Wilson Center

2015 GLOBAL ENERGY FORUM | REVOLUTIONARY CHANGES AND SECURITY PATHWAYS

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Wilson Center
Washington, DC

Jan H. Kalicki (editor)

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INTRODUCTION

Jan H. Kalicki

Thanks to Kathy Butterfield, Angelina Fox and Xuejiao Liu for their editorial and design assistance.

Revolutionary changes are occurring in the global energy landscape, as a wider number of producers and types of energy come into the world market. Most notably, the United States is becoming the world's largest energy producer; technology is multiplying the output of shale oil and natural gas; renewable energy and nuclear power are the fastest growing sources even if fossil fuels continue to dominate the energy mix.

At the same time, the carbon content of the earth's atmosphere continues to build, and more and more countries recognize the need for urgent action to contain climate change. Prospects for an adequate global response, at the UN climate change conference in Paris (COP-21) and elsewhere, are still insufficient, and more concerted – indeed, revolutionary – action will be required in both technology and politics.

To better assess both the realities and the action agendas, the Woodrow Wilson Center convened on September 21, 2015 a Global Energy Forum on Revolutionary Changes and Security Pathways. Adam Sieminski, Administrator of the U.S. Energy Information Administration, made keynote remarks on Global Energy Markets, followed by Robert Johnston, CEO and Natural Resources Head of Eurasia Group, who spoke to the Geopolitics of the New Oil Environment.

Amy Jaffe, Executive Director of Energy and Sustainability at University of California Davis, then probed further into the geopolitical equation by addressing regional turbulence and realignment, with reference to Middle East conflicts and the new geopolitics of oil.

Complementing the geopolitical perspective was the climate change agenda. David Victor, Professor of International Relations at the School of Global Policy and Strategy, University of California San Diego, addressed the need for a revolutionary energy system to help meet that agenda.

Security pathways are required to move forward the energy and climate agendas. David Goldwyn, President of Goldwyn Global Strategies LLC, discussed the continuing importance of the Strategic Petroleum Reserve

in meeting future emergency needs of the global energy system. And this writer described the building blocks that will be needed to achieve a coherent national, regional and global approach and to develop, in future, a global energy security system.

In the pages that follow, a full report is presented by the conference rapporteur, Julia Nanay, Principal of Energy Ventures LLC. The report is followed by the individual slides and written presentations of Adam Sieminski, Robert Johnston, Amy Jaffe with Jareer Elass, and David Victor.

Certain key points became clear in the course of the Global Energy Forum. First, the world is no longer beholden to a small number of energy producers. OPEC faces major challenges in maintaining its internal consensus, and non-OPEC members now represent over 56 percent of the world's energy production.

But second, the democratization of energy production faces two sets of challenges – and opportunities. Over $200 billion in new global oil and gas project spending is estimated to have been delayed or cancelled because of low energy prices, which have also impacted the development of shale and renewable resources. At the same time, they have inspired more technology innovation and provide a wider economic boost at a time of global recessionary pressures. Robert Johnston described a $50 per oil barrel pivot point for future investment – the rig count for U.S. shale in particular would grow above that price point – whereas Adam Sieminski noted an unusually wide market-implied price band between $25 and $100 per barrel.

Communication and decision gaps represent another challenge as well as opportunity. No organization currently assembles the right players to make the necessary security and climate progress required by the global system. This leads David Victor, for example, to suggest "technology clubs" to achieve the revolutionary changes needed to manage climate change. Similarly, as more consumers are producers – Russia and the United States, for example – and

as more producers are consumers – Saudi Arabia and the Arabian Gulf, for example – new forms of producer-consumer dialogue can and should be envisaged.

Third, it will take time for energy markets to rebalance above $50 per oil barrel. Johnston forecast prices continuing to languish in the $40 per barrel range for the remainder of 2015, before gradually being pushed to average in the low $50 per barrel range in 2016, with rebalancing and a price recovery not until Q3 2017 at the earliest. Sieminski points out that 2016 global demand forecasts have increased while supply forecasts have decreased; Johnston's overall view is that while non-OPEC production declines are significant, "a demand-led rebalancing of the global oil markets is much more likely than a collapse of supply."

Fourth, energy and geopolitical issues need to be re-integrated in light of current realities. As Jaffe and Elass makes clear, one cannot simply analyze individual shortfalls, as in the case of Iraq and Libya. Rather, it is necessary to assess the cumulative impact of shortfalls, augmented by the increased infrastructure targets and other risks resulting from the Islamic State and regional instability as a whole. A situation of relative energy abundance can devolve into one of relative shortages, making emergency response coordination as timely as ever – as pointed out by David Goldwyn in his call for a flexible and modernized Strategic Petroleum Reserve policy.

Fifth, energy and geopolitics interconnect with climate and should not be kept artificially separate from one another. The major progress needed on climate will call for major adjustments in the energy system – from marked reductions in coal to large-scale carbon capture and storage, from increased use of natural gas to marked increases in non-fossil energy sources. This requires major collaboration involving new technologies and advanced technology players. As David Victor points out, this entails international cooperation on innovation policy to a degree "so far unprecedented in most areas of the modern economy."

Sixth, just as issue areas need to be inter-connected, so do decision processes. Rather than "stove-piped" decisions on energy, climate and geopolitics, comprehensive strategies need to be fostered. In the U.S., this requires White House leadership and coordination – for example, by establishing a new Energy and Climate Security Council headed by an Energy and Climate Security Advisor. Internationally, global groupings such as COP and the G-20 need to be supplemented by more focused efforts involving smaller numbers of states, which can then bring more players into the fold as the necessary progress is achieved.

The Global Energy Forum highlighted many of these issues and opportunities for further progress in energy, climate and geopolitics. In future steps, the Woodrow Wilson Center will build on the Forum's discussions by sponsoring more focused dialogues on these issues, on an integrated basis, in the context of both regional and global initiatives which can be undertaken by the United States and our global partners.

FORUM AGENDA

2015 GLOBAL ENERGY FORUM:
REVOLUTIONARY CHANGES AND SECURITY PATHWAYS

Woodrow Wilson Center, Washington, DC
September 21, 2015

Keynote: The Energy World Ahead

Hon. Adam Sieminski, *Administrator,*
U.S. Energy Information Administration

Panel 1: A Global – and Revolutionary – Energy System

Moderator: **Jan H. Kalicki,** ***Woodrow Wilson Center***

Geopolitics and the New Oil Environment

Robert Johnston, *CEO and Natural Resources Head, Eurasia Group*

Toward a Revolutionary Energy System

David G. Victor, *Professor of International Relations, School of Global Policy and Strategy, University of California, San Diego*

Regional Turmoil and Realignment

Amy Myers Jaffe, *Executive Director, Energy and Sustainability, University of California, Davis*

The international energy system is going through revolutionary changes. Oil and natural gas production has grown in the United States and elsewhere in response to new technologies for unconventional and other development. Yet prices are falling as Saudi Arabia and other producers – including prospectively Iran – race for market share. Further revolutionary changes will be needed to cope with the challenges of climate change. Geopolitics face several inflection points, from a turbulent Middle East to increased Russian pressure in Europe and Chinese pressure in East Asia. Panelists Robert Johnston, David Victor and Amy Myers Jaffe will probe these changes and their future implications.

Panel 2: Pathways to Global Energy Security

Moderator: **Robert Johnston, Eurasia Group**

A More Resilient Energy System

David L. Goldwyn, *Principal, Goldwyn Global Strategies LLC*

A Global Energy Security System

Jan H. Kalicki, *Public Policy Fellow and Energy Lead, Woodrow Wilson Center*

New pathways must be developed to advance global energy security at a time of revolutionary change. The system must be more resilient, as energy trade is vulnerable to interruption, and as strategic petroleum reserves need to be modernized. On a global as well as national and regional basis, more far reaching steps are needed toward a global energy security system. Panelists David Goldwyn and Jan Kalicki will discuss these future pathways.

Forum Rapporteur: **Julia Nanay, *Principal, Energy Ventures LLC***

FORUM REPORT

Julia Nanay

On September 21, 2015, the Wilson Center brought together a group of experts to discuss revolutionary changes shaking up the international energy system and to offer pathways for promoting global energy security.

Revolutionary changes in the international energy system are occurring with respect to the availability and the composition of energy resources, geopolitical upheavals, and growing climate concerns.

The experts outlined how new technologies have triggered oil and natural gas production growth in the United States from unconventional resources (shale oil and shale gas). Shale now accounts for more than 50% of U.S. oil production and close to 50% of U.S. natural gas production. This U.S. success has increased the level of global supplies, which have outpaced global demand growth and helped drive oil prices lower. The downward pressure on oil prices has been further fueled by Saudi Arabia's strategy to build its market share by choosing not to cut its production last November and instead, raising its output to record highs. Low prices are now taking a toll on U. S. oil production, which also reached record highs earlier this year, but has since declined.

The expansion of global oil supplies could be affected by geopolitical developments, primarily in the Middle East, where conflicts are damaging or destroying essential oil production capacity and infrastructure in a region that accounts for 30% of global oil supplies.

Possible supply disruptions spur the need for defining pathways for energy security. Moving toward alternative fuels would be one of these pathways, dovetailing on concerns related to climate change. But progress on revolutionary technological breakthroughs to address climate change has been slower than needed, and low oil prices may impede serious advances.

In the short term, 2015 production growth in the top U.S. shale producing regions (the Permian, Bakken, Niobrara, and Eagle Ford) has recently been reversed. The Energy Information Administration (EIA) continues to show a U.S. shale oil downturn, which is reflected in their 2016 forecast of a decline in overall non-OPEC supplies.

In contrast, according to EIA Administrator Adam Sieminski, overall supply from the 12-member Organization of Petroleum Exporting Countries (OPEC) has been rising. This is due in part to Saudi Arabia's continued high production in line with its strategy of defending market share. OPEC supply is expected by the EIA to jump further in the second quarter of 2016 due to implementation of the Iran nuclear agreement's Joint Comprehensive Plan of Action (JCPOA). While there is a variation in estimates of projected Iranian production next year, EIA expects that 700,000 to 900,000 barrels per day (bpd) could come back to markets relatively quickly. Amy Myers Jaffe, Executive Director, Energy and Sustainability, University of California, Davis, argued, however, that there is considerable uncertainty related to the timeframe in which Iran can bring this level of production back to world markets.

While OPEC surplus production capacity is the lowest it has been since 2008, OPEC oil inventories are high and global oil stockbuilds are expected to remain strong. The oil inventories of the 34-member Organization for Economic Cooperation and Development (OECD) are also high and will continue to rise. Alongside the forecast global inventory rise and the drop in non-OPEC oil supplies, OECD demand is expected to grow in 2016. The growth in demand could pull the markets toward greater balance.

As for the broader picture, the long-term EIA supply outlook is for a decline in coal use, as renewables and nuclear energy take some of coal's share.

The issue of where the oil price will settle next year was addressed by Eurasia Group's CEO and Natural Resource Head Robert Johnston who projected an average price in the low $50 per barrel range in 2016. The EIA is advising policymakers and companies to be prepared for a wider range of possibilities, well below and above $50 per barrel. Adam Sieminski said that open positions in options markets notably reflect a wide disparity in market views that range between $25 and $100 per barrel for WTI for 2016.

In terms of U.S. natural gas exports, construction of plants underway will be completed. Because Liquefied Natural Gas (LNG) sales are indexed to the

oil price, the ability of U.S. gas exports to penetrate global markets will be constrained by pricing factors.

With the current low price environment, Eurasia Group notes that over $200 billion of global new project spending has already been delayed, postponed or cancelled as the budgets of oil and gas producers experience severe strains. Cuts in capital expenditures (capex) for oil sands are particularly steep, with a 40% decline in capex for Canada's resources in 2015. U.S. independent shale oil and gas producers reported losses of about $15 billion in the second quarter of 2015, compared to profits of nearly $5 billion in the second quarter of 2014. The result is that the default rate of U.S. energy companies has accelerated to the highest level since 1999.

Saudi Arabia's strategy will remain one of defending its market share, although the Saudis look for the markets to rebalance in 2016. While declines in U.S. crude production are significant – from a peak of 9.61 million barrels per day mmbpd in April 2015 to a forecasted 8.97 mmbpd in September 2015 – this will not be enough, according to Eurasia Group, to balance the market in 2016.

In light of this, growth in global demand is needed to rebalance global oil markets. A drop in non-OPEC shale output, along with production declines from deepwater projects and oil sands, will not be enough to underpin a market recovery. Global demand for petroleum and other liquids is expected by Eurasia Group to rise to a five-year high in 2015, growing by 1.7 (mmbpd) and then by 1.4 mmbpd in 2016 (based on IEA data).

Chinese oil demand, however, though still growing, has slowed since 2012. China's sluggish economic growth and the resulting contraction in the appetite for commodities are expected to continue. Slower demand growth means slower oil import growth, and greater competition for market share in China. State set prices for diesel and gasoline will limit the impact of low oil prices inside China on stimulating demand.

On the positive side for low prices, they have spurred advances in fossil fuels technology and software, allowing producers to remain resilient in the midst of

a market downturn. Wells are being re-fracked and well productivity is rising, while service companies are cutting costs. Technology and innovation in the shale sector will make some U.S. shale oil and gas plays economic at $40 per barrel. If oil prices rise, U.S. shale will be the first to make a comeback.

In order to move the dial on oil prices, market rebalancing will be required. While Eurasia Group does not expect oil markets to rebalance until the third quarter of 2017 at the earliest, EIA sees the market rebalancing in 2016. Factors which would lead to a market rebalancing are: decreasing U.S. and non-OPEC production, continued project cancellations, the end of OPEC supply growth, global oil demand growth, and U.S. gasoline demand growth. For now, while non-OPEC supply is dropping, OPEC supply is growing and the geopolitical context remains structurally bearish. U.S. gasoline consumption has been growing driven by the low oil price and the resulting "income effect." However, increased domestic gasoline consumption does not signal that the long term larger structural factors that have driven the slow decline in U.S. product demand due to tightening efficiency measures are reversing. To that end, the EIA forecasts that gasoline consumption will remain flat in 2016.

Geopolitics could, in fact, tip oil markets toward greater reductions in supply. Amy Myers Jaffe highlighted how the Arab Spring and subsequent regional conflicts are transforming the Middle East, fueling rivalry for influence between Saudi Arabia and its Gulf allies and Iran. The conflicts have spilled over into global oil markets, but instead of leading to higher prices, Saudi Arabia has raised its production to fight a market share war. With the resultant collapse in oil prices, Saudi Arabia seeks to influence military and geopolitical outcomes on the ground in regional wars. But as these conflicts seemingly spin out of control, major oil and gas infrastructure – most notably in Iraq, Libya, Syria and Yemen – is being destroyed and an estimated 1.9 mmbpd of production has been lost, potentially presenting a major challenge to global energy security in a three to five year timeframe.

Some capacity may be permanently damaged or destroyed. The rise of the Islamic State of Iraq and Syria (ISIS) has been particularly alarming for the oil industry. ISIS has set fire to Iraqi refineries and to oil fields they cannot operate.

If we stay on the trajectory we are on today and no one stops ISIS, there will be a supply hole. 30% of the world's oil supply comes from the Middle East, and we can probably no longer count on Middle East spare capacity.

At the same time, it is important to note that the oil industry is a cyclical business: oil prices are cyclical and the geopolitics of oil is linked to the same cycle. The oil price cycle, with alternating high and low prices, has brought alternating cash surpluses and budget deficits to the petro-states of the Middle East. In a high price environment, the petro-states accumulate the weapons that they then use when prices drop, driving regional instability, military conflicts, and the next supply crisis – which results in higher prices.

Oil markets may currently be underpricing the risks of attacks on infrastructure. As we get deeper into various wars, infrastructure is disappearing. If too much production disappears, prices will swing up.

The United States needs to position itself with a number of pathways to address energy security, given these troubling geopolitical trends. We need to be prepared to fill any supply gaps that might emerge due to escalating conflicts in the Middle East. We should stay on course with policies that drive down oil demand, such as promoting alternative fuel vehicles and stricter performance standards for cars and trucks. In addition, U.S. producers could reap the benefits of any global supply hole if the ban on oil exports were lifted. U.S. oil exports could be an important strategic replacement to any lost Middle East supplies on global markets.

The pathways to energy security, according to David L. Goldwyn, President, Goldwyn Global Strategies LLC, should also include maintaining the U.S. Strategic Petroleum Reserve (SPR) to hedge against market and security risks. The SPR's function is one of deterrence and shielding against the loss of supply, particularly as we reflect on the destruction of production and infrastructure in the Middle East. Goldwyn stressed the role of the SPR as a powerful tool in that it is the largest single source of excess supply in the world and shields the United States from catastrophic events or against smaller shocks.

Spare capacity in global markets is shrinking, which leads to the conclusion that we cannot count on a market balancer like Saudi Arabia in the future. There are even risks to Saudi production given the geopolitical tensions with Iran, as well as reports of increased infighting among Saudi royals and of ISIS-linked cells in the Kingdom that have already proven capable of carrying out attacks. If there were an attack on Abqaiq in Saudi Arabia, Basra in Iraq, or the Strait of Hormuz in the Gulf, oil from the SPR would be essential.

To ensure that the SPR can function efficiently, the United States needs to resolve key problems: fix the caverns and get the pipeline and marine loading capacity in place to bring it to market and get it to the water. This means that jetties will need to be installed for shipping the oil.

Given the geopolitical risks facing global oil supplies, SPR policy should be addressed at the White House level as a matter of national security. This will require that a well-staffed, clearly authorized White House official is put in charge of energy security coordination.

More difficult to manage for a pathway to greater energy security are the radical technological breakthroughs required for addressing global climate change. Except for the shale oil and gas revolution in the United States, David Victor, Professor of International Relations, School of Global Policy and Strategy, University of California, San Diego pointed to the fact that technology changes in the energy industry have been pretty unremarkable. The fuels we use have not changed much over time. The lack of revolutionary change for addressing climate change can be considered a major failure.

Historically, the energy sector has been slow to change. Yet, huge changes will be needed in the future to cut emissions at a rate that is much more rapid than ever experienced if we are to contain global warming. So far, there has not been much serious analysis about how such a transformation can occur in the real world. Governments have been good at talking about climate change but unable to put in place the policies that would guide investors to new technologies.

Climate talks have been focused on emissions mitigation more narrowly, without

stressing innovation. The main emissions are greenhouse gases from fossil fuels, which are rising rapidly but which produce useful energy services. Deep cuts in international fossil fuels emissions require new technological breakthroughs and greater international coordination around innovation. Innovation will be key to containing global warming below 2 degrees Celsius.

Companies and governments are not investing adequately in knowledge and innovation. Without a way to organize the energy business so as to bring about international cooperation on innovation, there may not be significant progress on addressing climate change.

The supposedly revolutionary rise of renewables has not made much of a dent in the global energy mix. In the electric power industry globally, centralized fossil fuel-power stations that rely on coal still dominate. Nor has there been much revolution in transportation, where oil continues to dominate. Containing global warming will require cutting global emissions of carbon dioxide (CO_2) by four-fifths over just a few decades, meaning that coal and oil would be heavily impacted. Rethinking supply would lead to rethinking the whole grid system, moving to more de-centralized electric power and away from fossil fuels.

Radical technological breakthroughs will require cooperation and coordination among the world's major polluters. A useful pathway forward, David Victor believes, would be to harness a club approach in climate talks, given that 10 to 12 countries account for 70% of emissions, with China and the United States in the lead. These 10 to 12 countries should form a club in which they work together on innovations to reduce emissions, with each country taking on a particular task. To make this work, governments will have to get more comfortable in collaborative research, development and demonstration (RD&D) projects. RD&D cooperation between the United States and China would be a key element of this club approach.

At the same time U.S. Federal spending broadly on energy RD&D, which has been dropping, must be increased and more incentives need to be created for the private sector to get involved. This could happen if there were more private beneficiaries of RD&D spending.

A big push on innovation will require working on many fronts. For example, there might be a need for coordination of global standards for automobiles. A nuclear breakthrough in small modular reactors would be important given that electric generation is a rich area for finding carbon reductions to retire coal. Significant investment in Carbon Capture and Storage (CCS) is also needed. We could grow plants to absorb carbon. While the market pull of carbon taxes and regulations creates some incentives to invest in new technologies, a market push is also required to test new ideas. Finally, the oil industry will need to play a more constructive role.

The EIA's oil demand forecasts account for carbon reduction, but a more significant impact would come from adoption of the Environmental Protection Agency's (EPA's) Clean Power Plan, which remains the subject of numerous legal challenges. The Clean Power Plan would allow renewables to gain market share in the United States over natural gas. For now in the United States, cheap gas has displaced renewables and coal. Europe, on the other hand, missed out on using gas to replace coal. Moving more aggressively with renewables in the United States could, however, send a conflicting message to the world about the benefits of developing shale gas.

Saudi Arabia understands carbon asset risk and, in response, it has decided to increase oil production and its global market share. It understands that U.S. shale production could be further reduced when the United States raises interest rates and with it, the cost of borrowing for shale producers. Saudi Arabia may be thinking that it should get its oil out of the ground as quickly as possible while it is still worth something. There could be an argument that oil companies are buying back stock because they also have a view on carbon asset risk and are reluctant to spend on assets that will not get produced until long in the future. Saudi Arabia may wait to see where things are in 2018 and if there is a supply hole, it will spend money on additional capacity to fill it, but mostly, it wants to see what happens with climate change policies and the demand for oil.

Up to and beyond the December 2015 United Nations (U.N.) Climate Change Conference in Paris (COP-21), U.S. national security, energy, and climate goals

must be better integrated so that constructive policies can be designed. Before Paris, the United States should decide where it wants to end up with the climate and begin organizing decision-making to get there. Clearly, with a low oil price, it is harder to push for innovation and it will be tempting to resort to more direct regulatory pressure because of the lack of a price pressure that would be there with a high price.

Jan H. Kalicki, Public Policy Fellow and Energy Lead, Wilson Center, concluded that governments more generally - and the U.S. government in particular - need to be better organized to put the right policies in place to address both the revolutionary changes in international energy systems and the pathways that this requires for greater energy security. Decision-making will need to adapt to these revolutionary changes, and U.S. cooperation with other countries will be essential.

While the United States has made progress with the Department of Energy's (DOE's) Quadrennial Energy Review (QER) and the State Department's Bureau of Energy Resources (ENR), greater White House leadership on energy security issues will be required. The United States is already in a dialogue with Canada and Mexico over energy policy, but should pursue this dialogue with other regional groupings as well.

The International Energy Agency (IEA) should have the full membership of China and India. The bottom line is that we need to move forward with a more coordinated global energy security policy that integrates energy and environmental policies, and brings together producers and consumers in more robust dialogue – taking into account that consumers are increasingly producers, and vice versa.

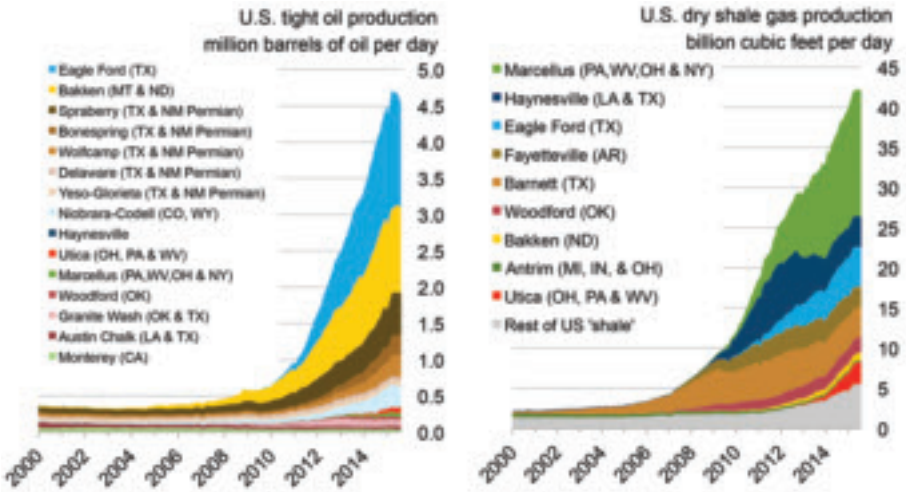
A global energy security system should have seven building blocks: more cohesive national energy policies, integration of energy with environmental goals, global shale oil and gas production, competitive gas markets, a stronger IEA emergency response, an end to energy poverty, and protection for global sea lanes.

GLOBAL ENERGY MARKETS

Adam Sieminski

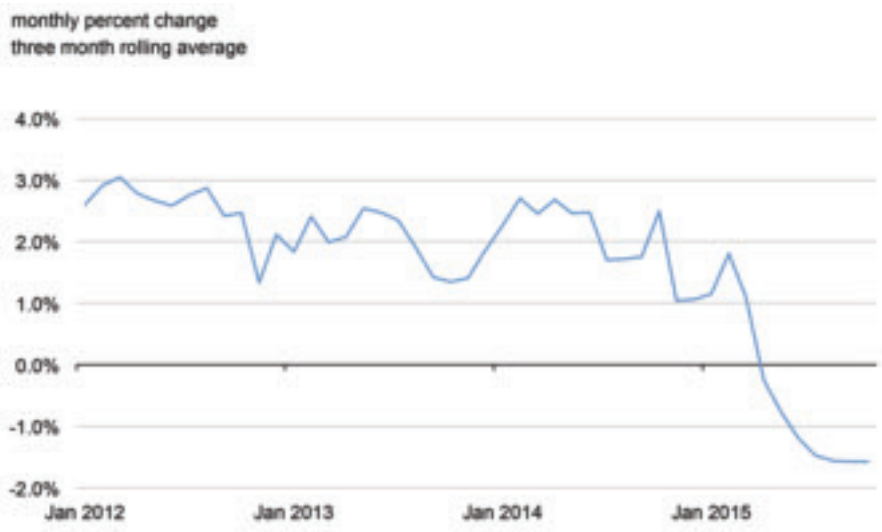
Short-Term Outlook

The U.S. has experienced a rapid increase in natural gas and oil production from shale and other tight resources



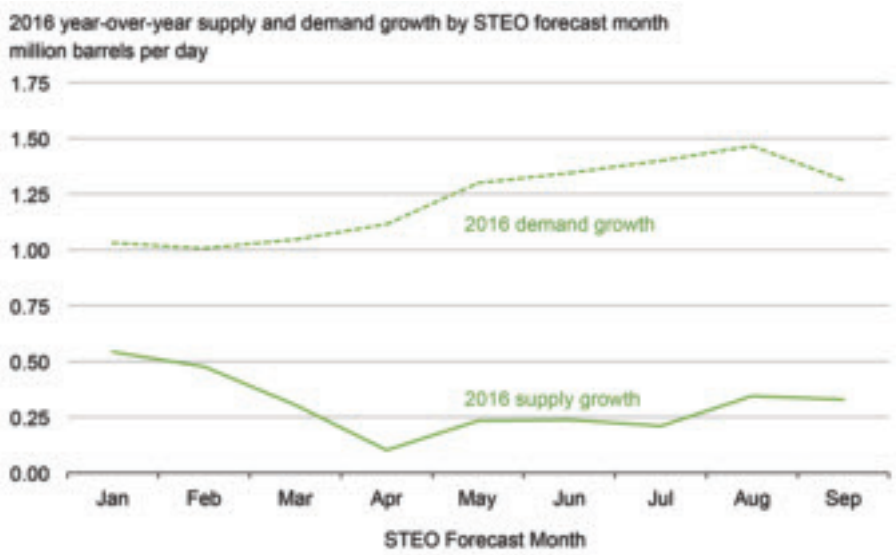
Sources: EIA derived from state administrative data collected by DrillingInfo Inc. Data are through August 2015 and represent EIA's official tight oil & shale gas estimates, but are not survey data. State abbreviations indicate primary state(s).

Production growth in top U.S. crude producing regions (Permian, Bakken, Niobrara, and Eagle Ford) reverses in early 2015



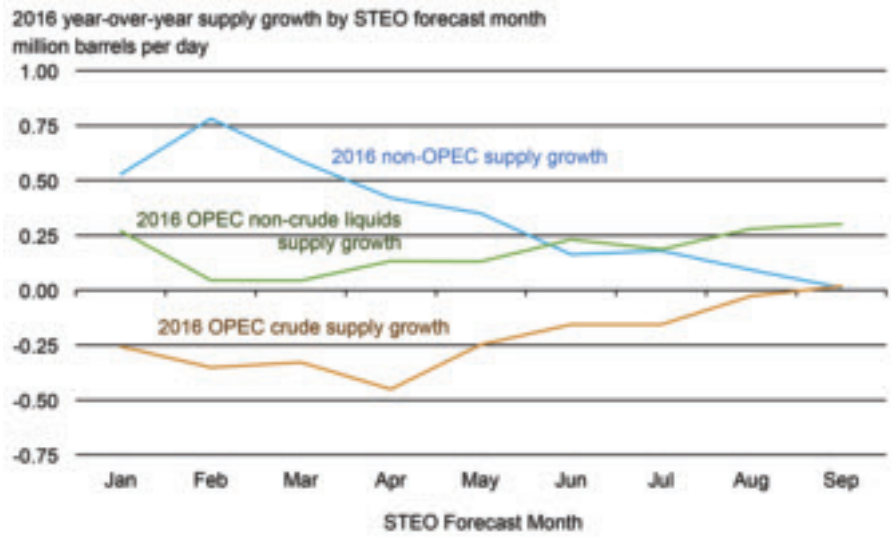
Source: Energy Information Administration, Drilling Productivity Report, September 2015 (chart extends to October 2015)

Forecasts for 2016 global demand have increased while supply forecasts have decreased



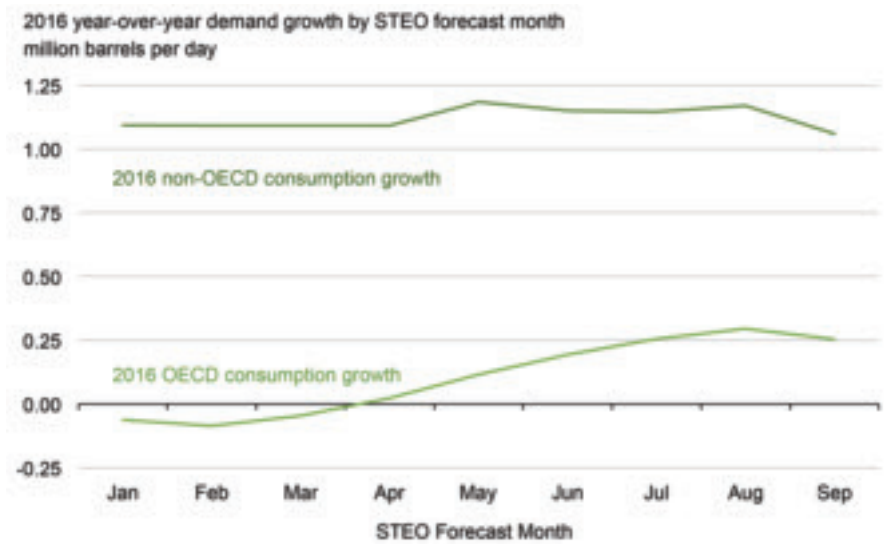
Source: Energy Information Administration, Short-Term Energy Outlook

Forecast for 2016 OPEC supply have risen on the Iran deal, while non-OPEC forecasts have declined, driven by lower U.S. growth



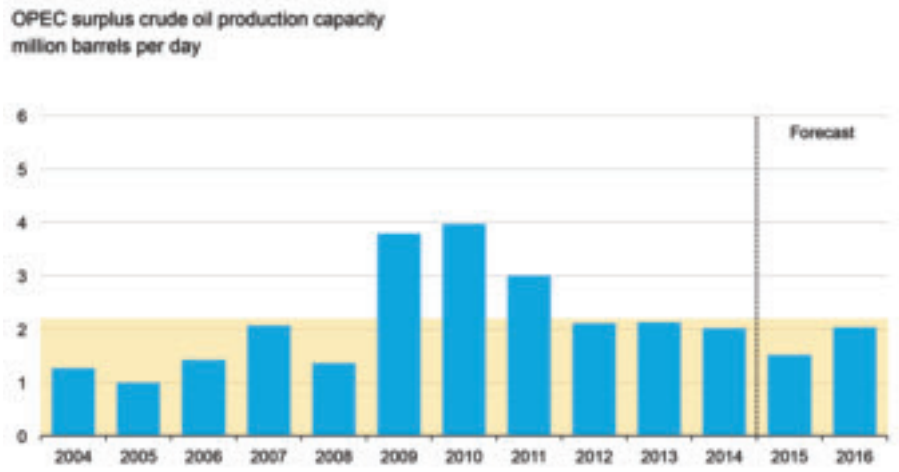
Source: Energy Information Administration, Short-Term Energy Outlook

Forecast OECD demand growth for 2016 has been revised higher



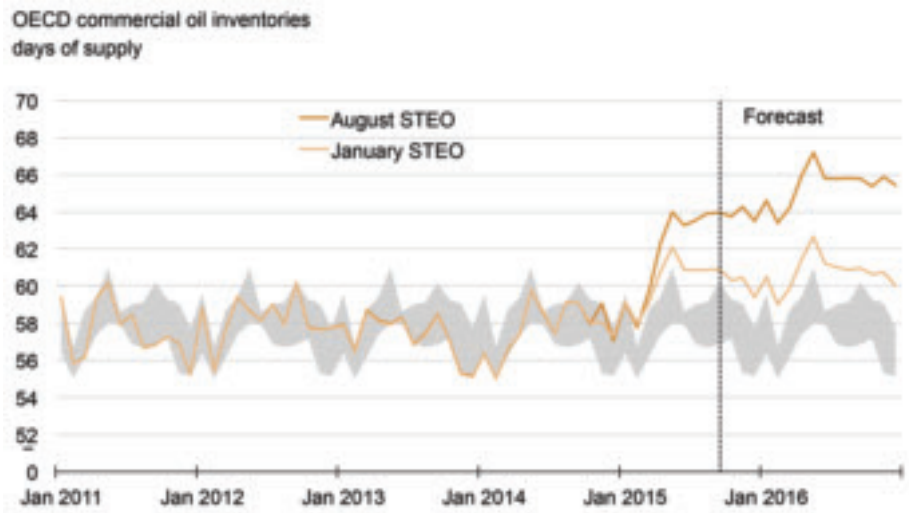
Source: Energy Information Administration, Short-Term Energy Outlook

OPEC surplus production capacity in 2015 is lowest since 2008



Note: Shaded area represents 2004-2014 average (2.2 million barrels per day).
Source: Energy Information Administration, Short-Term Energy Outlook, September 2015

OECD oil inventories are very high on a days of supply basis and are projected to continue increasing

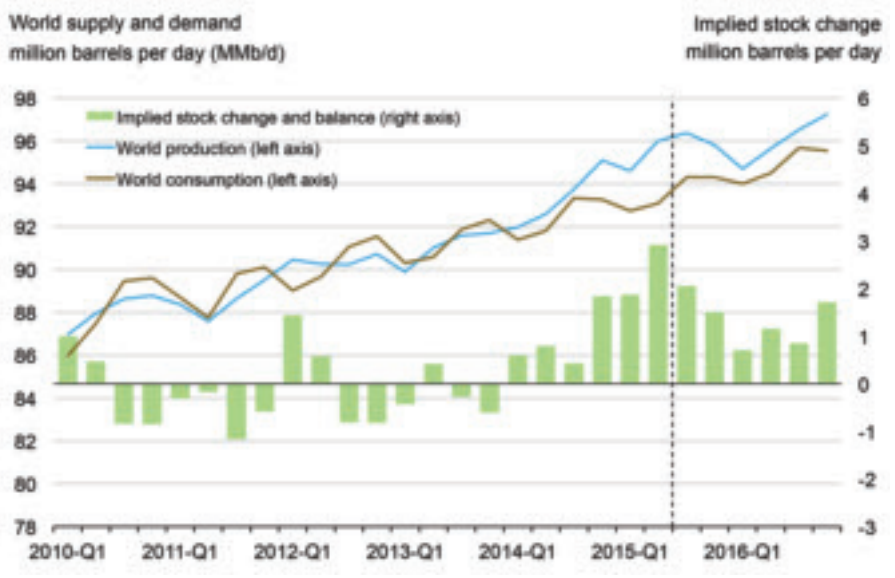


Source: Energy Information Administration, Short-Term Energy Outlook
Note: Colored band around oil stocks days of supply represents the range between the minimum and maximum from Jan. 2010 - Dec. 2014.

Iranian crude oil production is expected to begin increasing in the second quarter of 2016, supply out of inventory will be sold before that

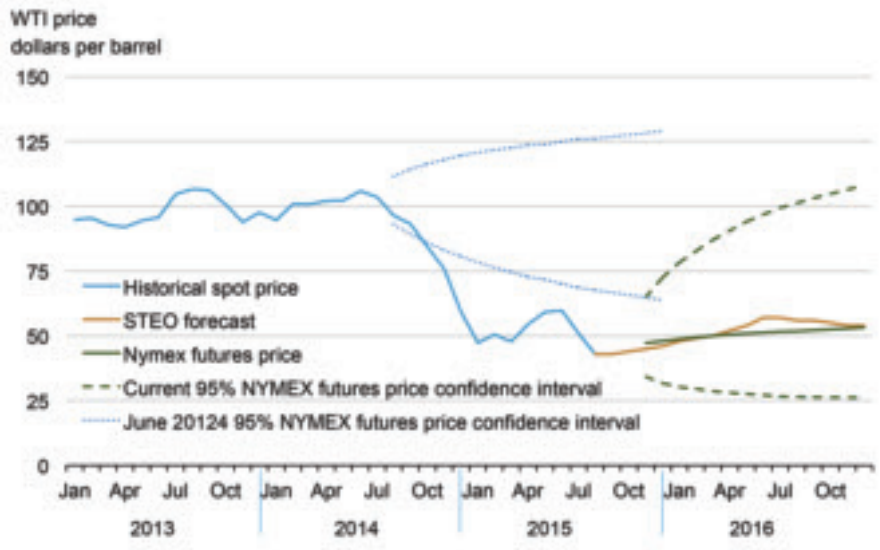
Source: Energy Information Administration
*EIA's assessment

Oil supply and demand begin to rebalance in 2016



Source: EIA, Short-Term Energy Outlook, September 2015

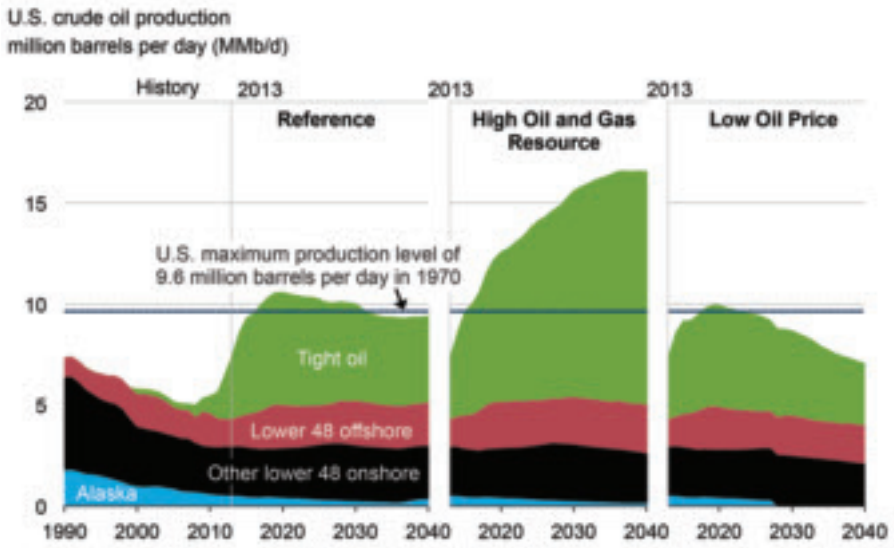
For oil prices, the market-implied confidence band is very wide



Source: EIA, Short-Term Energy Outlook, July 2015

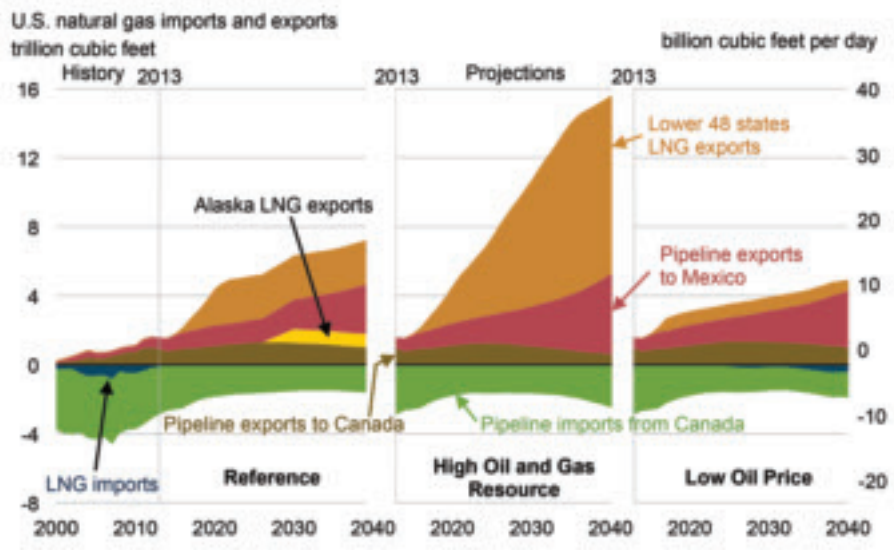
Long-term outlook for the United States

U.S. crude oil production: Supply rises above previous historical highs before 2020 in all AEO2015 cases, with a range of longer-term outcomes dependent on prices, resources and technology



Source: EIA, Annual Energy Outlook 2015

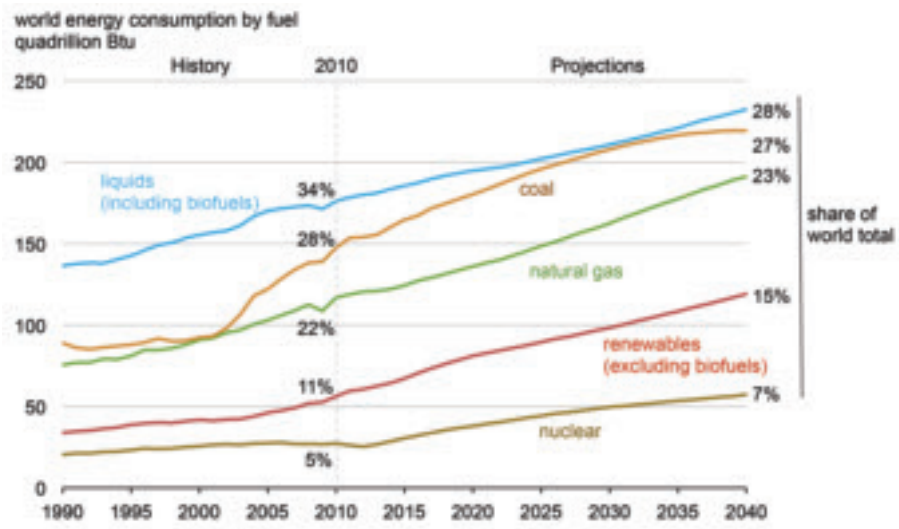
U.S. natural gas trade: Projected U.S. natural gas trade reflects the spread between domestic natural gas prices and world energy prices, along with resource outcomes



Source: EIA, Annual Energy Outlook 2015

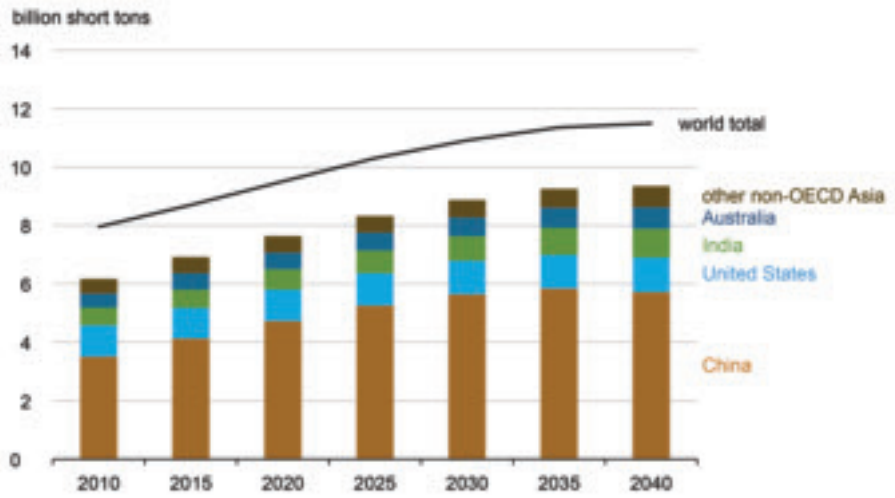
Global long-term outlook

Renewable energy and nuclear power are the fastest growing source of energy consumption



Source: EIA, International Energy Outlook 2013

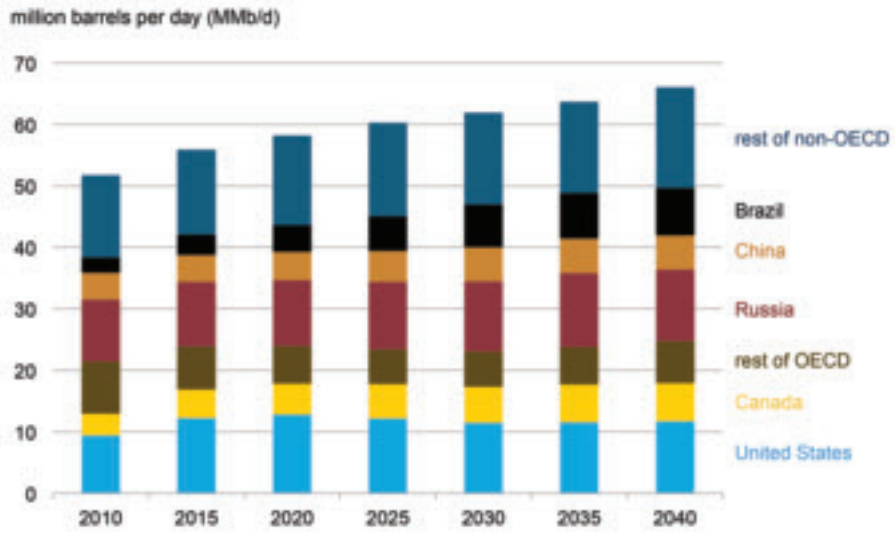
World coal production



Note: Indonesia accounted for 72 percent of the total coal production in Other non-OECD Asia in 2010, rising from 52 percent in 2000. Throughout the projection period, Indonesia continues dominating the region's coal production.

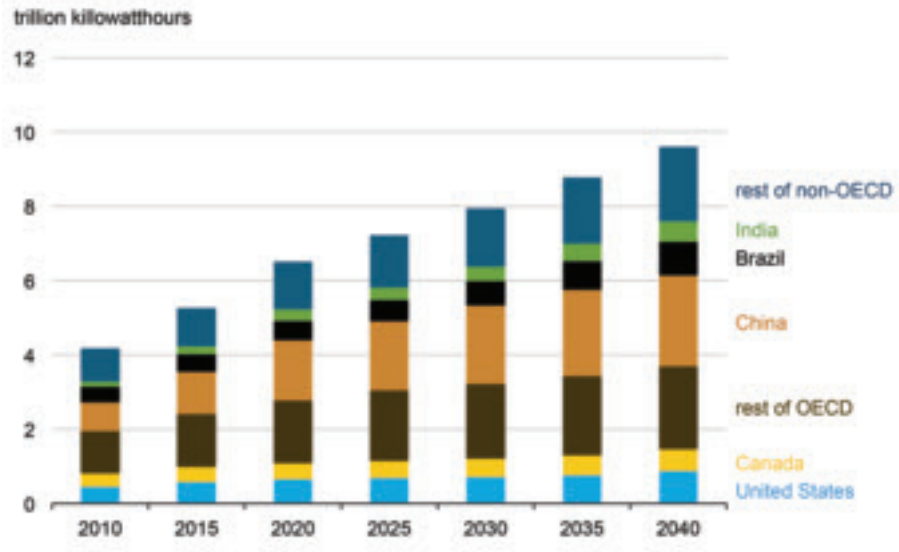
Source: EIA, International Energy Outlook 2013, Reference case

Non-OPEC petroleum and other liquids production



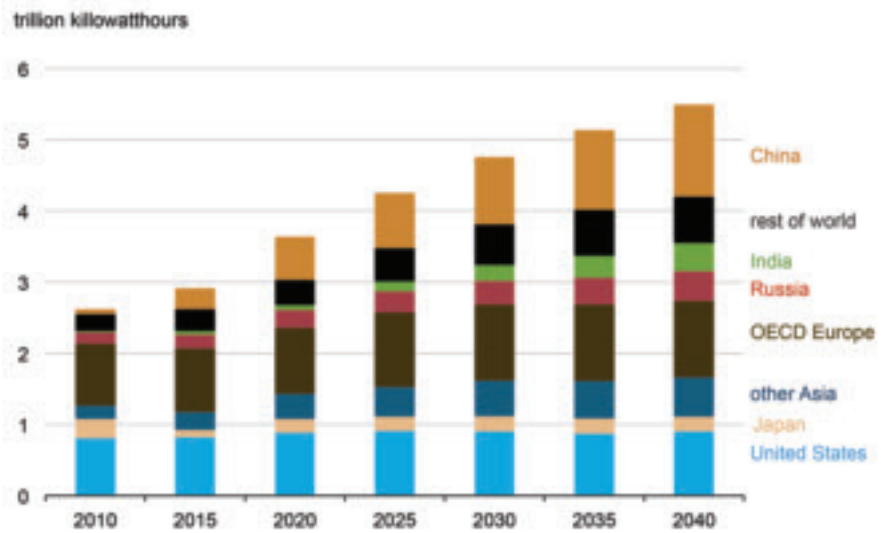
Source: EIA, International Energy Outlook 2013, Reference case

World net hydropower and other renewable electricity generation



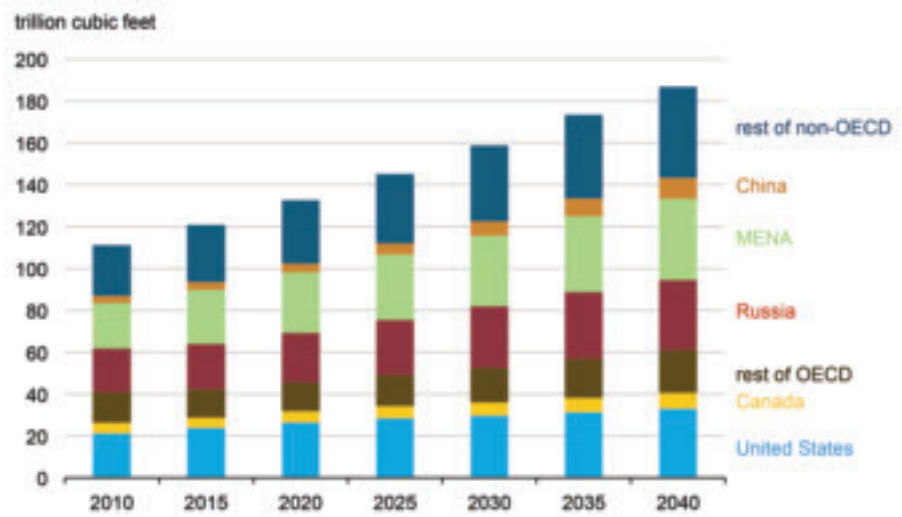
Source: EIA, International Energy Outlook 2013, Reference case

World net nuclear electricity generation



Source: EIA, International Energy Outlook 2013, Reference case

World natural gas production



Source: EIA, International Energy Outlook 2013, Reference case
Note: The MENA region consists of the Middle East and North Africa countries

For More Information

U.S. Energy Information Administration home page | www.eia.gov

Annual Energy Outlook | www.eia.gov/aeo

Short-Term Energy Outlook | www.eia.gov/steo

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GEOPOLITICS AND THE NEW OIL ENVIRONMENT

Robert Johnston

The dynamics of the global oil market have fundamentally changed, in large part due to the tremendous production growth in the United States over the past five years and the decision by OPEC, led by Saudi Arabia, last November to not cut production and let prices plunge. The "new normal" operating environment is hinging at $50 per barrel, where if prices go above $50 for an extended amount of time, non-OPEC production such as U.S. shale becomes profitable again and there would be a resulting rise in U.S. rig count. If prices remain below $50, then non-OPEC output continues to decline as project cancellations are accelerated and capex further reduced.

The current operating environment and lingering low oil prices have already taken a toll on industry and so far estimates show that over $200 billion of global new oil and gas project spending has been delayed or cancelled, with Canada's oil sands taking a disproportionally large hit due to the high cost nature of the industry. U.S. shale producers are also taking a hit, and have reported losses of about $15 billion in Q2 2015 compared to profits of nearly $5 billion in Q2 2014. Smaller shale producers will also feel financial pressure exacerbated by the forthcoming redeterminations of exploration and production (E&P) companies' borrowing bases from banks this fall. Wall Street is now warning about the risks involved in lending to U.S. producers. Shale producers have been very dependent on lenders and capital markets, but as hedges roll off, lenders may start reducing credit lines.

However, the U.S. is not a marginal producer as its shale oil plays remain "sticky" in the face of low prices. While the U.S. Energy Information Administration (EIA) has revised down its production forecasts through the end of 2016, the difference between its January 2015 and September 2015 forecast for December 2016 is only about 800,000 bpd. This decline is definitely significant and should not be overlooked, but it will not be enough to balance global supply and demand in 2016.

In light of this, a demand-led rebalancing of the global oil markets is much more likely than a collapse of supply. According to the International Energy Agency (IEA), global oil demand is forecasted to grow above trend to a

five-year high of 1.7 million bpd in 2015 (averaging 94.4 million bpd) and then by 1.4 million bpd in 2016, all thanks to support from a strengthening macroeconomic backdrop and a significant decline in fuel prices in many consuming countries. A demand-led rebalance does not negate the importance of a decline in non-OPEC non-shale output, which will be an important factor that underpins the eventual market rebalance, but an incremental growth in global oil demand and U.S. gasoline demand (which accounts for 10% of global crude and condensate production) will be the most significant factors.

So far, the U.S. is seeing an increase in domestic gasoline consumption, driven by low prices and the resulting "income effect." Although the typical increased demand during the summer driving season did in part contribute to rising consumption, total gasoline demand in August 2015 averaged 9.5 million bpd, reaching its highest seasonal level since 2007. Also, according to the EIA, motor gasoline consumption is forecasted to increase by about 210,000 bpd in 2015, compared to growth of 80,000 bpd in 2014. However, increased domestic gasoline consumption does not signal that the long term larger structural factors that have driven the slow decline in U.S. product demand due to tightening efficiency measures are reversing. To that end, the EIA forecasts that gasoline consumption will remain flat in 2016.

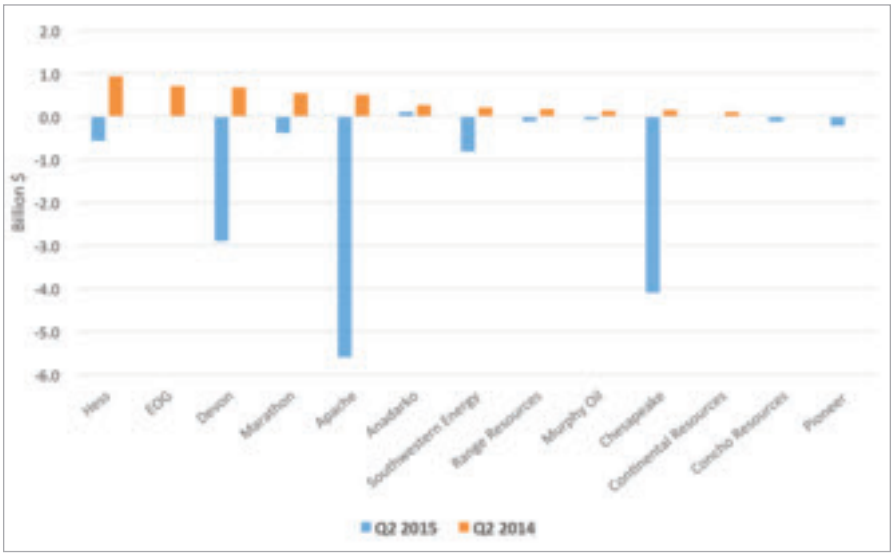
On the other side of the equation though is Asian demand, spearheaded by China. Major headwinds remain for China's oil demand which continues to grow, but at a much slower pace than had been expected. Eurasia Group expects continuing slower growth in product demand in China, rather than any sort of hard landing, which along with slowing economic growth in many emerging market economies will contribute to a slowing of oil demand growth in 2016.

Accordingly, rebalancing the global oil markets will take time as the "lower for longer" price scenario plays out. On the supply side, a structural market rebalance will depend on a number of factors including decreasing U.S. and other non-OPEC production, continued project cancellations and deferrals,

and a flattening of OPEC supply, particularly production from Saudi Arabia levelling in 2015 from a reluctance to add new capacity combined with decline rates of older fields. Meanwhile Iranian supply growth would also need to flatten in late 2016 following the "big bang" impact of sanctions relief. Still, the geopolitical context into 2016 remains structurally bearish and there are unlikely to be any major disruption events that would interrupt supply in Iraq, Nigeria or Libya (albeit there is the potential for choppy exports from those countries).

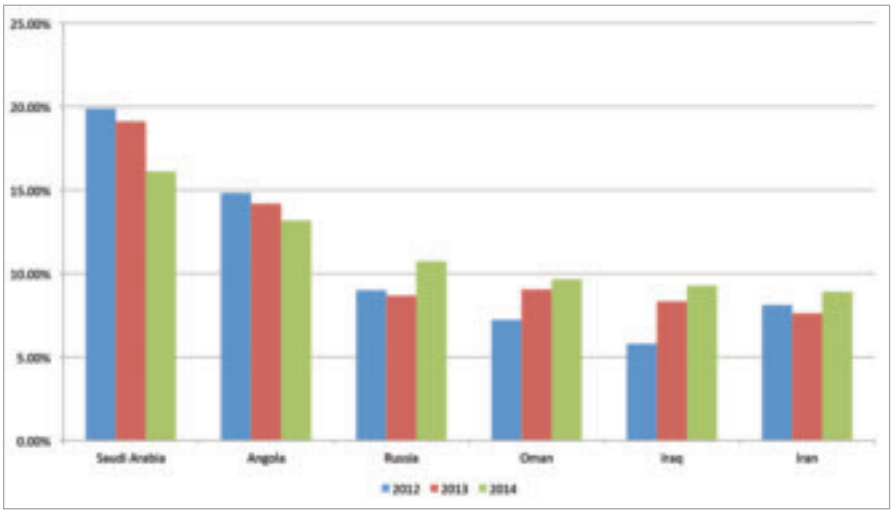
Finally, slowing non-OPEC production and flattening OPEC supply combined with incremental growth in global oil demand and U.S. gasoline consumption could lead to a price recovery and rebalancing of global oil markets, however not until Q3 2017 at the earliest. For the remainder of 2015, prices will likely continue to languish in the $40 per barrel range, before gradually being pushed to average $50 per barrel in 2016.

Net income for various shale oil and gas companies



Source: Company websites, Eurasia Group

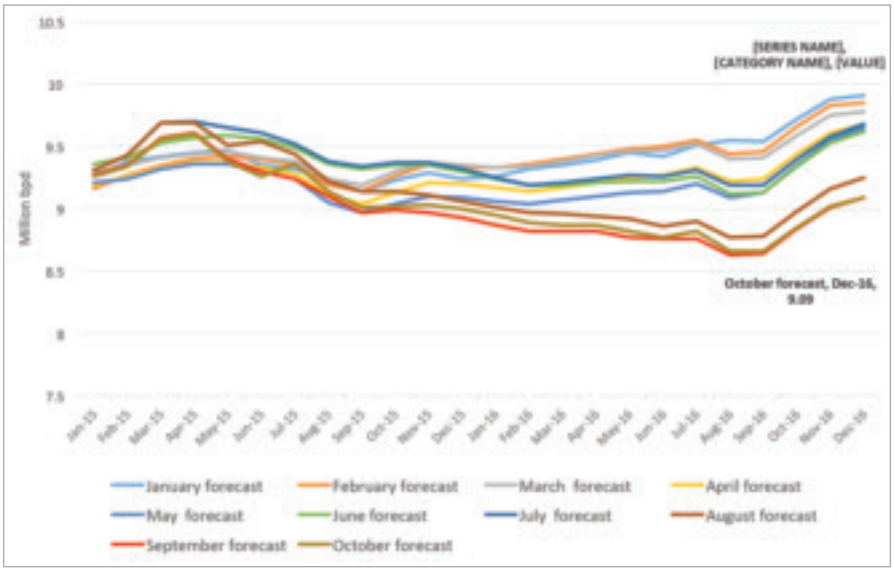
Selected suppliers' shares of China's crude imports



Source: General Administration of Customs

US supply remains "sticky": Declines in U.S. production significant, but not enough to balance market in 2016

Revised EIA monthly forecasts of U.S. crude production

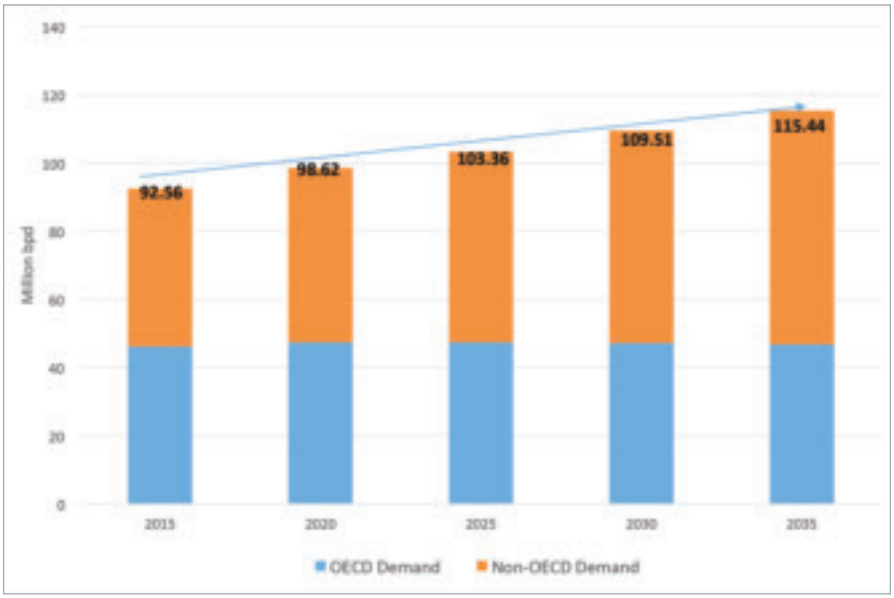


Source: EIA, STEO, January-September 2015

Bakken production

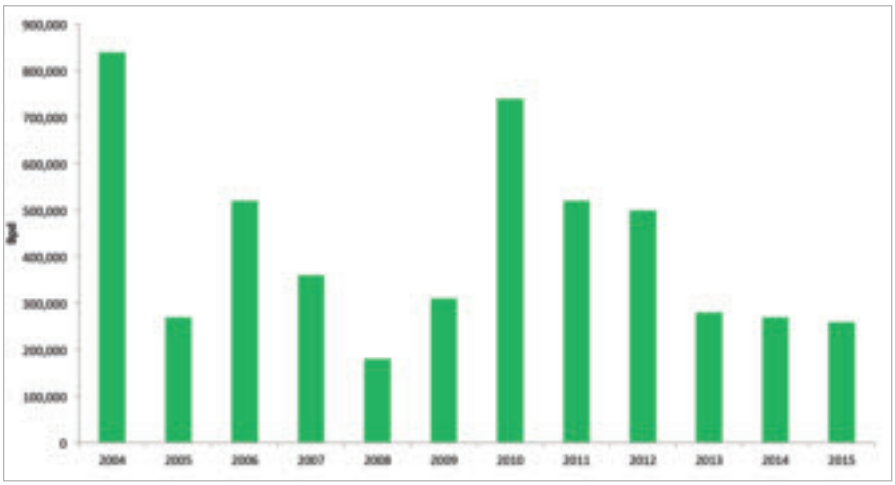
Source: EIA

Petroleum and other liquids demand forecast



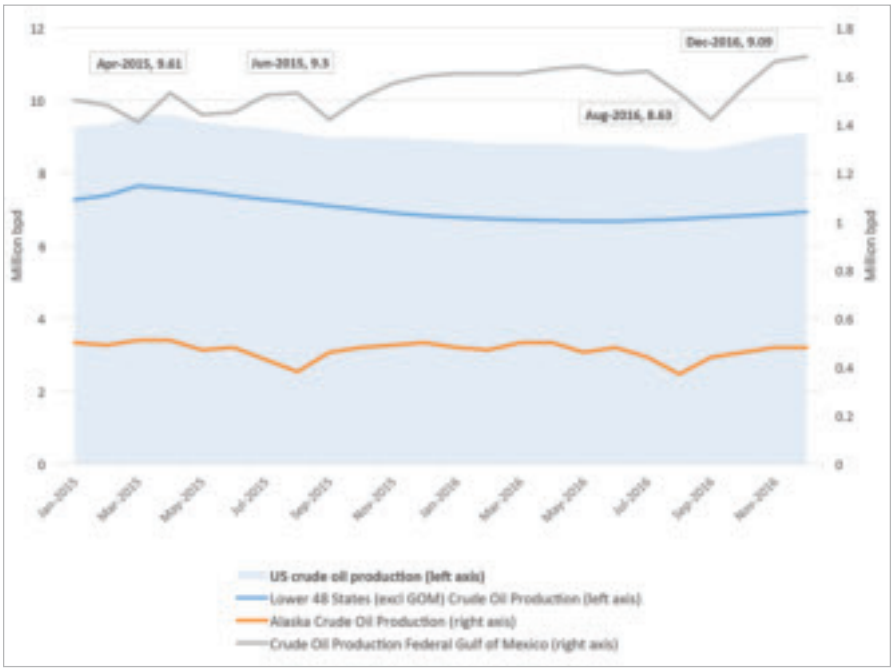
Source: EIA (AEO 2015, High resources case)

China's incremental oil demand growth



Source: Inernational Energy Agency

US crude oil production forecast



Source: EIA, Company websites, Eurasia Group

REGIONAL TURMOIL AND REALIGNMENT:

Middle East Conflicts and the New Geopolitics of Oil

Amy Myers Jaffe and Jareer Elass

Thanks to Jan Kalicki, David Goldwyn, and Leon Fuerth for comments. Thanks also to the Harvard Kennedy School Geopolitics of Energy project for their excellent seminars which contributed to our deeper understanding of the topic as well as to Meghan O'Sullivan for her insights and suggestions.

This paper examines how regional conflicts in the Middle East, including the Syrian civil war and the rise of Islamic State of Iraq and Syria (ISIS), are shifting the geopolitics of oil and raising serious new risks that regional oil facilities will be considered both strategic assets and spoils of war not only in the greater battle for Syria and Iraq and the struggle against ISIS but also potentially in the wider superpower "Cold War" context. Current diplomacy to resolve the conflict in Syria faces serious challenges but is increasingly imperative not only on humanitarian grounds but also as a key to preventing a continued destruction of major regional oil and gas infrastructure that could represent a major challenge to global energy security in the three to five year time frame. Energy dimensions must be considered carefully to ensure Russia does not gain increased leverage over the energy supplies of the industrialized West.

The Middle East is experiencing a period of great transformation that is fueling rivalry for influence among both the major regional powers such as Saudi Arabia, Iran, Turkey, the United Arab Emirates and Qatar and also importantly, among external global powers such as the United States, Europe and Russia. As local borders and ruling institutions in the Middle East have become contested, so have the geopolitical levers provided by oil. The risks posed by accelerating conflicts in the Middle East are multifold. In this paper, we examine how current trend lines raised the possibility that influence over Middle East oil and gas resources could become contested as part of the conflict, with dire consequences for the stability of global trade, the global economy and well-functioning global financial markets.

Geopolitical rivalries over the influence of oil are not new. They span decades and cover a wide range and scale of international conflict.[1] The academic literature on oil and war in the Middle East is extensive, ranging from studies on conflict between state actors as well as oil's central role in intra-state civil war violence.[2] Jeff Colgan in his book *Petro-Aggression: When Oil Causes War* notes that "petro-states are among the most violent states in the world" and while his study qualifies that not all petro-states have a propensity to

aggression, he notes that oil and gas producing countries are "targets of attack 30 percent more frequently than non-petro-states."[3]

What makes the oil element to current conflicts in the Middle East particularly problematical to global energy security is the more precarious backdrop of the Arab Spring and dashed expectations of a new generation of youth from the Middle East. Today's Middle East is characterized by heightened political instability where borders and identity politics in the region have become blurred in a manner that will be hard to reconstitute. Institutions and infrastructure are being rapidly destroyed all across the region, making diplomacy and conflict resolution more challenging than in the past. Involvement of distant geopolitical actors comes in the context of this regional and sectarian complexity, with adverse impacts to oil development. For oil resource development, a business that requires huge capital inflows, long lead times and complex engineering, the rising instability and devolution of government organizations in key Mideast countries bode ill for future economic progress for the region and for continued oil market surpluses in the long run.

Regardless of the promise of new oil and gas supplies from shale formations in North America and beyond, a third of global oil production is still sourced from the Middle East and North Africa. While this might be able to be reduced over time, for the next few years, the fate of Middle East oil will still have huge impacts on the global economy. This fact colors the calculation of all actors in the various conflicts across the Middle East and needs to be better understood. Since many of the major parties to the wars in Syria, Iraq, Yemen and Libya are oil producing states themselves, the zero sum nature of eliminating oil productive capacity in any given location via war must be fully taken into account in analyzing not only the motivations of various actors but also in understanding any unintended oil-related consequences that might come to pass from continuation or escalation of the conflicts.

Moreover, unlike past regional wars, like the 8-year Iran-Iraq war or Iraq's invasion of Kuwait, which involved mainly state-to-state conflict, this time

around subnational groups, like ISIS, Al Qaeda and other local militias, are among the warring parties focused on maintaining or gaining control of oil production and refining installations in contested areas. Initially an outgrowth of disunity inside Iraq, warring militias, ISIS, and Al Qaeda know that access to oil is critical to their ability to challenge state actors. The political impermanence of these sub-groups creates unique problems, not the least of which is the inclination to use force to deny others access to the facilities by regional rivals or the devolved state government. To date, 1.905 million barrels per day (bpd) of oil productive capacity in Yemen, Syria, Libya and western Iraq has been lost in the last year due to violence and operational mismanagement. So far, the negative economic consequences of this destruction of energy infrastructure has been limited to the countries in question, since rising production from the United States and Saudi Arabia has more than replaced lost production in the Middle East. But there continue to be high energy security risks at stake, given that the Middle East and North African (MENA) region produces 32.5 million bpd, about a third of total world production. Saudi Arabia's Eastern province, which has been targeted by ISIS, is the home to over 90% of the Kingdom's oil production and the vast majority of world's spare oil production capacity. Saudi infighting about how to approach wars and sub-groups could cause the Kingdom itself to fray in ways that could negatively impact its oil industry which employs a high proportion of citizens of Shia faith in its workforce.[4]

The energy security consequences of Russia's involvement in this morass of instability and conflict have been masked by the breadth and complexity of its differing interests in the outcomes.[5] On the one hand, Russia appears to have the same strategic interest as the United States in containing the threat of jihadist extremists in the Middle East and beyond.[6] On the other hand, Moscow is also motivated to eliminate the threat that Saudi Arabia and Qatar can collude with the United States to weaken Moscow via an energy market share war.[7] Russian president Vladimir Putin appears to be keenly aware of the role such a policy played in the collapse of the Soviet Union.[8] Russian dependency on oil and gas revenues is substantial.[9] Oil and natural gas comprised 68% of Russia's export revenue in 2013 and accounted for

about half of the federal budget.[10] Russia's high dependence on oil and gas income gives Russia the additional interest to escalate conflicts militarily beyond a "jihadist containment" goal to a broader level that threatens oil and gas infrastructure, thereby underpinning the very oil and gas prices that are the lifeblood of the Kremlin. A Russian victory against jihadists that unfolds in a manner that destroys local Middle East oil and gas infrastructure would be a double boon to Moscow. By creating escalation in conflicts, Russia de facto accelerates the current trend where conflicts with Islamic militants are leading to the destruction of oil and gas facilities. Under this scenario, Russia can score a giant strategic and economic victory, if it survives as one of the leading major international oil and gas industries fully intact in a world where substantial Middle East oil export capacity is destroyed by war. In the recent past, Russia has tried to tap its large energy resource endowments to reassert its place as a global superpower.[11]

Russia's military intervention in Middle East conflicts gives Moscow an additional optionality beyond the destruction of infrastructure, however. To the extent that escalating conflicts destabilize the governments of rival oil and gas producers such as Saudi Arabia, Kuwait, the United Arab Emirates and Qatar, the greater the possibility that the world will have fewer energy allies to align with to weaken Russia's own petro-power. To achieve this aim, Russia doesn't have literally to take over the Persian Gulf by force. All it needs to do is credibly intimidate the Gulf Arab states that it can impose negative costs on them, should they continue to align their energy policies with the West instead of with Moscow. The escalating war in Syria and Yemen could potentially achieve this goal, were it to drain economic resources and internal support for existing Gulf Arab regimes to the point where these governments are forced to capitulate to Moscow's authority or interests. The U.S. posture in the conflict is pivotal to this process and the prospects of a U.S. withdrawal or disengagement in the region would strengthen Russia's hand.

The risks to Russia in this strategy are also huge, however, since it is unclear who can better survive the escalation of conflict, the Kremlin or the ruling governments of the Gulf. Conflicts have already spilled over into global oil

markets as Saudi Arabia and its Gulf allies have initiated a market share war that has brought about a collapse in oil prices, intended in large measure to influence military and geopolitical outcomes in the regional wars on the ground. Russia's economy is highly battered by the combination of economic sanctions from the West and the 50 percent collapse in the price of oil. Moreover, Moscow also has to concern itself with the possibility that its direct military engagement in the Middle East raises the risks to both its economy and its internal security. As Russian attacks on Islamic militants escalate in the Middle East, its citizens could become more susceptible to terrorist attacks at home.[12]

The longer these conflicts fester, the more energy infrastructures could potentially become at risk. Combined with lost investment in other parts of the world like Canada's oil sands and the Arctic due to low oil prices, the destruction of the oil sector in many locations around the Middle East may be laying the seeds for a future oil supply crunch in the three to five year time horizon. The level of damage will be related to the effectiveness of the United States and its allies to contain the spread of ISIS to new locations and the possibility of peaceful resolution to regional proxy wars among regional powers including Saudi Arabia and Iran.

Russia's buildup of troops in Syria has complicated the limited options facing the United States as it tries to build coalitions for a political transition in Syria. Since the United States might wind up with few levers to protect the various societies from the destruction of energy infrastructure in the region, Washington needs to avoid complacency about global energy security. Ironically, the recent success of the U.S. shale industry has created optimism about oil supplies just at a time when they are increasingly threatened. Talk of U.S. energy independence has fostered a domestic political atmosphere where Washington appears less apt to intervene to defend the free flow of oil from the Middle East. But U.S. power, national security and economic health are still tied to its vast architecture of global alliances and trade relations. The U.S., by virtue of these alliances and dependence on the health of the global economy, still needs to care about the safety of existing oil and gas

production and export infrastructure in the Middle East. Moreover, the U.S. needs to consider energy carefully in its role as a major ally to Europe and membership in the North Atlantic Treaty Organization (NATO). The U.S. needs to recognize the energy elements in Moscow's calculations in the Middle East and to fashion strategies that reduce its influence on energy markets not only in the short term, but also over the next five to ten years. Russia, by contrast, also needs to realize that the vast potential of the U.S. shale industry, combined with the aggressive renewable energy policy of Europe is a serious threat to its long term energy future and therefore continuation of current military policies is likely to eliminate potential export markets forever to substitution.

First and foremost, given the high risk that more oil and gas production and export infrastructure could be affected by escalating conflicts in the Middle East, the United States needs to position itself to fill any supply gaps that might emerge from the troubled region by lifting the decades-old ban on U.S. crude oil exports. Lifting the ban on crude oil exports would allow U.S. oil producers to reap the benefits of any supply hole that might come after 2016 as a result of escalating conflicts in the Middle East. In addition, to optimize this policy, the U.S. must stay the course on the successful energy security policies that are currently driving down U.S. domestic oil demand, such as promoting adoption of advanced alternative fuel vehicles and stricter performance standards for cars and trucks. By lowering demand generally, the United States can contribute to lowering the oil intensity of the global economy and also free up a large volume of its own production that can supply its allies either directly or via displacement.

U.S. exports strengthen our ties to important allies and trading partners and thereby enhance American power and influence. U.S. exports would be an important strategic replacement to any lost Middle East supplies, much the way the U.S. served as an oil swing producer back in the 1960s, rendering an Arab oil boycott during the 1967 Arab-Israeli war infeasible. Our ability to serve as a source for critical swing energy supplies – oil and natural gas--enhances our importance to our energy trading partners in other geopolitical

and economic spheres and allows us to help our allies in times of market instability.[13] U.S. exports also constrain Russia's ability to use its energy supplier role as a wedge between the United States and its European allies.

Europe is also playing its own important role by lowering its own oil and gas demand through substitution and efficiency standards. Russia announced recently that its gas sales to Europe were hitting historical lows.[14] To the extent that Europe can continue to diversify its energy mix away from Russian oil and gas, the less exposed it will be to undue Russian leverage.

War, Oil and ISIS

Data shows that military conflicts over oil can result in significant oil supply disruption in the medium term and beyond, driving prices higher for some period of time until markets can adjust. In a study with co-author Mahmoud El-Gamal, who utilizes Discrete Wavelet Transform (DWT) analysis to measure the effects of price and investment return variables on oil production at various frequencies, we found that wars in which oil production and export infrastructure are damaged or destroyed, can produce significant oil market discontinuities.[15]

Analysis conducted by Peter Toft reveals similar findings. By recording oil production changes during the course of the 39 civil wars in oil producing countries between 1965 and 2007, Toft concludes that intrastate conflict intermittently leads to oil supply disruptions – around fifty percent of the time.[16] Toft's assessment covers the short-term impacts of civil war. Our work adds an element by considering the long-term political and social changes that drive down oil production post factum. A protracted process of consolidating power that follows the transformation of internal politics can be far more harmful to oil sector investment – and thus production capacity – than simply the infrastructural damage incurred during the initial course of the conflict. Our research indicates that war damaged facilities often remain offline for prolonged period of years following conflict, if not for an indefinite timeframe.[17]

Militias throughout the Mideast have learned they can undermine the authority of existing political leadership in the region by overtaking oil facilities.[18] A prime example of this strategy has been amply demonstrated in Libya where what might have been a successful transitioning government fell into disarray as rebel factions grabbed and turned off key oil installations and denied access to eastern Libyan export ports. The battle for key oil facilities by ISIS is another example of how conflicts in other parts of the Middle East are creating a threat to oil facilities not only in Iraq, Syria and Libya, but also potentially along the borders of Iraq and Iran with Saudi Arabia, Qatar, the United Arab Emirates, and Kuwait, should the conflict spread more directly to its principal sponsors. ISIS has already attacked soft civilian targets, including Shia populations, inside Saudi Arabia and Kuwait. Saudi Arabia has fortified its northern borders with Iraq with more military hardware and troops, while Iranian forces have moved into positions near the southern Iraqi oil fields, raising the risks of border skirmishes. The militarization of border areas so heavily populated with oil fields and export infrastructure brings with it unique risks, were the conflict to spread.

As Jeff Colgan notes, "externalization of civil wars" in petro-states and "financing for insurgencies" are contributing to violence across the region.[19] And the oil revenue of Saudi Arabia, the United Arab Emirates, Qatar, Russia and Iran has to some degree insulated rulers from domestic opposition, potentially making them, as Colgan's and others' analysis would suggest, "more willing to engage in risky foreign policy adventurism."[20]

The acceleration of conflict targeting of oil facilities is rooted in the history of repression of sectarian economic interests in key countries such as Iraq, Libya and Syria. In many cases, sectarian communities living in local oil producing regions did not receive an equitable share in wider national budgets during the reign of authoritarian regimes, and this reality has created larger problems in the post-Arab Spring environment. Disagreements over the divisions of state oil revenues have exacerbated ongoing sectarian conflict in not only Iraq, but in Libya and Syria.

In the case of Libya, long standing historical grievances from citizens of eastern Libya about the sharing of oil revenues under strongman Muammar Qadaffi undermined the initial coalition government and put military competition for control of oil facilities at the center of the civil conflict over power sharing. Without an effective Libyan government, a proxy war erupted in the country as rival nearby Arab states support competing leaders and militias (Qatar and Turkey backing the provisional government based in Tripoli and the United Arab Emirates and Egypt backing the opposition government and parliament situated in the eastern part of the country). The resulting chaos and violence created opportunity for extremist groups like Al Qaeda and ISIS who have been able to build their operations in the country and are currently engaged in a military campaign to seize control over Libyan oil infrastructure or deny it to competing factions. One theory suggests that depriving any potential Libyan unity government of oil wealth is aimed to prevent a new government from effectively fighting and defeating ISIS.[21]

Given the political instability and the fact that armed militias and air forces from both sides of the government struggle have targeted the country's oil fields and infrastructure, Libya's oil production has understandably fluctuated widely, with output currently at around 370,000 bpd, down from 1 million bpd produced in October 2014. Approximately 800,000 bpd of crude storage capacity at the eastern port of Es Sidr was demolished, leaving 3 million barrels, and both the ports at Es Sidr and Ras Lanuf have not been operating. This has resulted in the loss of some 600,000 bpd of export capacity.[22]

Armed forces affiliated with ISIS have conducted a string of attacks on energy facilities in central and eastern Libya, including on fields run by joint-ventures with Western companies.[23] One such attack occurred on March 6, when gunmen with allegiance to ISIS stormed the Ghani oil field, located in the prolific eastern Sirte Basin and operated by state oil firm Harouge Oil Operations in a joint venture with Canada's Suncor Energy, kidnapping at least nine foreign oil workers and reportedly beheading eight guards. Such attacks prompted Libya's National Oil Corp. (NOC) to declare force majeure at 11 fields operated by both Waha Oil. Co. and Mabruk Oil Operations,

while state oil firm Zuetina Oil Co. announced it had evacuated personnel from its NC-74A license.[24] The most serious damage occurred at surface facilities at the Total-operated Mabruk field in the Sirte Basin.[25]

ISIS is also engaged in a turf battle in Yemen with the more established AQAP, and first made its presence known in the country this March by taking credit for suicide bombings at two Sanaa Shi'ite mosques in which 137 people were killed and another 357 wounded.[26] ISIS militants have said they were responsible for a string of bombings in Sanaa and elsewhere in the country during this spring and summer, including a car bomb that exploded outside of an Ismaili mosque in Sanaa on July 29 that killed four people and wounded another six.[27]

The deteriorating situation caused by the multitude of warring factions in Yemen has raised the specter of extremist groups capturing oil infrastructure. In mid-April, the Yemeni army ceded control of a group of oil fields to a coalition of armed tribes to protect the acreage from being captured by AQAP, which had made territorial gains in the area.[28] The proxy war being fought between Saudi Arabia and Iran in Yemen has caused the country's oil production to fall off sharply, from capacity of 150,000 bpd in the first quarter of 2015 to around 16,000 bpd at present with production potentially totally stopping as storage becomes full and exports are embargoed.[29] The conflict has prompted Yemen LNG Co. to declare *force majeure*, halting output and exports from the country's single LNG facility.[30]

ISIS' Failure to Maintain Captured Oil Facilities in Iraq and Syria

When ISIS began its campaign in June 2014 to form an Islamic caliphate by seizing large swathes of land in northern Iraq and eastern Syria, of paramount interest to the group was gaining control of producing oil fields and capitalizing on existing oil smuggling operations out of Iraq and Syria to help fund the group's high operating costs. Initial high estimates of $1 to $3 million a day for ISIS' oil earnings were based on one time gain from "… draining down pipelines, storage tanks and pumping stations in northern Iraq."[31] But more recently, the extremist group is finding it cannot sustain oil

production, both because it lacks the technical know-how and also because its fighters cannot stave off attacks to recapture key installations. Few people with strong technical expertise have remained in ISIS-controlled territory and the group's efforts to coerce skilled staff into staying by threatening the lives of their families or seizing the assets of engineers who have fled in hopes of prompting their return have proved ineffective. ISIS has relied upon junior engineers whom it has either pressured to stay on at their jobs or recruited.[32]

However, anything involving serious repair or more complex procedures, such as water injection at Syria's mature producing fields, is proving a challenge for ISIS. As of the summer of 2014, ISIS had control over half a dozen Syrian oilfields (al-Furat, al-Omar, and Deir ez-Zor) that prior to the war had a capacity of 114,000 bpd.[33] In September 2014, the U.K. risk management firm Maplecroft assessed that the militant group controlled six out of Syria's ten oil fields, notably the largest, the al-Omar field, and in conjunction with the oil fields it had seized in Iraq, was selling up to 80,000 bpd of oil through the black market.[34] The fields most affected by the Syrian crisis are the fields formerly operated by Royal Dutch Shell and France's Total in Deir ez-Zor, which collectively contributed around 90,000-100,000 bpd in 2011 and today appear to be averaging between 15,000-35,000 bpd.[35] Gulfsands' Block 26 and some of state oil firm Syria Petroleum Co.'s fields in northeastern Syria are controlled by the Kurds and the Syrian regime and these fields have reportedly not been damaged but are also not officially producing.[36]

Through the course of the summer of 2014, ISIS had captured six oil fields in northern Iraq—the Ajeel, Himrin, Ain Zalah, Safiyah, Batmah, and Qayara fields, which collectively had pre-war nameplate production capacity of 58,000 bpd. But by early September of 2014, ISIS had relinquished three of those fields to Iraqi forces, leaving the Ajeel, Himrin and Qayara fields under the group's control, with production from these fields averaging less than 15,000 bpd.

The largest of the three remaining fields in ISIS' control was the 25,000 bpd capacity Ajeel field, located near Tikrit in the Salahuddin province. In early

August of last year, the Iraqi government bombed and damaged the Ajeel control room[37], with field production reduced to just under 5,000 b/d.[38] Prior to Ajeel having been seized, the field had produced 25,000 bpd of crude that was transported to the Kirkuk refinery as well as 150 million cubic feet a day of natural gas that was piped to the Kirkuk power station. Fearful that their lack of technical expertise could inadvertently result in the gas being ignited, ISIS militants operating the field purposefully had been pumping lower volumes of oil.[39]

During the assault made in March of this year by Iraqi forces as they moved to reclaim Tikrit and the surrounding towns, ISIS soldiers abandoned the Ajeel field and set oil wells in the field on fire as a means to protect themselves from aerial attack by Iraqi military helicopters.[40] Firefighting teams from Iraqi state-owned National Oil Co. (NOC) extinguished those fires at Ajeel, in addition to well fires lit by ISIS rebels as they also rushed to leave the Himrin field, which was producing around 6,000 bpd.[41] Retreating ISIS soldiers relinquished Qayara, the last Iraqi oil field the extremist group had under its control, in late April, again setting oil wells on fire as they left. The heavy oil Qayara field, had pre-war capacity of around 5,000 bpd, but was believed to be pumping at a mere 2,000 bpd,[42] and the field may have not been of great use to ISIS given that the crude quality from the field is similar to asphalt.[43]

The high value of Iraq's Baiji refinery to both ISIS and the Iraqi government cannot be overestimated. The 270,000 bpd capacity refinery located in the Anbar province has been the focus of intense fighting between ISIS militants and Iraqi government forces since June of last year and control of the refinery has exchanged hands several times. ISIS has held the town of Baiji for the past year and the town is strategically important because it lies on the road to ISIS-secured Mosul. The refinery, however, continues to be contested.

The Baiji refinery is critical to both sides as it is Iraq's largest refinery and processes one third of the country's crude output. Although Iraqi government forces had recaptured portions of the refinery in early June from ISIS militants and looked to be gaining total control over the facility in mid-June, a report

on June 24 claimed that ISIS soldiers had taken control and were offering 460 Iraqi troops near the refinery safe passage to Irbil in Kurdistan if they surrendered their weapons. Iraqi Foreign Minister Hoshyar Zebari denied this report, insisting that Iraqi special forces soldiers were in control of the refinery.[44] The Baiji facility, which was relatively unscathed during fighting in 2014, has apparently experienced major damage during the latest struggle for ownership of it.[45]

Iran and Iraq: Source of Rising Oil Supply or Chimera?

Global oil markets are currently sanguine about the losses in oil productive capacity taking place across the Middle East, anticipating rising supplies from a variety of sources including U.S. shale, Iran and Iraq. Indeed, over the past five years, U.S. oil production has risen by over 4 million barrels per day to close to 9.4 million bpd currently, more than replacing lost production from the Middle East and North Africa that has averaged between 1.5 to 4 million bpd since the start of the Arab Spring. And Iraq's oil production has made steady gains despite the escalating war against ISIS and widespread social unrest that has included major country-wide protests against corruption and electricity shortages. Iraq's production hit 4.2 million bpd this summer (including 235,000 bpd for direct crude burning for electricity), up significantly from year ago levels of 3.5 million bpd. Average Iraq crude oil exports from the southern fields around Basra via the Persian Gulf are only slightly higher so far this year at 2.72 million bpd, up from 2.46 million bpd in 2014, with most of the balance of the increase coming from new independent exports by the Kurdish Regional Government (KRG). In recent months, despite the ongoing war with ISIS, the KRG has been able to maintain mastery of their region, generally ensure continued protection and use of its own pipeline export infrastructure to Turkey, and last year even expanded the territory under its control to include oil producing areas previously in dispute in and around Kirkuk.[46]

But the risks that escalating conflicts or sabotage could disrupt Iraqi Northern

exports again in the future remain. Last year, Kurdish reinforcements managed to roll back ISIS incursions near the Mosul Dam region and keep its border areas near its oil industry uncontested.[47] The prospect of continued violence caused some Western oil companies to evacuate staff, raising the possibility of future interruptions to operations. Fields in eastern KRG remain in operation, including areas where key natural gas fields are located. Exports through the main oil pipeline to Turkey were cut off temporarily in March 2014 following a sabotage attack, and again this year sabotage and theft on the export line from Iraq to Turkey have risen with the outbreak of fighting between Turkey and the Kurdish insurgent group PKK. This summer, as the peace process broke down, PKK began bombing energy infrastructure all over eastern Turkey including the Iraq-Turkey pipeline.[48] The KRG's crude production capacity in 2014 was estimated at about 350,000 bpd, with roughly 140,000 bpd refined and consumed domestically. But now the KRG is also in control of the Bai Hassan and Avana fields at Kirkuk. KRG exports to Turkey have averaged 245,000 bpd in 2015 despite the PKK attacks. The KRG hopes to increase production to raise exports to a target 2 million bpd by 2019,[49] but this may prove ambitious given a slowdown in foreign investment in the face of regional instability. Oil export infrastructure remains at risk from any escalation in hostilities in the region.

Oil prices have also been under pressure in anticipation that post-sanctions, Iran will be able to significantly increase its oil production and exports. A recent report released by Harvard University's Belfer Center for Science and International Affairs on the "Energy Implications of a Nuclear Deal between the P5+1 and Iran" suggested that Iran might be able to supplement its current 2.8 million bpd production as sanctions are lifted by bringing on an additional 800,000 bpd of crude oil and condensate production in 2016. About 150,000 bpd of that would represent new oil production, with the rest achieved through improved technology for enhanced oil recovery (EOR) techniques, presumably with foreign assistance.[50] Last May, National Iranian Oil Company (NIOC) managing director Rokneddin Javadi told International Oil Daily at a conference in Kuala Lumpur that Iran's production would be able to pump an additional 1 million bpd within three

to six months but that marketing the oil might be more of a challenge than producing it. Javadi said that all of Iran's fields would be able to be restored to production levels seen prior to the 2012 sanctions regime.

Sara Vakhshouri of SVB Energy International says that Iranian engineers are suggesting the resting of some of Iran's older fields shut in because of sanctions has "enabled reservoir pressures to increase and allow production to resume at high rates." She writes "Gas injection might also boost production in mature fields in 3 to 6 months." Vakhshouri's published estimate is that Iran could physically boost crude oil production by 500,000 bpd to 700,000 bpd within three months, and 800,000 bpd within six. Iran is currently said to be producing 2.8 million bpd of crude oil and 679,000 bpd of condensates. Estimates are that domestic refining capacity totals about 1.8 million bpd, suggesting exports now range around 1 million bpd. Embedded in official Iranian estimates and other optimistic ones like Vakhshouri's is belief that Iran will be successful in bringing on new fields along the Iraqi border and achieve at least 200,000 bpd to 300,000 bpd of production from new fields quickly and then be able to accelerate at least another 200,000 bpd or more from enhanced oil recovery (EOR) at older fields, bringing 2016 production increases to at least 800,000 bpd of liquids, of which 600,000 bpd could be new or restored crude oil output and 200,000 bpd condensates. By 2020, an additional 1.2 million bpd of liquids is projected, allowing Iran to get to total production of 5.5 million bpd including condensates.

Vakhshouri and others have noted that Iran's industry has made strong progress on its own without international assistance. Iranian officials say that they have reduced production mainly by stopping natural gas reinjection programs at key fields. They suggest that a resumption of injection can quickly restore production while new fields near the Iraqi border are also coming on line this year. Still boasting of domestic industry competencies belie at least some problems that have made it to the public domain. Chinese upstream Iranian oil field projects have faced massive delays and the massive South Pars project has also had its own engineering difficulties including a very public embarrassment of a major platform sinking into the ocean.

WoodMackenzie Consultants, known for their field by field bottom up approach, tout far more conservative numbers of a growth in crude oil exports of only 120,000 bpd by the end of this year and a boost of an additional 260,000 bpd by end-2016, based on views that Iran's geologically complex, mature fields face a decline rate of 8 to 11% a year that is hard to reverse quickly. Citibank is projecting that Iran will try to surge its production immediately upon the lifting of sanctions but will have difficulty sustaining more than a 500,000 bpd incremental increase in 2016 and likely closer to 250,000 bpd average.

To date, Iran has focused its oil capacity expansion efforts on its West Karun fields, which include the giant multi-billion barrel North and South Azadegan and Yadavaran fields, which are currently producing about between 50,000 to 80,000 bpd and targeted to increase slightly in the coming months. Both fields were developed under buy-back agreements with Chinese NOCs but have experienced substantial setbacks and delays. Iran ended CNPC's contract for South Azadegan last year. Other fields on the Iraqi border are also targeted such as the Yaran field now producing 40,000 bpd. The Darquain field, which requires water and gas injections and was a project initiated with help from Italy's ENI, is another field on the Iraqi border that Iran is counting on to contribute to higher output as well as Jofier.

Part of the optimism about Iran's oil potential focuses on the many Western and Eastern oil companies gathering to negotiate for the new deals under the proposed "Iran Petroleum Contract" (IPC), a new service risk integrated exploration, development and production contract that is supposedly going to allow international companies to "book reserves." The large reserve potential in Iran is an attractive enticement for majors like ENI-Agip and BP who need a quick fix to their future reserve additions and believe that they could potentially return to fields they are familiar with and think have potential to be repaired quickly with Western intervention. The problem is that this kind of "afraid to miss out" reserve management, reserve replacement fantasy deals have lured these companies before to gloss over enormous technical and geological barriers, ending in writedowns or worse, in the Caspian, Iraq,

Venezuela and Saudi Arabia's gas initiative.

Past history has shown that oil fields are harder to rehabilitate quickly when they have been shut-in, regardless of the promise of "Western technology and know-how." Restoration of lost capacity in Libya by European firms was slow going in the 1990s and 2000s. And the concept that shutting Iranian fields is "enhancing" their pressure may be wishful thinking. When Saudi Arabia de-mothballed its giant, less complex fields in the 1980s, it encountered the stark reality that resting fields leads to field pressure problems and lost capacity, not pressure enhancement.

Iraq's own oil field expansion program was slow to recover in the first year after sanctions, and, for years after, companies operating in Southern Iraq have been hampered by many factors, including bureaucratic difficulties getting needed equipment procured and into the country, a problem more than likely to plague firms working with Iran's massive bureaucracy as well. Any return to Iran for upstream work will also have to overcome Iran's many local content provisions at a time when the lifting of sanctions will be complex and confusing. U.S. secondary sanctions related to terrorism and human rights will still be in effect and the Iranian Revolutionary Guard Corps (IRGC), which has several commercial enterprises in the Iranian oil sector, is deemed a terrorist organization by the U.S. The United States has also been aggressive in its foreign corrupt practices act (FCPA) prosecutions in recent years – as have its European counterparts – and European firms such as Total and Statoil have already run amok of Iranian corruption over the last decade.

In the late 1990s/early 2000s, Iran needed 100 (tcf) of natural gas (tcf) for field rehabilitation and the needs for future expansion will be higher still. Water encroachment and pressure problems plagued major fields such as Marun, Karanj, and Ahwaz, Parsi. Gachsaran and Bibi Hakimeh fields also depend on gas injection EOR. Iran has announced that it intends to increase gas injection to 330 million cubic meters per day by end-2016 and that the gas is available from the Iranian domestic natural gas grid from domestic associated natural gas production. However, in past years, the

country faced severe natural gas shortages and was banking on increases in foreign investment in the North and South Pars projects. Natural gas use by consumers has also been rising with the government's "resiliency" program for replacing gasoline and diesel with compressed natural gas (CNG) for vehicles and higher use in the residential sector.

Thus, it remains unclear how easily Iran will be able to access the natural gas it needs to drive a large EOR program which relies on large quantities of natural gas for injection. Moreover, Iran's fields have suffered strain and damage over the years and may take longer to restore and expand than expected, as has been the case in other countries like Iraq and Libya. Bureaucratic barriers may also slow the return of foreign investment, reducing the chances of a quick turnaround with the advanced technologies needed to enhance existing Iranian equipment and capacities.

In summary, although rising exports from Iraq and Iran may fill any supply gap created by the ongoing conflicts across the Middle East in the coming years, these supplies themselves are also subject to similar risks, leaving markets with a higher level of uncertainty for the future than may be currently recognized.

Oil Geopolitical Elements to Russia's Role in Conflicts

By backing Iran militarily over the past decade, Russia gained leverage with a regional proxy who could directly influence the security of Saudi Arabia and Qatar, Russia's main competing energy suppliers to Europe and China. Russia's alliance with Iran, while somewhat tenuous, is, from Moscow's perspective, a counterweight to the threat that Saudi Arabia and Qatar can collude with the United States to weaken Moscow via an energy market share war.[51] Russia is also motivated to support Iran to constrain the success of Sunni jihadist movements that might spread to its borders, as discussed above.

In 2009, Saudi Arabia began hinting that an oil price war could be in the

cards, should Moscow continue to provide military and nuclear assistance to Iran.[52] The Saudi threat was made in the historical context of similar Saudi strategic moves against the Soviet Union and Iran. Saudi Arabia provided financial and logistical support to the counter-insurgency that contributed to the Soviet failure in Afghanistan.[53] Saudi Arabia's ability to flood oil markets at will has also been instrumental to its role as a U.S. ally to weaken the Soviet Union after its invasion of Afghanistan and to lessen the impact on oil prices of the U.S. invasion of Iraq.[54] Saudi Arabia also pushed oil prices lower to pressure Iran during its eight year war with Iraq.

To date, the United States' close security relations with Saudi Arabia and Qatar have limited Moscow's ability to achieve resource rent-seeking alliances in the Middle East. In the aftermath of the Russian invasion of Ukraine, Qatari liquefied natural gas (LNG) exports to Europe have actively lessened Moscow's geopolitical influence, and Saudi Arabia recently announced new oil sales to Poland.[55]

The diplomatic back and forth between Saudi Arabia and Russia on the oil issue has been intensive over the past two years. In 2013, Saudi Arabia approached Moscow to end its support for the regimes in Damascus and Tehran in exchange for close coordination with Riyadh. The Saudi diplomatic overtures to the Kremlin came amidst Saudi displeasure with Washington for its lack of commitment to an intervention in Syria and Washington's pursuit of a diplomatic agreement with Iran regarding Tehran's nuclear aspirations. According to one media account, Saudi Arabia offered a guarantee that a post-Assad Syria would not become a transportation hub for competing Gulf natural gas shipments to Europe in exchange for a Russian withdrawal of military support for the Syrian regime.[56] An accommodation on oil price levels might also have been in the cards, had Russia been willing to trade its political stance on Syria for some sort of cooperation with the Saudis in energy markets. The initiative was a non-starter.[57]

By 2014, Saudi Arabia began to reduce its crude oil export prices to maintain market share. U.S. oil imports had been tumbling to their lowest levels in

16 years, with oil from the Organization of Petroleum Exporting Countries (OPEC) losing significant market share. By summer 2014, U.S. crude imports from Saudi Arabia lost about 440,000 bpd of market share, and state oil company Saudi Aramco responded by lowering its premium for Arab Light, Arab Medium and Arab Heavy crude oils relative to U.S. Gulf Coast benchmarks by 45 cents a barrel. The Saudi price reductions for U.S. customers were widely interpreted at the time as a sign that the Kingdom was starting to implement its price war for market share. The effort to defend U.S. sales came in the wake of similar moves earlier in the year when Saudi Arabia eased its premiums to Asia to ensure that the Kingdom could maintain its sales in the face of increased competition from other Mideast producers in Asia. By early 2015, oil prices had cratered to $50 a barrel.

Geopolitically, the fall in crude oil prices to $50 a barrel has been influential but not definitive. Lower oil prices have created fissures in the unity of the inner circle of Vladimir Putin as the Russian economy has faltered but Russia is still escalating its support for the Syrian regime of Bashir Al-Assad and so far, peace talks have failed to make progress. Tehran also expanded its regional power through proxy wars since the beginning of the oil price war. Iran's support for an escalation in the Yemen war contributed initially to a significant rebound in oil prices to $60 a barrel earlier this year, up from lows of around $40 a barrel. The Iranian military moves created a war premium since oil movements through the Suez Canal have to traverse the Bab El-Mandeb chokepoint which borders Yemen and Djibouti. Estimates are that roughly 3 to 4 million bpd of oil travels through the Bab El-Mandeb. Shippers can bypass the Suez Canal, but the escalation of the Yemen conflict unnerved oil markets for several reasons beyond fears of physical disruptions to tanker movements. Firstly, it demonstrated that the conflict between Saudi Arabia and Iran is likely to spread more widely across the Middle East, with potentially negative consequences for additional regional oil production. Secondly and most importantly, the escalation in Yemen and later in Syria revealed that both Russia and Iran were willing to use military force as a means to counter Saudi efforts to lower oil prices.

The successful conclusion of the P5+1 nuclear deal negotiations with Iran encouraged renewed efforts by the United States to broker a peace initiative regarding the war in Syria. The Obama Administration had a high domestic political incentive to show that the politically controversial Iranian deal could pave the way for a better Middle East. In doing so, the administration believed it could outflank Russia, especially in Syria, and restore broader support for U.S. policy across the Gulf and the wider Middle East.

A flurry of diplomatic activity included high level meetings between Russian and Saudi diplomats, Iran's foreign minister Javad Zarif and Syrian President Bashir al-Assad and Iranian and Lebanese officials. The blogosphere was buzzing with rumors, including one that Riyadh and Tehran might be able to agree on a formula that would restrict Hezbollah back to Lebanon, cordon Bashir al-Assad off to a limited titular role and begin serious negotiations for an inclusive political transition in Syria. The possibility that all parties might consider a change in Syria led to speculation that Saudi Arabia and Iran might be able to work more cooperatively inside OPEC, with rumors that Saudi Arabia might be inclined to consider an OPEC floor price of $60 to $65 a barrel, were Iran's actions in Syria to demonstrate a serious commitment to a peace process.

Russia had other ideas, unfortunately. As predicted by Robert Blackwill and Meghan O'Sullivan, "… a weaker Russia will not necessarily mean a less challenging Russia…Russia could seek to secure its regional influence in more direct ways – even through the projection of military power."[58] Russia has changed the facts on the ground, adding to its military base at Latakia and increasing the number of its military advisors in Syria. The move has so far staved off a sudden collapse of the Assad regime. Russia's military involvement is said to aim to prevent any armed opposition to Assad to gaining power and jeopardizing Russian interests including its preference for an Iranian bulwark against Sunni jihadists.[59]

Some analysts suggest that Moscow is overly optimistic that ISIS and the non-ISIS opposition will battle each other in eastern parts of the country, giving Russia and the current Syrian regime a reprieve in Western Syria. Instead, it is suggested speculatively that the war in Afghanistan may prove instructive with all opposition forces still focusing in earnest on the Assad camp, and saving energies against each other for a later day.[60] In any case, it is not clear whether Russia intends to use its military role to gain a leading role in peace talks on Syria (as suggested by Pavel Baev and Jeremy Shapiro of Brookings)[61] or whether the Russian engagement on behalf of Assad is meant to hold Iran and Moscow in a position to use Syria to assert themselves against the Kingdom and restore oil prices via the uncertainty surrounding regional conflict. While the outcome in Syria is uncertain, the Russian move clearly complicates the landscape in the region, and leaves open the possibility of escalating violence.

Implications for US Strategy

As conflicts continue to simmer in the Middle East, militias and extremist groups will aim to capture oil fields and infrastructure for their territorial domain. This turn of events is a serious challenge to stability across the Middle East and for the global economy.

The parties to the conflict in Syria may be so numerous and the dynamic fueling conflict across the wider region so complex, it is hard to see how the United States would be able to influence the outcomes it might consider desirable. It has been argued that "complementary international missions to degrade ISIS from the air, and train and equip the group's local adversaries," are the key to the needed ingredients to containment.[62] And, the U.S. continues to seek diplomatic solutions to the conflict.

But whereas the United States' military strategy on Syria may be complicated by the unanticipated actions of other parties to the conflict, the U.S. response to the energy security challenges posed by violence in the Middle East is clearer.

The United States has a leading role to play in ensuring global energy security and is not doing all it can to avoid a crisis down the road. It runs the risk that it could inadvertently assist Russia in gaining more energy leverage over our allies and trading partners, and this situation needs to be more carefully assessed and dealt with more comprehensively in a manner that the U.S. can control and implement itself with as little dependence on Middle East oil and gas assets as possible.

The outlines of a U.S. policy aimed to address the risks to global oil supply described in this article are straightforward:

1. The United States needs to increase its own energy supply -- both of renewable energy and of oil and gas - and then make this energy available not only at home but also to U.S. allies and major trading partners both directly and by displacement.

2. The United States needs to end its decades-old ban on crude oil exports.

3. The United States needs to maintain the Strategic Petroleum Reserve (SPR) and upgrade and update its facilities and operational triggers to be effective under new market circumstances.

4. The United States needs to stay the course on policies designed to lower oil demand and promote energy efficiency and substitution.

The United States can prepare itself for the energy consequences that might come of continued violence and destruction in the Middle East. The United States has hampered its own leadership in global energy security by maintaining the U.S. crude oil export ban. U.S. tight oil could be a major factor benefiting U.S. allies and global free trade in energy, were the Congress to lift the 40 year old crude oil export ban. The U.S. should also maximize its own energy production and surpluses by preserving the intangible drilling credit (IDC) that assists smaller operators to maintain investment in U.S. oil and gas shale development and maintain existing tax credits for renewable energy.

The United States is not properly tapping its advantageous energy position to enhance its global power and leadership role. As Blackwill and O'Sullivan note, the U.S. shale boom provides the U.S. with the tools to "sharpen the instruments of U.S. statecraft."[63] Our current policies of limiting natural gas exports and banning crude oil exports must be considered in the global context of our international leadership role. Hoarding crude oil supplies inside our borders sends the wrong message to other countries. It is in no one's interests that all nations hoard their energy. Such attitudes were precisely what worsened the economic damage to the global economy during the 1979 oil crisis. America is bound by our membership in the International Energy Agency (IEA) emergency stockpile system to share crude oil stocks in times of emergency or major disruption. Thus, it is irrational to be currently hoarding our supplies now while energy supply is plentiful.

But as falling oil prices have shown, it is not enough to have our own oil resources which in themselves are also vulnerable to the globalized oil price cycle. The U.S. must stay the course on policies that are actively lowering oil demand. By lowering the amount of oil that might be needed in three to five years through efficiency and substitution, the U.S. could lessen the impacts of any supply gap that could emerge if conflicts in the Middle East continue to escalate. By improving its own energy balance and increasing exports of oil and gas, the U.S. can counter Russian leverage that might be gained from losses in oil production capacity in the Middle East.

U.S. demand-side management policies are already making a significant contribution to the lessening of oil intensity of the global economy. As U.S. Energy Information Administration (EIA) analysts Shirley Neff and Margaret Coleman show in the lead analysis article in the Special Issue of *Energy Strategy Reviews* on "U.S. Energy Independence: Present and Emerging Issues", U.S. oil consumption has fallen almost 10 percent between 2005 and 2013 and is expected to decline further in the coming decades.[64] U.S. oil demand could fall as much as an additional 20 to 30 percent over the

next twenty years, Neff and Coleman argue, demonstrating the importance of well-designed transportation policies. Significant savings can take place as tightening corporate average efficiency standards kick in but loopholes should be eliminated to broaden momentum. The U.S. government is currently working on new performance standards for heavy duty trucks which carry roughly 19 billion tons of freight a year. More ambitious targets for all trucks should be immediately sought. Stricter targets for efficiency of large and medium trucks could significantly lower U.S. future oil use, as the freight sector is expected to constitute a key sector for growth in oil use out to 2040. Globally, ExxonMobil projects that total world energy demand from heavy duty vehicles will increase 65 percent by 2040, compared to 2010 levels.

There is no question that technological innovation and new investment strategies by U.S. independent oil companies have brought about a renaissance in U.S. domestic oil and gas production, creating a prolific U.S. energy supply outlook. But without government intervention to curb our appetite for oil, this rising production might have done little more than meet increases in incremental demand.

The consequence of the U.S. oil export ban has generally been the accumulation of high, surplus crude oil inventories that tend to depress U.S. crude oil prices relative to global markets. The extra revenue that might come from export access would benefit the U.S. trade deficit. Exports might also sustain some marginal investment for some domestic oil that might have gotten shut-in as falling oil prices dent drilling economics for small U.S. domestic producers. If and when the destruction of oil production capacity in the Middle East contributes to a tightening market, allies such as Mexico and Europe will be eager to have access to U.S. condensates and tight oil. Such energy trade strengthens our ties to important allies and trading partners and thereby enhances American power and influence.

Years of conflict have taken their toll on the state of the oil industries across the Middle East. Take the case of Iran, for example: Iran's oil production averaged around 6 million bpd in the late 1970s. Following the Iranian Revolutions of 1978-1979, Iranian output fell to 1.5 million bpd; three decades later, the country's oil output capacity stands at less than 60% of its pre-revolutionary levels. In Nigeria, regime change prompted a similar outcome: the Biafran civil war in 1967 sank oil production by around 40%.[65] During the transition from military rule in 1979, oil production dropped 30%, continuing its decline until 1983.[66] In Libya, the historical links between regime change and oil output offer a prelude for today's revolutionary state: Muammar Qaddafi's ascension to power in 1969 led to a rapid evaporation of foreign investment and operations in the oil sector. By 1975, the previous regime's average output of 3.2 million bpd had sunk over fifty percent; and by 1985, oil production had dropped to a mere 430,000 bpd.

The possibility that Middle East production may decline instead of increase in the coming years needs to be considered in fashioning new policies for the Strategic Petroleum Reserve (SPR). Any sell-down of the SPR, now contemplated in bills passed by the U.S. Congress, needs to factor in the possibility that a Mideast oil supply disruption could reemerge as a problem for the already tenuous global economic situation. SPR policy and U.S. export policy must also consider Russia's motivations in its widening engagement in the Middle East and the possibility that the U.S. will need to counter Russia's using its energy exports as a geopolitical lever or "weapon" of blackmail or as a means to create a wedge between the U.S. and its allies. The existence of the SPR, combined with the surge potential of U.S. crude oil exports, is a key asset to constrain the petro-power of Russia to the detriment of the U.S. and its allies. A strong U.S. oil and gas sector provides greater diversity to global oil supply at a time when Russia's military involvement in the Middle East and beyond increases the chances of an oil supply disruption down the road. The United States needs to give more serious attention to the role of oil and gas in the current conflicts and consider its own energy policies in that context.

Finally, U.S. diplomacy needs to provide more active engagement regarding the distribution of oil revenues inside war torn societies. To date, the U.S. diplomatic efforts to resolve conflicts over revenue sharing in Iraq and Libya have failed miserably and this failure has crippled American efforts to stabilize those countries. As this paper and other studies on the links between oil and gas show, conflict resolution activities that consider oil aspects could prove a fruitful element to resolving the larger dimension of ongoing military conflicts.

Endnotes

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TOWARD A REVOLUTIONARY ENERGY SYSTEM

David G. Victor

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Historically, the energy sector has been very slow to change. Yet huge changes will be needed in the future—at a rate much faster than ever experienced—if the sector is to make deep cuts in emissions and stop global warming. So far, however, there has not been much serious analysis of how such a transformation could occur in the real world—where governing institutions are far from perfect and where governments find it very difficult to establish clear and credible policies needed to guide investors to new technologies.

This essay argues that a technology strategy for transforming the energy system will require a global perspective because today, unlike even 2-3 decades ago, technology markets are global. Making that strategy work will be difficult, but one bright spot is the ability to devise global solutions in relatively small "clubs" of countries and then scale up the best strategies to other countries in time. Only a few countries account for nearly all cutting edge investment in new energy technology, and a club that begins with those nations could be highly effective. The design of the club strategy will need to address not just the total level of spending on new energy technology but also the efficacy of national policies aimed at promoting innovation—suggesting that the club, if it is to be effective, will require a degree of cooperating on innovation policy that is so far unprecedented in most areas of the modern economy.

In 1970 the world's fastest business computer, the IBM Mainframe, operated at a speed of 12.5 MHZ and cost $4.6m. Today, that same processing power is 2 million times cheaper. Across the frontiers of modern economies similarly revolutionary stories abound. Wireless communication has spread from a few wealthy customers with car phones and the military to the world's poorest. In a world with population of 7.2 billion there are now 7.22 billion cell phone

subscriptions, up from just one third coverage in 2005.[1] Four decades ago grocery retail was dominated by local neighborhood stores—with customer service often so doting that it was impossible to choose one's own vegetables. Today, three quarters of the U.S. public buys at least some groceries from stores that aren't mainly in that business.

Meanwhile, the energy business has changed little. The average kilowatt hour (kwh) in the U.S. cost 7.5 cents in 1970 and barely changed for thirty years—climbing a bit in recent years to about 11 cents. The grid system is little different—slightly higher voltages for some lines, more supervisory control and data acquisition (SCADA), and few other modifications. The fuel mix has changed a bit—thanks notably to the rise of gas and the exit of oil—but the rank of important electricity generation fuels in 1970 in the U.S. is nearly identical today. The supposedly revolutionary rise of renewables is not yet evident in the data—solar energy, for example, accounts for just 0.8% of the global energy mix even though it first started gaining market share more than three decades ago.[2] In the electric power industry, centralized fossil fuel-fired power stations reign supreme. And globally coal is the king of central power. Nor has there been much revolution in transportation where oil continues to dominate. Then as now, oil products dominate the market for transportation. Total annual worldwide sales of Tesla's electric cars equal just 14 hours of conventional vehicles in China. Across the energy system, efficiencies have gone up—but at steady rates typically measured as a few percent per year, if that. Hardly the stuff of revolution.

Although the energy business does not yet reek of revolution, calls for revolutionary change abound. The prime driving force is environmental—in particular climate change. Stopping warming will require cutting global emissions of carbon dioxide (CO_2) by four-fifths over just a few decades. Doing that means, most likely, the removal of nearly all fossil fuels from the energy system—and with that, radically new systems for power supply. Rethinking supply might, as well, lead to rethinking the whole grid system—perhaps moving radically to more decentralized electric power. It may, as well, largely end the use of conventional oil.

It is hard to see how the existing energy system will rise to this challenge. Today, the energy industry is dominated by state-owned enterprises (SOEs) that are hardly paragons of innovation. The electric power industry, in particular, is heavily regulated—another force that often impedes change. Incumbents are extremely powerful politically and unlikely to welcome a revolution.

Why a revolution is needed and how it might arise is where I now turn.

The Scale of the Challenge

The field of research on the global energy system is complex, but three iconic results stand out.

First, the rates of change in the global energy system are very slow. Revolutions are century-scale phenomena. Typically, as shown in figure 1, whole energy infrastructures change on a time scale of about 70 years. Individual components might come or go quickly—for example, the recent rise of natural gas or the exit of oil from the U.S. power supply system, both of which occurred with time constants of about 10-20 years. But the whole system is much slower to change because infrastructures are interlocking and those interlocking effects tend to reinforce the dominance of incumbents. New entrants gain small market shares and must work hard—usually failing—to make inroads.[3]

Economically and politically these incumbency advantages are essential to understanding why rates of change in the energy business are so slow. For example, the late 19th century was the golden era of coal. That primary fuel came with a set of interlocking infrastructures, notably railroads, that further reinforced the advantage of a bulky fuel that required combustion in large plants—steam engines. The trifecta of coal, steam and railroads dominated the market for energy services—such as transportation—until a new cluster of rivals (automobiles, roads and oil) slowly took market share.

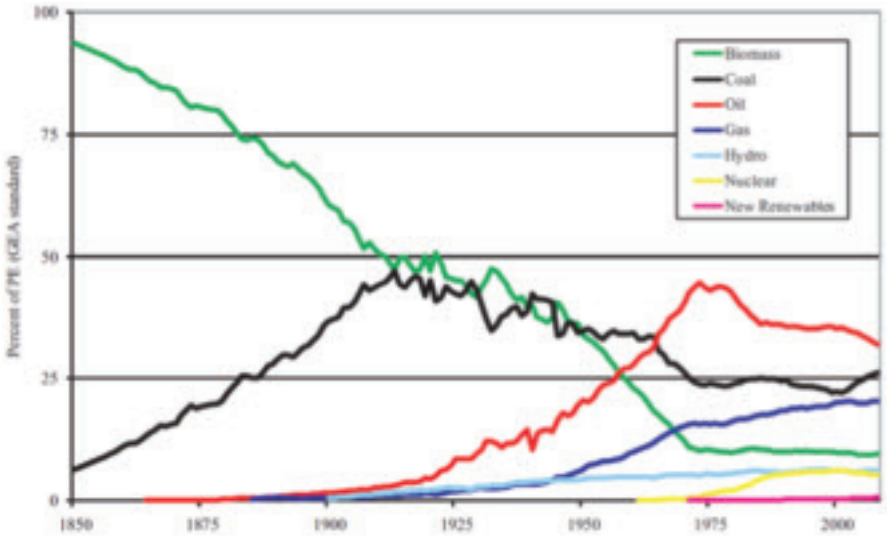

Figure 1. Structural change in world primary energy (in percent). Source: reprinted from figure 1.10 in Grübler, A., *et al.* Energy Primer, in *Global Energy Assessment - Toward a Sustainable Future* (Cambridge Univ. Press, & the International Institute for Applied Systems Analysis, 2012), updated from Nakićenović et al., 1998 and Grübler, 2008.

Clusters of reinforcing technologies don't determine which fuels dominate, but they put a big thumb on the scale. Efforts to shift away from favored fuels and infrastructures—which, in effect, is what is behind calls for revolution in the energy system—face strong headwinds and the need for an active push by policy makers. The heavier the thumb the stronger the headwinds and the harder it is for policy to make a difference.

Second, over time, energy systems electrify. In the era of coal dominance fuel was burned directly at the place where energy was needed—in a turbine located at a factory, on a steam engine connected to a long line of rail cars or in a pump used to remove ground water from mines. Electrification has made it possible to separate—financially and geographically—the investment in technology needed to make power from the places where it is used. It has allowed for much greater efficiency—big power plants are usually a lot more economical than many smaller ones. It has also made geographically dense

consumption of energy—whether on the confines of a factory floor or in the concentrated living of a city—feasible because power arrives by wires with a tiny footprint while the pollution and noise of the venture are shifted to remote areas.

Indeed, all modern economies electrify. Figure 2 shows, for example, the case of the United States over the last century (top panel). At the beginning of the period essentially all primary energy was consumed at the point of use. Over time, very slowly and steadily the fraction of primary energy converted into electricity has risen—it is nearly half today. In effect, the energy system has largely bifurcated into two systems (figure 2, bottom panel). One is dominated by electricity, which is the main carrier of energy for stationary applications. The other is transportation, the one area where electricity—until perhaps recently—can't occupy because moveable systems are hard to wire. The rest of energy goes into more diverse applications.

Electricity could prove particularly important for deep and rapid decarbonization for two reasons. First, electric networks are designed for large power generators and thus well suited to the large engineering systems that might be needed for low- and zero-carbon energy supplies—such as carbon capture, advanced nuclear and central station solar systems. Second, and perhaps even more importantly, electric infrastructures can facilitate a more rapid change in emission profile—while the infrastructure has, in the past, been the handmaiden for a high carbon power system it is equally supportive of low carbon systems. If decarbonization happens through electrification then the 50-70 year time scales for change that have dominated in past might not apply.

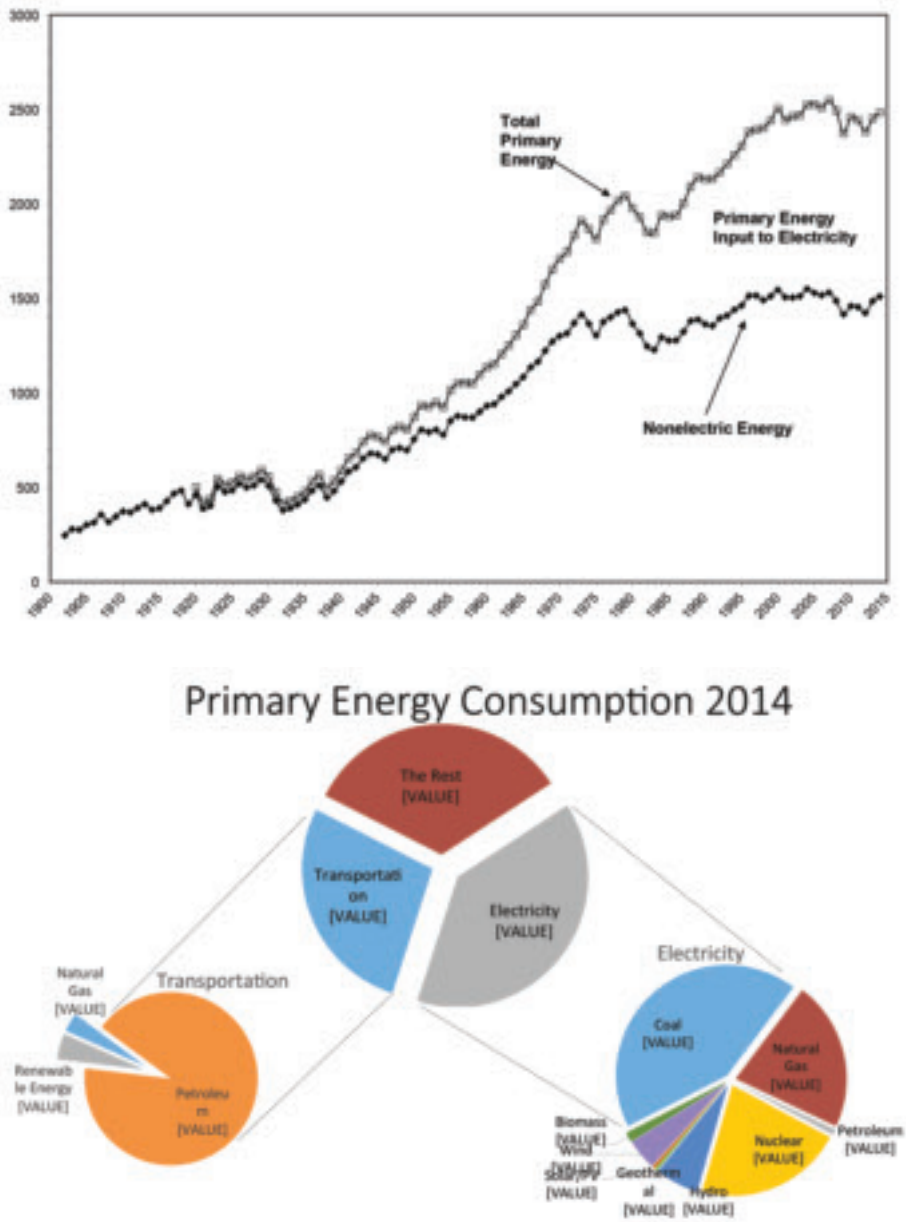

Figure 2. *Source:* ILAR analysis using data from EIA Monthly Energy Review, Table 1.1 and Table 2.6 (August 2015).

Looking globally, emission statistics reveal these dominant roles for transportation (and thus oil) and electrification. Figure 3 shows the allocation of all emissions of warming gases by sector. About one-quarter relates to agriculture, forestry and land use (AFOLU), a fraction that is declining steadily as deforestation slows and reverses. The rest are in transport applications (left side of the chart) and electricity (right side) along with a host of mainly industrial applications where large scale allows for direct combustion of fuels.

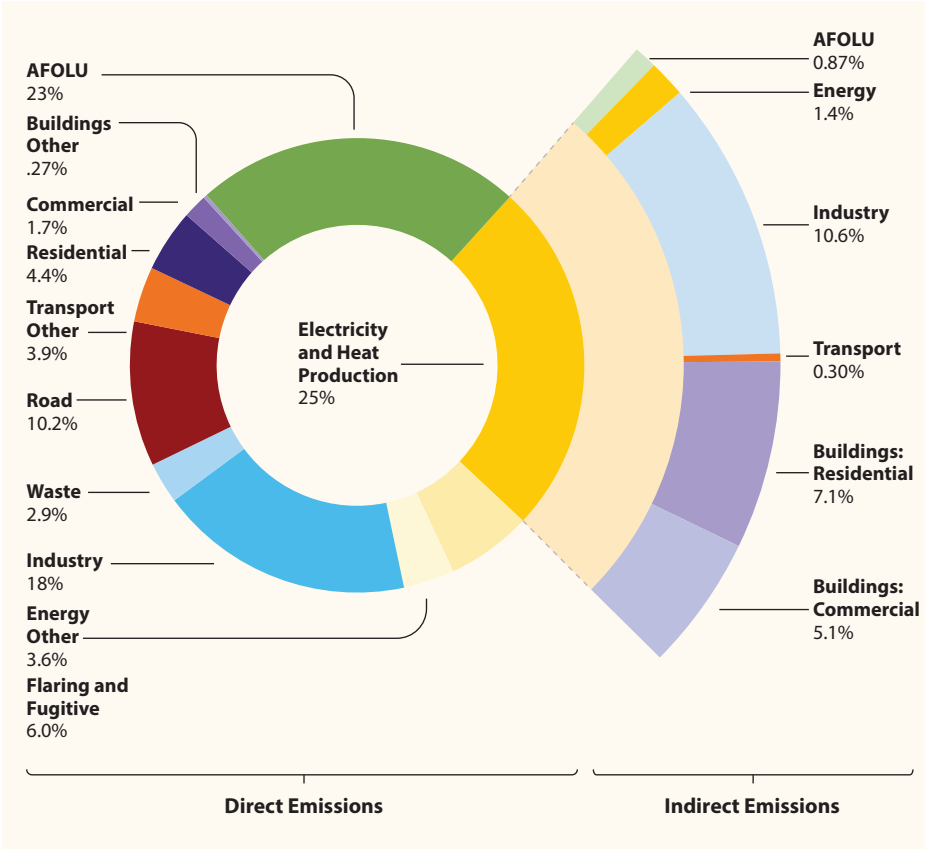

Figure 3. *Source:* reprinted from figure 1.3a in Victor, D. G. *et al.* in *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (eds Edenhofer, O. *et al.*) (Cambridge Univ. Press, 2014).

These first two iconic results reveal that, over time, the greatest leverage on emissions and other side-effects of the energy system lie with electricity and transport. And they tell us that rates of change in those systems are likely to be many decades long.

The third iconic result from energy research is quite inconvenient. If the world is to stop climate warming then emissions from the energy system must reduce radically and rapidly. Figure 4, drawn from the latest report of the Intergovernmental Panel on Climate Change (IPCC), shows historical patterns of emissions (rising steadily) and future projections under different scenarios. Business as Usual (BAU) projections, which assume a continuation of historical patterns of gradual improvement in efficiency and evolution in energy infrastructures, lead to a doubling of emissions. Other research shows that doubling, in turn, can lead to climate warming of perhaps 4 degrees Celsius above pre-industrial levels, with catastrophic consequences.[4]

If aggressive efforts are made to improve efficiency then emissions still rise (purple scenarios). Only with deep cuts in emissions (blue scenarios) is it possible to stop warming at about 2 degrees above pre-industrial levels, a goal that has been widely discussed although is now essentially impossible to achieve.[5] Even scenarios that probably overshoot 2 degrees but at least stop warming at modestly higher levels (yellow scenarios) envision deep, prompt cuts in emissions.[6]

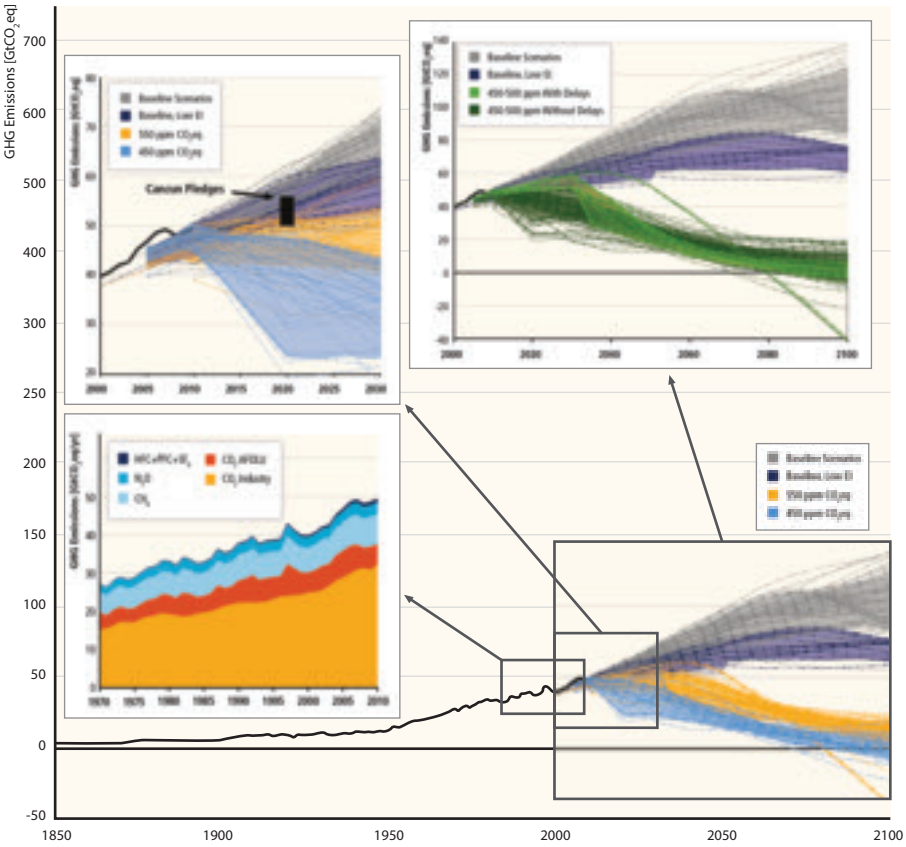

Figure 4. Source: reprinted from figure 1.9 in Victor, D. G. *et al.* in *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (eds Edenhofer, O. *et al.*) (Cambridge Univ. Press, 2014).

The inconvenience in all this is rooted in the fact that deep cuts in emissions require rapid changes in energy systems—changes that must begin immediately and unfold over a matter of just a few decades despite the fact that energy systems don't normally change so quickly in history. Indeed, that awareness of history and of the feasible rates of change has been lacking in many analytical studies. For example, many models show that very deep and rapid cuts in emissions are feasible, but recent work probing the assumptions

in those models find that they typically assume that new-fangled power plants will quickly appear and become pervasive in the energy system even though no such power plants actually exist today.[7] Studies that have added more real-world assumptions to these models—for example, giving the models information about how real firms invest in the face of large policy risks—show that actual rates of technological change are likely to be much slower and more in line with what has been observed historically.[8]

There have been calls for revolution in the energy system for many other reasons as well, such as improved energy security and better control of local pollution. But none of those other demands has created the same level of challenge as climate change. Existing power grids can be built in ways that make them more reliable. Existing and new power plants can be built with more equipment to control local pollution. But carbon requires a revolution.

Toward a Revolution

With luck, a revolution might happen on its own. Historically, new technologies periodically emerge largely on their own—because a new frontier is discovered and technologies, on their own, become "ripe" for change. The fundamental innovations around recombinant DNA and modern biotechnology emerged in this way. Much of the IT and computing revolution sprung forth autonomously as well—thanks to radical innovations in chip technologies and software. In energy, the revolution in gas supply emerged largely autonomously—bringing with it much cheaper natural gas that, in turn, displaced a large fraction of the coal-fired power market. Of course, when one looks closely at any of these autonomous revolutions the guiding hand of policy usually comes into focus—notably with investments in basic research.[9][10] But the technology, for the most part, followed its own nose.

A major revolution across the whole energy system seems unlikely to emerge on its own. A steer from policy will be needed. But how? The answers lie on two fronts—at the micro level with policies aimed at individual technologies, and at the macro level with coordination across countries.

Micro-incentives

At the micro-level, the central challenge is to get firms and other users of technologies (e.g., governments, armies, schools) to invest in better systems. In most economies, most efforts to create incentives for innovation and investment focus on firms since it is thought that the private sector makes most decisions related to the deployment of new technology and the private sector is more skilled at making those decisions wisely.

I will focus on the private sector in this essay, but I note that a singular focus on the private sector might not always be best for at least two reasons. First, governments often have a hard time developing the administrative skills and political consensus needed to adopt and implement policies that affect the private sector. Thus governments often pursue "second best" policy strategies—such as orders by government officials that government, itself, procure new technologies. In California, for example, there are policies in place to require the whole state economy to reduce emissions of warming gases by 15% by year 2020.[11] However, an order from the Governor requires that state facilities do more—a cut of 40% by 2030.[12] Second, in many countries the private sector isn't that important in the energy business—state owned enterprises (SOEs) reign supreme, often because governments don't trust the private sector to manage vital national resources or don't have the administrative systems in place to be able to regulate private firms effectively. In those countries, national oil companies (NOCs), state owned power companies, and other forms of SOEs occupy the commanding heights of the energy system.

In the private sector, the incentives to adopt new technologies can arise either from a "push" or a "pull." The best policy strategies blend the two.

Policy can "push" new technologies into service by funding research—often basic research into fundamental new technologies. That was the insight from early government investment in information technology, software and health—that sponsorship for fundamental research from the National Science Foundation (NSF), the Office of Naval Research (ONR), DARPA, DOE's

Office of Science, NIH and other basic science enterprises pushed new ideas into viability. Some of these agencies were interested in basic research for its own sake. Others had directed missions that happened to overlap with the interests of basic science. ONR, for example, was interested in improving the capacity to detect enemy submarines and thus funded basic research in acoustics and ocean propagation—leading to whole new branches of science as well as unforeseen applications.[13]

One of the central challenges in fostering a revolution is creating a big enough push. Figure 5 shows total federal spending on energy-related research development and demonstration (RD&D)—a broad category that includes basic science as well as applied ventures such as demonstration projects. RD&D data are, in many ways, flawed measures of how much a country actually spends pushing basic ideas, but they are a good place to start. In real dollars, spending has been flat since the early 1980s. (Other data show that the focus of spending has shifted quite a lot—away from nuclear power and toward renewables, for example. Globally, nuclear power accounted for more than half of all energy-related RD&D spending in 1980; today it is about one-quarter. Renewables and energy efficiency account for about half of today's energy-related RD&D spending globally, up from about one-fifth in 1980.[14]) The stimulus package in 2009 caused a huge pulse in spending, but when that ran dry the patterns reverted to much lower levels. Figure 5 also shows several proposals for the level of RD&D that the country should pursue—typically twice to three times current levels. Many have called for such changes but the budget has not followed.

Government has central roles to play in pushing new ideas into service—especially as funding shifts from basic research (where it is important to spend money widely) to more costly demonstration projects where winners must be chosen. It is fashionable to say that government should not choose winners when, in fact, such choices are essential. It is also fashionable to say that government performs this task poorly when the track record is, actually, better. Failures such as Solyndra are not, by themselves, evidence that government can't choose the right technologies and firms—instead, they are usually evidence that government is rightly taking risks. Taking risks is not

the same as blind faith, of course—a point that will be tested in the coming years with carbon capture and storage (CCS) technologies. A large number of studies point to CCS—including negative emission bioenergy CCS (BECCS) technologies as pivotal to deep cuts in emissions. Yet the actual investment in CCS has been slow to respond, and costs remain high—problems that are even worse for CCS schemes that would utilize natural gas, a suite of technologies that would be particularly pivotal in a world that is awash in natural gas. Some hard decisions about picking winners are long overdue on CCS.

U.S. Federal Energy RD&D Spending: 1980 to 2014, Major Proposals to 2025

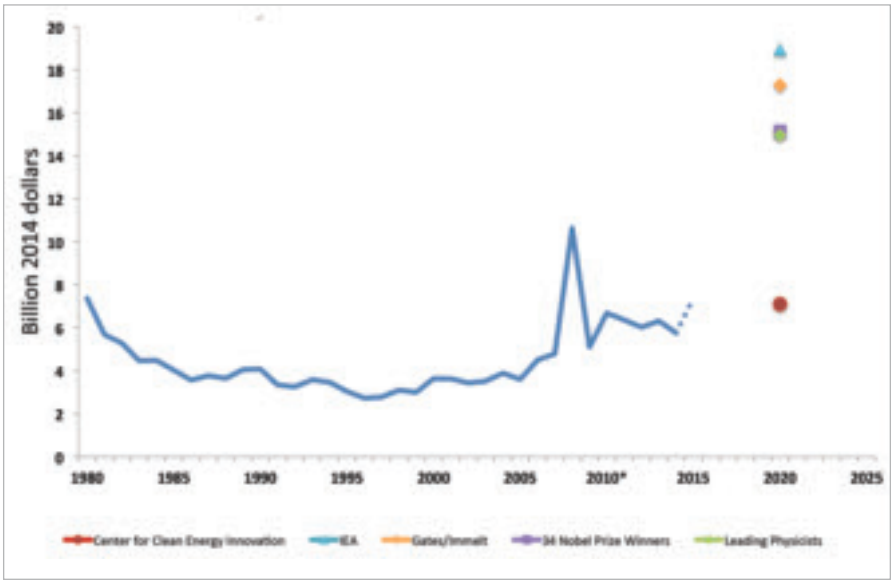

Figure 5. *Source:* ILAR analysis using data from International Energy Agency Energy Technology RD&D; The President's Budget FY2015 & FY2016; American Energy Innovation Council "Restoring American Energy Innovation Leadership: Report Card, Challenges, and Opportunities" (2015); The President's Climate Action Plan (2013).

In some fields, proving the existence of a new scientific concept can be enough to bring the new idea into service. In pharmaceuticals, for example, many ideas for new drugs spring directly from basic science—which helps to explain why profit-seeking pharmaceutical firms spend so much money on basic research whereas most firms tend to view basic science as a public good that government should provide. But few of the innovations that are likely to cause a revolution

in the energy system will spring forth directly from basic research. The "push" helps to improve the supply of new ideas. But a "pull" from the market is needed to convince firms to invest.

Pulls can come in many forms—here I will focus on two broad categories. One comes in the form of direct regulation—a requirement that firms install new technology, such as the mandate under the Clean Air Act that all new power plants install scrubbers to cut emissions of sulfur dioxide (SO_2). When those mandates first appeared no utility knew exactly how to comply so they invested in research and demonstration projects—notably investments by Southern Company and by a consortia of utilities through the Electric Power Research Institute (EPRI)—that proved scrubber technology, lowered costs and improved reliability. Absent the regulatory mandate that investment would have been much slower to unfold.

Another form of pull comes from market incentives—such as pollution taxes or tradable emission credits. The U.S. and a few other jurisdictions have experimented with emission credits with mixed but encouraging results. What is clear is that these schemes are very good at encouraging firms to find least cost ways to comply—often cutting total costs by half when compared with a plausible regulatory alternative.[15] What's more hotly contested is how these different systems affect innovation. There is some evidence to suggest that strict regulatory mandates promote more innovation—perhaps because firms treat them as more credible and the very inflexibility forces innovation.[16] (Often these are called, in fact, technology-forcing standards.) Economists, for the most part, have been very uncomfortable with these findings because the boost for innovation can come at a huge economic cost—in effect, forcing firms to comply through innovation rather than hunting for the cheapest strategy.

Whether regulation or market-based, the effectiveness of forces that pull new technologies into service is based on credibility. If firms believe that new standards or market signals will come into force then they will make anticipatory changes in behavior. When the U.S. sulfur trading program was created in 1990, for example, firms immediately saw this legislation as credible

and had assumed (erroneously) that permit prices would rise over time. They invested, in anticipation, in new scrubber technologies. One of the reasons that emission credit systems for CO_2 and other warming gases have not yet had much impact on innovation is that firms do not know whether these schemes will yield credibly higher prices. Europe's Emission Trading Scheme (ETS), for example, generated high prices for several years and inspired firms to look at new technologies such as carbon capture and storage (CCS). But when policy makers allowed ETS prices to fall sharply and offered no credible solution that would raise prices in the future firms lost faith that market signals, by themselves, merited much investment.

Macro-coordination

Back in the late 1980s, when the climate change issue appeared on the agenda, the macro dimension of this story was not particularly important because individual countries—notably the U.S. but also Japan, Germany, France and the U.K.—could have a huge impact on technologies within their borders through policies that operated at the level of the nation-state. If those countries pursued a strategy aimed at creating a revolution in energy supply systems then the revolution would follow—first in those lead markets and then eventually in the rest of the world. But the rest of the world didn't matter much since it accounted for a much smaller share of global emissions.

Today that is quite different. The advanced industrialized countries that have traditionally been the epicenter of innovation account for much less than half of world emissions—perhaps one-third or less—and that share is declining. Real leverage on emissions requires looking to other economies, notably the emerging economies. Moreover, the market for energy technology is fully globalized. Korean firms are building nuclear plants in Abu Dhabi. The frontier of innovation in advanced coal-fired power plants has shifted from western Europe to China. Advanced smart meters are being built from components sourced in many countries and deployed at frontier markets as diverse as Italy, California and India.

Put differently, knowledge is a global public good. This globalization of

technology is an opportunity because it means that the most efficient technologies can quickly spread from centers of innovation to the rest of the global economy. But it creates a huge new challenge for policy makers since national governments, looking at their own incentives, will tend to under-invest in global public goods. Everyone benefits from additional knowledge, but since those benefits are difficult to exclude in a global economy individual nations will be inclined to free ride.

Figure 6 illustrates this shift by showing global investment in innovation (measured in dollars) for the IEA regions. And figure 7 shows the lagging pattern in the actual output of new ideas (measured in patents—in this case, patents filed in the U.S.).

Global Total RD&D Spending by Regions

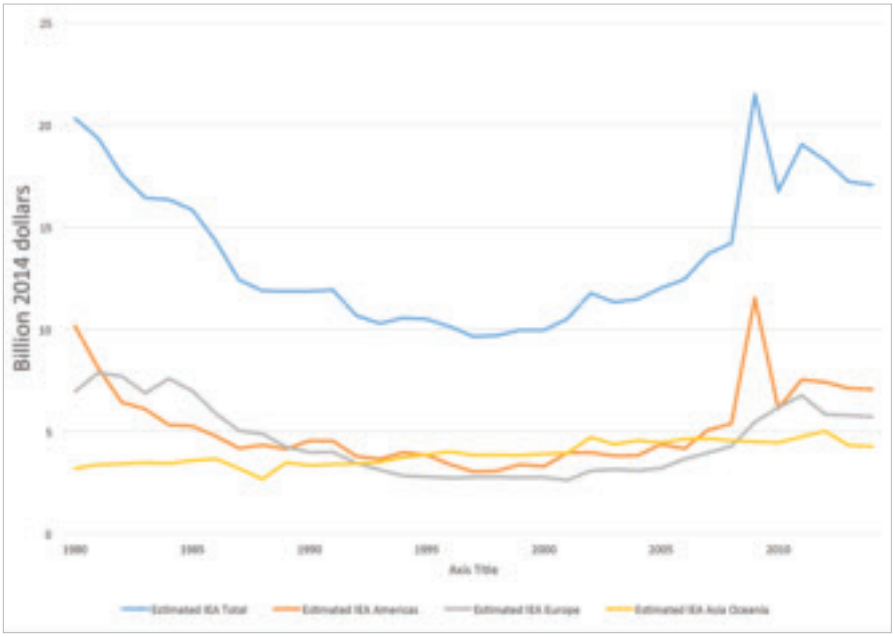

Figure 6. *Source:* International Energy Agency Energy Technology RD&D

USPTO Patents Granted in Alternative Energy and Pollution-Control Technologies

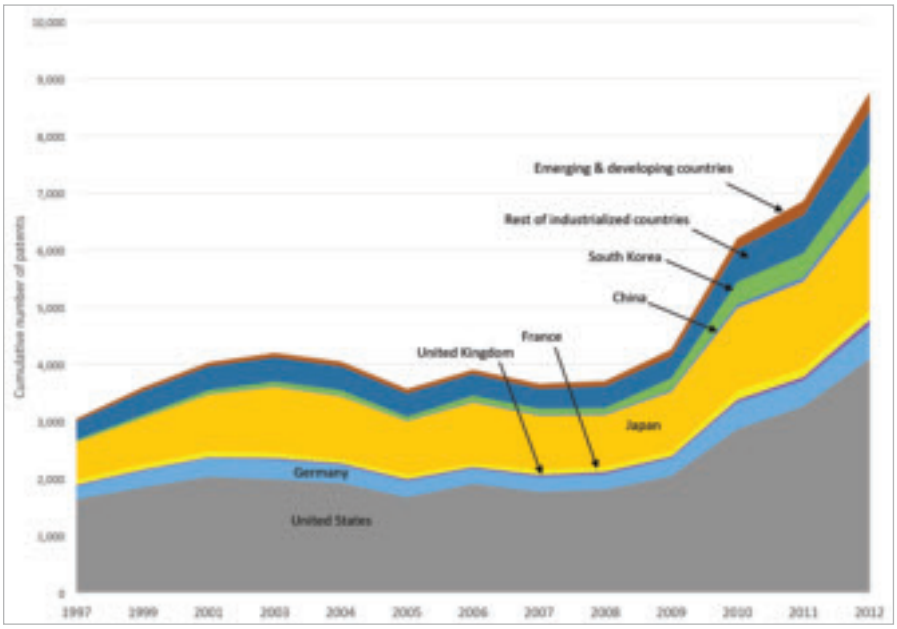

Figure 7. *Source:* The Patent Board (2013) & NSF *Science and Engineering Indicators* (2014)

Because knowledge is a global public good a measure of cooperation is needed. Each nation that is relevant in the production of knowledge should adopt national policies that help to address the tendency to under-invest in energy-related technologies and ideas. And each nation, seeing that others are doing the same, will be more likely to do more on their own than if they evaluated their policies solely from the perspective of the individual country. This is the essence of a global collective action problem—a problem that is familiar in international trade, coordination of mitigation of climate emissions, protection of the ozone layer, and a host of other challenges that require global cooperation.[17]

Because international cooperation is implicated, crafting effective energy innovation policies will be more difficult than in earlier days when one country (the U.S.) was so dominant that it could set the global tune through

its own actions. The good news, however, is that the number of countries relevant to energy innovation is small. Unlike cooperation on the control of emissions—which must involve at least a dozen countries and eventually many more—coordinating policies on innovation can work effectively in a much smaller club. Figures 6 & 7 suggest that perhaps half a dozen countries matter.

Getting the club together will not be easy, but nothing in the realm of climate policy has proved easy so far. Worse, very few efforts to build an innovation club have actually been tried. Instead, for more than 20 years international climate diplomacy has focused on mitigation of emissions—so far, achieving very little in that realm. Now there is more attention to the need to prepare for climate impacts—a field known as adaptation. But technology and innovation have been essentially ignored. Outside the institutions focused on climate change—such as the United Nations Framework Convention on Climate Change (UNFCCC)—there also hasn't been much real attention to building a serious innovation strategy globally. In the International Energy Agency (IEA) a series of excellent reports on energy technologies has been issued regularly,[18] but not much else has happened on innovation. The G7, G20, MEF and other forums for high-level political discussions have largely ignored the topic as well.

The difficulties in building an effective international innovation strategy lie on two fronts. First, few governments are under much pressure to act. In democratic countries—and in authoritarian countries where leaders fear for their survival—public pressures about energy-related topics have focused more directly on emissions and on locally visible environmental harms. That focus has inspired political leaders to concentrate on mitigation and on making bold promises but not on the hard work of devising long-term emission control strategies. Second, real innovation policies are complex. They involve not just spending of money on RD&D but also protection of intellectual property, the creation of credible market "pulls" for new technology that can complement the push from RD&D, and in many cases reform of governing institutions such as the firms that are dominant in the energy sector. Not surprisingly,

these are tasks for which individual countries vary in their preferences and capabilities. Even if governments act in good faith they may not know exactly what they can achieve—making it hard to offer credible (let alone binding) promises to other countries.

In other realms of international cooperation problems of this type—where the gains from cooperation are huge but spread far into the future, where preferences vary across the key players, and where there are high levels of uncertainty about the best policy strategies—are solved not through big, global diplomatic conferences. Those conferences lead to deadlock because the process of bargaining is too complex and the enterprise is highly vulnerable to just a few countries blocking progress—a particularly severe problem when diplomacy occurs within the UN system where consensus is usually required for decisions.[19] Instead, progress comes from working in smaller groups focused on particular tasks. In effect, governments and firms run experiments to see what works (and not) and then use what they learn to make more precise commitments over time. In other terms, what is needed is an experimental governance (XG) approach to policy coordination.[2021]

The XG approach to policy coordination is on display, perhaps, with the US-China bilateral cooperation on climate change.[22] While most press attention has focused on the emission pledges made in November 2014 when the bilateral agreement was announced, much more important for the long-term is probably technology cooperation. The U.S. and China are top spenders of RD&D. China is rapidly increasing its output of new knowledge as well—such as measured by patents. China offers the partnership, as well, a convenient location to build demonstration projects since large-scale engineering projects are much less expensive (by a factor of 2 to 3) in China when compared with the west.[23]

Making an XG approach to technology innovation actually work will require an agenda that is much more focused than most of today's diplomatic discussions. Real experiments require real areas of policy action—including real projects. The membership in policy clubs will usefully vary with the

substantive topic. China will be a pivotal member of clubs that involve demonstration of advanced coal technologies since that country is a leader in the field and has also proved its ability to build large projects at low cost. Korea, among others, is a logical partner for advanced nuclear projects. And so on.

One challenge will be to find the right balance between tangible projects—such as demonstration of advanced technologies—and coordination around supporting policies. Striking this balance may prove most difficult is in intellectual property (IP). There has been a tendency, especially for American policy analysts, to equate innovation with protection for IP and to assume that more IP is always better—despite all the evidence that IP can often be overly protective in ways that stifle innovation. IP has a role to play, but the full range of relevant policies is much broader.

Making It Happen

The climate problem is plagued by a string of inconvenient facts about the energy system. Most emissions come from the production of useful energy services, and changing that will require fundamental changes in energy technology. Over history, those changes have happened—but only over many decades and at a rate that is about two to three times slower than the rate of reduction that many climate scientists have said would be needed to protect the climate system. Directing that change with policy, rather than just letting it happen autonomously, will require very complex policies that vary across countries. Innovation is central, but so far the countries that do the most on innovation still probably under-spend by a factor of two to three. And politically, no government is under much pressure to be bold about innovation.

Putting all these inconvenient facts together explains why politicians have been good at talking about climate change and energy revolutions for more than 20 years but not so good at doing much.

Today, some governments may be on the cusp of a shift. There is now widespread recognition that the diplomatic strategy followed for the last two decades on climate change has failed. It has tried to do too much within a framework that is too inflexible. In its place is a new strategy based on breaking the climate problem down into smaller, manageable pieces and into smaller groups.

One of the central problems that should be on the agenda of these small groups is innovation. It won't be possible to make deep cuts in emissions without new technologies that make it feasible to provide useful energy services without all the warming pollution.

There are some auspicious signs for technology clubs already. Those include the fact that most innovation actually occurs in just a few countries—making it easy to identify and gather the nations that matter without (at least initially) the complexities of engaging a much larger group of nations with diverse preferences. In addition, some technology clubs are already taking form—most notably the US-China bilateral partnership announced in November 2013.

At the same time, there will be many difficulties in actually making these clubs work. An XG strategy will require that governments be willing to fund (and assess) many experiments to see which technology policies actually work—something that some governments have done but have not, so far, been willing to share fully and openly through international peer review. And the clubs will need to include commitments of many different types. Some will relate to the level of funding for energy RD&D that each club member makes—assuming that countries are willing and able to spend those resources, that should be straightforward. But equally important will be commitments to spend RD&D resources efficiently—and to coordinate, to some degree, national RD&D portfolios internationally. There are some precedents for that—such as when countries are required to coordinate because they are physically joined together at a single large facility, such as a space station, telescope or collider. But serious cooperation of this type in energy is relatively rare—when models

are sought the architects should look to fields such as the human genome project where countries have actually achieved a measure of coordination while still preserving a large degree of autonomy for themselves.

This is not the first time that countries, dissatisfied with global cooperation on climate change, have shifted to small groups. The Bush administration did that with the Asia Pacific Partnership. Other countries, in alliance with the U.S., did that with the G20 and the MEF. And those smaller efforts have, so far, achieved very little.

Whether the same thing happens, again, after Paris will depend on whether countries see tangible value in cooperation on technology. Small groups, such as the U.S.-China bilateral, must pivot from being places where there is talk about innovation to being vehicles for generating tangible new ideas as well as sufficiently exclusive markets where there are gains for the firms and countries that make an investment.

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