrier to increased demand response participation in the ERCOT market is the requirement that aggregated generators be able to adjust energy production within five minutes. Otherwise stated, when demand increases, generators must be able to “ramp-up” energy production within a 5-minute interval. This requirement does not acknowledge the reality of equipment, systems and processes for generators. Specifically, according to the PUCT comment submitted by MP2 Energy, five minutes is not enough time “to safely and reliably reduce load for most electric consumer’s equipment and processes; most equipment cannot be turned off and on every five minutes as might be required by SCED, and consumption

generally cannot be moved up and down incrementally at a customer’s location with fine granularity.” Implementation of a Multi-Interval Real Time Market could address this issue by changing the requirements of SCED to allow for slow demand response loads to participate in the real-time electricity market.

The PUCT has always been innovative when it comes to enhancing the ERCOT grid and improving overall reliability. Issuing new rules supporting demand response is the logical next step in the face of more extreme temperatures. It will become even more crucial with the increased integration of intermittent renewable energy sources that are less reliable than coal and natural gas.



Published on October 9, 2019 on Forbes.com

CAN CORPORATE SOCIAL RESPONSIBILITY BE LEGALLY ENFORCED?

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We live in a society that increasingly prioritizes accountability in all aspects of life, from the way our food is grown to the way men treat the women around them. People are tired of the “business as usual” approaches embedded in our culture and are demanding new social norms that take into consideration the marginalized and voiceless. Corporations, particularly oil and gas entities, can either recognize this trend towards social accountability or ignore it to their detriment, as weak corporate social responsibility is increasingly recognized internationally as a basis for transnational tort liability.

Corporate social responsibility (CSR) is a form of soft law. It is not required by U.S. statute or regulations, i.e., “hard law,” but is nonetheless seen as obligatory by most corporations because of consumer expectations and internal norms. Examples of CSR initiatives would be internal policies such as reducing carbon footprints to mitigate climate change, improving labor policies and embracing fair trade, engaging in charitable giving and volunteer efforts within the surrounding community, and making socially and environmentally conscious investments.

The expansion of the CSR business model can be seen in the number of major companies that have improved their environmental disclosure by publishing annual sustainability reports. For example, “85% of the companies in the S&P 500 Index published sustainability or corporate responsibility reports in 2017.” This is significantly up from the year 2011, when “just under 20% of S&P 500 companies reported on

their sustainability, corporate social responsibility, ESG [Environmental, Social and Governance] performance and related topics and issues.”

Consumer preference for social and environmental accountability is growing in the United States, and major companies are taking note.

Although Corporate Social Responsibility is a form of soft law, there is a trend internationally to move it to more legally enforceable hard law. Specifically, in 2011, the United Nations endorsed the “UN Guiding Principles on Business and Human Rights” (“UNGPs”). The UNGPs “provided the first global standard for preventing and addressing the risk of adverse impacts on human rights linked to business activity.” The principles build a legal framework of specifically defined rights, duties and causation, have been almost universally embraced and apply to all businesses, large and small. Thus, companies should have CSR programs that are “litigation ready” when it comes to human rights, because the UNGPs will inform the content of reasonable business practices, which has critical implications for transnational civil and commercial disputes. In other words, the UNGPs create transnational tort liability of corporations to third parties.

The Corporate Human Rights Benchmark, the first public benchmark of corporate human rights performance, illustrates that U.S. oil and gas companies are not currently doing enough to address human rights through their CSR initiatives. For example, in 2018, the Benchmark scored ExxonMobil at 18.5 out of 100 and Chevron at 28.8 out of 100. Factors that make up the score include governance and policies, embedding respect and human rights due diligence, remedies and grievance mechanisms,

company human rights practices, responses to serious allegations and transparency.

Thus, because U.S. oil and gas companies have numerous international operations, many of which are in areas that have prevalent human rights issues, oil and gas companies need to go above and beyond what U.S. law requires in order to meet the UNGPs and avoid future transnational tort liability.



Published on October 16, 2019 on Forbes. com

ENERGY PROJECTS AND ENDANGERED SPECIES DON'T HAVE TO BE AT ODDS

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The tiny dunes sagebrush lizard has proved a tenacious obstacle to energy production in the Permian Basin, as conservation groups urge its protection from risks posed by hydraulic fracturing and the mining of frac sand.

But protecting endangered or threatened species doesn't have to pose an insurmountable barrier for energy companies. It's possible for companies to take proactive measures which result in benefits for wildlife without wrecking their bottom lines.

The Endangered Species Act (ESA) states that species are to be protected because of their "esthetic, ecological, educational, historical, recreational, and scientific value" to the United States. It provides the procedures and standards for determining which species should be protected and how much of their habitat needs to be protected in order to conserve those species.

Two sections of the act are relevant to energy projects, both those dealing with renewable energy and those involved in fossil fuel extraction. Section 7 imposes both procedural and substantive duties on federal agencies whose actions may jeopardize the protected species or adversely affect their habitat. Section 9 prohibits anyone from engaging in actions that might harm threatened or endangered species.

The Trump administration has issued rules that interpret the Endangered Species Act in three major ways expected to weaken protection for threatened and endangered species – definitions inscribed in the act that indicate the level of risk faced by a species. First, instead of giving the U.S. Fish and Wildlife Service the authority to give threatened species the same protections as

are given to endangered species, the new rule tailors protections to each threatened species. Thus, threatened species are now given fewer protections than they had previously, and thus are more likely to end up endangered.

Second, unoccupied critical habitats – areas recognized as important for the recovery of a species – will only be designated when the habitats currently occupied by the species at risk have become inadequate to ensure the preservation of the species or if there is some other specified benefit for the designation. Accordingly, less habitat is protected and preserved, even though scientists say more habitat will be needed as species migrate in order to adapt to climate change.

Third, the ESA provides that listing decisions be made "solely on the basis of the best scientific and commercial data available." However, the new Trump administration rule allows for a cost-benefit analysis to be included when a new listing is proposed. The administration argues the cost-benefit analysis will be used for information purposes only, but it appears likely the results will sway decisions on whether to list an animal as endangered, even if the listing agencies choose not to admit it.

Although the changes have weakened the act, it might actually be more prudent for energy companies to take a proactive approach when it comes to addressing threatened or potentially threatened species on land intended for the project. For example, one could argue that the cost of seeking a Habitat Conservation Plan or a Candidate Conservation Agreement with the Fish and Wildlife Service is much less expensive than fighting a lawsuit instigated by environmental or citizen groups halfway through a project.

Habitat Conservation Plans are conservation plans required as part of an application for an incidental take permit, which allows one or more members of a listed species to be killed if the activity is otherwise in accordance with the law. These plans can be sought for both listed and non-listed species, including those that are candidates or have been recommended for listing.

Candidate Conservation Agreements are voluntary agreements between the Fish and Wildlife Service and one or more private or public parties that design and implement conservation measures to protect species that are candidates, or likely to become candidates, for listing under the Endangered Species Act. The agreements can include assurances that participating property owners will not later become subject to more severe conservation measures beyond those in the agreement.

By conserving species before they are on the brink of extinction, energy companies can potentially prevent the need for listing and avoid the possibility of more stringent regulations. Stated differently, energy companies have the opportunity to negotiate conservation methods, as opposed to having stringent regulations forced upon them. Additionally, the companies can avoid the cost of litigation with environmental groups and the risk of losing a project after significant investment.

A little foresight and ownership by energy companies in regard to threatened species can save a time and money in the long run.



Published on October 22, 2019 on Forbes.com

SMART LOW-CARBON CITIES – BIG CHANGES AHEAD

BRUCE RACE

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Research by climate scientists has shown that CO₂ levels and global temperatures are climbing faster than previously projected, and cities around the world increasingly are taking action, pursuing strategies to both reduce the amount of greenhouse gas (GHG) emissions they create and to increase the supply of renewable energy they consume.

As U.S. cities prepare their own pathways to becoming low-carbon communities, they will need to anticipate big shifts in energy generation and distribution, as well as how people move about the city and the way in which new structures are built.

The move to deploy internet-of-things (IoT) technologies to better monitor, track and optimize the performance of energy use, transportation systems and buildings will be crucial, as will new ways of thinking about infrastructure, transportation and building design.

A smarter grid

Our energy grid is designed to go one direction – out. It is big, complex and almost always reliable. Optimizing its climate performance means managing its complexity and making room for innovation, allowing communities to employ localized decarbonization strategies. The grid needs to be smarter.

Top-down vs bottom-up

For most of the United States, the national grid has been restructured to separate power generation (generation companies, or gencos) and transmission (transmission system operators, or TSOs). Generally, our national grid is a top-down and one direction operation. A bi-directional grid that incorporates local renewable energy strategies – that is, a grid that allows customers to feed excess power back into the grid, to

be distributed to customers that need it – can be greener and more resilient by allowing innovative power generation and sharing at the local level. Smarter community-scale solutions can reduce GHG and improve resilience.

Local community solutions and innovation

Electricity travels along regional high-tension power lines that connect to community-scale substations. These regulate the voltage for local power lines that again get a voltage adjustment on the pole-mounted transformers you see in your neighborhood. The power then comes off the local system through your meter. What if you could manage your power use and supply behind the meter, taking little or no energy from the grid? Or if you could even push power back into the grid, perhaps offering the system surplus power generated by rooftop solar panels?

And what if enough customers served by the community-scaled substation could do the same, avoiding the need to draw energy from the regional grid? A local system like this is called a microgrid. It has a reliable demand and supply of energy.

Resilient Microgrids

Microgrids and bi-directional systems can be connected to the regional grid as a backup or even a supplemental source of power. This type of diversified approach to electric power generation and distribution can add redundancy and modularity to the grid, making it more resilient to weather or other disruptions. It is also more complex, requiring a new approach to managing the grid in partnership with local communities and customers.

Blockchain ledgers and managing complexity

Blockchain is a method of digitally tracking complex sets of transactions. It can result in a ledger recording energy use

and supply for partners and customers within a microgrid. Blockchains are secure because everyone has an up-to-date version of their ledger. This approach to managing district-scale energy development merges microgrid and blockchain technologies and frees communities to pursue climate friendly solutions.

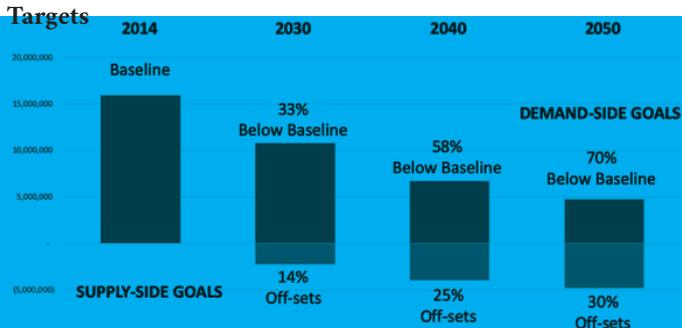
The smarter car

What we will be driving by 2025 will reflect the convergence of energy, technology and how we define transportation services. Auto manufacturers have ramped up research and development and are bringing the first generation of smart electric vehicles (EVs) to the marketplace; technology companies are exploring how to integrate their products into cars; and carsharing platforms are exploring a redefinition of personal transit.

A shift in transportation technologies and fuels

Cities are partnering with energy companies, universities and auto manufacturers to modernize the fleet and its supporting energy infrastructure. The transition from the petroleum-fueled internal combustion engine to electric vehicles powered by renewable energy will be key to meeting targets to reduce greenhouse gas emissions. For example, 89% of Houston’s on-road emissions are from household vehicles. The city’s Climate Action Plan emphasizes a transition in technologies and fuels for cars and small trucks in order to meet an overall target of reducing GHG emissions to 70% below 2014 levels by 2050. The gap in emissions performance is intended to be offset with additional renewable energy supplies (see graphic).

Houston Climate Action Plan On-Road Transportation



Source: B. Race, Center for Sustainability and Resilience, University of Houston.

The city of Houston and its partners are getting proactive. They have formed a collaborative approach to develop a regional electric vehicle (EV) infrastructure to support growing demand and to meet environmental goals. EVolve Houston is a partnership between the city, CenterPoint Energy, the University of Houston, and others, with a goal that electric vehicles will comprise 30% of the fleet by 2030.

Smart cities will provide systems of interactive devices connecting the grid, buildings and cars. Cars will become smarter, automated and up to eight times more fuel efficient. Imagine riding home in a car that you own or share as a transportation service, to a building that is expecting you.

More energy efficient intelligent buildings

Globally, buildings are responsible for 40% of GHG emissions. Building stock will increase by 60% by 2040 but will need to use 40% less energy to meet global targets for reducing GHG emissions. This will require innovation in building design, high expectations for energy performance and buildings that learn from the people who inhabit them.

Passive strategies are the smartest

My students in the University of Houston Gerald D. Hines College of Architecture and Design are learning to design buildings that respond to and improve their natural and built environments. They are learning that the smartest buildings are the ones designed to respond to the sun and prevailing breezes. They are starting with strong, passive strategies and augment them with active design and technology solutions.

Codes and building performance

Today’s students will be innovators, because building and energy codes are going to require them to be. In the U.S., states are using various versions of the International Building Code (IBC) and International Energy Conservation Code (IECC). This code system is reducing energy use in buildings by 30% every six years. By 2030, the codes will require new buildings to be net zero energy by reducing energy demand, offsetting the remaining energy demand with onsite renewable sources and incorporating energy from the grid generated by renewable sources. Starting in 2018, the IBC and

IECC has allowed two tracks: a traditional prescriptive track that spells out the performance of building components and a performance-based track that measures design innovation with energy model simulations. Existing buildings undergoing deep retrofits using the new codes can also greatly improve their energy performance and comfort.

Buildings that learn from us

The Internet of Things will connect our workplaces, homes, the grid, and cars in ways allowing them to learn to anticipate our energy use and reward good behavior, that is, behaviors that reduce energy use. There are already IoT products and services available that early adopters are purchasing to improve thermal comfort, energy efficiency, security and environmental (fire, flooding and air quality) monitoring. What if you could program these smart services just by living in your home? What if your workplace and home learned from you?

In the near future, these internet-connected services will use a combination of sensors, artificial intelligence and machine learning to anticipate and improve your user experience. In addition, they will reward good behavior, which reduces peak energy use and conserves resources, with lower energy costs.

Smart Low-Carbon Cities – Big Changes Ahead

There are big changes ahead for cities striving to reduce their climate impact. Leaders in these cities need to think about how and where the city should grow, about an equitable quality of life and about the ways technology can improve the social and environmental performance of cities. The IoT is becoming a key mode of information sharing and optimization, which can make cities safer and more comfortable while reducing their environmental impact. We also must remember that a spatially compact, social, stimulating and walkable city is a naturally low-carbon city. Adding smart technologies can make cities even better.



Published October 24, 2019 on Forbes.com

DO FALLING OIL PRICES MEAN TROUBLE AHEAD FOR HOUSTON'S ECONOMY?

BILL GILMER

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There are plenty of reasons to be concerned about Houston's economy: a national and global slowdown, a trade war with China, and political and economic problems emerging across Europe. For Houston, we add oil prices that have slipped from \$65 per barrel in 2018 to only \$57 through the first nine months of this year, and credit markets that have turned their back on the fracking industry. We are seeing an on-going credit crunch among local oil producers and service companies.

Houston's large oil base of 270,000 jobs is built on global engineering and manufacturing, and it is sensitive to the price of oil. How much does oil matter to the local economy? A combination of some careful statistical analysis and back-of-the-envelope calculations suggests that Houston's growth is about 10% from long-term advantages such as adequate land and limited regulation, 60% driven by U.S. growth, and 30% a product of oil. It is oil's volatility as much as its average contribution that makes it stand out in the local business cycle.

So far, it looks like alarm bells are premature. The decline in oil prices is modest, and despite some of the big industry names involved, the number and size of bankruptcies is a small uptick from last year. Certainly, current credit problems are far from comparable to 2015-16.

Houston's current oil struggles probably mean a modest downshift in growth from the healthy levels of 2018 and early 2019, but growth is still running just below trend rates and near 60,000 jobs per year. Of course, if we were to combine current oil problems with global or national recession, all bets are off.

A Decade of Boom and Bust

The last decade of boom and bust for the local economy has been mostly the product of oil prices. Figure 1 shows annual values for Houston's job growth, oil prices, growth in local oil jobs and national employment as measured by new jobs per month. Compare the stability of the national payroll figures during a decade-long national expansion to volatile oil prices that averaged \$96 during the boom years of 2011-14, \$46 during the 2015-16 bust, and \$58 since the bust ended. During the bust years, Houston saw the loss of 74,800 oil-related jobs and no overall job growth despite strong U.S. expansion. Recovery from the oil downturn since 2017 has brought moderate growth in total payrolls at 62,300 jobs per year.

What happened? Oil prices fell hard in 2014 with OPEC's decision to withdraw as swing producer in world oil markets, which was intended as a preemptive strike on American fracking. It was a project that largely failed, with U.S. production shrinking by less than a million barrels per day in 2015-16.

Then as soon as OPEC tried to raise oil prices in late 2016, U.S. fracking responded by soaring to all-time high levels by 2018 and beyond. OPEC learned two lessons: (1) It can't afford to hold prices low enough for long enough to do damage to U.S. fracking, and (2) Holding prices too high is just an incentive for the U.S. to produce too much oil. The current OPEC approach is to find a path between high and low, and just low enough to at least slow progress in American fracking. Oil prices near \$55 per barrel seem fit the bill, and with the help of a slowing global economy OPEC may be having some success in slowing the growth of U.S. production.

Figure 1: Houston's Economy in Boom, Bust and Recovery

	Houston Job Growth	WTI Oil Price (\$)	Houston Oil Job Growth	U.S. Job Growth (000/month)
2009	21,500	62.95	13,000	-297
2010	50,500	79.85	10,700	79
2011	82,900	94.88	25,200	173
2012	117,500	97.05	16,300	187
2013	90,000	97.98	11,400	194
2014	116,700	93.17	12,400	252
2015	-2,500	48.66	-46,700	228
2016	-2,400	43.29	-28,100	184
2017	54,200	50.80	9,200	188
2018	73,300	65.2	12,400	222
2019*	60,900	56.82	18,300	170
averages:				
2011-14	101,775	95.77	16,325	202
2015-16	-2,450	45.98	-37,400	206
2017-19	62,800	57.61	13,300	193

*To September and extrapolated or estimated by author. Sources are Bureau of Labor Statistics, FRED St. Louis Federal Reserve, and calculations of author

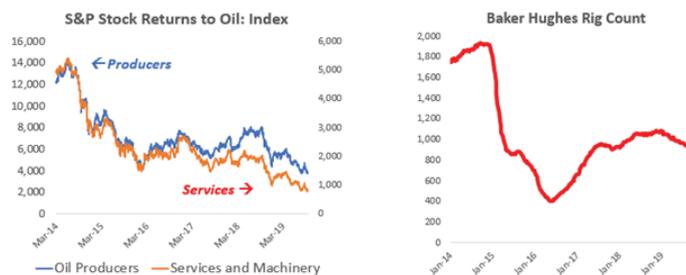
Credit Crunch and Industry Bankruptcies

The second concern for Houston's oil sector is the ongoing credit crunch, a leftover problem from the early years of U.S. fracking. The relatively new fracking industry is a clear break from the era of a few large oil companies dedicated to multibillion-dollar projects that take a decade to deliver. These producers form a competitive industry comprised of many small operators and price-takers; there are low barriers to entry; traditional drilling risk has largely disappeared; and there is a quick and certain return to the price incentives offered.

The current problems are less technical and more financial, the end of dreams of easy riches from overleverage and unlimited supplies of cheap capital. The industry has repeatedly failed to deliver either on either adequate profits or promises of a quick killing in the stock market. The result has been Wall Street largely turning away from the business, with the left side of Figure 2 showing the S&P stock price indexes for both U.S. producers and services. Both industries have seen their stock prices tumble to levels under even the lows of 2015-16.

Figure 2 also shows one practical consequence of the ongoing capital squeeze, with the rig count falling by more than 230 rigs so far this year, or 21.4%. Producers have been rationing capital all year in the face of limited access to capital and general economic uncertainty, cutting both capital spending and drilling activity. An upturn is not expected before sometime next year.

Figure 2: Lower Oil Prices and Efficiencies Pressure Profits, Lead to Lower Stock Prices, and Less Capital Spending



Baker Hughes, S&P Dow Jones to Oct 21, 2019

The other consequence of capital tightening has been a rise in the number of 2019 bankruptcies. There were 33 producer bankruptcies through September of this year based on secured and unsecured debt of \$12.98 billion, and 15 bankruptcies for service and machinery companies involving \$7.81 billion. As Figure 3 shows, while these numbers are concerning, they are an uptick from 2018 and far from a return to the 70 producer and 72 service bankruptcies in 2016, with a combined \$70.29 billion at stake. Given current trends, observers see industrywide financial stringencies required by management for several years, but it is not a business that looks like it is about to go over the cliff.

Figure 3: Oil Bankruptcies Tick Up in 2019: But Not an Epidemic

	Oil Producers		Oil Services		Billion \$ Bankruptcies 2019		
	Number	Debt (\$ bil)	Number	Debt (\$ bil)	Producers:	Debt (\$ bil)	
2015	44	17.38	39	5.31	Legacy Reserve	2.62	
2016	70	56.80	72	13.49	Sanchez Energy	2.28	
2017	24	8.54	52	34.74	Halcon Resources	1.66	
2018	28	13.15	12	3.89	Sheridan Holdings	1.11	
2019*	33	12.99	13	7.81	Jones Energy	1.06	
Services:							
						Weatherford	7.43

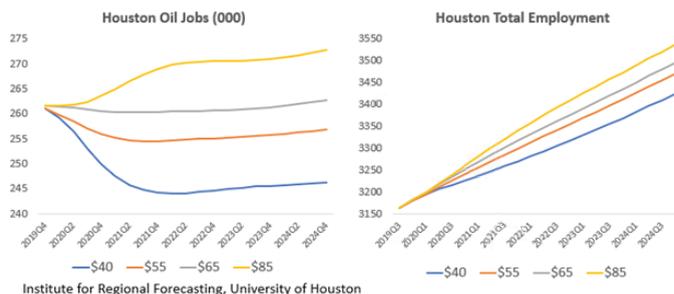
* Through September

Haynes and Boone, Oil Patch Bankruptcy Monitor

What Does it Mean for Houston?

If we see a downward adjustment in oil prices from last year's \$65 per barrel to a steady \$55 per barrel, and if credit problems remain contained to a relatively small number of specific firms, Houston oil problems should have limited consequences for its economic outlook. Using some statistical analysis, the oil price effects would work their way through the local economy by the end of 2022, and Houston's oil sector would then stabilize with 5,600 fewer oil-related jobs than it had in late 2019, a loss of about 2%. (See Figure 4.) On average, each year the sector would lose around 1,700 jobs compared to prior expectations. In contrast, if oil price rose to \$85, it would take Houston's oil-related employment up by an additional 9,700 jobs before leveling off in 2020; \$40 would have cost the region 16,500 oil jobs. It is the relatively narrow swing from \$55 to \$65 that limits today's damage.

Figure 4: By the End of 2022: \$55 versus \$65 Oil Means the Loss of Only 2.1% of Houston's Oil Jobs and 0.64% of Total Payrolls



Total employment in Houston by the end of 2020 would be 21,400 jobs fewer with oil priced at \$55, or total employment falls each year by about 6,600 job relative to what was expected. Fortunately, this slowdown is modest and begins from very healthy levels in 2019, with 2019 annual growth running near at 62,900 jobs, and then falling to only 56,300 by 2022. It is a modest adjustment to a forecast that moves local growth from trend to just below trend.

If Houston faces an economic setback soon, it is unlikely to be led by current oil problems. But as noted earlier, there are still plenty of other reasons to be concerned about the economic

future. Certainly, all bets are off in the face of recession. So far in 2019, the U.S. economy has slowed, but is not struggling. Indeed, the slowdown seen so far was built into most forecasts of 2019 and beyond, such as the Survey of Professional Forecasters from the Philadelphia Fed. This forecast was used as the economic backdrop for the oil price calculations above, and if it proves wrong and we see recession, both oil markets and Houston will suffer the consequences.

Published October 29, 2019 on Forbes.com

ENERGY SECURITY AFTER ABANDONING THE KURDS AND KILLING BAGHDADI

EMRAN EL-BADAWI

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Let someone else fight over this long blood-stained sand.” So said President Donald Trump after pulling US troops out of northern Syria. His announcement on October 6 gave Turkey the green light to cross the Syrian border and to storm Kurdish towns.

The Turkish onslaught continued for weeks, creating over 300,000 refugees almost overnight. The death toll rises, as Kurdish, Syriac Christian and other local populations have been killed. At least 100 ISIS fighters have escaped confinement by the Syrian YPG, the defense forces in Kurdish-held territories. Turkish-backed Syrian rebels are accused of committing atrocities. The Kurds have fled, with one-time foe Syrian president Bashar al-Assad appearing as an unlikely rescuer, while the Turkish and Russian premiers brokered a ceasefire and control over northern Syria.

Kurdish populations throughout the region, residing principally in Syria, Iraq, Turkey and Iran, see American withdrawal as an act of betrayal.

This disastrous sequence of events was described by President Trump as a “success.” Even he knows this to be false.

This is why on October 22—17 days after Trump ordered US troops stationed in Syria to finally ‘come home’—he announced plans to send them back to secure Syrian oil fields. In neighboring Iraq, retreating American forces from Syria were pelted with rocks. The Kurds there have initiated talks with Iran about oil trade.

Just days later, on October 27, President Trump announced US troops killed ISIS leader Abu Bakr Al-Baghdadi in northwest Syria. How does this latest wave of conflict in the Middle East impact the regional energy balance and global energy security?

Dividing the Energy Spoils

Despite the renewed violence, the Syrian civil war (2011-2018) is effectively over, thanks in large part to the Syrian and Iraqi Kurds who defeated the scourge known as the Islamic State (also known as ISIS or ISIL). Assad and his allies won. And to the victor go the spoils.

The Iranians and Russians now have greater control of the region’s oil and gas fields than ever before. This includes influence over vital energy arteries feeding Europe and Asia. Among these is the critical oil pipeline between Kirkuk, Iraq and Ceyhan, Turkey. After a failed bid for Iraqi Kurdish independence in 2017, the Iraqi central government and Iranian-backed Shia militias seized the disputed Kirkuk oil refinery from the Kurds by force. The U.S. and European Union did little more than express displeasure, essentially throwing Kurdish allies under the bus and ceding further power to Iran.

So the Kurds went to the Russians. In 2018 the Russian energy giant Rosneft both invested in and helped rebuild the energy infrastructure of Iraqi Kurdistan, damaged after years of war against ISIS. By year’s end, oil production had recovered and exports had resumed. Even oil exports to Iran resumed by early 2019, despite several interruptions.

To say this all differently: Moscow, Tehran and Baghdad worked out their differences, and restarted oil exports after ISIS. Washington had no part to play.

Lonely Empire

This puts the abrupt US foreign policy move in context. Trump wants to pull out of Syria, but he can't because that would leave Russia as the uncontested oil czar of both Syria and Iraq. Say what you will about the Russians. They have been competent partners in building up the region's energy infrastructure.

Syria exports a little more than 30,000 barrels of oil per day, mainly to Europe. That modest oil output pales in comparison to its strategic energy significance. Some blame the war in Syria on lucrative plans to build a pipeline between vast oil and gas reserves in the Persian Gulf on the one hand, and Europe on the other. Only time will tell if now is the end of the "pipeline war."

Still oil exports make up a quarter of Syrian GDP. The industry is nationally run, with European, Chinese and Indian investment. Syrian oil fields are concentrated in the southeastern province of Deir El-Zor, an Arab region bordering Iraq and controlled by Assad. The risk of conflagration is high. The US is already stretched thin, and its military interventions in Yemen have garnered widespread international condemnation. In the words of Russian president Vladimir Putin, US dominance is ending after mistakes "typical of an empire."

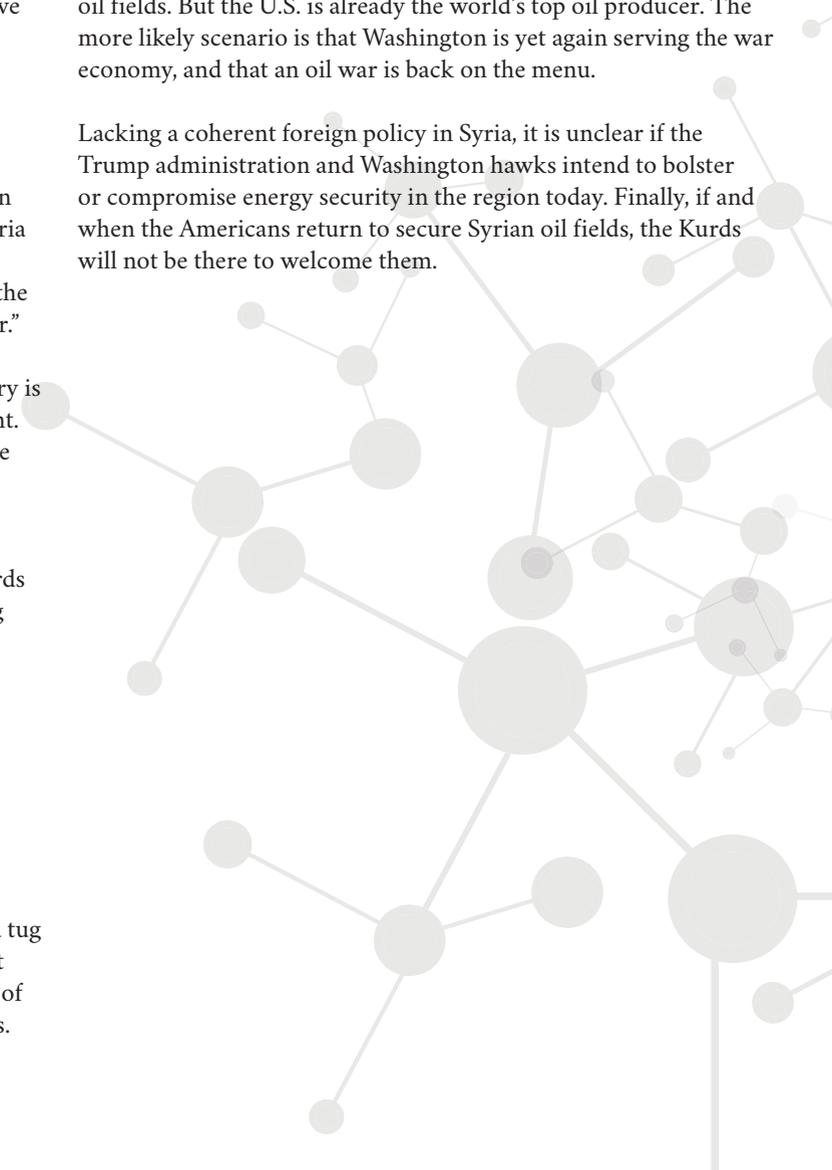
After Baghdadi: A Return to Oil War?

The pitfalls of policing Middle Eastern oil fields are many, namely: mission creep, quagmire and a return to endless war. In coordination with Syrian Kurds, and despite abandoning them, on October 27, US troops killed ISIS leader Abu Bakr Al-Baghdadi in northwest Syria. He was holed up in the last precarious Syrian rebel stronghold, Idlib, which is caught in a tug of war between Syrian president Assad and Turkish president Erdogan. The Americans appear as involved today in the fate of Syria as ever before, but they have ceded power in the process.

These developments culminated in President Trump's

bewildering announcement October 28, "we're keeping the oil... perhaps...make a deal with an ExxonMobil or one of our great companies to go in there and do it properly." Analysts claim this would violate the Fourth Geneva Convention (1955), to which the U.S. is a signatory, and the U.S. War Crimes Act of 1996. Doing so, furthermore, would mark a return to conflict with Damascus. Pillaging Syrian oil may be considered 'payment' for securing the oil fields. But the U.S. is already the world's top oil producer. The more likely scenario is that Washington is yet again serving the war economy, and that an oil war is back on the menu.

Lacking a coherent foreign policy in Syria, it is unclear if the Trump administration and Washington hawks intend to bolster or compromise energy security in the region today. Finally, if and when the Americans return to secure Syrian oil fields, the Kurds will not be there to welcome them.



Published October 29, 2019 on Forbes.com

CARBON STORAGE IN TEXAS: WHO OWNS THE UNDERGROUND PORE SPACE?

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Texas is the largest producer of greenhouse gases in the United States, accounting for over one-eighth of all U.S. emissions. Interestingly, Texas also has the largest potential for carbon storage in its vast underground formations, should geological carbon sequestration at scale become a reality. The U.S. Department of Energy has estimated that Texas has onshore storage capacity for between 661 million and 2.4 billion tons of carbon dioxide.

Clearly, Texas has an enormous opportunity to help U.S. and global efforts to reduce atmospheric carbon emissions. But the lack of clear laws governing who has the right to use that underground space poses a stumbling block that could delay or even cripple efforts to capture market share for this nascent environmental solution.

In order for Texas to fully take advantage of this potential, the Texas legislature and/or the courts must unequivocally clarify who has ownership rights to the underground pore space where the carbon would be injected and stored.

Property rights in land use can be divided into two distinct estates—the mineral estate and the surface estate. When it comes to who owns the underground pore space in situations where the mineral and surface rights have been separated, states in the U.S. follow either the ownership-in-place theory, known as the “American” rule, or the non-ownership theory, known as the “English” rule. Under the English rule, the mineral estate holds ownership of that pore space. Under the American rule, which the majority of U.S. states follow, the mineral estate has ownership of the underground minerals but not of any geological

formations – those remain the property of whoever has the surface estate.

However, the American rule does give owners of the mineral estate the right of reasonable use of the pore space during mineral extraction. Thus, in jurisdictions which follow the American rule, the surface estate may not lease the underground pore space until the mineral estate has completed extraction and has completely depleted the minerals.

Under Texas law, when the mineral estate has been severed from the surface estate, the mineral estate is dominant and can use the surface as is reasonably necessary to develop oil and gas or other minerals. However, while most states have clearly expressed whether they follow the American rule or the English rule, Texas law has not settled the issue of who owns the rights to lease subsurface pore space for the storage of carbon when the mineral and surface estates are separate.

There are several Texas cases that give conflicting answers when it comes to which rule the state follows.

In the 1991 Texas Court of Appeals case *Mapco, Inc. v. Carter*, the court concluded that the mineral owner was entitled to payment for storage rights in an underground salt cavern, even though all the salt had already been harvested, thus following the English Rule. This ruling conflicted with *Emeny v. United States*, a previous case in the United States Court of Claims applying Texas law that held that the surface owner should be compensated for pore space storage rights, following the American Rule. Specifically, the court ruled that rights conveyed in an oil and gas lease did not include the rights to “the geological structures beneath the surface, including

any such structure that might be suitable for the underground storage of foreign or extraneous gas produced elsewhere.”

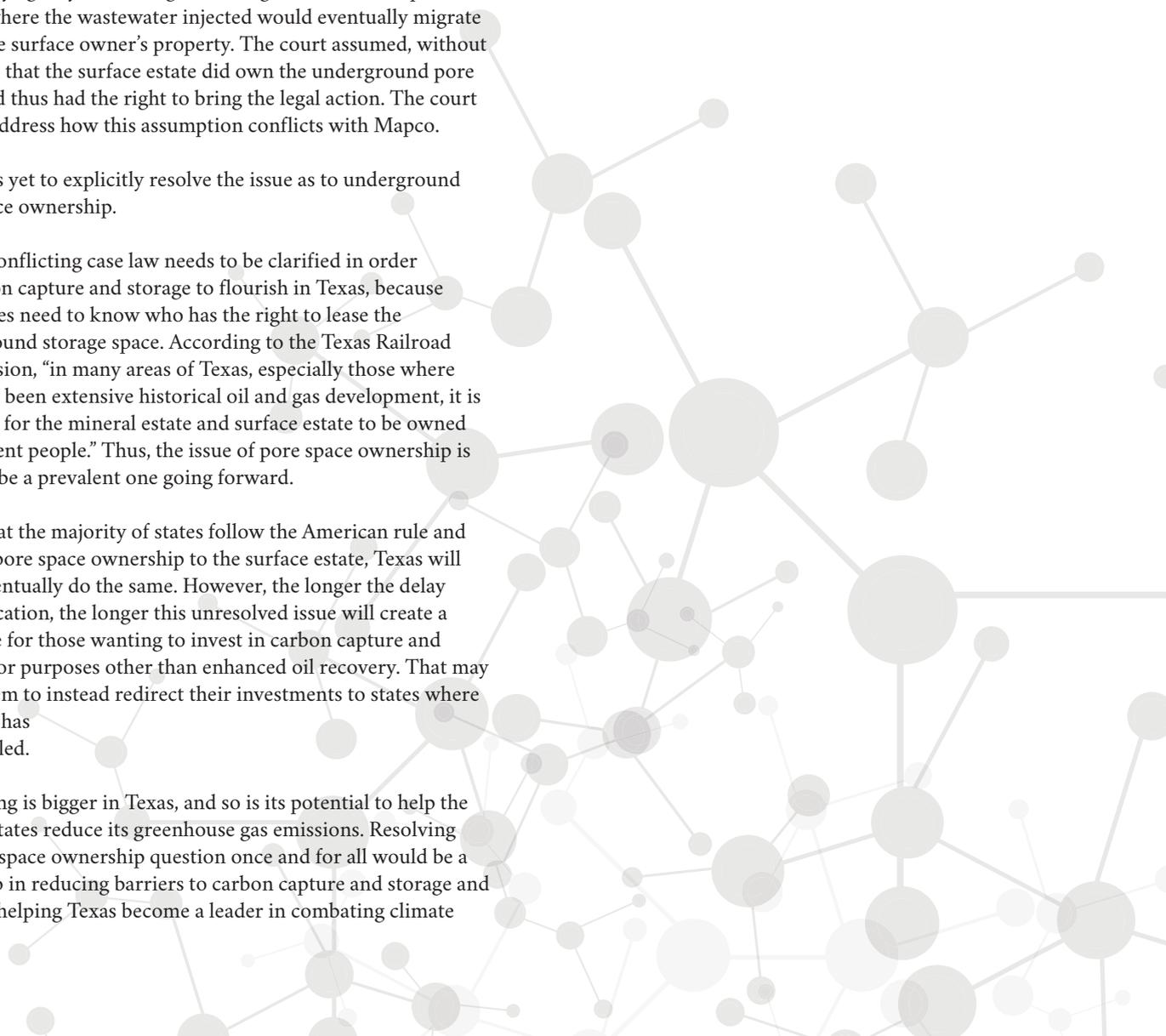
In the more recent Texas Court of Appeals case, *FPL Farming, Ltd. v. Texas Natural Resources Conservation Commission*, a surface owner alleged trespass against the Texas environmental regulatory agency for issuing an underground waste disposal permit where the wastewater injected would eventually migrate below the surface owner’s property. The court assumed, without deciding, that the surface estate did own the underground pore space and thus had the right to bring the legal action. The court did not address how this assumption conflicts with *Mapco*.

Texas has yet to explicitly resolve the issue as to underground pore space ownership.

Texas’s conflicting case law needs to be clarified in order for carbon capture and storage to flourish in Texas, because companies need to know who has the right to lease the underground storage space. According to the Texas Railroad Commission, “in many areas of Texas, especially those where there has been extensive historical oil and gas development, it is common for the mineral estate and surface estate to be owned by different people.” Thus, the issue of pore space ownership is going to be a prevalent one going forward.

Given that the majority of states follow the American rule and allocate pore space ownership to the surface estate, Texas will likely eventually do the same. However, the longer the delay in clarification, the longer this unresolved issue will create a headache for those wanting to invest in carbon capture and storage for purposes other than enhanced oil recovery. That may cause them to instead redirect their investments to states where the issue has been settled.

Everything is bigger in Texas, and so is its potential to help the United States reduce its greenhouse gas emissions. Resolving the pore space ownership question once and for all would be a huge step in reducing barriers to carbon capture and storage and towards helping Texas become a leader in combating climate change.



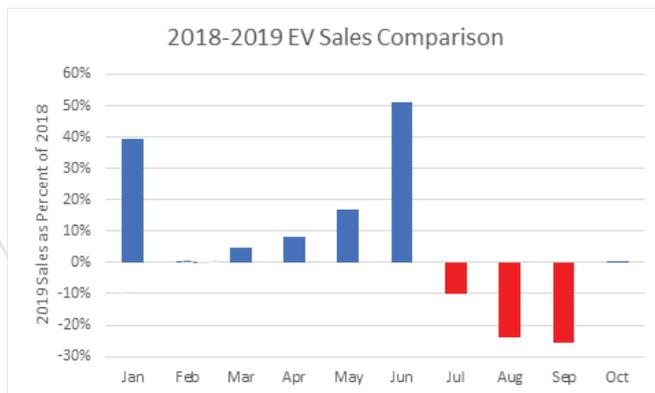
Published November 18, 2019 on Forbes.com

WHAT'S HAPPENED TO US ELECTRIC VEHICLE SALES?

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There was much cheering in 2018 when plug-in electric vehicles (EVs) hit a US sales record of 361,000. Sales started strong in 2019 but declined beginning in July. The pronounced drop in sales, along with a similar decline in China, has prompted concern that future sales may fall short of expectations.

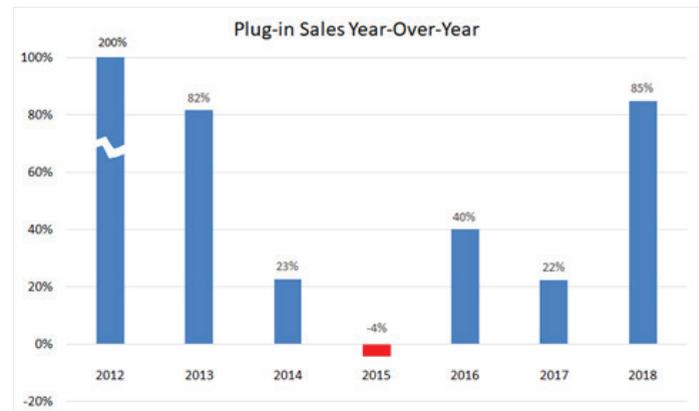


Source: Data from InsideEVs

However, ups and downs have occurred before. The current slump in electric vehicle sales does not necessarily indicate a change in trend.

Ups and downs are normal

Long-term forecasts of EV sales are typically smooth, ever-increasing curves. In reality, there is considerable variation. US year-over-year sales have ranged from a 4% drop in 2015 to over 80% increase in some years. Even if 2019 sales prove flat to 2018, the growth rate since 2013 will still average an impressive 25% per year.



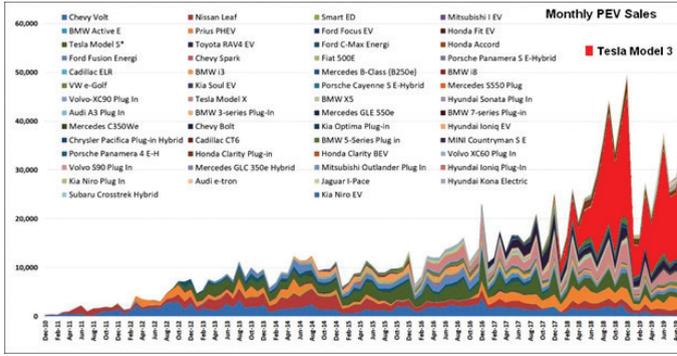
Source: Data from Alternative Fuels Data Center and InsideEVs

Is there really a problem?

Recent growth in US EV sales is almost entirely due to the Tesla Model 3. Based on estimates from InsideEVs, the Model 3 represents almost half of all plug-ins sold so far this year. This is great for Tesla, but it doesn't look good for the 40-odd other models on the market. Total sales of all EVs except the Model 3 are down 20% year-to-date. And EV share of US sales is still less than 2%. Historically, about half of EV sales have been plug-in hybrids, which use gasoline when outside a typically short battery-only range.

There is general agreement that the sales slump in China is due to cuts in subsidies and a slowing economy. Suggested explanations for the US slump include limited geographic availability, restricted supply, consumers waiting for new models, lack of comparable models and lack of consumer knowledge, as well as the perennial issues of cost, range and charging time. These may be barriers, but there are some advantages to gasoline-powered cars and many consumers are not ready to replace them with an electric. Slow sales of some EV models have resulted in heavy discounts. A Hyundai

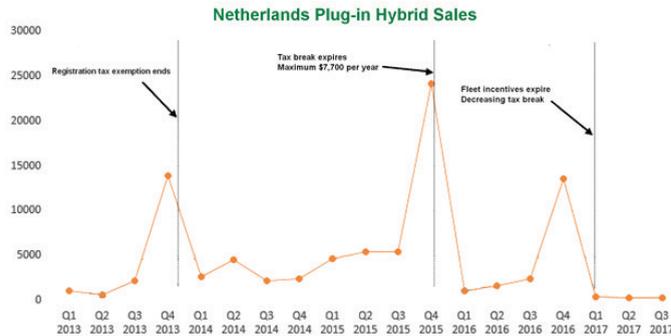
spokesperson predicted an oversupply.



Source: Modified from Argonne National Laboratory

Incentives matter – a lot

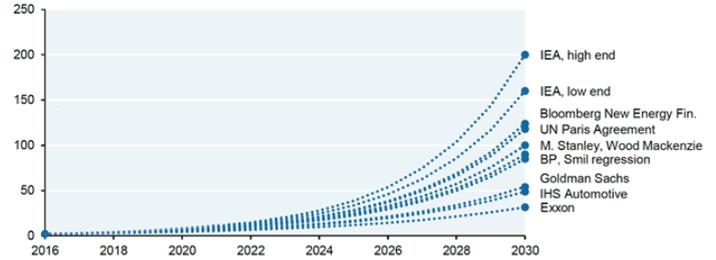
Enthusiastic predictions of EV sales often ignore the role of incentives and mandates. Both financial and non-financial incentives strongly influence sales. Almost half of US EV sales are in California, where state and local incentives are added to the federal tax credit and a complicated Zero Emission Vehicle (ZEV) mandate requires that EVs be a certain percentage of sales. The effect of incentives is illustrated by a characteristic pattern of a spike in sales before the incentives expire and a sharp drop afterwards. This is illustrated for the Netherlands PHEV incentives below. The current slump in China is another example.



Source: Modified from UC Davis Institute of Transportation Studies

Where are EV sales going?

It would be foolish of me to add another forecast to the large number currently available. EV sales are still in their infancy. Too wide a range is possible when projecting high growth rates from a tiny base. Even ignoring some extreme predictions, there is more than a five-to-one range in projections of EV fleet size by 2030.



Source: Modified from J. P. Morgan

Government mandates and incentives will play a major, if not the major, role in the near-term rate of EV growth. California, with the longest history of EV support and most stringent requirements, has over 10 times the EV sales of the next highest state. Nine states have joined California in principle with a ZEV plan, but the details differ by state. How many others will join and how fast they will act is speculative. In addition, the Trump administration's planned withdrawal of California's Clean Air Act waiver has prompted a lawsuit by California and 22 other states. The crystal ball of government action on EVs is cloudy.



Published November 19, 2019 on Forbes.com

THE TOP FIVE LEGAL BARRIERS TO CARBON CAPTURE AND SEQUESTRATION IN TEXAS

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At first blush, Texas holds the best position in the U.S. to lead in carbon capture and storage. It boasts vast underground formations suitable for storing CO₂, and its proximity to major anthropogenic carbon sources – drilling, refining, chemicals and other energy-intensive industries – means it needs fewer miles of pipelines and other transport vessels to get the carbon from production source to storage.

Additionally, Texas has long been home to a large number of U.S. oil and gas companies with the technical and industrial know-how to tackle the hurdles of capturing, transporting and storing a gas thousands of feet underground. These advantages will play an important part in the global dialogue over the best ways to explore carbon sequestration options. The U.S. Energy Information Administration and the International Energy Agency, for example, have identified carbon capture, utilization and storage, or CCUS, as having the potential to play a critical role in reducing global CO₂ emissions, and Congress recently expanded a tax credit intended to spur more sequestration projects.

But the reality is more tangled. Texas will need to surmount several major legal hurdles before it can take advantage of its enormous opportunity to mitigate atmospheric carbon levels.

1. Permitting for Class VI Wells

Texans have long relied on injections of CO₂ to enhance oil production and temporarily store gas for future use. Getting

permits for those injection wells, however, is a bit of a welter. If operators inject CO₂ to wring more oil from a depleted or balky field, they must first obtain a Class II well permit from the Texas Railroad Commission. If their well injects that CO₂ into state lands (including coastal or offshore formations), the General Land Office must approve the operation. And if the operators simply want to permanently store or sequester the CO₂ underground, they need an entirely separate permit for a Class VI well from the U.S. Environmental Protection Agency through a different set of federal regulations under the Safe Drinking Water Act.

The blurry lines between these types of wells, including wells that start in one role and move to another, creates a tricky regulatory regime that forces operators to navigate in stop-step fashion. Texas can substantially clear up the permitting pathway by simply applying to take over the authority from EPA to issue permits for Class VI wells in the state. The Safe Drinking Water Act allows states to shoulder permitting programs if they meet certain minimum requirements, but the federal law doesn't set out any mandates or deadlines to complete this process. While North Dakota has taken primacy to run its own Class VI well permit program (and Louisiana and Wyoming have applied for delegation of their programs), Texas has not yet submitted an official request to take over its Class VI program.

In Texas, the Railroad Commission and the Texas Commission of Environmental Quality (TCEQ) divide statutory authority over most CO₂ injection wells. Both of these agencies therefore would need to work together to apply for delegation (even if one agency

simply cedes authority to the other). The Texas Legislature can help spur movement here by clearly designating one agency as the primary permitting venue for all CO₂ injection wells, setting deadlines to request that EPA delegate the Class VI program to Texas and providing the necessary funding to get the job done.

2. Classification of CO₂ as waste, rather than a beneficial product

Many states, including Texas, allow pipeline operators to condemn land only when their pipeline serves a public use. In other words, when courts determine if a pipeline is a “common carrier,” they look to whether the project in question will benefit the general public. For example, a pipeline company transporting natural gas for reasons other than the company’s own consumption is generally seen as a common carrier because that gas reaches third parties and the natural gas is seen as a beneficial product.

In return, a pipeline company designated as a common carrier has the power of eminent domain to expropriate property for public use. It has to compensate property owners for their lost land, but the company’s path to build the pipeline is usually much easier.

But that process has become more complicated for pipeline companies dealing with CO₂ sequestration in Texas. Before carbon capture and sequestration can become a recognized industry in the state, additional pipelines will have to be built to transport anthropogenic CO₂ between the source – a production facility, for example – and the storage facility. Federal environmental regulations, however, can classify some forms of CO₂ destined for permanent sequestration as an air pollutant or as a solid waste (when sealed in a container), and therefore pipelines that transfer such “waste” for disposal may not offer a direct benefit to the public that satisfies traditional justifications for condemnation authority. Due to this classification, the Texas Supreme Court ruled in 2012 that some private landowners could challenge a CO₂ pipeline owner’s self-designation as a common carrier, and the court allowed them to bring their claim even after the agency had issued the permit.

3. Liability for Future Releases of Sequestered CO₂

Texas currently does not cap civil liability for non-economic losses that arise from mishaps or failures at carbon capture and sequestration operations. Texas law also does not allow the state to take over any perpetual long-tail liabilities after the carbon facility is closed.

As a result, a facility operator may face the risk of liability in the far-flung future if a sequestration facility fails and releases its CO₂ back into the atmosphere, or if captured CO₂ in the closed facility causes unexpected damage (e.g., seismic disturbances or risks to future unanticipated uses of nearby land and resources). Liability caps and risk-shifting to states would allow operators to determine their true exposure to future liability from closed facilities. In turn, this additional certainty would help them obtain the financial assurances they need to safely operate.

Other states, including Louisiana and North Dakota, have already adopted liability caps or set out a pathway for the state to assume any long-term liability for a closed CO₂ sequestration facility. A similar approach, with proper oversight and rigorous transparency, could greatly increase the viability of carbon capture and storage in Texas.

4. Lack of Unitization Legislation

When one large pool of oil lies under multiple pieces of property, the neighboring owners tend to squabble over extraction and drilling arrangements. To solve this problem, Texas allows an operator to “unitize” the formation by aggregating the property owners’ rights into one unit. That’s helpful for oil and gas producers because it allows them to operate and manage the reservoir as a single unit. When done well, unitization can improve production efficiency, avoid fractious property spats and assure that each owner receives their due royalties. And in all of the states with major oil and gas operations - except for Texas - unitization becomes compulsory once a certain percentage of landowners agrees to unitize. Property owners forced to participate in a unitization still maintain their rights and receive their share of the benefits, but they also have to share in the operation expenses.

When we move to CO₂ sequestration, however, the Texas regulatory stance on unitization gets blurry. While Texas law allows unitization for enhanced oil recovery (including the use of CO₂ through Class II wells), it lacks any specific provisions for geological storage of CO₂ solely for sequestration or disposal. Compulsory unitization for CO₂ sequestration operations could allow operators to negotiate a single agreement to a sequestration facility and its associated geologic storage formation rather than hammering out individual operating contracts with each landowner. Both specific legislation for compulsory unitization and for Class VI well unitization would help to expedite the expansion of carbon capture and storage in Texas.

5. Pore Space Ownership

While Texas law leaves some ambiguities over how to authorize a CO₂ sequestration facility and assure its safe operation, it also leaves open a rather fundamental question: who owns the spaces in the rock that actually contain the CO₂? While a surface owner can sell her separate rights to oil and gas under their property to the mineral estate purchaser, that oil and gas doesn't necessarily include the spaces in the rock remaining after the oil and gas is extracted.

In Texas, conflicting court decisions have left it unclear who would need to be approached to obtain underground storage rights to open a carbon storage facility in Texas. One Texas Supreme Court case, *Mapco v. Carter*, awarded the mineral estate with the ownership right to underground formations (which presumably includes pore spaces). This decision, however, may conflict with a prior U.S. Court of Claims decision, *Emeny v. United States*, which held the surface estate owns associated underground formations, although that ownership right must bow to right of reasonable use by any productive oil and gas lessee. Other cases have tackled varying scenarios (including the use of salt domes created by production operations), but no subsequent Texas court case or legislation has indisputably resolved the issue. As a result, operators of CO₂ sequestration facilities may find themselves negotiating with both mineral estate and surface owners to obtain clear title to the property needed to permanently store the gas.

Texas isn't the only state that needs to clear some legal underbrush before it can fully exploit its capacity to capture and store CO₂. In part, similar concerns led the U.S. Department of Energy last year to request a report from the National Petroleum Council on carbon capture, use and storage, and this report will comprehensively explore the regulatory and policy pathways needed to ease the adoption of these technologies in energy production and other industries. The Council should issue its report by the end of 2019, and it will hopefully outline a roadmap for action on a national level.

But given Texas' enormous capacities and relative economic advantages over other states as a carbon capture and sequestration hub, national attention will inevitably turn to it for a glimpse of our collective future road to carbon management in energy.



Published December 6, 2019 on Forbes.com

HOW MUCH IS A CLIMATE CHANGE 'SOLUTION' WORTH?

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Numerous policies are being proposed to combat climate change. The cost of some of these policies are estimated to be in the trillions, tens of trillions and even near 100 trillion dollars. By claiming their policies resolve an “existential” threat, some advocates justify implementation at any cost. Governments would impose these costs on the public, reducing standards of living and quality of life.

But what is the true nature of the presumed threat? Is it existential? If not existential, then what are the potential costs to human welfare, and what is the largest price the public should reasonably be willing to pay to counter the threat?

Public interest in the thesis of climate change (previously termed “global warming” in public discourse) has steadily grown since June 23, 1988, when NASA’s James Hansen gave testimony to the United States Senate’s Committee on Energy and Natural Resources’ Subcommittee on Water and Power, supporting the claim that global climatic effects may result from carbon dioxide (CO₂) emitted by combusting fossil fuels for energy. Politicians have since commissioned a plethora of studies to explore the issue.

The Fourth National Climate Assessment (4NCA) is one such recent study published in November 2018, just a few months following the 30-year anniversary of Hansen’s testimony. It makes many predictions that are now quite familiar – the marginal growth in atmospheric CO₂ levels caused by combusting fossil fuels will cause temperatures and sea levels to gradually increase over the next 100 years at greater rates than the existing natural trends already in place.

By itself, this information does not suggest any cause for

extraordinary action.

Of course this conclusion distinguishes those who may be motivated by a philosophy of disallowing global effects by humans from those who are motivated by interest in human welfare.

In the latter case, a cost-versus-benefit analysis needs to be part of evaluating the best course of action and deciding what level of effort should be expended to prevent or mitigate human-induced climate change. The conclusion will depend on a comparison of the costs of proposed preventive policies with the value of avoiding climate change induced by CO₂ emissions from fossil fuel combustion.

The prognostications of the 4NCA includes estimates of the economic effects of climate change. This information can be used to estimate the value of avoiding climate change, thereby setting a maximum value for a climate change “solution.” As a society, we should not want to pursue any solutions whose costs exceed that value.

Before building on information from the 4NCA report, it is important to understand its limitations. Predictions from this, as well as other climate change reports, are based on a pretense of knowledge and understanding of earth’s complex climate system, the many natural systems affecting it, and the resulting effects on human economy and welfare that are sufficiently complete to make century scale forecasts.

Unfortunately, such capability is untested and empirically unproven.

From a scientific point of view, this is a critical flaw. Scientific methodology requires empirical verification. Even Einstein’s



work in relativity was not accepted as valid until experiments demonstrated it capable of making more accurate predictions than previously accepted theory. (The year 2019 marks the 100-year anniversary of the first experimental confirmation of Einstein's relativity.) Experiments compare concepts we imagine to the reality of the physical universe. Our concepts are never complete. Physical reality, particularly under conditions previously unobserved, is routinely found to be much more complicated and surprising than anticipated.

Because underlying capabilities are empirically unproven, long-term climate predictions from the 4NCA and other climate change reports are best understood as hypothesis or conjecture rather than scientific conclusion.

This caveat notwithstanding, one may hypothetically consider a case where predictions made by the 4NCA are assumed to be usefully accurate. In particular, the report's predictions for global temperature rise and consequential effects on U.S. gross domestic product (GDP) can be used to evaluate the potential value of a climate change solution.

The 4NCA predicts an increase in global average temperatures by 4.2o to 8.5o F (2.4o to 4.7o C), relative to the 1986-2015 average, for the years around 2090 under the RCP8.5 scenario. The burnt orange shaded area in Figure 1 (taken from the 4NCA) illustrates this prediction. RCP stands for "Representative Concentration Pathways", and the RCP8.5 scenario is the so-called "worst case" scenario where fossil fuel use continues unimpeded and no extraordinary efforts are made to counter growing CO2 emissions.

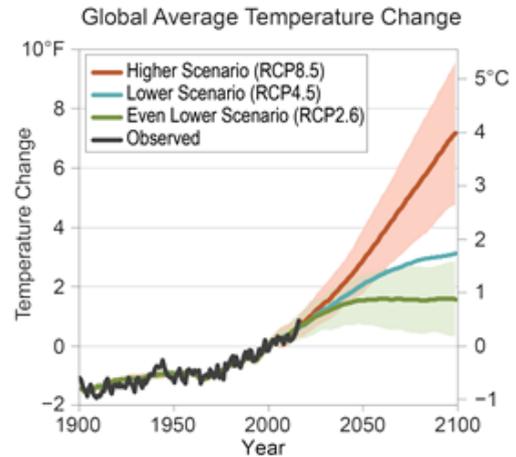


Figure 1: Human induced global average temperature change. Figure taken from 4NCA.

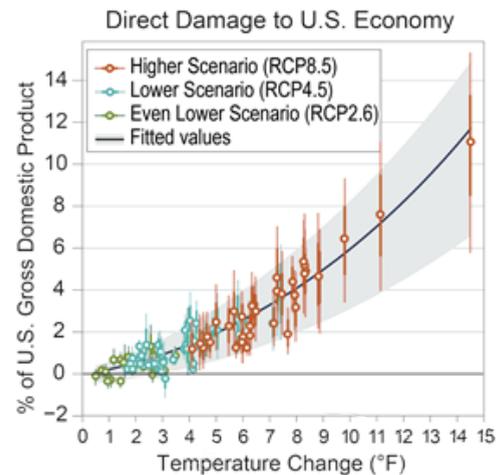


Figure 2: Direct damage to U.S. economy from human induced climate change. Figure taken from 4NCA.

Figure 2 (also taken from the 4NCA) shows the percentage loss of U.S. GDP in 2090 (average of 2080 - 2099) as a function of global average temperature change (given in Figure 1). The gray shading represents the 90% confidence interval around the best prediction shown by the black line.

This information tells us that, if we take no action to counter rising CO₂ emissions and the use of fossil fuels continues unimpeded, the temperature rise may be as low as 4.2o F (2.4 o C), with a corresponding GDP loss in 2090 somewhere between 0.5% and 2.5%, and may be as high as 8.5o F (4.7 o C), with a corresponding GDP loss in 2090 of between 2.0% and 6.0%. So, GDP loss in 2090 is predicted to be anywhere between 0.5% and 6.0%.

To help illustrate this prediction, consider the case of 4.0% GDP loss in 2090 corresponding to the best estimate of GDP loss for highest predicted temperature rise of 8.5o F. Assuming a constant rate of change in GDP loss between 2018 and 2090, this amounts to a loss rate in GDP increasing by 0.05% every year. (This observation was also made by Steven Koonin in a Wall Street Journal article.)

Keep in mind, the 4NCA report does not try to predict what the economic growth will be over the rest of the century. It only tries to predict what marginal effect climate change may have on economic growth. Though predicting economic growth over the rest of the century is a far simpler problem than predicting the climate, few economists are reckless enough to venture such predictions.

So, an economic growth rate over the rest of the century can only be assumed. Figures 3 and 4 show two prospective futures based on two possible economic growth scenarios and a 4.0% loss in 2090 GDP. The red solid line in figure 3 illustrates 3¼% annual GDP growth as might be realized by a future of pro-growth policies (the historical average for the U. S. is between 3 and 3¼%). From 2018 to 2090, GDP grows from about \$20 trillion to about \$200 trillion (2019 dollars). The predicted losses due to climate change reduce the 2090 GDP by 4%, to about \$192 trillion. This is still an economy nearly 10 times bigger than today!

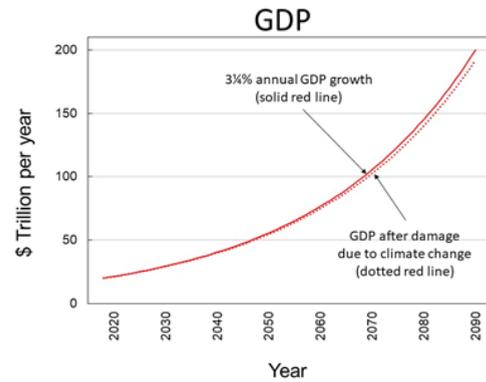


Figure 3: Annual GDP growth at 3¼% (solid line), and GDP after damage due to climate change (dotted line).

The blue solid line in figure 4 illustrates 2% annual GDP growth. Rates of growth near this value have been described as “the new normal” by political economists favoring low-growth policies. In this case, GDP grows from about \$20 trillion to about \$83 trillion. The predicted losses due to climate change reduce the 2090 GDP by 4%, to about \$80 trillion. Even this economy is four times bigger

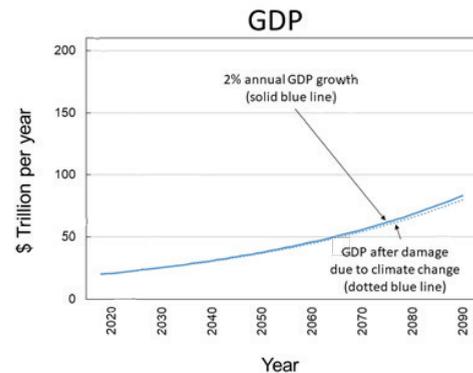


Figure 4: Annual GDP growth at 2% (solid line), and GDP after damage due to climate change (dotted line).

In each case, the GDP after losses due to human induced climate change is shown by the dotted lines of corresponding color. The figures show that GDP loss from human induced climate change is difficult to distinguish under either growth scenario due to

its relatively small size. Clearly, the costs due to human induced climate change from CO₂ emissions are unimportant compared to other choices between pro-growth and low-growth policies. Pro-growth policies leave our society in 2090 nearly two and a half times wealthier than it would be under slow-growth policies.

What we want to know is the value of recovering that portion of GDP between the solid and dotted lines. For this, the concept of “present value” is needed to account for the time-value of wealth. That is, receiving a dollar today has more value than receiving that dollar (inflation adjusted) 10 years from today. This is extremely important because we are considering value over a period of nearly a century.

To compute present value, an assumption of “annual rate of return” must be made. Typical values used in commercial planning can be around 15%. (That is, a dollar today returns two dollars in five years.) According to a study by the Copenhagen Consensus, it is possible to reach returns of 21% to 30% from public spending on global scale problems by prioritizing 19 (out of the UN’s 169) development goals.

In the interest of understanding a maximum possible value for recapturing lost GDP, a rate of 15% is used for present value calculation. (Higher rates will result in smaller present value results.) In this case, the present value for lost GDP in figure 3 is \$0.97 trillion. For figure 4, the present value is only \$0.78 trillion.

Imagine it was possible to purchase a climate change solution that would be immediately effective. That is, the solution is purchased today and, the very next day, the climate change solution is immediately 100% effective; meaning there is no longer any net contribution of CO₂ to the atmosphere nor any additional human induced effects on climate change. In this case, GDP would grow without damages due to human induced climate change (the solid lines in figures 3 and 4) instead of growing at the slightly slower rates (the dotted lines in figures 3 and 4).

How much would we be willing to pay for this solution? Well,

if we pay more than \$1 trillion, we are being foolish since the value of the recaptured GDP is less than that. We may not even want to pay the calculated \$0.97 trillion since that estimate is based on assumptions favorable to high valuations, such as high-end temperature and GDP loss rate assumptions, high-end GDP growth assumption and relatively small rate of return requirements.

Of course, the existence of such an immediately effective solution is highly unlikely and does not reflect the nature of preventive policies that are being proposed. Many proposals take a more realistic, though still incredibly ambitious, goal of implementing a solution over a period of 10 years. Suppose then that there is a solution that results in net contributions of CO₂ to the atmosphere and human-induced climate change ceasing around 2030, and GDP growth returning to an undamaged growth rate beginning around 2030.

The present value of this solution is much smaller due to the delayed effectiveness. In this case, the present value under the same assumptions of 15% return and 3¼% annual GDP growth is only \$0.39 trillion. If we raise the rates to the range of the Copenhagen Consensus study, 21% to 30%, the present value for this solution falls between \$0.19 trillion and \$0.08 trillion.

It is evident that the value of a climate change solution is at most in the tens to hundreds of billions of dollars, and may be considerably less. It is certainly not in the trillions, tens of trillions, or one hundred trillion dollar range. And an existential threat is clearly not indicated.

Of course, this conclusion is based on the findings of climate change reports such as the 4NCA. As we noted, century-scale predictions from these reports are severely limited by the lack of scientific capability and are best understood as conjecture or hypothesis. Nonetheless, if we accept these reports as best available guidance, it is clear that expensive solutions for human-induced climate change are not justified.

Published December 10, 2019 on Forbes.com

PLASTIC: WHERE IS IT GOING, AND WHAT IS THE LAW DOING TO CONTROL IT?

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“Avoid using plastic, and if that is not possible, try to reuse it as much as you can.” This is what experts familiar with the latest scientific research on plastic advise nowadays. Plastic, in fact, seems to have gotten a bad reputation lately. But is plastic the problem, or is it an issue of recycling, waste management and society’s lack of knowledge about what happens to plastics after we use them? Is there a sort of irresponsible attitude, “Après moi le déluge!” – “After me, the flood,” as King Louis XV of France famously said?

Besides, where is plastic headed?

We know where it currently is: in our clothes, in the containers holding our food, in the chairs where we sit and in our cars. Plastic is everywhere. Is it too much?

Over the past few decades, many issues have been raised scientifically around plastic: from the challenges of reducing its use related to its extended presence in our lives, to its possible connection to diseases in young marine life and the consequences for the food chain that may turn plastic soon into a public health issue; about its toxicity related to its life cycle; the resiliency of the ecosystem, and what actions we can take to re-use plastics more efficiently. The focus on compostable and biodegradable plastic – meaning that 90% will biodegrade after six months – still leaves the question of whether plastic is a net benefit for society, considering its impacts on the ocean, the environment and biodiversity.

In fact, many studies still need to be done to analyze these

issues from a multidisciplinary dimension, where the scientific, engineering, societal, legal, political, energy and business sectors establish a dialog. That way, we might find solutions that would not later create unintended new environmental problems.

The law, too, must be brought onto the scene. Actually, what is the law doing in the U.S., Mexico or France to address the problem of plastic? What is the current situation? Let’s see from a comparative law perspective how legislators of these countries are limiting its use and taking steps with different degrees of intensity, to deal with plastic.

First steps: recycling plastic

From a legal point of view, this has mostly been approached as a matter of regulating waste management, first in terms of recycling. In the United States, plastics recycling first drew attention in the early 1990s; in 1991 Maine became the first state to legally require to retail stores to participate in recycling.

In Mexico, the General Bill for the Prevention and Integral Management of Wastes, was approved at federal level in October 2003, based on the right of every citizen to a healthy environment, promoting the integral management of waste and avoiding contamination.

In France, the earliest efforts go back to 1870, when garbage in public roads was forbidden after biologist Louis Pasteur discovered the role bacteria plays in human health. In 1883, a local official, The Prefect of Seine Eugene Poubelle, invented the container that

was named after him – La Poubelle – a divided container to hold degradable materials in one section, with paper, crystal or china held separately. Other materials that were recycled were metals, clothes and, surprisingly, buttons.

Plastic became relevant to the recycling and waste management discussion in France more than 100 years later, in 1992, with a bill obliging French cities to recycle waste. More recently, regulations have prohibited the proliferation of plastic and forbidding its use outright in some instances.

Second steps: limiting plastic

Laws to deal with plastic have been passed in the United States, as well, although some states have been more active than others. Eight – California, Connecticut, Delaware, Hawaii, Maine, New York, Oregon and Vermont – have banned single-use plastic bags. For example, in Aug. 2014, California became the first state to enact legislation imposing a statewide ban on single use plastic bags at large retail stores. Only reusable grocery or recycled paper bags purchased for 10 cents or more were allowed.

But the Golden State had adopted regulations dealing with plastic waste before the ban. In 2006, Senate Bill 2449 called for retail stores to adopt at-store recycling programs, asking customers to return used plastic bags to the retailers. A few years later, Senate Bill 228, required manufacturers of compostable plastic bags to ensure the bag could be easily distinguished from other bags. And In 2011 with Senate Bill 567, California prohibited the sale of plastic products labeled as compostable, home compostable or marine degradable unless the products met standard specifications, providing a civil penalty for violation.

California isn't alone. Hawaii, for example, has since 2015 prohibited the use of non-biodegradable plastic bags at checkout; paper bags must contain a minimum of 40% post-consumer recycled content and display the words "reusable" and "recyclable" in a "highly visible" way.

Mexico, too, is building upon the federal 2003 General Bill for the Prevention and Integral Management of Wastes. New plastics legislation is in the process of adoption at state level, for instance,

in Mexico City, following a report issued in May 2019 by the Mexico City Congress. By January 2020, single-use plastic bags will be forbidden in Mexico City; by January 2021, plastic plates, cutlery, cups, lids, balloons, covers for cups, platters and any other products totally or partially made of plastic will be banned.

This report will reform Article 3 of the 2003 Bill on Solid Waste of the City of Mexico, *Ley de Residuos Sólidos del Distrito Federal*. Joining the efforts already made by Mexico City in the 2010 reform of this bill, by which every plastic bag had to be biodegradable and compostable in order to be commercialized, distributed and given to consumers in retail stores, as article 25 XI BIS of the bills stands. The detail of the Mexican bill – clearly defining the terms – provides the necessary legal certainty for the different actors in the plastic sector.

In France, the 2015 Energy Transition for Green Growth Bill, is intended to encourage diversification of the country's energy mix and help meet climate goals and sets targets for prohibiting the use of certain plastic packaging. The French legislation gradually expands plastic sorting, giving priority to recycling. Since January 2016, no retail use of plastic bags is allowed, either free of charge or as an additional purchase. Since January 2017, single-use plastic bags have been outlawed, unless they are bio-based and compostable at home. From January 2020, plastic cups, fiberglass and plastic plates used in kitchens will be forbidden unless bio-based and compostable at home.

In the United States and internationally, the different legal systems are attempting to deal with the issues arising from society's reliance on plastics, but there is still so much we don't know about the material. There are many actors with different interests involved.

For now, plastics are necessary in our lives, even as lawmakers in the United States and globally try to manage the resulting environmental damage, enforcing recycling and limiting the use of plastics.

The demand for plastic remains very high. We should think about sustainable alternatives to plastic, and in the meantime, society must be educated so we can start to cultivate the necessary change of behavior, kindly refusing to buy or use non-biodegradable plastics.

Published December 23, 2019 on Forbes.com

YOUR ELECTRIC CAR MAY OR MAY NOT SAVE YOU MONEY

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There are a lot of good reasons to buy an electric vehicle (EV), but most buyers want to know whether it will save them money. This story is complicated, so let's start with the bottom line: An electric vehicle may or may not save money, depending upon a host of factors, which will vary depending upon your location, driving habits, and choice of vehicle. The range in cost can be large, and generic comparisons will probably not match your situation. In order to estimate how much your EV purchase will save or cost you, you'll have to do some calculations.

What we're comparing

In this article, the examples will be battery electric vehicles (BEVs) compared to similar gasoline-powered models (ICEs). The same methods can be used to compare hybrids and plug-in hybrids (PHEVs).

It is generally agreed that EVs cost more to manufacture. Most have a higher list price than their gasoline-powered equivalents. However, we're looking from the viewpoint of the consumer, whose purchase price may be lower due to federal and local tax credits, and who may also gain from free charging, preferential electricity rates and other benefits. Exactly which vehicles are being compared is very important.

The fuel cost savings

If you do an internet search for electric car savings, the vast majority of hits will be the savings on fuel cost. This makes sense in that you will probably pay more for the EV and expect to make it back by fuel savings. In all but a few extreme cases, fuel costs will favor EVs.

The table below compares the fuel cost difference between a Nissan Leaf EV and gasoline-powered Toyota Corolla for annual driving of 13,500 miles based on statewide average gasoline and electricity prices. The annual savings range from \$288 to \$948 per year. Local prices have a big effect. The ratio is about 3:1.

	Annual Fuel Savings
Oregon	\$948
California	\$910
Louisiana	\$555
Minnesota	\$501
Texas	\$479
Hawaii	\$324
Maine	\$362
Connecticut	\$288

The differences depend upon the local price of gasoline and electricity. Oregon, with high gasoline price and low electricity price, favors the EV. The EV advantage is small in Connecticut, which has cheap gasoline and expensive electricity.

The examples in the table do not capture the range of possibilities. Your fuel cost savings may be higher or lower, depending upon local prices, miles driven, choice of automobile and other factors.

Fuel cost is not the whole story

As nice as these fuel savings may be, fuel is a fairly small part of the total cost of ownership, typically between 12% and 25% for gasoline-powered cars. Let's look at this cost comparison between a Nissan Leaf and a Honda Civic from Corporate Knights.

2019 Honda Civic LX (Automatic)



TOTAL COST OF OWNERSHIP
\$66,020

2019 Nissan LEAF S



TOTAL COST OF OWNERSHIP
\$63,815



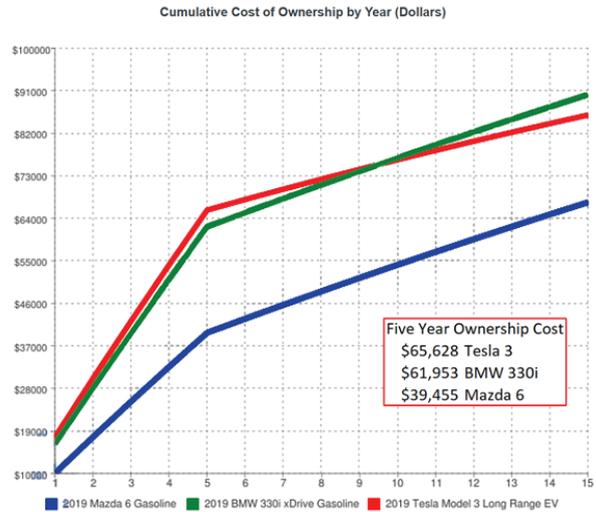
Source: Corporate Knights

It says for the conditions the author assumed it would be \$2,205 (Canadian) cheaper over a 10-year life to own the Nissan Leaf. That's only 3% of the total cost and that small difference is likely within the range of error of the estimate, but the EV is lower. Compare that to an estimate by the American Automobile Association that the average annual cost of an EV is 17% higher than a small gasoline-powered sedan (\$8,320 vs. \$7114). How can there be such a large difference? In part, it's because, like Oregon, gasoline is expensive in Canada, roughly 50% more than the US average. But other assumptions are also make a difference. Other differences include length of ownership (10 years vs. 5 years), depreciation (total vs. 5-year trade-in) and choice of models (specific vehicles vs. average over five models). It's not very helpful to think you could save 3% and lose 17%. You really need an estimate for your own circumstances.

A good total cost estimate

The Department of Energy's Alternative Fuels Data Center (AFDC) has a very sophisticated total cost calculator. It includes electricity and gasoline costs, annual mileage, city/highway split, initial vehicle cost, cost escalation, discounting and other factors. You can use defaults or enter your own values for many of the parameters.

An example of the output is shown below. It compares the Tesla Model 3, BMW 330i, and Mazda 6, using AFDC's default values and current nationwide average gasoline and electricity prices of \$2.50 per gallon and \$0.13 per kilowatt-hour, respectively.



This example illustrates the importance of the choice of comparable. If you consider the Tesla Model 3 to be equivalent to the BMW 3 series, the cost is essentially break-even. If you consider the Tesla Model 3 equivalent to the Mazda 6, you're way ahead with the 6. At five years of ownership, the Mazda 6 is some \$26,000 cheaper than the Model 3.

Online calculators are not perfect

As with any online example or calculator, the assumptions in the AFDC calculator may not fit your circumstances. It assumes you finance the vehicle and does not include depreciation or incentives, such as tax credits. The electricity cost is set by state and not editable. It has non-editable costs for tires, maintenance, loan rates and other factors.

I have not found any comprehensive online calculator. If you want a truly accurate comparison, you will have to do it yourself. How wonky do you want to be?

If you want to undertake the considerable task of doing your own analysis, you can start with the equations in the AFDC calculator and add factors they left out, such as trade-in value and sales tax. You'll need input values unique to your circumstances. Your actual purchase cost will depend upon available discounts and which model and options you choose. The fuel efficiency of both EV and gasoline cars depends upon your driving style, terrain, temperature and whether you're using the air conditioner.

The differences are significant. Discounts can be on the order of 10 to 20 percent and may vary between the EV and gasoline alternative. Individually, low temperatures, aggressive driving, hilly terrain and AC use can increase EV energy use from a few percent to 20 percent. The combined effect can almost double it. These factors also affect gasoline fuel mileage but generally have less effect.

Even if you account for all of these factors, there are still uncertainties. The prices of gasoline and electricity will change. Your driving distances may change. The best estimate is still just an estimate.

Where you can save money

If you're an average mileage driver, your fuel savings may be anything from a couple of hundred dollars to well over a thousand dollars per year. If you're a high-mileage driver, you will save more. This is great and allows you to smile as you drive past the gas station. However, that may not save you money on the total cost of owning a car.

If you're not interested in doing the calculations, here are the circumstances that favor the EV:

- Little or no added cost for the EV
- High local and federal incentives
- High local gasoline cost
- Low local electricity cost
- You drive a lot
- You drive mainly in the city
- You keep the car a long time

- Moderate temperatures
- Flat terrain

Or you may just choose to enjoy the other benefits of EVs and not worry about the cost difference.

Published January 3, 2020 on Forbes.com

THE CYBER CONSEQUENCES OF KILLING QASSIM SULEIMANI

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It is somewhat remarkable that the commander of the Iranian Revolutionary Guards Corps' (IRGC) Quds Force, General Qassim Suleimani, chose to fly into Baghdad so soon after Iranian-backed militias had ransacked and burned portions of the U.S. Embassy 104-acre, Green Zone compound in Iraq. Nonetheless, he did. The decision led to his killing via a drone strike upon his motorcade shortly after departing Baghdad International Airport. What could have been chocked up to be covert action has been acknowledged by the U.S. Secretary of Defense.

At the direction of the President, the U.S. military has taken decisive defensive action to protect U.S. personnel abroad by killing Qasem Soleimani, the head of the Islamic Revolutionary Guard Corps-Quds Force, a U.S.-designated Foreign Terrorist Organization.

Now the geopolitical experts will go into high gear assessing what this escalation of the Iranian-U.S. conflict in the Greater Middle East means. Some will argue new surprises of asymmetric conflict will no doubt be next. Others will opine that such bold action will lay Iran's ambitions to make trouble across the region low. This will largely add up to so much jibber-jabber. The real work to do is in figuring out how this act of conflict escalation may lead to new forms of action from Iran or its allies that can be hurled against the United States. In the area of cyber and information operations related to conflict with Iran, there are some things for which we need to prepare.

First, the Iranians may decide that launching operations against American military leaders or service personnel is an orthodox,

symmetric response. Concern about such attacks is not new. The House Homeland Security Committee prepared an extensive report on the vulnerability of U.S. military service members to forms of terrorism including on and around domestic bases in 2011. That is the soft underbelly of the U.S. military, but pulling off such attacks on U.S. soil would be quite difficult. Radicalizing Americans to attack such targets might be a different story, however.

The Internet and social media make this task easier than before. Tracking down servicemembers or their families via the Internet remains a less than formidable task as social networks make easy work of establishing family linkages and providing intelligence to pull off kinetic or cyberattacks. Four Iranians have been charged in the United States District Court, District of Columbia with, "furtherance of a malicious cyber campaign targeting current and former members of the United States Intelligence Community." Those able to blunt Iran's strategic ambitions are now targets.

Beyond intelligence collection, we are probably not far from a time where hacking someone's automobile becomes a reasonable attack option that requires little or no indiscreet presence on U.S. soil. The unclassified computer networks of U.S. military installations have plenty of holes to be compromised by competent cyber adversaries. The IRGC's cyber wing plus Shodan, with its comprehensive listing of compromised Internet of Things (IoT) devices, should give us pause.

In response, the Defense Department and intelligence community should be creative, developing ideas of how unorthodox actions, enabled or delivered primarily through cyberspace may be part of any return volley from Tehran in the coming days. Iran's cyber

capabilities are not to be dismissed out of hand, something my colleague Eneken Tikk and I warned in our case study of the 2012 Iranian hack of Saudi Aramco. Furthermore, Iran may well be able to enlist the aid of Russian and Chinese cyber forces in a proxy cyber conflict with the United States.

Such activity could also include significant propaganda operations aimed at shaping perceptions of the American and other publics with regard to a major military intervention in Iran. My colleagues in the world of geopolitical cyber analysis will be busy piecing together data on targets Iran is probing as well as the influence operations, aimed at the U.S. and elsewhere, that it is undertaking. We should not underestimate Iran's capabilities.

If Iran chooses to escalate, mayhem may well break out. We should be prepared for the types of attacks it and its allies have launched previously as well as new departures from existing norms in international conflict. These attacks may be landed everywhere from military neighborhoods of base towns across the country to financial markets, energy grids, and other pieces of critical infrastructure. If the U.S. should end up engaging in war with Iran, it will be the first time that it enters into full hostilities with an enemy with the capability to effectively shoot back in cyberspace. Anticipate the unexpected.



Published January 13, 2020 on Forbes.com

TEXAS POWER GENERATION: DID COAL GET BLOWN AWAY BY WIND?

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The precipitous drop in coal-based power generation in Texas, from 32% of consumption in 2017 to 20% in 2019, has been hailed as the most significant step in decarbonizing electricity production in Texas. The narrative in the media has suggested that the rapid demise of coal has resulted from the growth of wind power.

The data suggest a more complex narrative. While wind has grown considerably, especially early in the last decade, the decline of coal has largely been due to a resurgent natural gas industry.

Annual Distribution of Sources for Texas Electricity Production (percentage): Trends over the last three years (from ERCOT)

	2017	2018	2019
Gas	39	42	47
Coal	32	25	20
Wind	17	19	20
Nuclear	11	11	11

The data for Texas' power production over the last three years indicates that coal has instead been replaced largely through the growth of natural gas and only to a small extent due to wind. Specifically, the growth of high efficiency combined cycle natural gas production has driven most of the surge to replace aging coal assets. Coal-based power generation is expected to continue to slide as more coal-fired power plants are retired in favor of renewables (wind and solar) and, more frequently, natural gas-based power generation.

Annual Distribution of Sources for Texas Electricity Production (percentage) over 2007 - 2019 (from ERCOT)

	2007	2013	2019
Gas	45	41	47
Coal	37	36	20
Wind	3	10	20
Nuclear	13	12	11

However, the growth of natural gas has not been smooth. And contrary to the recent trends, growth of natural gas has not directly caused the shift in the energy mix of Texas. A longer snapshot of consumed electricity over the last 12 years paints a more complicated picture. Between 2007 and 2019, onshore wind has grown from making up 3% of power generated to 20%, or a 17% growth, while over the same period, coal-based power generation has fallen from 37% to 20%, a 17% drop! Interestingly, over that same period, gas-based electricity generation has grown a meager 2%, while nuclear power has fallen by a similar value.

Understanding the transformation of the electrical mix is important: Natural gas derived from hydraulically fractured shale reservoirs has been a primary driver. Further, coupled with the oversupply of cheap natural gas, the displacement of many aging, low-efficiency single turbine natural gas plants by high-efficiency combined cycle plants has built the resurgence of natural gas based power by substantially lowering the cost of the electricity being produced.

Moreover, the sharp decrease in the cost of installed wind capacity, along with the on-again off-again production tax credits (PTC)

for wind, has been instrumental in the rise of wind power. In Texas, the foresight to authorize and pay almost \$7 billion for the Competitive Renewable Energy Zones (CREZ) by state leaders and the Electric Reliability Council of Texas, or ERCOT, has been unprecedented. (ERCOT operates the majority of the Texas grid.) Between 2006 and 2013, CREZ has enabled the construction of 2,400 miles of transmission lines to carry 18,500 megawatts of West Texas wind generation to major load centers in Dallas, San Antonio and Austin.

With the continued growth of Texas' population, the slow but definite shift of passenger mobility to electrical vehicles – Houston is aggressively looking to transform 30% of its transportation fleet to EVs by 2030 – and the increasing electrification of industrial energy needs, the growth of power production and transmission in Texas is anticipated. So with substantial growth in natural gas and wind over the past decade, what's the most likely source to fill this increased electricity demand in the future?

Natural gas seems like an obvious answer, but despite its rapid growth over the past decade, continued growth is likely to slow, both because of public resistance to building new pipelines to bring gas from the state's shale drilling fields to its population centers and because of growing environmental concerns about damaging methane released by flaring. Additionally, the underlying technology of hydraulic fracturing that has enabled the shale revolution is under increased scrutiny.

Expansion of onshore wind along the Gulf Coast offers potential because of the proximity to urban areas with high demand and an established infrastructure for gathering, transmission and distribution. Offshore wind production from the Gulf of Mexico, on the other hand, is a slow work-in-progress and unlikely to compete with other sources of electricity for at least the next decade, as the cost of offshore wind remains substantially higher than onshore wind, solar and natural gas in Texas. This is in spite of significant expansions of offshore wind occurring in Europe, China and along the East Coast, and the favorable climate for offshore wind in Texas originating from excellent wind resources, a shallow shelf and existing infrastructure from ongoing oil and gas operations.

The bet seems to be on solar power: utility-scale solar power, close to population centers and coupled with modest energy storage options.

Solar power today accounts for less than 1% of Texas' energy mix, but the amount of installed solar power in the state is expected to almost triple by 2021.

With strong overlap between peak production and peak demand, especially in the summer, utility-scale solar is especially well-suited from a grid integration perspective. Moreover, with significantly lower soft costs as compared to rooftop and distributed solar, utility-scale solar combined with modest storage seems an attractive solution.

Installing solar projects near urban load centers would also address one of the key challenges to the expansion of onshore wind, especially in West Texas, where significant increases in wind capacity are hampered by potentially saturated transmission lines and the absence of affordable large-scale storage.

Texas clearly has the natural resources to power the transition to a cleaner energy future – large reserves of natural gas, abundant winds both onshore and along the Gulf Coast, and plenty of sunshine. Decisions made now will shape the energy mix and the grid of the future.



Published January 15, 2020 on Forbes.com

OIL & GAS FOR 2020—FOLLOW THE MONEY

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Expect low and lower prices for oil and natural gas during Election 2020. Since long before he was elected, President Trump consistently called for lower oil prices, and he has strived to maintain low oil prices with his Middle East policies. The third rail of energy policy for every elected official in Washington D.C. is that no one is re-elected if prices increase at the pump or the electricity meter. Not Republicans. Not Democrats. This is why there is no national carbon pricing mechanism and no leadership from Washington to address climate change, even though a majority of all voters favor biting the bullet and paying for action to reduce carbon emissions in the US.

With this landscape in place, the one positive federal action that would benefit industry, consumers and the environment would be the construction and completion of natural gas pipelines to New England. That could buy votes for both Republicans and Democrats this year.

Notwithstanding the political climate, last year's forecast for 2019 in these pages played out as expected. OPEC+ Russia proved to be unreliable, (once again) renegeing on their promise to maintain higher oil prices and instead kept prices low as President Trump demanded. Wall Street investors forced a number of mergers and reorganizations. The Wall Street Journal exposed the dirty secret of US shale operators: "child" wells in the shale plays do not perform as well as the initial or parent well. Further research confirmed the findings and, in fact, demonstrated that the "child" wells are 30% to 40% less productive than predicted by operators in 2018. The rig count is down. Some operators kindly postponed layoffs until after the holidays. But the inventory of Drilled Uncompleted wells, the DUCs, finally began to diminish as operators took massive write-downs on their sunk drilling costs. The last of the write-downs should be realized with the 2019 yearend reports.

The natural gas industry also suffered from low prices, as the associated production of gas in the Permian drew negative (!) prices, as low as -\$8/mcf, or thousand cubic feet, as supply overwhelmed capacity to take the gas to market.

That the Permian Basin flares more gas than many states consume is a problem for industry, consumer and environment. Chesapeake issued a going concern warning. Chevron wrote down billions relating to its natural gas assets—not because the production of the gas is noneconomic at current prices but that the horizon for bringing that gas to market is now indefinite. The pipeline projects planned in 2010 to take gas from West Virginia and Pennsylvania to New England are no closer to construction. As a consequence, the residents of Boston pay more than \$8/mcf for natural gas delivered as LNG vs. customers just 400 miles away, who pay less than \$3/mcf. That every oil-burning house in New England belches at least 30% more CO₂ with \$60 oil than it would with the \$18 heating equivalent amount of natural gas is ludicrous by any measure.

The first week of 2020 began with a display of exactly how dependent the US oil markets are upon the Middle East. Even though President Trump declared that the US is energy independent, consumers who purchase fuel at the pump every day know better. US oil production is up to 12+ million barrels per day. Some will point out that production of NGLs, natural gas liquids, are up to 6 million barrels per day and call that "petroleum production" to match the approximately 18 million barrels per day of US oil consumption. But they dissemble by mixing apples and oranges. NGLs are not refined into transportation fuels in the US.

Of the US oil production of 12+ million barrels per day, fully 4 million barrels are exported because US refineries are not configured to process the lighter grade of crude produced here.

The US still requires imported oil to fuel our transportation infrastructure. And of course, with the recent ability to export crude, US consumers could find themselves bidding for US-produced oil against China or Japan in the event of catastrophe in the Middle East.

The exposure to lower oil prices continues. US domestic production is just 12% of the daily world market of 100 million barrels per day. Only 4 million barrels per day of US production could compete on price with members of OPEC in another all-out predatory price war such as the one experienced in 2015 and 2016.

Eventually, the newly publicly-held Saudi Aramco will go for market share, so US shale plays must improve productivity and reduce costs. Some of these shale plays will likely go into a form of suspended animation, much the way the Barnett Shale has for gas. For years, the granddaddy of horizontal fracking natural gas plays has had practically zero new drilling, with only one active rig this past year. The Barnett's economics are beaten by more prolific basins.

Strategy—Follow The Arbs And Fundamental Investors

The major oil companies, so called because they are vertically integrated from wellhead to end product, have done well. ExxonMobil began a massive expansion of their Baytown, Texas refinery complex, but only after acquiring a major position in the Permian. ExxonMobil's huge oil find in Guyana proves again the value of scale. Total acquired Anadarko's Africa assets after Anadarko's stumbles in US shale plays led to its acquisition by Occidental Petroleum. Chevron's aforementioned write-down did not diminish cash flow or prospective rates of return—again, if ever there was an argument for scale, a company that takes a write down of \$11 billion and does not miss a beat is certainly one.

Oil and gas thrive in the rest of the world. Rates of return for drilling offshore Western Africa, Israel, Brazil and almost any other nation are greater than that for the US shale plays. Of course, that is where the capital is headed. But there is great difficulty in valuing the 80% of the world oil market that is

controlled by the national oil companies and regimes that can change the rules when it suits—to wit, the past deals between US companies with Russia, or with Mexico, or with Israel. Investors in the publicly listed Chinese oil companies had a rude awakening when the government directed the companies to increase spending on more domestic exploration. Sovereign risk is real. The Saudi Aramco IPO was Exhibit A for 2019. Saudi Aramco is not equivalent to any US listed and operated company, and it cannot be similarly valued.

US independents and those backed by private equity firms that were funded prior to the price war of 2015-16 have lived through capital destruction of more than \$250 billion. Among the worst performing asset classes of the S & P 500, these companies remain in a financial limbo with no clear exit. For these companies, Tobin's q , the ratio of the market value to replacement value, is less than 1. As Anadarko exemplified, these companies are acquisition fodder. Strategic investment in prime candidates may be rewarded. Each investment bank has its Top 10 list that usually contains Apache Corporation, EOG Resources and Noble Energy.

A contrarian thesis would be to start now. Pick up the castoffs of the independents and private equity firms. Conventional oil and gas plays in the US offer attractive rates of return, hampered only by the herd mentality of “professional” investors.

Most of us are short oil. We do not have enough fuel in the tank to get us through the month, week or maybe even today. Our exposure to catastrophe in the oil supply markets is less than one in 10, but significantly more than being hit by lightning or other natural disasters for which we buy insurance. Long dated, out-of-the-money call options on oil would be the equivalent of fire insurance for consumers, and we are all consumers.

Published March 13, 2020 on Forbes.com

WHAT DOES THE OIL PRICE CRISIS MEAN FOR THE ENERGY TRANSITION?

RAMANAN KRISHNAMOORTI

Chief Energy Officer, University of Houston

The current crisis facing the oil industry happened seemingly overnight, the result of a two-pronged situation: the economic slowdown caused by the global COVID-19 pandemic and the predatory attempt by Saudi Arabia and Russia to eliminate competition from the American energy industry.

The fallout, however, may be felt for years, and in disparate ways. The move to zero-carbon energy and even the electrification of the vehicle fleet are likely to be slowed. The oil majors' hold on the Permian Basin will grow stronger. And traditional energy companies may shift priorities from environmental and corporate social responsibility initiatives preferring instead to focus on employee safety, community health and profits over a broader remit.

How did we get here?

The American energy revolution, centered around the Permian in West Texas and New Mexico, was fast-evolving from an industry dominated by small and medium sized independent producers, powered by ingenuity and the clever application of disruptive technologies and business ideas, to an industry dominated by integrated energy companies. Those oil majors swept into the shale fields and have used assembly-line methods to optimize exploration and production of the oil-rich shale fields while also integrating that production with their supply chains for midstream and downstream assets.

It paid off – production had grown to 4 million barrels per day by last year, about one-third of total U.S. production. It's been hard for independent producers to compete, and the

resulting flight of capital from the Permian has further weakened independent producers. The combination of COVID-19 and geopolitics might just seal their fate.

How does this new dynamic in the oil and gas market impact the energy transition, the effort to transform the global energy sector from fossil fuels to zero-carbon energy by 2050, in order to limit climate change?

Simply put, this new dynamic might jeopardize the significant gains made in advancing the energy transition. And this largely derives from the cost of the transition.

Developing a strategy for the deployment of affordable, reliable and sustainable energy – a strategy that can satisfy both the world's growing demand for energy and concerns about carbon and other climate-damaging emissions – is key to this transition. And there have been plenty of hopeful signs, especially in the U.S. and Western Europe.

Pressure to de-carbonize energy sources has resulted in a rapid drop in the use of coal over the past five years, especially in the United States. Flaring and venting of natural gas remain significant issues but have increasingly become visible challenges as the true extent of the practices are only now being measured. And what gets measured, gets monitored!

Wind, solar and other renewable energies have become more affordable and certainly more robust, despite continuing challenges with reliability. Less than a year ago, Bloomberg NEF forecast that solar and wind would provide have the world's energy by 2050.

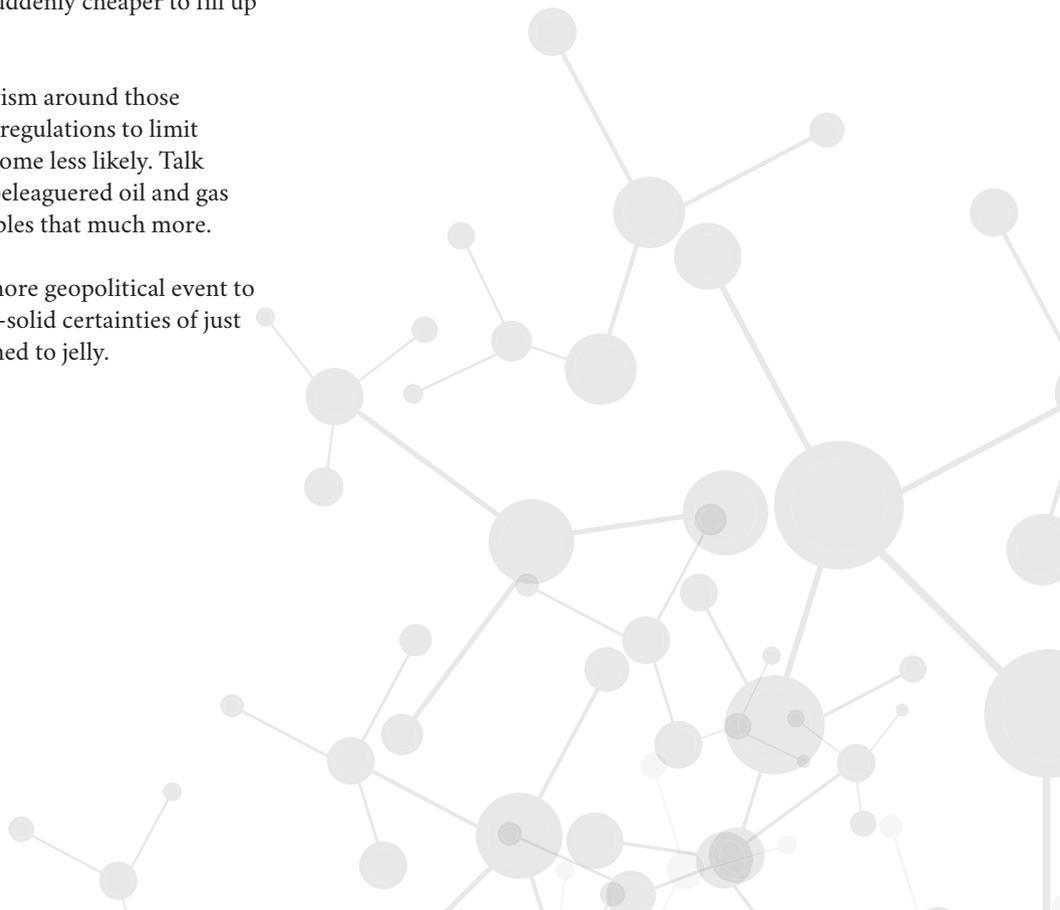
Things look substantially less rosy today.

Driven by the coronavirus and pledges by Saudi Arabia and Russia to flood the world market with low-priced oil, the cost of electricity generated from fossil fuels is likely to remain low. The growth of renewable power in the U.S. already has been hurt by the lack of incentives – subsidies for solar installations have been limited and production tax credits for wind energy will be phased out in 2021 - but low prices for fossil fuels won't help.

Those low prices also mean lower gasoline prices – AAA reports the price of a gallon of gasoline dropped six cents between March 9 and March 12. That, combined with a bear market and an overall gloomy economic outlook, isn't good news for those expecting a rapid expansion of electric vehicles. Why pay a premium for an electric car when it's suddenly cheaper to fill up your old gas-powered ride?

Climate concerns – and the social activism around those concerns – aren't going away. But new regulations to limit fracking or reduce flaring have just become less likely. Talk of government relief for the suddenly beleaguered oil and gas industry will slow the push for renewables that much more.

Hold on tight. All it might take is one more geopolitical event to reshape our energy future. Those rock-solid certainties of just 10 days ago suddenly seem to have turned to jelly.



Published March 22, 2020 on Forbes.com

LOWER FOR LONGER: COVID-19'S IMPACT ON CRUDE OIL AND REFINED PRODUCTS

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The price of crude has dropped to levels that we have not seen in a generation. The driver for this has been the disagreement between Russia and Saudi Arabia about decreasing production by 1.5 million barrels per day and instead increasing production by about 2 million barrels per day.

The global demand for oil until recently was about 100 million barrels per day. After nearly five years of oversupply, supply had finally come into close agreement with demand.

COVID-19 is adding another, and by most accounts a more serious complication, and one that will last longer.

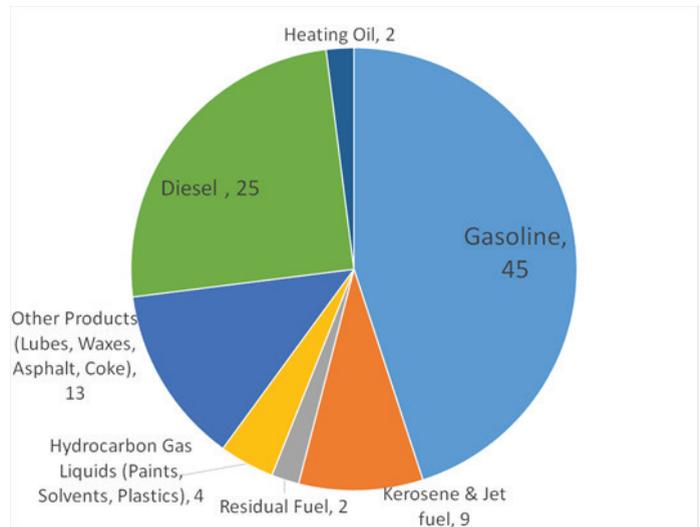
The impact of COVID-19 has been vastly underestimated by agencies such as the International Energy Agency. They had recently suggested that demand might drop by 90,000 barrels per day; that compares to a prediction in December 2019 that demand would go up by 900,000 barrels per day.

A recent estimate by IHS Markit suggests that we might be in for a bigger shock. They predict that gasoline consumption in the US will drop by 55% for March and April due to COVID-19. They also indicated that jet fuel demand would be halved over the same period. Lastly, they suggest that diesel demand would be down by 20%.

What does this mean? In 2019, the US consumed 20.5 million barrels of crude oil per day. How was that crude oil consumed? On average, 45% of each barrel goes towards making gasoline; 25% towards diesel; 9% towards jet fuel and kerosene. The remaining 21% goes to heating oil, residual fuel, feedstock for

plastics manufacturing and other products including paints, resins, etc. If the IHS numbers are correct, then COVID-19 would result in US demand for crude oil dropping to 12.5 million barrels per day. That's a drop of a whopping 8 million barrels per day of crude oil, or 8% of global crude production!

Figure 1. Average use of each barrel of crude oil in the US



Source: Breakthrough Advisor Brief

However, refineries don't work that way. They take in a staple diet of crude oil and churn out products in roughly the same proportion. Changing the output proportions would cause significant disruptions to refinery operations. Since diesel's demand is least

impacted because of its use in freight transport and will control refinery output, we anticipate that the crude consumption by the US will instead drop by 4 million barrels per day. But this will be accompanied with the rapid growth of inventories for gasoline and jet fuel, at rates of 30% to 35% of average daily consumption accumulating in storage tanks. Should COVID-19's direct effects on the demand in the US last for two months (roughly how long it took China to start the recovery process), we would have built up additional reserves of gasoline and jet fuel that would last at least an additional month.

With the exception of China, the rest of the world's economy, notably Western Europe and to a lesser extent South Korea and Japan, is under similar stress as the US economy. China has started to slowly recover after four months of economic pain. Given that, we anticipate that world demand for crude oil is probably down more than 10 million barrels per day, or down more than 10% from last year's average consumption and production. The additional amount of crude being added into the market by Saudi Arabia and Russia will exaggerate this oversupply. The inventory of crude and refined products will continue to grow, so this oversupplied situation will persist for months after we have overcome the COVID-19 crisis.

It is no wonder that the Texas Railroad Commission, which oversees oil and gas production in Texas, and the US government are considering intervening to slow this inventory buildup using mechanisms not employed in at least 50 years. The Texas Railroad Commission is contemplating restricting production from the state's oil fields and therefore putting its thumb on the price of oil – a role it had held until the OPEC-led price shock in the 70s. Similarly, the US government is contemplating barring imports of oil, a position it has not taken since the late 50s. While these are unusual times, such measures are unlikely to change the continued depressed price of crude and refined products that exist now and that will exist well after the COVID-19 crisis starts to recede.

We in Texas are looking at lower-for-longer for crude oil no matter what the Saudis and Russians do. And with the buildup of refined product inventories, the refining industry will continue to be depressed.



Published April 6, 2020 on Forbes.com

WORRY AND APPRECIATION: THE ENERGY WORKFORCE REACTS TO COVID-19

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The oil and gas industry is facing unprecedented headwinds, buffeted by the intertwined forces of the COVID-19 pandemic which has sickened more than a million people across the world and killed more than 58,000, dropping oil prices, the result of drastically lower demand, and uncertainty about how much oil will keep flowing into the global markets.

The industry's workforce is caught in the crossfire, labeled "essential" employees in the United States and elsewhere but all too aware of the risks to both their livelihoods and their industry. A University of Houston survey of workers from across the industry found points of optimism – workers gave their employers overwhelmingly high marks for how they have handled the crisis, from pre-crisis planning to support for workers struggling to juggle work-life balance as schools and many businesses shut down. But the workers also reported worries about both their immediate job security and about the future of the industry as a whole.

The survey findings suggest that, despite the market turmoil, companies will need to remain tightly focused on core issues to maintain strong relationships with their workforce, relationships that will be critical when the market stabilizes. This includes continuing strong, two-way communication with employees – most employees currently say their companies have done a good job with this, but continuing lines of communication over the long haul will take conscious effort – as well as a heightened awareness of potential safety lapses as workers are distracted by concerns about the coronavirus and job security. More than ever, best practices for environmental, social and corporate

governance will require providing support for the workforce and engaging in community concerns when possible.

The project is designed to offer industry leaders data-driven insights into best practices for managing energy-focused companies throughout a crisis of enormous and evolving magnitude. UH Energy worked with three industry associations, including PESA, the Petroleum Equipment and Services Association; Pink Petro; and IPAA, the Independent Petroleum Association of America, to gather data from workers across the industry spectrum. Data were collected from over 400 energy workers through an online survey between March 25 and April 1. Participants averaged 16 years of experience in the industry, and while more than 80% worked in the oil and gas sectors, alternative energy, and the power and utility sectors were also represented.

The workforce has not been immune from the virus itself, as 5.4% of workers reported symptoms consistent with COVID-19 but said they had been unable to get tested. One respondent reported to have tested positive. On this issue, we recommend that the industry advocate for widespread testing of energy workers, along with strict guidelines prohibiting reporting to work when employees are sick and paying all workers who experience symptoms.

Our other key findings include:

- Almost 90% said their companies effectively reacted to the pandemic, primarily based on three issues: whether the company had provided clear information to workers about their jobs, the pandemic and adjustments to prior plans based on the outbreak;

whether it had provided support for helping employees manage the intersection of their work and personal lives; and whether the company had been prepared operationally for the prospect of a global viral pandemic.

- Concerns about the future of their employment were widespread: 53% reported concern about the future of their jobs; 39% said they are concerned about being able to cover their mortgage and other bills.
- Just 46% described themselves as optimistic about the future of the energy industry. While we thought people who had been in the industry longer, weathering previous boom and bust cycles, would be more optimistic, that didn't hold true.
- 83% said their company had provided appropriate technology to allow them to work remotely. 71% credited their supervisor with helping employees resolve conflicts between work and family life caused by the COVID-19 pandemic.
- Although workers overwhelmingly said their companies are still focused on safety, several issues raised potential red flags: 37% said concern about the virus had affected their sleep; something that was especially true for people whose workload has increased due to the virus, who struggled with work-family conflicts and who were worried about job security. Poor sleep carries potential implications for workplace safety.
- Situational awareness is another safety concern. 27% said they are having trouble remembering instructions, and 21% said it has been difficult to pay attention to details since the outbreak began.
- 55% of respondents believe the current pandemic indicates the energy industry should invest even more in employee health and well-being. Similarly, 51% agreed that COVID-19 crisis shows that energy companies should engage further in projects supporting their local communities.

For energy leaders, the report offers affirmation for what they are doing right. It also suggests several actionable policy implications:

- Even in times of uncertainty, employees benefit from timely, sincere and transparent information about their company's plans. This is particularly true for plans that affect long-term job security and processes used to make reduction in force determinations. Mitigating the stressful effects of job insecurity

is important.

- First-line supervisors play a critical role in supporting employees dealing with work and family demands that were covered by routine care arrangements only weeks ago. Employees benefit greatly from supervisors who recognize that both work and life demands need to be effectively navigated. Brief training for supervisors on supporting work-life interface issues are likely to result in positive outcomes for employees and their organizations.
- Employees involved in crisis planning are at particularly high risk of experiencing fatigue and may struggle to retain much-needed focus. We recommend energy companies consider reallocating routine work tasks for individuals heavily involved in crisis planning. This would be expected to mitigate the safety and performance risks associated with fatigue. Techniques and trainings geared towards improved sleep hygiene (such as mindfulness and physical exercise) may also prove useful for those dealing with changed work scopes associated with pandemic planning.
- Continued engagement in elements of environmental, social and corporate governance (ESG) that highlight the commitment to the well-being of employees as well as engagement with the local communities is a high priority for employees. Initiatives to engage with the workforce through clear communications and transparent information has been the hallmark of crisis management by the energy industry towards their most valued asset and must continue.

It may be too early for the energy industry to predict long-term priorities for sustainability efforts and other ESG engagement, due to the ongoing COVID-19 outbreak, disruptions in the supply chain, low oil prices, and plunging demand. A better understanding of what the future will hold for the industry is at least a few months away.

Nonetheless, companies should be aware that the uncertainty surrounding those issues is keenly felt by industry employees. Communication on these topics, as with other aspects of the job, will continue to play an important role in helping employees retain crucial ties to their companies and the industry.

Published April 17, 2020 on Forbes.com

WILL TEXAS FORCE OIL PRODUCTION CUTS?

ED HIRS

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On Tuesday, April 14, the three commissioners of the Railroad Commission of Texas convened an extraordinary virtual hearing to obtain testimony as to whether the RRC should limit production of oil in Texas. I was asked to provide testimony, and my comments are included below.

The hearing ran for 10-plus hours as the commissioners unwearingly waived the strict 3-minute limit for the 58 listed speakers, who were evenly distributed among those for production cuts and those against. Speakers included producers—small, large, from Texas and from other states—midstream (pipeline) companies, investors, consultants and academics. The hearing had all of the drama of theater: anger, pathos, frustration and humor.

The RRC has the ability to order Texas oil and natural gas producers to limit production but last imposed such limits in the early 1970s—as one speaker noted, all of the RRC staff who knew how to do that are dead now. The question of whether a new regime of RRC limitations could withstand federal court challenges as restricting interstate commerce went untouched at the hearing.

Some producers damaged their own arguments in favor of cuts as they stated that the oil industry has destroyed billions of dollars of capital over the past decade, even before the onset of the Russia vs. Saudi Arabia price war and the COVID-19 economic recession. One lamented that no industry could survive the volatile price moves oil has sustained over the past decade, even as the domestic industry has pushed forward with ever increasing amounts of oil production. There was no irony intended in the statement by some producers that this same growth in production has taken place even as there has been a

lack of capital flowing to the industry.

One pipeline executive suggested pro-cut producers were looking for a RRC edict in order to duck contractual obligations—perhaps to pipelines, royalty owners, landowners or lenders.

Another speaker, with no production in Texas but significant production in other states, suggested Texas should “be honorable” and cut production. But by then, the commissioners had recognized the futility of ordering a production cut without cooperation from other states and nations. The RRC cannot order refiners to buy from specific producers, or at what price. Any Texas supply cut would be countered by supplies from other states or nations, trading houses or hedge funds.

The day’s economics argued in favor of producers voluntarily shutting in and selling forward at next year’s price—a guaranteed 60-plus percent rate of return.

Testimony of Edward Hirs before the Railroad Commission of Texas

My name is Edward Hirs. I am UH Energy Fellow at the University of Houston and BDO Fellow for Natural Resources. My testimony is mine alone and does not represent views on this matter held by the University of Houston or BDO USA, LLP.

Chairman Christian, Commissioner Craddick, Commissioner Sitton, ladies and gentlemen, thank you.

I will address the matter at hand: whether the Railroad Commission of Texas should unilaterally restrict Texas oil production by using its power to impose proration.

The short answer is no. Here's why.

On January 1, 2020, the price for Texas crude was roughly \$60 per barrel. Now it is close to \$22 per barrel for May, and \$29 per barrel in June. The price at the wellhead is less. The precipitous drop is primarily due to two factors: an increase in supply due to a foreign price war, and decreased world demand (from 100 million barrels per day to 80 million or less) resulting largely from the current coronavirus pandemic.

Oil is a relatively fungible commodity, and one that can be shipped worldwide, so competition in the market is global. Because the U. S. oil market is a free market with imports and exports, Texas oil producers compete with oil producers everywhere.

Texas produced approximately 3.9 million barrels of oil and condensate per day in January 2020 (according to recent Railroad Commission data). This is roughly five percent of current global demand. Reducing production in Texas would not bring supply and demand anywhere near the balance they enjoyed at the beginning of the year and would do nothing to raise the price of Texas oil.

Any producer can choose to shut-in production. At the current low prices, all but the most desperate high cost producers will stay out of the market and wait for prices to recover. Proration cannot help them, but proration will hurt low cost producers who can still produce profitably and want positive cash flow now. Over the past few days, we have seen that the global supply cut agreement has had little impact on price. But we have seen some American producers embrace government intervention. This quaint nostalgia for price supports invites a return to price controls and windfall profits taxes when the inevitable oil price spike occurs, and consumers vote with their pocketbooks. The industry spent decades ridding itself of this kind of socialist intervention.

I have read many of the comments submitted for this hearing. Producers in other states and nations will laugh all the way to the bank if Texas cedes market share by prorationing. Some producers argue that prorationing will save those that are

teetering on the edge of bankruptcy—but if a producer must rely upon Saudi Arabia and Russia for success it has already failed. Any producer is free to sell at \$6 per barrel. Any reckoning will come at the shareholders meeting. The Commissioners are the wrong trinity to ask for help.

The solution is to let oil producers and oil consumers reach a market equilibrium without government intervention. The well-known cure for low oil prices is low oil prices.

Published April 21, 2020 on Forbes.com

THE STATE OF INTERNATIONAL OFFSHORE REGULATION A DECADE AFTER THE DEEPWATER HORIZON

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This week the oil and gas industry commemorates a decade since the tragic events of the Deepwater Horizon rig accident. The industry also honors the memory of the 11 deceased platform workers, and recalls the 17 platform workers who were injured and the population along the Gulf coast that was affected by what has been defined as the largest environmental disaster in U.S. history.

The accident, also known as the “Macondo Disaster,” has been the focus of a decade of studies. The lessons learned from the accident would help the international oil industry avoid, as much as possible, this type of major accident, caused by the failure of effective industry and regulatory checks and balances to counteract a cascade of operational failures, revealing, among other issues, the lack of industry contingency plans for deep-water oil spills at the time.

The consequences of the Deepwater Horizon accident did not stop at the limits of the contractual area, nor did the accident only impact the parties involved: BP as the operator and the other partners in the consortium, Anadarko and Mitsui; the drilling contractor, Transocean; the cementer, Halliburton; and Cameron, which manufactured the blowout preventer.

The major oil spill of about 4 million of barrels of oil over 87 days certainly surpassed the contractual area and was felt globally. It affected other operators in the Gulf of Mexico which should comply with a drilling moratorium, also caused the halt of offshore bid rounds and the suspension of operations in other offshore oil-producing countries. It additionally brought a temporary increase in insurance costs, triggered government

review of offshore regulation in the U.S., Europe and Brazil; and even threatened modification of standard clauses that traditionally limit service contractors’ liability towards big oil and gas operators. In other words, the incident imposed a stigma on the entire offshore oil and gas industry, which after a decade continues to review and improve technology, industry practices and environmental and safety rule models worldwide.

However, the platform explosion did not cause the collapse of offshore oil and gas drilling and production. During the last decade, offshore oil continued providing almost 30% of the global oil production despite the challenges imposed by price volatility and the current COVID-19 pandemic crisis.

Moreover, offshore oil industry organizations have proliferated and increased their stake in training programs and publications, providing more worker hours invested in research in compliance with international oil industry standards. This is the case of the International Association of Drilling Contractors (IADC), the Center for Offshore Safety (COS), Oil and Gas UK, the International Association of Oil & Gas Producers (IOGP), the International Regulators’ Forum (IRF), and OPITO, which have increased activities promoting compliance with industry practices and training. This has also been the case at the University of Houston, which has been part of the efforts from academia to contribute to research and development of best practices and studies through the Subsea Systems Institute (SSI), and scholarly regulatory works on the U.S. and comparative offshore regulation and transnational offshore regulation.

As we see today with the COVID-19 pandemic, catastrophic events give rise to the belief that government should intervene and offer solutions to the crisis, as well as that more robust regulation would solve the recurrence of these events. In the short run, it seems politically and technically appropriate, particularly in cases where industry has failed to improve its own standards to frontier or non-conventional operations. This is also known as the prescriptive approach where, in the oil and gas industry, national hydrocarbons regulators tend to impose on oil companies the methods, procedures and practices that operators must follow when carrying out oil and gas operations.

Nevertheless, that approach alone fails in the long term, mainly because of two factors: 1) The lack of appropriate R&D budgets for the regulators of hydrocarbons (even in developed oil-producing countries) to keep regulation updated to meet industry challenges and the evolution of technology; and 2) hydrocarbons regulators should not bear the burden of something that is a contractual obligation of oil and gas operators to the nations they operate in. In other words, states attract companies to invest and provide capital, know-how, technology and human resources for the exploration and production of hydrocarbons. The performance of exploration and production activities is an obligation widely standardized in contracts that require oil companies to carry out exploration and production operations with respect to international oil industry practices. The rules are defined as the generally accepted methods, procedures and practices normally followed by prudent operators in the international oil industry to produce hydrocarbons resources in an economically and environmentally sustainable manner. Examples of these rules commonly used in the international oil industry are standards issued by the IADC, API, NORSOK, IMO and ISO, among many other professional organizations.

Far from the common characterization of the industry standards as “voluntary industry rules,” a legal framework for international oil industry practices exists and is perfectly enforceable. These rules have a contractual and customary legal nature that provides them with a level of compliance, which made them enforceable before international arbitration tribunals, as well as in national courts.

The economic and legal rationale responds to the interest to keep the burden of proof to demonstrate the appropriateness of the practices employed on the operator. Indeed, in performance-based regulation, it is the operator, the industry actor, that is better prepared in terms of the analysis of the geological data, to assess the technical risks of an operation and, more importantly, to assume the financial risk of an accident. It is also economically efficient to shift the burden of investment in research and development to operators while maintaining the burden of proving that their operations follow the generally accepted practices of the international oil industry. Thus, why transfer that burden to national hydrocarbons regulators? The regulation of industry practices does not only fall into the interest of government oversight. As described above, the global consequences of an offshore accident can potentially end up impacting the international oil and gas industry.

Therefore, transferring the burden of compliance to the operator should indeed follow the needs and interests of all industry players, placing the charges to the appropriate actors.

Instead of focusing on regulating the industry practices that guide E&P operations, regulators should instead focus on an appropriate system of sanctions, including enforcement for damages sustained by third parties – such as the population living along the Gulf Coast – and sanctions for environmental pollution. This would help to create a system of incentives for compliance.

In these cases, hydrocarbons regulators will have their say by imposing appropriate sanctions for actions involving the direct liability of operators, or based on acts of negligence or wrongful negligence. That would be the appropriate moment for government agencies to intervene, applying national law and providing adequate access to justice. And always having in mind, that the actions of the host-state should be in compliance with the protection provided by international investment law treaties to oil and gas investors, which comprises access to international arbitration in cases of arbitrary and discriminatory treatment by government actions.



A decade after the Deepwater Horizon accident, the international system of best industry practices is still the prevailing and governing set of rules applying to the international oil and gas industry. The rules perfectly apply to the offshore oil and gas operations in the U.S., as well as in other offshore oil-producing countries. This contributes to the citizens' demands that oil operators have a heavy burden to respect industry standards in all countries where they operate, limiting the possibility of hiding behind less strict local regulation. The responsibility is today at a global scale and under the scrutiny of the global community.

BP's bill for the cleanup, environmental and economic damages and penalties is over the \$65 billion. This shows that failure to operate under appropriate practices can dramatically impact the liability of any operator in the offshore sector.

Published April 27, 2020 on willistonherald.com

NORTH DAKOTA OIL—WASTED OR JUST CHEAP?

ED HIRS

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The effects of the COVID-19 virus have been felt around the world. Unfortunately, beyond health risks, bad actors are using the pandemic to capitalize off unsuspecting victims. Scams are nothing new, even in the utility world. Scammers prey upon victims by manipulating their emotions and creating fear. Like other legitimate businesses, utility companies will never ask for personal information over the phone or by email to satisfy payment on a past-due account. Never give out your Social Security number, date of birth or other critical identifying information. If you ever receive a disconnect notice by email or over the phone, verify the sender's address or telephone number is your utility's. Remember that phone numbers and caller IDs can be spoofed or mimicked. If in doubt, hang up and call your utility company's customer service department to verify a request is valid. A utility company will never call you and threaten immediate disconnection if you do not provide a credit card number by phone. Never pay your utility bill by giving your bank account, credit card or CVC number over the phone. Also, never purchase a prepaid debit card or anything else someone tells you to that is not traceable by your credit card company. Throughout the COVID-19 pandemic, utility companies continue to work with customers on payment options, including balanced billing, when necessary. If you are experiencing a financial hardship, contact your utility provider to discuss a plan that works for you. Be smart, be safe and always verify any requested information with your utility provider. Always call the utility customer service department using the telephone number listed on their website or your utility bill. Report to your local authorities any suspicious phone calls or emails posing as your utility provider. This is criminal activity. You can find more information about utility disconnection rules on the Public Service Commission website at <https://psc.nd.gov/public/consinfo/ysk.php> Brian Kroshus – Chairman, North Dakota Public Service Commission Kroshus holds the portfolio for regulation of investor-owned

utilities operating in North Dakota.

Will the Oil and Gas Division of the North Dakota Industrial Commission choose winners and losers in the midst of a global recession? After deciding last week that current oil production is not "waste," the NDIC will hold a hearing on May 20 "to consider how to determine the oil price at which the production of oil in excess of transportation or marketing facilities or in excess of reasonable market demand constitutes waste..." North Dakota producer Continental Resources has declared force majeure, a legal term dened in contracts, in shutting in its oil wells and breaking contractual obligations to deliver oil. If the NDIC decides North Dakota oil production is waste, then the midstream and pipeline companies who committed billions of dollars to build pipes to North Dakota lose out.

Since 2005, North Dakota has produced more crude oil than North Dakota refineries can handle. To reach distant consumer markets, the state's producers have relied successively on trucks, railroads and nally pipelines. North Dakota oil competes against oil that costs as little as \$15 per barrel to produce.

Pre-virus, the global crude market was 100 million barrels per day. The U.S. consumed approximately 20 million barrels per day, produced approximately 12.5 million barrels per day and exported 3 million barrels per day. "U.S. energy independence" is a myth. North Dakota produced approximately 1.0 million barrels per day while, for comparison, Texas produced approximately 4.5 million barrels per day.

World consumption is temporarily down between 20 million and 30 million barrels per day because of the COVID-19 recession. Even before the virus, prices were falling and world oil consumption was down 800,000 barrels per day due to the warmest January on

record. Why does this matter? Our research shows that for a 1% increase in quantity supplied to a balanced market, the price will fall 20% to 25%. Volatile oil prices are a fact of life in the best of times.

The negative oil price on April 20 was due to a meltdown in the futures market in the May contract. Crude oil buyers continued to buy. Oil prices remained positive in California. Carl Icahn, the investing legend, gratefully accepted payment from May contract holders to take their oil off their hands! Some speculators lost out. Some quick-thinking producers could have joined Icahn and received cash to keep their oil in the ground. Hedge funds and others who bought the oil are paying as much as \$1 per barrel per month to store purchased oil for a year in offshore tankers, salt domes, old depots and even frac tanks. The May 2021 price is much higher than the current price of crude plus the \$12 per barrel cost of storage.

On April 21, the Railroad Commission of Texas took up the question of a temporary cut to Texas oil production. Jim Teague, the pragmatic co-CEO of midstream company Enterprise Products, speculated that the companies who called for the hearing were simply looking for government cover in order to duck contractual obligations to make deliveries to pipelines, refiners and other buyers. The commissioners and every participant at the hearing knew that cutting back oil production in Texas—whether state-mandated or voluntary—would have zero impact on the oil price in Texas. In fact, everyone knew that shutting in all of U.S. production would not bring the crude market back into balance. The Railroad Commission decided to commission a study.

Shale producers are among the high-cost producers in the global oil market and are vulnerable to predictable price wars with low-cost producers. Necessarily, North Dakota producers receive relatively lower prices than other nodes in the global market because of transportation costs. The least expensive transport from North Dakota is by pipeline, and in exchange for cheap pricing, the producers contractually agreed to sell the pipelines. These guaranteed contracts were then taken to Wall Street by the pipelines for financing. Had the pipelines assumed all of the risks, the costs to producers and consumers would be higher.

Continental Resources aligned with the Obama administration to deny market pricing to the Seaway pipeline owners and maintain the regulated contracts. Now, they want the NDIC to protect them from their contracts without making pipeline owners whole.

Of course, North Dakota producers can always go back to shipping crude by rail or trucking.



Published May 4, 2020 on HoustonChronicle.com

OPINION: UH ENERGY EXPERT LAYS OUT STEPS TO MAKE HOUSTON THE SUSTAINABLE ENERGY CAPITAL

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The city of Houston released its climate action plan last week amid calls to make Houston the Sustainable Energy Capital of the World. This may seem far-fetched to those that see not just the city but the entire Gulf Coast and state as simply a large emitter of greenhouse gases, but that's exactly why the region must play a critical role in driving the energy transformation. We already have many of the pieces in place.

Yes, it will be hard. No single fuel, technology or magical thinking will make it happen overnight. It is not a generational issue, and it should not be a partisan issue. It is about all of us having the necessary will and committing to real solutions.

In fact, getting to zero carbon will require letting go of the popular idea that fossil fuels and the legacy energy industry are to blame and cannot be part of the solution. It's essential that these companies instead invest and lead.

The industry has the scale, the technological and leadership capacity to forge the public-private partnerships with communities and academia that will be required to transform all sectors of the energy industry, from oil and gas to petrochemicals and electric power. The Houston area is headquarters to many of the world's leading energy companies, and when you count the refining and petrochemical plants along the Gulf Coast, we are the leading producer and consumer of energy in the United States — and the leading exporter to other states.

So what needs to happen to get us to a sustainable future? I see five major opportunities:

Carbon management is at the top of the list. We must attack emissions of both carbon dioxide and methane by improving energy efficiency — more efficient systems will lower the overall amount of fuel used, thereby minimizing emissions — and by using advanced technologies to capture the emissions that do occur. Those emissions can be converted to useful products or safely and permanently stored. The National Petroleum Council last year issued a report suggesting a path to making this economically and environmentally sustainable. Hydrocarbons make up 85 percent of the world's energy sources and will not vanish overnight. We have to invest in technologies to capture and reuse carbon emissions now.

Hydrogen receives much global attention, and the fossil fuel industries in and around Houston produce and use more hydrogen than anywhere in the world. Pipelines and other hydrogen infrastructure here can be expanded, allowing for greater use of hydrogen as a carbon-free fuel and energy carrier. Transformation in the form of fuel cells will lower the transportation emissions that make up the majority of carbon emissions today.

Integrating renewables into the electric grid is essential to controlling emissions. Texas produces more wind power than all but four countries, and solar capacity is expanding rapidly. Yet we still burn more coal and natural gas to generate electric power than any other state. Our growing population and our energy-intensive manufacturing sector demand affordable energy that is reliable 24/7. We need to use all energy sources, taking advantage of the lower cost of renewables but mindful of the reliability provided by fossil fuels. This means investing in advanced grid management,

energy storage, advanced emission controls and efficiency.

Petrochemicals and plastics reuse and recycling is receiving greater global attention, as well. That's not just about emissions but about the impact of plastic waste on rivers, oceans and other waterways. Houston can lead here through efforts ranging from engineering more earth-friendly plastics — some of which may be produced from plants, rather than fossil fuels — and pioneering the recycle and reuse of plastics.

None of these things will happen without workforce training to ensure workers have the skills in digitalization, computational proficiency and a basic understanding of STEM skills. Expanding education for the regional workforce is critical and will involve not just traditional classroom learning but remote learning and in-field experiential learning.

We are often told not to waste a good crisis, and this one provides an opportunity to jumpstart the re-invention of Houston as we get our economy back on track and generate employment and investment. We offer a fertile field in which to catalyze the energy transformation.

Much of that work has begun in partnerships between energy and the University of Houston and other research institutions. The difficulty will be making the smart investments and policy decisions as the nation emerges from the COVID-19 pandemic. We have to walk the talk.



Published May 27, 2020 on Forbes.com

AMERICAN OFFICES ARE REOPENING. MANY EMPLOYEES AREN'T READY

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States are slowly reopening after two months of stay-at-home orders. For workers in the energy industry, COVID-19 has been a perfect storm: Fewer flights, no summer road trips, and no work commutes have severely limited demand for oil. Along with geopolitical events, the demand slump has put one of America's most conservative industries and its workforce in turmoil.

Energy industry layoffs are anticipated to surpass a million workers. For the past 10 weeks, the vast majority of office-based energy workers in Houston, the world's energy capital, have worked from home. Now, with the state of Texas re-opening, so are many energy company offices. But are workers ready to transition to office work despite continued risk of COVID-19 and reports of new transmissions? How do they react when they read that the social media platform Twitter is letting employees decide if they want to permanently work from home or in an office? Our research team collected survey data from more than 900 energy workers throughout the stay-home order.

Energy workers tell us they are not ready, with many voicing a strong preference to continue working from home if given that option. So what is stopping energy workers – who are historically more likely to vote Republican than Democrat and who on average believe regulatory oversight of the industry is excessive – from wanting to return to their offices?

We find that three factors drive employee perspectives on returning to the office, and employers need to account for them if their goal is to build long-term employment relationships built

on mutual trust. Otherwise, while employees may return to the office now due to high levels of job insecurity and the threat of job loss, their long-term loyalty to the industry is unlikely.

1. Demographics matter. Interestingly, employees at heightened risk from COVID-19 complications based on their health or age were no more reluctant to return than those who described themselves as being in excellent health. However, employees are wary of putting family members and relatives at risk. Employees who live in multi-generation households are more likely to want to continue working from home – for them, getting exposed at the office may mean exposing vulnerable family members at home. African American workers are also more concerned about returning to the office than their white counterparts, likely reflecting higher exposure and death rates in communities of color.

2. Trust – in employers and especially supervisors – matters. Employees who believed their supervisors would do all they could to protect them from workplace transmission were more likely to want to return to physical office spaces. Provision of masks, sanitizer and gloves are, according to employees, also critical in making employees feel safe at the office.

3. Flexibility matters, especially for workers with children. With schools still closed and summer camps not opening for the year, workers feel stranded, and in many cases overwhelmed. Work demands occur simultaneously with family demands, and for many finding childcare is a massive obstacle. If the industry wants to avoid putting an undue burden on women and minorities

after years of working to build a more diverse workforce, the transition of workers to their physical office spaces needs to be slow, allow for flextime, and give workers with COVID-cancelled childcare the option to continue to work from home.

Employees report that the best thing their employer has done during the crisis was enabling and empowering the transition to work from home. Research tells us over and over that managers' concerns about letting employees work from home ("Won't they binge-watch Netflix during work hours? Will they take naps or play with their kids all day? Will collaboration suffer?") are generally unsubstantiated. To the contrary: employees who work from home tend to be more productive and experience less work-family conflict. Collaboration also does not seem to suffer.

It may be time to remember that mutual flexibility and trust are crucial when it's time to make decisions about fully re-opening company offices. We believe energy workers are telling us that for most of them: It's not yet time.



Published June 8, 2020 on [HoustonChronicle.com](https://www.houstonchronicle.com)

THE SMART POLICY BET FOR CARBON NEUTRALITY

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Paying tribute to 50 years of citizen-led action on environmental protection, the City of Houston launched its Climate Action Plan on Earth Day 2020. The energy capital of the world committed to carbon neutrality by 2050. Meanwhile, global energy companies located in the city have reiterated their pledges to decarbonize, despite the challenges of the COVID-19 pandemic, low oil prices and the resulting global recession.

Enacting smart policies now will allow us to repair the economy while meeting long-term climate objectives. Direct air capture technology must be part of both goals.

Direct air capture works by filtering ambient air through a series of chemical processes to remove carbon dioxide from the atmosphere. The carbon dioxide can then be stored, or sequestered, in underground geological formations or converted to new products, including carbon-neutral fuels.

We know direct air capture is technologically feasible, but its economics can't yet drive broader adoption. The right policies could change that.

First, we must take advantage of the ability to use it almost anywhere. This can solve the cost problem - direct air capture is energy-intensive, and expensive, as much as \$600 to capture a ton of carbon dioxide. By co-locating DAC systems with renewable energy facilities and close to where the captured carbon dioxide can be geologically stored, the cost can be dramatically reduced.

The coronavirus lockdowns haven't only lowered emissions; electricity demand has dropped as much as 21 percent in much of the United States. Increasing the use of renewable energy to

meet climate goals by mid-century without storage technologies can exacerbate the gap between supply and demand. Instead, excess renewables can be a free and low-carbon source to power direct air capture systems, lowering the costs.

The U.S. is well-suited for this. It has the greatest global capacity for both onshore and offshore geological sequestration of carbon dioxide, often overlapping with regions that produce wind and solar energy.

Integrating direct air capture with renewables and using these sequestration sites offer multiple competitive advantages. The renewables industry can advance without fear of over-generation, cost recovery challenges, supply-chain instability and stranded assets, while direct air capture can achieve economies of scale with safe and reliable sequestration.

The projected growth of renewables by 2030 could support the removal of 650 million tons of carbon dioxide via direct air capture, equivalent to 11 percent of 2019 U.S. emissions.

Policy incentives are crucial to changing where and how direct air capture facilities are located and powered.

Only one federal policy conceivably addresses direct air capture. Section 45Q of the FUTURE Act of 2018 offers a \$50 credit for geologically storing a ton of carbon dioxide, but only if a minimum of 100 kilotons is sequestered annually. Hence, small-scale projects do not qualify. Without a progressive set of policies, new concepts that initially target small quantities of carbon dioxide will not be commercially viable.

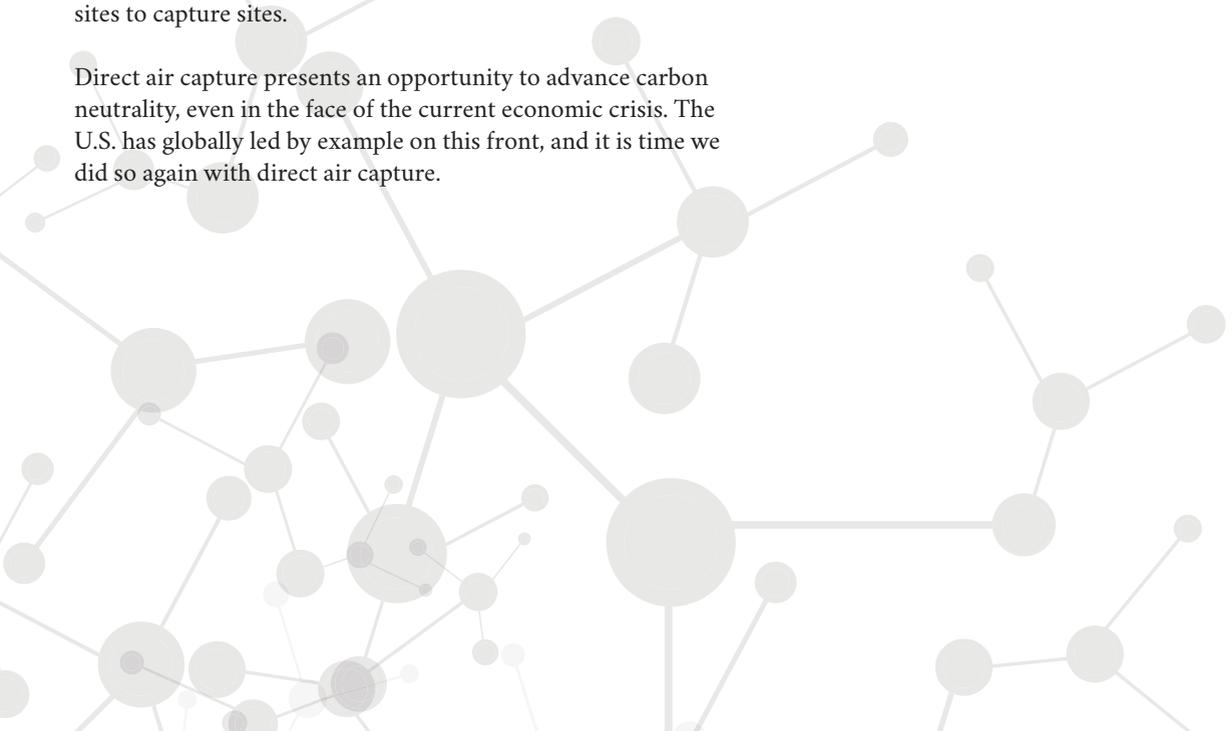
A second proposed policy change would lower costs and ensure a steady supply of low-carbon energy for direct air capture. Production tax credits, which have enormously benefited the wind and solar industries, are set to expire this year. This expiration will magnify challenges facing renewables, ranging from tariffs on international imports to disrupted supply chains.

Production tax credits must be extended to target co-located direct air capture and renewable projects. This could support up to 100,000 new jobs by 2030, critical for a sustainable economic recovery.

A third issue ripe for policy support is transport of carbon dioxide, the critical link between capture and sequestration. Pipeline projects are often caught in onerous permitting processes, predominantly because carbon dioxide is classified as a waste stream.

Appraising it instead as “gainful” and classifying all carbon dioxide pipelines as common carriers would consolidate policy and close the decarbonization cycle by connecting sequestration sites to capture sites.

Direct air capture presents an opportunity to advance carbon neutrality, even in the face of the current economic crisis. The U.S. has globally led by example on this front, and it is time we did so again with direct air capture.



Published July 23rd, 2020 on Forbes.com

HYDROGEN IS A TOP CONTENDER IN THE RACE TO ZERO CARBON

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The goals of 100% renewable energy and zero carbon emissions are at the forefront of all energy transition/transformation conversations. However, the prospect of fully electrifying certain sectors of the transportation industry is daunting because of electricity's limited capabilities regarding heavy-vehicle transportation. Tesla says its electric-powered Semi model will be available later this year, but the reality is electric power coupled with battery storage is not yet powerful enough to realistically and sustainably power things like trains, ships and big-rig trucks. That makes it critical to find alternative low- or no-emission solutions for heavy duty trucks if meeting zero-carbon goals is to remain feasible. The U.S. Environmental Protection Agency says medium and heavy duty vehicles – things like dump trucks, tractor-trailer rigs, trains, and ships – account for over 11.5% of all US greenhouse gas emissions.

That has spurred long-overdue interest in hydrogen fuel cells, which represents an opportunity to make this portion of the transportation sector fully green.

Among signs of this heightened interest: the European Commission recently released a report on hydrogen, and the investment community is seeing increased attention surrounding Nikola, which focuses on electric and hydrogen fuel cell transportation systems, even though it has yet to release a single product.

Hydrogen Power

Hydrogen is unique in terms of energy carriers. Typically

compared to natural gas, hydrogen has much higher energy density, meaning it has a much higher potential energy output per unit of weight. It makes economic sense, at least on paper, to transition from natural gas to hydrogen.

Hydrogen also burns cleanly, with no greenhouse gas emissions from its combustion. The key limiting factor in the use of hydrogen, which does not exist in nature as a separate molecule, is that it can't be mined, extracted or otherwise produced in its desired state without a manufacturing process. Producing zero-carbon hydrogen on the scale required for industry typically requires either large-scale electrolysis (splitting water into hydrogen and oxygen) or carbon capture technology being coupled with fossil fuel plants. After capturing the carbon of fossil fuel production with carbon capture technology, hydrogen can be separated from the carbon and stored independently.

Industrial electrolysis is not quite at the viable operating stage, and using carbon capture to produce hydrogen is less than desirable as it relies upon the combustion of fossil fuels. Despite this, there are key developments on the way for transportation. Hydrogen's energy density makes it an attractive candidate for medium and heavy-duty transportation, including rail and shipping. These transportation modes are very energy intensive, which comes with associated logistic, environmental and economic problems.

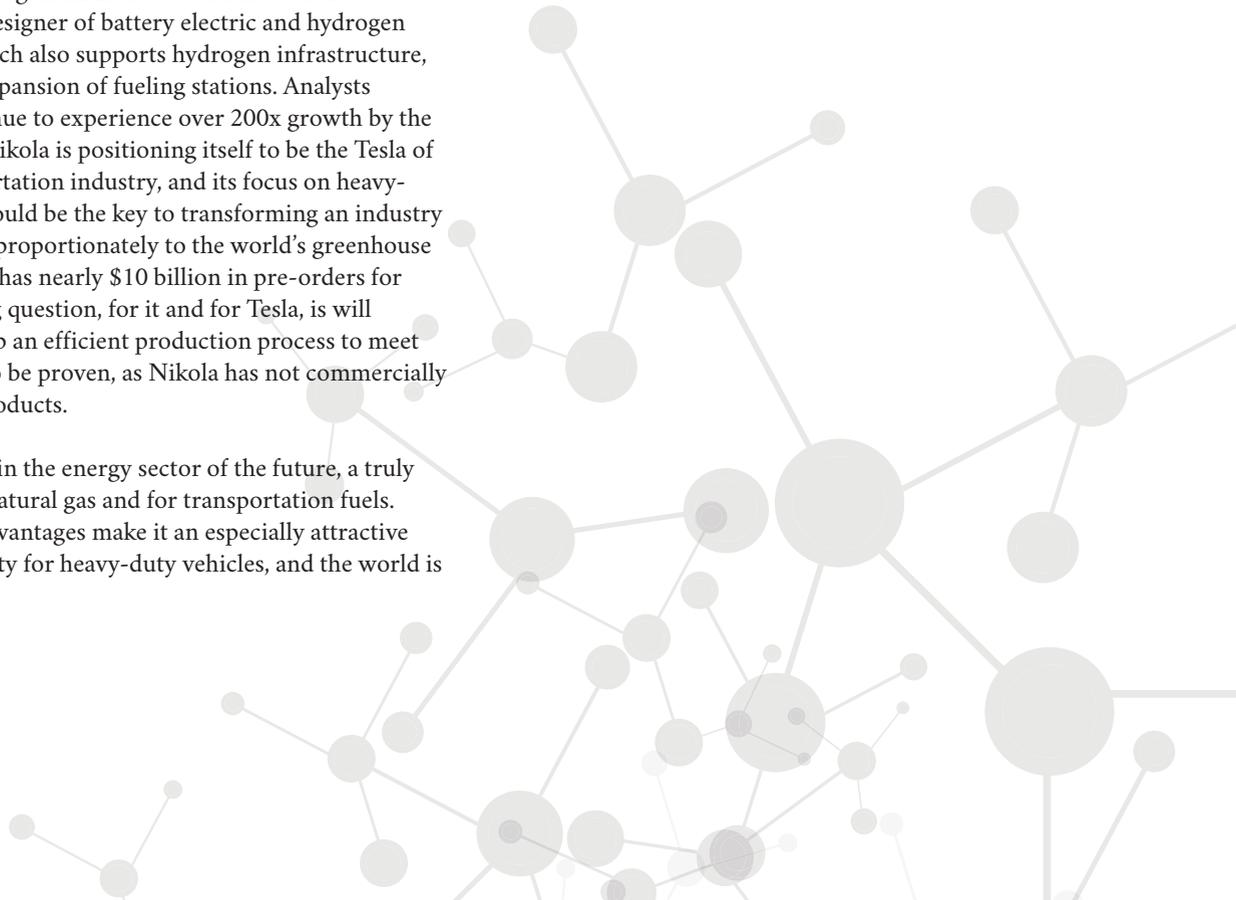
Despite the need, most of the focus on hydrogen in both research and deployment concerns hydrogen as a mechanism to transport or store energy or combust for electricity generation. Hydrogen can be

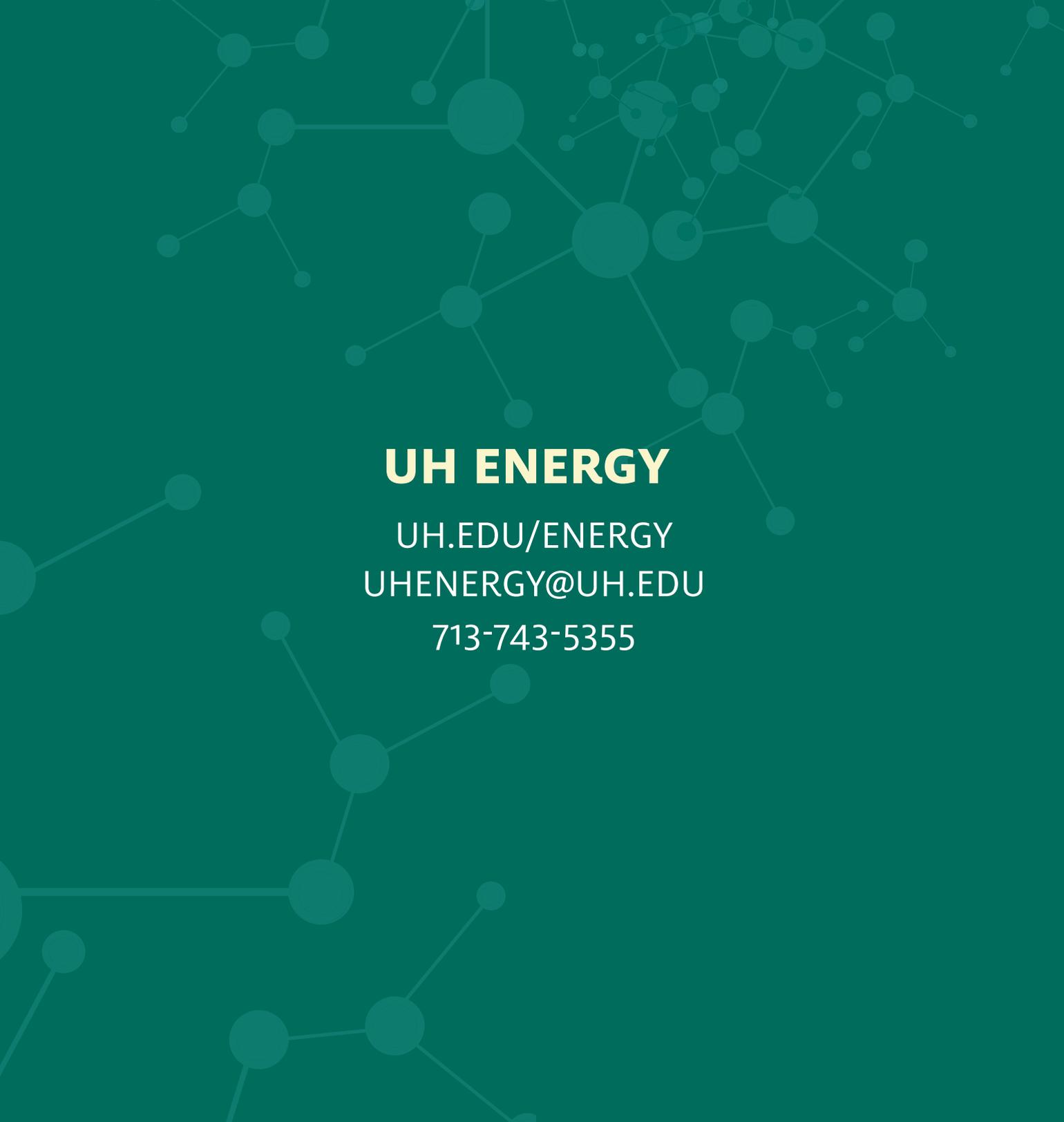
used very effectively for these purposes, but the lack of attention to hydrogen's ability to transform the heavy-duty transportation sector has caused a corresponding lack of investment.

Government response has been generic until recently. Although most governments across the world have yet to recognize the potential, the European Commission recently unveiled its plans for hydrogen in the coming decades. It calls for investments of at least €65 billion – about \$75 billion – over the next decade in order to fully deploy this technology. In response, the commission created the “European Clean Hydrogen Alliance,” whose goal is to build a pipeline of viable investment projects involving hydrogen.

There is one company diving into the transition of heavy-duty transportation to hydrogen: Arizona-based Nikola. Nikola is a manufacturer and designer of battery electric and hydrogen powered vehicles, which also supports hydrogen infrastructure, mostly through the expansion of fueling stations. Analysts expect company revenue to experience over 200x growth by the conclusion of 2021. Nikola is positioning itself to be the Tesla of the hydrogen transportation industry, and its focus on heavy-duty transportation could be the key to transforming an industry which contributes disproportionately to the world's greenhouse gas emissions. Nikola has nearly \$10 billion in pre-orders for their trucks, so the big question, for it and for Tesla, is will they be able to develop an efficient production process to meet demand? This is yet to be proven, as Nikola has not commercially deployed any of its products.

Hydrogen will be key in the energy sector of the future, a truly clean alternative for natural gas and for transportation fuels. Hydrogen's unique advantages make it an especially attractive investment opportunity for heavy-duty vehicles, and the world is beginning to notice.





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