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FACULTY *ENERGY* FELLOWS

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2016 - 2017 | AN ONLINE BLOG FORUM COLLECTION

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

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VOLVO'S ELECTRIC CAR ANNOUNCEMENT: TURNING POINT OR NONEVENT?

EARL J. RITCHIE
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Volvo's recent announcement to have all new models "electrified" beginning in 2019 has received wildly enthusiastic responses from the environmental and electric car communities. Response in the business and automotive press has been more muted. Many articles have pointed out that other manufacturers are introducing electrified models and the move to electrification is driven largely by European emissions requirements.

The decision has been a great PR move for Volvo but carries some risk and will have little impact in the broader auto market.

What the Volvo announcement actually means

Volvo did not say they would do away with fossil fuel powered cars. The planned model mix would include pure electrics, plug-in hybrids and conventional hybrids. The latter two run on a mix of fossil fuel and battery power. They will continue to sell existing fossil fuel powered models to the end of their model life.

Not including numerous engine and trim variants, Volvo has six models on the U.S. market. The luxury SUV XC90 is available as a plug-in hybrid, which adds an electric motor to the standard gasoline engine. Two additional models will be available as hybrids in the 2018 model year. Given normal model life, gasoline engine models will likely be available through 2025.

What the announcement means to the market

There are at least 35 electric or hybrid models already available from other manufacturers, with dozens of forthcoming models announced. The Volkswagen Group alone plans more than 10 models next year and more than 30 by 2025.

Volvo is a niche player with well under 1% of the market, both U.S. and worldwide. Given their small market share and the number of competing models, Volvo's overall impact is likely to be insignificant. They may continue to have a significant presence in limited markets, such as in European plug-in hybrid sales where Volvo currently has about 5% market share.

The announcement as a symbolic act

The Volvo announcement has been called historic, a landmark, a major move, the beginning of the end of the internal combustion engine and similar dramatic phrases. It has certainly been an effective attention-getting device for both Volvo and the media.

However, forecasts of dramatic increases in the share of electric vehicles resulting from the European Union's carbon reduction targets have been around for some time. Visions of the market range from forecasts of "modest levels" of electric vehicle market share to proposals to completely ban gasoline powered cars.

Predictions of a shift to electrification due to EU emission regulations and proposed bans by Germany and France have received extensive press coverage. The Volvo announcement is unique in coming from a mainstream auto manufacturer. A similar announcement by a major car manufacturer, such as Volkswagen or Toyota, would be much more significant.

What the policy shift means to Volvo

Volvo Car Corporation had been a struggling manufacturer, threatened with bankruptcy during the 2008 financial crisis. Turned around following the sale to Chinese manufacturer Geely, Volvo reached record sales in 2016.

The decision to discontinue non-electrified cars can be called a bold or risky move. Having battery electrics and additional hybrid models was necessary for Volvo to stay competitive with other manufacturers. Limiting the line to strictly those vehicles runs the risk of not having cars for an important segment if the industry transition to electric vehicles is slow.

The majority of forecasts have fossil fuel cars still above 50% of the market in 2030. Volvo's sole hybrid accounted for only about 5% of its sales in 2016. Of course, the company can always change strategy.

The bottom line

Volvo's announcement was a great marketing decision. It drew attention to Volvo and establishes environmental cred. It turned a business necessity to a sign of virtue. IHS Automotive analyst Tim Urquhart was quoted as saying it was a "clever sort of PR coup."

By adding electrified models, Volvo is only doing what all manufacturers are doing, although others have not committed to restricting their model lines to electrics. The much debated actual pace of electrification will depend upon government regulation and consumer tastes, not Volvo's strategy. ■

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AMERICA STILL USES A LOT OF NONRENEWABLE ENERGY : THE PROS AND CONS

DEBORA RODRIGUES
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There is a lot of talk about the rapid growth of renewable energy, including wind and solar. It can be easy to forget that at least for now, we still rely heavily on nonrenewable energy sources, such as oil, natural gas, coal and uranium.

Today, it's hard to imagine the western standard of living without fossil fuels and nuclear energy, and many developing nations still struggle to be able to generate enough power to serve their populations. Nonrenewable energy – especially coal – enabled the industrial revolution and has traditionally been the cheapest way to improve standards of living for people in far flung corners of the earth.

These old-school sources of energy each have their pros and cons, but I think the transformation to renewables will come more quickly than many people think. With a new fossil fuel-friendly presidential administration and growing global concern over climate change, the issue of what forms of energy we should use, and for how long, may be the subject of a hot debate.

I've outlined the basics of what people need to know about nonrenewable energy to adapt to a changing energy future:

Hydrocarbons

Hydrocarbons – oil, natural gas and coal – have been produced over millions of years, transforming the buried remains of ancient plants and animals into the products we use to power modern life. Uranium is a naturally occurring element.

Oil

Oil is the major source of energy used worldwide, and it is used mainly to produce gasoline, heating oil and diesel fuel. Industries also utilize oil as the base product in the manufacture of plastics and industrial chemicals.

Natural Gas

Natural gas is the second most commonly used nonrenewable energy source in the world. This energy source is often extracted at the same time as oil, since it often shares space with underground oil reserves. Natural gas is used mainly for cooking and heating, but it also has begun to be used to power some vehicles. The third most used energy source is coal. While coal has been losing market share to natural gas in the United States, it remains a key source of electricity generation across the globe. Five countries – China, the United States, Russia, India and Japan – account for over 75% of worldwide coal consumption.

Coal

Coal, like other fossil fuels, is the product of pressure exerted on organic matter from plants buried underground for millions of years. In U.S., the most common type of coal is bituminous coal, which is made up of about 85% carbon, along with water, air, hydrogen and sulfur. About one-third of the electricity produced in the U.S. comes from coal-burning plants.

Uranium

Uranium is used to produce nuclear energy, which accounts for about 20% of U.S. electricity generation. Natural gas became the top generating source in 2016, accounting for 34% of the nation's electricity generation.

Currently, these nonrenewable sources of energy are still abundant and more affordable than the renewable ones. These make these sources of energy, in the short term, very attractive.

But there is a downside. Unfortunately, these nonrenewable energy sources will be at some point depleted.

Once the fossil fuel reservoirs are completely depleted – or before – we will be forced to find alternative energy sources. But these nonrenewable fossil fuels have other drawbacks, as well. They typically are not environmentally friendly, since they increase the production of greenhouse gases responsible for global warming. They also produce sulfur dioxide, which is responsible for acid rain, and nitrous oxides, which generate photochemical pollution including smog.

Today, uranium reserves are still more abundant than those of several other metals, such as mercury, cadmium and silver. However, the radioactive uranium used as fuel in nuclear plants is very rare.

Unlike fossil fuels, uranium does not generate greenhouse gases, but it can cause environmental harm in other ways, including through radioactive byproducts that can cause severe health and environmental problems.

Another concern in the United States is that no long-term storage plan for spent fuel rods has been approved. Based on all these issues, in the long term, we will need to find alternative and green energy sources to supply the world needs. ■

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ENVIRONMENTALISTS, LOOKING FOR OIL

JULIA WELLNER
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Despite a lingering downturn in the oil industry, which has led to the loss of 100,000 jobs in the United States alone, most of my students are studying geology with an eye towards a career in the industry. This is an understandable choice. Houston is the hub of the world's petroleum industry.

In Houston, it is likely that the person in front of you at the deli studies the same type of sediment-transport modelling you do, or that your child's baseball team is entirely made up of families with parents who have all been on the same field trip to the middle of nowhere Utah.

In addition, the jobs also pay well right out of college, with geoscientists in the petroleum industry starting with salaries over $100,000. Many of the classes offered in my department, included those that I teach, are geared towards the skills specifically needed in the industry, and many of our students are recruited by companies interviewing on campus.

With that said, most of my own training and research is about glacial history and how it relates to climate and sea-level changes. The graduate students I supervise study the sedimentary signature of glacial changes in Antarctica; many of them complete their own field research during travels to the south.

The experience of working in Antarctica has a lifelong impact on most of those lucky enough to have the opportunity. Environmental change does not occur on the scale of a single season. But students or tourists visiting the region gain an appreciation for the vast areas that appear to be pristine but which research shows to be changing at an accelerating rate.

When they complete their graduate degrees though, most then go to the work in the oil industry. They are, after all, learning the same basic skills as other geologists, and there just aren't that many jobs for glacial geologists in Houston.

I am often asked if I am disappointed to see my graduate students go to the oil industry. No! I am proud of them and, moreover, I believe that more geoscientists with such backgrounds will be good for the industry, and all of us.

The icebreaking ship we work on in the Antarctic burns 6,000 gallons of fuel per day. We all take airplanes to get there. At home, we heat our homes, drive or rely on those who do, and rely on plastics and petrochemical products, at least to some extent. We need the oil industry now and in the future, just like the rest of the population, even though we understand the impact of burning fossil fuels on global climate.

More than just recognizing that all of us need the oil industry, though, I believe the industry needs my students and more like them. With the impact of climate change forefront in their minds, they will automatically balance choices in oil exploration and production with a broad set of concerns.

Maybe they will push to move away from tar sands and towards a more sustainable option. Maybe they will think about groundwater when a pipeline is being designed, rather than after construction has already begun. And maybe their backgrounds can help build trust with communities worried about fracking in their backyards when they explain that the cleaner-burning gas it will generate is, on the whole, an environmental benefit.

Companies, governments and schools often focus on diversity in hiring and recruiting. That diversity includes race and ethnicity, gender and physical abilities, among others.

Diversity with respect to environmental backgrounds has a role to play in the energy industry of the future. ■

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HOW BAD WILL DONALD TRUMP BE FOR RENEWABLE ENERGY?

EARL J. RITCHIE
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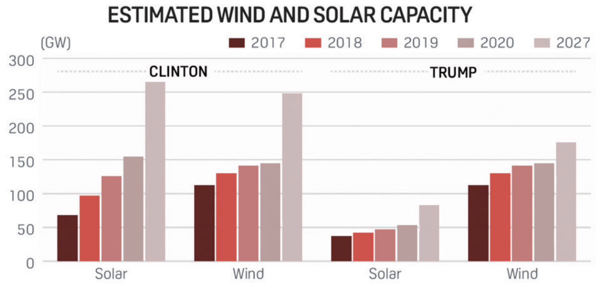
There are varying opinions of Donald Trump's likely effect on the growth of renewable energy in the U.S.: He's bad for it; he's not bad for it. Trump has called climate change a hoax and said he would abolish the Environmental Protection Agency, abandon the EPA's Clean Power Plan, pull out of the Paris Agreement and boost coal and natural gas, positions which he has since largely moderated.

Certainly, Trump's pre-election statements on fossil fuels and renewable energy were worlds apart from Hillary Clinton's. A pre-election estimate of their comparative effects can be seen in this Platts analysis.

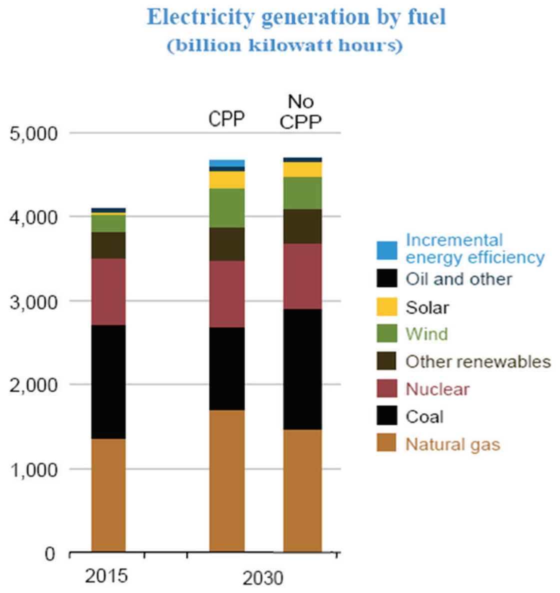


So, Clinton would have been great for renewable energy, Trump not so great. Everybody knows that. But, how bad would Trump be?

The pace of renewables growth will be affected by numerous separate policy decisions. These include the Clean Power Plan, the Investment Tax Credit and Production Tax Credit for renewables and the addition or reduction of restrictions on fossil fuel production and consumption.

Let's look at the analysis in the EIA's 2016 Annual Energy Outlook of the Clean Power Plan (CPP), which Trump said he would eliminate. In the base case, the impact of the CPP on renewables is actually relatively small. By 2030, the amount of electricity generated by wind and solar are 683 billion kWh; without it they are 571. These are annual growth rates of about 7.5% and 6%, respectively. The big impact is on coal, which declines by 28% under the CPP but grows by 5% without it.

The CPP mandates targets, not methods, so other scenarios are possible, some of which are shown in the EIA report.



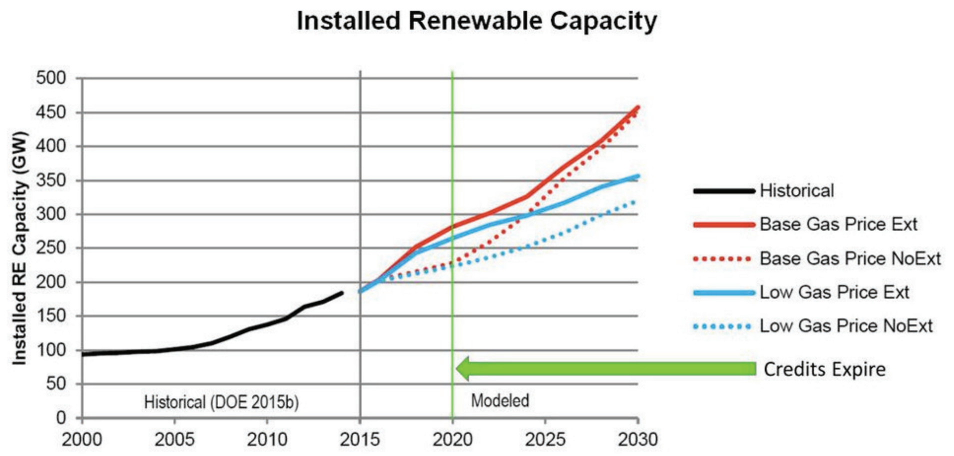
U.S. Energy Information Administration | Annual Energy Outlook 2016

The Clean Power Plan is only one factor in potential growth of renewables. As I pointed out in earlier blogs, subsidies have a big impact. The two important ones at the federal level are the Investment Tax Credit and the Production Tax Credit. The estimate in the graph below, modified from a National Energy Renewable Laboratory report which modeled the effects of the five-year extension passed in 2015, shows the difference that the extension of these credits makes. Added renewable generation capacity due to the credits is about 50 gigawatts in just five years, or about 25% of currently installed capacity. The growth rate with the credits is about twice the rate without.

Continued differences could be expected if subsidies are extended beyond 2020. Trump has not specifically threatened these credits, although he has promised to "cancel billions in climate change spending."

The 2020 gas price in the low price scenario was about $3 per thousand cubic feet, significantly higher than the current price. If government policies favoring the industry result in continued low natural gas prices, it would further suppress renewables growth.

Arguments for the continued rapid growth of renewables include the possibility that the Clean Power Plan, Investment Tax Credit and Production Tax Credit will not be repealed, that state mandates and subsidies will continue and that the continuing cost decrease of renewables will make them more competitive. The latter two factors will almost certainly continue, so the important differences will be in the federal credits and fossil fuel policies.



National Renewable Energy Laboratory

Assuming the credits for renewables are not extended beyond 2020, natural gas prices, which will also be affected by Trump's policies, will be a more significant factor. In the National Energy Laboratory's analysis, both the extension and no extension scenarios show slower renewables growth when gas prices are low. In the extension scenario, renewable capacity in 2030 is about 100 gigawatts lower in the Low Gas Price case than in the Base Gas Price case; in the no extension scenario it is about 125 gigawatts lower.

It is impossible to tell which policies will be implemented at the national level. The Investment Tax Credit and Production Tax Credit may stay in force because they are favored by many Republicans in states that benefit from these credits. Policies favoring the oil industry and weakening or abandoning the Clean Power Plan seem likely.

It looks virtually certain that renewables growth will continue, but at a much-reduced pace. ■

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INVENTORY, DEMAND AND THE ENIGMA OF THE MISSING BARRELS OF OIL

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The Yom Kippur War, Ramadan War, or October War, also known as the 1973 Arab–Israeli War, was fought by a coalition of Arab states led by Egypt and Syria against Israel from October 6-25, 1973. The fighting mostly took place in the Sinai and the Golan Heights, territories that had been occupied by Israel since the Six Day War of 1967.

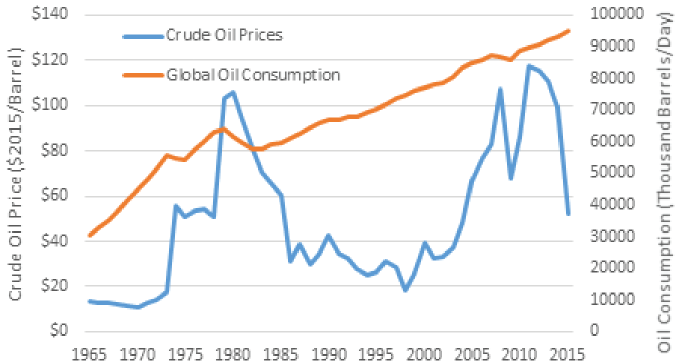
In retaliation against Israel's perceived allies, Arab OPEC members cut production and embargoed the U.S., Netherlands and a few other countries, causing spot oil prices to rapidly increase; OPEC solidified the increase into its Saudi Arabian Light "marker" crude oil reference price.

The consequences of the price increase and embargo were compounded by ill-advised price controls installed by the Nixon administration and caused lengthy gas lines in the U.S. The global economy contracted. Oil consumption declined in 1974 after a decade of 7 percent growth per year, during which demand for light, low-sulfur crude oil had been particularly strong as utilities responded to the 1970 Clean Air Act by switching from high sulfur coal and No. 6 Fuel Oil to low sulfur fuel refined mainly from North African crude oils.

The sudden escalation of crude oil prices led to the nationalization of major oil companies' oil production in most OPEC countries, and the new national oil companies had to face the reality that oil consumption was not inelastic. They could control production volume or price, but not both.

This lesson was relearned most severely in 1980 and again in 2009 (Figure 1).

Figure 1: Oil Price and Consumption



But back to the 1970s and the disruption of the Arab oil embargo. My colleagues and I had been consultants for several years for the Algerian national oil company Sonatrach, and for the first time we and our client were facing a weak crude oil market. The question was raised: how long will this trough last? We created a methodology to track and develop an outlook for future oil supply and demand on a quarterly basis, which helped our client understand how prices responded to the fundamentals of supply and demand.

The methodology migrated out to Petroleum Intelligence Weekly and on to the International Energy Agency(IEA), where it is the basis for its monthly Oil Market Report (OMR), which is closely studied by oil companies and traders. A critical element in the methodology has always been a reconciliation of observed imbalances between oil supply and demand, from which apparent inventory changes can be calculated, with observed actual changes in global inventories.

The problem has always been the integrity of the data: Most countries in the Organization for Economic Co-operation and Development – an international group promoting economic and social well-being – publish reliable data on oil production and consumption, but data outside the developed world are less reliable. Similarly, inventory data for the developed countries is well documented. Indeed, the IEA's initial mandate was to propose minimum strategic oil storage levels to be adopted by members as a buffer against possible future oil supply interruptions. In addition, there are large quantities of oil stored temporally in transit on tankers, which the OMR estimates, and there are unpublished quantities in countries such as China stored as strategic oil reserves and elsewhere as a bet on future price increases.

So the data integrity is fragile, and analysts expend considerable energy tracking tanker movements and picking up clues and anecdotes that can illuminate the overall situation. Despite its best efforts, the OMR retains a line item called "Miscellaneous to Balance (MTB)" as an admission that the difference between supply and demand does not match observed changes in inventories. That line item exposes a serious gap in our understanding.

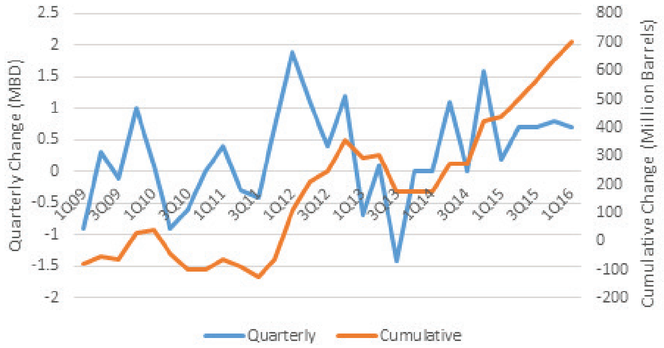
Moreover, it has been getting worse.

From the first quarter of 2009 through the fourth quarter of 2011, quarterly changes in the calculated MTB varied seasonally, and the cumulative change was slightly negative (Figure 2), suggesting that either demand was a little higher than assumed, that supply might have been a little lower, or that there had been a small withdrawal from inventories outside those reported. However, the differences were small, and the OMR presented a reasonable picture of the overall market situation.

That changed in the first quarter of 2012, and cumulative MTB increased to 700 million barrels by the beginning of 2016. This means either demand is higher than reported, production is lower That changed in the first quarter of 2012, and cumulative MTB increased to 700 million barrels by the beginning of 2016. This means either demand is higher than reported, production is lower than reported, or there is a massive overhang of oil in storage in addition to the observed 400 million barrels increase in reported OECD inventories.

If these missing barrels are, as in the U.S., in excess of the amounts required to support the oil supply chain, they could act as a serious drag on the market and slow the process of rebalancing of the market.

Figure 2: Missing Barrels since 1Q09



A lot depends on which is the correct interpretation of where these barrels are held. Let's try this one:

- OECD inventories held by industry in the first quarter of 2011, when inventories were thought to be "normal", amounted to 2,562 million barrels, which represented 57.1 days of average yearly demand. Non-OECD oil demand grew from 43.1 million barrels per day in 2011 to an expected (by OMR) 49.7 million barrels per day in 2016. If industry holds similar inventories in non-OECD countries as in the developed world, this would require an increase in working inventory from 2,460 to 2,836 million barrels, an increase of 376 million barrels.

- The U.S. holds approximately 700 million barrels in its Strategic Petroleum Reserve. China has reportedly been building and filling its own strategic oil reserve, which is aimed at being sufficient to cover 90 days of net imports. Chinese oil demand in 2016 is expected to be 13.1 million barrels per day; with production expected to be 4.1 million barrels per day that would require a reserve of 810 million barrels. It seems quite credible that China may have added at least 300 million barrels since the beginning of 2012.

This interpretation seems plausible: if correct, the missing barrels are safely tucked away in inventory required to meet growing demand in non-OECD countries and in the Chinese strategic petroleum reserve. History suggests that governments are very reluctant to deplete their strategic reserves except in moments of extreme supply insecurity. So there may in fact not be a substantial inventory overhang outside the OECD that could amplify the known overhang of about 400 million barrels within the OECD.

The Oil Market Report is projecting global demand growth of 1.4 million barrels per day in 2016 and 1.3 million barrels per day in 2017, along with declining non-OPEC supplies in 2016, then flat in 2017.

If they are right and OPEC producers maintain current production levels, excess inventories should start being depleted fairly soon. Then prices and rig activity should strengthen further. We shall see. ■

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THE MURKY UNDERWORLD OF OIL THEFT AND DIVERSION

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Earlier this month I attended the Association of International Petroleum Negotiators' 2nd annual International Petroleum Summit, held in Houston. The group is made up of attorneys, petroleum economists and others who cut long-term oil exploration and production deals with foreign governments. Of the dozen or so panels or presentations, none were more interesting than a panel on preventing fuel theft. Anyone who has spent decades in the international oil industry has heard plenty about oil theft, but I came away with a much deeper understanding of how widespread the problem has become, and what countries are trying to do about it.

I have written about oil theft in a previous blog post on Nigeria. Oil thieves there engage in a practice known as "bunkering," where pipelines are tapped and crude oil or refined products siphoned off for use or sale on the black market. Money from illicit oil helps fund militant groups like the Movement for the Emancipation of the Niger Delta (MEND) and the Niger Delta Avengers (NDA), and it lines the pockets of garden-variety crooks and corrupt public officials.

The corruption associated with oil theft runs so deep in Nigeria that both the Nigerian Navy and the government's own anti-insurgency Joint Task Force of the Niger Delta – along with other rogue security forces members, politicians, customs agents, tanker captains and countless other shady characters – have been accused of aiding and abetting bunkering schemes. According to one estimate, the Nigerian government spends $1.5 billion per month combatting oil theft and diversion.

This much I knew before attending the panel. What I learned – and think is worth sharing here – is three-fold: First, oil theft and diversion are far more widespread than I realized, and the causes or motives are multiple. Second, the ways oil is stolen and transported goes far beyond bunkering. Third, despite the fact that oil theft and diversion are a way of life in some countries, and have been for decades, the innovative measures and new technologies authorities are adding to their long-standing anti-theft efforts are beginning to pay off.

The panel frequently referenced a January 2017 report on oil theft and diversion by the Atlantic Council, a Washington D.C.-based organization comprising 100 or so international relations experts and policymakers. The report, *Downstream Oil Theft: Global Modalities, Trends, and Remedies,* written by Dr. Ian M. Ralby, covers 10 countries ranging from major oil producers (Azerbaijan, Mexico, Nigeria) to countries that produce very little oil (Morocco, Mozambique, Turkey). I draw extensively on various parts of the report here.

As one might guess, the highest level of oil theft and diversion occurs in countries that have the most oil. Both Azerbaijan and Mexico, with a few differences, look a lot like Nigeria. In Mexico, fuel theft is on the rise as criminal gangs look for ways to lessen their dependence on earnings from narcotics trafficking. In 2006, state oil company Pemex reported that the country's pipeline system had been tapped by oil thieves 211 times; last year the hits numbered nearly 7,000. But in the case of Mexico, it's gasoline – not crude oil – that's stolen. Thieves take the gasoline and sell on the side of the road for half what it costs at the pump.

In Azerbaijan, the thieves are not gang members but instead, members of organized crime syndicates; crude oil is the thieves' target, not oil products or gasoline; and it doesn't stay in the country – it's bunkered and secretly taken to neighboring countries via train and tanker truck, taking advantage of open borders and a multinational agreement that prohibit searches of commercial vehicles.

If crude oil production doesn't suck a country into the oil theft business, geographic location often does. Morocco, Thailand, Turkey, as well member countries of the European Union, all play a role in the smuggling or diversion of stolen oil, most of which is refined products. These countries shine an interesting light on the phenomenon, but Morocco and Thailand are especially instructive. For example, because of bad blood between Algeria and Morocco, the vast, desert border between the two countries has been closed for more than two decades, but sizable amounts of illicit Algerian fuel still make it into Morocco with ease. Indeed, according to some estimates, hundreds of thousands of cars in Morocco (and Tunisia) run on fuel smuggled from Algeria. Even more interesting is evidence uncovered in 2014 that stolen Nigerian crude oil was smuggled into Ghana, "laundered" or mixed with crude oil from Ghana's Saltpond field, and then shipped as Ghanian crude to Morocco (and Italy), refined and sold on the open market.

Oil smuggling is big in Thailand, with gasoline and diesel coming in from Malaysia by land and by sea through the Gulf of Thailand. In addition, liquefied petroleum gas (LPG) comes in from Malaysia in specially converted trucks and then is smuggled into neighboring Myanmar and Cambodia.

The difference in gasoline and diesel prices in Malaysia and Thailand is the main reason for the rampant fuel smuggling. Malaysia subsidized fuel prices for many years, until 2014, while Thailand did not, so fuel prices were and still are much higher in Thailand. Everyone needs fuel, and everyone likes cheap prices at the pump – so smuggling and use of stolen fuel is extensive in Thailand. Aside from Nigeria, there is perhaps no other country with such a wide array of individuals and groups so deeply involved in oil theft, ranging from organized crime and gangs to prominent figures in business and elected public officials in both Thailand and Malaysia.

The individuals involved in the theft or diversion of oil are as smart and sophisticated as any drug trafficker or money launderer. The thieves not only have all the usual tools in their toolkit – fake shipping documents, knowledge of shipping and checkpoint schedules, inside information from oil workers, public officials on the take and the like – but plenty of other options as well. In Nigeria, for example, bunkering can be done using "hot" or "pressure" tapping (as mentioned above) while the pipeline is still in operation, or the thieves can engage in "cold bunkering," where they blow up a pipeline and install a permanent underground tap leading to a storage facility while the line is out of operation. No one knows the difference once the pipeline is back in operation. If need be, the crude can be moved through any number of standalone, illegal crude oil or products pipelines. If the thieves can't steal the oil by tapping into pipelines, they can steal it from export terminals or storage facilities.

When it comes to moving crude oil or refined products by sea, the cargo can be sold or moved once the ship reaches its destination. But it can also be sold while still at sea, especially if the cargo is refined products. Tankers filled with stolen gasoline or diesel can be turned into floating filling stations. In Malaysia and Thailand, completely fake fishing vessels are used to smuggle gasoline and diesel, which can then be sold at completely fake filling stations onshore.

Stolen and diverted oil disrupts the supply chain and can cause environmental degradation, fill the coffers of insurgents, gang members, organized crime, corrupt politicians and others with money, and costs oil companies and governments billions of dollars in lost revenues.

Bad things all, but what to do?

The steps usually proposed to mitigate oil theft and diversion are similar to those taken to stop international drug trafficking – crack down on corruption, wipe out gangs, tighten borders, deploy more manpower – and they are not likely to be any more effective. Fuel theft in Nigeria is so systemic it will not be slowed or stopped any time soon. Doing so would be tantamount to eliminating drug trafficking in Colombia. Mexico could be almost as bad in less than a decade.

But there are some things that might counter fuel theft and diversion in other countries.

Tankers and inventories can be tracked better. Eliminating fuel price discrepancies between neighboring countries like Thailand and Malaysia would be helpful, as would blacklisting the filling stations that sell illicit gasoline and diesel. The most promising means of combating fuel theft and diversion, however, is fuel "marking." Fuel marking has been around in one form or another for some time, but in recent years, covert molecular fuel markers have been developed that are virtually impossible for thieves to detect. Such markers allow stolen or diverted fuel to be identified and recovered, and perhaps more importantly, used as admissible scientific evidence to prosecute fuel thieves and smugglers in courts of law. One of the most successful programs to date is Ghana's Petroleum Product Marking Scheme (PPMS), instituted by the country's National Petroleum Authority in 2013. The program allows inspectors to determine if the gasoline or diesel sold at filling is legal and offenders are subject to being fined or jailed. ■

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WIND AND SOLAR POWER SEEM CHEAP NOW, BUT WILL THE COST GO UP AS WE USE MORE OF IT?

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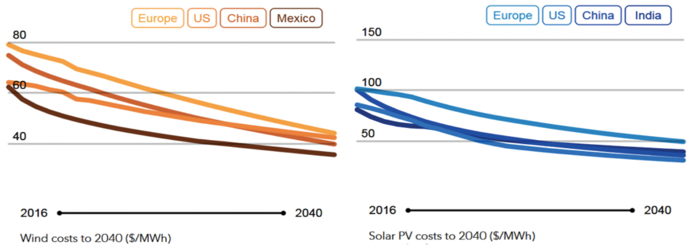
Everyone talks about wind and solar power becoming cost competitive, but the cost will rise as its share of generation increases and we have to pay more to integrate it into the electrical system. How much it will rise remains the subject of debate.

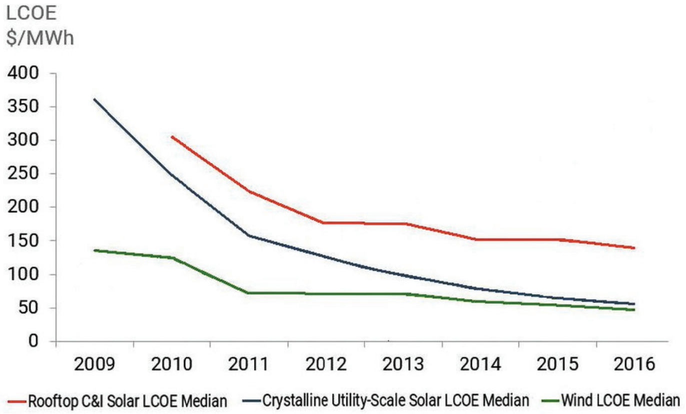
The cost of electricity from wind and solar energy, as well as other variable sources, has two components: the cost of generation and the cost of integration into the electrical system. As discussed in an earlier post, integration costs are expected to increase disproportionately as the share of wind and solar increases, potentially offsetting the decreasing cost of generation.

The cost of generation alone is fairly well defined. There is some disagreement about the likely extent of future cost reduction but the ranges are relatively narrow. The Bloomberg New Energy Finance estimates of about $40-$50 per megawatt-hour (MWh) are typical.



Source: Bloomberg 2016

As shown below, except for utility scale solar, the rate of cost reduction has slowed in recent years, so estimates for future reductions in wind power and rooftop solar costs may be optimistic. These are levelized costs, estimates of the actual cost of generation. They do not include integration costs and may differ from reported auction costs, which are affected by market conditions and subsidies.



Source: Lazard 2016

The IPCC estimate

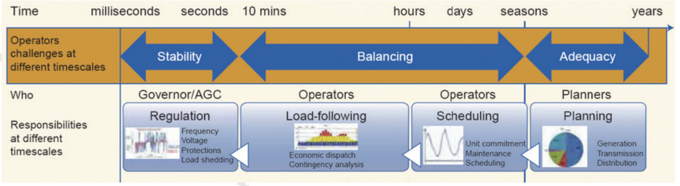
As addressed in Section 7.8.2 of the IPCC's fifth Assessment Report, there are three components of integration cost: (1) balancing costs (originating from the required flexibility to maintain a balance between supply and demand), (2) capacity adequacy costs (due to the need to ensure operation even at peak times of the residual load), and (3) transmission and distribution costs.

The IPCC does not give specific costs at high penetration levels. Their ranges for levels of 20% to 30% penetration are $1-$7 for balancing, $0-$10 for capacity adequacy, and $0-$15 for transmission and distribution. Total range is $1-32.

Even at these levels the integration costs are significant. At an estimated future generation cost of $45, the middle of the IPCC range of integration costs adds 37%. It is generally recognized that the integration cost of variable renewable energy (VRE) penetration above 30% will be higher but is difficult to estimate.

The complexities of integration

Dealing with intermittency must be managed at a continuum of time scales from milliseconds to years. There are costs associated with all timeframes; however, published analyses focus primarily on the longer intervals of balancing and adequacy.



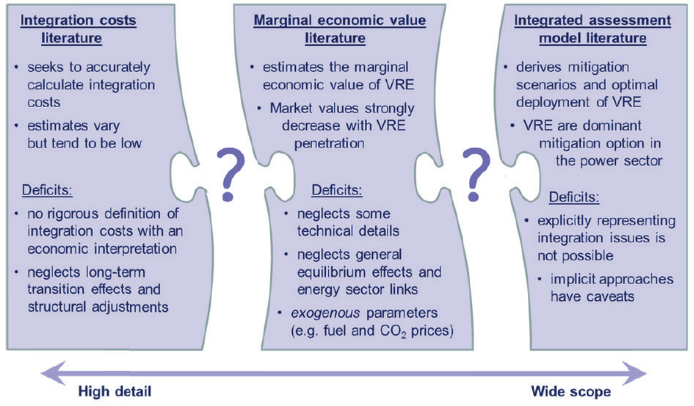
Source: World Bank 2015

Various measures to manage this variation – storage, source mix, overcapacity, demand management, etc. – have differing costs, advantages and disadvantages which can be traded off. This results in a complex situation in which the optimum solution is typically not obvious.

Estimates of integration cost at higher levels vary so widely that it is almost impossible to generalize. Local conditions and design choices significantly affect cost. As a study by the Danish Association of Engineers put it "the design of future 100% renewable energy systems is a very complex process." An almost infinite number of possible combinations of sources is possible depending upon location, anticipated demand, degree of decarbonization and emphasis on economics.

How future costs are estimated

Both optimization and cost forecasting are done with mathematical models. Significant differences may result from the model used. Some characteristics and weaknesses of the three main classes of model are shown below.



Source: Ueckerdt 2015

Limitations of the models mean that not all aspects of the system can be incorporated in any one model. This may result in overestimates or underestimates. In addition, published studies frequently consider only one aspect, such as the addition of wind power alone.

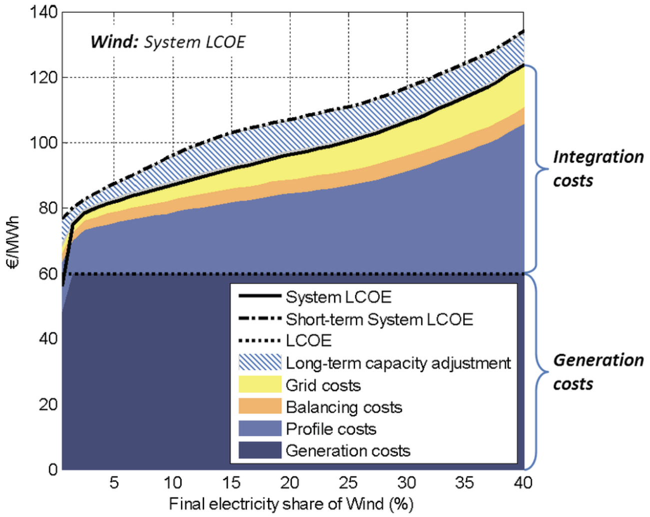
The limitations and possible sources of error in these studies are normally well understood by the authors, and explained in the original articles. Such caveats rarely reach popular articles quoting the results. There is also deliberate or subconscious bias in the choice of parameters due to the prejudices of the authors.

The variation in estimates

The result of these factors is considerable variation in cost estimates, even when similar systems are being analyzed. Two examples demonstrate the range:

The first estimate below is a model of adding wind energy to an existing grid similar to the European grid. It does not consider externalities, such as renewables mandates, but does include a carbon tax of 20 Euros per ton of CO2. The upper dashed line shows short term costs, and the solid black line long term.

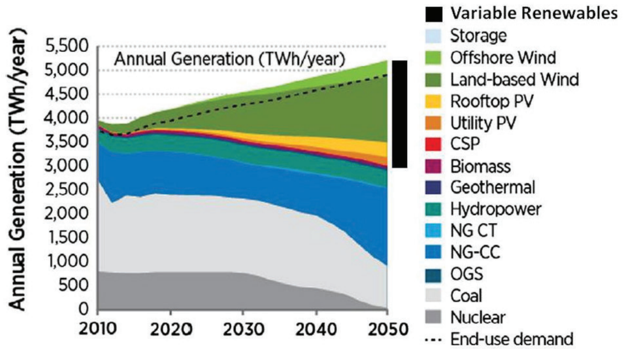
The model shows integration cost equal to generation cost at 40% penetration. That is, the cost doubles. It does not consider possible storage or extending the grid to optimize the system.



Source: Ueckerdt, et al. 2013

A 2016 US study by Lantz, et al., showed a mix of about 42% variable renewable energy to have a net present value cost $59 billion higher than an economically optimized scenario. They did not give a per kilowatt-hour cost, but modeled a modest 3% increase in retail electricity cost in 2050. The authors comment that the cost may be understated because of lack of detail in the model.

Further examples include the widely publicized papers by DeLucchi and Jacobson, which estimate transmission and storage costs as $20/MWh for 100% variable renewables, and the 2012 NREL study, based on somewhat dated costs, which estimates up to $54/MWh over a fossil fuel dominated scenario for 90% renewables (48% wind and solar). Published scenarios are hotly debated.



Source: Modified from Lantz, et al. 2016

The headline cost in such studies cannot be taken at face value. In addition to variances due to choice of model, such obvious influences as assumed fossil fuel prices and future cost reductions in generation methods must be weighed in assessing the estimates. As might be expected, proponents of a particular technology will frequently make assumptions favorable to their preferred energy source.

Other renewables and the social cost of carbon

Some issues not discussed in detail here include the other variable renewables, wave and tide; the dispatchable renewables, hydroelectric, geothermal, and biomass; and the social cost of carbon.

Wave and tide are expected to contribute only a small fraction of future electricity generation. They may be complementary to other forms of variable renewable energy.

Hydroelectric and geothermal can be highly desirable as low carbon, low-cost and dispatchable. Very high renewables penetration has already occurred in areas where these resources are abundant. New Zealand is above 80%; Norway and Iceland are over 90%.

Electricity generated from biomass is dispatchable but creates greenhouse gases at the site of generation. The extent to which this is offset by land use changes and carbon storage of the fuel crops depends upon the generation technology, the type of fuel crop and management of the crop. Estimates of offset are controversial but most calculate net reduction in greenhouse gases compared to fossil fuel generation.

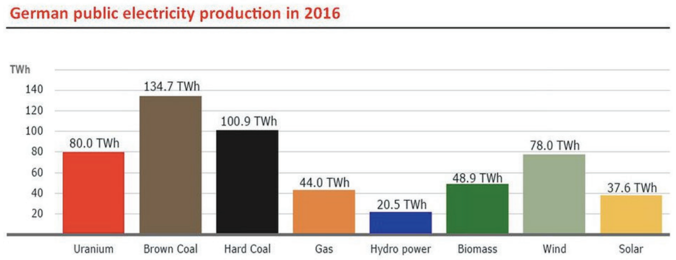
The social cost of carbon (SCC) is not the focus of this article, which concentrates on the actual cost of generation. SCC is speculative, with typically quoted numbers from about $5 per ton of CO2 to $100, although extremes can exceed $1,000. The US government's 5th percentile to 95th percentile range of the cost in 2020 is from zero to about $180. Obviously, the inclusion of any positive SCC will shift economic analysis toward low carbon sources.

Little effect in the short run

Wind and solar intermittency are not likely to be very costly in the near-term, say to 2030, because most scenarios do not have them reaching high penetration levels by that time. For example, wind and solar are 15% of electricity generation in the Reference Case of the EIA's 2016 Annual Energy Outlook.

Even the highly publicized German Energiewende (Energy Transformation) has wind and solar currently at 21%, below the level of potential significant cost increase. Intermittency is still being handled by fossil fuels, dispatchable renewables, and exports. Germany's target for 2030 is 33%.

Local areas with more ambitious goals will be an interesting test. California has a goal of 50% of retail electricity sales from renewables by 2030. A 2014 analysis by the consulting firm E3



Source: Burger 2017

modeled reaching this goal with 43% wind and solar. The report said "This is a much higher penetration of wind and solar energy than has ever been achieved anywhere in the world." Capital costs under various scenarios ranged from $89 billion to $128 billion in 2012 dollars, with electricity rates increasing between 15% and 30% solely due to the renewables standard. An additional 40% would be due to infrastructure replacement and other factors. The report further says "overgeneration and other integration challenges have a substantial impact of (sic) the total costs for the 50% RPS scenarios."

Will intermittency costs limit high penetration?

It is clear that there is a cost to managing intermittency and this cost will likely be greater than the decrease in generation cost itself. Actual experience suggests that this cost will be higher than is envisioned in the more optimistic scenarios.

However, cost is not the only consideration. High cost generation may have value where the cost of alternative sources is higher or the match to demand is good. Carbon taxes and renewables mandates will increase the share of renewables, regardless of the underlying economics.

Predictions of whether costs associated with increasing share of variable renewables will outweigh future cost reductions depend upon expectations of both, as well as future costs of storage and other means of dealing with intermittency, all of which are speculative. Storage costs are a topic for another day. ■

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WATER, ENERGY, FOOD – INCREASINGLY, EVERYTHING IS CONNECTED

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People often think of scientists as solitary types, working alone in our labs, focused on a narrow topic. But if that was ever true, it's not now. Scientific discovery and creating new technologies don't fit in a box.

That's certainly the case with questions involving water and energy, and the so-called water-energy nexus has gained attention from both the government and from researchers over the past few years.

The two intersect like this: Producing clean water requires energy – to treat the water, to distribute the water and so on – while it takes water to produce energy, from generating electricity to blasting chemicals and sand into shale rock to extract oil and natural gas. Water is a key component of the cooling process in utility plants powered by fossil fuels, and it generates electricity directly in the case of hydroelectricity. Drought can affect power plants by limiting water availability. Similarly, water treatment plants can be shut down when a storm knocks out the power supply.

I experienced the connection in my work, which focuses on bio- and nanotechnologies for water and wastewater treatment. Growing up in Brazil, I saw firsthand that people in rural areas too often were sick or even died because they didn't have access to clean, safe drinking water. Established techniques such as reverse osmosis – which forces water through a membrane to remove bacteria and other particles – requires huge amounts of energy, driving up the cost. That may not be a concern for richer countries, but in the developing world, clean water solutions need to be simple and inexpensive.

And now we know it's not just energy and water. More recently, food has been added to the wheel.

The United Nations reports that agriculture accounts for 70 percent of global freshwater use. Food production and transportation consumes about 30 percent of global energy use. As the demand for food increases to meet projected population growth, it will require both more water and more energy.

It doesn't stop there, however. Runoff from agricultural operations can lead to pollution, requiring the water to be treated. The treatment requires energy. But agriculture doesn't just consume water and energy – crops and agricultural waste are used to produce biofuels. About 42 percent of Brazil's gasoline requirements are fulfilled with ethanol made from sugar cane.

There's no place to get off the wheel. It goes in so many directions, and if we want to manage our resources sustainably, we have to pay attention.

Why do all of these connections matter? Maybe they don't to the average consumer. At the height of the California drought last year, the news was full of stories about how much of the state's dwindling water supply went to almonds, walnuts and other nut crops – almonds and walnuts both require about 50 gallons of water per ounce, a figure that rises almost to $100 an ounce when the nuts are measured unshelled, according to the UNESCO U.S. Institute for Water Education. But people didn't stop eating pistachios.

Researchers are paying attention, however, and that already has changed the way we think about solving problems. My lab is no longer focused just on finding ways to remove microbes and other toxins from water; instead we make sure the coatings, filters and other technologies we develop are reusable and require little if any energy.

Other researchers are working to reduce water requirements for food production, to more efficiently convert agricultural waste to biofuels, and to address other issues along the wheel.

The Food and Agriculture Organization of the United Nations has called for more data and research to help nations around the world navigate the decisions that these interrelationships will require, allowing individual countries to better manage the tradeoffs that will be required.

We have learned that nothing happens in isolation, and we are moving out of our silos. ■

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OIL AND VIOLENCE IN THE NIGER DELTA ISN'T TALKED ABOUT MUCH, BUT IT HAS A GLOBAL IMPACT

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There have been numerous reports over the last 18 months about terrorist attacks in Europe, the United States and elsewhere. But one long-running hotbed of political violence, Nigeria's oil-producing Niger Delta, has garnered only a modest amount of media attention.

Maybe it's because the conflict between anti-oil insurgents and the government has gone on for so long, some 20 years, that there's a bit of "Niger Delta fatigue." Or perhaps it's because the Niger Delta militants have no ties to radical Islamic groups like al-Qaeda or ISIS and have shown little or no interest in maiming or murdering the innocent – opting instead to attack targets like drill sites, pipelines, tankers and facilities in order to stifle oil production and cripple the Nigerian government economically.

Or it could be that the conflict hasn't gotten as much play in the press as it deserves simply because international oil companies working in dangerous places is "old news."

Because crude oil is such a valuable commodity, international oil companies are practically fearless, impervious to the threats posed by guerrillas, terrorists and insurgents; many of the oil workers are rough and tumble types – "adrenalin junkies" who enjoy the rush of going into such areas to get hydrocarbons out of the ground. But regardless of why the conflict has flown under the radar, what's gone down in the Niger Delta over the last two decades is worthy of attention – much more so than Boko Haram – for it has a direct impact on the level of oil sector investment and operations in the area, Nigeria's oil production and economy, and even world oil markets and oil prices.

Peace won't be easy, but an uneasy détente is possible. Whatever happens will affect not only on oil companies, but consumers, too.

The story, in brief, is as follows: In the late 1980s, several indigenous tribal groups began raising concerns about international oil company operations in the Niger Delta, a region of about 27,000 square miles, larger than the state of West Virginia. The largest and best known of the groups was the Ogoni, an indigenous people of (now) nearly 1 million people. The Ogoni and other ethnic groups – the Ijaws, Itserikis, Urhobos, Isikos, Liages, Ikwerres, Ekpeyes and Ogulaghas – complained that Shell, Mobil and other oil companies were prospering at their expense, as the ethnic groups saw little of the wealth generated by the oil production, while suffering the fallout from widespread environmental degradation caused by exploration and production efforts.

The Ogonis' response to these perceived wrongs was confined, at least initially, to protests, low-level acts of civil disobedience and minor, occasional acts of sabotage, along with the formation in 1990 of the Movement for the Survival of Ogoni People (MOSOP), led by author and environmental activist Ken Saro-Wiwa. The conflict escalated over the next few years, and in November 1995, Saro–Wiwa, and eight other activists were hanged by the Nigerian government.

The hangings radicalized the Niger Delta opposition groups, which began to organize and engage in acts of violence and terrorism directed at oil interests.

Over the next decade, a host of loosely-formed rebel groups, funded by kidnappings for money and "bunkering" (stealing oil from pipelines and selling it locally or taking it to tankers offshore to sell on the larger world market), came and went. The attacks were generally viewed by the oil and service companies as simply part of doing business in the Delta.

A new group emerged in early 2006 – the Movement for the Emancipation of the Niger Delta (MEND) – that upped the ante and radically altered the operating climate. MEND was founded and led by Henry Okah, whose leadership showed a level of sophistication and innovation that had not been seen before in the Delta. For example, he coordinated operations and attacks from his home in South Africa via cell phone, and under his guidance, MEND became adept at using e-mail for press releases and orchestrating media campaigns to get the group's message out. But Okah's luck didn't last long. He was arrested in September 2007 while trying to buy weapons in Angola, extradited to Nigeria, tried and convicted behind closed doors, and then incarcerated.

From the very beginning, MEND was better equipped and trained than the militant groups that came before (camouflage body armor, speedboats, shoulder-held rocket-propelled grenade launchers, Kalishnakov assault rifles, Czech machine guns), and the group consistently demonstrated superior tactical skills, fueling speculation that MEND had links to the Nigerian military. And while MEND gave the outward appearance of being a large, well-organized and coordinated group – an estimated 100,000 strong– it was in fact more of a loose, fluid, protean and almost virtual network of smaller groups, mercenaries and individuals that didn't necessarily need Okah's hands-on leadership to conduct operations. This actually worked to MEND's advantage, for the group could continue with little drop in attacks when Okah landed in jail.

But what is perhaps most interesting and important about MEND is the way Okah and the group managed to shift the focus of the conflict.

The oil interests attacked were no longer simply targets of opportunity – they were *strategic* targets. MEND's goal was to destroy the Nigerian government's ability to produce and export oil, and to make it clear that the government could not protect oil company personnel or assets. Indeed, MEND warned in no uncertain terms that the oil companies and their personnel should leave the Niger Delta while they could – or else they were likely to die.

To that end, MEND proceeded to engage in every kind of attack at anything linked to oil in the Niger Delta, especially kidnappings, which markedly increased the fear factor, along with a few killings of oil company personnel. It even took the attacks offshore, targeting platforms, tankers and FPSOs – Floating Production, Storage and Offloading vessels – once considered out of reach.

There is even some evidence to suggest that MEND orchestrated attacks to coincide with oil market conditions and maximize the effect of shut-in Nigerian production and overall supply anxiety. At their peak, the MEND attacks cost the Nigerian government billions of dollars in lost oil earnings.

Over the last 10 years or so, the Nigerian government has attempted to quell the rebel attacks with a combination of military force and appeasement. The military actions have been generally ineffective. The Niger Delta terrain is dense and difficult, and it gives the rebels plenty of cover – as Henry Kissinger once remarked about the Vietcong during the Vietnam War, the Niger Delta rebels are "at once everywhere and nowhere."

Appeasement efforts have fared a bit better. In 2009, the Nigerian government announced an amnesty program, which paid MEND militants millions of dollars and released Henry Okah from jail; in return, MEND declared a ceasefire. Although the ceasefire didn't stick immediately, many members put their guns down and for the most part, the group ceased active operations.

Okah was tried in South Africa in 2013, found guilty on 13 counts of terrorism and sentenced to 24 years in prison. His conviction spurred a minor flurry of new attacks by MEND, but they didn't last long.

Fast forward to last year. In February 2016, a new group, the Niger Delta Avengers (NDA), emerged on the scene. Think of the NDA as MEND 2.0, only smaller, reportedly just a few hundred men. The NDA has the same goals as MEND, namely running the oil companies out of the Niger Delta and giving the folks who live there as much control over oil operations as possible. The group is as well-armed as MEND, too, having at its disposal weapons and materiel ranging from machine guns to speedboats to rocket-launchers. And, like MEND, the NDA has been successful at hitting high-value, strategic targets – Shell's Forcados oil pipeline, Chevron's Okan platform and ExxonMobil's Qua Iboe terminal (Nigeria's largest). Not surprisingly, the attacks have had the same crippling effect on Nigeria's oil production as those by MEND – a drop of 800,000 barrels per day in 2016, from 2.2 million barrels per day to 1.4 million, the lowest production level in 25 years.

After a collective pat of the back for a job well-done, NDA announced "plenty of surprises" and an "all-out" war against the Nigerian government and oil interests for 2017.

It is not clear what the group will do or how the government will respond. The only thing that is clear is that ending the conflict will not be easy.

The oil companies are not going to leave. A military solution to the conflict, reportedly favored by Nigerian President Muhammadu Buhari, is not likely. The Nigerian government has never successfully defeated a militant Niger Delta group via military action, and the Nigerian army would never be able to protect all the infrastructure, facilities, etc. The Nigerian military already is stretched thin because of the campaign against Boko Haram.

Buying off the militants with money and amnesty is a possibility, but the Nigerian economy isn't in the best shape and history suggests money and amnesty alone may not be enough to convince the militants to stop their attacks. However, a prudent mix of military force and money/amnesty – something along the lines of the carrot and stick approach used to combat MEND – could have some success.

Still, a truly satisfactory, long-lasting settlement to the conflict would probably need to include more environmental clean-up and compensation for damages, along with some percentage of oil earnings going to the people in the Niger Delta.

This is a tall order, but not impossible. It will take time, diligence and discipline on the part of the government, and buy-in by the oil companies. Should peace eventually come to the Niger Delta, the Nigerian economy will benefit from higher oil earnings and more exploration. New discoveries are likely, and more than a million barrels a day of currently shut-in or yet to be produced oil could hit the world oil market. This would mean more downward pressure on crude oil prices – good for consumers because of lower prices at the pump, but not so good for the job market in the oil patch. ■

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HOW LONG WILL IT TAKE ELECTRIC CARS TO MATTER? MORE THAN 10 YEARS

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Hopes for a quick reduction in crude oil consumption and carbon dioxide (CO_2) emissions have been raised by improvements in range of electric cars (EVs) and the introduction of new models by all major auto manufacturers. Despite this, barriers to general popularity remain. It is unlikely that electric cars will make a significant dent in U.S. gasoline consumption in the near term.

Pure electrics, hybrids and plug-in hybrids

Commonly available electric cars come in three forms:

Conventional hybrids (HEVs) run on a combination of an electric motor and another engine, commonly gasoline. Most get significantly better gas mileage than an equivalent gasoline powered model; however, most luxury and sports versions do not because they use the electric motor primarily for added horsepower. Small, economy oriented models typically get around 50 mpg. Most large hybrids, hybrid SUVs and hybrid pickup trucks range from 20 to the low 30s.

Pure electrics, also called battery electrics (BEVs), run on an electric motor alone. They consume no oil in daily use, although some fossil fuels are used in the manufacture and, in most cases, generating the electricity. They are the cleanest alternative among the electrics, but are not CO_2 free. The Union of Concerned Scientists estimates lifetime emissions to be about 40% of that of an equivalent gasoline powered vehicle. The equivalent gasoline mileage (MPGe) depends upon gasoline and electricity prices but is usually around 100.

Plug-in hybrids (PHEVs) are similar to conventional hybrids but can be charged from an external source. They can run on battery alone for short distances. When used for driving within their electric range, they function as a pure electric. As with HEVs, they may be economy oriented or luxury. Economy oriented models get about 100 MPGe in electric mode and 40 mpg in hybrid mode. PHEVs are not yet widely available in the U.S.

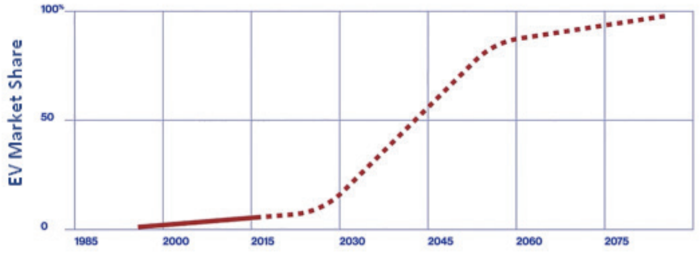
The explosion in electric car models

The first mass-produced hybrid, the Prius, came out in 1997. By 2012, some 40 models were available, the majority of which were HEVs. Currently, over 80 models are available, not including variants such as battery size, transmission and trim level. Certainly, manufacturers expect to sell these cars, implying significant sales growth.

Actual and forecasted sales

In 2016, U.S. sales of grid-connected cars – battery electrics and plug-in hybrids – made up less than 1% of new light vehicles; conventional hybrids were about 2%. Estimates of future market share of electric cars vary widely. Bloomberg New Energy Finance predicts that sales of battery electric and plug-in hybrids will reach 10% of auto sales worldwide by 2026. While this is impressive growth from their current share, it's still a fairly small fraction of overall sales.

In order to have a significant impact on oil consumption, electric vehicles must sell in significant volume, and the fuel economy differential must be large. Bloomberg and others speculate that a tipping point in sales may be reached roughly in a decade.



Source: Modified from Bloomberg

Even if this happens, it takes some time for the existing stock to be replaced. Predictions of future share of electric vehicles in the fleet depend upon sales of both EVs and fossil fuel-powered cars, as well as retirement rates of existing stock.

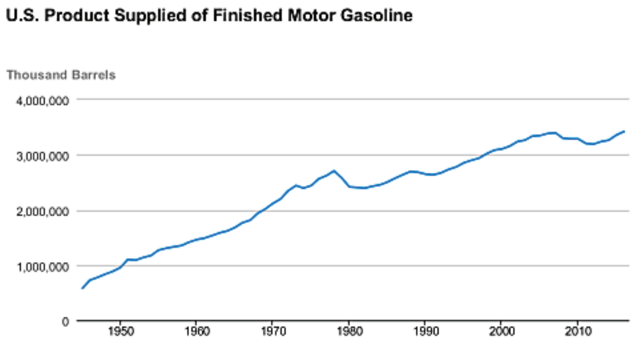
What this means for CO2 reduction

The U.S. consumes about 20 million barrels of oil per day, about half of which is motor gasoline. In 2013, the Union of Concern Scientists (UCS) projected electric cars in the U.S. could save 1.5 million barrels per day by 2035 or 7.5% of current U.S. consumption. This is reasonably consistent with more recent worldwide projections by Bloomberg and McKinsey of 2 million by 2028, and 3 million by 2035, respectively.

Let's say the UCS projection could be done by 2027. Since electric cars do create some CO2, emissions reductions are less than the reduction in oil consumption. The difference depends upon the mix of hybrid car types and percentage of fossil fuels used in electricity generation. For a fleet dominated by conventional hybrids, as is expected to be the case during this period, emissions are about half of fossil fuel cars.

As an approximation, reduction in CO2 from EVs would be about 4%, and an overall reduction in U.S. CO2 would be about 2%. This is an improvement, but much less than many might have anticipated.

The emissions of electric cars will improve as a larger share of electricity is generated by renewables, but electric cars will continue to be a substantial source of pollution for years. The emissions of electric cars will improve as a larger share of electricity is generated by renewables, but electric cars will continue to be a substantial source of pollution for years. These observations are not intended to be pessimistic as to the ultimate success of electric vehicles; however, the reality is that even very optimistic assumptions of growth in electric vehicle sales do not yield significant CO2 reductions in the next decade.



Source: EIA

The real payoff is in later years when electric vehicle penetration is predicted to be much higher. This is a bad result for those who believe that rapid reduction in greenhouse gasses is necessary to prevent further climate change.

The future of oil consumption

Electric cars are not currently a major factor in U.S. gasoline consumption. Despite a pronounced temporary decline caused by the Great Recession, the long-term trend is decidedly up. Increasing population, increasing affluence, continued suburban growth, low oil prices and the American propensity for large cars and sport-utility vehicles tend to increase consumption; efficiency mandates, technological improvements and lifestyle factors, such as the extent of ridesharing and use of public transportation, bicycles and walking, tend to reduce it.

How we can do better

Bloomberg says at least one of the following four items must happen in order for electric cars to achieve widespread adoption:

1. Governments must offer incentives to lower the costs.
2. Manufacturers must accept extremely low-profit margins.
3. Customers must be willing to pay more to drive electric.
4. The cost of batteries must come down.

These may be necessary, but they are not enough. Several other barriers remain.

A great deal of research has focused on the psychological and practical factors that influence EV buying decisions. I'll comment on these in a later post. ■

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FLARING IN THE EAGLE FORD SHALE AND RULE 32

BRET WELLS George Butler Research Professor of Law, UH Law Center

The oil downturn offers an opportunity to reconsider rules for flaring natural gas.

The Eagle Ford shale has provided an economic boom to South Texas. It is the source rock for the storied East Texas Field and also for the Austin Chalk formation, but it wasn't until 2008 that the industry discovered the viability of producing directly from the Eagle Ford shale using horizontal drilling and hydraulic fracturing techniques.

However, the state of Texas finds itself at an important transition point. The severe downturn in oil and gas development has given regulators and the industry an opportunity to calmly assess whether current development practices in the Eagle Ford shale are appropriate. One of the most visible and controversial practices has been the flaring of commercially usable and profitable natural gas that could have been efficiently produced but instead was burned off in the rush to bring crude oil to market.

In the oil-rich portions of the Eagle Ford, the formation produces enormous amounts of associated gas along with the liquid-rich crude oil. But pipeline construction was not able to keep pace with the number of wells completed before the downturn. Statewide, the Texas Railroad Commission reported that Texas flared or vented more than 47.7 billion cubic feet (bcf) of associated gas in 2012. According to the commission, this was the largest volume of gas flared in the state since 1972. In 2012, based on the amount of flaring nationwide, the United States had the dubious distinction of being one of the most prodigious countries for flaring in the world.

This downturn, therefore, represents an appropriate time for the Railroad Commission to reassess its existing regulations on flaring. The industry should know the rules of the game before significant new capital is invested.

Under existing Rule 32, the Railroad Commission accepts that flaring commercially profitable associated gas is "a necessity" any time an oil well is capable of producing crude oil in paying quantities and there is no immediately available pipeline or other marketing facility for the natural gas. Rule 32 doesn't require weighing the relative benefit of producing the crude oil more quickly versus the economic loss caused by the flaring of the natural gas, nor does it require any factual showing that crude oil would ultimately be lost if it were not produced immediately.

Instead, the only evidence needed to flare an oil well for as long as 180 days is proof that a pipeline is not immediately available. An application does not need to contain a statement that correlative rights are at risk or that the operator is in danger of suffering either drainage or the permanent loss of oil. Instead, the operator need only show that crude oil production would be delayed (not lost, but delayed) if the requested flaring exception were not granted.

In the past, flaring exceptions were requested and granted even though gas pipeline connections were within three miles of the new well and connections were expected to be completed within a matter of a few months. Exceptions were also routinely granted for flaring profitable associated gas even when the operator only needed a few months to remove excessive hydrogen sulfide from the gas. What is more, Rule 32 allows the commission to provide a flaring exception after the 180-day period as part of an administrative hearing and via the issuance of a final order signed by the Railroad Commission.

Turning reality upside down

The commission has historically provided numerous exceptions for flaring in the Eagle Ford shale. Routinely issuing permits to avoid any delay in crude oil production highlights the oxymoronic reality of the existing Rule 32 exception practice. Within the construct of Rule 32, flaring commercially profitable associated gas is viewed as "not wasting," while conserving the natural resource and deferring crude oil production until pipeline connections are made is defined as "waste." It is ironic to suggest, as Rule 32 currently does, that burning a valuable natural resource directly into the atmosphere is "nonwasteful," while waiting until the crude oil and natural gas could be efficiently and commercially produced is "wasteful." Rule 32 currently turns reality upside-down.

There is some hope the Railroad Commission may be rethinking its existing rules. On June 3, 2016, in an interview with the Texas Tribune, Commissioner Ryan Sitton indicated the commission is using this downturn as an opportunity to reconsider rules that are "outdated and need to be updated," and he specifically referenced rules on flaring as one example. See Texas Tribune Interview of Commissioner Sitton. This is encouraging, as it is time for the Railroad Commission to revise Rule 32 so that it affirmatively states that flaring gas represents "waste" unless an operator can prove a delay in access to pipeline connections would diminish the ultimate recovery of crude oil or result in significant drainage from neighboring tracts. Said differently, the flaring of natural gas should be allowed only after proof is given that a "no-flare" policy would itself result in the loss of the ultimate recovery of crude oil or would represent a potential loss of one's opportunity to obtain a fair share of the oil and gas in place.

The mere delay in crude oil production should not be considered "wasteful" for purposes of Rule 32. The Railroad Commission did not think flaring associated gas from oil wells in conventional oil formations made sense in 1947 when it issued no-flare orders to stop massive flaring. That logic still holds in today's unconventional shale formations. Amending Rule 32 in the manner I have described would elevate natural gas produced from an oil well to its rightful status as a valuable natural resource that must be produced in accordance with sound conservation practices, rather than a byproduct that need only be conserved if there is an immediately available gas pipeline connection.

If the commission were to amend Rule 32 and grant fewer flaring exceptions in the Eagle Ford shale, the oil would still be in place. Given the low permeability of the Eagle Ford shale formation, the historic issues of conventional formations — the risk of substantial drainage from neighboring tracts and the risk of not allowing the formation to produce at its maximum efficient recovery rate — would appear to be largely inappropriate for today's unconventional shale formations. Flaring of associated gas in the context of the Eagle Ford shale, therefore, provides an even easier factual case for the Railroad Commission to issue "no-flare" orders than the situation it confronted in 1947.

And this dramatic downturn means now is the time to act. Operators should use sound conservation-minded operating practices to efficiently produce the state's natural resources before the next upturn, hopefully next year. Changing the standards now gives the industry time to consider how it will complete future oil wells in the Eagle Ford without wasting a valuable natural resource. ■

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GREEN PARASITES, OR HOW WE CAN LEARN TO TAKE ADVANTAGE OF NATURE

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Before air conditioning became ubiquitous, designing with the local climate in mind was not a virtue but a necessity. Passive design – taking advantage of the cyclical nature of the sun and maximizing natural ventilation – was widely practiced centuries before that phrase was coined. In Houston and similar climates, cooling southeasterly breezes were encouraged to flow through the inhabited section of buildings during the hot months, while northerly winds were blocked during the colder months. And solar orientation had to be carefully considered in order to live more comfortably.

That gradually fell out of favor as air conditioning – so comfortable, at the touch of a button – took over. But growing environmental concerns and simple economics are bringing a renewed interest in passive design.

Every spot on the earth receives sunlight at a particular angle that changes continuously following a fixed pattern, repeated every year as our planet revolves around the Sun. These recurring angles are easily predicted for any given day and time, simply by knowing the latitude of a particular place.

Project Row Houses (Latitude 29.731855°N) has provided a living laboratory for marrying art, sustainability and utility. The organization, a community-based arts and culture nonprofit in Houston's Third Ward neighborhood, has hosted many artists in their house-galleries over the past 20 years; in 2001 it invited architects from around the country to make installations that reflected on their built environment.

Felecia Davis, now an architecture professor at Penn State University, conceived a memorable project, "One Week, Eight Hours," that recorded the movement of sunlight along the interior surfaces of one of the row houses over the length of a week. Making graphic the patterns that most people rarely notice, the project highlighted not only natural phenomena, but also the history and experiences of those who once lived there.

Kim Tanzer and I included Davis' project in our book, "The Green Braid: Towards an Architecture of Ecology, Economy, and Equity." As Davis wrote: "The houses are very small, 31 x 17 feet wide typically, with front and back porches that are cut out of the main volume. … The name 'shotgun house' was coined because it was said a bullet could pass through the clear view from the front door to the back door without hitting any interior walls. They are quite simply built and recall a housing building type in Western Africa brought to the United States as a remembered building method by African slaves."

We can learn much from these modest buildings. The window placements of traditional shotgun houses encourage cross ventilation that functions well even when the interior doors are closed. The close proximity of the row houses to one another, while a significant challenge to privacy, shade the neighboring walls and create narrow airflow corridors that accelerate the wind at precisely the right place to pull out air through the side windows, thus creating a cooling breeze across any room when the windows located on opposite walls are open.

During the Fall of 2016, University of Houston graduate architecture students were challenged to design what eventually came to be labeled as Green Parasites — devices that can easily be attached to existing buildings to improve their energy efficiency by maximizing the potential benefits of sunshine, wind or rain. Since the Project Row Houses galleries on Holman Street have large front windows facing southwest — and facing southwest is the most challenging orientation for windows in places with exceedingly hot days, like Houston — these buildings are ideal to demonstrate the performance of the sun-shading devices designed by the architecture students.

The projects take advantage of the recurrent annual and daily cycles of the sun to block as much heat as possible in the summer months without blocking breezes or views, while allowing warm rays into the house during the winter months. The sun-shading devices could easily be mass-produced at an affordable cost and have the potential to considerably improve the comfort and energy performance of existing buildings.

Among the students' suggestions: the use of a double trellis to block southwestern sun rays during hot months; pivoting shutters – a cheaper alternative to louvered shutters – which allow users to switch out laser-cut perforated panels to customize the degree of privacy and airflow; an origami awning, designed to be assembled from triangular components of perforated sheet metal that block the harsh summer sun; and a "folding L" device, which relies on a hinge to transform from an awning to a shelf, depending on the season and time of day.

An influential report issued by the World Commission on Environment and Development in 1987 defined sustainability as: "meeting today's needs without compromising the ability of future generations to meet their own needs." After three decades it remains a most succinct statement, and the design community is catching up with the concept. Achieving that simple but elusive goal can be started by working on seemingly small but easy to implement improvements than can move our building practices in the right direction.

Few people want to return to the days without air conditioning, certainly not in Houston. But as sustainability moves from a buzzword to an increasingly important part of design and building, we can learn from the past and tweak our designs in more environmentally sustainable ways. ■

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CHARGING NETWORKS, NEW MODELS, ENVIRONMENTAL AWARENESS KEYS TO ELECTRIC CAR GROWTH

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An article of faith among many advocates of battery electric and plug-in hybrid cars (collectively referred to as EVs) is that once price becomes competitive with fossil fuel powered cars and the range on battery exceeds 200 miles, there will be a leap in public acceptance, eventually leading to the complete replacement of fossil fuel cars by electrics.

Two new moderately priced battery electrics, the Chevrolet Bolt and the latest version of the Renault ZOE, have over a 200 mile range. The CEO of Renault has said the last psychological barrier has already been removed.

Perhaps so, but there are both practical and psychological factors that make it not that simple. In order for EVs to be successful in the mainstream market, they must compete in both price and function.

The practical factors

Practical requirements may be seen as falling into three categories: economic, utility and environmental.

The economic value might be seen as a straightforward issue involving the lifetime cost of operating the vehicle, however, many consumers are not good at determining the lifetime cost and put undue emphasis on quick payout. In addition, the economics are locally variable, depending upon the costs of the vehicle, electricity and gasoline; subsidies; availability of free charging and other factors.

Utility includes not only driving range and recharge time but also the size of the vehicle, acceleration, handling, cargo capacity, perceived safety, status value and other characteristics. Individual buyers have vastly different requirements. The diversity of interests is illustrated by the amazing variety of vehicles available in the market today. There are over 200 models and 30 brands of cars and light trucks available in the U.S.

Electric vehicles are clear winners on environmental benefit, however, it has been a minor factor in sales to date. Surveys show that cost savings and utility are the primary factors. A UC Davis report listed the factors below as key to electric vehicle adoption.

- Vehicle price
- Vehicle operating (e.g. fuel) cost
- Driving range
- Recharging time and availability/location of chargers
- Vehicle performance and reliability
- Other attributes of utility (e.g. vehicle interior volume, number of seats, trunk space)
- Environmental factors (e.g. CO_2 and pollutant emissions)
- Operational incentives or disincentives (e.g. access to “clean vehicle zones” or “high occupancy vehicle” lanes)

The psychological factors

Buying decisions are frequently not made on a practical basis. A German study (Buehler et al. 2014) focusing on the difference in perception before and after experience with EVs describes a long list of positive and negative factors. The most reported factors, ranked in order of most cited before experience with the vehicle, include:

Advantages	Percent of participants	Disadvantages	Percent of participants
Environmental friendliness	85	Limited range	56.4
Low noise	38.5	Purchase cost	43.6
Uses alternative energy	26.9	Limited space	41
Driving experience	17.9	Charging	34.6
Low refueling cost	11.3	Battery	32.1

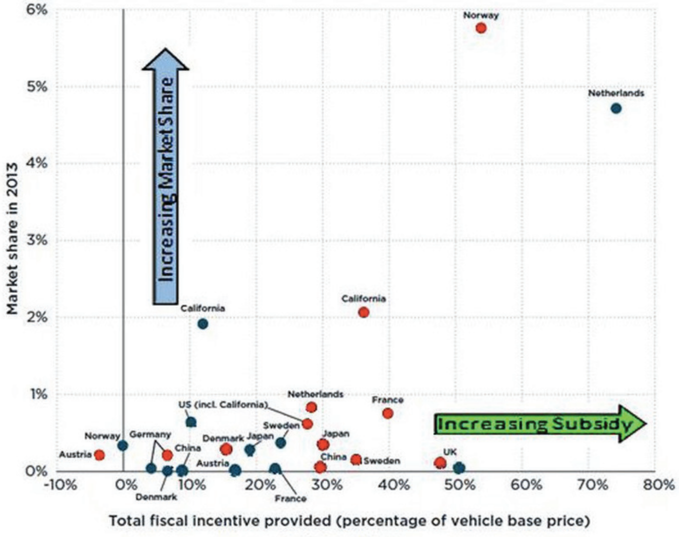
Buehler et al. 2014

Germany has particularly strong environmental sentiment; studies in other locations have identified different priorities. Economic factors are important almost everywhere.

Clearly, this is not a simple issue. A further complication is that positive attitudes toward electric vehicles do not necessarily translate to the intention to purchase.

Incentives

Because cost is important, financial incentives have played a major role in EV sales.



Modified from Mock and Yang 2014

The remarkable success in Norway and the Netherlands is primarily due to subsidies greater than 50% of the vehicle price. Additional benefits are provided in preferential lane access, free parking, free charging and exemption from ferry tolls. By 2016, EV sales in Norway had reached 40% of the market. Similarly, local subsidies contribute to the sales rate in California being more than twice the average in the remainder of the U.S.

Subsidies are an important consideration in future sales. The $7,500 U.S. federal tax credit begins to phase out for each manufacturer when their sales reach 200,000. Inside EVs predicts this will happen in late 2018 for Tesla and General Motors, later for other manufacturers. Phase-out of subsidies is also planned in many European countries.

Despite the clear influence of subsidies, they are not the whole story. There are differences in market share and type of EVs purchased in countries with similar subsidies. Environmental awareness is important, not only directly, but also in willingness to support subsidies and mandates.

The next barrier: availability of charging stations

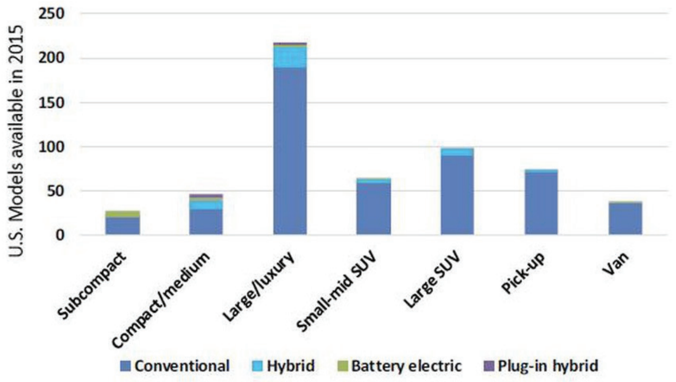
In addition to characteristics of the vehicle itself, charging infrastructure potentially limits growth rate. This is already a problem in some areas.

The optimal number of public charging stations per EV has not been established. A European Commission guideline calls for at least one recharging point per 10 EVs. There are about 200 gas pumps per vehicle in the U.S., implying that a much larger number of charging points than is provided by the 150,000 conventional service stations in the U.S. will be needed. Building these will take time and money. A significant increase in the number of EVs will also require added capacity in the electric grid.

The long term

Substantial reduction in market share of fossil fuel vehicles, if not their complete elimination, seems certain. How quickly this will happen depends not only on the considerations discussed above, but on emerging technologies, such as fuel-cell and self-driving vehicles, and societal changes, such as rejection of car ownership.

However, plug-in hybrid models to date have only about a 30 mile electric range in the midsize class and 15 mile in luxury and SUV. Most market segments do not even have an EV model available, and with the possible exception of Teslas, no class of electric cars currently competes without subsidy in price and function with gasoline automobiles.



Source: Modified from Fulton et al. 2016

In the U.S., widespread adoption will require either a shift away from the large vehicles that dominate sales or EV models to fill those niches. The Tesla Models S and X demonstrate what can be done at luxury car prices. Technology will undoubtedly improve both price and range. How fast this happens remains to be seen.

Of course, electric cars could be mandated. KPMG predicts environmental regulations will be up to four times more important than consumer demand by 2023. This prediction includes conventional hybrids. Regulation is expected to be particularly important in Europe.

Even excluding unforeseen technological breakthroughs, there are so many moving parts to this issue that longer-term prediction, say beyond 2030, is virtually meaningless. Published scenarios of market share in 2030 range from less than 5% to over 60%. The 100 million electric car target of the Paris Declaration on Electro-Mobility and Climate Change and Call to Action, considered difficult by most, implies a global market share around 20%. Even if this happens, share of EVs on the road would still be well below 10%.

Even though I like EVs and think they will replace fossil fuel cars, I have not bought one. I'll explain why in a future post. ■

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FEDERAL BUDGET CUTS TO SCIENCE AND RESEARCH COULD BRING BACK PEAK OIL CONCERNS FOR THE U.S.

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Natural oil seeps have been known for millennia in places like Southern California's doubly-named La Brea Tar Pits in downtown Los Angeles. There, Native Americans used the oily material seeping out of the ground for many purposes, including sealing wooden boats.

Move forward in time and to the other side of the country to where scientists realized in the middle of the 1800s that similar seeps in Pennsylvania and New York yielded material that could be turned into clean-burning kerosene. The timing was right as whale oil was becoming more difficult to obtain due to the extreme pressure on the populations that overhunting had created. Natural gas was also found near the surface and used for lighting but only in limited areas close to the source of the gas.

It wasn't long after the discovery that these seeps leaked such useful materials, that more of it was needed. The history of oil drilling in the U.S. usually starts with the Drake Well in Titusville, Pa., drilled in 1859 seeking oil, which was found after drilling to depths that today would be considered essentially at the surface (tens of feet). There wasn't much research done to pick the drilling sites near Titusville, and maybe that is why the first several wells were dry. They just drilled near the areas with seeps and hoped for the best.

We've gotten steadily better at finding and extracting fossil fuels in the ensuing 150 years, each advance depending both on what had been learned from previous drilling and on the technological and analytical advances developed in research laboratories.

After Titusville, the next big discovery was in 1901 at Spindletop, near Beaumont, Texas. There, drilling into a salt-formed trap led to the famous gusher that started the Texas and Gulf Coast oil rush. The high rate of production of oil from Spindletop only lasted a few years, though, and then started to decline as the reservoir was depleted. Around the same time, major oil fields were developed in and around Los Angeles, including at La Brea, again, following known seeps.

As production rates at each of these early fields started to decline, just as whale oil had before, exploration and drilling for new sources moved to areas without the obvious clues of seeps. This meant drilling into more deeply-buried reservoirs, or sites ever farther offshore in deeper and deeper water, or in regions distant from where anyone was living, or in sites that were all of the above.

Once seeps were no longer used as a guide for new drilling prospects, the science of geologists and geophysicists became more and more important. Geophysicists created tools for looking into the subsurface prior to drilling and for logging the details of the holes once drilled. Geologists interpreted these new datasets and developed prospects for new drilling sites.

King Hubbert was a geophysicist at the Shell research lab in Houston in the middle part of the last century. Working with a team of bright young geologists and other assistants, he developed the idea of the bell-shaped production curve for any given oil field: production would ramp up quickly after discovery, have a period of high production, and then rates would decline quickly. Applying this to all the petroleum resources on Earth at once became known as "peak oil." A related idea, also from Shell, is the "creaming curve." The creaming curve suggests that in the beginning of a field, or of exploration around the planet, the easiest and/or largest targets – the seeps and the mega-fields – will be produced first and then the harder to find or harder to produce reservoirs will be targeted, just like skimming the cream off the top of the milk.

Through advanced technologic developments, production is now possible in reservoirs thought useless a decade ago. We can see ever deeper into the Earth with details that tell us what is there.

There is ample literature about peak oil, whether it really exists, whether we have passed it or not or ever will, or if it is based on a set of arbitrary curves.

I am not going to take sides in that argument, as it doesn't really matter to this discussion. What does matter is not in dispute anywhere: targets are getting harder to find and more costly to produce. No longer are we drilling a few feet below a known seep. Now geoscientists, trained with years of calculus and physics and chemistry classes, plus biology for paleontologists, just to get to graduate school, spend years in specialized study focused on how to predict new reservoirs, how to image them, how to determine the likelihood of a "charge" from an oil reservoir. Students and researchers at universities, sometimes working on joint projects with industry, use satellite data that is sponsored by NASA and NOAA (the National Oceanic and Atmospheric Administration) and others. They study the ocean sediments (where most oil comes from) through drilling programs like IODP, the International Ocean Discovery Program. They learn about the structure of continents through programs like IRIS, the Incorporated Research Institutions for Seismology. All of these are federally-funded programs.

In President Trump's latest budget proposal, the National Science Foundation (NSF) is scheduled for almost an 11% cut in the name of small government. But most of NSF's money is not spent on government. It is spent on developing the work force and on the advanced technology that drives much of the economy, especially

The modern oil industry is based on just such scientists and technology. Some of those drafting the budget and science plan, including leaders from Texas who purport to be pro-industry, are cutting the support from the future industry in order to claim a bit of immediate savings. The creaming curve depends on continuing development of newer technologies to let us keep getting to the smaller and harder-to-get resources. Cutting off the development of technology and a trained workforce will push us off the expected curve and limit our ability to produce resources for the future.

An alternative title for this post might have been "Why My Fear for the Environment is Also My Fear for the Oil Industry." Federal policies currently being changed at places like the Environmental Protection Agency are likely to have a direct and lasting negative impact on the environment. But limiting the training of new scientists and putting the brakes on active research programs in science and technology development by cutting federal funding will limit our ability to respond to environmental emergencies in the future, as well as to find the next petroleum source to keep us moving forward.

Labs and research programs are built over careers. If they are dismantled due to a few years of lack of funding, it could take a generation to recover. ■

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HOW MUCH IS SAUDI ARAMCO WORTH? IT DEPENDS ON THE COUNTRY'S INSTITUTIONS

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Saudi Arabia plans a public offering of 5% of its national oil company, Aramco, sometime in 2018. As the world's largest energy producer and with the largest proved reserves, Saudi Arabia believes that the capital market will value Aramco at some $2 trillion, making it the world's most valuable publicly traded company. At this price, the government's 5% would bring in $100 billion, which is supposed to be devoted to diversifying the Saudi Arabian economy away from energy.

In anticipation of the offering, the Saudi government has lowered taxes and royalties (previously 85% and 20%, respectively) on Aramco to make it more attractive to outside buyers. Saudi officials are currently weighing whether to list the privatized Aramco on the London or New York stock exchanges. A New York listing, with its more stringent disclosure requirements, would signal the Saudis' intent to operate Aramco in a commercially responsible fashion.

The eventual valuation of Aramco is hotly disputed. The Saudis have thrown out a figure of $2 trillion. Analysts doubt this figure. Some put the valuation as low as $500 billion, which would mean a lean diversification fund of $25 billion.

Given the wide divergence of estimates of the upcoming market capitalization of Aramco, we can examine the determinants of value of publicly traded international energy companies to determine possible pricing ranges. My own analysis uses back-of-the-envelope statistical calculations, which show the possible determinants of market value and where Aramco might fit into this analysis.

My model (if we were to call it that) assumes that market capitalizations of major energy concerns depend on current production, proved reserves and the institutions – such as rule of law and strength of property rights – under which the company operates.

Figure 1 shows what Aramco's value would be if we apply its production to the market cap per unit of production of the 17 international energy concerns in my sample. This production-based exercise yields Aramco market caps of between $885 billion, if it achieved Exxon's market cap per unit of production, and $77 billion if it matched Russia's Gazprom.

Figure 2 is a reserves-based calculation that applies Aramco's 262 bboe, or billion barrels of oil equivalent, reserves to the market cap per unit of reserves of the same 17 international energy concerns. This exercise yields an $8 trillion market cap for Aramco if it matched Exxon's market cap per unit of reserves and $662 billion if it equaled Gazprom's.

The wide variation between an Exxon-like and a Gazprom-like Aramco requires us to ask whether Aramco will be run like Exxon, Gazprom or somewhere in between?

Figure 3 shows the complex relationship between rule of law, property rights, and market cap per unit of output for the 17 international energy concerns. The top Western majors (Exxon, Shell and Chevron) have strong economic institutions. Those at the bottom (Petrobas, Rosneft, and Gazprom) have weak property rights and a weak rule of law.

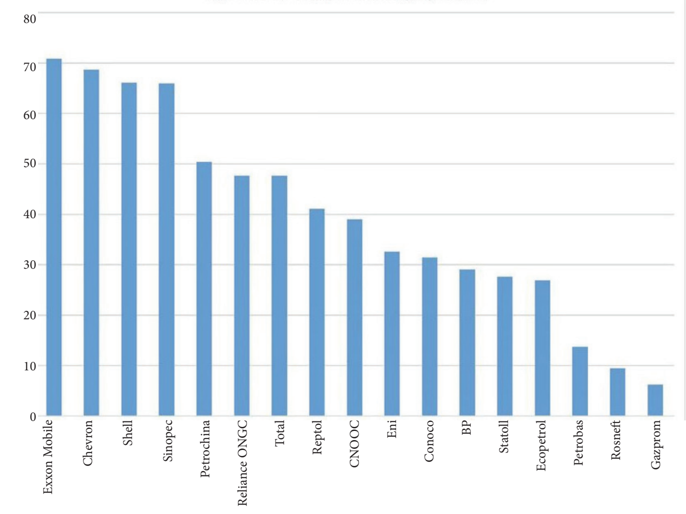

Figure 1: Market cap per unit of oil/gas production

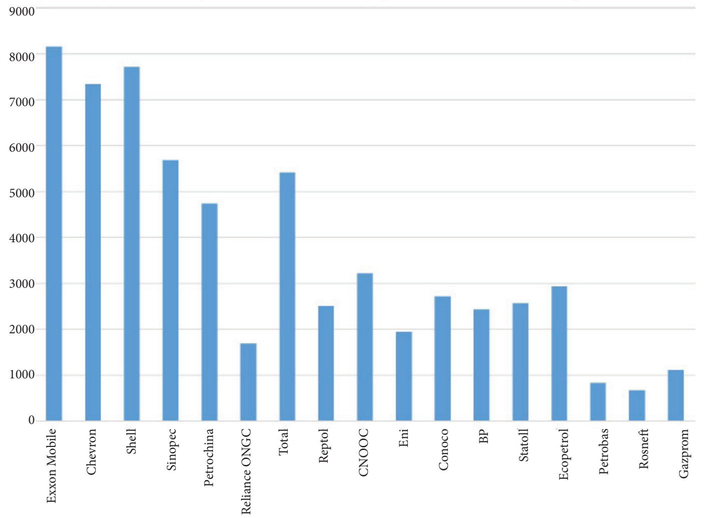

Figure 2: Market cap of Aramco with market cap per unit of reserves of other companies

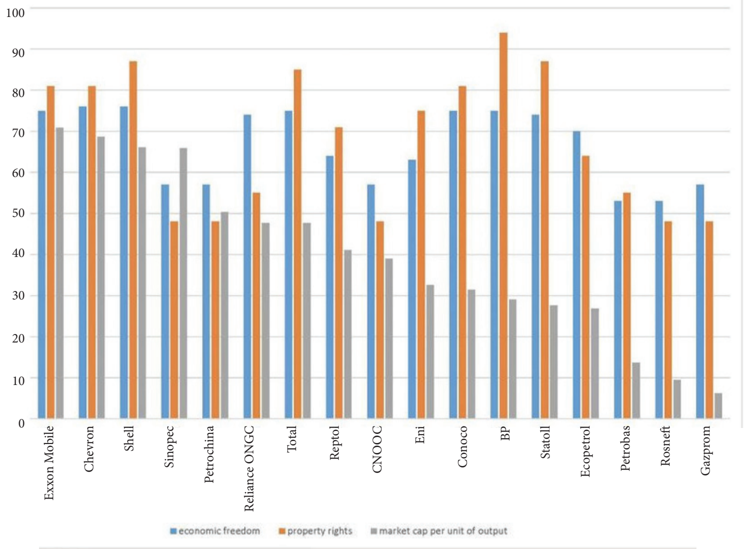

Figure 3: Market cap per unit of output, Economic Freedom, and Property Rights

The exceptions seem to be the large Chinese energy concerns, which have weak institutions but strong market caps. Investors seem to be willing to give China the benefit of doubt.

Will they do the same for Aramco?

Where will international capital markets place Aramco along this spectrum? Its economic institutions are somewhat better than those in Russia and China, but international investors must worry about Saudi Arabia's long-term political instability and whether Aramco will heed to the interests of minority shareholders, who constitute only 5% of ownership. Will a future Saudi regime decide to renege on promised lower taxes?

Will the privatized Aramco act as an arm of government to build magnificent congress palaces, roads and hospitals?

Will Aramco, like its Russian counterparts, be run like a ministry of government and as an instrument of foreign policy, or in the interests of all shareholders? If the former, Aramco can look forward to a Gazprom-Petrobas-Rosneft like valuation, and its weakness can no longer be hidden as reflected in its market share price.

The Aramco IPO will be a landmark case of price discovery. How much will informed investors be willing to pay for 5% of the production and reserves of the world's largest energy company? The price will be a reflection of investor evaluations of Saudi social, political and economic institutions.

If capital markets apply a very weak-institutions valuation, like Gazprom-Petrobas-Rosneft, Aramco's market cap would be between $100 billion (based on production) and $890 billion (based on reserves). These would be the worst-case figures. If Aramco is valued according to southern European standards (Eni and Repsol), it would be worth between $450 billion (production method) and $2.2 trillion (reserves method). The valuation will probably lie somewhere in between.

Capital markets are harsh judges. They lay bare the immense social costs of the poorly-run and corrupt energy companies of the world, such as Gazprom, Petrobas, and Rosneft. We now await its judgement on Saudi Aramco. ■

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GOOD INTENTIONS: WHY ENVIRONMENTAL AWARENESS DOESN'T LEAD TO GREEN BEHAVIOR

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Polls consistently show a high level of environmental awareness in the U.S. However, awareness frequently does not translate into action.

Use of mass transit has shown almost no per capita growth despite substantial investment in light rail and other transit improvements. Carpooling has declined.

The use of environmentally friendly technologies such as solar and wind power has grown modestly, except where subsidized or mandated. In part, this is because they have been more expensive than their fossil fuel using counterparts. However, even as those costs approach parity, growth rates drop significantly when subsidies are removed.

Models of environmental decision making

There was once, and to some extent continues to be, a belief in the simple model shown below: knowledge of the environment leads to a positive environmental attitude, which results in pro-environmental action.

Source: Modified from Kollmus and Agyeman (2002)

This has not happened consistently, either in the U.S. or Europe. In a European study, Ortega-Egea et al. say "Over the past two decades, increased media coverage – coupled with economic incentives, subsidies, and related interventions – has substantially raised citizens' awareness and concern about climate change, but has typically failed to induce persistent behavioral changes."

The root cause of the problem is that protecting the environment is not the only goal that people have. Individuals choose actions based upon priority between conflicting goals. In addition, there are multiple sources of influence affecting environmental choices. The influences are often subconscious.

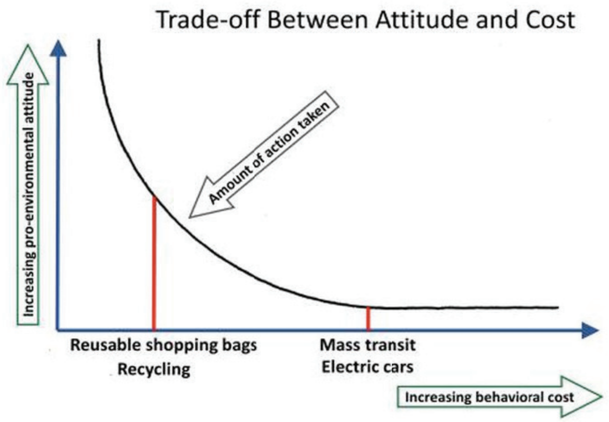
A large number of theories have been proposed to explain what motivates environmental behavior. An entire journal, the Journal of Environmental Psychology, is devoted to the topic. A model described by Steg and Vlek includes five categories, paraphrased below:

1. Perceived costs and benefits
(including nonmonetary costs and benefits)
2. Moral and normative concerns
(what you think you should be doing)
3. Emotion
4. Contextual factors
(primarily available means)
5. Habits

In addition to these factors, political orientation, age, gender, education and other individual characteristics influence environmental behavior.

Perceived Cost and Benefits

Making or saving money is a powerful motivator. It is the primary reason for the rapid growth of subsidized solar energy. However, there are differences in perception and in importance of cost, as well as nonmonetary costs, such as comfort, time and convenience. The graph shows a model of the trade-off. Things that make you feel good but require little cost, discomfort, convenience and effort, such as recycling, are likely to be done; those that have a significant number of these negatives, such as riding mass transit instead of driving, are not.



Source: Modified from Diekmann and Preisendörfer (1998)

Moral and normative concerns

Individuals have multiple moral codes governing different situations and aspects of behavior. They may belong to multiple groups (friends, neighborhood, political party, nation) that do not have the same values. They vary in the extent to which they are influenced by group norms. They vary in the importance they place on environmentally friendly behavior. This creates not only conflict between norms, but the opportunity to rationalize away environmental actions.

Emotion

People derive pleasure or displeasure from actions that affect the environment. They may derive pleasure from driving a powerful car or from the status that owning such a car gives them. Environmentally oriented individuals may derive pleasure from installing a solar panel or bicycling to work.

Contextual factors

The ease or availability of means for environmentally friendly actions, or the extent to which individuals are reminded of such actions, may influence whether those actions are taken. For example, riding mass transit may not be done if the routes are inconvenient. A person may be motivated to recycle if he or she sees others recycling.

Habits

People often do not consider alternatives to their customary way of doing things. They may reject alternatives without investigation or discount evidence of their desirability.

Other behavioral models

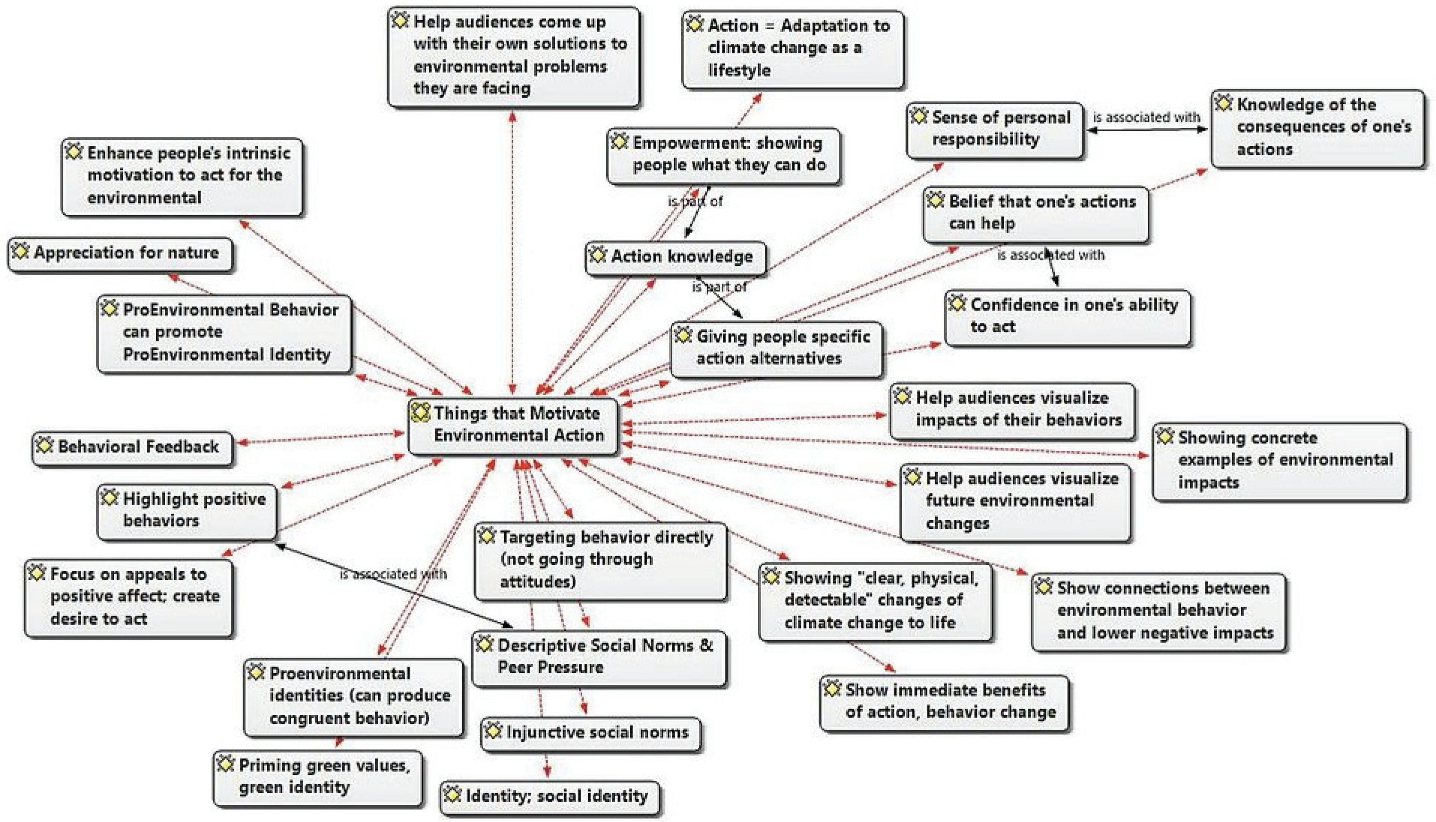
The Steg and Vlek model is only one example of numerous published explanations of environmental choice. It is presented in outline here and does not include all factors.

There are other theories and other ways to illustrate motivating factors, such as this one from Jarreau(Figure on next page). It's a complex subject.

Education may not lead to pro-environmental actions

Nearly all of the literature is normative, that is, it is assumed that individuals should adopt pro-environmental behavior. The reasons that they do not do so are usually called barriers.

It is possible to have environmental knowledge and not develop a pro-environmental attitude. For example, there is widespread belief that so-called climate change "deniers" or skeptics will be converted to belief if they are presented with scientific argument and data. However, many, including some with a strong scientific background, reject the argument.



Paige B. Jerreau, Things that Motivate Pro-Environmental Behavior

Hornsby et al. said "A critical mass of people is skeptical that anthropogenic climate change is real." As was shown in an earlier post, there is a strong political divide in climate change belief.

Alternatively, one might have a pro-environmental attitude but believe that other concerns have higher priority. This is a particular problem at the governmental level, where there are many demands for available funds. Environmental measures compete with social programs, national defense and other programs.

There are a number of behaviors that can be considered pro-environment, for example, reducing air pollution, protecting endangered species, preserving natural environments and reducing carbon dioxide emissions. Although there is a tendency for these beliefs to be correlated, individuals may have strong feelings about one but little interest in another. This dilutes political support.

Summary

There are numerous psychological factors influencing whether a person will take individual environmentally friendly actions or support collective and governmental actions. These can be influenced, vary over time and interact. They will have strong influence on the pace of adoption of electric vehicles, ride sharing services, and other lifestyle changes that are expected to reduce CO2 emissions and fossil fuel use.

Behavioral theories are often used as the basis for methods to increase support for environmental measures. This will be the subject of a later post. ■

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FAREWELL DODD-FRANK. SOMETIMES WE DON'T LIKE WHAT MAKES US STRONGER

TOM MITRO

Co-founder and Co-Director, UH Graduate Certificate in Global Energy, Development, and Sustainability (GEDS) and Visiting Lecturer at the UH Center for Public History

Work is underway in Congress to repeal the Dodd-Frank Act, as Congress voted earlier this month to dismantle rules requiring oil companies working in foreign countries to disclose payments and other dealings with foreign governments.

The rules, part of the broader financial regulations passed after the Great Recession, are aimed at the corruption that can keep a country's citizens from sharing in the wealth generated by that country's natural resources. The industry argues the regulations make it harder to compete.

But after 30 years in the oil industry and another decade as an advisor to governments and national oil companies in Africa, that's not what I have seen, either with Dodd-Frank or similar precursors.

Oil companies and the developing nations in which they do business have both prospered when they are more open about the enormous sums of money involved in energy exploration and building a producing oilfield.

First, a little background:

Congress passed the Dodd-Frank Act in 2010, primarily focused on the financial industry and banking practices. Section 1504 required petroleum companies to disclose payments to foreign governments.

But the U.S. petroleum industry resisted the regulations and even sued to have them suspended. Congress recently voted to overturn implementation. The intent was to codify and expand voluntary industry efforts undertaken though the Energy Industry Transparency Initiative (EITI) to disclose payments to governments so that citizens and civil society could better understand what has been received by their governments and independently evaluate whether the amounts are in line with contracts and whether the government has spent the amounts wisely and legally.

But the U.S. petroleum industry resisted the regulations and even sued to have them suspended. Congress recently voted to overturn implementation.

The U.S. petroleum industry, through its trade group, the American Petroleum Institute, has argued that the Section 1504 disclosures were focused on foreign policy, not shareholder protection, and that the data would overload and confuse investors, create an administrative burden, make it harder for U.S. companies to compete and violate confidentiality requirements of agreements in the countries in which they operate.

Quite a list. Over the last four decades, the industry has made exactly these arguments in response to a variety of legislative and administrative requirements; yet they have always ultimately been proven wrong in their assessments.

In almost all cases, significant new regulations and disclosure requirements focused on petroleum companies ended up strengthening the competitive positions of U.S. companies.

In my previous career in the industry, I was involved in each of these regulations, planning the initial implementation and even on the front line overseeing compliance as I worked in Angola, Nigeria, Papua New Guinea, the United Kingdom and at corporate headquarters in the U.S. I also saw how investors and lenders used the same requirements and disclosed information.

A few examples might help to illustrate this point:

1. When the Foreign Corrupt Practices Act was enacted in 1977, forbidding U.S. companies and individuals to pay bribes to obtain business overseas, U.S. industry complained that it would lose business to competitors from countries that allowed bribery. But in almost every way, U.S. companies gained a competitive advantage overseas – it became well known that they could not bribe, so most officials stopped asking. And in legitimate deals, it made U.S. companies more attractive, not less, to governments and potential partners. I certainly experienced that firsthand in my career. Today it would be hard to imagine a world without this type of law.

2. When standardized upstream accounting principles and disclosure requirements were instituted and required by Financial Accounting Standard 19 and the Securities and Exchange Commission (SEC) in 1977, the industry claimed it would unduly add to administrative costs and investors would not understand how to read their balance sheets, meaning they would not be able to obtain financing. The Financial Accounting Standards Board, acting with the SEC, noted that many opponents of establishing one standard approach "have said … adoption of the successful efforts method of accounting will inhibit the ability of oil and gas producing companies to raise capital to finance their exploration activities … exploration companies will have special difficulties in obtaining capital because … their income statements will be more likely to report earnings fluctuations … and their balance sheets could even show cumulative deficits. Potential suppliers of capital will not understand those fluctuations, losses, and deficits, it is argued, and sources of capital will diminish or be more costly. Those results, they say, are at variance with national economic goals."

Of course, the exact opposite happened – investors and lenders gained confidence from being able to rely on standardized accounting and reporting to evaluate and compare investment opportunities. The methodology adopted in 1977 for U.S. companies eventually became the international standard.

3. As part of that effort, the SEC began requiring disclosures of reserves, production and spending by region; the industry claimed these disclosures would add administrative burden and violate confidentiality agreements with foreign governments, which would make U.S. companies less competitive or cause them to lose mineral rights.

Yet companies and governments were able implement the disclosures without losing business or violating agreements. Today most agreements with governments include a specific clause that recognizes exceptions to confidentiality clauses for reporting and disclosure requirements imposed by the respective governments. This information on reserves, production and spending is considered essential by investors and the financial community. And petroleum companies themselves use that information as part of their public corporate targets and goals. It would be hard to imagine investors living without it now.

4. When Sarbanes-Oxley ("SOX") was put into place in 2002, partly in response to the Enron meltdown, petroleum companies complained about the administrative burden without any real benefit of having to better document and review all of their management and control procedures. Around the same time, various anti-money laundering regulations were put into place in response to the 9/11 attacks, which also required enhanced due diligence to avoid parties that could be involved in illegal activities.

Certainly, the original compliance did take a lot of money and effort, but much of the burden was self-inflicted by overly zealous implementation; it later became more practical and workable. (It should be noted here that once regulations are enacted, petroleum companies tend to implement them with great seriousness and vigor – no simple task for organizations operating in scores of countries.) But as part of this SOX implementation, companies often discovered that many of their procedures and policies indeed were out of date or in need of improvement. Most ended up strengthening their business practices and further added to investor confidence and ability to raise funds.

Companies have faced opposition from some foreign governments who do not want to see further disclosures. Most concession agreements or production sharing agreements do contain strong confidentiality clauses; Angola is one of those countries.

Yet even these objections and legal constraints are not necessarily a large barrier. Since the mid-2000's, the Angolan Ministry of Finance has been of its own accord disclosing on its public websites details of petroleum tax and royalty payments by block and by company. The ministry even bought space on public billboards in Luanda to advertise the website.

In addition, Angola has voluntarily released information on payments received from oil companies under EITI. Dodd-Frank requirements would entail disclosing somewhat more detail. But the precedent has been set.

And as the Open Society Initiative for Southern Africa correctly points out, Angola's production sharing agreements provide a standard exception from confidentiality "to the extent required by any applicable Law, Decree or regulation (including, without limitation, any requirement or rule of any regulatory agency, securities commission or securities exchange on which the securities of such Party may be listed)." The Angola Petroleum Activities Law Article 77 on Confidentiality contains similar exceptions.

Oil companies themselves have often helped nudge governments to permit greater disclosures. As one example, in 2004 when Chevron and the government of Angola agreed to a 20-year extension of the term of the Block 0, part of the negotiation involved Chevron working to convince the government that everyone would benefit if the amount of the bonus was publicly disclosed. In their press release at the time, Chevron stated "In a move welcomed by international observers, Sonangol made public the $210 million 'signing bonus' and an additional $80 million 'social bonus.' Chevron CEO Dave O'Reilly said his company supported the "bold move to …tackle such a difficult issue as transparency and good governance."

So it is often a matter of companies working with governments to convince, cajole, encourage and nudge them that disclosure can be in the government's interest as well. It can and has been done, but not when the oil companies are publicly resisting such efforts.

Would there really be a risk that this will "inundate investors with unhelpful information and risk investor confusion" as the API asserts? Most Wall Street analysts are a tough crowd to confuse by providing more information. Wouldn't investors gain comfort from knowing the companies haven't been involved in corrupt practices? Might not institutional investors at universities and unions gain confidence in that oil companies are operating above board?

History has shown that these types of disclosure requirements, like regulations and requirements that have come before, ultimately make U.S. companies stronger, improve their reputation and attractiveness to investors and are well worth the cost of hiring a dozen extra accountants or making a few minor amendments to their accounting systems.

There is no sin in companies acting in their own self-interest. But in this case, like others in the past, companies may be ignoring history and not be giving sufficient consideration as to how a the Dodd-Frank requirements can ultimately help them and their industry over the longer term. ■

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WHY I HAVEN'T BOUGHT AN ELECTRIC CAR (AND PROBABLY WON'T)

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Like most Americans, I think of myself as environmentally conscious, and I like the idea of electric cars. They can potentially save money and reduce pollution. Nonetheless, I haven't bought one or even seriously considered the purchase. The reasons I have not done so are the same ones that keep the vast majority of the public from buying one: they wouldn't actually save money and have disadvantages which outweigh the benefits.

My wife and I are low mileage drivers, putting less than 5,000 miles per year on each of our vehicles, so there is little potential for fuel savings. My annual gas savings between the battery electric Chevrolet Bolt and the gasoline powered Honda CR-V is about $250 per year. The cost difference, including the $7,500 tax credit and sales tax, is about $6,000. The payback period is 24 years, obviously not economic.

Numerous studies have shown that poor economics is true for most drivers. Calculations by FleetCarma showed that, except when comparing luxury models to Teslas, mileage to payback was between 50,000 and nearly 120,000 miles. Furthermore, most consumers give lip service to fuel economy but don't actually give it much weight.

Of course, if you drive a lot or live where gasoline is expensive or subsidies are high, you can potentially save money. None of these apply to me.

Some benefits and disadvantages are subjective. I like the convenience of owning a pickup and I like large cars. There are no electric pickups currently available. Until recently, all of the available electrics and plug-in hybrids were either small or very expensive.

In the battery electrics I have driven, back seat headroom was tight. The interiors were very basic, perhaps no worse than comparable economy cars, but lacking compared to larger cars. The Prius plug-in hybrid had a very loud engine, a criticism reported for other plug-in hybrids.

One might reasonably argue that I don't need a pickup truck. After all, I use the pickup bed only infrequently to haul garden supplies and do-it-yourself materials. Similar considerations likely apply to most pickup truck owners, yet models of full-size pickup are the No. 1, No. 2 and No. 3 best-selling vehicles in America. The majority of these are used primarily for general transportation, rather than hauling.

One might also reasonably argue that I don't need a large car. I rarely drive with more than one passenger. However, on the occasions when I do have two or three passengers, it is convenient to be able to take them in one car. I also like the spaciousness and comfort. It's a question of how much you're willing to sacrifice for the sake of the environment.

A commonly cited barrier is limited range, or "range anxiety," as it is described in the literature. This is not so much a problem to me as charging time, since affordable vehicles with longer range are coming on the market. The Chevrolet Bolt has a 200 mile range, more than adequate for my daily driving. The problem comes in for longer trips. Even the "super-fast" charge times are well over an hour, enough to add measurably to travel time.

The common theme in nonmonetary disadvantages is convenience. It's convenient to be able to carry more passengers when I want to, to drive long distances without stopping to recharge, and to be able to haul large objects when I want to. These infrequent needs could be satisfied by using Uber or renting a vehicle. Those are also inconvenient, taking time and costing money.

I have great hopes for plug-in hybrids. They can potentially provide environmental benefit, while avoiding most of the disadvantages of battery electrics. At present, they just don't get there. The electric only range of the larger models is ridiculously small, 15 miles or less.

Realistically, when I buy my next car I will probably buy a gasoline powered midsize SUV or large car. This would cost me about $2000 more over the life of the car, but would be worth it for the conveniences. ■

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DON'T EXPECT CARBON CAPTURE TO SAVE COAL

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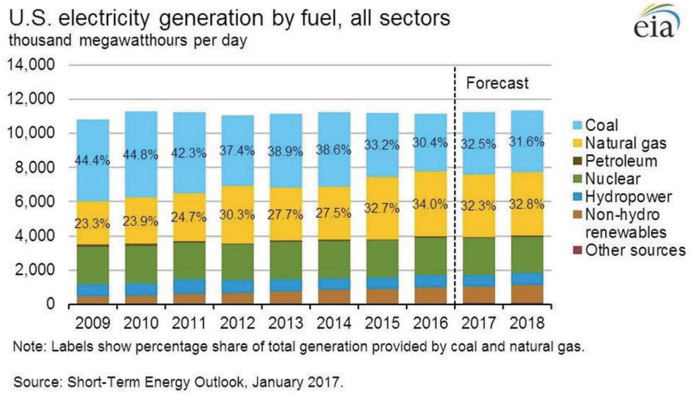
There has been a lot of excitement around the recent startup of commercial scale carbon capture and sequestration operations by NRG Energy at the W.A. Parish coal-fired power plant near Houston. The reason is clear: the technology offers the promise of "clean" coal, with little or no CO2 emission, and the potential to revive the coal-based power generation industry, which has declined nationally from about 44% of electric power generation in 2009 to 31% today.

Moreover, effectively sequestering and using the CO2 to enhance oil recovery operations in declining oil and gas fields bolsters the case, both from an environmental perspective and an economic perspective.



Source: EIA

This raises the question of why I was less than enthusiastic about the scale out and advancement of this technology in a recent Houston Public Media interview.

Let's start with economics.

Capital expenses required for the technology, the energy required to power the CO2 capture system and the current price of crude oil that would be recovered through the enhanced oil recovery process, mean that operating costs for a coal-fired generating plant coupled with carbon capture technology are 30% to 35% higher than the operating costs for a coal-fired plant alone This is consistent with extensive life cycle analysis studies of carbon capture and sequestration reported by Sathre, R. 2011.

NRG executives, I should note, disagree and say the technology is essentially cost-neutral when oil is $50 a barrel, as profits from the additional oil harvested with the use of the sequestered carbon cover both capital and operating expenses. Moreover, they estimate that with scale up and improvements in technology, the W. A. Parish plant operates its carbon capture and sequestration with a parasitic energy load of 21% or lower and not the broad industry standard of 30% to 35%.

Their bigger argument in support of the project is that investing in this technology now will pay off globally down the road. Even if the decline of coal in the United States isn't reversed, due to concerns about climate change and because cleaner-burning natural gas is cheaper, this thinking suggests that new markets for the capture technology may open in China and India, where new coal units continue to come online. They also see it as an important step toward developing other low-carbon technologies, including the use of this carbon capture at natural-gas fired power plants.

I respect that argument, and NRG's investment. Their project at the W.A. Parish plant has moved us further along the learning curve for this and future technologies that would allow for a more sustainable use of hydrocarbon fuels.

But I question whether the project and technology is economically scalable to other locations – especially coal-fired plants that aren't near an existing oil or gas field in the U. S. and in the absence of substantial economic incentives for the use of such capture technologies. And there are other concerns:

The physical footprint.

The technology will significantly strain the need for physical space associated with the power generation unit, and if scaled up to accommodate the average 1 to 4 gigawatt coal-based power plant, I believe it would be a significant impediment. In an era where most communities globally operate with a "not in my neighborhood" philosophy, the physical size of current technology will pose a serious barrier to adoption on a wide scale, especially in new construction of coal-fired power plants.

The price of oil.

Using the captured CO2 to improve oil production, and storing it geologically in oil formations, is the critical piece in making carbon capture and sequestration technology economically viable, whether it involves coal or natural gas.

The proximity between power plant and oilfield will matter – sending the CO2 by pipeline to a field 100 miles away is far different than sending it to an oilfield 1,000 miles away. NRG and its partner in the Parish plant, JX Nippon, are sending the CO2 about 90 miles away, to a field in South Texas.

But the price for which a producer can sell the additional oil harvested by the CO2 injection is a more fundamental issue for the technology's viability. With oil hovering around $50 per barrel and the expected improved production of four barrels per ton of captured CO2, the economics of the combined process is not promising.

Should the price of oil increase to between $80 and $100 per barrel, or if a considerable carbon tax is incorporated and natural gas prices stay near their current prices, this technology might, in fact, be economically viable in spite of the high capital costs.

Competing technologies, especially solar, solar thermal and wind.

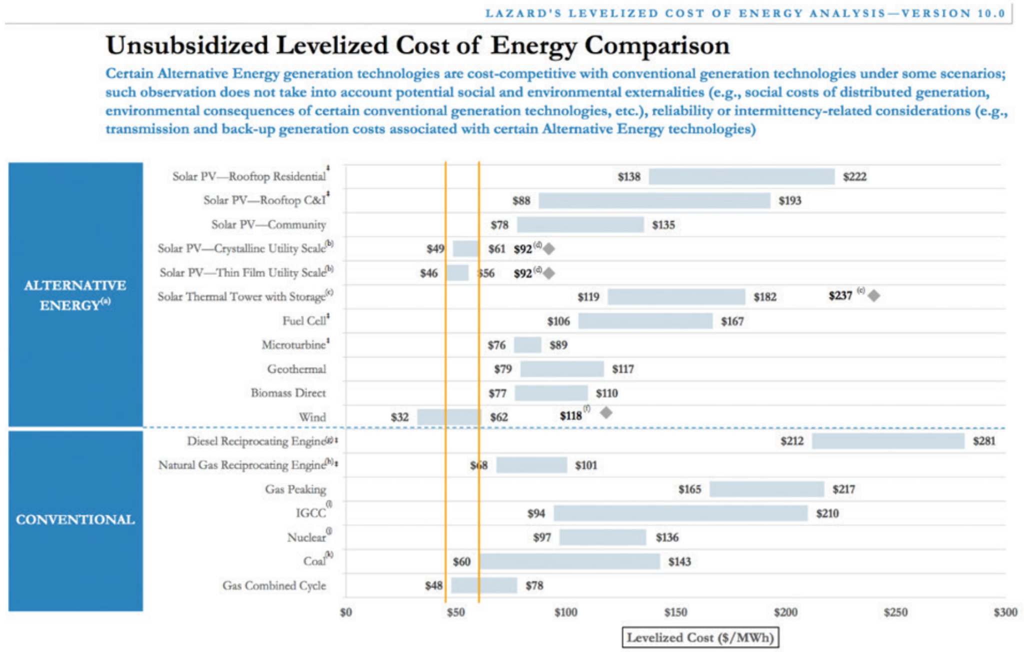
Renewables are becoming increasingly cost competitive with coal and natural gas; the unsubsidized levelized cost of wind energy has dropped by 66% since 2009, and the unsubsidized levelized cost of photovoltaic solar has dropped by 85% over the same time period. New power generation from utility scale solar and wind are now cost comparable to that from combined cycle natural gas.

There are legitimate questions about how soon these intermittent energy sources can be incorporated into the grid without improvements in affordable grid-scale storage technology. Storage technologies are still being developed and are likely to increase the cost of using renewables, although how much is an open question.

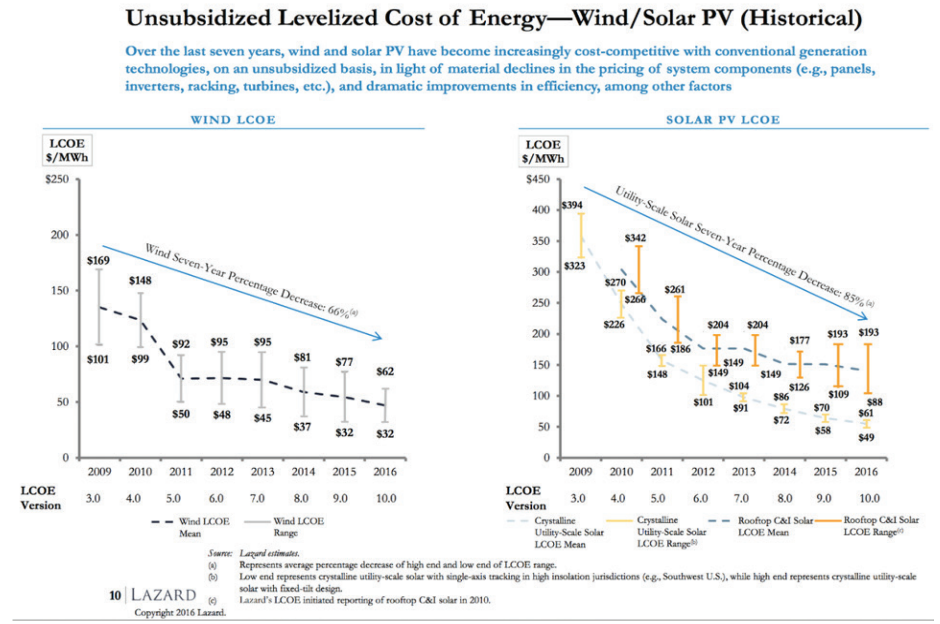
Undoubtedly, however, the share of renewables on the nation's power grid will grow, along with the deployment of other novel technologies that can render natural gas power generation nearly carbon neutral. One example is using the patented Allam cycle to drive generation turbines with high pressure, high temperature CO2 and then capturing the carbon, a less expensive and possibly less complicated process.

These competing technologies are likely to be adopted much more rapidly than the current technology based on coal, even if the lessons learned from NRG's Parish plant serve to guide research into other sequestration technologies.

Renewables, backed by newer competing technologies, and the low price of natural gas-based power generation in the United States, will be a significant challenge to the continued nationwide deployment of this clean coal technology deployed in Texas. ■



Source: Lazard Consulting Firm



Source: Lazard Consulting Firm

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AN UPSIDE TO LOW CRUDE OIL PRICES – INTERNATIONAL OPERATIONS MAY FACE FEWER RISKS

TERRY HALLMARK Instructional Assistant Professor, Honors College

As the saying goes, trying to predict long-term crude oil prices with any precision is the business of fools and liars. I try hard not to be either, so I'm not going to predict crude oil prices here. However, for the sake of argument I will say this much: it's reasonable to assume we are in a period of sustained low crude oil prices in the $40-$60/barrel range, and that will likely last awhile. I have no idea exactly how long, but I'd guess at least five years – maybe 10 – and longer still before the world sees $80/barrel crude oil. We may never see $100/barrel crude oil again, absent some cataclysmic geopolitical development.

Oil prices are one of many factors that shape the host-country environments in which international oil companies (IOCs) operate. Over the years, as oil prices have gone up, the above-ground risks that threaten oil company operations have tended to go up as well (e.g. political violence, regime instability, adverse contract changes). It stands to reason: when crude oil is worth more, attacks by insurgents or terrorists hurt IOCs and the governments of oil producing countries more. This is not to suggest that oil price is the sole driving force behind above-the-ground risks – it's only one piece of a much larger puzzle – but I got to thinking: what effect, if any, might today's low crude oil price environment have on above ground risks in the near-to-medium term?

The initial efforts at oil industry-specific risk assessment by exploration companies focused mostly on identifying the potential nationalization or confiscation of company interests by foreign governments.

This was a response to the emergence of "resource nationalism" and a rash of expropriations of oil sector interests between 1960 and 1976, as well as the expropriation of all foreign oil company holdings in Iran after the 1979 revolution. Countries came to understand that they possessed a valuable commodity and wanted to control it.

Beginning in the mid-1980s, the relationship between foreign operators and host-country governments changed. The governments realized the uncompensated taking of oil company assets severed ties to the funds, expertise and technology needed to sustain their petroleum sectors and secure economic growth. Further, there was a general turn toward free-market economics and progressive petroleum laws to make exploration more attractive to foreign companies. These moves were, in large measure, a response to generally low oil prices.

But even though oil prices were low, so long as the geology looked promising, acreage was open and fiscal terms guaranteed an acceptable rate of return, oil companies were willing to explore for oil almost anywhere in the world. Nationalizations and expropriations slowly faded from the scene, and oil exploration companies and analysts alike began to speak in terms of a "post-nationalization" operating environment.

As expropriations and nationalizations became a thing of the past, other threats materialized. During the 1990s, a mix of less-than-completely democratic governments in lesser developed, oil-producing countries (which frequently filled their coffers with oil earnings at the expense of the citizenry), sizable new discoveries and rebounding crude oil prices all came together to spur countless attacks on oil installations, pipelines and personnel by rebels and political activists in Latin America, Africa, Asia and elsewhere. The work of the political risk analyst shifted from trying to predict if, and when, an uncompensated taking of an IOC's interests might occur to trying to figure out when and where attacks might take place, who or what was the likely target or targets, and whether the attacks might shut down operations or force the evacuation of personnel – and *then* whether the attacks might ultimately destabilize the host-country government.

Something unexpected happened in the early 2000s. Resource nationalism, along with expropriations and numerous other adverse contract changes (increases in "state take" – royalty and tax rates), re-emerged. The reason was jacked-up crude oil prices, along with the nationalist or leftist ideological leanings of the host countries. Unlike the earlier nationalizations and expropriations that claimed oil assets the host countries believed were theirs, this new batch of takings were more akin to an "oil weapon" used to punish adversaries and advance a broader foreign policy aimed at securing certain geopolitical or geostrategic ends.

Consider Venezuela. While President Hugo Chavez did not execute a complete expropriation in one fell swoop, he did implement several adverse contract changes that amounted to creeping expropriations. For example, in 2004, with prices hovering around $40/barrel, Chavez raised taxes on a handful of heavy oil projects. In April 2005, with crude oil prices near $60/barrel, Venezuela announced existing operating agreements would be converted to joint ventures. Two years later, as crude prices trended upward to $80/barrel, Venezuela took operational control of the holdings of BP, ChevronTexaco, ConocoPhillips, ExxonMobil and Statoil – so that Venezuelan state company PDVSA could secure a minimum 60 percent stake in projects in the Orinoco Belt.

And in 2008, with crude oil prices headed to $147/barrel, Chavez imposed a 50% windfall profits tax on oil company earnings whenever crude oil prices exceed $70/barrel. Given Chavez's political leanings, it is no accident that the companies affected were all Western oil companies.

Nor was Venezuela the only country that tightened its grip on its energy sector at the expense of the international oil companies. During the same period, there were partial or wholesale adverse contract revisions in Bolivia, Ecuador and Russia.

So, what does this brief history tell us about above-ground risks in the current low oil price environment? To begin with, crude oil producers and exporters will be out a good deal of money because of lower oil prices. This is likely to increase the social, political and economic pressures on the governments in these countries – to the point they could become destabilized, making exploration operations in-country more difficult.

At the same time, there will be more competition between countries for exploration dollars, and thus oil producing or prospective countries will be less likely to squabble over contract terms.

National oil companies (NOCs) will be less assertive or adventuresome than in recent years because they have less money in their coffers as well; governments will, in general, be less inclined to view their resources as an "oil weapon" or means for advancing foreign policy. Nationalizations and expropriations are unlikely, because they typically occur only when oil prices are higher than usual and when governments don't think they're getting their fair share of oil earnings. If anything, governments will probably improve their contracts and petroleum terms to encourage exploration.

International oil companies will probably take less political heat, at least in some circles, because earnings will be down and gasoline prices lower, but there will be less money available for exploration. With fewer exploration dollars available, fewer new projects will be sanctioned. Deepwater drilling may slow a bit, but not stop.

But there is some upside to all this. First, lower oil prices will force the international companies to be innovative and reduce costs. Second, since oil is worth less and there will be fewer new projects, the international companies will make less attractive targets, and the number of attacks aimed at pipelines, oil installations and personnel will likely drop.

Groups that get money from attacking the international companies through extortion and kidnappings will have less money. Oil theft will likely continue in all the usual counties, but there may be less of it because oil isn't worth as much. Renewables and alternatives, while still attractive, will not be in play as much – at least in the near-term – because oil is relatively cheap. However, as oil companies make the transition to energy companies by adding wind and solar to their portfolios, attacks aimed specifically at oil interests should decline.

It must be said that some above-ground risks or the risk environments in some countries are not likely to change because of low crude oil prices. For example, MEND, the Niger Delta Avengers and other activists and insurgents operating in Nigeria's Niger Delta will keep attacking facilities and personnel, blowing up pipelines and stealing crude oil and refined products for the foreseeable future. Likewise, Russia, under Vladimir Putin, will continue to use resource nationalism whenever necessary – e.g. expropriations and adverse contract changes, as well as its European oil and gas exports "weapon" – to advance the country's political and foreign policy interests.

And finally, there's Venezuela.

Because more than 90% of Venezuela's export earnings comes from crude oil, the country's economy has been devastated by the recent low crude oil prices, along with underinvestment and gross mismanagement of the country's oil sector. Indeed, Venezuela is, for all intents and purposes, a failed state. It boggles the mind, then, that the government is finalizing plans to complete, in full, the 2007 partial 60% expropriation of the Orinoco Belt holdings of BP, ChevronTexaco, ConocoPhillips, ExxonMobil and Statoil (and now others) by taking over the 40% stake originally retained by the oil companies.

The government is doing this because BP and the other companies are paid in crude oil – which would go to PDVSA and then be sold on the market to boost the company's revenues. However, the only Orinoco Belt projects successful to date have been those funded by the foreign oil companies. A 100% ownership by cash-strapped PDVSA surely spells nothing but doom for any new projects in the works. ■

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SAUDI OIL MINISTER SOUNDS TROUBLE FOR RUSSIA AT HOUSTON CONFERENCE

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Energy producers and OPEC ministers, meeting at CERAWeek in Houston, grappled with a global glut of oil that was not supposed to be. Back in November, OPEC and non-OPEC oil producers agreed to their first production cut in eight years. Thus ended a Saudi-led experiment with free markets that had driven down crude prices to historic lows. The Saudi gamble was that low prices would dry up U.S. shale investment, rig counts, and hence crude production, that competes with OPEC and Russian output.

The experiment apparently failed.

Meeting in Houston with $50 plus crude, the OPEC team, represented by the Saudi oil minister, Khalid Al-Falih, and Russia's energy minister, Alexander Novak, grudgingly acknowledged being caught off guard by a second wave of U.S. shale production at prices they had thought would throttle the shale industry. The production quotas orchestrated by OPEC and Russia were supposed to stabilize prices below production costs of shale producers and drive them from the market. To everyone's surprise, shale producers had used technological advances and short start-up times to push down break-even costs, below $50 in the Permian Basin.

Even the shale oil producers themselves were surprised by the speed of recovery. U.S. crude output rose to nine million barrels a day, and the global glut as expressed by rising crude inventories refused to go away, despite OPEC actions.

The OPEC-Russia coalition apparently did not anticipate that they were facing a new type of competition, one that could respond quickly and innovate to plumb the depths of cost economies.

The OPEC-Russia production cuts had been scheduled to last a half year, and they appear to have been implemented. With crude prices falling and inventories rising, OPEC – mainly Saudi Arabia – must decide whether to extend the cuts, even though the first set of cuts did not work out as planned.

The Saudi minister's comments in Houston must have sent a chill down the spine of his Russian counterpart, as he announced that Saudi Arabia will not "bear the burden of free riders." He also warned U.S. producers that it would be "wishful thinking" to expect Saudi Arabia and OPEC to "underwrite the investments of others [US shale producers] at our expense" through production cuts. Don't expect us to keep prices so high that your investments are safe and you are freed from the pressure to push down costs to stay in business.

Translated, the Saudi minister warned his fellow OPEC members and Russia that Saudi Arabia is not prepared to cut its own production, which it can pump at low breakeven costs, to keep prices up for high-cost "free riders," such as Russia. Russia, with its depleting reserves, antiquated technology, isolation from Western capital and technology, and Petrostate dependence on oil revenues must learn to live with $50 (or below) oil.

Energy producers from the Middle East. Latin American, Africa and North America must come to the realization that the energy market has reconstituted itself, with the U.S. as the swing producer. U.S. breakeven costs on unconventional oil will henceforth determine the long-run price of crude. Over the next decade, there will be fluctuations in crude prices as world demand fluctuates and political disruptions interrupt supplies, but the price should tend towards the equilibrium set by marginal costs in the U.S.

Two further factors could push the price even lower. The United States has elected a pro-energy president, who will lessen environmental and other regulations on energy production. These steps will drive break even cost even lower. If Europe and other countries follow the United States' political changes, restrictions on unconventional oil would begin to disappear worldwide. If so, the world economy can look forward to cheap energy for decades to come.

In the meantime, Russia's Putin will be on the outside looking in. The Russian economy and state have survived two plus years by tapping foreign reserves and depressing living standards. It is unclear how it could survive decades of energy prices below what Russia needs to stabilize its economy and provide the government with the funds it needs to maintain political harmony while fighting its hybrid wars abroad. ■

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THE SHIFT TO RENEWABLES: HOW FAR, HOW FAST?

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Powering the United States or the world with 100% renewable energy is the stated goal of many individuals and organizations. What they are really talking about is 100% renewables to generate electricity, because it's not feasible in the near-term to replace motor fuels with renewables. Views of how quickly this can be done are highly polarized – some predict less than two decades, while others see fossil fuels as the dominant source at least through 2050.

The primary argument for renewable energy is to avoid anthropogenic, or human-caused, climate change by reducing CO_2 emissions. Progress toward that goal has fallen well short of reductions believed by the Intergovernmental Panel on Climate Control (IPCC) to be necessary to avoid catastrophic climate change. In fact, the only year in the past 40 in which CO_2 emissions decreased was the first full year of the 2008 recession. The rate of growth of carbon emissions has slowed over the past five years, however, giving proponents of carbon reduction some encouragement.

Let's look at some of the claims of the feasibility of going to 100% renewables.

How quickly can it be done?

In a 2008 speech, former Vice President Al Gore said it was "achievable, affordable and transformative" to generate all electricity in in the United States using wind, solar and other renewable sources within 10 years. One might dismiss this as political hyperbole, and it has not happened.

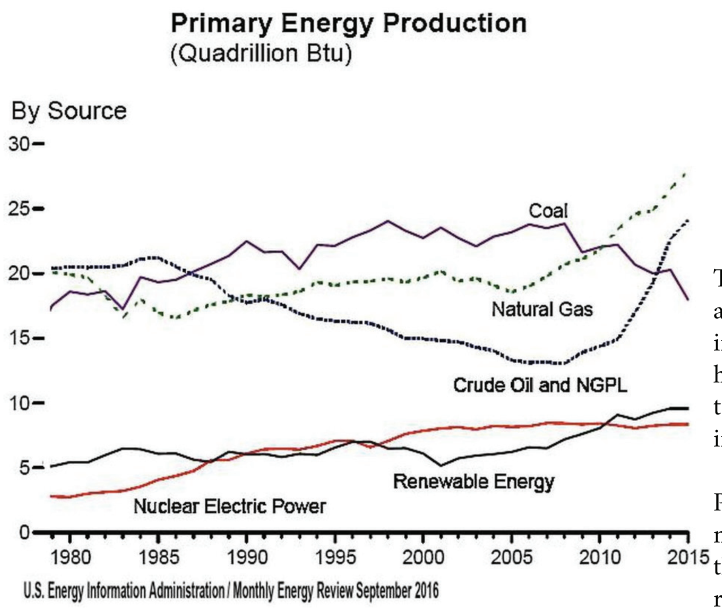
A claim that arguably has a better technical basis appeared in a widely publicized November 2009 Scientific American article by Mark Jacobson and Mark Delucchi, professors at Stanford University and the University of California respectively. They suggested all electrical generation and ground transportation internationally could be supplied by wind, water and solar resources as early as 2030. Even that is wildly optimistic, since the median of the most optimistic of the projections in the latest IPCC assessment has low carbon sources (which include nuclear, hydro, geothermal and fossil fuels with carbon capture and storage) generating only 60% of world energy supplies by 2050; wind, water and solar are less than 15%.

In a 2015 report addressing only the U.S., Jacobson, Delucchi, and co-authors revised the schedule to 80-85% renewables by 2030 and 100% by 2050. As with nearly all low carbon scenarios, their plan depends heavily on reducing energy demand through efficiency improvements.

Other forecasts are considerably less optimistic. Two examples: the 2015 MIT Energy and Climate Outlook has low carbon sources worldwide as only 25% of primary energy by 2050, and renewables only 16%; the International Energy Agency's two-degree scenario has renewables, including biomass, as less than 50%. Even the pledges of the widely praised Paris Agreement of the parties to the United Nations Framework Convention on Climate Change (UNFCCC) leave fossil fuels near 75% of energy supply in 2030, when the commitments end.

How are we doing?

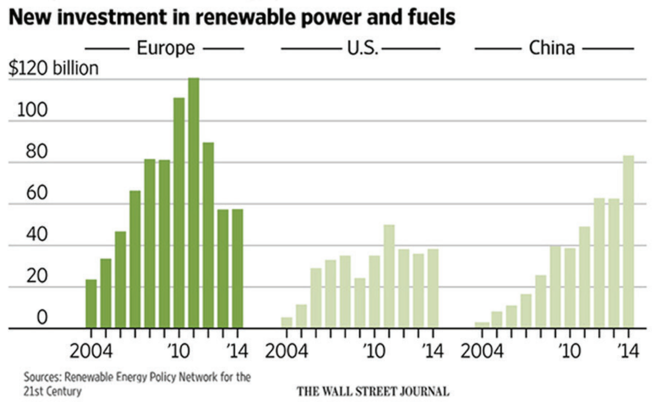
Growth of renewables as a fraction of the overall energy supply has been slow, although recent growth of wind and solar is impressive. This graph shows the annual growth rate of renewables in the U.S. since 1980 as less than 2%.



Since 2007, wind and solar have grown over 20% per year in absolute terms, and about 15% as a percent of supply. There was no growth in other renewables during that period. The international numbers are similar.

What is possible?

Proponents of renewable energy are fond of saying that 100% renewable is technically feasible; it only requires political will. With some caveats, this is true. There is theoretically enough sunlight and wind, and a growth rate of 20% means a doubling every four years. If sustained, this would mean we could have 500 times the existing amount of wind and solar by 2050. However, there are both economic and technical barriers.



The rapid growth of renewables in both the United States and Europe has been due in large part to subsidies that make investment in renewables highly profitable. As installed capacity has increased, both state and national governments have tended to cut subsidies, resulting in substantial decreases in renewable investments.

Per the United Nations Environment Programme, worldwide new investment in renewable energy has been basically flat for the past five years. This overall view masks substantial local and regional differences. Investment in the developed countries has declined about 30% since the 2011 peak, while investment in the developing countries has almost doubled.

Technical barriers to wind and solar are largely the result of intermittency and the location of favorable areas. Intermittency is not a problem as long as the proportion of renewable energy is small and excess capacity exists in conventional generating plants. It begins to become a problem when intermittent sources reach 30% of capacity and is very significant when it reaches 50%. The numbers are somewhat variable depending upon the makeup of existing plants. A 2008 report of the House of Lords estimated that reaching 34% of renewable energy in the United Kingdom, largely with wind power, would raise electricity costs 38%. The cost goes up as the share of variable renewables increases due to storage and grid flexibility requirements.

Intermittency can theoretically be handled by diversification of sources, load shifting, overbuilding capacity, and storage. All add cost. Diversification on a broad scale would require substantial changes to the energy grid. Storage on a utility scale is in an early stage of development, so costs remain uncertain. A large number of technologies exist, with varying estimated costs and applicability.

A 2012 Deutsche Bank report estimated that renewables plus storage could be competitive in Germany by 2025, however, the calculation included a carbon tax, effectively a subsidy for renewables. Any such comparisons of future costs depend upon assumptions of technological improvements and fossil fuel costs.

100% renewable electricity generation is technically feasible. However, even if you assume cost competitiveness, money has to be spent in the near-term to not only add capacity but to replace existing plants. In the industrialized countries, this is not an insurmountable problem but it does require allocation of funds that have competing demands. In some developing countries, there is just not money available.

Some proponents of accelerating the replacement of fossil fuels advocate a massive effort, which they call a “moon shot” or compare to World War II. But this transition requires a great deal more effort than the moon shot, and there is serious question whether there is political motivation comparable to World War II. I’ll talk about that in a future post. ■

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U.S. NUCLEAR ENERGY: TRANSFORM OR BECOME IRRELEVANT

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S. RADHAKRISHNAN Managing Director, UH Energy

The recent financial crisis facing Toshiba due to construction cost overruns at the newest nuclear power plants in the U.S. brought home the message: the nuclear power industry in the U. S. must change or become increasingly irrelevant.

This latest financial crisis strikes an industry that already has undergone a radical slowdown since the Fukushima disaster in 2011, which followed stricter regulations and safety concerns among the public after the Chernobyl disaster in 1985 and the partial meltdown at Three Mile Island in 1979. The increased cost of building traditional high pressure light water reactors comes at a time when natural gas prices have plummeted and grid-scale solar and wind are becoming price competitive. So with all the financial and environmental concerns – including the very real issue of where and how we should store spent nuclear rods – why should the world even want nuclear power?

Several reasons.

First, nuclear power represents nearly 20% of the electricity generated in the U.S. Only coal and natural gas account for a higher percentage. More important than the total percentage, nuclear has the ability to provide highly reliable base load power, a critical factor as we go towards more intermittent sources, including wind and solar. The power generated using nuclear power has the highest capacity utilization factor – that is, among all fuel sources, it has the highest ratio of power actually produced compared to potential power generation, highlighted by the fact that it represents only 9% of the installed capacity in the U.S.

Clearly, nuclear, combined with natural gas, could be a great mechanism for replacing coal as base-load power. Moreover, natural gas power plants can be rapidly mobilized and de-mobilized and effectively offset the inherent intermittency of solar and wind in the absence of effective grid-scale storage.

Which points to the second reason: energy sources not based on hydrocarbons have become the de facto option to decrease anthropogenic carbon dioxide. Thus, along with solar and wind, nuclear represents a significant technological solution to address the human-caused CO_2 issue.

A strong case for nuclear was recently presented at a symposium hosted by UH Energy, especially if we are looking for a rapidly scalable solution. Nuclear power technology continues to evolve away from the concrete-intensive light water high pressure process and toward a modular and molten salt-based process, especially outside the U.S. With the broad availability of nuclear fuel, especially in a world where thorium and other trans-uranium elements are increasingly becoming the fuel of choice, this technology is scalable and ready for global consumption. If done right, the use of thorium and some of the trans-uranium elements might quite substantially scale-down the issue of spent fuel disposal.

But other, less tangible barriers remain. Perhaps the single largest barrier for nuclear energy, after the economics associated with traditional nuclear power plants, is one of social acceptance. The near-misses such as Three Mile Island and the catastrophic incidents at Chernobyl and Fukushima highlight the challenge of gaining broad societal acceptance of nuclear energy. Compounding these challenges is the much publicized possibility of a "dirty-bomb" based on nuclear material from rogue nations.

Reducing the amount of fissile material in a power plant and reducing and even eliminating the risk are crucial to gain the public's confidence. One significant advancement that might help minimize the challenges with public confidence is that of fuel reprocessing and, with that, the virtual elimination of nuclear fuel waste. While these technologies are in their infancy, rapid advancement and scale-up might result in a significant shift in public perception of nuclear power.

Despite the barriers, several symposium speakers argued that the increased use of nuclear energy is not only possible but the best bridge to a low-carbon future. They did not deny the concerns, especially the staggering upfront cost of building a new nuclear power plant. Jessica Lovering, director of energy at The Breakthrough Institute, acknowledged the upfront cost has quadrupled since the 1970s and '80s in the U.S., largely stemming from increased safety engineering in response to tougher regulations and the custom development of each nuclear facility. In contrast, Lovering has reported that the cost in France, through standardization of equipment and centralization of generation capacity, for new generation capacity has risen far more slowly. And therein lies a potential path forward for how the nuclear industry may adapt.

Perhaps the biggest disruption to the current nuclear paradigm are two large changes that are just getting started: First is the global reach of South Korea and its desire to become the leading global supplier of nuclear energy production. Based on imported technologies from Canada, France and the U.S., and using the key lessons from the success of the French nuclear industry due to standardization and centralization, Korea has taken on building modular nuclear power plants, assembled at a single site. And the site that they are working from is the United Arab Emirates! Using these advances, they have been able to keep capital costs for new generation capacity to under $2,400 per kilowatt hour. That compares to $5,339 per kilowatt hour in 2010 in the United States, according to the Nuclear Energy Agency. Interestingly, China is looking to emulate the Korean model and with as many as 30 new nuclear reactors for power generation planned over the next two decades in China alone, the global competition is heating up.

Second is the advancement of small modular nuclear reactor (SMR) technologies, which have now achieved prototype testing. The opportunity and challenge associated with SMRs is captured in a recent DOE report. These reactors are designed with smaller nuclear cores and are inherently more flexible, employ passive safety features, have fewer parts and components, thus fewer dynamic points of failure, and can be easily scaled-out through their modular design.

Done at scale, these would result in reactors being constructed more quickly and at much lower capital costs than the traditional reactors. Aside from technical advances that would enable this technology to be produced at scale, issues of public policy, public perception, regulatory predictability and (micro) grid integration need to be resolved.

The U.S. nuclear power industry needs to embrace the Korean model and SMR technologies in order to transform and provide the base load capacity. The traditional model has failed us in too many ways. ■

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HAVE WE PASSED THE CLIMATE CHANGE TIPPING POINT?

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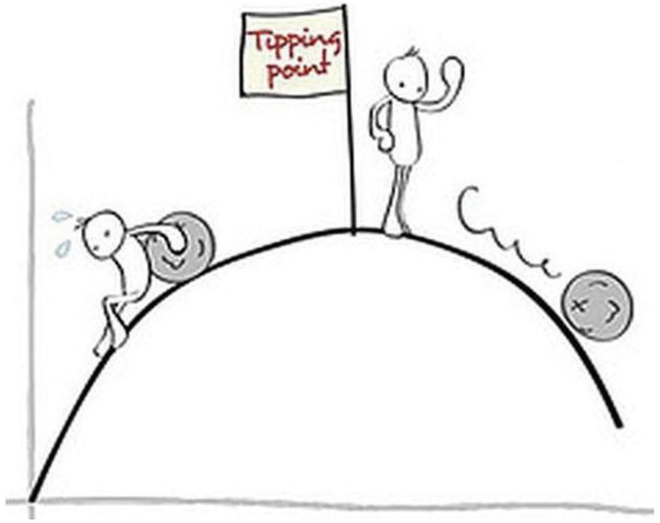
A few years ago, 400 parts per million for carbon dioxide was widely cited as the tipping point for climate change. Now that we have passed that value, it has become common to say that it wasn't really a tipping point, that it was symbolic or a milestone.

Whether it's a tipping point or a milestone, we have decisively passed it and CO_2 levels appear certain to continue higher. Ralph Keeling, the originator of the famous Keeling Curve, said "it already seems safe to conclude that we won't be seeing a monthly value below 400 ppm this year – or ever again for the indefinite future."

Let's consider what a tipping point actually is. The IPCC describes it as "abrupt and irreversible change." Lenton, et al. say it "will inevitably lead to a large change of the system, i.e., independently of what might happen to the controls thereafter." In other words, past the tipping point there will be drastic changes even if we stop emitting CO_2. Rather than staying "well below 2 degrees Celsius above pre-industrial levels" as is the target of the United Nations Framework Convention on Climate Change (UNFCCC), there could be warming of several degrees, with associated sea level rise and rainfall changes.

In contrast to these definitions, others say climate change at projected CO_2 levels may be reversible. Reversibility is important because otherwise it's impossible, or at least very difficult, to do anything once you have passed the tipping point. I'll return to this.

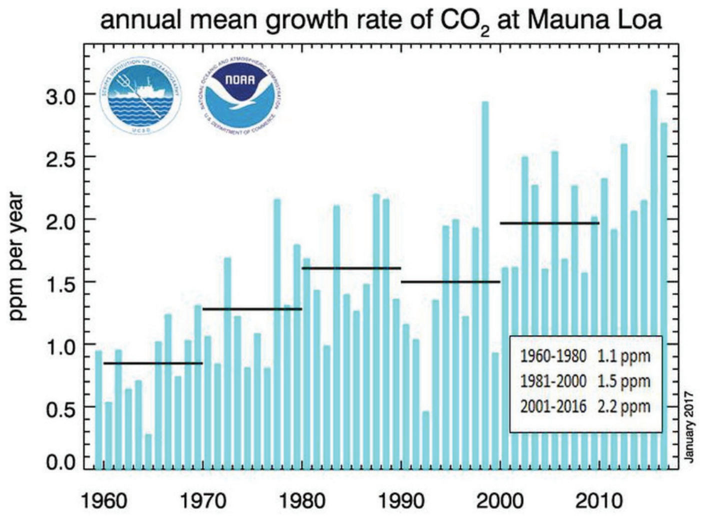


Source: Alchemy 4 The Soul

Where do we stand on CO_2?

Atmospheric CO_2 has not only been increasing; it has been accelerating. The 2001-2016 annual average increase is double that of 1960-1980. As pointed out in an earlier post, commitments under the UNFCC Paris Agreement do not decrease global CO_2 emissions, so it is virtually certain that CO_2 concentrations will continue to rise.

Much has been made of the potential impact of Trump's policies on CO_2 emissions. The frequently quoted Lux Research analysis of Clinton and Trump policies projected a difference well under a billion metric tons in 2025. This is just over 1% of the world total under the Paris Agreement commitments. The difference is not significant insofar as it relates to tipping mechanisms.



Source: Modified from NOAA

Climate tipping mechanisms

There are multiple possible tipping mechanisms, some of which are shown on the map below. Several of these are occurring today: Arctic sea ice loss, melt of the Greenland ice sheet and boreal forest dieback (and range shifts) are well documented. The extent of permafrost loss, instability of the West Antarctic Ice Sheet and slowing of the Atlantic deep water formation (also called Atlantic Thermohaline Circulation or Atlantic Meridional Overturning Circulation) are less well supported, but there are indications that these are occurring.

These mechanisms are not directly dependent on CO2 concentration; they are triggered by warming alone. Given the amount of warming in recent decades, it is not surprising that they are occurring.

The effects of potential tipping mechanisms are difficult to judge. It's generally agreed that Arctic sea ice melting is a positive feedback event. Less ice means a darker ocean and more warming. Others are not so clear-cut.

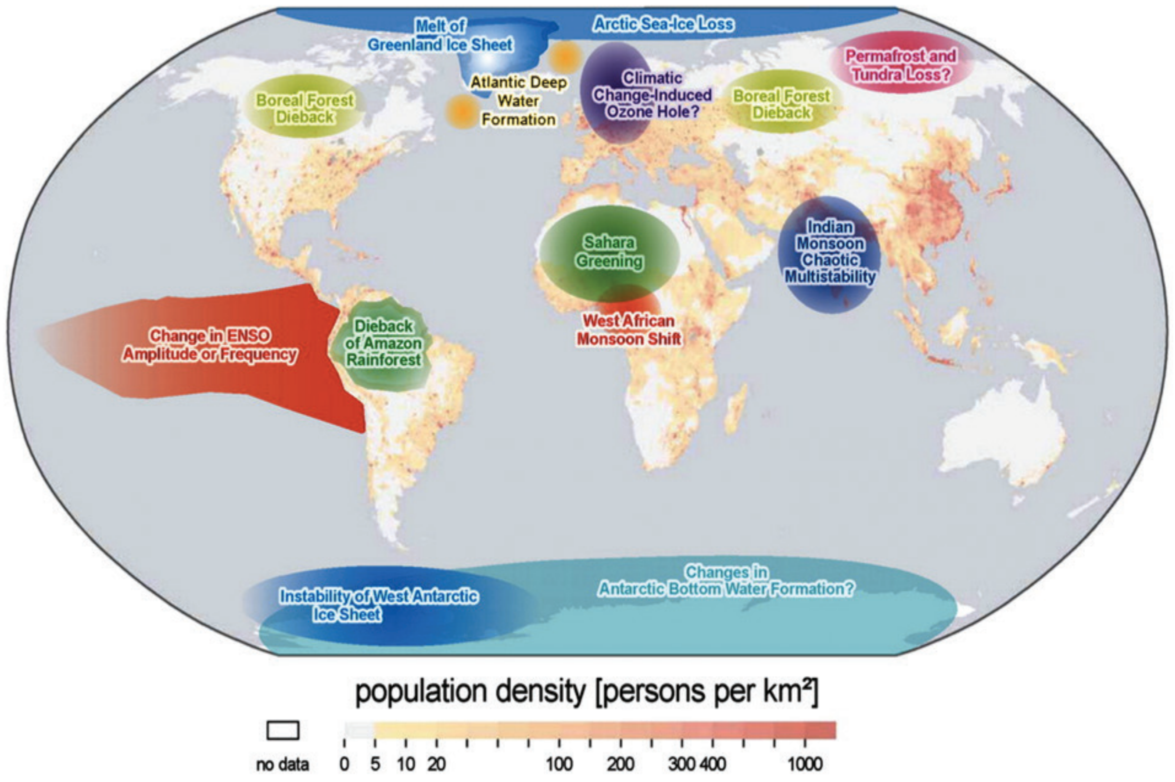
For example, boreal forests, which represent about one-third of the world's forest cover, are carbon sinks but have variable reflectance depending upon the season, snow cover and vegetation type. Compared to tundra and deciduous forests, they have a net warming effect. The extent to which they will migrate due to warming, and the type of vegetation which will succeed them, are speculative.

Further uncertainty exists because climate effects interact. It is possible to have a cascade, in which increased warming from exceeding one tipping point triggers another.

Is climate change reversible?

The IPCC considers some additional warming irreversible. They say "Many aspects of climate change and associated impacts will continue for centuries, even if anthropogenic emissions of greenhouse gases are stopped. The risks of abrupt or irreversible changes increase as the magnitude of the warming increases."

Per the models cited in the IPCC assessments, anthropogenic climate change can be halted at 2 degrees, although this scenario requires negative industry and energy-related CO2 emissions later this century. By this interpretation, a tipping point has not been reached.



Source: Lenton, et al. PNAS 2008

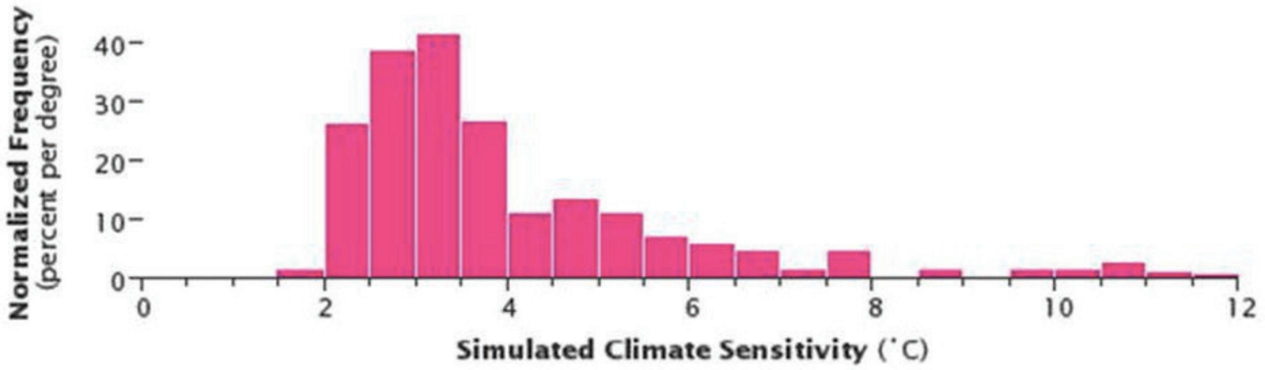
Accomplishing the 2 degree scenario may be difficult. The world's track record in emissions reductions is poor. According to Friedlingstein, et al., "Current emission growth rates are twice as large as in the 1990s despite 20 years of international climate negotiations under the United Nations Framework Convention on Climate Change (UNFCCC)."

There has been a reported flattening in fossil fuel emissions for the past couple of years, due primarily to reported coal reductions in China. It remains to be seen whether this is the beginning of a reversal. Even so, emissions would have to decrease rapidly to meet even the 2 degree goal.

Prescriptions for reversal of global warming include proposed geoengineering methods for removing CO2 from the atmosphere and cooling the Earth by reflecting or blocking solar radiation. These do not mean that a tipping point was not passed. In the analogy shown in the cartoon above, one can push the rock back up the hill even after it has rolled to the bottom.

Have we passed the tipping point?

Observed advances in multiple tipping mechanisms certainly raise the question whether the tipping point has been passed. However, these mechanisms are accounted for to at least some degree in climate models, so interpreting that we have passed the tipping point requires that the models understate warming effects.



Source: NASA Earth Observatory

This is essentially an issue of the sensitivity of climate, that is, how much warming results from a given greenhouse gas concentration. The IPCC's analysis concludes the likely range of equilibrium sensitivity for doubling of CO_2 is 1.5 degrees to 4.5 degrees. As the graph below shows, there is reasonable probability that it could be substantially higher.

If the actual value of sensitivity falls in these higher ranges, warming will be greater than predicted by the IPCC models and a tipping point or points may have been exceeded. I'm not sure that anyone actually knows the answer, which leaves me with the unsatisfactory conclusion of not having answered the question I have raised.

Regardless of whether we have passed the tipping point, continued warming, rainfall pattern changes, significant sea level rise and continued northward and vertical migration of plant and animal species in the Northern Hemisphere seem certain. We are looking at a changed world and must adapt to it.

Not an excuse for inaction

One should not view the possibility that we have passed a significant tipping point as a reason for inaction. Although I remain somewhat skeptical of the degree of human contribution to climate change, it is prudent to take reasonable actions that may reduce the problem. In addition, there are multiple possible tipping points with different thresholds. Exceeding one does not mean you cannot avoid another. ■

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INTERNATIONAL POLITICS IS ALWAYS A RISK FOR OIL COMPANIES, BUT BUSINESS CONDITIONS MAY MATTER MORE

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The field of political risk assessment has been in existence for roughly 40 years, and I was a practitioner in the international oil and gas industry for 30 of those, from 1983 to 2013. When I told someone that I was a political risk analyst, the next question was usually "Do you travel?" (not as much as one might expect); and then, "How many countries do you cover?" (90).

Once the preliminaries were over, the conversations usually turned to the risks themselves – all the "shoot 'em up" stuff folks might come up with if they think about political risks – war, civil unrest, political violence, regime instability and the like. It always came as a surprise, though, when I noted that while international oil companies care about such risks – because they can mess up operations in a big way and the mitigation takes time and money – they're not the oil companies' primary concern.

International oil companies are more interested in what might be called commercial risks – opposition to foreign investment, repatriation difficulties and adverse contract changes.

Last year was a busy one for contract changes – 40 countries changed contract terms in 2016, and predictions are that 2017 will be just as busy. That has implications that go beyond a company's bottom line, potentially even affecting the price of oil.

Opposition to foreign investment can range from a country being completely closed off to foreign oil exploration to protests by environmentalists or indigenous peoples. Oil companies will simply look elsewhere if they can't get in or if working in a country is too big a hassle. Repatriation of oil earnings can be a problem, too, but it is more an irritant than anything else, since the regulations are either stipulated in the contract or set forth in standing law.

Contract changes – especially adverse contract changes – are a different story. Oil companies expect the contracts they sign to hold, but that's not always the case. There are three kinds of adverse contract changes – nationalizations, expropriations, and simple, unilateral changes by the government to existing contracts. The first two aren't contract changes in the usual sense of the word, although tearing up an existing contract surely is a "change." Nationalizations occur when a government takes over a complete industry; in the oil patch, that typically means establishing a national oil company to run things. Expropriations occur when a country unilaterally seizes control, through extra-legal means, of a project or facility. Both are "oil weapons" in a country's arsenal that can be used to exert power, gain influence and implement foreign policy

There have been several nationalizations over the years – the Soviet Union in 1918, Mexico in 1938, Iran in 1951 and Argentina, Egypt, Indonesia, Iraq and Peru in the 1960s. And while most analysts believed that nationalizations were long gone and a thing of the past, Bolivia nationalized the country's natural gas sector in 2006.

Expropriations are more frequent. For example, Russia took a 50 percent + one stake in Shell's Sakhalin Island project in late 2006. In May 2007, a subsidiary of Venezuela's national oil company, PDVSA, assumed control of the Cerro Negro heavy oil project following a decree issued by then-President Hugo Chavez.

Simple contract changes happen all the time. There are two kinds (and this isn't rocket science): contract changes that are anticipated or known that pertain to new projects and those that are not – contract changes that may come out of the blue and affect existing projects. Wood Mackenzie, a United Kingdom-based oil and gas consulting firm, classifies contract changes as "evolutionary changes" (changes for new projects) and "disruptive changes" (contract changes for existing projects).

Oil companies can generally deal with contract changes that are evolutionary. They simply decide to invest in given country under the terms of the new contract or not.

Disruptive changes can be more problematic in that they can, and frequently do, result in a negative change in cash flow from a given exploration project. However, some disruptive contractual or legislative changes can be positive – i.e. designed to spur exploration activity and investment, such as recent cuts in corporate income tax rates in several countries around the world.

Things have been quite fluid lately, as some 40 countries changed contract terms in 2016. The changes were mostly in response to low oil prices and the subsequent budget shortfalls in oil-dependent countries, which resulted in higher tax rates for foreign oil companies. However, some countries, like the United Kingdom, lowered taxes to help oil companies break even in the low crude oil price environment.

Mexico was the most active country. The United States' neighbor to the south changed contract terms five times, as it ended more than 70 years of government control of the oil sector. Other contract changes occurred in Russia (which seems to make contract changes constantly), the state of Rio de Janeiro in Brazil and Alaska in the U.S. This year looks to be just as busy as 2106, maybe even busier, as Wood Mackenzie anticipates evolutionary contract changes in Brazil, India, Indonesia, Iran, Mexico, South Africa, Thailand and Trinidad and Tobago; and disruptive changes in Australia, Alaska, Nigeria, Russia and parts of the North Sea. Some of the changes are expected to be positive, others negative, and some are likely to be mixed.

So why does all this matter? Who cares what kind of contract is in effect in a given country or if contract is evolutionary or disruptive or whatever? There are several reasons. At the simplest level, it's about money. Dealing with an unstable investment climate takes time and trouble, and time is money. Anything that costs major oil companies money has an effect at the pump. Changes in contracts – especially something like a nationalization or a major expropriation – can roil oil markets and drive crude prices through the roof. They can shut a country off from foreign investment altogether.

Further, a host country's petroleum legislation, and the contracts that flow from it, is instructive, for it says something about how a country views its position in the international oil arena and what it hopes to gain from its oil sector. Is the country trying to maximize its oil earnings by establishing higher tax and royalty rates or is it trying to induce new investment by cutting taxes and royalties or sweetening the pot in other ways? Also, frequent contract changes, especially if they are adverse changes, are an indicator of how a country does business, how it views foreign investment, and perhaps most importantly, how it views the sanctity of law.

Finally, it's worth reiterating: international oil companies are far more worried about getting into a country, getting the company's money out of the country and being able to work under the auspices of a stable, signed contract through the life of the project than they are about the political risks in the country. And since contract changes – especially adverse or "disruptive" ones – usually occur unexpectedly, an effort to develop a method perhaps capable of anticipating such changes would seem in order.

That could be a good topic for another blog post down the road. ■

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100% RENEWABLES BY 2050 –GERMANY PAYS THE PRICE FOR ITS AMBITION

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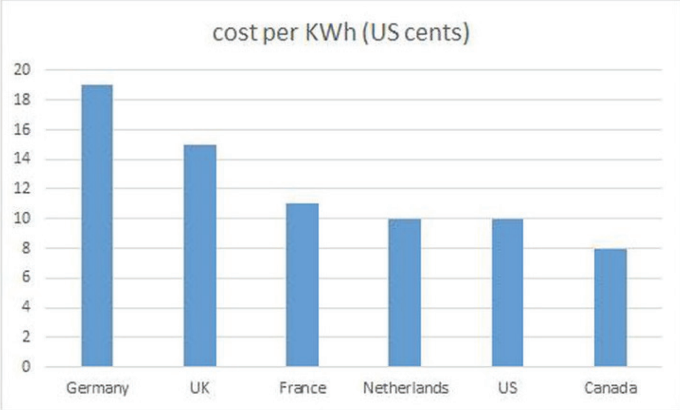
Germany has set the most ambitious agenda for renewable energy. According to Germany's *Enegiewende* program, the share of renewables in electricity generation should reach 45 percent by 2030 and 100% by half century. Complicating matters is Germany's *Atomstop* decision to close down its nuclear power plants under pressure from the powerful Green movement. The *Atomstop* agreement calls for substantial payments by electrical utilities into a special fund for storing nuclear waste.

Germany's mechanism for achieving its ambitious renewable-energy goals is not direct subsidies but the requirement that its utilities must take wind and solar energy first into the power grid.

With wind and solar energy costing multiples more than conventional energy, their increasing share will continue to raise Germany's wholesale electricity prices above those in other countries with less ambitious renewable energy policies. (See Figure for 2016 price comparisons).



Germany's increasing reliance on renewables has imposed direct and indirect costs on its citizens and companies.

First, Germany's fabled manufacturing sector cannot afford much higher energy costs than its rivals. Hence, Germany offers substantial discounts to heavy energy users, such as its automobile plants. As a consequence Germany faces lawsuits from the European Union that charge it with illegal subsidies of heavy industry. Second, German households must bear the financial burden of paying among the highest electricity costs in the world as utilities pass the higher costs of renewables on to them. Third, Germany's landscape is being ruined by unsightly wind turbines that spoil pastoral landscapes in virtually every community. Fourth, the supply of renewables varies dramatically in the course of a day or week.

This intermittency requires conventional backup sources, making coal the major source of electricity generation, but coal power is expensive because coal plants are fired up and down depending on the supply of renewables.

Germany's two major electricity companies, E.ON and RWE, have announced stunning losses. For E.ON, these will be the highest losses in its history. Both companies are cutting employment. RWE has cut its dividend entirely, and EON has slashed its dividend more than half. Part of E.ON's loss is due to a $10 billion payment into the nuclear energy waste storage fund.

The financial losses by Germany's two energy giants raise fundamental questions about who will pay for the country's ambitious renewable energy program. To date, German households and small businesses have borne the burden in the form of high electricity prices. Now the shareholders of E.ON and RWE are being asked to step up. If they continue to face losses and cut dividends, they will not be able to attract the capital necessary for Germany's electricity grid to survive. At that point, Germany's tax payers will be invited to the payments window to keep companies like E.ON and RWE in business.

Germany's electricity market, with its super ambitious goals for renewables, again illustrates Hayek's point that the road to serfdom is paved with good intentions. ■

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DESPITE CLAIMS OF 'GRID PARITY,' WIND AND SOLAR ARE STILL MORE EXPENSIVE THAN FOSSIL FUELS

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There has recently been a rash of articles saying that wind and solar have reached grid parity, that is, the cost of electricity generated with them is as cheap as (or cheaper than) electricity purchased from the electrical grid. That can be misleading because there are a number of definitions of grid parity.

It sounds counterintuitive but even when renewables reach grid parity, they are not necessarily cheaper than fossil fuels. Wind and solar, particularly rooftop solar, remain more expensive than fossil fuels in most locations despite the fact that they have reached grid parity in some areas.

The idea that wind and solar are currently cost- competitive with fossil fuels is largely a myth.

Generation costs defined

Discussions of grid parity commonly use one of these four definitions:

1. The subsidized retail cost: The lifecycle cost of generation, including tax benefits, credits and subsidies. This is the most meaningful cost for an individual or business considering an investment. Sources favorable by this measure will typically not be the cheapest method of generating the electricity but will be financially attractive due to the subsidies.

2. The unsubsidized cost at the plant: The lifecycle cost of generation, excluding tax benefits, credits and subsidies. This is the cost estimated by the so-called levelized cost of energy (LCOE). Levelized cost estimates are approximations, however, they identify the cheapest generation method based on actual out-of-pocket cost at the source. This is not necessarily the cheapest delivered cost.

3. The unsubsidized retail cost: The lifecycle cost of generation, excluding credits and subsidies. Sources reaching unsubsidized retail parity may not be the cheapest method of generating the electricity.

4. The all-in wholesale cost: The levelized cost, including cost of storage, grid modifications, backup generation and other measures necessary to deal with intermittency. As I discussed in an earlier post, these costs can be considerable as the share of variable renewable energy increases. This is the most meaningful cost to the utility, however, it can be difficult to estimate because of the variety of options.

Generation cost in the popular press

The two most widely quoted LCOEs for the United States are those of the U.S. Energy Information Administration (EIA) and the investment firm Lazard. Both exclude intermittency costs and the imputed cost of environmental damage.

A large number of assumptions underlie any cost estimate. Significant differences between EIA and Lazard include that Lazard's estimates are based on the "current state" of technology, whereas the EIA's estimates are presented for several future dates, and while both present nationwide and regional averages, Lazard's utility scale solar costs are for a favorable location, such as the Southwest U. S.

EIA and Lazard levelized costs are sometimes used as the basis for statements that wind and solar are or are not at grid parity. These averages are essentially meaningless for determining parity because there is so much local variation in both generation cost and electricity prices.

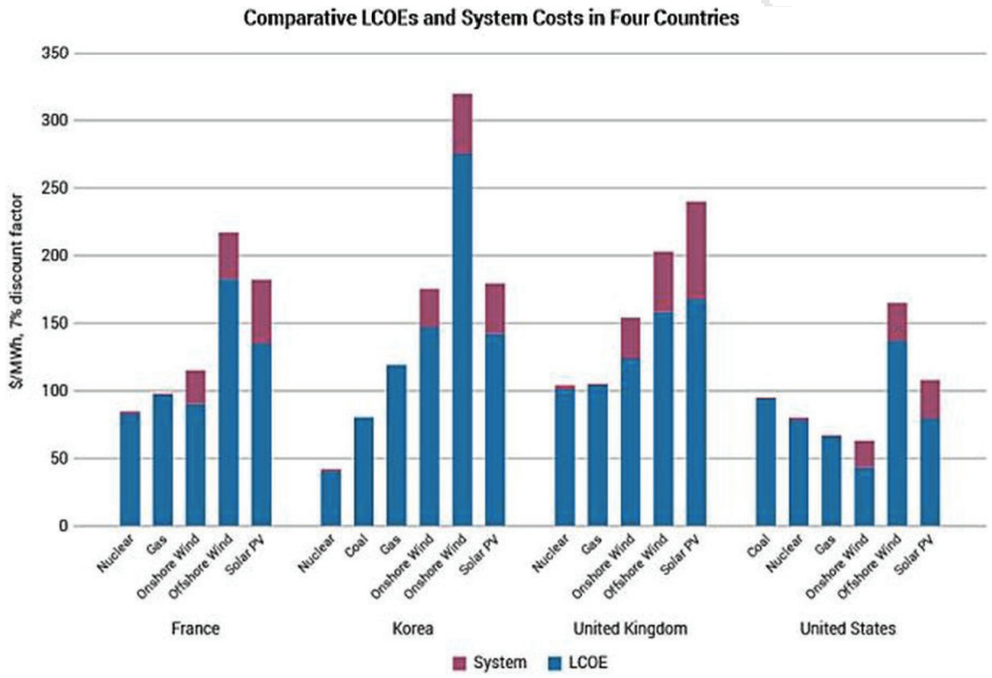
Cost variation illustrated

The chart below shows estimated costs for four countries. A carbon tax of $30/metric ton and estimated system costs at a 30% share of renewables are included.

The ranking is consistent with the EIA and Lazard estimates, that is, offshore wind and solar photovoltaic (PV) are expensive; onshore wind and natural gas are relatively cheap. One might wonder why we choose to subsidize solar PV heavily when it is one of the most expensive sources.

Although these figures include more than a 2:1 difference between countries in offshore wind and solar photovoltaics, they do not begin to reflect enormous variation in cost based on location and different assumptions. These differences are discussed at length in the Organisation for Economic Cooperation and Development report Projected Costs of Generating Electricity.

The debate over the cost of electricity is extensive. No figures quoted here will satisfy everyone.



Source: World Nuclear Association

Grid parity is not enough

Surveys have shown that the public is most likely to install renewable energy sources when they can save money by doing so. This requires a cost not only equal to, but lower than, grid prices. Unless there is a significant cost margin, adoption rates are low.

There has been an expectation that when renewables reach grid parity, their growth rate will increase substantially. In practice, this has not happened, and the rapid growth rate has been due primarily to subsidies and mandates. This is no secret.

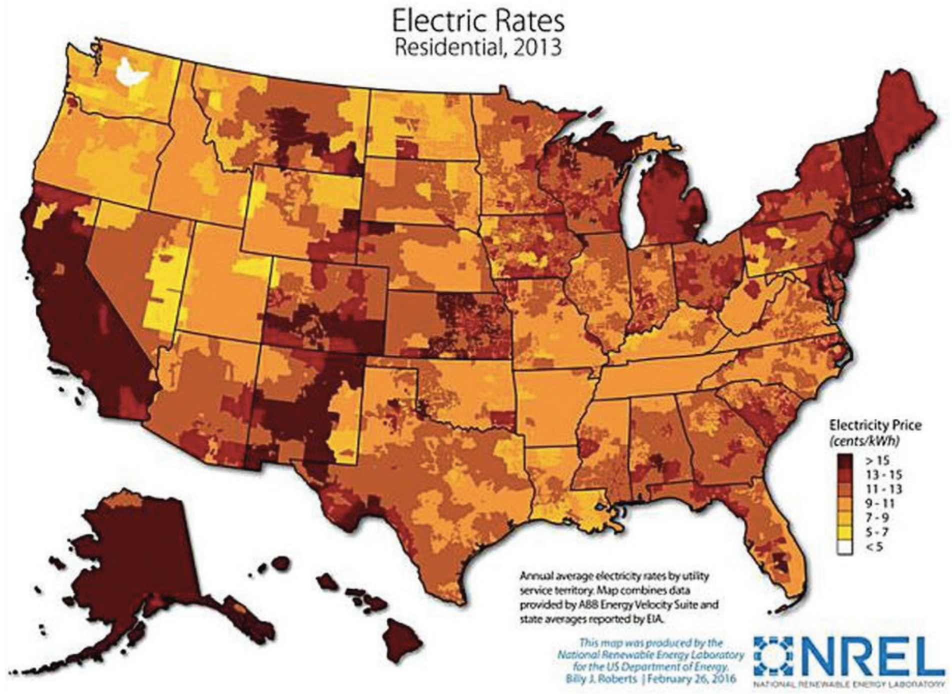
The effect of subsidies

The map below shows U.S. residential electricity rates as of 2013. There is more than a 3:1 difference, with the highest rates primarily in California, Alaska, Hawaii, New England and portions of the Rocky Mountain states and the Midwest.

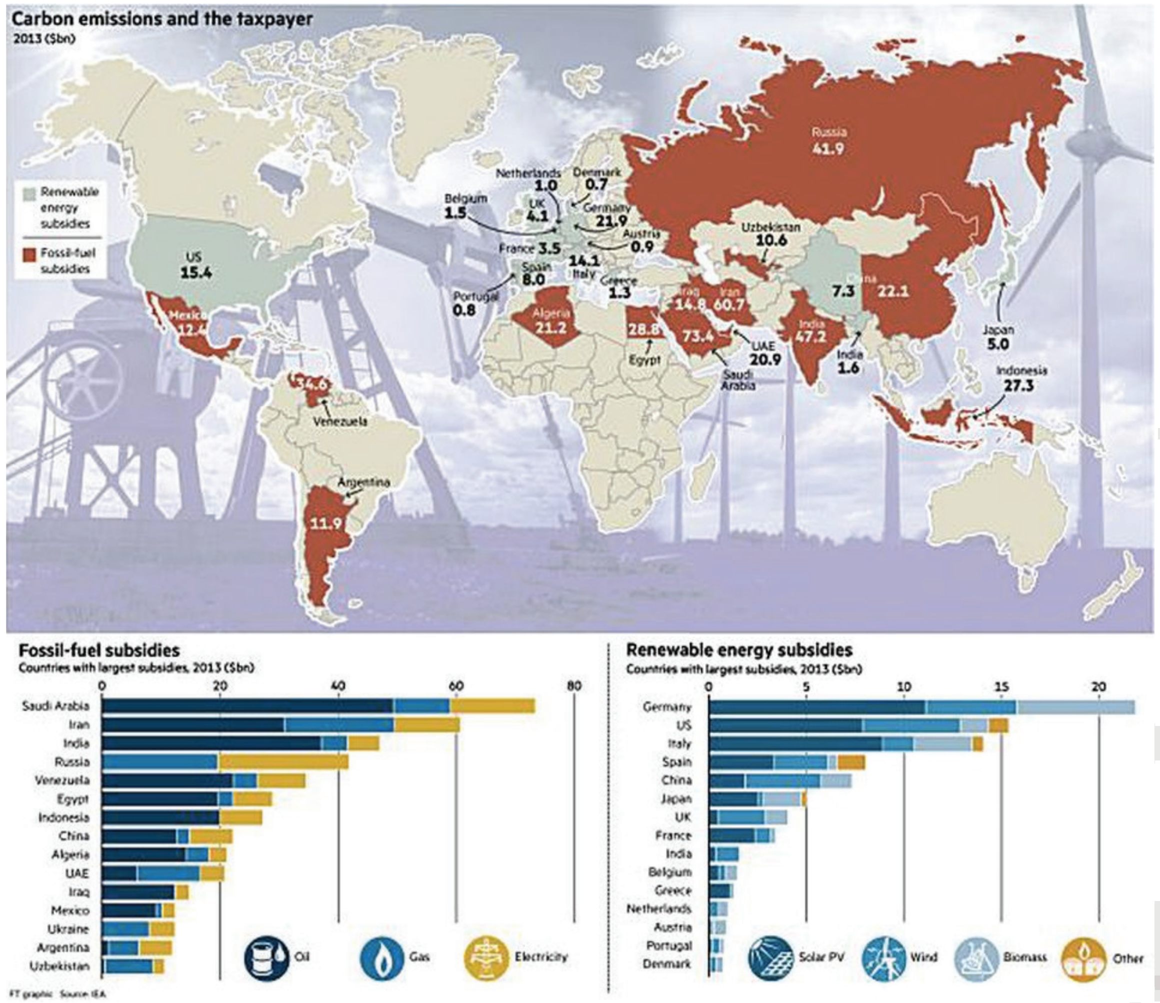
All other things being equal, grid parity will be reached earlier in high-cost areas. All things are not equal since costs also vary locally. The U.S. Southwest and Hawaii are particularly favorable for solar, so grid parity is more easily reached there. Even so, the growth rate of solar installations dropped considerably when subsidies were reduced. The same is true of wind.

The significance of economics is illustrated by a 2016 GreenTech Media report that concluded 20 U.S. states are already at grid parity. This finding included subsidies. However, the report also found that only two states would be at grid parity if a $50 monthly charge is applied.

The relative extent of energy subsidies is shown in the image on the next page. Renewable energy is most heavily subsidized in the industrialized countries.



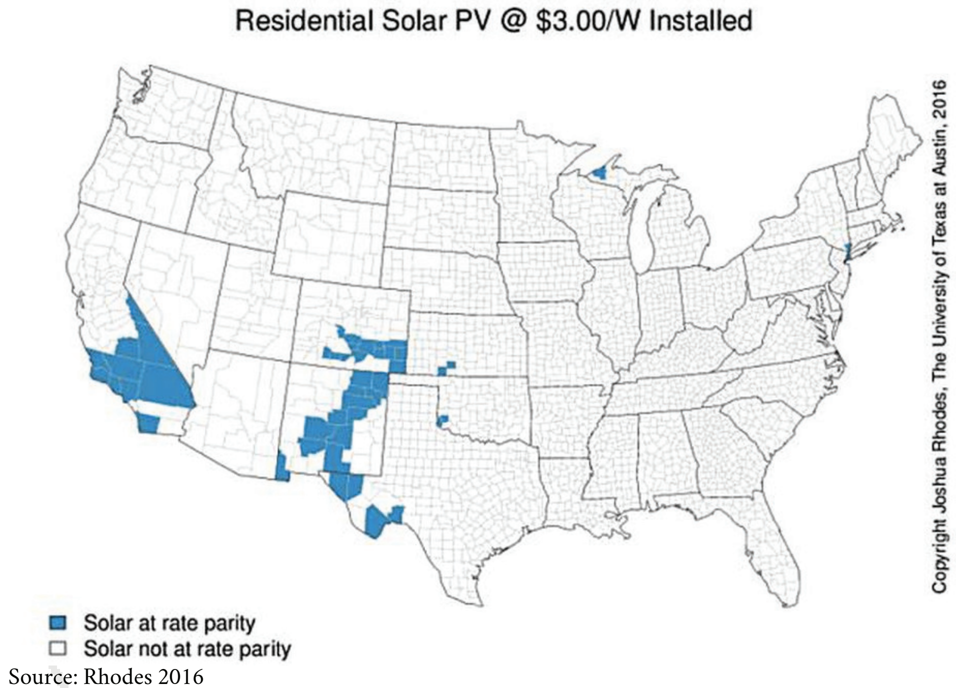
Source: National Renewable Energy Laboratory



Source: Financial Times

Where are wind and solar at grid parity?

Unsubsidized wind and utility scale solar are competitive in some local areas where electricity costs are high. Rooftop solar is not cost competitive anywhere. Even with subsidy, it is at grid parity only in the few areas shown below. Utility scale solar, at roughly half of rooftop cost, is more attractive.



Source: Rhodes 2016

Wind power has grown rapidly in Texas and the Midwest, even though electricity is generally cheap there. This is due to subsidies making this development highly profitable. Warren Buffett has said "… we get a tax credit if we build a lot of wind farms. That's the only reason to build them. They don't make sense without the tax credit."

What we're willing to pay for wind and solar

There is a curious dichotomy in acceptance of renewable energy. Numerous surveys show that individuals installing rooftop solar are overwhelmingly motivated by cost savings, with environment as a secondary consideration, yet a 2016 Pew poll shows over 80% of Americans favor expanding wind and solar.

Why are individuals unwilling to pay an equal or slightly higher amount for solar installed at home but willing to have government mandate that utilities build more expensive renewables? Perhaps it's because they don't think it will cost much. A 2015 University of Michigan poll showed support for state renewable energy mandates dropped at relatively modest costs: 58% supported the standard at an annual cost of $25; 45% supported at an annual cost of $50. A $2 per month added cost resulted in a 13% decrease in support.

Attempting to determine the average cost of renewable energy subsidies puts one in a thicket of federal, state and local incentives. The Production Tax Credit alone adds about two cents per kilowatt-hour to wind and solar costs (about 1/6 of average U.S. retail cost). Like many subsidies and credits, the consumer does not see this on his or her electric bill; it is paid out of general revenue. A 2014 California Energy Commission report showed solar is 10% to 50% higher than natural gas, even after tax benefits.

Wind and solar costs will continue to drop, but rooftop solar will still be more expensive. It seems to me that we should be encouraging wind and utility scale solar more and rooftop solar less. ■

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ENERGY POLICY UNDER THE TRUMP ADMINISTRATION: UNCERTAINTY, OPPORTUNITY AND RISK

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RAMANAN KRISHNAMOORTI
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A little over two months since the inauguration, the Trump administration has begun to issue executive orders, make appointments and reveal positions on tax and trade issues, and the energy industry is reading the tea leaves. A gathering late last month offered a look at what people are thinking.

Some of it might surprise you, including the reactions from industry to dropping environmental regulations.

The workshop, hosted by the Gutierrez Energy Management Institute, part of the Bauer College of Business at the University of Houston, operated under the Chatham House rule of no attribution to individuals or their employers. That encouraged an open discussion among participants from the major sectors of the energy business (upstream, midstream, downstream and power).

The findings:

A series of sector panels set the context for discussions.

• An upstream panel expected lower global economic growth, along with success in the oil and gas tight formations, would lead to a challenging "lower for longer" oil price outlook. There is a need for a set of stable rules to enable long-term energy planning.

The decision to dismantle environmental regulations tends to stir up grassroots activism without significant benefit in terms of returns for the oil and gas industry, as compliance from the previous administration has already been engineered into systems and work flow. Dealing with activism at the local and state levels is often more challenging than dealing with regulations at the federal level.

• New midstream infrastructure is sorely needed but faces substantial permitting obstacles and opposition by non-governmental organizations. Water act permits and air permits are administered by the states using state procedures; the process is now slower than when under federal control and can take years, as in New York. The ability to produce hydrocarbons here in the U.S. and move the product to international markets can change geopolitics in Europe and Russia. There is also a good reason why the secretary of state is advising the current administration not to pull out of the Paris agreement – since exiting will diminish the leadership role of U.S. in the global economy.

• Refiners expect declining domestic demand for transportation fuels but see opportunities to successfully compete internationally through exports, as do LNG developers. The Environmental Protection Agency's loosening restrictions on environmental policies does not necessarily improve the bottom-line of the industry. The facilities are already compliant with industry standard best practices, which often are above and beyond federal regulations. The big issue is how the U.S. interacts with other countries, since the industry is part of a global supply chain. There is a valid concern that buyers in Latin America might buy their products elsewhere. There is not a lot of upside with current administration policies. The concerns are how large the downside will be.

• In the power sector, the rise of natural gas and decline of coal is probably unstoppable; consumer demand for distributed and clean energy will continue to be a strong driver with costs reducing and sustainability agendas here to stay. Although power demand has been flat, power companies have benefited from growth opportunities in utility scale renewable projects, new transmission lines and natural gas combined cycle plants competing with coal and providing back-up power to supplement intermittent solar and wind based supplies.

•An environmental panel noted that public concerns over global warming related to fossil fuels remain strong: there is large potential for biochemical carbon sequestration through planting trees and marsh and prairie grasses that grow massive root structures, to complement advances in energy efficiency and zero carbon nuclear and renewable energy in reducing atmospheric CO_2.

In break-out sessions, workshop participants recognized the new administration is friendlier to the energy business than its predecessor, though energy policy seems a lower priority than health care, tax reform and immigration. Nevertheless, it was a refreshing change from the previous hostility to hydrocarbon fuels.

There was concern that President Trump "risks doing exactly what President Obama did: leaving no long-term impact because of the unilateral executive branch decision-making that only has meaning while the incumbent is in office." The roll-back of prior environmental orders through contrary executive orders amplifies divisiveness and makes productive legislation more difficult and long-term corporate planning for capital investments even more difficult.

Participants were encouraged by administration support for energy infrastructure investments manifested by approval of the Keystone XL and Dakota Access pipelines and by the promise of better access and more streamlined permitting for federal lands. But forcing the use of U.S. steel would cause project delays, increase costs, raise tariffs and reduce U.S. energy competitiveness.

Furthermore, there was grave concern on the apparent incoherence of rhetoric on trade and tax reform with the nascent energy policy. All energy sectors depend on free access to export markets: upstream companies export light crude oil and natural gas; refiners and petrochemical companies leverage abundant and relatively inexpensive indigenous feedstocks into comparative advantage over international competitors; power companies benefit from enhanced infrastructure to optimize fuels supplies. Restrictions on trade and disputes over NAFTA would harm the whole industry, since Mexico and Canada are vital oil and gas trade partners for the U.S. Proposed tax reform would have implications for energy sectors that are difficult to predict.

A shift in regulatory focus from federal to state level gives energy companies the opportunity to strengthen their ability to cooperatively help develop smart regulation in receptive jurisdictions. On the other hand, major projects must pass through the National Environmental Policy Act (NEPA) process, parts of which are administrated by the states. Less receptive jurisdictions may slow-walk the process to indefinitely delay approval, and protests may delay project execution. The current administration is sending signals that the states will have more control over our industry. This will mean there will be little to no federal oversight to prevent states from acting against the best interests of the U.S. as a whole.

There was an overall concern that the downside risks of the current apparent energy and trade policy pathway were high, while the benefits of an administration more favorable to energy development may be slow and difficult to deliver. There is a high level of uncertainty on whether and over what time frame good intentions will be translated into clear, stable and productive rules and concern that they might induce “Black Swan” surprises:

- •Very high levels of uncertainty about the direction and implications of both tax and trade policy, with the potential for contentious winner/loser outcomes and currency disruption;

- •Unfortunate behaviors of a few companies with respect to environmental incidents or inadequate consultation with communities might risk heightened environmental activism aimed at withdrawing the industry’s license to operate, and amplify legal challenges to administration actions;

- •Serious risks to global economic growth and therefore energy demand if trade disputes cause slower economic growth.

These unknown uncertainties related to emerging energy, tax and trade policies compound existing known uncertainties over instability in the Middle East and the risks of supply shortages that might again align environmental with energy security concerns and reignite the shift away from hydrocarbon fuels. This will add to decision-making challenges for companies’ governing boards.

The energy industry is accustomed to taking the long view, in which fundamentals are more important than political cycle policy changes. Energy companies are not likely to dial back their own operating standards in safety or environmental performance. That’s true even if regulation is less restrictive – reputational risk and sustainability will remain clear priorities. However, all sectors of the industry should combine to make the case for expanded energy infrastructure that will allow the right energy form to get to the right customer at the right time and further enhance the US international comparative advantage in secure, affordable, reliable and clean energy. “The industry needs to be proud instead of being defensive and crouching.”

Lastly, it was agreed that the energy industry cannot “stand behind” the new administration waiting on industry favorable actions at the federal level; our industry must strengthen its capabilities to engage respectfully with local, state and federal agencies, local landowners, communities and other stakeholders.■

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100% RENEWABLE ENERGY? HERE’S WHY IT’S NOT HAPPENING ANYTIME SOON

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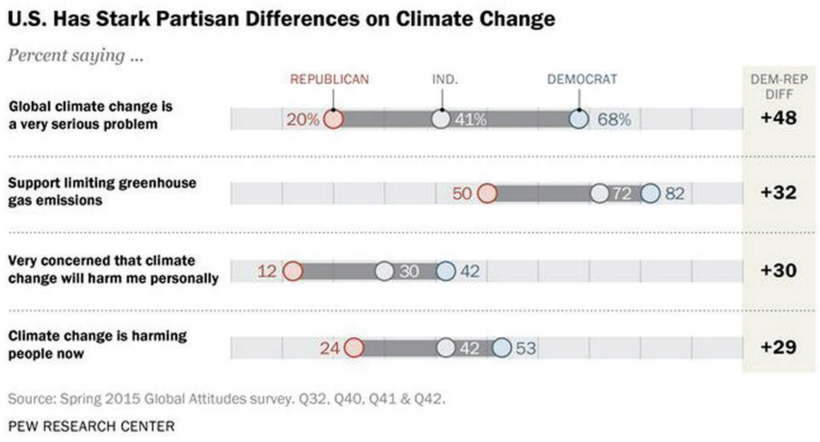
In an earlier post (*The Shift To Renewables: How Far, How Fast?, Page 59*), I established that, with massive effort, it would be possible to generate all electricity and a substantial fraction of transportation energy with renewable fuels. The pace of conversion is said to depend upon political will.

“Will” is not the correct term. Will implies both desire and determination. A substantial fraction of the public do not have the desire. Some do not think it is necessary, some do not want to sacrifice conveniences, some are not willing or able to pay. On one hand, there is a highly vocal contingent that believes anthropogenic climate change is literally a life or death issue; on the other hand, there are groups that do not see it as a major problem or have a vested interest in the existing energy structure. It is difficult to predict the relative influence these two radically different viewpoints will have on how quickly it will happen.

Public Support

The Gallup Poll results for the past several years show that only about 40% of Americans believe global warming will be a serious threat to them personally. A 2015 Pew poll indicates higher concern internationally, with 54% saying that climate change is a very serious problem and 78% saying greenhouse gases should be limited.

There is a strong component of political orientation in support for carbon reduction measures, both in the U.S. and internationally. In the Pew poll, Democrats score approximately 2 to 3 times higher on questions of climate change concern. The pace of carbon reduction will be significantly influenced by which party is in power.



U.S. Has Stark Partisan Differences on Climate Change, Spring 2015 Global Attitudes Survey

Expression of concern says nothing directly about willingness to spend on carbon reduction or change lifestyle. For example, the average size of American houses continues to increase. Three-fourths of Americans drive to work alone, and electric and plug-in hybrid cars are currently less than 1% of U.S. auto and light truck sales. The strong correlation between subsidies and renewable energy spending indicates the pocketbook is more important than the environment.

The majority of people just don't put their money where their mouth is.

What will happen?

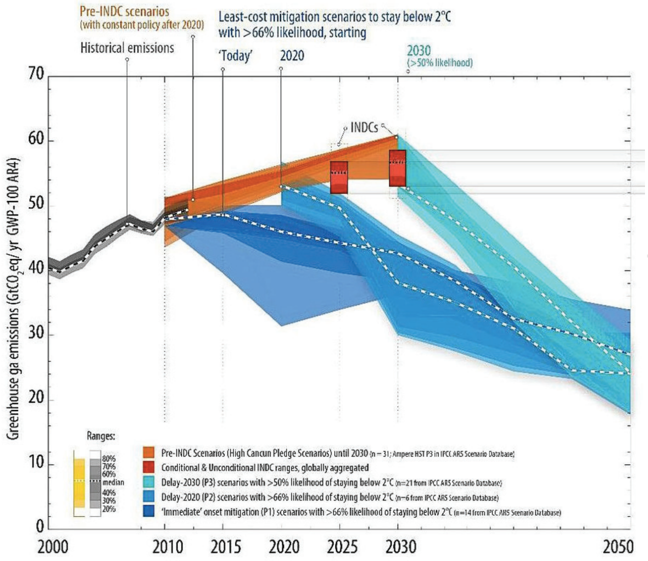
It's hardly earthshaking to predict the outcome will fall between predicted extremes. A couple of observations can be safely made:

1.It will happen faster than supporters of traditional energy sources think. There is already considerable support at the government level and the decreasing cost of renewables will favor their use.

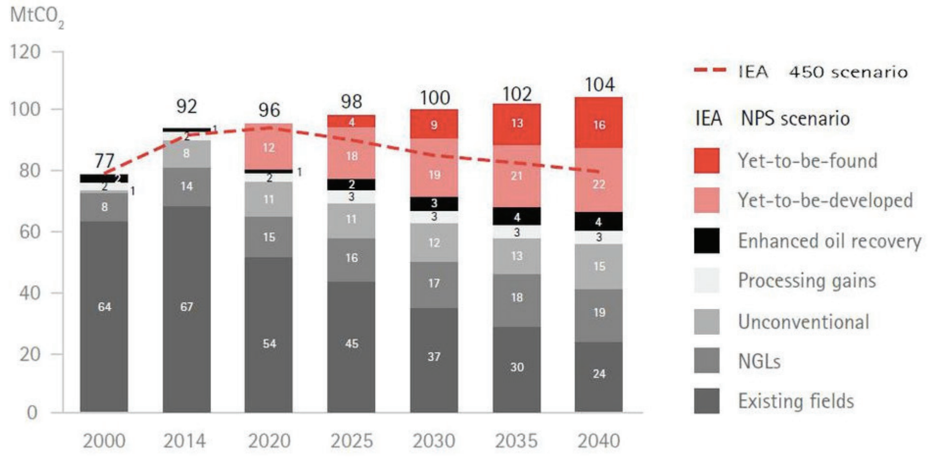
2. It won't happen as fast as the proponents of 100% renewables predict. The rapid growth of solar and wind power is largely due to projects supported by other people's money. As cumulative cost increases, there will be resistance by those paying the freight. This is already happening. The technical and economic barriers that begin to become important with a higher share of renewables will slow implementation further.

Perhaps the best indicators of the pace in the near term are the pledges made in the Paris Agreement. While the agreement is hailed as a milestone, it is generally recognized that the INDCs (Intended Nationally Determined Contributions), if implemented, will not decrease CO2 emissions, will not keep global warming below 2 degrees C, and will not mean the end of fossil fuels. CO2 equivalent emissions rates expected to be attained through the agreement are indicated by the red bars in this graph from the United Nations Framework Convention on Climate Change. Emissions increase throughout the commitment period and end well above the historical levels shown in dark gray.

Note also that limiting warming to 2 degrees C requires the sharp decrease, shown in aqua, immediately after the end of the commitment period. This pattern is the same as has been the case since the first Intergovernmental Panel on Climate Change report in 1990: Each report says we have to start reducing greenhouse gas emissions immediately. Although estimated CO2 emissions have recently flattened, measured greenhouse gas concentrations not only have not decreased, they have continued to increase at an accelerating rate. The discrepancy may be due to errors in the estimate or reporting of fossil fuel consumption from the various countries but, in any case, there is no indication in the measurements that emissions have actually decreased.



Greenhouse Gas Emissions, 2000-2050



Source: IEA, "World Energy Outlook 2015"; Accenture Strategy, Energy analysis

Accenture Strategy, Energy Analysis; IEA "World Energy Outlook 2015"

The effect of the Paris Agreement on fossil fuel consumption is illustrated by this graph of oil consumption in the IEA New Policies Scenario, which incorporates the INDCs. The growth rate through 2040 is about 0.5% annually, about one third of historical but still increasing. Natural gas (not shown) grows at 3%.

Even the IEA 450 scenario, consistent with a 2 degree target, leaves oil consumption in 2040 above that in 2000. Natural gas grows at close to 1%.

Barring a drastic change in policy, we will not get anywhere near 100 % renewables by 2050. Low carbon energy sources will likely be less than 40% of total energy supply; the "new renewables," wind, water, and solar, will be less than 15%. This is not a happy scenario for those who worry about anthropogenic climate change. Several analyses of the impact of the INDCs forecast global warming in the range of 2.7 degrees to 3.5 degrees by 2100. Since the commitment period ends in 2030, such analyses require assumptions of actions beyond that date.

Of course, other predictions are possible. Expectations of faster replacement of fossil fuels rely upon more optimistic assumptions of adoption of government policies, speed of implementation, reduction in energy demand, and the availability of funding. Other conditions – not strictly necessary, but probably realistically needed – are continued significant reductions in the cost of renewables and improvements in energy storage methods and carbon capture and storage.

The public has not shown much willingness to sacrifice, unless it's someone else making the sacrifice. I don't have a crystal ball but getting even as high as 50% renewables by 2050 seems highly unlikely to me. ■

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INDEPENDENT ENERGY E&PS: IT'S A NEW GAME, BUT NOT EVERYONE PLAYS THE SAME WAY

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Independent oil and gas exploration and production companies have enjoyed or endured a roller-coaster ride over the past 15 years as oil prices increased strongly from 2001 to 2008, recovered from the sudden drop of the financial crisis to find a new plateau through 2013, and then collapsed in 2014-15.

Total Shareholder Returns (TSR) generally followed oil prices, but some companies provided much higher returns than others. In general, when oil prices were strong, companies delivered shareholder value by delivering high growth in production. More recently with weaker prices, the strongest driver of shareholder value has been high returns on assets, and most companies are adopting a more conservative game plan. But some are not, and they may be changing the rules of the game, as well as the ultimate outcome.

Last spring, a group of my finance students studied the drivers of shareholder value for 13 independents over different time periods in an effort to understand why some had provided higher returns to shareholders than others. This course built on the findings of a 2013 course.

Overall, this analysis provides some interesting insights on the drivers of Total Shareholder Returns for the independents as the price cycle evolved (Table 1):

Table 1: Most significant TSR Drivers (R-Squared)

	2008-2013	2013-2015
Production CAGR	71.9%	3.0%
Capex/ Total Assets	60.6%	74.8%
EBITDA/ Total Assets	18.7%	76.4%
Beta	52.4%	5.0%

- 2001-08 Rising Oil Prices: Investors rewarded leaders who captured new plays at low entry costs and invested vigorously in expanding production, regardless of returns on capital.

- 2008-13 High Price Plateau: Investors continue to favor production growth fueled by high capital spending, with little concern for returns on investment, but became more discriminating: activists attacked companies with incoherent or low value portfolios while rewarding risk taking and growth by companies with greater strategic clarity.

- 2013-15 Price Collapse: Investors withdrew from companies without strategic clarity or with low value portfolios; returns on total assets became as important as reinvestment in future growth.

This should send a clear message to executive teams and boards of directors to rethink how they gauge performance, focusing on greater returns while reducing their emphasis on growing reserves and production.

But not everyone has taken that message. Some companies are, in fact, doing something quite different.

Most of the companies we studied appear to have received the message and have simplified their portfolios around a few core assets, increasing exposure to liquids-rich shales and reducing their exposure to international exploration and production. ConocoPhillips, Apache, Devon, Encana, Hess and Marathon are examples of companies that divested many international properties while strengthening their North American shale holdings through acquisitions. ConocoPhillips and Marathon spun off their downstream assets, and Hess sold its downstream businesses.

These companies are broadly embracing a value proposition that promises shareholders moderate rather than frenzied growth, with higher return on assets, a stronger balance sheet, increasing dividends as free cash flow grows and lower risks. The strategies designed to deliver on this comprise:

- Swap assets with rivals in certain basins to create scale economies, such as more efficient supply chains, longer laterals and reduced complexity.

- Plan capital investments that are comfortably within cash from operations to allow debt reduction.

- Be mindful of stakeholder demands: maximize safety and minimize emissions from drilling, gathering and processing to reduce local opposition.

- Focus on being among the lowest cost producers, prioritize assets with stacked plays and those with the most productive wells.

- Use big data analytics to identify the most prospective drilling locations and optimize fracking geometries to fit the rock properties.

- Increase intensive fracking techniques, using more horsepower to inject more fluids and more proppants to increase total hydrocarbons recovered from each well.

- Use pad drilling to drill and complete multiple wells from each location, reducing the visible footprint.

- Reduce well costs by safely drilling faster and optimizing supply chains across multiple service and supply contractors.

Companies with healthy balance sheets will continue investing in attractive acreage to increase options for future growth. We now have two strong illustrations of what that means in Apache Corporation's announcement of a major new discovery in a previously discounted area of West Texas and in EOG Resources' acquisition of Yates Petroleum. Both represent major strategic moves which were quickly applauded by investors as providing new options for profitable growth and significantly changing perceptions of the companies' intrinsic value.

Continental Resources, Pioneer Natural Resources and Newfield Exploration are similarly playing a different game, paying out no dividends and investing for production growth even in the current low price environment. They enjoy strong positions in the lowest cost Permian and Anadarko Basin plays, and may be rewarded if prices strengthen, as they will have built momentum while more conservative companies may be scrambling to mobilize equipment and crews.

The two contrasting strategies may reflect different views of the future oil market, a sense that the drivers of shareholder value may be due for another change, different break-even prices required to make a target return on investment from drilling their different resources, different executive reward systems, or different discount rates making future production more or less valuable compared to production today.

Companies with positions in the core of the SCOOP or STACK plays of the Anadarko Basin, or in the Bone Springs/Wolfcamp plays of the Delaware Basin of the Permian, may take a view similar to that of Saudi Arabia: that companies in the Eagle Ford and Bakken should cut back production, not them. But like the Saudis, they will by aggressive production growth provoke unexpected responses from rivals that cause oil prices to be lower than they may have assumed in their decision to invest.

This is a complex dilemma that could be informed by game theory analysis of the motivations, risk tolerance, strengths and weaknesses of the different participants in the game. At the very least, it will be a fascinating game to watch. ■

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IS FLARING JUST BAD FOR BUSINESS, OR IS IT A VIOLATION OF THE LANDOWNER'S CONTRACT?

BRET WELLS George Butler Research Professor of Law, UH Law Center

I have previously argued that the downturn in oil and gas development is the perfect time for the Texas Railroad Commission to change its regulations on flaring associated gas.

The current rules – known as Rule 32 – allow drillers to burn off natural gas produced along with more profitable crude oil if there isn't an immediately available pipeline or other marketing facility to take it. That's been generously interpreted, despite the fact that the gas could be captured and sold.

And while energy companies working in the Eagle Ford and other shale fields may find it more expedient to flare off that excess gas, landowners and other royalty owners may not be so quick to agree.

The landowner does not typically have a working interest in the oil, gas and other minerals that lie beneath their property; instead, mineral rights are typically transferred to an oil and gas operator through a lease. In return, the landowner typically reserves the right to be paid a royalty. Royalty clauses differ, but a typical clause would call for the landowner to be paid a royalty based on the amount of oil and gas that is produced and saved from the well, traditionally 1/8th of the gross production. At the peak of the last boom, that percentage rose to a higher fraction of the gross value of production.

If an operator flares commercially profitable associated gas, however, under the "expressed" terms of many leases, the landowner and other royalty owners would not be due any payment.

But there's another factor at play, too. Texas courts have ruled that oil and gas leases create implied obligations among the parties, an effort to enforce the intent of the parties who executed the lease. Under implied covenant law, the Texas courts require the operator to act in a reasonably prudent manner. Under this standard, the producer is required to consider not only its own financial interest but also that of the royalty owner. The producer is also required to act in a manner that prudently administers the mineral estate. If the operator fails to do any of that, it can be sued over the lost royalty that the landowner would have received had the mineral estate been operated in accordance with this reasonably prudent operator standard.

So, the legally relevant question is whether flaring commercially profitable natural gas in order to accelerate the production of crude oil violates this implied covenant standard.

Certainly the operator, which has a significant financial investment, may want to accelerate the timing of cash flow in order to recover its cost from its investment. But again, the reasonably prudent operator standard requires the operator to consider the financial interest of the royalty owner as well. The royalty owner has no cost investment and would likely want the operator to pursue a strategy that maximizes the amount of gross royalties paid on the associated gas over time. Flaring commercially profitable natural gas diminishes gross royalties. So, although a factual issue, a jury could well conclude that the reasonably prudent operator would have employed a strategy to minimize the flaring of commercially profitable natural gas.

If so, then an operator would be subject to a claim for damages for failing to live up to this standard, and the measure of damages would be the gross royalty that should have been paid on the imprudently flared gas. Determining a damage award would be provable because the operator is required to meter and file a monthly, public report to the Railroad Commission on the amount of natural gas that it flares.

Successful damage claims for lost royalties on flared natural gas would send a clear message to the industry that it must immediately adopt sound conservation practices in the Eagle Ford shale, including not flaring commercially valuable natural gas. In the end, sound public policy is promoted when private litigation and the Railroad Commission's own rules work together to motivate operators to conserve finite natural resources.

Providence, coupled with the ingenuity of the oil and gas industry, has blessed the state of Texas with another chance at a prolonged development of its natural resources in ways that were unimaginable less than 20 years ago. Now is the time to ensure the Eagle Ford shale is developed in accordance with sound conservation practices — flaring commercially valuable natural gas is not one of them. The benefits of private litigation and regulatory changes that discourage flaring are two-fold: helping to create positive public policy for the state of Texas and assuring that reasonable expectations agreed to in oil and gas leases are met. ■

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WHEN THE LARGEST OIL EXPORTER QUITS THE GAME

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"We have a case of oil addiction in the Kingdom of Saudi Arabia which is dangerous." So says Muhammad ibn Salman Al-Saud, deputy crown prince and minister of defense in his highly publicized April 25, 2015 interview with Al-Arabiyya. He continued, "We should treat oil as an investment, not a primary or absolute commodity."

This is precisely the impulse behind the "Saudi Vision 2030." The plan was crafted by Prince Muhammad – a young but shrewd visionary in his own right – and its aim is to wean the world's largest oil exporter of its 'dangerous addiction' by 2030.

The 15-year plan comes at a time of historic economic and political instability. Since June 2014 oil prices that typically had been over $100 per barrel fell to below $50 and have not recovered. Going from "hero to zero" cut over 350 thousand energy sector jobs in just one year – 120,000 jobs in the U.S. alone – and starved the Venezuelan economy, literally. Meanwhile much of the Middle East still suffers from war, popular demonstrations and renewed government crackdowns since the so-called "Arab Spring" of 2010/2011.

The Impact of Oil on MENA Societies

Studying the Saudi 2030 Oil Plan, its political context in the Middle East and North Africa (MENA) region, and the global energy market became part of my mission as a researcher and educator at the University of Houston. I piloted an interdisciplinary course last summer for UH Energy and the C.T. Bauer College of Business on "Oil, Religion and the Middle East."

In this course, students of engineering, political science and the humanities came together to discuss the impact of oil on MENA societies. We examined in detail:

•The "oil curse" and the phenomenon of the "rentier state"

•How the oil and gas sector shapes cultural and social norms

•Initiatives promoting transparency, corporate social responsibility (CSR) and environmental sustainability.

And what does religion have to do with oil in this region? Everything. Or as Prince Muhammad summarizes, "Our constitution has become scripture, tradition and oil!"

King Salman Al-Saud remains the "custodian of the two holy mosques." His Kingdom is simultaneously the most powerful member state of Organization of the Petroleum Exporting Countries (OPEC) as well as the Organization of Islamic Cooperation (OIC).

In other words, Saudi Arabia controls global oil as much as it does modern Islam. Therein lies the gravity of this economic plan.

Vision 2030: Growth, Diversification and Investment

Currently Saudi Arabia remains the largest global exporter of oil at about 360 million barrels per year; it is home to the largest proven oil reserves at almost 260-270 billion barrels (18 percent of global reserves). So how does the leader of the pack quit at the top of his game? Among the plan's details are three sweeping economic changes:

1. Selling 5 percent of government-run Saudi Aramco in the largest IPO in history

2. Reducing government subsidies and introducing taxes for the first time

3. Establishing a $2 trillion national investment fund

Valued at several trillion dollars Saudi Aramco remains the largest corporate entity in the world – state-run or otherwise. Aramco's precise value is a state secret, which is a problem for any investor. So the plan calls for increased transparency. The size and importance of the company mean the Saudis are unlikely to give up the strategic value of oil itself. They might instead turn over logistics or petrochemicals to the private sector.

For an investment deal this big there are skeptics as well as optimists – and justifiably so. In sum, a successful IPO is critical to the plan's execution … and its credibility.

Reducing government subsidies is a must. Since its founding almost a century ago the Saudi welfare state has given generous lifelong subsidies to its citizens. There are no taxes to speak of, and immigrant workers make up 30 percent of the general population. Government hand outs and foreign labor are part of Saudi culture. This might explain why the government has begun to tax immigrant workers but not Saudi citizens – a highly problematic start. How will imposing income, property or utility taxes affect the demographics of the kingdom? What ripple effects will this have on GDP, labor laws, political reform? Only time will tell.

When it comes to his investment, Prince Muhammad is on more solid ground. He claims the "Saudi mindset is a financial mindset" – and he is right. The Saudi central bank holds $117 Billion in US treasury bonds – surprisingly low given its sheer wealth. On the private sector front, the billionaire Al-Waleed ibn Talal, a member of the Al-Saud royal family, has bailed out everyone from CitiGroup to GOP presidential candidate Donald Trump. This is to say nothing of domestic Saudi investment in infrastructure, healthcare and retail – which are all state of the art. In this vein a $2 trillion investment fund may have a chance of diverting resources from oil towards realizing the prince's dream to make Saudi Arabia a "global investment powerhouse."

The plan also calls for diversifying Saudi Arabia's economy – currently 90 percent oil driven. What other industries can flourish in the desert? The plan aims to spur growth in natural gas, real estate, mining, tourism and other sectors. The plan also calls for creating jobs for both men and women, improving people's quality of life and – given the government's religious mandate – improving the country's morals while empowering its global Islamic prestige. Overall, the stated goals of Vision 2030 are ambitious bordering on inconceivable. But they are steps in the right direction.

Why Now?

For energy economists and historians – even the skeptics among them – the 2030 Saudi Oil Plan is long overdue. It represents a milestone in global energy and geopolitics: using oil wealth to divest from oil. It also comes in the wake of the Kyoto Protocol of 2005, Paris Agreement of 2015, China's "five year plan" to reduce air pollution and other concrete efforts by the world's largest economies to cut emissions in response to climate change. By framing the plan as a "vision" and underscoring large government projects, the Saudis are doing business the "Arab way." President Abdel Fattah El-Sisi's "New Suez Canal" has been the region's most recent marvel, although revenues have been too low to help Egypt's struggling economy. But the Saudis are thinking much bigger than the Egyptians anyway. It was Prince Muhammad ibn Rashid Al-Maktoum's 2004 economic development plan, "My Vision," that transformed Dubai into the opulent global city-state it is today. (The Saudis and Emiratis are also competing for who can build the tallest building in the world – an entirely different matter!).

Saudi Arabia is also fighting a number of foreign as well as domestic battles. Quarrels over succession within the Al-Saud family have persisted for years; Saudi women are increasingly active in their fight for equality and the nation's youth are increasingly marginalized and open to radical influences. The kingdom is mired in wars in both Yemen and Syria, draining a record $100 billion out of the Saudi economy between 2015 and 2016 alone.

In both wars its arch nemesis is Iran, with whom U.S. president Barack Obama has made a deal. To complicate matters further, today's record low oil prices are the result of economic warfare between Saudi crude and U.S. shale. In this context, Vision 2030 means the Saudis are desperately getting rid of a depreciating commodity – some analysts say bursting the "oil bubble" – and adjusting their economy for a future where oil may be overtaken by alternative fuel sources. That, however, is a subject for another day. ■

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FACT CHECKING THE CLAIM OF 97% CONSENSUS ON ANTHROPOGENIC CLIMATE CHANGE

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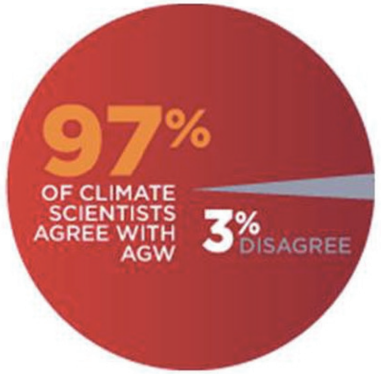
The claim that there is a 97% consensus among scientists that humans are the cause of global warming is widely made in climate change literature and by political figures. It has been heavily publicized, often in the form of pie charts, as illustrated by this figure from the Consensus Project.



Graph by The Consensus Project

The 97% figure has been disputed and vigorously defended, with emotional arguments and counterarguments published in a number of papers. Although the degree of consensus is only one of several arguments for anthropogenic climate change – the statements of professional societies and evidence presented in reports from the Intergovernmental Panel on Climate Change are others – there is data to suggest that support is lower. In this post, I attempt to determine whether the 97% consensus is fact or fiction.

The 97% number was popularized by two articles, the first by Naomi Oreskes, now Professor of Science History and Affiliated Professor of Earth and Planetary Sciences at Harvard University, and the second by a group of authors led by John Cook, the Climate Communication Fellow for the Global Change Institute at The University of Queensland. Both papers were based on analyses of earlier publications. Other analyses and surveys arrive at different, often lower, numbers depending in part on how support for the concept was defined and on the population surveyed.

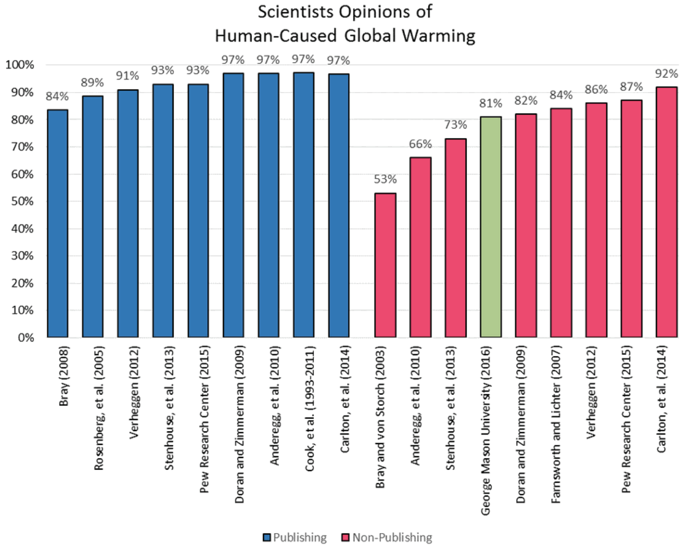
This public discussion was started by Oreskes' brief 2004 article, which included an analysis of 928 papers containing the keywords "global climate change." The article says "none of the papers disagreed with the consensus position" of anthropogenic global warming. Although this article makes no claim to a specific number, it is routinely described as indicating 100% agreement and used as support for the 97% figure.

In a 2007 book chapter, Oreskes infers that the lack of expressed dissent "demonstrates that any remaining professional dissent is now exceedingly minor." The chapter revealed that there were about 235 papers in the 2004 article, or 25%, that endorsed the position. An additional 50% were interpreted to have implicitly endorsed, primarily on the basis that they discussed evaluation of impacts. Authors addressing impacts might believe that the Earth is warming without believing it is anthropogenic. In the article, Oreskes said some authors she counted "might believe that current climate change is natural." It is impossible to tell from this analysis how many actually believed it. On that basis, I find that this study does not support the 97% number.

The most influential and most debated article was the 2013 paper by Cook, et al., which popularized the 97% figure. The authors used methodology similar to Oreskes but based their analysis on abstracts rather than full content. I do not intend to reopen the debate over this paper. Instead, let's consider it along with some of the numerous other surveys available.

Reviews of published surveys were published in 2016 by Cook and his collaborators and by Richard S. J. Tol, Professor of Economics at the University of Sussex. The 2016 Cook paper, which reviews 14 published analyses and includes among its authors Oreskes and several authors of the papers shown in the chart below, concludes that the scientific consensus "is robust, with a range of 90%–100% depending on the exact question, timing and sampling methodology." The chart shows the post-2000 opinions summarized in Table 1 of the paper. Dates given are those of the survey, not the publication date. I've added a 2016 survey of meteorologists from George Mason University and omitted the Oreskes article.

The classification of publishing and non-publishing is that used by Cook and his collaborators. These categories are intended to be measures of how active the scientists in the sample analyzed



Graph by IOPScience

have been in writing peer-reviewed articles on climate change. Because of different methodology, that information is not available in all of the surveys. The categorization should be considered an approximation. The chart shows that over half the surveys in the publishing category and all the surveys in the non-publishing category are below 97%.

Cook is careful to describe his 2013 study results as being based on "climate experts." Political figures and the popular press are not so careful. President Obama and Secretary of State John Kerry have repeatedly characterized it as 97% of scientists. Kerry has gone so far as to say that "97 percent of peer-reviewed climate studies confirm that climate change is happening and that human activity is largely responsible." This is patently wrong, since the Cook study and others showed that the majority of papers take no position. One does not expect nuance in political speeches, and the authors of scientific papers cannot be held responsible for the statements of politicians and the media.

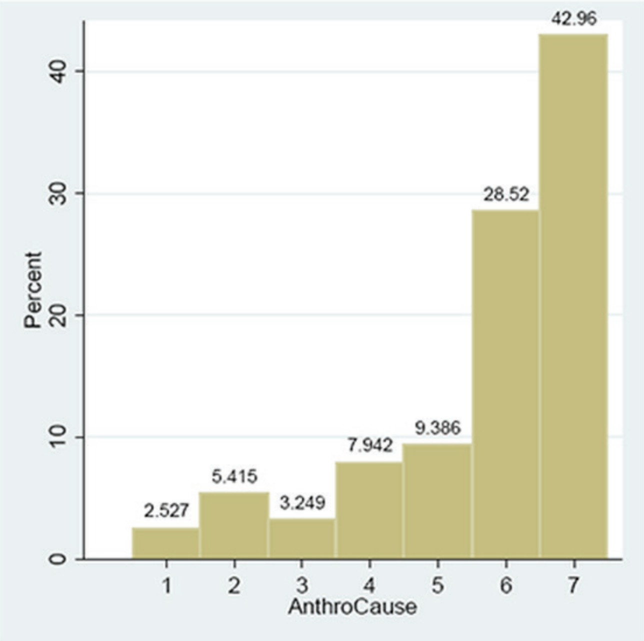
Given these results, it is clear that support among scientists for human-caused climate change is below 97%. Most studies including specialties other than climatologists find support in the range of 80% to 90%. The 97% consensus of scientists, when used without limitation to climate scientists, is false.

In the strict sense, the 97% consensus is false, even when limited to climate scientists. The 2016 Cook review found the consensus to be "shared by 90%–100% of publishing climate scientists." One survey found it to be 84%. Continuing to claim 97% support is deceptive. I find the 97% consensus of climate scientists to be overstated.

An important consideration in this discussion is that we are attempting to define a single number to represent a range of opinions which have many nuances. To begin with, as Oreskes says, "often it is challenging to determine exactly what the authors of the paper[s] do think about global climate change." In addition, published surveys vary in methodology. They do not ask the same questions in the same format, are collected by different sampling methods, and are rated by different individuals who may have biases. These issues are much discussed in the literature on climate change, including in the articles discussed here.

The range of opinions and the many factors affecting belief in anthropogenic climate change cannot be covered here. The variety of opinion can be illustrated by one graph from the 2013 repeat of the Bray and von Storch survey showing the degree of belief that recent or future climate change is due to or will be caused by human activity. A value of 1 indicates not convinced and a value of 7 is very much convinced. The top three values add to 81%, roughly in the range of several other surveys.

Even though belief is clearly below 97%, support over 80% is strong consensus. Would a lower level of consensus convince anyone concerned about anthropogenic global warming to abandon their views and advocate unrestricted burning of fossil fuels? I think not. Even the 2016 Cook paper says "From a broader perspective, it doesn't matter if the consensus number is 90% or 100%."



A survey of the perceptions of climate scientists 2013
Graph by Dennis Bray & Hans von Storch

Despite the difficulty in defining a precise number and the opinion that the exact number is not important, 97% continues to be widely publicized and defended. One might ask why 97% is important. Perhaps it's because 97% has marketing value. It sounds precise and says that only 3% disagree. By implication, that small number who disagree must be out of the mainstream: cranks, chronic naysayers, or shills of the fossil fuel industry. They are frequently described as a "tiny minority." It's not as easy to discount dissenters if the number is 10 or 15 percent.

The conclusions of the IPCC are the other most often cited support for anthropogenic climate change. These conclusions are consensus results of a committee with thousands of contributors. Although this is often viewed as a monolithic conclusion, the nature of committee processes makes it virtually certain that there are varying degrees of agreement, similar to what was shown in the Bray and von Storch survey. The Union of Concerned Scientists says of the IPCC process "it would be clearly unrealistic to aim for unanimous agreement on every aspect of the report." Perhaps this is a subject for another day. ■

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TRUMP, TILLERSON, NAFTA, MEXICO AND OIL COMPANIES

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On December 5, 2016, several U.S. oil companies were among the winners of petroleum contracts awarded by the Mexican Hydrocarbon Commission to develop deep water projects in the Gulf of Mexico. From a legal standpoint, an initial assumption could be that the North American Free Trade Agreement (NAFTA) became more relevant to these "American" companies entering into the Mexican oil market. Indeed, the legal regime provided by NAFTA Chapter 11, which was designed to protect property rights in long-term investments, could be essential to ventures involving operations that might last for over two decades.

Later, President-elect Donald Trump announced Rex Tillerson as his nominee for Secretary of State. Until 2016, Tillerson was the CEO of Exxon Mobil, one of the U.S. oil companies investing in the new projects in Mexico.

During the first year in office, Trump and Tillerson, assuming Tillerson is confirmed by the Senate, will navigate national and international politics to grapple with issues arising from promises made during Trump's presidential campaign. Among these promises was Trump's pledge to renegotiate or to terminate NAFTA.

Yet now that U.S. oil corporations plan to heavily invest in multi-billion dollar projects in Mexican territory, Tillerson should be aware that U.S. oil companies might prefer to keep NAFTA, in contrast with the anti-NAFTA rhetoric and nationalist positions expressed by some Trump supporters.

Nevertheless, both views require a closer look to identify the benefits of the agreement, since protecting U.S. oil investments in Mexico under NAFTA is far from a question with a unique and straightforward answer.

As a matter of fact, U.S. oil companies will initially face two NAFTA caveats. First, the conflicting interpretations of the agreement concerning the application of NAFTA Chapter 11. This is caused by the divided opinion of the legal community on the validity of the Mexican reservation to NAFTA that blocks protection of investment in the energy sector. For some, this reservation was implicitly waived after the approval of the Mexican energy reforms, whilst for others, the reservation remains and limits the application of some sections of the agreement.

Second, if one decides to ignore this debate and considers that NAFTA Chapter 11 applies, then they should bear in mind that, as Professor Gus Van Harten from York University has highlighted, NAFTA has no "survival clause." A survival clause is a provision typically included in treaties for the protection of investments, which provides the continuing protection of the agreement for existing investments for periods of 10 to 15 years, even after the treaty has been unilaterally terminated. Without this clause, a NAFTA party can terminate the agreement on six months' notice and could deprive foreign investors of the protection of international law and international arbitration. Hence, the framework, currently a subject of a public and politicized debate, seems far from providing the certainty of the rule of law required for these investments.

Then, why expose multi-billion-dollar projects to this degree of uncertainty? In recent years, U.S. investors have been able to place investments through subsidiaries incorporated in other countries to acquire the protection of an investment treaty. Indeed, in a time when oil majors operate around the world, corporation nationality has turned into a malleable concept.

Since the last decade, international arbitration tribunals have recognized "treaty shopping" as a legitimate practice to gain access to the protection of an investment treaty. For instance, oil companies like Exxon and Chevron (both among the winners of the Mexican deep water bidding round) have circumvented the lack of investment protection in countries like Venezuela, investing through Dutch or Danish subsidiaries that provide access to treaty protection. Consequently, we would expect that oil companies could use the Mexican network of several investment treaties to gain the protection provided by international law.

Moreover, this is not a one-sided legal agreement. NAFTA is not only relevant to U.S. corporations, but it has also become important to Mexican investments in the U.S. Mexican investments, such as those conducted by Carlos Slim, have invested in the U.S. real estate market; in the media sector through his ownership of 17% of the New York Times; and even in the oil and gas sector through the company Wellaware. Furthermore, Mexican investors have not ignored the investment treaty system. In fact, Slim's companies have recently profited from it and filed an arbitration claim against Colombia before the International Centre for Settlement of Investment Disputes at the World Bank. We may never know whether NAFTA was a topic during the recent meeting between the Mexican multi-billionaire and Donald Trump. However, what we certainly know from Trump's Twitter account is that after the meeting he called Slim a "great guy," and that Trump's relationship with the New York Times is far from being "great."

Based on the uncertainty created around NAFTA, the practice of "treaty shopping" reveals that NAFTA is one of a variety of options available to transnational corporations acting as foreign investors.

Does this make NAFTA a useless treaty? Of course not. NAFTA not only governs the protection of foreign investments. It has been the main legal framework that incentivized cross-border trade growth and investment relations between Mexico, the U.S. and Canada. Even Tillerson has publicly recognized the value of NAFTA in a conference before the Council on Foreign Relations in 2012. Despite Trump's position blaming NAFTA as the cause of all evils suffered by American workers, some scholars, such as Harvard Professor Ricardo Hausmann, have recently highlighted the benefits of NAFTA to the economies of the United States and Mexico, increasing trade and expanding markets.

Therefore, blaming international treaties for economic mismanagement seems like a misleading approach. Of course, treaties, investment protection and trade can always be improved. Moreover, States have the sovereign power to do so and the renegotiation of treaties could open the door for improvements. However, by focusing on the withdrawal from one or two trade agreements, neither the Republicans nor the Democrats will solve the biggest problem of global competition or undue globalization.

Mexican and U.S. investors should take a closer look at this situation. On the U.S. side, the final decision regarding whether to renegotiate or withdraw from NAFTA might also consist of a lengthy decision-making process that would require the agreement of Mexico and Canada, and the support of the U.S. Congress. In the case of NAFTA withdrawal, there are still legal uncertainties since there is not a definitive answer on whether the U.S. president has the power to withdraw the U.S. from NAFTA by an executive action, without consulting Congress. Nonetheless, if Trump decides to dispatch a notice of termination to NAFTA parties without the Congress' support, not only would this action spark a national debate, it would also be sufficient to terminate the agreement as a matter of international law.

Hence, the NAFTA case during the first year in office will show how the new administration will deal with national debates and the role of the U.S. finding new ways of leading in international trade and investment. ■

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WILL A TILLERSON APPOINTMENT FORCE AMERICANS TO FACE THE OTHER INCONVENIENT TRUTH?

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Living in the epicenter of the global oil industry, I have spent many years thinking, teaching and writing about oil, authoritarian governments and human rights. Because of this, I have felt exasperated, angry and fed up upon hearing lawmakers' posturing about the nomination of Rex Tillerson to be secretary of state and how his policies might threaten the United States' role as the primary promoter of human rights across the globe.

Upon leaving the nomination hearings, for example, Senator Marco Rubio stated: "I don't want to see us move toward a foreign policy in which human rights only matters when nothing else matters, when something more important isn't standing in the way." Really? Could Senator Rubio actually believe that such an approach would be new?

As any observer of African or Middle Eastern politics knows, this is a policy the United States has relied on for decades, especially if the nation in question is a producer of strategic minerals or oil. This is the other inconvenient truth about American oil dependence that Americans love to ignore. I am betting that with Tillerson in charge of U.S. foreign policy, this reality will become more apparent, more overt – and thus, in a good way, much more difficult for Americans to overlook.

In terms of Africa, I am convinced that our denial of this inconvenient truth derives from a reliance on two very old and constantly replayed tropes: that of the evil oil company and that of the corrupt African leader. Although one's political leaning determines which of the two will be used to explain away the problems facing many oil-producing nations, both are detrimental in that they divert attention from the full complexity of the geopolitics at play.

Such an act of diversion was apparent in the recent New York Times article chronicling Tillerson's "maverick oil diplomacy" with authoritarian governments around the globe. Although the author clearly culled data from Stephen Coll's 2012 "Private Empire: ExxonMobil and American Power" to illustrate scenarios from the Middle East, when it came to the two African countries mentioned (Angola and Equatorial Guinea), Coll's research was entirely ignored. Instead we are presented with the familiar story, always relayed in voyeuristic tone: a governmental elite rolling in extreme wealth, their children's lifestyles of profligacy and corruption, a political system that relies on imprisonment, torture and execution to quell opposition, and a population living on less than $2 a day.

I do not deny that these are realities, nor do I wish to serve as an apologist for the oil companies. I just wish that reporting and discussion on these issues would begin to embrace their full complexity. If they don't, how will we, or future generations, be able to think logically and seek solutions? How will we solve the energy issues that continue to vex the world?

In the case of Equatorial Guinea, Coll's research makes clear that since 9/11, when fears of terror attacks on U.S. oil installations emerged, and after a failed coup attempt against Equatorial Guinea's president in 2004, both the Bush and Obama administrations have worked quietly in partnership with not just ExxonMobil but an array of actors to keep President Teodoro

Obiang Nguema in place. These included key U.S. agencies – including the State Department, the National Security Agency and the U.S. military– two high-power Washington public relations companies, a Virginia-based private military company, and on the advice of the Bush administration, Israeli security contractors and arms suppliers.

The goal for all? To burnish Obiang's international reputation, convince him to improve on human rights issues, to protect American oil companies' installations offshore and to ensure that the oil continues to flow to the U.S., rather than to China or France. This is the realpolitick Americans need to be aware of if they want to critique Tillerson. Relying on false notions about concern for human rights will not do the job.

Obiang remains in power, president since 1979 of a country with vast reserves of oil, despite allegations of corruption, electoral fraud and abuse of power. He is Africa's longest-serving leader, ruling in a one-party state. But despite his baggage, the West continues to see him as a leader with whom it can do business.

When I teach about oil and Africa, I use Coll's chapters on Equatorial Guinea not to expose students to the tremendous power exercised by ExxonMobil at home and abroad – all Houstonians are aware of that. Instead I use them to illustrate just how complex and convoluted the systems by which we ensure our access to oil can become.

I was present at a trade conference held in Houston in 2012, organized by the Washington PR companies, where Obiang and his son Gabriel attempted to woo local business owners to invest in his country.

It was a surreal experience, watching the power of petroleum profits at work. Houston's most liberal mayor, Annise Parker, declared an honorary "Equatorial Guinea Week" by way of welcome, and Democratic U.S. Rep. Sheila Jackson Lee came to make a speech. I've wondered ever since, did they have any knowledge about Obiang's problems, any indication that the emperor wore no clothes?

Under a Trump/Tillerson administration however, with American lawmakers and citizens so wary about the latter's ties to ExxonMobil, such events will not go unnoticed anymore.

And that is a good thing. As I see it, Americans are about to get "woke" – not just to the maneuvering tactics or "diplomacy" of Big Oil, but also to the ways that our government, as well as our lifestyles, can contribute to diminishment of human rights for citizens of nations around the globe. ■

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WHEN FLARING NATURAL GAS BECOMES POLITICAL – NEEDLESS REGULATION OR GOOD CONSERVATION?

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One of us pointed out in a prior blog post that the oil and gas industry downturn represented the perfect time for the Texas Railroad Commission to change its regulations on flaring associated gas. The current rules – known as Rule 32 – allow drillers to burn off natural gas produced along with more profitable crude oil if there isn't an immediately available pipeline or other marketing facility to take it. That's been sweepingly interpreted to allow the burning of gas that could have been captured and sold.

In a subsequent post, the same co-author argued that the flaring of potentially profitable and economically valuable natural gas may give rise to common law claims for royalty owners. Under Texas law, the operator is held to an implied covenant to act as a reasonably prudent operator. As part of this implied duty, an operator must reasonably and prudently administer the leasehold estate in a nonwasteful manner. So that previous post argued that flaring commercially profitable natural gas may violate this implied covenant standard and thus subject the operator to damage claims by impacted landowners.

But recent events have made flaring a political issue. The Bureau of Land Management, which oversees the development of federally owned lands, proposed regulations last February to curtail methane emissions from public lands. As the Bureau of Land Management noted in its regulations, methane is the primary component of natural gas, and the venting or flaring of natural gas causes methane to be released into the atmosphere. Moreover, the Bureau of Land Management estimated that methane has a climate change impact 25 times greater than that of CO_2.

Whether or not one accepts the climate change concerns raised by these methane emissions, the fact remains that the Bureau of Land Management has a vital interest in ensuring that natural gas obtained from federally owned lands is put to a productive use. Thus, the Bureau of Land Management issued regulations that sought to curtail the amount of flaring that could occur on federally owned lands, and one of the rationales was to prevent the needless waste of an economically valuable and scarce natural resource.

Last week, it was reported that Congress and the President would seek to overturn needless regulations that inhibit business activity, and news reports identified the Bureau of Land Management's recent regulations as targets for elimination.

Flaring degrades the nation's air quality, adds to global climate change impacts and also wastes a valuable natural resource that could have had a productive use. The public should expect the Bureau of Land Management would ensure that federally owned lands would be developed in a way that minimizes the waste of natural gas. To that end, it is appropriate for the Bureau of Land Management to require businesses to use best practices in its oil and gas development activities conducted on federal lands.

The U.S is blessed with natural resources, but they should not be wasted. We should applaud regulations that minimize the amount of hydrocarbons immediately burned up in flares. These regulations support greater energy independence for the United States by ensuring that our natural resources are put to a productive use.

Thus, we hope that the current administration and Congress will defend these regulations as a reasonable effort to minimize the waste of our finite natural resources. ■

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THE COST OF WIND AND SOLAR INTERMITTENCY

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Until relatively recently, generation of electricity with wind and solar has not been cost competitive. Growth has largely been due to subsidies and renewable energy mandates. Due to decreasing cost, wind and solar are now cost competitive with fossil fuels in favorable locations.

The continuing decrease in wind and solar costs is a very positive development. However, this trend may reverse as the percentage of variable renewable energy (VRE) – energy that isn't available on-demand but only at specific times, such as when the wind is blowing – reaches high levels. Countries such as Germany that have integrated significant amounts of wind and solar have already seen price increases.

The levelized cost of electricity

Comparisons of electrical generation cost are usually based on the so-called levelized cost of energy (LCOE), an estimate of the total cost of generation expressed in dollars per megawatt hour ($/WMh). The calculation includes capital costs, operating and maintenance costs and fuel cost. It is affected by assumed utilization rate and interest rates.

The most widely cited levelized cost estimates are those of the U.S. Energy Information Agency (EIA) and the investment firm Lazard. Although these estimates are useful for comparison, they exclude such costs as network upgrades, integration and transmission, which can become significant as renewables penetration increases. As the International Energy Agency (IEA) put it in the context of integrating variable renewable energy, "comparison based on LCOE is no longer sufficient and can be misleading."

Levelized cost estimates are based on a large number of assumptions, not least of which is the future cost of fossil fuels. There are some differences in these estimates, with Lazard showing unsubsidized utility scale solar and onshore wind as competitive with natural gas and the EIA not.

The table (on the next page) shows national averages. For wind and solar, location is very important; they are in places locally cheaper than natural gas combined cycle. For the purposes of this discussion, these differences are not significant. The more important point is the added cost of factors not included in the levelized cost.

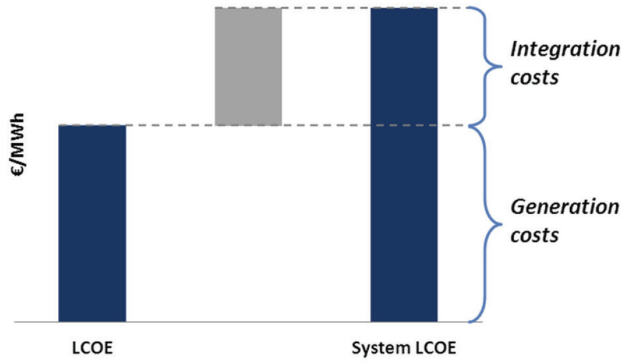
The sources of integration costs

As described by Mark Delucchi and Mark Jacobson, "any electricity system must be able to respond to changes in demand over seconds, minutes, hours, seasons and years, and must be able to accommodate unanticipated changes in the availability of generation." Traditionally, this is handled by base load and peak load plants, which handle the minimum load and increases above that level, respectively. This is an oversimplification, since supply is managed by the minute using a variety of sources with different response times.

Plant Type	Capacity Factor (%)	Levelized Capital Cost	Fixed O&M	Variable O&M (including fuel)	Transmission Investment	Total System LCOE
Dispatchable Technologies						
Advanced Coal with CCS	85	97.2	9.2	31.9	1.2	139.5
Natural Gas-fired						
Conventional Combined Cycle	87	13.9	1.4	41.5	1.2	58.1
Advanced Combined Cycle	87	15.8	1.3	38.9	1.2	57.2
Advanced CC with CCS	87	29.2	4.3	50.1	1.2	84.8
Conventional Combustion Turbine	30	40.9	6.5	59.9	3.4	110.8
Advanced Combustion Turbine	30	25.8	2.5	63.0	3.4	94.7
Advanced Nuclear	90	78.0	12.4	11.3	1.1	102.8
Geothermal	91	30.9	12.6	0.0	1.4	45.0
Biomass	83	44.9	14.9	35.0	1.2	96.1
Non-Dispatchable Technologies						
Wind	40	48.5	13.2	0.0	2.8	64.5
Wind – Offshore	45	134.0	19.3	0.0	4.8	158.1
Solar PV	25	70.7	9.9	0.0	4.1	84.7
Solar Thermal	20	186.6	43.3	0.0	6.0	235.9
Hydroelectric	58	57.5	3.6	4.9	1.9	67.8

Source: EIA

Wind and solar are non-dispatchable, meaning that they are not under the control of the operator. They only generate electricity when the wind blows or the sun shines. This adds integration costs, shown conceptually below.



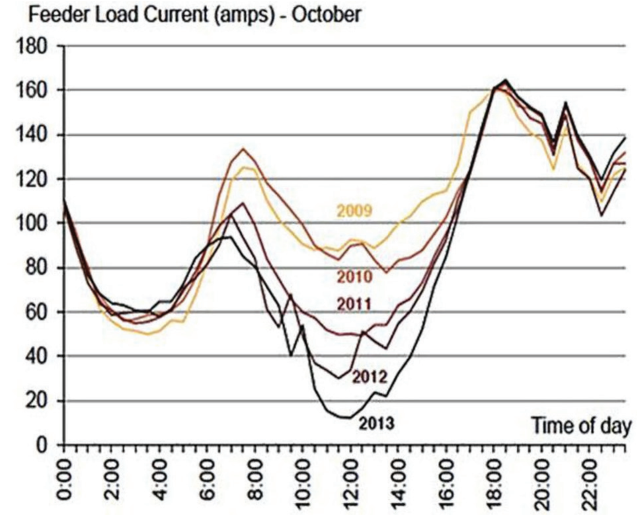
Source: Ueckerdt, 2015

When variable sources are a small fraction of electricity supply, the cost of integration is low. The current level of deployment is below thresholds where the cost of dealing with intermittency becomes significant.

There are numerous possible solutions to intermittency. These include diversification, redundancy, storage and demand shifting. That redundancy and storage add cost is obvious. Diversification also adds cost in control equipment and transmission capability between geographically separated sources.

Demand shifting can theoretically lower cost by reducing the peak capacity needed. It is often discussed jointly with efficiency improvement under the term demand-side management.

One issue in demand management is illustrated in this graph of daily load for a location in Australia. Solar is only available when the sun shines and peaks around midday. As solar generation increases, the average load on the remainder of the system decreases, but the peak is barely affected. Dispatchable sources must make up the difference between the midday low and the evening and morning peaks. This relationship is called the "duck curve."



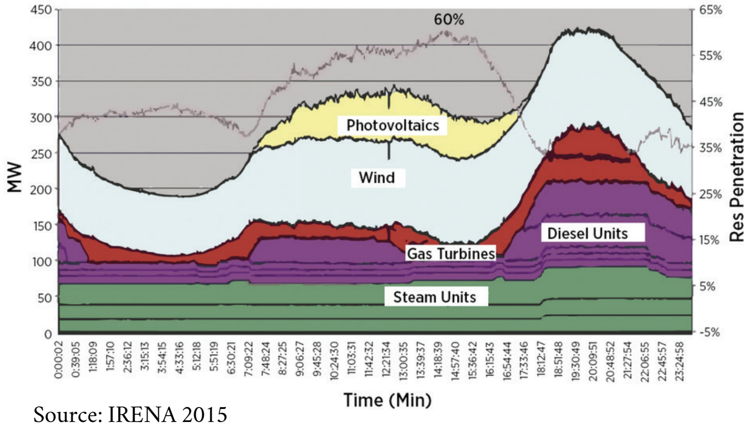
Source: Ledwich 2015

Measures to shift usage from peak periods include education, jawboning, differential pricing and control of end use by the utility through the smart grid. Education, jawboning and even differential pricing have had limited success to date. Time of day pricing and end-use control require a smart grid, with attendant cost.

Wind power typically will generate throughout the day, but it has its own limitations. It is less predictable, more variable over short periods than solar, may be seasonal and may need to be shut down when the wind is too strong.

The graph on the right shows generation for one day on the island of Crete. Renewables penetration reaches a peak of 60%, accommodated by curtailment of diesel and gas generation.

Even so, average annual renewable share is only 20%, and some difficulties were encountered during peak renewables generation periods.



Source: IRENA 2015

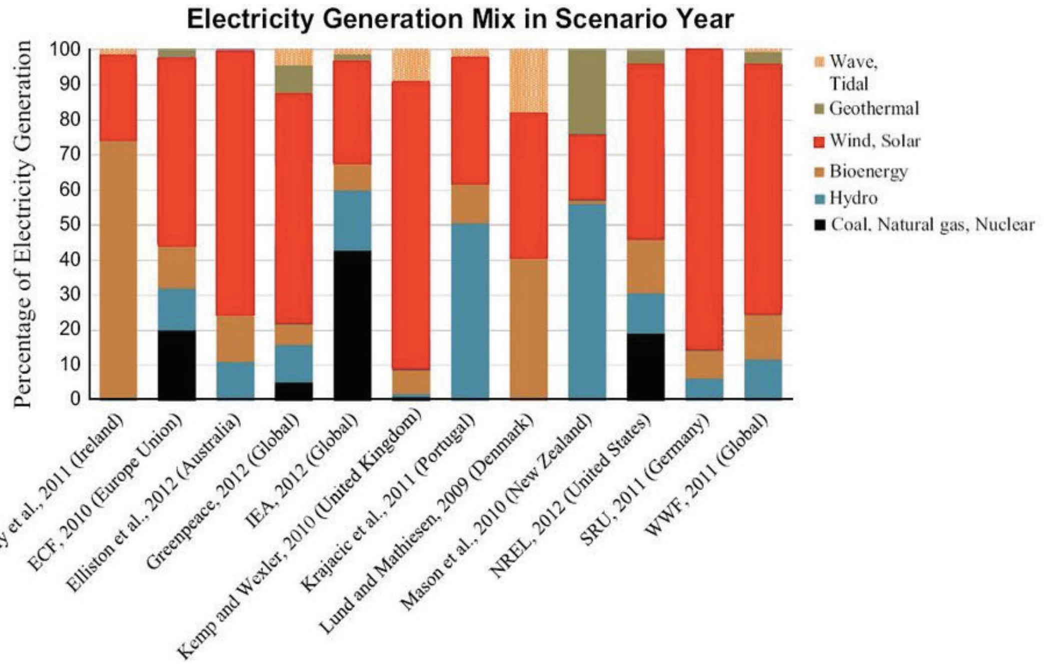
The Crete example is typical of existing systems in that balancing is done with fossil fuels. Balancing may also be done by dispatchable renewable energy, primarily hydroelectric and biomass, and with storage.

What's the best generation mix?

Due to the wide variety of generating sources and unique local circumstances, there is considerable flexibility in the design of generating systems. The trade-offs in cost and environmental benefit are complex.

Hundreds of studies which address increasing the share of renewables have been published. These vary greatly in scope and sophistication. Some do not include cost analysis or ignore integration costs. Adequate analysis of high levels of variable generation requires that balancing demand within short time frames be included.

The sample of published scenarios on the next page illustrates the wide range of possible combinations. Wind and solar range from less than 20% to over 80%. The mix is influenced by availability of other sources, and by ideology.



Source: Modified from Cochran 2014

Big differences result from design choices, such as whether expansion or retention of some fossil fuels are included. Accepting periods of inadequate capacity is also a factor.

Most scenarios with high percentages of renewables rely on substantial reduction in growth of electricity demand. It's questionable how realistic this is, particularly if strong growth in electric automobiles is anticipated.

What is the integration threshold?

There is no threshold, per se. The cost of managing intermittency is nonlinear and depends upon the mix and location of dispatchable and non-dispatchable sources, the match of local demand patterns with variable source pattern, and various other factors.

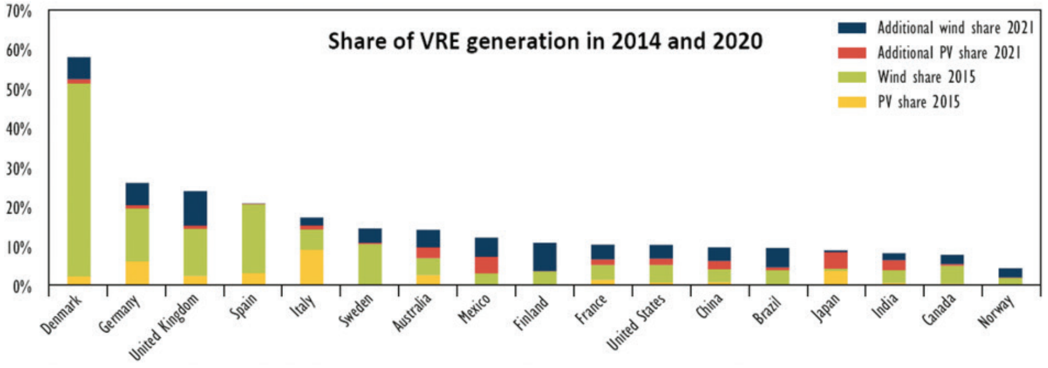
Based on model studies of Germany and Indiana, Falko Ueckerdt found integration costs began to become significant at 20%. As of 2015, only four countries have variable renewable energy over 20%.

Hawaii Electric recently approached 50% renewables; however, the share of wind and solar was only about 15%. Even so, they have requested a 6.9% rate increase based partly on the cost of renewables integration, and estimate the cost of grid upgrades necessary to reach 100% renewables as $8 billion.

Champions of wind and solar have characterized integration cost estimates as ploys to discourage renewable energy, but integration costs are real.

Isn't it being done already?

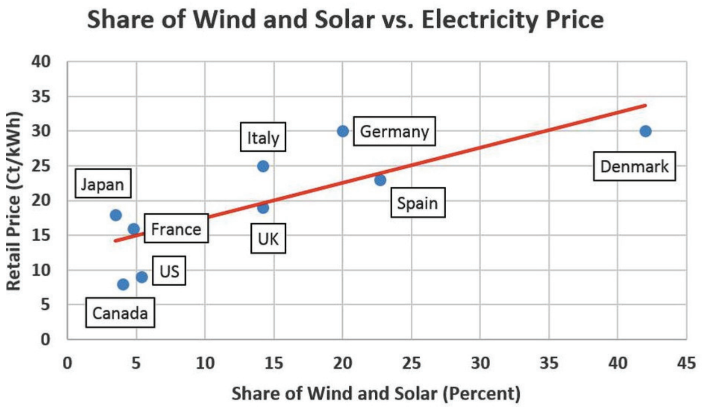
The poster child for variable renewable energy is Denmark, reported to be over 50% in 2015. Denmark's success is often used to illustrate that high levels are readily achievable. This is misleading in that Denmark is a small country tied into the European grid. Variable wind power is balanced with hydroelectric and other sources in adjacent countries. De facto share for the system is lower. Denmark's installed wind capacity ranks ninth among EU countries and represents less than 4% of EU.



Source: EIA

Germany's combined wind and solar has the largest capacity in Europe and is second highest per capita. Despite Germany's progress, the share of variable renewable energy for electrical generation is less than 25% and has been achieved at significant cost. The renewable energy surcharge is 22% of household electricity price.

Even at relatively low levels of renewables share, there is a clear correlation between the share of variable renewable energy and the retail price of electricity. This is largely due to feed-in tariffs and net metering, which transfer renewable subsidies costs to the retail customer.



Source: Data from Clean Energy Wire and World Energy Council

The range of published integration cost estimates at higher shares of wind and solar is very broad and dependent upon both parameter assumptions and model structure. I will discuss these in a later post. ■

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THE FUTURE OF OIL AND GAS? LOOK TO THE PAST

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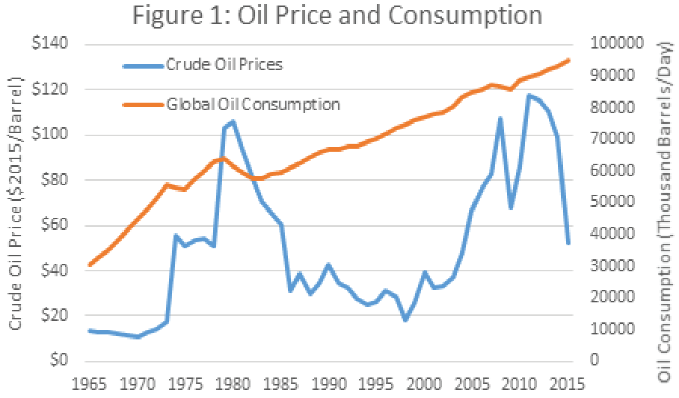
In the early days of 2017, it behooves oil and gas companies to reflect on the past, while making plans robust to an uncertain future outlook. There are several questions that should be asked:

- Where are we in the oil and gas price cycles?
- How will politics and policies affect the business outlook?
- What are the appropriate strategies?

Learning from the Past

It will not surprise any investor in oil and gas and related businesses that theirs is a cyclical business. Prices run up when supplies fall short of demand, hover on the summit for a few years, then tumble as new supply sources are developed and demand growth slows down (Figure 1).



Sources: BP Statistical Review of World Energy; EIA

After the collapse of 1986, oil prices remained volatile through 1990, then declined further through 1998 as production from the Middle East, Norway, Iran and Venezuela increased to meet demand growth and replace declines in Russia and North America. One consequence of the price decline in 1998 was major oil company mega-mergers. These resulted in high-grading of projects, reduction in aggregate capital spending and slowdown in production increases, setting the stage for the run-up in prices after 2002.

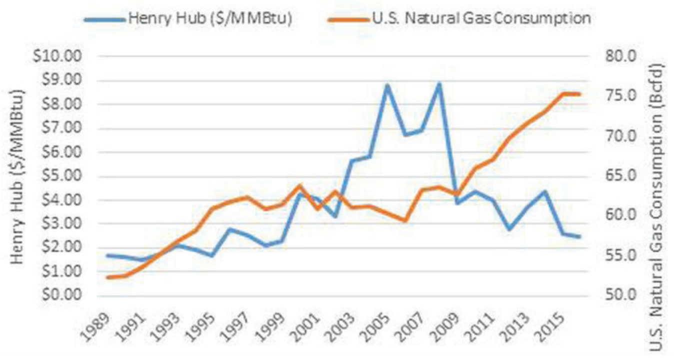
The period from 1986 through 2002 can be seen in retrospect to have been a "long grind," as oil prices were set by the long-term marginal costs of incremental production sources needed to satisfy demand growth and replace declining production from mature oil fields and political turmoil.

Tightly controlled wellhead natural gas prices in the 1970s led to supply shortages. The 1978 Natural Gas Policy Act (NGPA) started a process of decontrol and broadened the responsibility the Federal Energy Regulatory Commission held over the industry.

In 1985, FERC issued Order No. 436, which changed how interstate pipelines were regulated. This established a voluntary framework under which interstate pipelines could act solely as transporters of natural gas, rather than filling the role of a natural gas merchant. However, it wasn't until Congress passed the Natural Gas Wellhead Decontrol Act (NGWDA) in 1989 that complete deregulation of wellhead prices was enabled. Issued in 1992, FERC Order No. 636 completed the final steps towards a competitive market by making pipeline unbundling obligatory.

Natural gas became a traded commodity subject to its own cycles (Figure 2).

Figure 2: Gas Price and Consumption



Sources: BP Statistical Review of World Energy; EIA

The decontrolled market opened new sources of supply, enabled by new seismic technologies that uncovered large resources of natural gas under the Gulf of Mexico (GoM) continental shelf. A gas bubble was inflated, holding spot prices below $3/ million British Thermal Units from 1989-1999. New markets, notably independently owned cogeneration plants empowered to sell electricity to industrial plants and the grid at prices representing the "avoided cost" that new utility projects would have incurred, caused rapid demand growth. The bubble burst as gas production in the Gulf of Mexico peaked, natural gas prices increased and LNG import terminals were built.

Higher prices induced innovation on the supply side as George Mitchell figured out how to extract natural gas from tight shale rock, and the technologies were deployed in other gas and then oil shale plays. Natural gas prices collapsed in 2009: demand accelerated as natural gas displaced coal in the power sector, somewhat constrained by limitations on pipeline transportation. New pipeline connections were built despite opposition; LNG import facilities were converted to export facilities.

Mark Twain wrote "History doesn't repeat itself, but it does rhyme." If history were to repeat itself, oil prices would remain low for another "long grind", mirroring 1986-2002 by declining further over the next 15 years; natural gas prices would start strengthening in 2019.

Politics and Policies

For oil markets, turmoil in the Middle East and Africa withdrew about 3 million barrels per day from world markets between 2005 and 2015. Ideological conflicts, coupled with the demographic realities of a growing number of young men with few employment opportunities, suggest continued instability.

OPEC's agreement to reduce production with apparent support from Russia will be tested by inducing expansion of U.S. shale production. But the need for cash to meet social commitments is likely to reduce funding available for capital spending by the national oil companies and will lead to lower production, regardless of the OPEC quotas. The "long grind" seems likely to be shorter this time around, more likely five rather than 15 years.

The past eight years have seen a series of rules designed to suppress coal use, to the benefit of natural gas as well as renewables. Several of these rules are still being litigated, and the new administration may choose not to defend constitutional challenges by various individual states. There may also be a reduction in subsidies and mandates favoring renewables, but natural gas will likely find it difficult to displace coal at the pace seen in recent years. LNG exports will allow further production growth, but the resource available in shale plays in 2017 is significantly larger than the GoM shelf resource available in 1989. Expect natural gas volumes to grow but prices to remain capped by coal through the mid-2020s.

Strategies

For upstream companies, the not-so-long grind through the early 2020s calls for a conservative approach to strengthen balance sheets, sustain dividend payments and drill within cash flows. Prices will be volatile and excessive exuberance will be punished by periods of low prices. However, it will be important to see around corners and monitor closely the factors that could shift the outlook to a new run-up in prices, requiring an expansionary emphasis on capturing new resources and a greater tolerance for debt.

The oilfield services sector has been hammered by the downturn and will likely consolidate further. It remains to be seen whether the consolidation will be lateral or vertical. Halliburton failed in its attempt to strengthen its verticals by merging with Baker Hughes; Schlumberger and Technip have taken a French solution of lateral extension by acquiring Cameron and FMC Technologies, respectively, and the forthcoming merger between GE Oil & Gas with Baker Hughes is also mainly lateral extension of business lines. Historically, oil companies have preferred to purchase equipment and services from best-in-class providers, and the new conglomerates will need to work hard to overcome past preferences and create a persuasive value proposition for bundling purchases of equipment and services from a single vendor.

Midstream companies should be able to resume organic growth as companies "replumb" energy infrastructure, aided by a supportive rather than hostile federal government and underwritten by producers seeking access to liquid markets.

Refiners and petrochemicals companies should benefit from an increasing gap between natural gas (used as feedstock and energy) prices and crude oil (setting international petroleum and petrochemicals products prices) as the oil price cycle will be out of phase with the gas price cycle. Nevertheless, these sectors will see limited volume growth and should continue to focus on limited capital improvements, operations excellence and accretive, synergistic acquisitions.

Well managed companies created value for shareholders through the 1990s by leveraging new technologies, simplifying their organizations to improve productivity, partnering creatively with providers of equipment and services and making acquisitions when prices were low. That playbook should be dusted off and updated for the next five years. ■

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MANAGING WIND AND SOLAR INTERMITTENCY IN CURRENT AND FUTURE SYSTEMS

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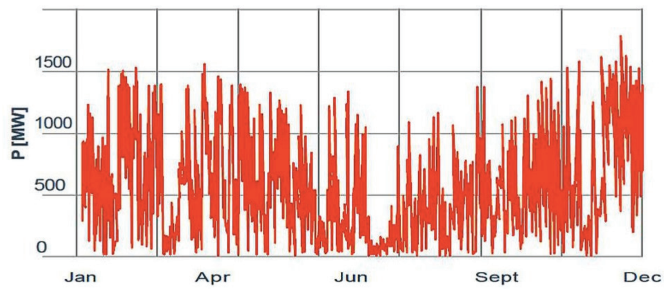
The problem with variable renewable energy (VRE) – primarily wind and solar – is sometimes it generates too much power and sometimes it doesn't generate enough. That's manageable, but it's more complicated than it may seem.

In the majority of today's installations, variability can be balanced with so-called dispatchable generation: traditional power plants, hydroelectric and biomass. Generation from traditional power plants is cut when generation from wind and solar is too high, and increased when it's too low. This creates some power management problems but is manageable at modest cost.

In a system with a large share of wind and solar, maintaining enough dispatchable power in reserve becomes expensive. The electrical grid must be modified to manage the increased variability. It remains to be seen how quickly the transformation to a high share of VRE can be made.

The nature of variability

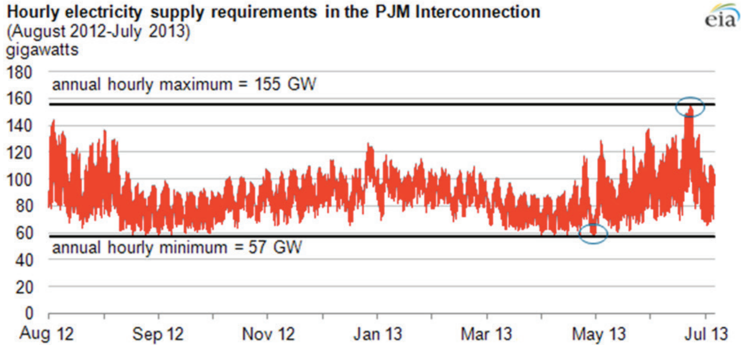
Power from wind and solar varies on all time scales from seconds to years. The graph below illustrates variation in Irish wind power over one year. The Irish example is pertinent because at 23% of electricity generated, they have one of the highest shares of wind power, and the wind farms are dispersed over the country. Despite the benefit of the geographic spread, there are moderately long periods during which little or no electricity was generated by wind. The historical average amount generated is 31% of installed capacity according to EirGrid and SONI, but the range is from near zero to about 50%.



Source: World Energy

Managing variability is not new

Variability is not a new issue in the power industry since traditional power sources have some variability, and demand is also variable over all timeframes. The graph below of demand in a large U.S. grid has much less variability than the Irish wind power example, but it is still almost 3:1 and has a noticeable seasonal component.



Source: EIA

Managing the system is a function not only of source variation, but also of matching generation with demand. In an earlier post I discussed the "duck curve" illustrating the ramp down and ramp up needed in dispatchable generation due to the mismatch of daily solar generation peaks with demand.

Reducing source variability

Variability can be reduced by combining different types of variable sources and by spreading sources over a large geographic area. Either of these will reduce short-term variability but may or may not significantly reduce variability on a scale of hours or days.

A study of the European Union showed that wind power in 2014 fell to as low as 4% of capacity and was less than 10% of capacity 11% of the time, even when aggregated over the entire EU. Since the countries are not all grid connected, the distribution was hypothetical. Variation on the actual smaller grids was higher.

Patterns of available wind and solar power vary tremendously with location. Wind and solar may tend to peak together or at different times. They may generate more during peak demand periods or during low demand periods. This makes generation design a local issue unless very widespread interconnections are available.

The potential for greater smoothing has led to the concept of the supergrid, connecting generating sources over larger areas than traditional grids. Some technological development is necessary to implement supergrids but they likely will be constructed. Even so, they will not completely eliminate variability since weather patterns tend to occur over large areas.

Reducing demand variability

Variability of demand can be reduced by a variety of techniques that shift usage from high demand periods. These include differential pricing, smart controls, jawboning and direct utility control of load. Perhaps the most obvious example is encouraging people to shift tasks such as washing and drying to the night in order to reduce demand during the daytime peak. These methods are discussed within the industry along with methods for reducing overall demand under the term demand-side management.

Managing the remaining variability

In existing grids and those foreseeable in the near term, substantial variability and mismatch between generation and demand will continue. Management methods include dispatchable generation, overcapacity, storage and tolerating insufficiency. All have costs.

Dispatchable generation is the traditional method. In effect, it is a form of overcapacity since the dispatchable plants run below capacity until more electricity is needed. The cost of maintaining standby capacity and efficiency losses associated with ramping and partial load operation can be substantial.

Renewables can serve as dispatchable sources, so this method would not preclude achieving 100% renewables. Some very high renewables scenarios use biomass to balance variability.

The premise of overcapacity is that if you build more generation than is necessary, you will have enough even when the variable sources operate at a fraction of their capacity. As the graph of Irish wind power shows, it is a practical and economic impossibility to build enough variable capacity to meet supply during very low periods.

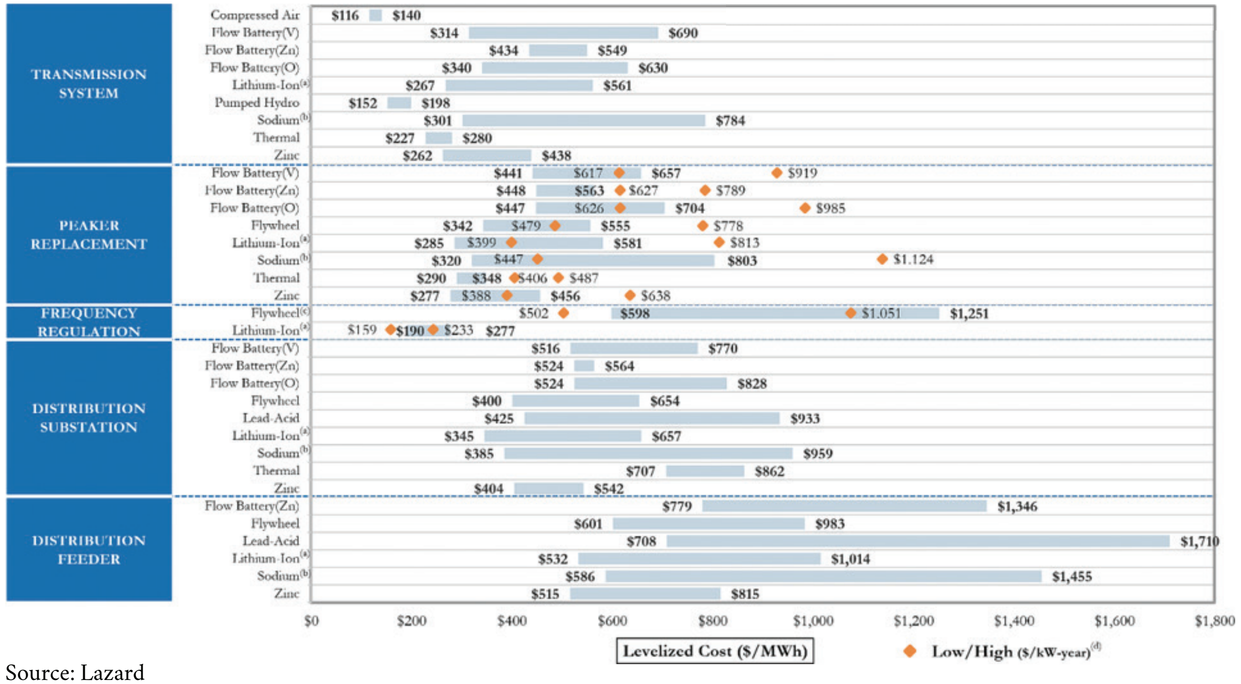
The downside of overcapacity is that you generate too much electricity during favorable periods of high wind or intense sunlight. Ideally, the excess electricity can be stored. This has some disadvantages which will be discussed below.

A possibility suggested by Mark Jacobson and Mark DeLucchi is generating hydrogen during periods of oversupply. In essence, this is increasing demand to match supply, and it could be applied to products other than hydrogen. It is conceptually similar to encouraging electricity use by very low or negative prices during oversupply periods, as has been practiced in Germany and other areas with moderately high VRE share.

Storage to clip the peaks and fill the valleys of demand is part of nearly all high VRE scenarios. There are numerous storage technologies with varying cost, scale, duration and technological maturity. This table from Lazard's 2016 Levelized Cost of Storage shows the cost of the primary technologies and applications. The costs should be taken only as approximations since some of the technologies are not mature, costs vary with location and future cost reductions are likely. Taken at face value, only compressed air, pumped hydro and lithium-ion are competitive today with natural gas peaking cost of about $200 per megawatt hour.

Storage cost depends not only on the cost per kilowatt hour, but also on the amount of storage capacity installed. There are no guidelines for the amount of storage needed for a given level of VRE. The optimum capacity is influenced by cost dependent tradeoffs between generation and storage, as well as the mix of sources and match with demand. A model study of the PJM Interconnection used as the demand example above showed the lowest cost alternative relied heavily on overcapacity, with little storage. Other locations and assumptions might give very different answers.

Storage technology is in an early stage of development. Most storage installations to date can only supply rated power for a few minutes to a few hours. Capability to handle extended shortage remains an issue. The extent of storage that will be incorporated in future systems will be heavily dependent upon development of storage methods and cost of generation.



Source: Lazard

It is likely impossible to build a grid with a very high share of VRE that has complete certainty of providing adequate power at all times. A necessity or deliberate choice may be to allow for curtailment, that is, not supplying some customers when generation does not equal demand.

Market mechanisms, such as interruptible supply contracts, are other ways to match supply and demand.

Optimizing the system

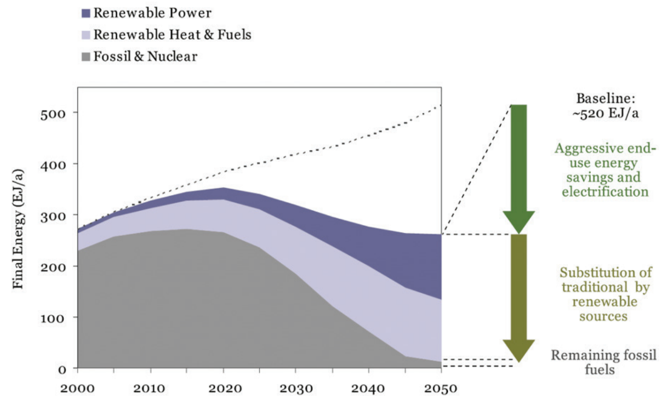
On a theoretical basis, an electrical grid can be optimized through the proper mix of sources, storage and locations. There is a question what is to be optimized. Is it lowest cost, least pollution, greatest economic benefit, energy security, social equity or some combination of factors? Once the measure is determined, assumptions must still be made regarding performance, cost and demand. Actual performance will frequently differ from modeled performance.

Since the amount of electricity generated by wind and solar vary somewhat randomly, statistical forecasting techniques are used. These generate a distribution of forecasted supply as a function of time. There will be some probability of extreme events, for example, a prolonged inadequacy of supply.

The choice of when, where, how much and what type of generation to build is decided in most countries by private companies. Their choices may be substantially influenced, but not controlled by, government policy. As a result, the grid will not be optimum. Renewables requirements and the structure of government incentives will be important factors.

Very high renewables scenarios

The majority of published scenarios, including those of the IPCC, have traditional sources – nuclear and fossil fuels – continuing to provide a significant fraction of electricity generation through 2050. A few have all electricity, or even all primary energy, from renewables. These scenarios depend not only on rapid technological advancement and implementation of renewable sources, but also on reduction of energy consumption, such as in this World Wildlife Fund (WWF) scenario of 95% renewables.



Source: World Wildlife Fund

The WWF scenario decreases overall energy demand by about 25% from a peak in 2020. It is at odds with many other scenarios that envision continued growth in energy demand due to increasing population and increases in consumption in the developing and less developed countries.

Similarly, this scenario envisions a decrease in annual energy cost of 4 trillion Euros by 2050, based on reduced demand and lower fuel costs. These numbers are at odds with the predicted increase in generation cost associated with high shares of VRE discussed in an earlier post.

It's not clear to me whether scenarios that envision drastic shifts in energy source are considered plausible or are thought experiments expressing ideal goals. The WWF report describes the task of transforming the system as "a huge one, raising major challenges." Considering the modest progress to date, differing views of the priority of decarbonization, the need for as yet unproven technology and the time needed to construct new systems, it seems unlikely that this transformation will be completed by 2050. ■

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TRUMP VS. CLINTON – NO ENERGY (POLICY)

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"Energy independence" is a catchy slogan, but it isn't an energy policy. You wouldn't have known that by listening to Harold Hamm, the chief executive of Oklahoma-based Continental Resources, as he spoke at the Republican convention in Cleveland.

The Democratic convention offered even less insight into energy policy, although Hillary Clinton has made clear she will cut tax breaks for oil and gas producers and tighten regulations on fracking. The Democrats adopted a refreshingly naïve policy to mandate clean and renewable energy without considering the profound lack of necessary technologies and the costs needed to reach the goals. Clean and renewable does not equal "free."

The noisy primaries and conventions left little room for detailed talk about energy. But the details are what we need to hear.

Hamm, rumored to be a front-runner for Energy Secretary if Republican nominee Donald Trump is elected, was full of feel-good platitudes when he promised the convention audience that a Trump administration will create energy independence and deliver lower gasoline prices.

That won't happen. It's also far from the only issue the new Energy Secretary will face.

U.S. energy policy also encompasses how we charge our phones and computers, how we run our air conditioners and how we avoid contaminating our environment with dirty emissions, coal and nuclear waste. Any new Energy Secretary needs to be versed in these areas.

Hamm's primary punching bag during his convention speech was OPEC; the fact that OPEC has been Mr. Hamm's greatest benefactor went unmentioned.

OPEC drove up the price of oil well beyond $100 per barrel after 9-11, making shale plays such as Continental's Bakken acreage economic to develop. But what OPEC giveth, OPEC can taketh away. The cartel's decision to drive down oil prices has resulted in more than 200 bankruptcies in the oil and gas industry, more than 250,000 lost jobs and has cost America more than $200 billion in direct loss GDP.

Chanting "Energy Independence" did not work for Presidents Nixon, Carter, Reagan, Ford, Bush, Clinton, Bush or Obama. President Dwight Eisenhower's 1959 import quota raised the price of U.S. crude encouraging conservation and production of a scarce resource. Today, it would encourage accelerated development of electric automobiles and other alternative modes of transportation, in addition to rescuing many in oil and gas. Under no circumstances would it provide lower gasoline prices to consumers.

But energy policy in 2016 also requires a coherent plan to address climate change. Public opinion research by Anthony Leiserowitz of Yale University has found that in spite of differences about the cause of climate change, more than 95% of people in the United States favor reducing pollution, including carbon emissions. That will take more than Clinton's call for a clean energy economy or Trump's pledge to resurrect slumping coal mines.

Cheap natural gas may make the Clean Power Plan's objective of closing coal plants a moot issue – when it's cheaper to build and operate generating plants fueled by natural gas than by coal, natural gas wins. As a result, the average price of electricity across the U.S. is less than the cost of building new generation capacity — including subsidized solar and wind energy.
The Department of Energy, the Federal Energy Regulatory Commission and grid operators are worried that announced nuclear and coal plant closures will destabilize the grid and ultimately drive electricity prices through the roof. No administration that ignores this impending disruption will survive to a second term.

U.S. consumers will have to supplement their own electricity supplies in the form of battery storage, generators and rooftop solar. These are real costs to consumers. That they do not show up at the meter is not a reason nor a defense for political inaction.

As the national struggles to maintain reliability, it is also under daily cyberattack by domestic and foreign actors. Remember the Stuxnet computer virus that destroyed Iran's nuclear centrifuges in 2007? Hurricanes Sandy, Katrina, Ike and Andrew caused electricity outages lasting more than a month in localized areas including New York City. A targeted cyberattack could do more damage.

The next administration needs a pragmatic policy that addresses the entirety of energy development, distribution and usage.
It is well beyond pandering platitudes and feel good statements.
A comprehensive plan is in order, and neither party has one. ■

Published on April 25, 2017

DEAR PRESIDENT TRUMP – WHAT ARE YOU DOING ABOUT ENERGY?

TERRY HALLMARK
Instructional Assistant Professor, Honors College

Dear President Trump,

I thought I'd drop you a line. They had a symposium at the University of Houston recently on "The Future of Energy Policy." It was good. Even tempered. A Democrat and Republican – Republican U.S. Rep. Pete Olson and Democrat Rep. Gene Green – even got along, and no one had a bad word to say about you.

That was refreshing, because lately everywhere I go on campus someone is cracking a joke every time your name is mentioned. Guess it's because it's a university campus – you know, where lots of left-leaning college professors hang out. A fellow who ran a bar in Brooklyn laughingly used to call professors "the Intelligenski," because they think they're smarter than everybody else. They can't believe anybody would be foolish enough to pick you over Hillary. Well, I think they're the fools. Plenty of folks voted for you – after all, you won – they're just afraid to admit it. Maybe there needs to be something like Alcoholic Anonymous, you know, like Trump Supporters Anonymous –TSA – although it might get confused with the gang that makes you take your shoes off at the airport.

Seriously, the numbskulls who don't like you say you're dumb as a shovel, but you don't get as rich as you are by being dumb – and besides, shovels are useful, especially when you're digging holes. Plus, you've got the support of some smart, conservative academic types. A few weeks ago, the Chronicle of Higher Education published an article about a bunch of political scientists at the Claremont Colleges in California you're apparently leaning on for advice. That's where I got my Ph.D., so I know nearly all of them. Charles Kessler, who got most of the coverage in the article, was the chairman of my dissertation committee. He's an expert on American Political Thought (back when Americans were thinking) and on the U.S. Constitution and the Federalist Papers (the "go to" handbook on how the Constitution is supposed to work). He and his buddies will be handy.

And what about your cabinet appointees, especially those who know something about energy? Rex Tillerson was a bold pick as Secretary of State. I used to work in the oil industry for this outfit called IHS, and the firm has a week-long shindig every spring called CERAWeek, where all the energy execs hang out, network and give talks. It's run by a member of your Strategic and Policy Forum, Dan Yergin. I spoke there once. Tillerson spoke there in 2015. He has a presence, as they say. He is an Eagle Scout, and he's from Texas. That means he's solid and will probably do a good job.

And since he used to run ExxonMobil, he knows energy and has experience with Vladimir Putin and other heavy-handed types. He also knows about oil exploration in garden spots like Chad and Equatorial Guinea – where the people don't give a flip about their Size 3 carbon footprint and the leaders have names that are impossible to pronounce. (Try saying Teodoro Obiang Nguema Mbasogo three times fast.) I'm a little bit worried, though, because you're both big time wheelers and dealers at the highest levels of Big Oil and Big Buildings. Hope you guys don't have to have your egos shoehorned into the Oval Office just to have a chat.

I'm not quite as gung-ho about your pick for Secretary of Energy, Texas' ex-Governor, Rick Perry (now a member of your National Security Council). Sure, he's smarter than folks think, he's won more races for governor than anybody in the state's history, and Texas is a big energy state – but I still wonder why you picked him. I'm not sure he's got what President George H.W. Bush used to call "the vision thing." He's run for your job twice, and you'll remember he wanted to shut down the Energy Department. Now I guess he doesn't. Kinky Friedman, this musician/comedian/writer from Austin, ran against Perry for governor a few years back and called him "Governor Good Hair." Maybe that's why you picked him. You clearly know a good 'do when you see one.

As far as the issues go, I think you've got some things right, including support for the Dakota Access and Keystone XL oil pipelines. You're going to take some heat from environmentalists, but don't let that bother you. Those pipelines mean jobs for Americans, and don't worry about all those reports casting doubt on that. If the Canadian oil intended for the Keystone XL pipeline doesn't come here, it'll go someplace else – like China. That's no good.

Kudos to you, too, for being bullish on fracking. The country's awash with shale oil and gas, and oil exports are back for the first time in years. Just when it looked like oil prices might put the kibosh on several fracking projects, low oil prices have allowed them to move forward. Voila, "Permania"! The giant shale play in the Permian Basin could have 20 billion barrels of oil and 16 trillion cubic feet of natural gas. That means more oil on the market and lower crude oil prices, which give our friends in OPEC and the Russians a bad case of nerves. Good.

All the shale oil and natural gas showing up to the Energy Prom brings me to my last point. A decade ago everyone was babbling about "peak oil" and the evils of those God-forsaken, gas-guzzling Hummers. Now the issue is "peak demand," and GM doesn't even make Hummers anymore (they were ugly). In 2006, the US ranked 11th in the world in proven oil reserves. Now, thanks to the fracking boom and shale oil, the U.S. is Numero Uno. Check it out. America is great again.

A speaker at the UH symposium said oil and natural gas are cheap, reliable and plentiful sources of energy. He's right, but that's just for now. A decade's nothing – just two years past the end of your next term in office. If nothing else, the last 10 years have shown us just how quickly things can change, and change is certainly in the air when it comes to energy. So, go long – take the blinders off and think about energy out 30 or 40 years. Don't be afraid to cozy up to new sources of energy, including renewables like solar and wind. Not many people know it, but Texas produces more energy from wind than any other state (plenty of hot air). I'm afraid you're going to have to finalize a split with coal, though. That miner's daughter's not coming back.

Well, that's it for now. I've got to go fill up my car and then wade through as much of Alexis de Tocqueville's Democracy in America as I can manage before noon (it's a beast – be glad you don't need to read it). Maybe I'll write again sometime. Until then, I remain,

Yours in oil (crude, that is – with associated gas),

Politicus Maximus Texanus ■

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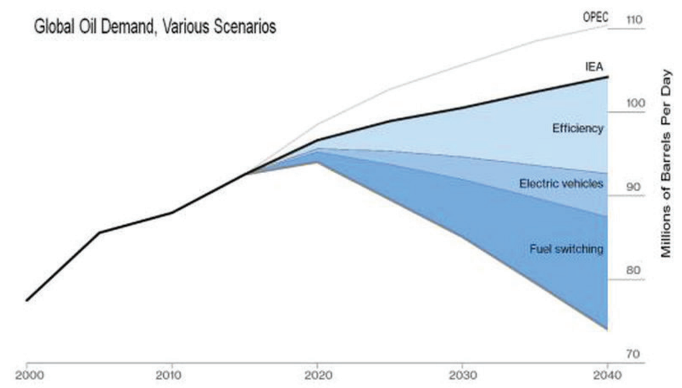
PEAK OIL DEMAND: WHEN IS IT REALLY COMING?

EARL J. RITCHIE Lecturer, Department of Construction Management, College of Technology

There is a widely held belief that the peak of oil consumption will result from demand reduction rather than depletion. Published scenarios depicting how soon this might happen are all over the map, ranging from less than three years to beyond the foreseeable future.



Source: Modified from Bloomberg 2017

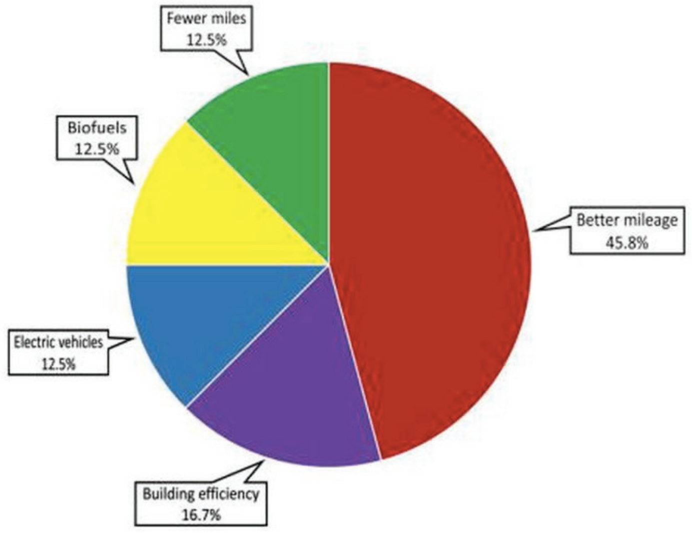
Three broad categories of means to reduce consumption are illustrated by the shaded areas in the graph above. Efficiency includes improved fuel mileage and ways to reduce miles traveled, such as mass transit and ride sharing, as well as efficiency in buildings and other non-transportation uses. Electric vehicles include hydrogen fuel cell vehicles. Fuel switching includes biofuels and natural gas.

Published scenarios are influenced by philosophy, with forecasts of later peak demand usually coming from oil industry sources or traditionally related organizations and forecasts of an earlier peak from the renewable energy industry and environmental organizations.

In addition to continuing progress in vehicle fuel economy, renewable fuels and electric cars, the pace of future reductions will depend to a significant degree upon behavioral factors: the willingness to reduce driving, use alternative transportation and abandon fossil fuel cars for electrics. In the US, these changes have been slow in coming.

How oil consumption can be reduced: The US case

Let's consider each of these measures, using the 2013 Union of Concerned Scientists (UCS) Half the Oil Plan as an example. This plan applies only to the United States, however, it illustrates potential reduction measures elsewhere.



Data from Half the Oil Plan

Improved fuel mileage - Light vehicle fuel economy is the largest single component of the UCS plan, accounting for a four million barrel per day reduction by 2035, one third of the total. Fuel efficiency of commercial vehicles and airplanes adds another 1.5 million. This reduction depends in part on increasing U.S. Corporate Average Fuel Economy (CAFE) standards, currently scheduled to approximately double fuel economy by 2025. A recent announcement by President Trump suggests these standards may be lowered.

Reducing miles traveled – This category includes a variety of measures requiring behavioral changes. They fall into three categories:

1. Substituting other means of transportation, such as walking, bicycling and mass transit
2. Increasing vehicle occupancy by carpooling, vanpooling and ride sharing
3. Reducing trip frequency or length by denser housing, trip chaining, decreasing discretionary driving, four day work schedules and similar methods

Changes such as carpooling require only a behavioral change. Mass transit and development patterns that reduce commute distance may require substantial investment and time to implement.

The UCS plan estimates a 1.5 million barrel per day reduction from these methods. The category includes "smart roads," a catch-all term encompassing a number of technologies to increase travel efficiency.

Electric vehicles – In most analyses, oil savings by electric vehicles is a significant but relatively small component of oil demand reduction, primarily due to slow adoption. The UCS estimate is 1.5 million barrels per day, about 12% of the total. This is a substantially lower share than in the Bloomberg estimate, however, Bloomberg includes ride sharing.

Fuel switching – Biofuels, primarily ethanol in the U.S. and biodiesel in Europe, currently represent less than 5% of world transportation fuel. The environmental benefit of first generation biofuels is controversial, and biofuel crops compete with food to crops, raising food prices. The UCS estimate of 1.5 million barrels per day is based on second generation biofuels, which do not compete with fuel crops. They have not proved commercial date.

Smarter transportation – The UCS attributes 1.5 million barrels per day to smart transportation, which they do not describe in detail. Postulated reductions in this category commonly result from ride sharing services, such as Uber, and car sharing services, such as Zipcar. These services only reduce miles traveled if the users drive less than they would in an owned vehicle. The underlying assumption seems to be that the need for driving will be reduced by mass transit, mixed use development or other measures, requiring only infrequent driving. It is these changes rather than the sharing services that cause the reduction.

Self-driving vehicles are predicted by some to reduce oil consumption. The timing and effect of autonomous vehicles has its own wide range of predictions. There's not agreement whether they would increase or decrease consumption.

Efficiency in non-transportation uses – Energy use in buildings is very important in carbon reduction, however, only about 5% of building energy worldwide is provided by oil. The UCS estimates improvements in building heating and industrial fuel use can save two million barrels per day.

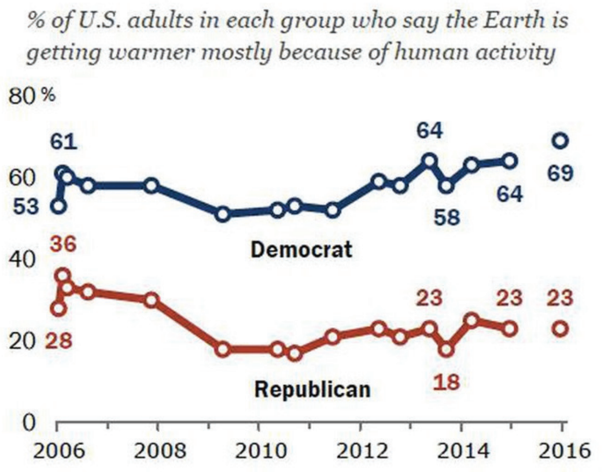
Scenarios are dependent on many factors, not all of which are mentioned above. Many technological factors, such as improvements in fuel mileage and building energy use, can be predicted with reasonable certainty. Others, such as commercialization of second generation biofuels and hydrogen fuel cell vehicles, are difficult. Population and economic growth will have strong influence.

The importance of behavioral factors

Perhaps the most difficult set of factors to anticipate are behavioral. Americans are notoriously wedded to their automobiles and are resistant to mass transit and carpooling. Per capita mass transit and carpooling have been basically flat since the 1970s, while per capita vehicle miles traveled have gone up 80 percent.

It is an item of faith among many climate change believers that once individuals appreciate the “fact” of anthropogenic climate change, they will embrace the low carbon lifestyle. There are two problems with this viewpoint: Not everyone believes human activity is the primary cause of climate change and many who do believe are more driven by economics and convenience than climate concern.

Although climate concerns have been rising, the share of the U.S. population that considers it a serious threat is still a minority. Belief is strongly divided politically and geographically.



Source: Modified from Pew 2016

A series of Pew surveys shows Democrats are three times more likely to believe than Republicans. I find this divide mystifying, since climate change is a science issue rather than a political one. Regardless, about half of the U.S. population does not see it as a major problem.

Perhaps the more significant problem is that climate belief often does not translate into climate action. There are many reasons for this, but it has been well demonstrated that economics, convenience and personal freedom usually have higher priority. This casts doubt of the likely pace of reducing miles traveled and adopting alternate transportation.

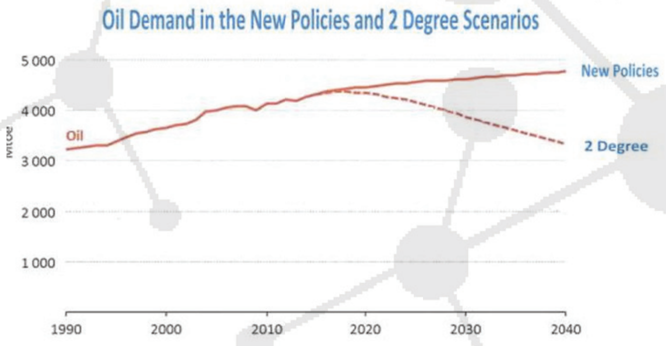
Millennials are often cited as being more receptive to an eco-friendly lifestyle; in particular, they are more likely to use mass transit. This is true, although it appears to be because they are poorer and more debt-laden than previous generations. Their car ownership is increasing with the improving economy.

The bigger picture

The U.S. is not the world. Environmental awareness is higher in Europe, so somewhat faster demand reduction might be expected there. However, it is almost universally believed that most demand growth will be in China and India, with substantial contributions from other industrializing countries. There are also variations in estimates of this growth and its energy intensity, depending upon factors similar to those discussed above.

What’s really likely to happen

It should be clear from the discussion above that a definitive answer is not possible. The IEA says “no path of development of the global energy system can be confidently drawn to 2040.” Let us consider the base case to be the Nationally Determined Contributions (NDCs) under the Paris Agreement. Per the IEA’s assessment of those commitments, the New Policies scenario, oil demand grows through 2040.



Source: Modified from IEA 2016

Although the IEA scenarios are among the most widely cited, they are often criticized by environmental groups for being too fossil fuel and nuclear energy oriented. I share some of those criticisms, however, relatively minor weaknesses in the IEA and other mainstream forecasts are not as important as whether the NDCs and additional measures that might significantly reduce oil demand are likely to be implemented.

There is some question whether countries will reach their commitments. A 2016 report by Averchenkova and Bassi assesses the credibility of pledges. Two key countries, China and India, are assessed as having “potential for increasing support to credibility,” the lowest category. The United States ranks near the bottom of the middle category, “moderately supportive.” The recent decision by President Trump to withdraw from the Paris Agreement adds further question to the pace and extent of U.S. carbon reduction measures.

Of course, there is some possibility that individual countries or the parties collectively will exceed their goals. There is also private action by companies and individuals. Still, more strenuous action would be necessary to achieve peak oil demand.

Council scenarios peak in 2030, however, these depend heavily on the development of second and third generation biofuels. It is fair to say that only scenarios with the most stringent CO_2 reduction result in a decrease in oil demand before 2035.

A 2014 report by Carbon Tracker compared forecasts of oil demand from the IEA, Shell, BP, ExxonMobil and OPEC. All except the IEA 450 Scenario, equivalent to the two degree scenario, forecast increasing oil demand through 2035. Even some scenarios with relatively stringent CO_2 limits in the Intergovernmental Panel on Climate Change Fifth Assessment do not have oil consumption peaking before 2040.

There are published predictions that petroleum fuels will be displaced more quickly. The Bloomberg article speculates it could be as early as 2020. Two of the three World Energy Progress made to date and the stated intentions of governments show definitively that renewables will grow faster than fossil fuels and carbon intensity will decrease. Nonetheless, the best evidence suggests that oil consumption will not peak before 2035, and may peak substantially later. ■

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BIG DATA COMES TO DEEP-WATER DRILLING

MATT FRANCHEK Professor, Cullen College of Engineering and Former Director, Subsea Engineering

An unexpected equipment failure can affect offshore producers much the way an unexpected closure of Interstate 10 affects Houston drivers. Everything comes to a stop. For drivers, that means lost time. For offshore operators, lost time means less money to the bottom line.

That's bad news for companies and their shareholders as unplanned equipment shutdowns cost billions of dollars each year, potentially driving the cost of producing offshore oil well above today's market prices

The safe and economical recovery of future oil and gas resources demands operational efficiency, and this efficiency can be realized only if there are no unplanned downtimes due to equipment failures. Almost all oil field equipment now is fitted with sensors that provide data about operations, and increasingly production companies are realizing that those terabytes of data streaming from the monitoring sensors built into equipment can be used to improve operational efficiencies and, ultimately, profit margins. Why shut down if they don't need to?

The traditional method of interpreting the data takes months and requires that it be stored for extended periods of time. Data analytics is changing that.

Data analytics uses mathematical modeling to harness "big data," the huge amounts of data that flow from the increasingly connected world around us. Posts on Facebook, Instagram and other social media sites can be captured and analyzed for trends and other useful information. Oil and gas companies are interested in using the industrial internet of things - the idea that "smart" machines using big data technology and machine learning are better than humans at accurately and consistently capturing data.

The goal is to perform maintenance as it is needed, rather than following a rigid, pre-set schedule - potentially losing production time for unnecessary maintenance or suffering an unanticipated shutdown when equipment fails before the scheduled maintenance time.

The system operates on the same principal as that used by your car to estimate how much farther you can drive without running out of gas, an estimate that is constantly adjusted based on your driving patterns. The potential benefit goes beyond financial savings through avoiding unnecessary shutdowns. It also is expected to reduce risks to both workers and the environment as companies gain advance warning before potentially disastrous accidents.

This technology goes one step further by analyzing overall operations, including worker performance. Complete coordination through the integration of data from both workers and equipment is now possible, with workers assured that the equipment is available and reliable. It can also reduce data storage costs - data can be stored in the cloud rather than on production platforms, where space is at a premium.

Beyond that, data can help identify future design modifications much like evolution. The reality is that the equipment can now "speak" through the data streaming from various sensors to identify when it is stressed, much like an athlete can report signs of injury before it becomes debilitating.

Companies already have begun to realize these savings; key players in the industry developed a process for using this data, which has gone through rigorous testing over the past 18 months. I worked with them to develop a curriculum to train engineers to use mathematical modeling, simulation and data processing to capture and use this data for real-time condition and performance monitoring of oil and gas production systems.

Monitoring and managing big data is a growing discipline, not just in the energy industry but also in health care, aerospace and other industries.

The large variety of data ranging from numerical to alphabetical to images, all streaming in real time from thousands of sensed values, is what makes big data analytics big. There is a renaissance underway in the oil and gas business, and model-based data analytics is its foundation. ■

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WELCOME TO 'ALL OF THE ABOVE' TRANSPORTATION

RAMANAN KRISHNAMOORTI Chief Energy Officer, University of Houston

Electricity generation has moved in dramatic fashion toward an "all of the above" strategy, especially in Texas and other states where wind and solar are responsible for an increasing amount of power flowing through the grid. Wind energy accounted for about a quarter of power generation in Texas during the first quarter of 2017.

Transportation, on the other hand, is still largely dependent on gasoline and diesel from crude oil, despite attempts to use hydrogen, biofuels and natural gas as cleaner alternatives. Recent announcements from Volvo and Tesla, however, signal a sea change. Volvo has pledged to become the first major car manufacturer to go electric, with every new model starting in 2019 equipped with an electric motor – all electric, hybrid or plug-in hybrid.

Tesla will deliver the first of its Model 3 all electric cars later this month, priced at about $35,000.

With that, the future of transportation began to shift, redefining personal and commercial transportation for the next 50 years in the United States and globally.

It won't happen overnight. Barriers remain, from range anxiety with full electric vehicles to an already overburdened and aging electric grid. Affordable grid-scale energy storage remains elusive. But the benefits for sustainability and the environment will be significant, and the decisions by Volvo and Tesla provide needed momentum.

Transportation makes up roughly a third of energy demand in the U.S. and is almost entirely based on crude oil. Efforts over the past 15 years have tried to incorporate ethanol, biodiesel, hydrogen and natural gas into the transportation ecosystem, but each has its own problems – corn-based ethanol has driven up food prices, for example – and penetration remains low.

The lower power density of these alternatives, coupled with an underdeveloped network of fueling stations, has stymied their use for freight hauling, and they have had little impact on carbon and other emissions.Clean diesel, a highly energy efficient technology, isn't an oxymoron, but the Volkswagen scandal soured those prospects, as well.

So clearly, something else is required to lower transportation's carbon footprint if we are to move to a more sustainable future, whether or not the United States is an official signatory of the Paris Accords.The Volvo and Tesla announcements are a start.

That doesn't mean the immediate end of the internal combustion engine. All electric vehicles will be a niche market for the foreseeable future, even as market share grows. Growth, especially when viewed globally, will be uneven, with gasoline and diesel vehicles shrinking more quickly in some regions of the world, even eliminated entirely.

The coming decades give us time to prepare for the challenges ahead:

•Without big jumps in energy efficiency and conservation, an all electric fleet will require doubling existing base load electricity generation in the United States. That's more complicated than it might seem. Nuclear appears stagnant or in decline, and coal, even coupled with carbon capture systems, faces environmental, cost and technological barriers. Expanding natural gas-fired generation will require a multi-trillion dollar infrastructure expansion in the U.S., and would require more exports to countries without domestic natural gas supplies.

•Grid-scale storage will allow a mix of distributed and intermittent sources – think solar and wind, which aren't available 24/7 – to power this emerging market, but that too will require investment and research.

•Until the energy density and life-cycle cost of replacement fuels such as natural gas, hydrogen and all-electric vehicles can match that of gasoline and diesel, fossil fuels will retain a price advantage. Booming production in Texas' Permian Basin suggests supply in the U. S. won't be an issue.

•Regulatory policy must be updated to accommodate new grid and microgrid networks.

These challenges do nothing to undermine the significance of the push for electric motors and cars to augment and replace the traditional internal combustion engine. Change is coming, and it won't be stopped just because questions involving regulatory policy, government subsidies and infrastructure projects remain unanswered.

Incremental and disruptive technology changes already are underway. Volvo and Tesla offer tangible proof of that. ■

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