S. HRG. 115–353

THE STATUS AND OUTLOOK FOR U.S. AND NORTH AMERICAN ENERGY AND RESOURCE SECURITY

HEARING

BEFORE THE

COMMITTEE ON ENERGY AND NATURAL RESOURCES UNITED STATES SENATE

ONE HUNDRED FIFTEENTH CONGRESS

FIRST SESSION

JULY 18, 2017

Printed for the use of the
Committee on Energy and Natural Resources

Available via the World Wide Web: http://www.govinfo.gov

U.S. GOVERNMENT PUBLISHING OFFICE
26–867 WASHINGTON : 2018

COMMITTEE ON ENERGY AND NATURAL RESOURCES

LISA MURKOWSKI, Alaska, *Chairman*

JOHN BARRASSO, Wyoming	MARIA CANTWELL, Washington
JAMES E. RISCH, Idaho	RON WYDEN, Oregon
MIKE LEE, Utah	BERNARD SANDERS, Vermont
JEFF FLAKE, Arizona	DEBBIE STABENOW, Michigan
STEVE DAINES, Montana	AL FRANKEN, Minnesota
CORY GARDNER, Colorado	JOE MANCHIN III, West Virginia
LAMAR ALEXANDER, Tennessee	MARTIN HEINRICH, New Mexico
JOHN HOEVEN, North Dakota	MAZIE K. HIRONO, Hawaii
BILL CASSIDY, Louisiana	ANGUS S. KING, JR., Maine
ROB PORTMAN, Ohio	TAMMY DUCKWORTH, Illinois
LUTHER STRANGE, Alabama	CATHERINE CORTEZ MASTO, Nevada

COLIN HAYES, *Staff Director*
PATRICK J. MCCORMICK III, *Chief Counsel*
BRIANNE MILLER, *Senior Professional Staff Member and Energy Policy Advisor*
SEVERIN WIGGENHORN, *Senior Counsel*
ANGELA BECKER-DIPPMANN, *Democratic Staff Director*
SAM E. FOWLER, *Democratic Chief Counsel*
SCOTT MCKEE, *Democratic Professional Staff Member*

CONTENTS

OPENING STATEMENTS

WITNESSES

ALPHABETICAL LISTING AND APPENDIX MATERIAL SUBMITTED

THE STATUS AND OUTLOOK FOR U.S. AND NORTH AMERICAN ENERGY AND RESOURCE SECURITY

TUESDAY, JULY 18, 2017

U.S. SENATE,
COMMITTEE ON ENERGY AND NATURAL RESOURCES,
Washington, DC.

The Committee met, pursuant to notice, at 10:35 a.m. in Room SD–366, Dirksen Senate Office Building, Hon. Lisa Murkowski, Chairman of the Committee, presiding.

OPENING STATEMENT OF HON. LISA MURKOWSKI, U.S. SENATOR FROM ALASKA

The CHAIRMAN. Good morning. The Committee will come to order.

We are here today to consider the status of U.S. and North American energy and resource security, to review our production, our imports and our exports and where we are as a country, as a continent, in light of them.

The good news, I think, is that we are in a much better place today than even a few short years ago. It was not long ago that peak oil and the need for LNG exports dominated policy discussions here on Capitol Hill. Prices were high, our production levels were low and our energy security was at risk as a result of outside decisions and disruptions, particularly those in the Middle East.

But I think we have seen that times have changed, and I would say for the better, due to tremendous innovation and technological advances, our nation has moved away from energy scarcity and isolation. We are in the midst of a significant surge in oil and natural gas production with renewables making a noteworthy contribution.

We have also taken steps to open up our markets, especially by lifting the ban on export of domestic crude oil which by all accounts stands as a smart, timely and beneficial move.

Today we are far more energy secure than at any point in recent memory, and we have reached a point where energy dominance, to borrow the Administration's phrase, has become a real and legitimate policy goal.

We are in a position to export energy to our allies, lessening their dependence on unfriendly and unpredictable regimes around the world. That will allow us to create new jobs, generate new revenues and improve our balance of trade, while also providing affordable and reliable energy supplies to countries around the world.

OPEC no longer holds all of the cards when it comes to the price of oil. Our friends in Europe and Asia have an excellent new option to reduce their dependence on natural gas from Russia. This Administration, I think, deserves support for its efforts to increase access to keep these good trends going.

Alaska is certainly ready to help strengthen our energy security. We are the most resource rich state in the nation. We currently account for six percent of the total energy production in the United States, but we have the opportunity to do a lot more.

Given recent discoveries both onshore and offshore in Alaska, along with our long-standing efforts to produce in our national petroleum reserve, the non-wilderness portion of ANWR and our offshore Arctic, we can and should celebrate this 40th anniversary of the Trans-Alaska Pipeline System by agreeing to refill it. Doing so would help our economy, our budget and our energy security while at the same time making sure that we protect the environment.

Of course, oil and gas are just a part of the energy security picture. We have abundant coal reserves, significant growth in renewable generation, a large nuclear fleet and a reliable electric grid. Yet, we should also recognize that some developments, especially those in nuclear energy, are not as positive and threaten our longstanding, global leadership in key fields.

We cannot forget about our mineral security either. It is routinely ignored but increasingly critical to our future. We are becoming more and more reliant on minerals for everything from smartphones and solar panels to advanced defense systems, but our mineral security has fallen dramatically year after year. I believe that we have to pay greater attention to this, and we have to take steps to resolve it.

This morning's hearing is also an opportunity to recognize our close ties with our neighbors, Canada and Mexico, which also have dynamic energy sectors. We have long had robust energy trade with both nations through both electric grids and pipeline systems. As we look to what the future will hold, we should consider not only our national security but also our continental security and the significant benefits that will provide to us.

I want to welcome our distinguished panel who will help us understand what is happening in global markets and with geopolitics, from domestic production and export policies to potential sanctions on other nations. There is a lot to consider, to understand and to work through right now.

I thank you all for being here to share your expertise with us, and I look forward to your testimony.

At this time, I will turn to Ranking Member Cantwell for her comments.

STATEMENT OF HON. MARIA CANTWELL,
U.S. SENATOR FROM WASHINGTON

Senator CANTWELL. Thank you, Madam Chair. Thanks for scheduling today's hearing on energy and resource security.

As we all know from the Quadrennial Energy Review that was done in the last Administration about the energy needs of our country moving forward, enhancements to our electricity grid for more renewable energy sources and the complexity of dealing with

aged infrastructure and what I would call, probably, robust commodity competition on our rail lines and the structure of where energy is developed and moved to, has created new challenges.

The Quadrennial Energy Review also pointed out the very important need to protect critical energy infrastructure from both physical and cybersecurity threats. I believe we must take this action very seriously in protecting our energy infrastructure from cybersecurity threats to ensure America's energy security of the future.

As was just reported last week by the Washington Post, it is clear now that there were Russian government hackers who tried to infiltrate a U.S. nuclear power plant. I believe we need to act and we need to act now.

Our grid and energy networks are under constant cyberattack. From 2012 to 2016, reported cyber incidents against U.S. critical infrastructure more than doubled. In December 2015, suspected Russian hackers infiltrated three Ukrainian utilities knocking out power to more than 225,000 customers and they did it again to a utility north of Kiev earlier this year. Recently, the U.S. Department of Energy described the incident in Ukraine as "step change in sophistication and intent of hackers."

My colleagues and I have repeatedly pressed the President and Secretary of Energy to take more aggressive cybersecurity action now. I would also say that our House colleagues need to get more serious about cybersecurity. As the Washington Post noted, "Russian government hackers have already shown their interest in targeting U.S. energy and other utility systems." In fact, the Russians have more than just a passing interest in infiltrating our grid. Just 10 days ago the Post reported that, "Russian government hackers were behind cyber intrusive attacks into the business systems of U.S. nuclear power plants and other energy companies in what appears to be an effort to assess their networks." This should set off alarm bells across our government and energy sector and the general public, and I have requested a secure briefing on exactly what has transpired in this matter.

In addition, the Christian Science Monitor has reported, "Cyber spies linked to China's military targeted nearly two dozen U.S. natural gas pipeline operators stealing information that could be used to sabotage U.S. gas pipelines."

Although we have mandatory cybersecurity standards for electric utilities, natural gas and pipelines are merely subject to voluntary agreements issued by the Transportation Security Administration, which has a small staff to oversee millions of miles of pipelines that transverse the country.

The security of our pipelines is not only important to prevent attacks, but also to protect the public. DOE's most recent Quadrennial Energy Review suggested it is important that we consider whether additional or mandatory cybersecurity guidelines are necessary for natural gas pipelines given their increased dependence between the electric and natural gas sectors.

Now that we see these vulnerabilities that the Russians have exposed to hacking our grid and the cybersecurity threat, we need to take additional actions. So I want to make sure that we are pushing the Administration in helping plan for the future.

Today, I am sending a letter to the Government Accountability Office to ask them to conduct an assessment that the United States must prioritize protection of our critical energy infrastructure and we cannot afford to wait before we have a large-scale attack. I hope to get an answer on where we are with our abilities on pipelines and making sure that our pipelines are secure for the future.

Madam Chair, we also, obviously, learned from the Quadrennial Energy Review that we need to continue to diversify our energy mix and the consequence of climate change that threatens the well-being and increases geopolitical issues around the globe. In the G7, they noted the importance of "reducing greenhouse gas emissions and accelerating the transition to a low carbon economy as a key contributor to enduring energy security." So I couldn't agree more. There is alot to do, and lots of changes have happened in the energy sector. We must prioritize those things that are going to help us be secure for the future.

I look forward to hearing from the witnesses today.

The CHAIRMAN. Thank you, Senator Cantwell.

We will now begin with our panel.

I would mention to colleagues that we had invited Dr. Fatih Birol, who is the Executive Director for the International Energy Agency. He has appeared before this Committee many times and up until yesterday we believed that we had been able to work a schedule. But he has not been able to work within the limitations that we had and not without great effort on his part as well.

I appreciate his willingness to testify. Even though he is not with us, we do have his written testimony which will be included as part of the record.

[The information referred to follows:]

Dr Fatih Birol, Executive Director, International Energy Agency

Written Testimony
Hearing of the U.S. Senate Energy and Natural Resources Committee

Dr Fatih Birol
Executive Director
International Energy Agency

"Hearing on the status and outlook for U.S. and North American energy and resource security"

July 18, 2017

Chair Murkowski, Ranking Member Cantwell, and distinguished Members of the Committee, thank you for the opportunity to appear before you today and talk about the status and outlook for the United States and North American energy and resource security. It has been my privilege to serve as the Executive Director of the International Energy Agency for the past two years. It is my distinct pleasure to share with you our latest analysis on a topic that is so central to our mandate.

I had the chance to meet with Madam Chair last May in Washington and we had an excellent discussion on developments in global energy markets and energy priorities under the new Administration. It was also a pleasure to exchange views on global energy issues with your fellow Senator from Alaska, Dan Sullivan, who is no stranger to the IEA as he previously served as a distinguished member of our Governing Board.

The IEA is fully committed to a strong relationship with the United States, a founding member that plays a leading role in our Agency's work. I was pleased to participate in the G7 Energy Ministerial meeting in Rome in April, where we worked closely with Secretary of Energy Rick Perry and other ministers to strengthen global energy security. I also appreciated the opportunity to participate with Secretary Perry in the Clean Energy Ministerial meetings in Beijing last month, where we jointly explored progress on advancing promising clean-energy technologies, including carbon capture, use and storage (CCUS).

The International Energy Agency

Madam Chair, you and many Senators here know the work of the IEA very well. However, I appreciate that may not be the case for everyone, particularly regarding our recent developments.

The IEA was founded by United States and 16 other countries in the wake of the 1974 oil crisis to promote energy security, cooperation and stable markets. It was Henry Kissinger, the Secretary of State at the time, who first called for a *"massive effort to provide producers an incentive to increase their supply, to encourage consumers to use existing supplies more rationally and to develop alternative energy sources."* His call to action led to the creation of the IEA.

The IEA has grown to become the world's pre-eminent energy-policy advisor across the entire energy mix, providing data, analysis and solutions to governments and industry on all fuels and technologies. In the four decades since we were founded, the energy world has changed, and we have evolved to tackle new challenges. While coordinating the collective response to oil-supply disruptions remains a central component of our work, our 29 member countries have asked us to take on additional responsibilities.

During our last 2015 Ministerial meeting, which was chaired by the United States, our members endorsed an innovative modernization strategy for the IEA resting on three pillars to enable us to more effectively address today's complex energy challenges.

The first pillar is opening the IEA's doors to emerging economies. In the last 18 months, we have welcomed six new IEA Association members – China, India, Indonesia, Thailand, Singapore and Morocco – reflecting more accurately the changing dynamics of the global energy system. Our Association countries are now developing closer relations with the Agency, participating in meetings of IEA committees and standing groups, working with us closely on improving energy data and statistics, strengthening energy security relationships, undertaking energy policy studies, and cooperating more closely with the Agency on their energy policies. I should also note that we will very soon welcome Mexico as our newest full member. As a result, our expanded IEA family is now much more global, accounting for 70% of the world's energy use.

The second pillar of our modernization agenda is to deepen our focus on energy security. This means broadening our horizons beyond our traditional focus on oil security to new issues affecting the security of natural gas and electricity supply. This is reflected in our recent work to understand the implications for gas security of a more globalized liquefied natural gas (LNG) market, as well as our pioneering work on the integration of larger shares of variable renewable generation into electricity systems, which I will expand on later in my testimony.

The third and final pillar of the modernization agenda is to strengthen the IEA's role as a leader in clean energy, including building a global hub for energy efficiency. The IEA looks at all fuels and technologies; and when we speak of clean energy, we include renewables and efficiency as well as CCUS and nuclear power. One key aspect of this approach is our work with almost 40 IEA Technology Collaboration Programs (TCPs), which are made up of 6,000 research analysts from around the world. The United States is represented in almost all of these TCPs – the most of any country – across a range of sectors and technologies from transport and electricity, to fossil fuels, renewables and other clean energy technologies.

The IEA also hosts the Secretariat for the Clean Energy Ministerial (CEM), a group of 24 industrialized and emerging countries, including the United States, who together promote policies and programs that advance a wide range of clean-energy technologies. As I mentioned earlier, at the CEM8 Beijing meeting I had the pleasure of hosting an event with Secretary Perry, along with energy ministers of Canada, China and Norway, on how to further drive the deployment of CCUS. I have also noted with great interest a new CCUS bill just introduced in the Senate by a bipartisan group, including key leaders from this Committee.

These three pillars represent the future of the IEA as a truly global institution with a comprehensive view across the entire energy mix and all energy technologies. Modernization of the Agency supports our core mission of energy security, which I will now address.

North American energy security

The IEA's commitment to energy security begins with individual members, whose collective efforts enhance energy security and shared economic and geopolitical benefits for all. For example, when Hurricane Katrina disrupted oil supply from the Gulf of Mexico in 2005, IEA members, including Canada,

took collective action to release 60 million barrels of oil to the market, calming markets worldwide and staving off potentially crippling oil-price spikes.

Yet collective action need not only take place in times of such supply disruptions. Continued dialogue on energy policy, increasingly interconnected markets, and further investment across North America all contribute to the long-term energy security and economic strength of the continent. Even as the United States moves towards greater energy self-sufficiency and net exports, the health of its energy system remains closely interlinked with that of its neighbors in North America and its partners further afield. All parties have much to gain from a strong and secure North American energy system and well-functioning international energy markets.

A twin oil and gas revolution

The United States stands today at the heart of a twin energy revolution: a booming shale oil and gas industry and rising supplies of liquefied natural gas (LNG). Over the last ten years, the United States accounted for more than half of the total increase in oil and gas production around the world. In fact, no country has ever achieved such a simultaneous and rapid ramp up of both oil *and* gas production. Since 2010, almost $1 trillion in capital investment has been committed to oil and gas upstream activities in the United States, with an additional $200 billion dedicated to pipelines and other midstream assets – all of which contributes to creating new, well-paying domestic jobs.

This upstream investment wave has had strong spillover effects. It played a major role in pulling the United States economy out of the financial crisis, since a substantial proportion of rigs, pipes, pressure pumps and other equipment are manufactured in the United States. Oil and gas development also generates substantial royalties for private landowners, boosting private consumption spending.

Most critically, such investment contributed to a remarkable growth in shale oil production over the last seven years of 4 million barrels per day (mb/d). Now, our latest numbers show the United States is set to lead the growth in global oil supply over the coming five years.

Turning to other North American producers, oil output from Canada increased more than 1 mb/d since 2010 and further growth is already locked in thanks to on-going projects. According to IEA forecasts, total supplies will grow to 5.3 mb/d by 2022. And in Mexico, where oil production is currently declining, the government adopted ambitious reforms to modernize the industry and improve its access to investment. Spurred by this investment, the IEA forecasts that production will begin to rise from 2020, with total output averaging 2.4 mb/d by 2022. This will further improve the supply-demand balance in North America and offer profitable investment opportunities for American companies and beyond.

The central importance of this growth in North American supplies for global energy security cannot be overstated. Since 2010, the world's oil supply has been hit by a series of geopolitical crises: Libya, Iraq, Nigeria and Venezuela among the most important ones. In the absence of production upswing from the United States and Canada, any one of these disruptions could have triggered a much more serious oil shock.

The prospect of continued remarkable growth in tight oil production from the United States, and its ability to respond quickly to price signals, provides a buffer against the risk of market disruptions in the coming years. However, at the IEA we are concerned at the contrast between the remarkable dynamism of shale producers in the United States and the suppressed level of investment and activity in

conventional oil elsewhere in the world. In this two-speed oil market, a key question for the future is for how long a surge in shale supplies can make up for the slow pace of growth elsewhere.

Even with promising progress with electric cars and other new technologies, investment in conventional oil supply remains an indispensable element of future market stability. The U.S. Administration's key policy contribution should be to maintain a supportive regulatory environment for private investment and engage where possible with other resource-rich countries around the world to encourage them to do the same.

U.S. LNG: a catalyst for the transformation of global gas markets

The United States – the world's largest natural gas consumer and producer – will account for 40% of the world's additional gas production in the next five years, according to our latest forecast. By 2022, gas production in the United States will reach 890 billion cubic meters (bcm), or more than a fifth of global gas output. Our most recent data confirmed that another milestone was reached in April of this year when the United States became a net exporter of gas for the first time.

Alongside wide-ranging domestic impacts on electricity generation and industrial competitiveness, exports of natural gas from the United States are now precipitating a second LNG revolution that is challenging both incumbent suppliers and traditional business models while transforming global gas security. In our flagship publication, the *World Energy Outlook*, the rise in LNG exports from the United States – eventually exceeding 100 bcm per year – will have a dramatic impact on global market liquidity and diversity of supply over the coming 25 years. This will change the way that gas is priced and marketed worldwide and chips away at the rigidities that have characterized gas trade arrangements in the past. Indeed, with supportive policies, a second wave of investment in liquefaction facilities in the 2020s could turn the United States into the world's top LNG exporter.

This has significant implications for energy security, not just for the Unites States and North America, but also for the world – including for some of the United States' closest allies. Today, ample supply, low prices, and the prospect of additional LNG from Australia suggest that a new era of enhanced gas security is coming, characterized by a rising share of LNG, a more diverse range of suppliers, less rigid contractual structures and greater market flexibility. All of this points to a more fluid movement of gas in response to price signals across increasingly interconnected regions.

LNG exports from the United States are already mitigating the market power of Gazprom in Europe, improving supply security and market efficiency across the world, and enabling a significant and environmentally beneficial switch from coal to gas in several countries. Meanwhile, pipeline exports to Mexico are enabling expanding electricity supply and the reduction of oil-fired generation there. The improving cost efficiency of shale also creates a robust competitive position for LNG compared to other new gas sources.

Yet even while current gas supplies are plentiful, thanks in no small part to production from United States, the current situation between Qatar and its neighbors reminds us that security of supply remains a concern. Due to the globalization of gas, through the expansion in the LNG trade and the deep interactions that gas has with the rest of the energy system, we are seeing a more interconnected environment where shocks in one region can reverberate in another.

Therefore confidence in the affordability and reliability of supply is essential if gas is to play a much larger role in the global energy system, especially in importing markets where gas faces strong competition from coal and where renewables enjoy strong policy support. By narrowing the gap between the economics of gas imports versus coal, LNG exports can reinforce the credentials of gas as a viable strategic policy choice, helping to underpin investment in connections to new end-users and accelerating air quality and other environmental benefits that come from switching to this cleaner fuel.

Electricity security

I have focused specifically on oil and gas until now but energy security in the 21st century includes rethinking electricity security. As our economies are more reliant than ever on electricity – for everything from digital communication to personal transport – ensuring the adequacy of power supply will be critical. For the United States, a key component of this challenge will be integrating higher levels of renewable power into the grid while maintaining security of supply and the viability of the nation's important nuclear power fleet.

Because wind and solar PV are variable renewable resources and their input cannot be fully forecast and programmed, the so-called system integration of these variable renewable sources has emerged as a major economic and policy challenge. And it is only set to grow, as wind and solar PV have become the two fastest-growing sources of electricity around the world since 2010, thanks to policy support and massive reductions in technology costs.

The United States is not alone in facing this challenge. Other countries already have much larger shares of wind and solar PV in their power system. For example, a number of European countries are dealing with double-digit shares, or up to six times higher than the United States, demonstrating that integrating high shares of wind and solar in a reliable and cost-effective manner is possible, provided that power systems become flexible enough.

The United States already boasts a number of power system flexibility resources, including more flexible thermal power plants (mainly gas, but possibly also coal), multiple storage options, and demand-side response. In addition to these flexible resources, market design also has a very important role to play in successfully integrating renewables. A good example of a well-designed market is the Electric Reliability Council of Texas (ERCOT), which successfully integrates growing amounts of variable renewable energy resources at costs that have generally been modest.

Ensuring digital resilience is another new and critical aspect of energy security, and an area that will become more and more important. The IEA will release a pioneering report in October focused on the intersection of digitalization and energy. This first-of-its-kind analysis will explore a variety of implications that digitization will have on the energy sector. Some of these impacts are positive, like improving efficiency and reducing emissions. Others carry significant challenges, including creating a greater potential cyber security risk.

System integration and security are areas that require additional analysis and tracking, and the IEA has taken a lead in helping to find answers. One of the IEA's contributions that is most valued by member countries is our ability to help countries learn from each other's successes and challenges.

Conclusions

The relationship between the IEA and the United States goes to our founding days. Now as then, we continue working for you and our other Member countries and stand ready to offer our analysis, advice and support as you oversee your great country's energy policies.

The first time I had the pleasure of testifying before this Committee was in 2006 when, as the IEA's Chief Economist, I spoke about the outlook for oil markets. Needless to say a great deal has changed since then. New challenges have emerged, as we've seen, along with new opportunities for the energy system. Energy markets are undergoing a tremendous transformation, led by the shale revolution in the United States. Renewables are transforming the power grid. Emerging countries are leading global energy demand growth.

The United States has made impressive strides recently to bolster its energy security, and the IEA remains ready, willing, and able to continue to help in this critical endeavor going forward. Well-connected regional and international markets bolster energy security, and the United States is fortunate to have North American neighbors in Canada and Mexico. The three countries are blessed with rich natural endowments in oil, gas, coal, hydro, solar and wind, and are front-runners in advanced energy technologies. As such, a well-integrated North American energy system is critical for global energy markets and energy security.

Chair Murkowski, thank you again for inviting me before your esteemed Committee. I look forward to answering any questions.

The CHAIRMAN. We have a very distinguished panel today.

We will begin with Mr. Jamie Webster. Mr. Webster is the Senior Director for the Center for Energy Impact at Boston Consulting Group.

Mr. Mark Mills has also been before the Committee. He is a Senior Fellow at the Manhattan Institute.

We have Brigadier General Stephen Cheney, who is the Chief Executive Officer for the American Security Project (ASP); and Mr. Robert Coward, who is the President of the American Nuclear Society. We welcome you to the Committee.

Mr. Dan McGroarty will wrap the panel up. He is the Principal of Carmot Strategic Group.

We would ask you to try to keep your comments to five minutes. Your full statements will be incorporated as part of the record.

Mr. Webster, if you would like to lead us off?

STATEMENT OF JAMIE WEBSTER, SENIOR DIRECTOR, CENTER FOR ENERGY IMPACT, BOSTON CONSULTING GROUP

Mr. WEBSTER. Thank you very much, Chairman Murkowski, Ranking Member Cantwell and members of the Committee. I appreciate the opportunity to testify before you today on the current status and outlook of the U.S. North American energy security. I appear before you in my role as a Senior Director at the Boston Consulting Group's Center for Energy Impact and also a non-resident Fellow at Columbia University.

The United States is undergoing an energy revolution that is expanding U.S. oil and gas capabilities in all ways, from production, to pipelines, refineries, storage facilities and export terminals. This has impacted the global supply balance, changed trade relationships and lowered prices for consumers. This increased energy security has allowed the United States to take a leading role as a global energy supplier.

The U.S. Energy Information Administration has noted that the U.S. has now, for the fifth year in a row, the largest natural gas and oil producers in the world. For U.S. natural gas that production rise began in 2006 and has expanded more than one-third since that time. In light of this, U.S. energy security, as it relates to natural gas and the concerns about a lack of natural gas and the need for imports quickly vanished as Henry Hub dipped below $5.00 in 2008 and have not risen above that level, sustainably, since that point.

Since that, since the price decline, the resilience of U.S. producers has been aided by finding new markets, with U.S. LNG now being offered for sale on a global basis. Far from imperiling U.S. energy security, these rising exports are actually increasing energy security for both the U.S. and the world. The ready export outlet will allow producers to keep natural gas flowing into homes and power plants at less cost, and exports of LNG are providing consumer countries with another choice of energy supplier, allowing them to negotiate better pricing and increasing market responsiveness.

The U.S. is now expected to be one of the top three natural gas exporters in the world by 2020. To meet this there are expectations of export terminals on all three coasts. Along with that is a growth

in natural gas storage which has expanded more than a trillion cubic feet in the past 10 years with more than 20 new fields added.

Oil from the shale region started to grow after production in natural gas was hit by the lower prices and arguably had its first significant impact in 2011 when U.S. light, sweet crude began to replace imported barrels from OPEC's Nigeria. This was an important energy security turning point as it blunted the risk of production outages from this country. A reminder that Nigerian production outages caused by strife in the Nigerian Delta region were a key factor in raising global oil prices above $100 in 2008, that summer U.S. drivers paid as much as $4.72 per gallon for gasoline. This past Fourth of July weekend, 20 percent of consumers were able to get natural gas—gasoline for less than $2.00.

There are concerns about the longer-term durability of North American energy security, particularly as it relates to oil. Those risks include: high decline rates; oil production in the shale regions decline by as much as 300,000 barrels a day, requiring substantial activity to keep going; drilled but uncompleted wells which are up by over 1,000 wells in the last year—the lack of being able to actually complete those is slowing down production growth; and a dependence on the Permian where most, 60 percent of production growth in the last year has actually come out of the Permian versus other places.

Now there has been substantial growth in terms of rig productivity. A rig brought on today delivers 2.5 times as much productivity as a rig that was brought on in 2014, a credit to what the United States energy industry is able to do.

The longer-term concern is the sufficiency in the global context that the U.S. oil is actually still a fairly small part of the system and a longer-term concern that there won't be enough investment to keep prices down in the three- to five-year timeframe.

We've also had extremely strong growth in refined product and being able to store oil over 100 million barrels a day. One hundred million barrels has now been put into capacity over the last several years, expanded storage capacity has also supported the operational needs for refineries, with refineries now producing or being able to produce 18.1 million barrels a day of capacity. This is the fifth year in a row that they've grown.

The advantage to increased production, pipeline refinery and storage capacity in the United States is an expansion of not just our own energy security, but the ability to extend that to other countries. Add to this impressive mix that the fact that the United States has the most transparent, frequent and capable energy data system in the world in the guise of the Energy Information Administration, and this allows the benefits of the U.S. to be known and transmitted to all market participants benefiting and increasing energy security in the U.S. but also globally.

Thank you very much.

[The prepared statement of Mr. Webster follows:]

U.S. Senate Committee on Energy and Natural Resources hearing to examine the status and outlook for US and North American energy and resource scarcity

Testimony by:
Jamie Webster
Senior Director, BCG Center for Energy Impact
Fellow, Center for Global Energy Policy, Columbia University

July 18, 2017

Chairman Murkowski, Ranking Member Cantwell, and members of the Committee, I appreciate the opportunity to testify before you today on the current status and outlook for US and North American energy and resource scarcity. I appear before you in my role as a Senior Director of Boston Consulting Group's Center for Energy Impact. I am also a Fellow at the Columbia Center on Global Energy Policy. In both roles I focus on the trends and expectations in oil and gas for the world and the United States in particular.

The United States is undergoing an energy revolution that is expanding US oil and gas capabilities in all ways, from production, to pipelines, refineries, storage facilities and export terminals. This has impacted the global supply/demand balance, changed trade relationships, and lowered prices for US consumers. This increased energy security has allowed the United States to take a leading role as a global energy supplier.

The expansion--first in natural gas and then oil production--in the United States has been nothing short of impressive. The US Energy Information Administration (EIA) has noted that the country has recorded its 5th year as the biggest natural gas and oil producer in the world[1]. US natural gas production began to rise strongly in late 2006, spurred by high prices and aided by technology breakthroughs and the benefits of the US system, to include infrastructure, a ready workforce, and mineral rights ownership. In light of this, US energy security concerns about a lack of sufficient natural gas in light of waning Canadian natural gas imports and the need for substantial LNG imports soon vanished. US natural gas production, as measured by gross withdrawals, have risen from 66 billion cubic feet per day (bcf/d) to 89 bcf/d[2] over the past 10 years. This glut resulted in lower prices causing some producers to turn towards the more lucrative business of tight oil production. The United States, formerly a powerhouse in global crude oil production had experienced continuous declines for more than 20 years. Thanks to shale, US production began to rise, eventually recording one of the highest growth years for a country ever recorded when in 2014, more than 1.5 million barrels per day (mmb/d)[3] was added to the country's already growing supplies.

The success in renewed natural gas and oil production has caused an oversupply in both markets, depressing prices. For natural gas the price decline began in late 2008 and Henry Hub natural gas prices have never sustainably risen above $5/mmBtu[4] since that point. US producers adjusted in several ways to this market change, allowing natural gas production growth to continue—it is now about 30% higher than when prices fell.

---

[1] https://www.eia.gov/todayinenergy/detail.php?id=26352
[2] https://www.eia.gov/dnav/ng/ng_prod_sum_a_EPG0_FGW_mmcf_m.htm
[3] https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=MCRFPUS2&f=M
[4] https://www.eia.gov/dnav/ng/hist/rngwhhdm.htm

The resiliency of US producers was aided by finding new markets, with US LNG now being offered for sale on a global basis. Far from imperiling US energy security, these rising exports are actually increasing energy security for both the US and the world[5]. The ready export outlet will allow producers to keep natural gas flowing into homes and power plants, and at less cost. Exports of LNG are providing consumer countries with another choice of energy supplier, allowing them to negotiate for better pricing, and increasing global energy security. US LNG, with its pricing usually tied to the Henry Hub in Louisiana is also reshaping how natural gas is priced, increasing liquidity and pushing what was once a local or regional market, into a globalized market for an increasingly vital fuel for economic development

This renewed capability to serve domestic and international consumers with reliable supply has been supported by an expansion in US infrastructure. The most notable example of this is the development of the Marcellus shale, a natural gas play that extends from New York to West Virginia[6]. This development is allowing the northeast to morph from the highest cost region in the country, dependent on natural gas from the Gulf Coast and Canada, into a producing giant expected to provide more natural gas than the rest of the entire United States. Since 2006 US natural gas pipeline capacity, as measured by state inflow, has increased by 112 Bcf/d, a 27% increase. Mush of this increase has occurred in the northeast and the Mexican border area as that country has increased its energy relationship and dependence on reliable and economic US natural gas supplies.

The US restarted exports of LNG in early 2016, and is now expected to be one of the top three global natural gas exporters by 2020. To meet this, the EIA expects LNG export capacity of more than 11 Bcf/d by 2020, with proposed projects on the East, Gulf and West coasts. The ability to store natural gas, important for operational, seasonal and energy security issues, has also expanded in recent years in tandem with the growth in production. Storage capacity is up more than a trillion cubic feet over the past 10 years, with more than 20 new fields added.

Oil from the shale regions only increased sharply after natural gas prices fell, ramping up beginning in 2009, and arguably had its first significant international impact in 2011 when US light sweet crude oil began to replace imported barrels from OPEC member Nigeria. This was an important energy security turning point as blunted the risk of production outages from the country. Nigerian production outages, caused by strife in the Niger Delta region were a key factor in raising global oil prices above $100/b in 2008. That summer US drivers paid as much as $4.72 for a gallon of gasoline[7]. US oil production has largely displaced Nigerian oil imports, which have dropped from 1.1 mmb/d in 2010 to just 0.2 mmb/d[8] today.

An example of this increased energy security was seen in 2011, as increased production of US light sweet crude oil helped to offset some of the barrels and quality differentials caused by the loss of Libyan barrels as that country's civil war raged and its oil production fell from 1.6 mmb/d to nearly zero[9]. This prevented already high prices from rising higher.

Turning to the ongoing low oil price environment, it was the growth of US and other production in 2014 amid temporarily weak demand that catalyzed the price decline beginning in the third

---

[5] https://blogs.wsj.com/experts/2017/05/25/how-liquefied-natural-gas-will-transform-global-energy-markets/
[6] https://www.eia.gov/maps/pdf/MarcellusPlayUpdate_Jan2017.pdf
[7] Per Patrick DeHaan at gasbuddy.com
[8] https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=MCRIMUSNI1&f=M
[9] http://www.jodidb.org/TableViewer/tableView.aspx

quarter, with WTI dipping below $100/b at the end of July 2014. Prices continued to fall to as low as $26/b in early 2016, a price not seen since the early 2000s. However, in the wake of sustained low prices since then US producers have remained resilient. In response to low prices, US producers cut costs, streamlined processes and utilized new techniques to get more oil out for less resources and time. 8% of drilling companies shuttered their doors[10], but the capacity of the industry was largely undamaged. A rig brought on today delivers 2.5 times the production of a rig in 2014, and more than 3 times for a rig in the Permian basin in West Texas[11]. Production out of the shale regions is now an estimated 0.4 mmb/d higher than it was when prices began to collapse.

There are concerns about the longer-term durability of North American energy security despite the continued production growth, particularly around oil. Most of these stem from the fact that the analytical community is still learning about shale as its production evolves, and how it will fit into the global picture. These risks include:

- **High decline rates**. Oil production in the shale regions currently declines by as much as 0.3 mmb/d[12] every month, requiring substantial activity and investment to both offset this decline and deliver growth. Any sharp curtailment of drilling in core areas could allow decline rates to overcome the underlying growth of new wells.
- **Drilled but uncompleted wells.** Drilled but uncompleted wells in the Permian basin have risen by an estimated 80% in the past year, but oil and gas extraction employment is only up 0.4% and hourly pay is down 2.1%. If shale is choked back because of insufficient manpower or other inputs, production growth could decline.
- **A dependence on the Permian.** Oil from shale and tight formations has changed from a growing resource in many regions, to only one. Since the OPEC cut in November 2016, more than 60% of increased production has come from the Permian, placing additional pressure on a region that has had difficulty bringing on sufficient frac crews.
- **Sufficiency in the global context.** The oil in the US shale regions produce an estimated 5.4 mmb/d, or ~6% of global production, while all the US produces 13.1 mmb/d, ~13% of production[13]. This relatively small quantity of US production helped bring prices down in 2014, but a sharp potential rebound in price could occur as waning investment in conventional production impacts the roughly 60% of global non-OPEC supplies.

The story of the renewal of US oil and gas production is increasingly well known. Less well known is the increased capacity that is supporting it, increasing energy security for the United States but also the world. The Permian basin, the source of most of US shale's current production growth, would be nowhere without the supporting, existing pipeline infrastructure in place. This light sweet crude would not find its way into the gas tanks of US automobiles, without the world class refining system centered on the US gulf coast. US refining capacity has reached 18.6 million barrels per day (mmb/d), up more than 1 mmb/d in the last 5 years[14]. Aided in part by cheap natural gas, these refineries can efficiently deliver a variety of economical fuels to vehicles and other end users.

---

[10] https://data.bls.gov/timeseries/ENUUS000205211?amp%253bdata_tool=XGtable&output_view=data&include_graphs=true

[11] BCG CEI analysis with raw data from EIA and Baker Hughes

[12] https://www.eia.gov/petroleum/drilling/pdf/dpr-full.pdf

[13] IEA Oil Market Report, EIA Drilling Productivity Report

[14] https://www.eia.gov/todayinenergy/detail.php?id=32012

The capacity to store oil and refined products has also expanded. In the last 5 years crude storage capacity has increased by more than 100 million barrels[15]. The ability to store oil is crucial for the expanded operational needs of the producers and refiners and has proven useful during the global oil market oversupply of the past several years, allowing crude and refined products to be ready for use when the market requires it. This expanded storage capacity will also support the operational needs of the rapidly expanding crude export capabilities, made possible in part by the efforts of some of the members of this committee. US crude oil is now reaching more than 26 countries, decreasing prices and increasing energy security around the world.

The advantage to increased production, pipeline, refinery and storage capacity in the United States is an expansion of not just our own energy security, but the ability to extend that to other countries. Add to this impressive mix the fact that the US has the most transparent, frequent and capable energy data system in the world. This allows the benefits of the US to be known and transmitted to all market participants.

[15] https://www.eia.gov/petroleum/storagecapacity/

The CHAIRMAN. Thank you, Mr. Webster.
Mr. Mills, welcome.

STATEMENT OF MARK P. MILLS, SENIOR FELLOW, MANHATTAN INSTITUTE

Mr. MILLS. Good morning. Thank you, Madam Chairman and thank you, Senators, for the opportunity to testify.

I'd like to begin—I'm going to focus on geopolitics and security as well. I'd like to begin with, sort of, a mea culpa.

It was about five years ago I published a paper titled, "Unleashing a North American Energy Colossus." And in the introduction of that paper I suggested that it was time that we begin to think in different terms and stop talking about energy independence and think in more of terms of energy influence and even, I wrote, "energy dominance."

Setting aside the fact that that word has gained political salience, I'd like to say that it is, in fact, obvious that the reality is America is already dominating global energy markets. No one in Moscow or Reade doubts that the global price collapse in gas and oil happened for any reason other than the fact of this astonishing revolution in the American shale fields. They're worried not about what has already happened, but what could yet happen.

Henry Kissinger, who all of us know, is a great statesman and sometimes the greatness expands with the passage of time which is a wonderful thing for statesmen. He wrote something that was, I thought, very insightful in 1999 in his book. He said, and I quote that, "Statecraft is the ability to recognize the real relationship of forces." Let me very briefly summarize some real forces, three real forces of geopolitics.

The first reality is that oil petroleum is more important to the global security and to the United States today than it was at the time of the Epoch setting 1973 oil embargo. The world consumes 150 percent more oil today than it did then. Oil is the world's largest traded commodity and the largest single source of energy supply in civilization today. In fact, 95 percent of all transportation, over 95 percent, is powered by fuel-burning engines. And 60 percent of all oil is now used to—for transportation. That share in 1973 was just one-third.

The second reality is that every credible forecast says that petroleum, and especially these days its hydrocarbon cousin, natural gas, will be more, not less important in the coming two decades. This is true, notwithstanding what I would call a universal affection for alternative energy, political, universal affection and literally hundreds of billions of dollars spent over the last four decades trying to replace oil and natural gas as primary sources of the world's energy. There are simply no prospects for reducing today's already enormous consumption of global gas and global oil, never mind reducing the increase that will come as the world's economies expand. Really the only debate today, at the fundamental level, is how big the increase will be, not whether or not there will be an increase in global consumption of oil and natural gas.

The third reality is, of course, the wild card that no one expected a decade ago or, in fact, I'd even say, expected five years ago, which is the emergence of the technology that we now call the shale revo-

lution. The United States is now not just a major player, but also a major exporter and a growing exporter in world markets for both oil and natural gas. I think the magnitude of that revolution is still underappreciated. As much as we talk about it and hear about it, it's still fundamentally unappreciated.

Let me put it in this context. The quantity of energy and the velocity with which the amount of energy produced by the shale fields of America that secured in the past decade is the largest, single increase of energy supply to the world that has ever occurred in history, period.

I'll put it in domestic terms. The increase in domestic energy production, the shale fields of the United States over the last 10 years is 2,000 percent greater than the subsidized increase of combined increase of wind and solar in the United States. This is an astonishing transformation of energy markets which is still, I think, profoundly underappreciated.

And the world has been doubly impacted by the shale revolution. It's not just that the United States can export fuels; it's that we have taken hundreds of billions of dollars of purchases off of global markets. This has deprived oil exporting nations of literally trillions of dollars and most of that depravation has been borne by OPEC nations and by Russia.

Now as cheap domestic gas has also triggered a profound increase in domestic and foreign direct investment in manufacturing in the United States. Over the next several years we'll see the effect of that as something on the order of $160 billion in private capital and foreign capital has been put into over 200 chemical manufacturing plants in the United States that are slated to come online over the next few years. This will have profound economic and geopolitical implications.

What comes next? Let me, again, context what comes next briefly in two ways.

First, the EIA and the IEA, but in particular, the Energy Information Administration's two-decade forecast still sees the shale fields supplying 600 percent more net new energy to America than wind and solar combined. And that forecast from EIA assumes that over the next two decades the shale industry can only do as much as it did in the past single decade. I'd like to go on record here saying that that is almost certainly going to be an underestimate. Shale will do more. The reason it will do more is because of the information revolution that's now underway.

There's a lot of discussion about how old industries of all kinds from groceries and transportation and car rental, hotels, are being impacted by analytics and big data and machine learning, Internet of Things. The 80 percent of our economy is tied up in the old part of our economic infrastructure which is being unleashed and revitalized by the new information revolution.

Why would it not be the case that algorithms, if you like, won't unleash more productivity of the shale fields? I will tell you that not only are they likely to, they're already beginning to and in fact, one can argue they'll have a bigger impact there for the very simple reason that the shale industry has so far, to use an awkward phrase, is a least digitalized of our old economy.

So the—let me conclude by quoting from Dr. Birol, who recently said in an interview that we are now witnessing the second unleashing of the shale expansion of the United States in shale production. And he said then it was price that would determine how fast that new production would grow.

I'd like to respectfully disagree with half of what he said. The data are already in. The shale industry is in big resurrection mode from new technologies and from what Jamie has just said about the improvement in productivity, but we have just begun to see what will happen is information technology unleashes the second shale revolution, what I've called Shale 2.0.

I think the only question is not so much what the price will be, is the extent to which policy helps or impedes the unleashing of the second shale revolution.

Thank you very much.

[The prepared statement of Mr. Mills follows:]

Geopolitical Implications Of The 'Invisible' Digital Oil Revolution

Testimony of
Mark P. Mills, Senior Fellow, Manhattan Institute
Before
U.S. Senate Committee on Energy and Natural Resources Hearing On The Outlook For U.S. and North American Energy and Resource Security
July 18, 2017
Washington D.C.

Good morning. Thank you for the opportunity to testify before this Committee. I'm a Senior Fellow at the Manhattan Institute where I focus on the policy implications at the intersection of technology and energy, and where I have advocated for years that America should have a more realistic and aggressive geopolitical energy policy posture.

I am also a Faculty Fellow at the McCormick School of Engineering at Northwestern University where my focus is on the technology and future of manufacturing. And I'm a strategic partner in a boutique venture fund dedicated to startup companies creating digital oilfield technologies. You will of course notice that my focus in all these pursuits is on the role of technology, a key force in our economy and in geopolitics which, despite popular enthusiasm for tech, is – as I will shortly explain – still under-appreciated in terms of what is about to unfold in global energy markets.

Five years ago this summer, when a different party was in charge of both the White House and Senate, I proposed in my Manhattan Institute paper entitled "Unleashing the North American Energy Colossus," that new realities should lead policymakers to "go beyond the pursuit of energy independence" and instead "push beyond self-sufficiency to energy influence, even dominance." I have emphasized the idea of "dominance" as a replacement for the anemic policy mindset of "energy independence" both in earlier Congressional testimony and in other Manhattan Institute policy papers nearly every year since then.

There is no dispute over the fact that food, water and energy security are critical drivers of domestic and geopolitical policies. But it's important to note that, as the great economist, and a great friend of mine, Julian Simon once said--energy is the "master resource." That elegant distillation of reality has far-reaching implications when it comes to geopolitics.

And in geopolitics, as in domestic politics and business in general, much of what matters gets thrashed out by means of negotiation. This is hardly news to any student or practitioner of foreign policy. And when it comes to negotiation, no one wants to come to the table as a supplicant. The preferred posture sought by everyone, everywhere and always, is to engage from a position of strength ... even, ideally, one of dominance. Dominance is, by definition, having "power and influence over others." That power can be military, with all of its attendant risks, or it can reside in the so-called soft power derived mainly from economic forces.

In his 1999 book, "A World Restored," Henry Kissinger wrote that statecraft required the "ability to recognize the *real* relationship of forces."[1] [emphasis added] While aspirational goals are important, ignoring the real forces that are extant in the world is not only

[1] Kissinger, *A World Restored*, Oxford University Press, p. 258.

problematic but dangerous. And as aspirations become fanciful rather than anchored in reality, dangers rise proportionately.

When it comes to the geopolitics of energy, there are three primary forces in play.

First, petroleum today is more important to our economy, our security and geopolitics, than it has ever been in history. This is true notwithstanding popular and near universal political enthusiasm for alternative forms of energy, as well as the hundreds of billions of dollars spent in pursuing those alternatives. Consider a handful of indisputable facts.

Marked from the epoch-setting Arab oil embargo of 1973/74, global petroleum use is up 150 percent. Over 95 percent of all ground transportation is still powered by oil-burning engines. And air travel, which is completely dependent on petroleum, has increased 700 percent since then. In overall terms, transportation accounted for one-third of world oil use a half-century ago, while today it accounts for 60 percent. And oil is both the world's biggest traded commodity and the world's largest single source of energy.

The second primary force: For the foreseeable future, petroleum, and increasingly its hydrocarbon, natural gas, will be more not less important.

Regardless of subsidies or vigorous assertions, there are simply no prospects for reducing today's enormous levels of oil and natural gas consumption. In fact, every credible forecast sees demand rising as global economies grow. The only debatable variable is just how big the increase in oil and natural gas demand will be over the coming couple of decades.

Not withstanding the now popular meme of peak oil demand, such a peak, when it occurs, is so far in the future as to be more relevant for purveyors of fiction rather than federal policy. And with more than one billion more automobiles expected to be added to the global fleet over the next two decades, even the most optimistic forecasts for electric cars will not lead to a world using less oil than today. Indeed, we should hope the optimists are right in order to mute the demand that's coming. Similarly, even the most optimistic forecasts for alternative sources of electricity—whether to power cars or the information ecosystem—show that natural gas is the dominant go-to fuel for the foreseeable future.

The future is one of clearly increasing dependencies on energy imports for four of the world's five major regions that together account for three-fourths of global GDP. China, Europe, Japan, and India are all net and rising importers of both petroleum and natural gas. Of the five major economic regions of the world, only North America is essentially energy self-sufficient and moving rapidly towards becoming a net exporter.

This rising force of energy import dependencies in all non-North American economic regions has deep geopolitical implications. Note that until very recently, the Middle East and Russia were the primary sources of new marginal supply in world energy trade.

And now the third tectonic force in the geopolitics of energy. It is a wildcard that no one expected: the role that shale technology has played in the re-emergence of the United States as both a major player, and exporter, in oil and gas markets. Shale technology is the only real energy revolution that has occurred in 50 years.

The magnitude and velocity of the shale revolution is still underappreciated. Quite simply, it was the fastest and biggest addition to world energy supply that has ever occurred in history. The only time something almost as dramatic occurred was in the decade following the 1968 opening of Saudi Arabia's giant Ghawar oil field.

Or put in domestic terms, the increase in American energy production from shale hydrocarbons over the past decade was 2,000% greater than all the additional supply from solar and wind combined.

This revolution occurred without federal stimulus or special subsidies; nor was it the result of new "discoveries." The location and extent of shale hydrocarbons have been known for a century. The shale revolution was the product of technology fueled by America's capital markets combined with unique private ownership rights.

America is now not only a net exporter of natural gas – on the way to becoming a major player, perhaps "dominant" on the margin, where prices are set – but is also exporting well north of 1 million barrels a day of crude oil. That's the highest rate of U.S. crude exports since 1958, by a factor of two, and even exceeds the exports of five of OPEC's members. We can credit this Committee with the legislation that recognized and allowed a restoration of a legal right to export crude – something, as you know, I've long advocated. And we can credit President Obama for signing that legislation in late 2015. Now credit this committee and President Trump for realizing the enormous implications and pushing the idea forward still.

Importantly, world markets are impacted not just by the act of America physically exporting fuel, but also the fact that U.S. domestic production has eliminated billions of dollars of purchases of oil and gas on world markets. Both these realities triggered the collapse of global prices and kept trillions of dollars from flowing to exporting nations, mainly OPEC and Russia. No one can doubt the geopolitical ripples from such a financial disruption.

Similarly, no one doubts the subtle "soft power" impact of the massive rise in foreign direct investment into U.S. manufacturing triggered by cheap natural gas. Foreign and private domestic investments in U.S. chemical manufacturing have exceeded $160 billion in the past half decade. The full geopolitical, never mind domestic, impact of this shift is about to be realized as over 260 new chemical manufacturing projects start to come on line in the next few years.

Given these three primal forces, what comes next?

Looking to the future, the Energy Information Administration's (EIA) "optimistic" forecast -- which assumes subsidies continue -- has solar and wind energy production growing three-fold by 2035. Meanwhile, EIA's similar forecast for shale hydrocarbons (without subsidies of course) for the next *two* decades has that industry replicating its growth of the past *single* decade, probably a huge underestimate.

What we have already learned from the cyclical downturn in oil prices is that the technologies involved in shale production are getting better at an amazing rate. The efficacy of shale rigs – the amount of physical production per capital dollar spent – has been improving by more than 20% per year on average. Put another way; the rigs are getting roughly twice as productive every three years. No other energy technology is improving that quickly. And while, EIA data shows that the rate of improvement actually jumped

during the last couple of years, the evidence now suggests that there's much more yet to come yet.

Most forecasters today are making the same mistake they made a decade ago. They are failing to spot a revolution that is already underway. What if the shale disruption is not a one-time event in our recent history, but is only the beginning of a massive structural revolution still unfolding?

In every other corner of our economy – from retail and groceries, to housing, transportation, manufacturing and agriculture – we are everywhere reading breathless speculation about the emerging impacts of the Internet of Things, of machine learning, artificial intelligence and digital ecosystems, all enabled by cheap, ubiquitous super-computing in the Cloud.

The new and still untapped features of this next information revolution are, properly, expected to bring unprecedented power in extracting profoundly greater efficiencies, and thus economic value from every corner in the so-called "old" industrial and business activities that still comprise over 80 percent of our economy. Why should the power of algorithms combined with the Internet of Things be any less impactful in shale domains? In fact, the impact may be larger precisely because the shale industrial ecosystem is still largely untouched by the emerging digital revolution.

The category error many forecasters are making is in thinking about the new U.S. hydrocarbon industry in the same terms as the old one which was dominated by a small number of mega players each developing a small number of mega projects. In contrast, the new shale industry's ecosystem is comprised of thousands of companies in dozens of states. It is now generating a kind of ecosystem of digital entrepreneurs -- as did Silicon Valley with other industries – in small, tech-savvy start-ups which will create the tools and solutions that will disrupt oil and gas in the same way that taxis and retail were disrupted. As I outlined in my 2015 paper titled *Shale 2.0*, digital disruption is coming at least as fast now in how we produce oil as in how we use it for transportation.

The emerging digital acceleration of shale fields has been noticed by Wall Street even if it has yet to be incorporated into geopolitical thinking. A new Goldman Sachs report is telegraphically titled, *Shale Innovation: Brawn to Brains to Bytes.* Goldman concludes that we are at the "very early stage…of the application of big data analytics and Artificial Intelligence/Machine Learning techniques to improve decision-making, equipment reliability and productivity,"

Earlier this year analysts at BofA Merrill Lynch released their report titled "The Internet of Oil." And a new report from McKinsey calls it the "invisible revolution" … which it certainly appears to be in terms of how most energy policy is being formulated.

It's taken time for the punditocracy to realize that the shale business more closely resembles a manufacturing industry than an "extractive" one, and it's about to benefit from Silicon Valley-class tools as a spate of startup tech companies start chasing the big prizes associated with the world's biggest energy market.

But many still believe that a future energy revolution depends on solar and wind. Of course those technologies will get far better. And of course they're useful and important. But, as is

clear from DOE's National Renewable Energy Labs data, both wind and solar are now experiencing a declining rate of improvement as those technologies start to approach their limits in terms of what physics permits. They still improve each year, but now necessarily at a slower rate than in the past – and more relevant to our geopolitical future, at a slower rate than shale technology.

Policymakers are left with a simple immutable fact set. The world's nearly 8 billion people and $80 trillion economy is utterly dependent on hydrocarbons. Oil, natural gas, and coal together supply 85% of global energy, and oil itself supplies 99% of world transportation. The only prospects for meaningfully impacting those realities, and for forging new beneficial geopolitical outcomes, will be found in recognizing and capitalizing on the nature of these very real forces. It will be anchored in recognizing that America can sit at the table as an increasingly dominant player in these tenuous geopolitical times.

Former Secretary of Defense and former CIA Director Leon Panetta had it right when he said in 2015: "Too often foreign-policy debates in America focus on issues such as how much military power should be deployed .... Ignored is a powerful, nonlethal tool: America's abundance of oil and natural gas." The only modification to Secretary's Panetta's formulation I would suggest is changing the word "abundance" to "dominance."

The CHAIRMAN. Thank you, Mr. Mills.
Brigadier General Cheney?

STATEMENT OF STEPHEN A. CHENEY, BRIGADIER GENERAL USMC (RET.), CHIEF EXECUTIVE OFFICER, AMERICAN SECURITY PROJECT

General CHENEY. Thank you, Chairperson Murkowski and Ranking Member Cantwell and members of the Committee for inviting me to testify at today's hearing.

The American Security Project was founded in 2005 as a bipartisan initiative to tackle long-term challenges from a national security perspective, not encumbered by political bias. Our founders, Senators Kerry, Hagel, Hart and Rudman, asked to host the retired general and admirals to join ASP because their only interest was the security of our country.

Our Chairperson, former New Jersey Governor, Christine Todd Whitman, and our entire board share a strong belief that energy security for the United States and how we produce energy is a national security issue of preeminent importance.

My role in today's hearing will be to offer a perspective of a national security professional. Having spent over 30 years as a Marine I know that, for the military, assured access to energy is a prerequisite to any operation. In the last 15 years the military has learned the hard way that energy should not be taken for granted. Our supply lines in Iraq and Afghanistan were a constant target for insurgents. In response, all four services have taken significant steps to both increase energy efficiency and reduce their single source dependence on petroleum fuels. Our country can learn a lot from our military's experience.

Before we can discuss where we are in energy security, we have to understand what we are asking. Energy security is generally defined as the ability to have uninterrupted access to energy resources at an affordable price. That's a start, but I don't think it's enough because of the indelible link with global affairs.

Our nation's concept of energy security was defined in the American mind by the two oil crises of the 1970s. To ensure that nothing like that ever happens again should be our goal in building energy security; therefore, I would propose that we define energy security as the ability of a country to define its interest overseas independently from how it uses energy domestically.

More importantly, energy security must not mean energy independence in the sense that all energy used in the United States comes from within its borders without international trade. In today's globalized world, this is neither attainable nor desirable. Even domestically-produced energy sources are subject to fluctuation in global commodity markets. We must see energy security in today's world as where countries, businesses and people share and compete in the global marketplace. In today's globalized world, if one country doesn't have security, their neighbors and allies don't have security either.

Finally, I will argue that we must see energy security as a long-term process, not as a moment frozen in time. Some policies and actions could build security today while harming our future security. Climate change is already affecting security both at home and

around the world, so we must make sure that we take the greenhouse gas emissions from energy into account less we trade increased energy security today for a warmer, more unstable world in the future.

Thinking long-term, this way also means that we must invest now in scientific research and development into the next generation of energy technology. Factoring together each of these variables, my message to you Senators is that the current status of North American energy and resource security is good, but the outlook is hazy.

There are few threats to America today that could stop our access to global energy markets, but I am concerned that there are emergent threats that could undermine our future security, if not addressed soon. Moreover, we must guard against bad policy that could undermine our future security.

Our amazing increase in the production of oil and gas has given us some breathing room and the opportunity to invest in other long-term sources of energy. We cannot sit back and revel in our success with fossil fuels. We should not let our expertise in nuclear energy atrophy and ought to be pursuing small modular reactors. We ought to be continuing to support the rapid proliferation of renewables of all kinds to include wind, solar and biofuels. We ought to take advantage of this remarkable progress made in metallurgy and science to pursue fusion energy. We have seen far too many countries rely on a sole source of energy and look what has befallen many of them, not the least of which, perhaps, are Venezuela and Nigeria.

We have a golden opportunity in front of us right now and we need to capitalize on it.

Thank you.

[The prepared statement of General Cheney follows:]

Written Statement by

Stephen A. Cheney, Brigadier General USMC (ret.)

Chief Executive Officer
American Security Project

on

The Status and Outlook for U.S. and North American Energy and Resource Security

Submitted to the

Committee on Energy and Natural Resources
United States Senate

July 18, 2017

Stephen A. Cheney, Brigadier General USMC (ret.)
Chief Executive Officer
American Security Project

The Status and Outlook for U.S. and North American Energy and Resource Security
Committee on Energy and Natural Resources
United States Senate

July 18, 2017

Thank you, Chairperson Murkowski, Ranking Member Cantwell and members of the Committee for inviting me to testify at today's hearing on "The Status and Outlook for U.S. and North American Energy and Resource Security."

The American Security Project was founded in 2005 as a bipartisan initiative to tackle long-term challenges from a national security perspective, not encumbered by political bias. Our focus issues range from non-proliferation to counter-terrorism, American competitiveness to energy security. Our founders, Senators Kerry, Hagel, Hart, and Rudman, asked a host of retired general and admirals to join ASP because their only interest was the security of our country; they had spent years defending our country and planning for how to address threats. Our Chairperson, former New Jersey Governor Christine Todd Whitman, and our entire board share a strong belief that energy security – how the United States uses and produces energy – is a national security issue of preeminent importance.

My role in today's hearing will be to offer a perspective of a national security professional. I spent 30 years in the Marines where my primary specialty was artillery, but I focused extensively on entry-level training, commanding at every echelon at both Marine Corps Recruit Depots, to include being the Commanding General at Parris Island. For the military, assured access to energy is a pre-requisite to any operation. In the last 15 years, the military has learned the hard way that energy should not be taken for granted: our supply lines in Iraq and Afghanistan were a constant target for insurgents. In response, all four branches of the military have taken significant steps to both increase energy efficiency and reduce their single-source dependence on petroleum fuels. My testimony will show how our country can learn from the military's experience.

What is Energy Security?

Before we can discuss where we are on energy security, we have to understand what we are asking. Too often, policymakers use terms like "Energy Security" or "Energy Independence" – or now "Energy Dominance" without defining them: these mean different things to different audiences. For politicians, that can be a good thing! But for those of us trying to devise policies on how to build energy security, we need a definition.

Energy Security is generally defined – including by some of my co-panelists – as the ability to have uninterrupted access to energy resources at an affordable price. That's a start, but I do not think it is enough, because of the indelible link with global affairs. Our nation's concept of energy security was defined in the American mind by the two oil crises of the 1970s, where our country found its economy held hostage by hostile foreign powers over decisions that our leaders made in international affairs. To ensure that nothing like that ever happens again should be our goal in building energy security. Therefore, I would propose that we define energy security as ***the ability of a country to define its interests overseas independently from how it uses energy domestically***.

Most importantly, 'energy security' must not mean 'energy independence' in the sense that all the energy used in the United States comes from within its borders without international trade. In today's globalized world, this is neither obtainable nor desirable: even domestically produced energy sources are subject to fluctuations in global commodity markets. We must see energy security in today's world as one where countries, businesses, and people share and compete in the global marketplace. I will discuss the importance of trade relations in building shared energy security. In today's globalized world, if one country doesn't have security, their neighbors and allies don't have security either.

Finally, I will argue that we must see energy security as a long-term process, not as a moment frozen in time. Some policies and actions could build security today, while harming our future security. Climate change is already affecting security both at home and around the world, so we must make sure that we take the greenhouse gas emissions from energy into account, lest we trade increased energy security today for a warmer, more unstable world in the future. Likewise, we should be very careful about selling the Strategic Petroleum Reserve – our national hedge against oil shortages – in exchange for a short-term way for Congress to get around budget caps. Thinking long-term in this way also means that we must invest now in scientific research and development into the next-generation of energy technology.

Factoring together each of these variables, my message to you, Senators, is that ***the current "Status" of North American Energy and Resource Security is good, but the "Outlook" is hazy***. There are few threats to America today that could stop our access to global energy markets, but I am concerned that there are emerging threats that could undermine our future security, if not addressed soon. Moreover, we must guard against bad policy that could undermine our future security.

Security Built by an Energy Revolution – And Good Policy

I am certain that several of my co-panelists will talk about how the shale revolution has increased American energy security. And that is true. The events of the last decade in American energy production have been nothing short of revolutionary. The United States has gone from a major importer of natural gas, with plans for new Liquefied Natural Gas (LNG) import terminals along the East and West Coasts, to a point where the U.S. will be a net exporter of gas for the first time this year. For context, in April 2007, the United States imported 98,742 million cubic feet of LNG, a record. A decade later, in April 2017, by contrast, there was only 5,171 million cubic feet of LNG imported into the US, a 95% decline. LNG exports went from zero as recently as 2013 to a pace of almost 600 billion cubic feet this year.

In oil, the difference is just as stark. After three decades of decline, oil production surged 88% in just six years, from 5 million barrels per day in 2008 to over 9 million per day by 2015. To reflect the new

abundance, Congress allowed crude oil exports in 2015. Just a year and half later, exports are now shooting up, with exports of over 900 thousand barrels per day in the first week of July. In our exuberance, however, we must remember that the United States still remains the world's second largest oil importer, behind only China.

However, we should not make the mistake of thinking that security comes from domestic supply alone. Policies implemented in the 1970s, like the creation of the International Energy Agency (IEA), have built a coordinated global response to shared energy security. International trading markets allow for a true global price of energy commodities – oil prices are seen on newscasts every night – allowing policymakers to see potential shortages and problems before they occur. The Strategic Petroleum Reserve – which holds oil stocks capable of replacing 90 days' worth of imports – acts as a strategic buffer against threats and manipulation by energy-producing states.

Another key part of America's energy security is our fleet of nuclear reactors. We are nuclear proponents. The 99 currently operating nuclear reactors provide about 20% of the electricity our country uses. They have a commendable service record as an always-on baseload supply of energy. They are the largest source of carbon-free energy we have. Although there are political questions about how to store spent nuclear fuel, it would be good for our security to increase our investment in nuclear power. It is somewhat ironic that the energy revolution of the last decade was supposed to be paired with a "Nuclear Renaissance." Unfortunately, lower cost natural gas, combined with regulatory uncertainty, appears to have limited the number of new nuclear plants. Developments in the next generation of nuclear power, like small modular reactors, will help us build a predictable energy supply. For those worried about safety, we should note that the Navy has operated varieties of "Small modular Reactors" aboard ships and under the seas for 60 years with no adverse effects at all.

Role of Efficiency, Renewables in Security

This massive change in fossil energy production has been matched by dramatic (if less reported) increases in energy efficiency and renewable energy. Our cars and trucks now go further on a tank of gas than ever before, as new vehicles are surpassing stringent federal fuel economy standards. The price of solar and wind have dropped dramatically. New technology means that even old-line hydropower can increase its utilization level. Emerging techniques for battery manufacturing will ensure that the electricity grids of the future are able to bring more variable renewable power onto the grid than had been thought possible.

What does the boom in renewables mean for security? Any form of renewable power presents few concerns about energy security because they do not use a fuel that has to be imported.

While some complain about dependence on imported solar panels or other energy-producing goods from China, but this is not the same as energy security. Unlike dependence on a commodity like oil, importing solar panels – for example – constitutes a one-time-only fixed cost. Once the cost is borne, there is very little variable cost for generating renewable energy.

An economy that relies on renewable power for its energy needs would be fundamentally more secure. Centralized electrical grids are threatened by physical disruption from the weather or attacks, cyber

disruption, electromagnetic pulse attacks and regulatory disruption. A renewable grid, on the contrary, is a fundamentally distributed grid.

A grid of distributed power sources would generate electricity from many smaller and more secure energy sources in contrast to large centralized power plants, with expansive and vulnerable infrastructure.

However, given the separation in fuels between electricity generation and transportation, policymakers should not be deluded into thinking that increasing renewable electricity generation will automatically increase energy security. There also needs to be a coherent strategy to use more renewable power in transportation. Only by giving consumers a choice about how to fuel their cars will policymakers be able to break the grip that oil has on transportation.

In the United States, transportation is primarily by automobiles, so any proposal to use more renewable energy to increase security (particularly with respect to oil) must begin by either electrifying the auto fleet or significantly increasing the availability and use of ethanol and advanced biofuels.

Trade and Global Markets Build Security

Energy security is only possible is a "shared" environment. No nation can really be secure in energy if its neighbors or its allies are insecure. The recent developments in both energy supply and demand that have boosted America's energy security can also be used to boost the security of our allies and neighbors.

NAFTA has been critically important in integrating the North American energy market. To our north, the Canadian and American energy market has been thoroughly integrated for years, both in oil and the electric grid. Only recently, however, has that changed to our south. Mexico's recent efforts to liberalize its energy investment laws will allow deeper cross-border integration between the U.S. and our southern neighbor. We must be careful in the proposed renegotiation of NAFTA that we do not allow the growing integration between Mexico and the United States to be harmed by unrelated tensions.

Often overlooked, our smaller neighbors to the South, in the Caribbean and Central American are some of the most energy insecure places in the world. They do not have assured access to energy, and they often depend on the whims of one country (Venezuela) to supply their energy. The American energy revolution can supply investment in both renewable energy and the local grid, while also acting as a much-needed alternative source of fuel. I must add that perhaps the greatest opportunity in this region is Cuba. American businesses and investors could thrive in our nearest overseas neighbor if only Congress would allow them. Instead, the Cubans rely on imports from our global adversaries like Russia and Venezuela. It does not have to be this way.

The new tool in our trade toolbox is LNG exports, and they can help American allies in two key regions – Europe and Asia – by undercutting the political clout of dominant producer states and by expanding the quantity of total energy supplied to allies starved of energy. LNG exports could improve the energy security of America's closest allies. Exporting LNG can help America's allies around the world bridge from dirtier sources of energy, like coal and oil, to cleaner, carbon-free sources of energy. U.S. LNG exports would create a more liquid market, with deliveries based on supply and demand fundamentals.

This would allow America's allies to diversify their energy sources, reduce the burden on their economies, and free themselves from dependence on unfriendly countries.

New Threats to Critical Infrastructure: Cyber Security

For decades, we have primarily thought of energy security as through the dependence on imported commodities. However, a new threat is emerging in the form of cyber-attacks. Although "hacks" by our global adversaries are in the news all the time, the threat to our grid is different – and more dire – than someone stealing your email. Recently, the FBI and the Department of Homeland Security alerted the energy sector that "advanced, persistent threat actors" were behind recent cyber-intrusions into the business systems of U.S. nuclear power and other energy companies. The fear is that these foreign agents could find weaknesses that allow a hostile actor to shut-down the American energy system from afar.

One doesn't need to think too hard to imagine the potentially devastating effects this threat poses to U.S. energy security. The energy sector is the major source of essential services provided to billions of Americans daily- namely water and electricity- services upon which we depend.

We need to develop a public-private partnership to implement increased cyberdefenses. Unlike the previous responses to cyber threats, we cannot afford to wait to implement counter measures until after an attack. The allowance of continued cyber security breaches by both nation states and individual hackers leaves the door open for increased threats to our nuclear infrastructure.

Tomorrow's Security from Today's Investments: More R&D Needed

If events of the last decade have taught us anything, it should be about making predictions based on recent trends. We make a fundamental mistake if we assume that today's energy mixture is what the energy mix of 2030 or 2050 will look like. The fact is, the energy mix will change – because of concerns about climate change, accelerations in technology, and changes to global markets.

The downside risk on energy security comes from not investing in research and development. If other national countries, particularly competitor countries like China, are successful in commercializing breakthrough energy technologies, then they will sell the technology abroad, at the expense of U.S. competitiveness. I am particularly concerned that the U.S. is pulling back from technology R&D programs like ARPA-E that provide smart federal investments in high risk, high reward technologies that boost our competitiveness by keeping America at the forefront of global energy technology research.

We also believe that America needs more investment into game-changing energy technology, like fusion energy. An American Security Project report lays out a roadmap for how an investment of $30 billion over 10 years could lay the groundwork for a fusion-powered economy much faster than anyone is predicting.

In all of these, the danger to our energy security comes from *not* investing for the future. Just because we are secure now, does not mean we will always be.

We Should Take A Lesson from the Military

Over the last decade, the Marine Corps has worked to create an "Energy Ethos" – a shared vision that the efficient use of energy is a critical component of mission readiness. They say that Marines must be aware of and value limited energy and water resources. They don't do this because they've suddenly become tree huggers, they do this to enhance mission readiness and resiliency on installations and operational effectiveness in combat.

Other services have similar programs, like the Army's "Net Zero" program for installations, the Air Force's "Energy Flight Plan," and the Navy's "Great Green Fleet."

These have had an effect. According to the Department of Energy's Federal Energy Management Program (FEMP), by 2015 energy used by the US Department of Defense has fallen to its lowest recorded level since fiscal year 1975 (FY 1975). Reducing DoD dependence on petroleum and expanding into alternative energy sources will not only promote efficiency, it will save lives, and there is arguably no better barometer for success than that.

Conclusion: Energy and Resource Security Come From Variety and Variety Alone

When Americans talk about energy security and energy statecraft, too often we forget that the rest of the world gets a vote as well. As the sole superpower, American policy is watched closely around the world. That's why we should ensure that we do not become complacent about our current time of relative energy security.

Over a century ago, after he ordered the Royal Navy changed from coal to oil, Winston Churchill said that "safety and certainty in oil lie in variety, and variety alone." That decision was a farsighted investment in the future that helped the navy beat Germany. Today, energy security depends on variety as well – variety in all sources of energy. Maintaining energy security for the future will rely on the same farsighted thinking that allows us to perceive looming threats and coming opportunities, while maintaining our security today.

Thank you for the opportunity to testify today, and I look forward to your questions.

The CHAIRMAN. Thank you.
Mr. Coward, welcome.

STATEMENT OF ROBERT COWARD, PRESIDENT, AMERICAN NUCLEAR SOCIETY

Mr. COWARD. Chairman Murkowski, Ranking Member Cantwell, members of the Committee, thank you very much for the opportunity to testify today.

I am here in my role as President of the American Nuclear Society. Our society is dedicated to the peaceful use of nuclear science and technology. Our 11,000 members come from all sectors of the nuclear energy community: utilities, suppliers, national labs, universities, government agencies.

We commend the Committee on its bipartisan work to modernize U.S. energy research and development and production policies.

The focus for today is energy security, and by energy security I'm going to agree with Brigadier General Cheney, what we really mean is resiliency. I'm going to focus on the electricity and the electricity grid since that's my main area of experience. And for the grid, energy resiliency is a simple concept. Independent of whether the sun is shining, the wind is blowing, the coal pile is stocked or the natural gas pipeline is flowing, we have confidence in our ability to deliver electricity to the grid.

If you think about the Polar Vortex in 2014 in the Northeast, coal piles froze, natural gas pipelines were choked. Without the nuclear plants that remained online, we very likely would have faced widespread blackouts.

Nuclear power plants refuel every 18 to 24 months, so they don't rely on just-in-time fuel delivery or specific weather to operate at full power. Over the past 15 plus years, U.S. nuclear plants have operated over 90 percent of the time. Typically shutting down only for long-planned refueling. This is truly the definition of resilient.

Resiliency also extends to stability and predictability of pricing and cost. A nuclear power plant can accurately predict the cost of the power it will produce for every day of the coming year and, often, for multiple years.

Nuclear power plants also help anchor the electricity grid in the U.S. Grid operators rely on nuclear's roughly 20 percent share of power production to maintain stability as electricity demands rise and fall throughout the day. A crucial attribute as intermittent sources become a larger percentage of our generation portfolio.

Energy security also demands that we generate power in ways that preserve our resources and protect our environment. This is where nuclear power begins to truly stand out.

Nuclear power accounts for about 60 percent of all U.S. non-emitting electricity generation, emitting essentially no greenhouse gases or pollutants. Yes, nuclear power generates used fuel and other waste, however, those are small in volume, contained in space and can be handled and disposed of with safe, non-hazardous methods.

Nuclear power plants also have a high energy density, very small, physical footprint. For example, the electricity generated from a 1,000-megawatt power reactor which typically sits on about

1.5 square miles would require about 50 square miles of solar panels or a wind farm over about 300 square miles of wind turbines.

Finally, the U.S. nuclear power sector contributes to our national security, a factor sometimes as misunderstood as it is important. Almost all nuclear power programs around the world trace their technology back to U.S. origins. For decades, our role as the worldwide leader in nuclear technology has enabled us to positively influence the nuclear safety and non-proliferation norms of the world.

Right now, dozens of nations are building nuclear power plants or actively considering adding nuclear to their portfolio for all the same reasons I described for us. These countries are going to proceed whether we participate or not. If U.S. suppliers cannot compete in this geopolitically significant marketplace, our competitors in Russia and China will and they will win. And it is unrealistic to think that U.S. suppliers can compete in world markets without a healthy nuclear power program here at home.

Nuclear power is the ultimate, strategic, long-term asset; however, we increasingly find ourselves in a tactical, short attention span, "what have you done for me yesterday" world. As leaders and policymakers, we cannot allow our long-term energy and national security interests to be determined by how much electricity costs on a spot market at two a.m. on a Monday morning.

Resilient, reliable, non-emitting and clean power plants are shutting down. We must be strategic.

With that goal in mind, we recommend Congress consider the following strategic directions: support the current U.S. nuclear fleet—they are vital U.S. assets; equalize the level of subsidies, tax credits and regulatory costs for all non-emitting sources and fund continued R&D to extend the life of these valuable facilities; continue and expand support for the development of small modular and advanced reactor systems; continue to invest in the development of the next generation workforce and the research and development infrastructure at our national labs and universities; demonstrate forward progress on fixing our broken nuclear waste policy; and last, improve our nuclear export regulations and financing opportunities to ensure that U.S. nuclear manufacturers and suppliers can be competitive in the international markets. It's important.

I thank you again for the opportunity to speak today, commend the Committee for its leadership in nuclear technology policy and I look forward to answering any questions.

[The prepared statement of Mr. Coward follows:]

Testimony before the Senate Committee on Energy and Natural Resources
Mr. Robert Coward
President, American Nuclear Society
Principal Officer, MPR Associates, Inc.
Tuesday, July 18, 2017

Thank you, Chairman Murkowski, Ranking Member Cantwell, and members of the Committee for the opportunity to testify before the Committee today. I am here in my role as President of the American Nuclear Society (ANS). Our society is dedicated to the peaceful use of nuclear science and technology. We have about 11,000 members spread across all 50 states. We also have 41 local sections near key commercial and government nuclear technology facilities, as well as 48 student sections at major U.S. universities and 9 local sections in other countries.

Our members come from all sectors of the nuclear energy community: utilities, research laboratories, government and state agencies, industrial vendors and suppliers, universities, and other areas of nuclear science and medicine. We have 22 technical divisions that cover essentially all aspects of nuclear science and technology, from the mining of uranium ore to the disposal of fuel cycle byproducts, and all the valuable uses in between.

We commend the Committee on its bipartisan work to modernize U.S. energy research and development and production policies. This includes the recent progress on the crucial research and development for advanced reactors. We appreciate that important attention.

The focus of today's hearing is energy security. By energy security, what we really mean is *resiliency* – the ability to provide reliable, cost-effective energy regardless of unexpected or abnormal conditions. Energy security and resiliency are critical to our country. Indeed, they are the basic foundation upon which our modern economy and high standards of living are built.

We believe nuclear energy is arguably the most important energy source in our portfolio. During his turn as Secretary of Energy, Samuel Bodman stated, "nuclear power in this country goes to the very intersection of our energy security, our national security and our economic security." I agree, and my testimony today is intended to reinforce this conclusion.

Energy resiliency is a simple concept – no matter what is happening around us, energy continues to be delivered in a reliable and stable manner. Whether the sun is shining or not, the wind is blowing or not, the coal pile is stocked or not, or the natural gas pipeline is flowing or not can have significant impact on our ability to deliver electricity to the power grid. For example, during the polar vortex of 2014 in the Northeast, the coal piles froze and the natural gas pipelines were choked. Luckily, or should I say by design, the nuclear power plants remained online generating power reliably throughout the event. Research indicates that, if not for those plants, widespread blackouts likely would have occurred, threatening lives and livelihoods. We truly did dodge a rather large bullet.

Nuclear power plants typically reload about 1/3 of their fuel every 18 to 24 months. They don't rely on just-in-time fuel delivery or specific weather conditions to operate at full power. Over the past 15 years, U.S. nuclear power plants have typically operated over 90% of the time, with hardly any shutdowns other than for refueling. This is truly the definition of resilient.

Resiliency's definition also extends to stability and predictability of pricing and cost. Continued availability of power isn't acceptable if variable weather and market conditions can cause prices to spike by 10 to 20 times or more. In comparison, on January 1 of each year, a nuclear power plant can predict with very high accuracy the cost of the power it will produce for every day of the coming year. In fact, they can typically look out multiple years – the costs are stable and predictable.

Nuclear power plants also help anchor the electricity grid in the U.S. Grid operators rely on nuclear' s roughly 20% share of power production to maintain the stability of their systems as the electricity demand of our factories, businesses, and homes rise and fall throughout the day. This anchoring function has become increasingly important as intermittent sources makes up a larger percentage of our overall electricity generation portfolio.

Finally, an often-overlooked element of resiliency is industrial safety. Industrial safety events can shut down facilities, drive up costs, and present risks to operations. The U.S. nuclear power industry has an industrial safety record that most other industries would aspire to. Indeed, as a worker today, you are more likely to be injured if you work in an office building than if you work in a nuclear power plant.

I'm here today as the President of the American Nuclear Society. However, I also wear another hat. I'm Principal Officer, i.e., president, of MPR Associates, the leading specialty engineering firm in the power industry. Our firm was founded by the three chief lieutenants of Admiral Hyman Rickover. They worked as his right-hand men in the development of the naval nuclear propulsion program and the origins of the commercial nuclear power industry. We are widely recognized in the industry as the owners of the Rickover legacy for excellence and professionalism. I have been blessed with the opportunity to know, work with, and learn from our founders. One key lesson I learned was the need for stewardship in all of our endeavors, in particular stewardship for our natural resources. It isn't enough to reliably generate power; we need to strive to generate that power in ways that preserve our resources and protect our environment.

This is where nuclear power begins to truly stand out from the rest in the value it provides.

Nuclear power accounts for about 60% of all U.S. non-emitting electricity generation, providing large-scale power while emitting essentially no greenhouse gases or pollutants such as sulphur monoxide, nitrogen oxides, mercury, or particulates. Yes, nuclear power plants generate used fuel and other contaminated waste. However, those products are small in volume, contained in space, and can be handled and disposed of in safe, non-hazardous, and clean methods.

Nuclear power plants also have a high *energy density*, producing significant amounts of energy without requiring a large physical footprint. For example, the electricity generated from a 1,000 MW nuclear power reactor on about 1.5 square miles, would require about 50 square miles of solar panels or a collection of wind turbines over an area roughly 300 square miles. As we look forward to the societal challenges of balancing the demands of delivering needed energy, food, and water in a manner that balances environmental impacts and land use, the energy density issue will become ever more important.

At a local level, nuclear power plants are engines that drive economies across the country. Unlike fossil energy generation, the budget of a nuclear power plant is mostly driven by the cost of people. Fuel is typically less than 25% of the total expense; the majority of the remainder is dedicated to paying salaries for highly skilled, professional careers – the kind of good jobs we are seeking more of in the U.S. These salaries drive the local economy around the power plants. The power plants themselves tend to be the largest or among the largest taxpayers. Those taxes support local schools, first responders, and the local infrastructure. Beyond the direct financial benefits, the hard work and professionalism nuclear plant employees bring to their day jobs also extend to the community through charitable works and local leadership.

Finally, the U.S. nuclear sector contributes to our national security in ways that are as important as they are misunderstood.

Nuclear power was born in the U.S. Almost all nuclear power programs around the world can trace their technology back to U.S. origins. For decades, the U.S. has been recognized as the worldwide leader in nuclear technology, a role has enabled us to positively influence the nuclear safety and nonproliferation norms of the rest of the world.

Right now, dozens of nations around the globe are building nuclear power plants or actively considering adding nuclear to their energy generation portfolio. These nations recognize the same energy security and societal benefits reasons I've just described. In my MPR role, I have engaged with some of those decision-makers and I am confident that many will succeed. Through the development of a regulatory authority, plant construction, supply of fuel and services, operations, and eventual decommissioning, there is a commercial and civic force that binds together the supplier and host nations in a partnership which can endure for decades. These countries are serious, and if U.S. suppliers do not or cannot compete in this geopolitically-significant marketplace, our competitors in Russia and China will win. I don't think we want that to occur. Similarly, it is unrealistic to think that U.S. suppliers can compete effectively in world markets without having a healthy domestic nuclear power program here at home.

Nuclear power is the ultimate strategic long-term asset. However, it feels like we have all together wound up in an overwhelmingly tactical, "what did you do for me yesterday" world.

The strategic benefits of nuclear power are significant, yet current electricity markets do not value those benefits. The practical result is that resilient, reliable, non-emitting, clean, and

economy-driving power plants are shutting down because of the spot price of a kilowatt of electricity at 2:00 am on a Monday.

As leaders – industry leaders, policymakers, and others – when we talk about energy and make decisions about energy, we need to spend more time considering energy security. And when we think energy security, we need to automatically think "strategic." Our energy decisions needs to be strategic rather than tactical decisions.

With that goal in mind, we recommend Congress consider the following strategic policy directions:

1. Support the current U.S. nuclear fleet by equalizing the level of government subsidies, tax credits, and regulatory costs for all non-emitting energy sources and fund continued investment in R&D to extend the life of the reactors.
2. Continue and expand support for the development of small modular and advanced non-light water reactor systems.
3. Continue to invest in training and development of the next generation workforce and our U.S. R&D infrastructure at national laboratories and universities.
4. Demonstrate some forward progress in fixing our broken nuclear waste policy.
5. Improve our nuclear export regulations and financing opportunities to ensure that U.S. nuclear manufacturers can be competitive in international markets.

I thank you again for the opportunity to speak today. I'm happy to answer any questions.

The CHAIRMAN. Thank you, Mr. Coward.
Mr. McGroarty, welcome.

STATEMENT OF DANIEL McGROARTY, PRINCIPAL, CARMOT STRATEGIC GROUP INC.

Mr. MCGROARTY. Thank you.

My thanks to Senator Murkowski, Ranking Member Cantwell and members of the Committee for the opportunity to take part in the hearing this morning.

I am Principal of Carmot Strategic Group, an issues-management firm based here in Washington, DC, and strategic resource issues are a core element in my practice.

By way of disclosure, I advise Texas Mineral Resources, Graphite One, American Manganese and Rio Tinto, companies that are working to develop new sources of metals and minerals ranging from copper and graphite to cobalt, manganese and rare earths.

I also run the American Resources Policy Network, a virtual think tank that focuses on all aspects of domestic non-fuel resource production, and I consult to the Institute for Defense Analyses, which supports the Department of Defense on issues related to strategic materials and resource security. In my testimony today, the views I express are my own.

The focus of today's hearing, the outlook for U.S. and North American energy and resource security, offers a starkly differing portrait. On the energy side, as we've heard, the emergence of a vibrant oil and natural gas sector after generations of energy dependence, a resurgence so remarkable that we are now seeing the U.S. transformed into an energy exporter. On the hard-rock side of the resource sector, the picture is dramatically different, a deepening dependency on foreign supply for more and more metals and minerals.

According to the most recent USGS Mineral Commodity Summary, the United States is now 100 percent import-dependent for 20 metals and minerals, up from 19 a year ago. Meanwhile, there are now 50 metals and minerals for which we are more than 50 percent import-dependent, compared to 43 just one year ago. That's roughly half the naturally-occurring elements on the Periodic Table.

As for where our metals and minerals come from, the USGS map shown here, the heat chart, shows which nations provide the minerals for which the U.S. is more than 50 percent dependent. Of the 50 metals on that list, China is a significant supplier of 28. That's up from 21 just one year ago. As just one indicator of our resource reliance on China, in the 206 pages of the current USGS report, the word "China" appears 384 times.

Let me share with the Committee a quick snapshot of the degree of our dependency. We are 100 percent dependent for graphite and manganese, needed in the lithium-ion batteries that power our electric cars as well as the drones flying over Iraq, Afghanistan and our southern border. We're 100 percent dependent for the rare earths used in wind turbines and in our F–35 Joint Strike Fighter. We're 100 percent dependent for the indium that conducts heat from our fingertips to our touch screens and enables our special operators' night vision goggles. We're 99 percent dependent on

gallium needed for solar panels as well as missile defense radar. We're more than 80 percent dependent on imported rhenium used in jet fighter turbines and more than 70 percent dependent for the tellurium used in solar panels and for the cobalt used in EV batteries and jet aircraft super-alloys. And this, in spite of the fact that the U.S. is resource rich, blessed with known resources of dozens of the critical metals and minerals that are shaping our 21st century.

Without in any way diminishing the dangers of our resource dependency, I do want to note some positive developments taking place, largely in the area of process improvements that point to the ability to extract minerals from unconventional sources. I'm talking about reclamation programs supported by the Department of Energy and the Critical Materials Institute to extract rare earths from coal deposits, from waste piles left behind by prior mining and to advance recycling efforts to recover metals from eWaste. Add to that, projects backed by the Defense Logistics Agency to encourage domestic production of metals and minerals needed for advanced weapons platforms.

But in a $4 trillion federal budget, spending more than $10 billion each day, every day, the collective funding for these innovative efforts amounts to just a few hours of federal spending at a time when state-backed enterprises from China and Russia are focused on locking up metals and mineral deposits worldwide. On a geo-political level, a resource war is underway, but for the U.S. the battle has not been joined.

If we are serious about ensuring U.S. military power and reviving American manufacturing, we must reverse the deep dependency on foreign metals and minerals and treat American resource security with the same seriousness and one would hope, the same success, as our approach to American energy security.

Thank you.

[The prepared statement of Mr. McGroarty follows:]

Senate Committee on Energy and Natural Resources

Hearing

to Examine the Status & Outlook for U.S. and North American

Energy and Resource Security

366 Dirksen Senate Office Building

10:30 a.m.
July 18, 2017

Written Testimony of

Daniel McGroarty

Principal, Carmot Strategic Group Inc.

My thanks to Senator Murkowski, Committee Chair, and to Ranking Member Senator Cantwell for the opportunity to appear here this morning. My name is Daniel McGroarty. I am principal of Carmot Strategic Group, an issues-management firm based here in Washington, D.C. Strategic resource issues are a core element in my practice.

As noted in my disclosure, I advise Texas Mineral Resources, Graphite One, American Manganese, and Rio Tinto – companies that are working to develop new sources of metals and minerals ranging from Copper and Graphite to Cobalt, Manganese and Rare Earths. I also run the American Resources Policy Network, a virtual think tank that focuses on all aspects of domestic non-fuel resource production – and I consult to the Institute for Defense Analyses (IDA), which supports the Departments of Defense and Homeland Security, the Joint Chiefs' Joint Staff and the Intelligence Community on issues related to strategic materials and resource security. In terms of my testimony today, the views I express are my own.

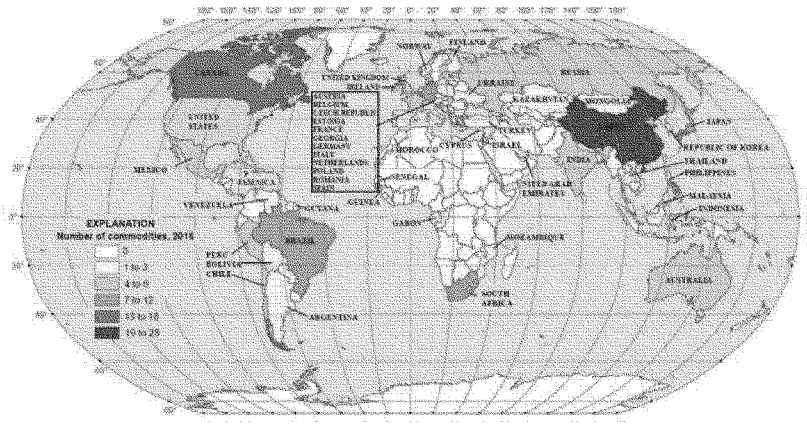
The focus of today's hearing – the outlook for U.S. and North American energy and resource security – offers a starkly differing portrait: on the energy side, the emergence of a vibrant oil and natural gas sector after generations of energy dependence, driven by technology advances and market demand – a resurgence so remarkable that we are now seeing the U.S. transformed into an energy exporter.

On the hard-rock side of the resource sector, the picture is dramatically different – a deepening dependency on foreign supply for more and more metals and minerals.

According to the most recent USGS Minerals Commodity Summary, the United States is 100% import-dependent for 20 metals and minerals – up from 19 in 2015. Meanwhile, there are now 50 metals and minerals for which we are more than 50% import-dependent – compared to 43 just one year ago. That's roughly half the naturally-occurring elements on the Periodic Table.

As for where our metals and minerals come from, the USGS map shown here – a geo-political heat chart – shows which nations provide the minerals for which the U.S. is more than 50% import dependent. Of the 50 metals on that list, China is a significant supplier of 28. That's up from 21 just one year ago.

MAJOR IMPORT SOURCES OF NONFUEL MINERAL COMMODITIES FOR WHICH THE UNITED STATES WAS GREATER THAN 50% NET IMPORT RELIANT IN 2016



Source: U.S. Geological Survey

As just one indicator of our resource reliance on China, in the 206 pages of the current USGS report, the word "China" appears 384 times.

Let me share with the Committee a quick snapshot of the degree of our dependency. We are 100% dependent for Graphite and Manganese, needed in the Lithium Ion batteries that power our electric cars and so many other tech devices we carry with us every day – as well as the drones flying over Iraq, Afghanistan and our southern border. We're 100% dependent for the Rare Earths used in wind turbines – and in our F-35 joint strike fighter. We're 100% dependent for the Indium that conducts heat from our finger tips to our smart phone touch screens – and enables our special operators' night vision goggles. We're 99% dependent on the Gallium needed for solar panels as well as missile defense radar. We're more than 80% dependent on imported Rhenium used in jet fighter turbines – more than 70% dependent for the Tellurium used in solar panels, and for the Cobalt used in EV batteries, permanent magnets and jet aircraft super-alloys.

As these examples make clear, at a time when we are engaged in a serious national debate on how best to revive American manufacturing, we are increasingly dependent on foreign sources for the

metals and minerals we need for major weapons platforms, alternative energy applications, and all manner of high-tech devices from smart phones to smart bombs.

And this, in spite of the fact that the U.S. is resource-rich, blessed with known resources of dozens of the critical metals and minerals that are shaping our 21st Century.

Without in any way diminishing the dangers of our resource dependency, I do want to note some positive developments taking place – largely in the area of novel metals and minerals processing. These are advances arising out of necessity – the need to efficiently extract minerals from low-grade deposits. In some cases, this effort is driving process improvements that point to the ability to extract minerals from unconventional sources, feedstocks if you will. I'm talking about historic mine waste piles, eWaste, and potentially and perhaps most interesting, extracting rare metals from coal deposits.

As for policy reforms that could reverse U.S. dependency and enhance our resource security, I'll limit myself to a few brief points. As this Committee knows well, federal permitting reform is key -- particularly for metals and minerals known to be critical and strategic. But any change in federal policy will need to tackle the "co-product challenge:" The fact that dozens of the critical metals and minerals needed for tech applications are not mined in their own right – but are recovered as "by-products," or given their rising importance, "co-products," of major industrial minerals not often thought of as critical. In a study done with co-author Sandra Wirtz, we found that five "gateway" metals – Aluminum, Copper, Nickel, Tin and Zinc – provide our access to 25 of the more arcane "technology metals" discussed here.[1]

And from the Executive Branch, we should not underestimate the power of a clear presidential pronouncement that resource security is every bit as critical to U.S. economic and military strength as we now know energy security to be.

But there are other positive steps, supported by Congress and translated into policy and programs by key departments: Reclamation programs supported by the Department of Energy and the Critical Materials Institute to extract Rare Earths from coal deposits, from waste piles left behind by prior mining, and to advance recycling efforts to recover rare metals from eWaste. Add to that projects backed by the Defense Logistics Agency to encourage domestic production of metals and minerals needed for advanced weapons platforms. But in a $4 trillion dollar budget, spending more than $10 billion each day, every day, the collective funding for these innovative efforts amounts to just a few hours of federal spending – at a time when state-backed enterprises from China and Russia are focused on locking up metals and mineral deposits worldwide. On a geo-political level, a resource war is under way, and the U.S. has not entered the battlefield.

If we are serious about ensuring U.S. military power and reviving American manufacturing, we must reverse the deep dependency on foreign metals and minerals, and treat American resource security with the same seriousness – and one would hope, the same success – as our approach to American energy security.

Thank you.

---

[1] http://americanresources.org/wp-content/uploads/2012/09/ARPN_Fall_Quarterly_Report_WEB.pdf

The CHAIRMAN. Mr. McGroarty, thank you. I appreciate your comments there just in reminding us some of the daily uses that we all take for granted and the vulnerability that we have.

I would like to start off my questions this morning focused a little bit on oil, and specifically, to the oil export ban.

It has been a couple years now, 19 months exactly, since we lifted the domestic ban on crude oil. There was a lot of discussion at that time about what may or may not come about were we to roll back that policy that had been in place for decades.

There were some who said, nobody is going to want U.S. oil. There were those that predicted that the price would skyrocket if anybody did actually buy it. But instead what we have seen are prices that have been relatively moderate, even as our exports have now topped over a million barrels a day, just in some recent weeks.

I guess I would direct this to you, Mr. Webster, and to you, Mr. Mills, in terms of where we are with the opportunities that we have as oil exporters and the international benefits that then come to it. Mr. Webster, you certainly referred to that. But again, there was a lot of speculation that there was going to be, not a doomsday scenario, but that some of the fears that have been talked about were going to materialize and 19 months, perhaps, is not enough of a test case for us. Do you see this moving forward into the out years in terms of stability of prices and, again, just the opportunities that come with developing these alliances with other nations that are eager to receive our oil?

Mr. Webster?

Mr. WEBSTER. Thank you, Chairman Murkowski, for that question and thank you for, I know you worked on this issue quite a bit when it was coming up. I remember your speech at the Brookings Institution some years ago to, kind of——

The CHAIRMAN. We dared to raise the issue.

Mr. WEBSTER. Yes.

The CHAIRMAN. And low and behold.

Mr. WEBSTER. I will answer your question on has there been enough time. I think there actually has been enough time, that this has been fantastic for U.S. producers, U.S. consumers and the concerns that this would really hamper U.S. refiners and cause them to stop investing and there would be a real loss is belied by the recent EIA report that refinery capacity in the United States has actually grown again. And so, this is despite the view that, you know, the concern that some had at the time that we'd be exporting our resource and leaving us in a worse spot.

We're exporting, as you said, more than a million barrels a day at times to as many as 26 countries per the EIA. Prices and the differentials that are required to allow exports but still allow refineries to take on that oil have been there, so you have seen a lot of oil go in other places.

The interesting thing is that it has given both domestic and international refiners a greater range of choice. Refineries don't just use one particular type of oil, so they can now more tailor make their slate of oils. That's why you're starting to see, actually, an increase in crude oil imports back into the United States as they are blending that increased production out of the United

States, crude oil which is quite light, as you know, and blending it with other, sort of, material from other countries.

This has been a benefit in that this extends U.S. production to other countries. And obviously, at least in my opinion, any oil that comes out of the United States is generally more stable than just about any other, sort of, oil in terms of that going forward.

So I think it's been extremely positive.

The CHAIRMAN. Mr. Mills, do you care to comment?

Mr. MILLS. Let me agree with Jamie and also thank you for your leadership on this. It was those of us in the community who thought we should export oil were, seemed to be a minority, even on both sides of the political aisle for quite a long time.

I think it's unequivocally the case that the experiment of 19 months has demonstrated the benefits overall for consumers everywhere, not just America. We've helped stabilize the world.

Let me answer the question about what could be done next, where could we go? I think we have untapped opportunity to do far more. We're now a larger exporter of crude than five OPEC nations, four or five OPEC members. We could become one of the largest, by that I mean North America, one of the largest exporters of both crude and natural gas in the coming decades.

This would be astonishingly impactful and very beneficial, not just to our security but to our economy and to the world because we play a role in, not only stabilizing prices, we're now, in effect, half of the throttle. It used to be OPEC was the entire throttle on oil prices. We now, we have our hands firmly on the wheel and one foot on the gas pedal as well which means that oil prices are going to be range bound in the future by American behavior.

We could change the game, not just by helping the shale industry by getting out of the way, so to speak, but there's a lot more to be done yet. I mean, I'm saying the obvious to you but when you think of a combination of what Alaska can yet do and has not been unleashed to do, what the Gulf of Mexico is just starting to do and the new leases that the nation of Mexico has granted to foreign entities to begin producing from the shallow waters, the very productive shallow waters that they own. If we add to that the rest of the Atlantic Coast and the other conventional deep-water capacities we have which are getting better, this combination in the United States, I think, is reasonable to think in terms of, not just increasing a little bit, we could double, triple and quadruple our exports of oil and natural gas. This is profoundly impactful.

And it doesn't mean, and I'll state for the record because when you, when one is bullish about oil and gas the implication is that one doesn't think that we should pursue alternatives for oil and gas. The reason in my opening remarks I pointed out the realities is that realities are what they are.

Airplanes in the world fly on oil and they will for a long time. Most cars, even if Elon Musk is astonishingly successful, even more successful than he's already been, most cars will still burn oil 20 years from now. The world needs lots of oil and gas. We can do both, and we can generate the economic foundation if we're doing the alternatives by having cheap energy in the primary areas. And that's where all the United States, and in particular, unleashing

that trapped oil that I'm very familiar with in Alaska that needs to get down in that pipeline and get into world markets.

The CHAIRMAN. Thank you both.

Senator Cantwell.

Senator CANTWELL. Thank you, Madam Chair.

Gentlemen, I think in a different decade we would be here talking about supply disruptions and challenges, but today we are here and the issues of supply disruption now take a new twist and turn and that is the issue of cybersecurity.

Brigadier General Cheney, you mentioned this. How much do you think we need to think about upgrading our security of our critical infrastructure as it relates to these recent attacks, both internationally and domestically?

General CHENEY. Well Senator, thanks for your question and there is no doubt cyber is a huge threat, a threat to our security, threat to our energy sources.

As you well explained, there's been multiple attacks on all of our grids and if we just put our head in the sand and don't put the funding toward it or the research that's needed to counter these, it's going to get worse, significantly worse. If the Administration reduces funding to those opportunities that we have to counter cyber threats, then they're just going to get worse.

So this is a tremendous threat to our national security, and it's worldwide. The military sees it every day, and that's why we created Cyber Command. We put our best and brightest over there to counter those threats. When you see what can be done to the grids worldwide and can be done here, it's a tremendous national security threat. So perhaps I'd rate it almost at the top.

Senator CANTWELL. Okay. So, what do you think are some of the things that we should be doing to pursue better alignment? Some of the things that are being done right now are, you know, voluntary. And what do you think we should be pursuing?

General CHENEY. Well, of course the vast majority of our utilities are privately owned in this country and enforcing upon them to do the research and then necessarily help to counter cyber threats is not the way to go about doing that.

I think you need to fund that from the federal level. You need to do research and development on cyber. You need to have a healthy Cyber Command that's looking at these threats and you need to assist all the utilities in the country in countering these threats. DHS needs to be involved. They need to be robustly funded to counter the threat that's there.

Senator CANTWELL. One of the things that Senator Murkowski and I were able to do is have a discussion in the Pacific Northwest when we were out there looking at a variety of grid issues, both in Alaska and Washington. The State of Washington has gone to a great degree in getting the National Guard to also plan on a response side so there is a response mechanism to cyberattacks.

Do you think that is a wise——

General CHENEY. It's absolutely wise.

When you look at any catastrophic event that happens in this country, for instance, Superstorm Sandy, Katrina, they all become joint events. The Army, Navy, Air Force, Marines, Air Guard, the National Guard, all respond to those events. And I don't think you

can segregate cyber from that type of catastrophic event where there's something that's going to happen. You have to have the Guard involved. They have to be planned.

If all the power went out in your state, it's going to be chaos. You need the Guard to help put that chaos down or assist. So, undoubtedly, they have to be involved. And I think all of the Department of Defense needs to be involved.

Senator CANTWELL. Thank you.

Thank you, Madam Chair.

The CHAIRMAN. Thank you, Senator Cantwell.

Senator Cortez Masto is not here.

Senator Heinrich.

Senator HEINRICH. General Cheney, I want to follow up on the question that Senator Cantwell brought up and take it one step forward because, kind of, there are the challenges inherent to managing a grid today where we have cyber threats that simply were not at the top of our mind when we designed this architecture and designed it for reliability and oftentimes don't upgrade the software on some of these controls because we just like it running the way it runs.

I say this as somebody who was somewhat exposed to these things growing up in a utility household where my dad was responsible for a lot of that reliability.

Have you thought about the next step of how changing the grid architecture itself moving from the 1970s, 1980s model of one-way generation as we get more distributed energy resources into that grid whether that is distributed generation, whether that is storage in exchange for, maybe, new transmission or new substations, et cetera, how that will impact the resiliency of the grid and what we should be thinking about as that natural evolution occurs?

General CHENEY. You know, Senator, great question.

I think there's no doubt and I hear my contemporaries talking about oil and the future of oil, but you need to diversify your source of energy here. I mean, you can even look at Saudi Arabia today and they're thinking long, long-term that somehow they've got to wean them off this oil economy. The same thing applies to our infrastructure. The same thing applies to bases and stations.

When I was a Base Commander down at Paris Island, we relied entirely on the local grid. If that grid went out, we had an alternative backup, an oil-fired power plant that would temporarily provide us power. But if we had a long-term source of our own power, as is being developed in the DoD today with net zero programs in the Air Force and Army at a huge number of bases, Fort Bliss, Nellis Air Force Base, what they're doing is going to a case where they would produce more power than they can consume and not have to depend on the local grid in case that goes down. It's a tremendous security issue. Your base would shut down if that was the case. So you have to diversify and these are some of the ways you can do that.

Senator HEINRICH. Right. We saw that just a few years ago with Kirkland Air Force Base as we saw gas come offline, natural gas losing pressure and having to shut down, doing millions of dollars of damage as we lost that source of energy.

And you mentioned Saudi Arabia. I don't think you have to look to the other side of the world to realize how much things are changing, and a lot of it has to do with economics.

You look at New Mexico and we have a chunk of that Permian Basin production. But at the same time, when you look at the electrical generation side of the scale which has seen more change than the transportation side, we are seeing two and three cents power from solar PPAs and from wind farm PPAs that are driving this change and driving an awful lot of economic development as a result.

Which brings me to a question for you, Mr. Coward, because as you mentioned there are a lot of nuclear power plants that are currently shutting down because of economic conditions, because the reality is we do live in a spot market. And I don't know how you make ten cents power function in a four-cent spot market.

So what are we doing to make the U.S. nuclear fleet more economically competitive at a time when you are seeing it undercut by a factor of two or three from other generation sources?

Mr. COWARD. Well, I think, if you look at the industry, got together, to use a phrase, about a year and a half ago, two years ago and said, we're going to leverage the experience, the insights, the knowledge of all of us in the industry and work together to identify all the various opportunities to be more efficient, more effective, eliminate non-value work. That program is working right now and we're seeing the costs go down some. There are still regulatory costs which the industry believes are higher than they need to be.

I think the simple fact, I'll just cut to the end, I think the simple fact is a nuclear power plant can put power onto the grid. A reliably, well-run plant can put power onto the grid. It goes over the fence at about three cents a kilowatt-hour. When you add T&D, all the overhead from the utility system, that's how it gets to ten.

It's competing right now with natural gas plants which are somewhere in the teens and it's competing with wind which is getting a little bit, which is getting about 2.3 cents a kilowatt-hour tax credit.

And so, you know, you mix all that together and the reality is in the end, I'll be honest, a nuclear power plant is not going to compete with——

Senator HEINRICH. We can all play the levelization game, but you also get a benefit having to do with your insurance that is substantial. And so, if levelized everybody was going to say, okay, this is the future. Why aren't you attracting more investment?

Mr. COWARD. I think we're not attracting more investment because it is difficult for nuclear power to be the low-cost provider in a low-cost decision market. We don't believe the decision should be made on low-cost today. We believe decisions should be made on a strategic, longer-term, diversity, resiliency, security basis and that, just like some people buy an Accord instead of a Civic, that there are reasons to still promote a nuclear power program, that the value is there overall.

Senator HEINRICH. I think that is a tough sale to the consumer.

Mr. COWARD. We know that.

The CHAIRMAN. Senator Heinrich, thank you.

And my apologies, Senator King, I skipped right over you. Mea culpa, mea culpa. It is now to you.

Senator KING. I will find a way to get back at you, Senator.

[Laughter.]

Thank you very much. No problem at all.

I have to note that I think every single one of you have mentioned EIA somewhere in your testimony and the data that was provided. The current Administration budget cuts EIA.

We have also had quite a bit of discussion about energy reliability and the grid. The budget cuts the Electric Delivery and Energy Reliability Office in the Energy Department by 40 percent. So I just note those data points in terms of our consideration of this budget.

The Chair and I were at a conference this morning on the Arctic. Arctic sea ice has declined by two-thirds in about the last 15 years. I was in Greenland this time last year and saw what is happening there where the retreat of the ice sheet is accelerating in ways that no one imagined, even five or six years ago. There is a cost to this.

General Cheney, I want to complement you on your testimony. You were balanced, and you talked about the costs and the benefits. I suggest you and Mr. Mills have lunch together and talk about that because the growth of the fossil fuel dependency is not an unalloyed good. We are going to spend a lot of money dealing with the consequences of climate change. We are going to be building walls. They may not be in Mexico, but they are going to be sea walls all up and down the coast of this country that are going to be incredibly expensive.

And this is after spending most of my adult life in energy, my conclusion is there is no free energy lunch. Everything has a consequence. Everything has a result. Everything has a cost. I just think that is something we have to really focus on.

Mr. Webster, a specific question. You mentioned about LNG and I understand the shale revolution, natural gas has been enormously beneficial to New England and to Maine. Here is my concern. Unrestrained LNG exports, explain to me how that doesn't relate, result, in higher domestic prices.

I am a country lawyer from Brunswick, Maine, but if you drastically expand the sales and the demand with the supply somewhat constant, although I understand it is growing, there seems to me, increases in prices are inevitable.

Mr. WEBSTER. Thanks for your question, Senator.

So there is some concern that prices might rise marginally because of exports. That was said, I think, in the first export application that was put in some years ago that I think that first one was that they might rise as much as six cents.

With the rise of the Marcellus and the production growth that you've seen out of the Marcellus, you do have a lot of LNG export that can go elsewhere. The difference is that because of the increased cost on liquefaction, transport and then moving it to whatever market you're talking about, that price is still fairly cheap back here in the United States.

Senator KING. It is about——

Mr. WEBSTER. Sorry.

Senator KING. ——between $2 and $3 a million BTU?

Mr. WEBSTER. That sounds about right. That sounds about right, Senator, yeah.

Senator KING. And you think that is enough? I mean, I hope you are right.

Mr. WEBSTER. Yeah.

Senator KING. I don't know the answer but it just concerns me that we are not—there have been economic studies, but we are reaching a point on exports where there could be a more significant effect.

Do you share that concern that there is some point?

Mr. WEBSTER. Actually, the more global concern right now, certainly over the next several years, is actually the concern that from a market standpoint that there's far too much natural gas in the world than actually it's looking for places on where it can actually find a home.

You know, you've got increased exports out of the U.S., increased exports out of Australia. The demand that was expected in a couple of different countries is not quite——

Senator KING. Well Australia is one of the cases that worries me because they went into exports in a big way and their domestic price increased very substantially, something on the order of 100 percent.

You are not concerned? Do any of you want to comment on this problem? Is it not a problem? I don't understand how you drastically increase the demand for a product and don't increase the price and the market doesn't increase.

Mr. WEBSTER. I'll pass that on to Mr. Mills because I know he has something on this as well.

But certainly, we've also increased, again, we've also increased production more than a third just in the last few years.

Senator KING. So——

Mr. WEBSTER. So you are right, you're increasing demand.

Senator KING. If you increase demand and increase production, I understand, you will end up with a similar price.

Mr. Mills, are you worried about this at all or do you think we do not even have to consider the domestic effects?

Mr. MILLS. First Senator, I want to thank you for the opportunity to have lunch with the General. It would be a pleasure.

[Laughter.]

I suspect we'd probably have a lot of similar views—or more similar than dissimilar when you speak in five-minute bytes.

I would say the fundamental—I don't have deep concerns about it, the short answer is.

Australia did some structural things which, I would hope, we wouldn't do with respect to expanding domestic use of natural gas.

The real, the underlying question, you're absolutely right, if you have a limited supply and demand rises, you end up getting price increases. This is, sort of, Economics 101. It's a given.

The real question at the, sort of, high level of extraction is how big is the supply? If the supply can expand faster than demand, obviously.

Senator KING. Right.

Mr. MILLS. Right?

So the real question is looking at global markets, to Jamie's point right now, where the supply has expanded much faster than demand. This is why LNG prices and gas prices are in free fall globally, to everybody's benefit, except Putin and Cutter.

Our capacity to produce gas is so astonishing, I think it really has not been fully appreciated, not by this Committee, but in general. It is so astonishing and there's so much natural gas capacity, so much untapped capacity to produce it, that, I think, this really changes the game, not just the way you describe worrying about price pressures. But I think it has not been factored into how we think about alternatives.

My point about being bullish on oil and gas is not that's what we should use, that's what we are using.

Senator KING. Right.

Mr. MILLS. There are, just as you correctly said, that there are, sort of, limits to, you know, what can happen in reality, this is the physics of energy are what they are.

Oil is a very dense fuel. It's very good for flying airplanes with. It's much better than a battery for a car. It will take a lot of money, a lot of time, to beat it. So, the reality is that low cost energy is a benefit, not an alloyed benefit, but it is an overall benefit because we need new technologies.

So, I would just——

Senator KING. As long as we also consider the externalities of the costs of climate change, for example.

Mr. MILLS. Well——

Senator KING. And those sea walls and other costs that we are going to have to bear.

I am out of time. Can I just ask one question for the record, Madam Chair?

Mr. McGroarty, a question for the record and I think you touched on this in your testimony which, by the way, was very good and very sobering.

Do we have the minerals? Is this a case of us having to go abroad because they do not exist in this country? And if we do, what are the barriers to us being able to reduce our dependency on oversea sources for these critical minerals?

If you could give a written response on that?

Thank you.

Thank you, Madam Chair.

The CHAIRMAN. Thank you, Senator King.

Know that we might actually get that on the next round, because I would like Mr. McGroarty to speak to that.

We skipped over you already, Senator Cortez Masto, so now back to you.

Senator CORTEZ MASTO. Thank you. I appreciate that. And I apologize, excuse me, I have a Banking Committee going on at the same time.

I am going to ask that question because I am from Nevada and mining is very important in our state and we tried to——

[Inaudible comment from witness]

Exactly, so listen—rare earths, as you well know, we tried to mine it and it was cost prohibitive. And I have watched over the years as China has taken the lead on this.

In Nevada, as you well know, the innovation in clean energy is crucial. We have Tesla there. We have drones. This new area for renewable energy solar, hydroelectric, geothermal, is key.

So I was going to ask you the same question. What do we need to do? What are the barriers? How do we address this and is it too late for us to start looking at how we start investing in these metals and minerals that are going to be important for our clean energy future?

Mr. MCGROARTY. I hope it's not too late.

We certainly are resource rich. Now, I'll be careful on that and say, do we know that we have resources, known resources, for many of these metals and minerals? And the answer to that would be yes.

Do we know if they're economic or not? That's a different question, partly because of the barriers and the complexities of funneling capital and finding that out. Right?

Part of that is the permitting process which is, kind of, sprawled and is notoriously lengthy and opaque. And I would say the cost of that is higher for us as a country when the metals and minerals are critical and strategic, when there's, you mentioned, Senator, Nevada, the Gigafactory, for instance, right?

If you're looking to build EV batteries, you're going to need lithium. We know that from lithium-ion. The irony is lithium is the least in terms of volume. Why it's named that is a good question.

Graphite, manganese, nickel, cobalt, okay? We have deep dependencies in all of those.

And then the question is, to the extent that they come from countries where there is political uncertainty, possibly instability, where they are ranked very low in terms of, you know, Freedom House indices of whether they're free or not free. So, are we comfortable importing from those countries over time? The answer should be, if we could substitute our own, no. We should pursue the substituting of our own.

Are we giving leverage to the Chinese, to the Russians and others? I cited on the heat map there this growing, rapidly growing, dependency on China which is mining these metals and minerals. So, the question is going to be we're in the midst of this technology revolution. We're going to need this stuff.

I think we'd all like to see the United States manufacturing more of this, that we need, as opposed to being purchasers of it and then dependent for a price, dependent for, you know, geopolitical gamesmanship that could be played in the future of those kinds of things.

We do it. We are fortunate in contrast to many other nations where they're as dependent on these technology metals, but they do not have the resource underneath their land in order to remedy their dependency.

We, I think, are in a different place. The Committee is working on that, particularly on critical and strategic materials to create more incentives.

I mentioned a few small programs where this is happening. There are some very interesting things going on with some government support, you know, this idea of extracting rare earths from materials adjacent or associated with coal deposits is a remarkable

thing, right? And the Department of Energy is working on exploring that right now.

The same thing with, I am not at all opposed, I'm not only for primary mining. I'm not opposed at all to reclamation work from, you know, waste piles that have been sitting around for generations or recycling, to the extent that we can efficiently and effectively, reclaim metals and minerals, half of the Periodic Table sitting in our iPhones, like micro amounts. Can we figure out a way to do that effectively and efficiently?

Those are mines. Those are urban mines. And our dependency is so deep we have to get these materials from all of the above, new mines, reclamation, recycling, you name it.

Senator CORTEZ MASTO. I know my time is up, and thank you for the conversation.

Your testimony was sobering. It is an area, I think, I can hear from my colleagues, we would love to have further dialogue and discussion on how we try to ensure that we are leading the country in some of these, mining that is necessary for the future of our technology and renewable energy and where we would want to lead here in this country.

So thank you.

Mr. MCGROARTY. Thank you.

The CHAIRMAN. There is just such a codependency between the future for our renewables, and not just our renewables but in all aspects of economic growth, and these critical minerals. So, I appreciate that.

Senator Cassidy.

Senator CASSIDY. Can I defer to——

The CHAIRMAN. I am sure that Senator Hirono would be anxious to accept that deferral.

Senator Hirono. You are actually on my list ahead of Senator Franken, but if Senator Franken is being deferred to by Senator Hirono, who has been deferred to by Senator Cassidy—

[Laughter.]

Senator Franken, you are up.

Senator HIRONO. I will go.

Senator FRANKEN. You will go?

Senator HIRONO. Yes.

The Chairwoman recognizes me, so fine.

I was intrigued by Mr. McGroarty, with your testimony because while we have all these rare minerals, it is, sort of, that we have gotten to a position where we have not really exploited what we have. Why was that? Is it because it was just so cheap to get all of these materials from outside of our country? What? Why did we allow this to happen?

Mr. MCGROARTY. I think there is, yeah. We can blame Milton Friedman for that, right, I think, to some extent.

I think what I would like to see added back into that equation is the potential dangers or costs associated with—that come from geopolitics, where, you know, it's always nice to have something for the cheapest possible price, but there are certain things where, Senator, you referenced the fact that we were mining for a period of time some rare earths out of the Mountain Pass Mine in Cali-

fornia. It, you know, did not make it. It went bankrupt. Again, we're back at 100 percent dependencies.

There are active efforts to remedy that and not all rare earths are created equal. So I wouldn't go into all the details as to why that particular deposit might not have been optimal for what we needed because there are 17 rare earths and, you know, you need to be specific about which ones you're after.

But we, I think, a large part of it and this is something that this Committee knows well, but perhaps needs to be communicated far beyond this Committee, an understanding that our manufacturing might, our technology development is dependent on access to these things if we are going to win. You know, there's tremendous genius in America and a lot of innovation and inventiveness, but we need the materials, the materials science, in order to make those products here and make those advances here.

Senator HIRONO. I think that you describe an interesting scenario because for a state like Hawaii, I mean, we talk about depending on sources outside of our state for some very basic needs—such as in Hawaii we were the most oil-dependent state in the entire country for electricity.

I want to ask, General Cheney, since 2006 Hawaii has cut its annual use of petroleum by 41 percent, or 20.2 million barrels, while renewable energy grew from 9.5 percent on the electricity side of the market in 2010 to 26.6 percent in 2016.

The State of Hawaii has the most ambitious goals toward 100 percent renewable and alternatives for our electricity. I would like to see a similar transition in the transportation sector.

General Cheney, what policies do you recommend to accelerate the transition to electric vehicles or advanced biofuels that you referred to in your testimony?

General CHENEY. Senator, congratulations on your progress on using renewables. I think it's remarkable.

And you'll see tremendous progress, particularly in the Midwest, with the use of wind energy states that are coming now upwards of 40 percent of their energy provided by wind. So they certainly recognize the advantages of it, as you have as well.

When I heard Mark talk a little bit about aviation and their dependence on fossil fuels for their energy, FedEx has, at one time or another, fueled all their airplanes with biomass developed fuels. The United States Department of Defense has, at one time or another, put biomass fuels into almost all their aircraft. So there are ways to do this using biomass instead of just using straight fossil fuels that were not developed through biomass. That's one distinct way to encourage development on the biomass side of the house. The price of biomass fuels is coming down dramatically. And you will see this.

The same thing applies on the hybrid and battery side of the house. My biggest concern when I was an Executive Officer of an Artillery Battalion in the desert was where's the next gas station? If I had some source of renewable power or a hybrid energy which would get us off that tether of fossil fuels which General Mattis said when he was in Iraq. He said, "Please get me off this tether of fossil fuels" because the logistic trains were being attacked uni-

versally. There are much better ways to get off that tether. So certainly the Senate and Congress can help us with that.

Senator HIRONO. So, there are ways that we can move much faster in terms of the transportation sector and the reliance on renewables and alternatives in the transportation sector because we seem to be doing a much better job of it in producing electricity for consumption, electrical consumption. But on the transportation side——

General CHENEY. It's not the same.

Senator HIRONO. It's not the same. If you wanted to move faster toward that kind of reliance on alternatives and renewables because we care about things like climate change. I would welcome any further ideas that you would have to incentivize to move in the transportation sector.

I am running out of time; five minutes goes by awfully fast.

Thank you.

Thank you, Madam Chair.

The CHAIRMAN. Thank you, Senator Hirono.

It looks like Senator Cassidy is prepared to defer to our colleague from Minnesota, Senator Franken. Everyone is generating good will this morning.

Senator FRANKEN. Well thank you, Madam Chair and thank you to the Senator from Louisiana.

I was struck just now, General Cheney, when you talked about this tether to fossil fuels, to diesel fuel, I think, mainly for generators.

You know, I used to do USO tours. At that time there was both Walter Reed for Army and Bethesda for the Marines. You would go to Walter Reed and there would be guys who had lost limbs, et cetera, TBI, and ask them what they did and they, very often, were truck drivers. You go to Bethesda and those guys got shot up in places like Fallujah, but what it was is the supply line. I know that when I talked to the military, they talked about solar, trying to make tents out of solar so that you don't have to rely on the more efficient, even more official generators could save lives.

So when we are talking about security, I think that the first two gentlemen seemed to be talking mainly about domestic fuel production, but General Cheney, you have a different point of view. Can you elaborate on how increasing short-term energy security via increased fossil fuel production can have negative, long-term impacts on energy security?

General CHENEY. Well, I think I mentioned in my testimony and certainly in my written comments that this increase has given us breathing space now so there's obviously an advantage here, but long-term, I think we need to recognize we can't continue to rely entirely on fossil fuels.

The number one consumer of fossil fuels in the country and maybe the world is the Department of Defense, and they know this and they recognize it and they're searching for alternative ways to source their energy. And they know that now.

One quick comment about the soldiers who were in those logistics trains. Those young men and women got shot up too, so, I mean, they were in combat. They were on the front lines.

Senator FRANKEN. I understand that.

General CHENEY. I mean, they gave their lives for us to supply the fossil fuels to support our troops.

Senator FRANKEN. Yes, so much was IEDs though, yes.

General CHENEY. Yes, precisely.

So I mean it, long-term, overreliance on this abundance, overabundance of fossil fuels is not a good thing. The DoD needs to diversify. Any good commander needs to know he has to have alternative sources of all things, let alone fossil fuel or energy.

You will see that in terms of, also you mentioned the tents. Forward operating bases that are supplied their communications and electronics are, their energy, is supplied by solar arrays instead of having to hike batteries up there or diesel fuel to supply the generators. So there are ways for this to be done.

Senator FRANKEN. Well, I want to talk more about climate change and the Department of Defense because you are right about the Department of Defense using Algol fuels and other non-fossil jet fuels.

This is from the report to Congress from the Department of Defense in 2015, "Climate change is an urgent and growing threat to our national security contributing to increased natural disasters, refugee flows and conflicts over basic resources such as food and water. These impacts are already occurring and the scope, scale and intensity of these impacts are projected to increase over time."

General Cheney, I know that last week you spoke about the threat that climate change poses to national security at a House Science Committee Roundtable. Can you tell this Committee how the Department of Defense should be preparing for climate impacts and more broadly, how Americans should be thinking about the link between energy decisions and national security?

General CHENEY. Sure. Clearly this is a longer conversation than we have time for here, but I'll try to boil this down very quickly.

As I mentioned last week, I put it into two categories, strategic and tactical. And when they said it's the number one threat, when you go back to Admiral Locklear in the Pacific Command, he was looking over his whole area of operation and he said catastrophic weather like Typhoon Haiyan is becoming much more common and he's got to respond to those. Climate change is a contributor. He recognized the threat.

Refugee crisis, Bangladesh, foot and a half rise in sea level gives you 30 million refugees, not coming here, but they're going somewhere else in Asia.

Senator FRANKEN. It is destabilizing.

General CHENEY. Hugely destabilizing.

That's the strategic side of the House, the Sahel in Africa. When the temperatures there start to rise to 140 and 150 degrees Fahrenheit, those refugees are headed to Europe. If they think they have a migration problem now, just wait. So, that's the strategic side.

On the tactical side, our bases and stations that are on the coast are going underwater. Norfolk is the prime example, our largest Naval base, which gets closed dozens of times a year now because of flooding, both from rain and sea level rise, is really having a problem with that. We're going to have to talk about relocation of our bases and stations that are on the coast, and I can delineate

a number of these. The DoD understands that and looks at that and General Mattis, and now Secretary Mattis, has looked at that and said he understands climate change. He recognizes that as a threat. It's been written into the Quadrennial Defense Review before. Again, when you're talking long-term, strategic threat and where you're going to have instability, and in short-term, the tactical side, what bases and stations are going underwater and what you have to do to adapt to move those.

Then getting to your other question about fossil fuels, the mitigation side of the House, get off your dependence on fossil fuels. Stop contributing CO2 to the atmosphere. Stop making the problem worse.

Senator FRANKEN. Thank you.

Thank you, Madam Chair.

The CHAIRMAN. Thank you, Senator Franken.

Senator Cassidy.

Senator CASSIDY. Thank you, all.

Now, General, just to be clear, as we speak of needing not being tethered to fossil fuel on the front line, it is not to say that a transport truck would not be by fossil fuel, I presume you just mean the electricity for the tents providing the power?

General CHENEY. Senator, not so. You could have hybrid vehicles for sure.

Senator CASSIDY. Now that presumes that we continue to fight only in deserts. If we are in an overcast area to have, I can only imagine, if you have something with, I don't know, 50 troops and are in an overcast environment, you would need, probably, fossil fuel, correct?

General CHENEY. Well, like I said, if you had batteries that were recharged and they worked on a hybrid, just like Volvo stock——

Senator CASSIDY. It really does seem, though, a lot of ifs involved with that for something which absolutely needs certainty.

Mr. Mills, I enjoyed your testimony because you point out some certainties that we actually, since the Arab oil embargo, have become more dependent upon fossil fuel. I will note, however, that we have actually decreased global greenhouse gas emissions in the United States as we transition from coal to natural gas. Fair statement?

Mr. Mills, this is a little bit far afield, but I found your testimony very realistic if China, which gets 63 percent of its electricity from coal, converted to natural gas, any idea what the impact that would have upon global greenhouse gas emissions?

Mr. MILLS. Well, it would be a dramatic reduction in global gas, carbon dioxide emissions, for very obvious reasons.

Senator CASSIDY. As well as SOX and NOX, et cetera, right?

Mr. MILLS. Well, the air would get a lot cleaner in China. I've been to about a dozen cities in China, its particulate emissions are pretty severe.

Senator CASSIDY. I have actually seen graphs that show the SOX and NOX blowing from their coastal power plants falling on to Oregon, Washington and California. So not just globally, but locally, it would make our West Coast a little bit cleaner too.

I just see that because you point out that for the foreseeable future petroleum and natural gas will be more, not less, important.

I also like, now I will agree, that if we absolutely, that we produce, if we become energy secure, less dependent upon other countries, perhaps we need fewer troops committed to the Middle East to protect sea lanes. That would be something that would save a lot of young people's lives if we were not having to commit our troops to protect sea lanes for the sake of oil, if Israel develops Leviathan, as they appear to be, then that would, of course, insulate Israel from some of the shock.

I also liked your point, Mr. Mills, the degree to which we develop LNG exports, this is implicit in what you were saying, and perhaps Israel and Azerbaijan and others develop their gas exports, Russia is weakened. Isn't that a wonderful thing? That in itself might forestall some conflict. I think we can all agree upon that, right?

Mr. MILLS. You bet.

Senator CASSIDY. So that is a tectonic plate, as you mentioned that is almost amazing.

Now, somebody, I think I was told that Senator King was concerned. Do we have, oh, here we go, enough gas to fuel this, but Mr. Webster and Mills, perhaps you all followed up?

I am told we have at least 93 years of proven, technologically, we can get it, natural gas reserves which more than enough insulates us from price increases even if we continue to export.

Fair statement, Mr. Mills?

Mr. MILLS. I think it's fair and it's, in my view, an understatement of the magnitude of the resource that will be on tap through technology.

Senator CASSIDY. Now, I would argue that if we are going to increase our security through that subtle power you speak of in your testimony, of undermining the Russians' ability to come after us or to go after Europe by choking off their natural gas and if we are going to help China reduce their global greenhouse gas emissions by substituting natural gas for coal and thereby improve our West Coast environment as well, we actually need to do more exportation, more exploration of natural gas. Would anybody dispute that?

[Panel shakes heads no.]

I think that is, kind of, almost so self-evident.

Mr. MILLS. Sure it is.

Senator CASSIDY. So whatever we do with renewables which is laudable, the reality is we are going to have more of an impact upon global greenhouse gas emissions and our international domestic security by increased development of our natural gas as well as facilitation of that export. That is energy security.

I yield back. Thank you.

The CHAIRMAN. Thank you, Senator.

Senator Manchin.

Senator MANCHIN. Thank you, Madam Chairman.

Thank all of you.

I am so sorry. Sometimes our meetings run over and we are in different areas at different times, but I am glad to be here.

We are introducing what we call the Appalachian Storage Hub. With all the newfound gas we have, with the wet gas we have especially in the Marcellus/Utica shale, now the Rogersville coming on and then West Virginia, Pennsylvania, Ohio and maybe even Ken-

tucky too, hooking these up with a storage hub that basically would move some of our critical energy products that we have, which are now mostly located in the Southwest and giving us more opportunity and I think, more national security also because we are not in the path of a hurricane and we are pretty much protected by the mountains. So we think it would be a great opportunity. I don't know if you all know anything about that or have looked into that and what your opinion might be on moving that forward.

Yes, Mr. Mills?

Mr. MILLS. Senator, you put your finger on something that's critical for the grid and also for general domestic energy security of the Northeast, which is starved for storage capacity, as you well know. Adding a gas storage capacity, both wet and dry gas, is probably the single most important and simple thing that can be done to increase domestic reliability on the grid which is becoming increasingly gas centric.

If you look at the total amount of generation growth forecast for the next decade in the United States and in the Northeast, gas turbines are the go to. And you don't want to be dependent just on pipes, you need to have storage, 100 percent.

Senator MANCHIN. Well, if we can get you all—can we get any written statements in support of that because we are working with the Department of Energy. I think they feel the same thing, but coming from the expertise that you all have would be tremendously helpful, sir, tremendously helpful.

Mr. MILLS. Be happy to do that, Senator.

Senator MANCHIN. Next, speaking on reliability, in West Virginia we have been blessed with everything, but we are an all-in energy state. Everybody thinks it is all about just coal and just fossil, but really, we are trying everything that we can, but the baseload. There is a study being done by Department of Energy on the reliability of the grid.

And I am so sorry, I am sure you might have talked about this previously with other Senators, but I am very much concerned about that because I remember the Polar Vortex. I know we almost went down, especially the PGM system was very razor thin of collapsing. With more dependable, reliable, affordable coal plants coming offline, have you all looked at the critical factor that we have there and the jeopardy that we are putting into the grid system?

Mr. MILLS. Well, let me make an observation that was in the news with respect to South Australia which echoes the direction that a lot of people hope the grid will go.

As you know they have had several blackouts, one very recent. And the news and the Wall Street Journal said it was because we were exporting, they were exporting natural gas. That's not the reason the blackout occurred; it's because that part of Australia has 40 percent of its electricity currently coming from wind turbines. When you have wind subside, you have to have other capacity. If you can't import it and the import capacity is limited because the magnitude of the drop, you do rolling blackouts.

The answer that Elon Musk has proposed is to build a battery plant which is good. Batteries work. I ran a battery factory for a while. I know a little bit about batteries. But I would like to point out that in order to store half a day of no wind in South Australia,

Elon Musk would have to build 150 of the battery plants he's planning to build and he's building one which he says will be three times bigger than the world's biggest utility battery plant. And South Australia, I'll note for the record, has about one-third of the population of the grid of the Washington, DC, area.

So, when you begin to think about these energy solutions, scale matters and that's where storing gas and building more gas turbines actually matters.

Senator MANCHIN. Well, uninterruptible power, I mean, and I have understood it for a long time and tried to and a lot of my colleagues on both sides of the aisle, but on my side of the aisle, sometimes are in disagreement, but they just don't understand where the electricity, where it comes from. And it has to be uninterruptible.

The only two things you have uninterruptible in the United States or in the world that I know of, is coal and nuclear. Everything else is interruptible. And the only third one that has surpassed or is equal to coal is natural gas, even though that is interruptible, but you are still in jeopardy.

All of the renewables, God bless them, we like it. We like wind, solar, we like it all. So when people tell me they want everything on renewables, I say just tell me what five hours of the day you want your power, and I am happy to oblige you. I am happy to take care of you because that is what you are going to get and nothing more than that.

But in some parts of the country, unless that system, that grid can back it up, they are in great peril and they don't really realize it.

So we are looking at how do we continue to have a dependable, reliable delivery system? We need people like yourself speaking out in common sense until—see, I believe in my heart that we are going to find, eventually, commercial hydrogen, which is water vapors. I keep believing that. And maybe it will happen in our children or grandchildren's lives.

There is going to be some magical, clean green that everybody's happy with. But until you get to that day, you have to be in the real world. And the real world is you better have so much reliable power and coal is going to play a major part, 30 percent or more, for the next 20, 30 years. Do you all agree with that?

Mr. MILLS. Senator, coal use globally, as you know, is going up——

Senator MANCHIN. Oh, it is not going down.

Mr. MILLS. Let me just echo your sentiment.

Everyone agrees it would be nice to have different forms of energy. We need them at scale in reliability. In the world I've worked in for decades, as a physicist and looking at the physics of energy, we used to call that the search for unobtanium.

[Laughter.]

Senator MANCHIN. Unobtanium. Makes sense.

Anybody else want to comment?

General CHENEY. If I——

Well, Senator, what this has done is given us breathing room to pursue alternative sources of power. And I know Bob would certainly agree, small modular reactors, for instance, are possible——

Senator MANCHIN. You are talking about nuclear, nuclear reactors, right?

General CHENEY. You can do that.

Senator MANCHIN. Yes.

General CHENEY. Long-term, and I know some people laugh at fusion energy, but when you go outside and look at the sun, it's there. It can be done if you've got the right amount of research in it. And I think this is the time now to start investing long-term in some of those other sciences while we've got that ability to have an overabundance of oil and fossil fuels.

Senator MANCHIN. Yes, Mr. Coward?

Mr. COWARD. What I would add, Senator, just is, you know, obviously I have not seen the DOE study, but I think this is a very important, critical subject for our entire economy and standard of living, the continued, you know, every time you flip the switch, it comes on.

What I would suggest is, as we all move forward together, my organization, myself, we support the classic all-of-the-above. We should be pursuing all energy options. But as we go forward in the spirit of contingency, reliability, confidence, we need to make sure we don't inadvertently allow ourselves to make overly optimistic assumptions.

And the one, the example I'll give you is in the last several years the energy storage industry has moved forward by leaps and bounds. A tremendous accomplishment, it's great for the country. Absolutely wonderful.

I'm also the principal officer, I lead MPR, a leading specialty engineering company in the power industry. We were critical with our customer AES in delivering and building the largest battery energy storage facility in the world in Southern California. It went online in February. Its capacity is measured in tens of megawatts, tens of megawatt hours, alright? Which means that you take a large nuclear or coal-powered power plant and the largest battery storage, energy storage facility in the world, it handles minutes of capacity of that facility. So even though energy storage has—or an hour maybe.

So even though energy storage has made great progress and I think it will continue to make great progress and it is a definite critical part of our infrastructure going forward, all of us have to make sure that the pace at which we assume technology development will occur is appropriate so we don't wake up one day and be disappointed.

Senator MANCHIN. Well, West Virginia is happy to continue to provide the power that keeps the East Coast lit up.

[Laughter.]

If they shut us down, they are all going down, okay?

[Laughter.]

And it made it very difficult for our little state to produce the power we produce, but we have done it cleaner and better and made more advancements in the last 20 years than had ever been done in the history of the world. We still get the living crap kicked out of us every day by Washington. Unbelievable.

Mr. COWARD. Senator, I live in Virginia and I——

Senator MANCHIN. I want to flip the switch every now and then and just say, hey, how did you like that?

[Laughter.]

Mr. COWARD. I live in Virginia and I know that Virginia is one of the largest energy importers in the country, and we thank West Virginia.

Senator MANCHIN. Well, we are happy to do it. We like to do the heavy lifting, and we will continue to do it.

Thank you, Madam Chairman, I am so sorry.

The CHAIRMAN. Thank you, Senator Manchin.

I just have to say, I love these conversations.

[Laughter.]

I truly do.

When I think about our energy potential, when I think about what it is that we have and how we are able to supply it.

Senator Manchin, I have had an opportunity to go to your little state and see your all-of-the-above. We recognize the great contributions that come out of Nevada when we are talking about minerals.

I talk about Alaska all the time, but you know, when we think about diversity of energy supply I think it is important to recognize that within this country we have a diversity of supply based on our enormous geography and recognizing where we each can be those experts, those suppliers, those real drivers to our local, state and national economies. I think that that is quite significant to recognize.

You know, as much as contributes from the Gulf of Mexico, they talk about being the energy bread basket. Okay, that is one energy bread basket, but I think this is important to recognize that we all have so much to contribute in so many different areas. And oftentimes, we are just limited by the technologies that allow us to do a little bit more.

Mr. Mills, you mentioned the digitalization of energy in your testimony. Dr. Birol also mentioned that in his written testimony. I should note for the record, he was actually here for a few moments. I really appreciate him making that effort to try to join us, but his schedule was very, very complicated this morning.

But you think about that, the technology that we know today is what we know today, but the advances that we have made in the past 20 years, as has been noted by many of you, has just been nothing short of remarkable, beyond imagination. Think where we are going to be 10 years from now, 20 years from now, and particularly within the space of the renewables. I think we have so much that we can build out given, again, advancements in technologies.

But I come back to our hardcore reality, and that is not meant to be a pun on words, but so much of this is going to depend on these resources, these mineral resources that will be required to build out these technologies of the future.

For years we have talked about our vulnerability as a nation on oil. We still have that vulnerability when it comes to the Department of Defense and this extraordinary reliance on that fossil fuel. But I don't want us to go the same direction with our minerals as we used to be with our oil. So this needs to be an eyes wide open.

I have advanced my critical minerals bill. It is actually part of our energy bill that I am hopeful we will have an opportunity to advance on the Senate Floor shortly.

But how do we do more?

This is a question for you, Mr. McGroarty, in terms of building the awareness that we have this increasing dependency. It is kind of tough to move forward sometimes unless people recognize that this is a problem for us, but that we do have solutions here. I think federal permitting reform is one of the things that we need to be looking at, but how do we build a growing awareness?

I don't want to limit this to just Mr. McGroarty because, General Cheney, when we think about the implications, again, from a national security perspective, making sure that those who are part of this supply chain, understand that we have got to address this aspect of it as well.

We are going to have to conclude the hearing here because we have a vote that is coming on, but I would like to have a little conversation about how we do more on the awareness of this as a dependency issue.

Mr. McGroarty?

Mr. MCGROARTY. Yup.

Senator, it is really interesting to think, first of all, I mean, what we're up against is we have, we live in this marvelous world where so much of the things that we rely on every day seem to be magic and they just, kind of, happen. You know, there's a cloud and stuff goes up to the cloud and things, you know, energy moves to where it's needed and so on and so forth.

I think we forget the physicality of things. Now the physicality of things is rooted in material science, and it's rooted in materials. So I think what this Committee does, what these kinds of programs do, but more of it is to remind people that we're now using a far larger portion of the Periodic Table than we ever used in the history of mankind and we have to be attentive to where these materials are coming from. We're very fortunate. We're very blessed that we have these resources here.

I would say too, in some respects, it seems to me a very simple thing that government can do is even just an indication that you can send a signal to a market that there's a desire to source some of these products domestically and that that will have an effect.

I mean, and I don't mean to, I'm not casting dispersions on things done or not done, but for instance, I'm very focused on the Gigafactory, figuring out where they're going to get their materials domestically for a variety of different reasons, jobs, national security, but also, you know, if you think about it today, we're getting the bulk of our cobalt comes from DRC Congo. We can't be comfortable about that because we're not comfortable about that it's getting refined and smelted in China, creating leverage there where if we need graphite we're 100 percent dependent on graphite. We need manganese; we're 100 percent dependent on manganese. We need lithium, a lot of that is coming from a triangle in South America which is prone to instability over time.

So, figuring out how we could substitute with American-sourced materials is important, but the simplest way to do that is for someone to say we want American-sourced materials. We see that as a

positive and communicating that clearly is a market signal that would cause capital markets to look around and say, well, who could that be? Where would that come from? You know?

I sit here and I see the states and I think about, you know, Senator Franken is gone, but I could mention nickel and cobalt and there's Minnesota, on the upper part of Minnesota.

The CHAIRMAN. We have graphite.

Mr. MCGROARTY. Pardon?

The CHAIRMAN. We have graphite.

Mr. MCGROARTY. You have graphite. I was about to mention that. Thank you.

[Laughter.]

The CHAIRMAN. Yes.

Mr. MCGROARTY. So we have all of these different options. Gosh, there's some lithium in Nevada that could be just making a very short trip to the Gigafactory.

We lived and experienced the bad and the good of where our oil comes from and how we needed more of it for decades and the better part, you know, and how that skews national security and military strategy. I just don't think we're caught up yet in terms of this transformation that's happening in the rest of the Periodic Table and how much of it we need. And the stuff isn't fairy dust, you know?

The CHAIRMAN. Anybody else want to weigh in there?

I appreciate that, Mr. McGroarty.

Mr. MILLS. Senator, if I could add the elephant in the room with respect to mining in the United States.

Early in my career I was, I worked for a Canadian mining company and spent time on the border of Alaska, the Northwest Territories.

Canada mines a lot of its minerals. It's easier to open a mine in Canada than it is in the United States. That shouldn't be the case. So the elephant in the room is EPA and how we regulate. It's typically not the states, but it can be.

Until we make an affirmative decision that we care about having mining here, I know if you talk to capital markets people would invest in mining. They'll tell you unequivocally, hold a hearing on it, and I think you will hear every one of them tell you the same thing. The capital risks are high because of the regulatory delays and uncertainty. As long as we keep that in play we'll continue to source rare earths and everything else from other nations.

We provided 70 percent of the world's rare earths 20 years ago. As my colleague has just said, we now do zero. It's not because we ran out of rare earths. It's not because we don't have the technology to do it. We have some of the best miners on the planet and the best technology and the safest. But we've made an affirmative decision not to do it. I think that's a mistake.

The CHAIRMAN. Well, I agree, and it is a concern.

I think the statistic was that the United States ranks dead last or we are tied with Papua, New Guinea, in terms of the length of time it takes to permit a mine in this country. I think you are right. There has been a policy directive direction that has taken us on that path.

But I think it is something that we need to critically look at and evaluate because our situation is such that more and more we expect, without question, that these resources are going to be made available to us. And it seems that more and more these resources are coming from places that would not think twice about perhaps squeezing us a little bit. Recognizing that vulnerability is something that, I think, we must address and we must consider from a broader policy perspective.

Senator Cortez Masto, we have a vote going on, but thank you for staying throughout this very important hearing.

I know that many of my colleagues, not only some of those that were coming in and out, we have had a little bit of preoccupation with another subject matter this morning, so I apologize for that. But know that you all have cleared my head and given me focus in the energy space, and I greatly appreciate that.

Thank you for your participation this morning and for your ongoing leadership in these important areas.

We stand adjourned.

[Whereupon, at 12:22 p.m. the hearing was adjourned.]

APPENDIX MATERIAL SUBMITTED

U.S. Senate Committee on Energy and Natural Resources
July 18, 2017 Hearing: The U.S. and North American Energy and Resource Security
Questions for the Record Submitted to Mr. Jamie Webster

Questions from Chairman Lisa Murkowski

Question 1: One of the greatest challenges facing Alaska is that our economic backbone, the Trans-Alaska-Pipeline, is running three-quarters empty. It now carries just about 500,000 barrels per day—not due to a lack of resources, but instead an almost blanket lack of permission to access our federal areas.

a. What role do major energy infrastructure projects like TAPS play in the United States' energy security?
   - Energy infrastructure projects are critical for fully unlocking the energy resources within the United States. Infrastructure projects make it possible to move the resources from where they are brought to the service to where they can be processed and finally consumed by end users. Without adequate transport capacity, US production is necessarily lowered.

b. Can you discuss TAPS' importance to our energy security, and what it would mean, if we can refill it?
   - US crude and product imports continue to decline amid weak demand and strong growth from shale regions and the Gulf of Mexico. Additional supply from a geographically distinct region, with a wide range of crude qualities, further increases energy security, reducing imports and increasing exports. The changing trade balance is beneficial for US consumers and producers.

c. What happens if a nation simply stops building the infrastructure needed to move energy from where it is produced, to where it is consumed?
   - A lack of infrastructure decreases production, increasing prices for consumers. The reduced ability to transport hydrocarbons from one place to another can also potentially create short term shortages. International imports would likely rise, with the net effect being a reduction in US energy security.

Question 2: In your testimony, you wrote that "Far from imperiling U.S. energy security, these rising exports are actually increasing energy security for both the U.S. and the world. The ready export outlet will allow producers to keep natural gas flowing into homes and power plants, and at less cost."

a. Can you expand on this point, and discuss how our exports are providing a backstop for U.S. production that simultaneously benefits American families and businesses?
   a. US shale crude is very light and sweet, while the US refining system has spent billions over the past 15 years building up the capacity to process imported heavy sour crude oil. The advent of shale has shifted this investment profile but there is still much that cannot be economically absorbed in the US system without substantial oil discounts. Allowing crude exports permits US crude prices to be in alignment with global prices, maximizing US crude production and with it, the economic benefits of the associated employment. Pushing additional crude out

U.S. Senate Committee on Energy and Natural Resources
July 18, 2017 Hearing: The U.S. and North American Energy and Resource Security
Questions for the Record Submitted to Mr. Jamie Webster

into the global market helps to keep the price lower, and increases global energy security.

Question 3: Your testimony touches on the emergence of a global market for natural gas, as compared to what used to be local or regional markets for it. What should we expect as this global market continues to develop? Can we expect greater efficiency? What are some of the other potential benefits we could derive from it?

Growing LNG exports provide consumer countries with another choice of energy supplier, allowing them to negotiate for better pricing, and increasing global energy security. US LNG, with its pricing usually tied to the Henry Hub in Louisiana is also reshaping how natural gas is priced, increasing liquidity and pushing what was once a local or regional market, into a globalized market for an increasingly vital fuel for economic development.

Question from Senator Steve Daines

Question: Since coming to Congress I have been a strong supporter of opening up American Energy to our allies around the globe. I believe that this not only makes the U.S. more secure but it also promotes security for our allies in the East and West. I have seen major steps in the right direction with the lifting of the crude oil export ban and the building of new LNG export terminals but I have been disheartened by the blocking of coal export terminals on the west coast.

What policies can the U.S. enact to expand and strengthen energy exports, including coal, LNG, oil and even technology?

If the policy goal is to increase energy exports, several steps can be taken. Production could be boosted through ease of permitting and other regulations, and ready access to domestic and export markets (requiring adequate infrastructure). To increase the quantity of available exports, demand policies can be put in place to reduce domestic demand, either by allowing the increase of other, less expensive fuels, or regulations to push end users to use the fuel more efficiently. Increasing domestic supply, decreasing domestic demand and ensuring adequate takeaway capacity gives US commodities the best chance to compete more on the global market.

Questions from Senator Joe Manchin III

Question 1: I am working with a bipartisan group of elected officials on the concept of developing an Appalachian Storage Hub for natural gas liquids. When you consider the quad-state area of West Virginia, Ohio, Pennsylvania, and Kentucky, it is hard to avoid noticing the abundance of natural gas and natural gas liquids, expanding energy infrastructure and the

U.S. Senate Committee on Energy and Natural Resources
July 18, 2017 Hearing: The U.S. and North American Energy and Resource Security
Questions for the Record Submitted to Mr. Jamie Webster

naturally occurring geologic storage primed for receiving these products. These factors would make our region even more attractive to additional manufacturing investment. According to the Mid-Atlantic Technology Research & Innovation Center, about 20% of the value in the Marcellus Shale alone is ethane, propane and butane. So, the Hub would attract companies that need reliable affordable access to these products. But it would also provide the United States with access to supplies of these high value products in the event of an extreme weather event or other scenario that negatively affects the supply chain in the Gulf. With safety and the environment top of mind, I'd like to see a regional storage hub move forward and that's why I introduced a bill making this type of project eligible for the Title XVII Innovative Technologies loan program at DOE.

Please provide your understanding of the energy security benefits that development of a regional storage hub in Appalachia would provide.

I believe that the great news in expanded oil and natural gas production has overshadowed two other good news stories in US energy. Those stories are the increase in NGL production and the increase in the storage capacity for all types of hydrocarbons. While I have not looked at this potential project, it seems a regional storage hub in Appalachia could prove useful in that it connects supply and demand regions. Additional storage of hydrocarbons is useful for market liquidity, as well as reducing risks from supply or demand discontinuities.

U.S. Senate Committee on Energy and Natural Resources
July 18, 2017 Hearing: The U.S. and North American Energy and Resource Security
Questions for the Record Submitted to Mr. Mark Mills

Questions from Chairman Lisa Murkowski

Question 1: The *Wall Street Journal* recently ran a story with a headline that read, "How Energy-Rich Australia Exported Its Way Into an Energy Crisis." As the United States becomes an energy superpower, some may seek to use Australia as a cautionary tale for us. What did you think of that story? Was it complete, or were there a few key details missing, which have added to Australia's challenges?

> **Answer**: The headline was a mis-direction and misleading. The collapse of the South Australia (SA) electric grid occurred because the SA authority did not build enough gas-fired power plants and enough gas pipelines to that region and not because of natural gas exports. SA had opted in recent years to build an electric gird supplying 40% of that region's power with wind turbines. When the wind stopped inconveniently during the SA summer, there wasn't enough generation to make up the difference; hence black outs. Australia has enormous supplies of natural gas: while foreign entities are choosing to purchase that abundant gas (ie., Australian exports) apparently domestic SA entities are not. The SA blackouts are not a matter of too many gas exports to foreigners, but of too little domestic common sense to use abundant gas resources.

Question 2: You mention the digitalization of energy in your testimony, and the impacts that is projected to have going forward. Can you speak to the implications of the "Internet of Things" in the world of energy, and what that could mean for everything from production costs to production levels and, ultimately, consumer benefits?

> **Answer**: By "digitalization of energy" I meant precisely the advent of the Internet of Things (IoT) which is the use of ubiquitous sensors and networks to collect and analyze information associated with "things" rather than people: ie, industrial (or other) processes rather than people-to-people communications. The IoT combined with powerful analytics – now available at low cost via powerful Cloud computing platforms – is widely recognized as providing enormous gains in physical and economic efficiency in every industrial and business domain. This will happen in oil & gas now, and will bring not only greater profits for industries competing with foreign cartels (that manipulate prices), but also more competitive U.S. businesses (and thus jobs for Americas), and lower costs for energy for consumers.

Question 3: One of the greatest challenges facing Alaska is that our economic backbone, the Trans-Alaska-Pipeline is running three-quarters empty. It now carries just about 500,000 barrels per day—not due to a lack of resources, but instead an almost blanket lack of permission to access our federal areas.

a. What role do major energy infrastructure projects like TAPS play in the United States' energy security?

U.S. Senate Committee on Energy and Natural Resources
July 18, 2017 Hearing: The U.S. and North American Energy and Resource Security
Questions for the Record Submitted to Mr. Mark Mills

Answer: Energy infrastructure is the vital connectivity that makes delivering America's abundant and often remote resources – just as wireless networks are the vital connectivity that unlocks the power of remote cloud computing. While virtually every nation on earth not only celebrates but facilitates access to critical resources, the U.S. is unique in erecting barriers or bans to those resources, a posture that is both economically and strategically self-defeating.

b. Can you discuss TAPS' importance to our energy security, and what it would mean, if we can refill it?

Answer: TAPS is an established, under-utilized and essentially amortized vital asset that can unlock low-cost resources in Alaska. Every opportunity to facilitate greater access and use of oil & gas resources redounds to the benefit of America's strategic and economic strength.

c. What happens if a nation simply stops building the infrastructure needed to move energy from where it is produced, to where it is consumed?

Answer: All energy (and resource) assets are impossible to use without building, maintaining and expanding the associated infrastructure. Without that infrastructure at all, society literally dies.

Question 4: With scheduled closures of nuclear and coal generating stations and an increase in intermittent renewable power sources in the Northeast, many states and utilities are filling in the needed baseload generation with imports of Canadian hydropower. We have held hearings in this committee on the challenges of building new infrastructure, be it small hydro projects, pipelines, or transmission lines, in the Northeast. If these permitting challenges could be resolved, do you think the United States could source more of the electricity for this region domestically?

Answer: The U.S. has an abundance of domestic capability to meet the Northeast power needs, not least these days is to increase the transport of natural gas to the Northeast, which can be used both for heating (to eliminate the only region of America with significant amount of oil-fired home heating) and for power generation.

Question from Senator Joe Manchin III

Question: I am working with a bipartisan group of elected officials on the concept of developing an Appalachian Storage Hub for natural gas liquids. When you consider the quad-state area of West Virginia, Ohio, Pennsylvania, and Kentucky, it is hard to avoid noticing the abundance of natural gas and natural gas liquids, expanding energy infrastructure and the naturally occurring geologic storage primed for receiving these products. These factors would make our region even more attractive to additional manufacturing investment. According to the

U.S. Senate Committee on Energy and Natural Resources
July 18, 2017 Hearing: The U.S. and North American Energy and Resource Security
Questions for the Record Submitted to Mr. Mark Mills

Mid-Atlantic Technology Research & Innovation Center, about 20% of the value in the Marcellus Shale alone is ethane, propane and butane. So, the Hub would attract companies that need reliable affordable access to these products. But it would also provide the United States with access to supplies of these high value products in the event of an extreme weather event or other scenario that negatively affects the supply chain in the Gulf. With safety and the environment top of mind, I'd like to see a regional storage hub move forward and that's why I introduced a bill making this type of project eligible for the Title XVII Innovative Technologies loan program at DOE.

Please provide your understanding of the energy security benefits that development of a regional storage hub in Appalachia would provide.

Answer: The unexpected and expanding abundance of domestic capability to produce natural gas and natural gas liquids from the Northeast region offers important unrealized economic security and national security opportunities. In particular, since natural gas liquids (NGL) are so difficult to transport (compared to dry natural gas and oil), there are substantial advantages to expanding local storage infrastructure in order to attract those industries which use (low-cost) NGL for manufacturing a range of chemical products used in the multi-trillion dollar global plastics markets. NGL, and natural gas storage, in the Appalachian region would bring both domestic grid security benefits (the northeast region is short gas storage which puts reliability of future electric supply at risk) and broader global security benefits by shifting to the United States the opportunity to become a larger supplier of key commodities into world markets.

U.S. Senate Committee on Energy and Natural Resources
July 18, 2017 Hearing: The U.S. and North American Energy and Resource Security
Questions for the Record Submitted to Brigadier General Stephen Cheney

Question from Chairman Lisa Murkowski

Question: In your written testimony, you included these lines: "What does the boom in renewables mean for us? Any form of renewable power presents few concerns about energy security because they do not use a fuel that has to be imported." While I agree with your point on fuel imports, I want to make sure that we are thinking about mineral security, in the context of renewable energy.

a. Renewables do not rely on imported fuel—but these technologies can rely on imported minerals and metals. Do you believe it is possible to manufacture renewable systems, electric vehicles, and other technologies here, if we are not producing the raw materials that go into them?

There is no doubt that the dependency on imported rare earth minerals for production of renewable energy generators is a vulnerability. This is particularly evident with the importation of lithium and Rare Earth Minerals.

In 2011, the American Security Project released a report "Rare Earth Metals and U.S. National Security," which outlined the national security risks of US reliance on China as the sole supplier of rare earth metals—metals essential to the United States' military and economic needs. (available online at: https://www.americansecurityproject.org/new-report-highlights-us-national-security-challenges-given-us-dependence-on-rare-earth-metals-in-china/*)*

Since then, market conditions have changed, and I am hopeful that we are moving away from sole-source dependence on mined Chinese rare earth minerals. On lithium mining, I am also hopeful that domestic production, like we see ramping up in Nevada, can balance imports.

I would also caution about complaining about replacing dependence on oil with dependence on imported minerals. This is not the same as energy security. Unlike dependence on a commodity like oil, importing minerals – for example – constitutes a one-time-only fixed cost. Once the cost is borne, there is very little variable cost for generating renewable energy. I maintain that an economy that relies on renewable power for its energy needs would be fundamentally more secure.

Questions from Ranking Member Maria Cantwell

Question 1: Do you agree that the Russians and other state-sponsored cyber-attacks pose a significant threat to our energy networks and, as a result, our national security?

In my opinion, Russia's cyber-attacks pose a significant threat to our national grid and hence to our national security. Our grid system is vulnerable to attacks similar to the

U.S. Senate Committee on Energy and Natural Resources
July 18, 2017 Hearing: The U.S. and North American Energy and Resource Security
Questions for the Record Submitted to Brigadier General Stephen Cheney

one in Ukraine that severed power there for up to 6 hours impacting hundreds of thousands citizens.

Question 2: What do you think we should do to defend ourselves against these increasingly prevalent attacks?

Our grid system is predominantly privately held. Some would say this dispersion shields them from attack, but my take is just the opposite – differing defenses, lack of protection, and outdated infrastructure make us more vulnerable. This is a case where federal investment and protection is necessary immediately. A coordinated federal level effort is required, and there are several federal agencies which could handle this task given the adequate resources.

Question 3: How does energy diversification make our country more secure and improve our national security?

Diversification in terms of the sources of our energy increases our security. Reliance on any single source makes us more vulnerable to attack and fluctuations in market price – i.e. if Europe depends solely on natural gas for energy, then the suppliers control their future.

Question 4: What do you view as the role for the federal government in energy R&D?

Private investment cannot totally support research and development for future energy production. Whether it be support for R&D in fusion, or small modular reactors, fuel cells, or many other technologies, our federal government should work hand in hand with industry, our national labs, and universities to foster innovation for cleaner, more dependable energy sources.

Question 5: In your opinion, how does investing in energy R&D strengthen our nation?

Diversifying our energy sources while simultaneously reducing CO2 production will make us less vulnerable to attack, reduce climate change, and enhance our economy. ASP has long maintained that increased scientific R&D is critical to our national security leadership. As long ago as 2011, our Board Member Norm Augustine wrote about "The Research and Development Gap" for us. His article is available online: https://www.americansecurityproject.org/the-hill-norman-augustine-on-the-research-and-development-gap/

The federal government should invest in R&D through a series of public-private partnerships that can share risk and promote development. A good example of this can be seen in your home state of Washington, where Helion Energy, a start-up attempting to prove fusion energy as a viable energy alternative, has received funding from ARPA-E to accelerate their research. The University of Washington, too, has become a hub for research into fusion energy. ASP would be happy to facilitate a meeting for you with these organizations.

U.S. Senate Committee on Energy and Natural Resources
July 18, 2017 Hearing: The U.S. and North American Energy and Resource Security
Questions for the Record Submitted to Brigadier General Stephen Cheney

Question 6: Could you please explain why climate security is such an important national security concern and how it overlaps with energy security?

We know that climate change in an accelerant to instability worldwide and well as a threat to our bases and stations here at home. We see how it already is threatening our Homeland Security through extreme weather events. It is clear that CO2 is the primary cause of climate change, so any reduction in CO2 helps to stop that. Many actions that policymakers choose to take to reduce greenhouse gas emissions would have a double benefit of increasing energy security while reducing climate security risk. Ending any reliance of the burning of fossil fuels aids in this effort and makes us more secure. Specific policy options that would both increase energy security and reduce climate security risk include: increased renewable electricity penetration into the transportation sector, increased investment into next generation energy resources like fusion, increased penetration of natural gas as a "bridge fuel" to reduce coal burning, and investment into alternative sources of synthetic liquid fuels that could replace oil-based fuels.

Question 7: How does trade affect North American energy security?

Trade is an important factor in energy security. The abundance in oil and gas that we are now enjoying gives us an opportunity to go to cleaner sources of energy while pursuing advances in alternative energies. We no longer have reliance on Middle East oil, for example, and can even export oil. This gives us leverage over trading partners and leaves us less vulnerable to market swings. Energy security is only possible is a "shared security" environment. No nation's energy can really be secure if its neighbors or allies are insecure. The recent developments in energy markets that have boosted America's energy security can boost the security of our allies and neighbors.

NAFTA has been critically important in integrating the North American energy market. To our north, the Canadian and American energy market has been thoroughly integrated for years, both in oil and the electric grid. Only recently, however, has that changed to our south. Mexico's recent efforts to liberalize its energy investment laws will allow deeper cross-border integration between the U.S. and our southern neighbor. We must be careful in the proposed renegotiation of NAFTA that we do not allow the growing integration between Mexico and the United States to be harmed by unrelated tensions.

Question from Senator Joe Manchin III

Question: I am working with a bipartisan group of elected officials on the concept of developing an Appalachian Storage Hub for natural gas liquids. When you consider the quad-state area of West Virginia, Ohio, Pennsylvania, and Kentucky, it is hard to avoid noticing the abundance of natural gas and natural gas liquids, expanding energy infrastructure and the naturally occurring geologic storage primed for receiving these products. These factors would make our region even more attractive to additional manufacturing investment. According to the Mid-Atlantic Technology Research & Innovation Center, about 20% of the value in the Marcellus Shale alone

is ethane, propane and butane. So, the Hub would attract companies that need reliable affordable access to these products. But it would also provide the United States with access to supplies of these high value products in the event of an extreme weather event or other scenario that negatively affects the supply chain in the Gulf. With safety and the environment top of mind, I'd like to see a regional storage hub move forward and that's why I introduced a bill making this type of project eligible for the Title XVII Innovative Technologies loan program at DOE.

Please provide your understanding of the energy security benefits that development of a regional storage hub in Appalachia would provide.

Any time we have the ability to "store" energy for future use, particularly cleaner energies, we become more secure. The storage facility you mention would not be susceptible to adverse weather, imported sources, or cyber attack. The advantages are obvious and well worth investing in.

Questions from Senator Catherine Cortez Masto

Question 1: You mentioned that there needs to be a coherent strategy to use more renewable power in transportation. Companies like Tesla in my state are investing in energy storage and electric vehicle charging infrastructure. How can these investments work to reduce oil in transportation?

In the transportation sector there is overwhelming dependency on fossil fuels. But, as technology advances, we are seeing huge gains made in renewable energy sources that are rapidly overtaking fossil fuel powered vehicles. Our national labs and other research organizations continue to work on innovative technologies that will revolutionize the transportation industry, and they need to be encouraged and supported. We have only seen the tip of the iceberg when it comes to this sector. The advantages are many – from reduction in CO2 emissions, to much more economical sources of power.

Question 2: Electric vehicles are projected to become cheaper to own than cars with internal combustion engines. What are the factors that will lead to such a decrease in costs for EVs?

Two of the major limiting factors for electric vehicles are power storage and recharging. Advances in battery R&D here will be dramatic and eventually cause the demise of fossil fuel burning vehicles. We should note that Tesla's example shows that buying a car for individuals is never a purely "cost-benefit" analysis. Consumers will buy cars that meet their desires; otherwise cars like the Corvette would never have been built! While automakers should find ways to reduce battery costs, they should also work to make battery-operated cars more desirable to consumers.

Question 3: Nevada is leading the charge in innovation and utilizing renewable technologies. In fact, the city government of Las Vegas, encouraged by federal funding, is getting 100 percent of its energy for its buildings from renewable sources. What other federal government policies do you think will further encourage cities and businesses to adopt renewables?

U.S. Senate Committee on Energy and Natural Resources
July 18, 2017 Hearing: The U.S. and North American Energy and Resource Security
Questions for the Record Submitted to Brigadier General Stephen Cheney

The federal government is responsible for subsidies and tax breaks to the energy industry. We should ensure that these types of incentives are predictable and strong enough for widespread adoption. After all, the government gave these incentives to oil, gas, coal, and nuclear industries for years. Overall, though, state and local-based incentives may be best placed to find the most effective ways to increase incentives. I think the most important role for the federal government is long-term research and development that can bring the costs of renewable and zero-carbon energy down below the costs of dirtier sources.

Question 4: How can the government help educate the public about emerging energy technologies so they can more effectively incorporate them in their lives?

Many citizens are unaware of the considerable contribution renewables are making to their power supplies. However, I'm not sure it's the government's responsibility to educate the public: private businesses like Tesla, Apple, Google, or even utilities are increasingly finding that it is a competitive advantage to highlight their reliance on clean energy. We should encourage this.

Question 5: You mentioned that you are concerned that the U.S. is pulling back from R&D programs like ARPA-E that provide smart federal investments in high risk, high reward technologies. How do you believe DOE's proposed budget cuts will affect our country's ability to compete in the global market?

I am concerned this Administration is headed down the wrong path in regards to funding our Department of Energy. Budget cuts would curtail much of our R&D efforts, while giving other countries (China; Russia) an opportunity to take over the leadership here and corner the markets. Both the House and Senate Appropriations Committee have produced Energy and Water Appropriations bills that undo some of these cuts, but maintain others. I would particularly highlight the Senate bill for stopping the closure of ARPA-E, and the House bill for undoing the harmful cuts to our fusion energy research program. I would encourage that Congress include both provisions in the final bill.

Question 6: What can Congress learn from the Marines and the rest of the armed forces about their use of renewable energy to improve mission readiness, resiliency, and effectiveness in combat?

After his drive to Baghdad in 2003, General Mattis wrote in an after-action report that we must unleash the military from "the tether of fuel." Congress responded by creating the Assistant Secretary for Operational Energy position in the DoD; which helped to instill a much-needed focus on energy throughout the military. Over the last decade, for example, the Marine Corps has worked to create an "Energy Ethos" – a shared vision that the efficient use of energy is a critical component of mission readiness. Marines must be aware of and value limited energy and water resources. They don't do this because they've suddenly become tree huggers, they do this to enhance mission readiness and resiliency on installations and operational effectiveness in combat. The most important lesson the military can offer Congress is a focus on RISK. Thinking about threats and opportunities over the long-term can effectively reduce risk.

U.S. Senate Committee on Energy and Natural Resources
July 18, 2017 Hearing: The U.S. and North American Energy and Resource Security
Questions for the Record Submitted to Mr. Robert Coward

Question from Chairman Lisa Murkowski

Question: In the 20th century, the U.S. led the world in nuclear power and set the bar with the highest standards for safety, security, and non-proliferation. That meant we had the people and the know-how to drive international discussions around safeguards and non-proliferation, while transferring knowledge and technical skills to our allies through the "Atoms for Peace" program. The world is now accelerating toward a larger nuclear future – with some anticipating an additional 550 gigawatts of capacity in the next 30 years.

a. As we look forward, what are the practical implications if we cede this massive global market – and world leadership on nuclear energy – to Russia, China, and other nations?

Answer:

From a practical perspective, the implications are large to our national security, the US industrial base and our nuclear industry supply chain, and global trade.

Exports of nuclear technology provide the U.S. with important nonproliferation advantages, including consent rights on U.S.-manufactured nuclear fuel, the ability to control the re-transfer of nuclear technology, and greater general influence over the nuclear policies of U.S. partner nations. The United States possesses a strong nuclear technology portfolio and supply chain, but our competitive position is not fixed. The federal government should be an active partner in helping U.S. industry maintain and increase its market share of nuclear goods and services, as U.S. nuclear exports have the attendant benefits of improving global standards of nuclear safety and security and minimizing the risk of proliferation.

Losing our status as supplier of first choice in the global market will also impact U.S. bilateral trade relationships. Nuclear export trade agreements, also known as 123 Agreements, cement a bilateral relationship that can extend decades or even a full century into the future. This partnership is vital for influencing safety and security norms, as well as maintaining the highest nonproliferation standards. It is through our 123 Agreements that we maintain our global influence on nuclear safety and security. Letting these partnerships lapse by ceding our place in the international market allows other actors to impose their less-than-stringent policies, which could lead to greater proliferation threats and a weakened security standard across the globe.

The U.S. economy would certainly be affected by a withdrawal from the global nuclear market. As other countries continue to develop their domestic nuclear energy programs, they look to other supplier nations such as China, Russia, India and Korea to construct their newest reactors. While the U.S. is still considered the premier nuclear technology supplier, the less the U.S. nuclear industry is supported, the less it will be able to compete in this rapidly expanding global market.

U.S. Senate Committee on Energy and Natural Resources
July 18, 2017 Hearing: The U.S. and North American Energy and Resource Security
Questions for the Record Submitted to Mr. Robert Coward

Ceding international leadership could also have negative consequences here at home, including greater reliance on foreign suppliers to sustain our domestic nuclear program and the loss of thousands of high paying jobs and the economic benefits they drive in the local communities near our operating reactors.

Question from Senator Catherine Cortez Masto

Question: You mentioned that we should prioritize the development of small modular and advanced nonlight water reactor systems. Can you describe the advantages in developing these newer technologies?

Answer: Small modular and advanced nonlight water reactor systems have several distinct advantages over existing (and older) light water reactor (LWR) technologies.

Small modular reactors (SMRs) are able to be "right-sized" for the area and electricity demand they serve, allowing add-on capacity after the initial module begins operating. This scalable electricity generation can be a distinctive advantage in a low demand growth environment. SMRs are also advantageous for providing electricity to remote areas and their smaller size makes them more suitable as direct replacement for the many 300MW-class coal plants in operation in the U.S. today. SMRs are also designed from the start to "load-follow" – varying their output to adjust to changing demand as intermittent sources come on and off line.

Advanced nonlight water reactor systems, or advanced reactors, have further benefits when compared to LWRs. While providing the same reliability and clean energy benefits as SMRs and LWRs, advanced reactors take advantage of alternate fuel, core, and coolant designs to allow for longer periods between refueling, higher rates of fuel consumption, greater simplicity of design and operation, faster time from decision to operation, and reductions in the volume of waste generated. We expect to see these advanced designs in commercial operation in the 2030 timeframe, and are likely to play a role in any successful global effort to achieve deep decarbonization.

Finally, it is worth noting that significant electrification of our transportation grid is increasingly likely to occur in the coming decades, as cities grapple with air pollution and fuel supply issues. Both SMRs and advanced reactors have the unique potential to provide reliable, non-emitting 24/7 electricity needed to support transportation driven load growth that does not follow traditional daily energy demand patterns.

U.S. Senate Committee on Energy and Natural Resources
July 18, 2017 Hearing: The U.S. and North American Energy and Resource Security
Questions for the Record Submitted to Mr. Dan McGroarty

Questions from Chairman Lisa Murkowski

Question 1: You wrote about the "co-product challenge" in your written testimony, noting that many critical minerals and metals are not mined on their own, but instead coproduced with other "gateway" metals. Can you speak to the difficulties this presents, and the implications it has for our mineral policies?

The co-product issue stems from the realities of modern mining – and the materials science revolution that is discovering new uses for formerly "minor metals" and minerals than ever before. As mentioned in my testimony, five mainstay industrial metals and minerals – copper, zinc, aluminum, tin and nickel – provide our primary access to 25 or more elements which are not mined in their own right.

Take copper, for example (the most versatile primary metal in terms of the number of potential co-products associated with it), which is our "gateway" to selenium, tellurium, rhenium, molybdenum, cobalt and, as we are learning, potentially the 17 rare earths. Historically, these metals and minerals have been called "minor metals" or "specialty metals;" today, due to technological advances in materials science, these metals and minerals are increasingly essential to alternative energy, high-tech, and advanced weapons platform applications. As the 21st Century progresses, ensuring adequate access to supplies of these "minor metals" will be a major factor in our economic strength and national security.

Our federal resource policy does not reflect this new reality. The U.S. government does not consider zinc to be a critical material – even though zinc is a primary gateway to indium, for which we are 100% import-dependent, and which is critical to all touch-screen functions.

We do not consider aluminum to be critical, though it is the principle gateway to gallium, for which we are 99% import-dependent, and require for the solar PV cells many look to as the new future of alternative energy.

There is debate on whether copper is a critical material, even as there is a 600,000 MT "copper gap" annually in terms of the delta between U.S. demand and U.S. supply – and the fact that copper is our gateway to the 5 metals and minerals listed above, and potentially 22 critical materials, including the full range of rare earths. In other words, copper is our gateway to more than 1/5th of the entire Periodic Table.

Federal policy must devise a way to recognize the criticality of major metals and minerals, factoring in their status as gateways to metals and minerals where our import-dependence is more than 75% and in too many cases 100%. Whether this involves some sort of scoring protocol for co-product supply or other means of assessing criticality, the time has come to recognize that the U.S. simply cannot ensure access to many critical metals and minerals

without according the same critical status to the major metals that serve as our gateway to these co-products.

As I see it, this is the principle challenge in forging sound resource policy – in an age where access to adequate supplies of what were previously "minor metals" is now imperative.

Question 2: In your testimony you make the link between raw minerals and finished technologies. You point out our mineral dependence on graphite, manganese, rare earths, indium, gallium, and rhenium, among others.

a. Can you speak more to the minerals that we use for defense and energy technologies, and more critically, where they are coming from, right now?

b. What would be the impact on national security if access to those minerals is cut off?

Should those minerals and metals be cut off – due to conflict, or as a result of "economic warfare" to pressure the U.S. to change its military, foreign or trade policies – the U.S. would experience severe economic and defense platform consequences, as U.S. manufacturers work through the typically limited stock of on-hand supplies.

To be sure, the effect will differ in intensity industry-to-industry and application-to-application, but in this era of lean inventories and "just in time" manufacture, U.S. companies have deemphasized and dis-incentivized storing large ready stocks of raw materials. In contrast to our Strategic Petroleum Reserve, where we have a ballpark sense of how many days of oil we hold in reserve, we have little data on metals and minerals usage across our economy that would predict how many days/weeks/months of indium or rhenium or cobalt we have on hand before supply evaporates.

Bringing new mines on line, given our cumbersome permitting process, would ensure a "no supply" gap of uncertain duration. We simply cannot "surge" production of graphite or manganese or other metals and minerals when we have zero production at present.

This "no supply gap" would be a serious vulnerability for adversary nations to exploit. The dystopian novel "*Ghost Fleet: A Novel of the Next War*," which imagines a Chinese attack on the U.S., includes scenes where American families bring X-boxes and other tech-toys to collection centers so that their critical metals can be "urban mined" for the U.S. war effort – as our foreign supplies, largely from China, have been cut off. The U.S. needs to ensure that fiction does not become fact.

There are other instances where U.S. manufacturers and even defense integrators are not primary consumers of these tech-metals and minerals, but receive them in sub-components

from companies in often-times friendly countries and allies – Japan, Germany and South Korea, for instance. Yet this simply shifts the raw materials access problem, as in most cases these countries are receiving the metals and minerals from China or other nations that may or may not sustain supply in time of crisis.

The jargon for this vulnerability in defense circles is SPOF – "single point of failure" – a single point in lengthy supply chains that disrupts the path to finished products. Our severe and multiple mineral dependencies put us "at risk" in profound ways.

Question 3: I was pleased to see you list permitting reform as one of the best steps that we could take to address our foreign mineral dependence. Can you speak to what you believe it will take to resolve this challenge, starting with permitting reform, and then any other steps you believe are advisable?

Clearly, the measures included in Subtitle D/Critical Minerals of the proposed Energy and Natural Resources Act of 2017 will be a strong step in the right direction, both in terms of a) creating a single methodology for determining a federal list of Critical Minerals, ranking criticality of those minerals and metals, and providing for periodic updates of that list, and b) establishing a permitting reform regime that will address the cumbersome and duplicative labyrinth of federal rules that have grown up around federal mine permitting, delaying the average process to the point that it among the world's lengthiest in comparison to the major mining nations, with no concomitant improvement in environmental and safety concerns.

Studies that show the U.S. permitting process routinely runs 7 to 10 years compare with fellow industrial democracies Canada and Australia that complete permitting reviews in a fraction of that time.

Especially in the context of Critical Minerals – where issues of national security turn on the timely availability of specific materials, for many of which the U.S. is presently 50, 75 and even 100% import-dependent, often from nations that are either unstable or that could in crisis circumstances withhold supply – the U.S. cannot continue to watch the permitting process become longer and less transparent. That is deeply irresponsible, and puts U.S. national Security needlessly at risk.

I also believe federal policy would benefit by amending the so-called FAST 41legislation to explicitly apply to critical minerals development, using the same list established under Subtitle D. This should be done, however, in a way that is consistent with Subtitle D permitting protocols – and not constitute yet another layer of federal regulation.

While the following points may fall beyond the purview of the Committee, I would also like to see existing legislation – passages in the long-established Defense Preparedness Act – "re-discovered" and used to advance all aspects of U.S. critical mineral production, from mining through refining/smelting, recycling and reclamation, and into advanced material production.

U.S. Senate Committee on Energy and Natural Resources
July 18, 2017 Hearing: The U.S. and North American Energy and Resource Security
Questions for the Record Submitted to Mr. Dan McGroarty

I am thinking specifically of 50 U.S. Code 98h-6, "Development of domestic sources" which in addition to authorizing purchases of strategic materials authorizes off-take contracts and other forward-based contractual commitments to encourage U.S. companies to enter production, see below, Section (2) (underlined passages added):

> ***(a) Purchase of materials of domestic origin; processing of materials in domestic facilities***
> ***Subject to subsection (c) of this section and to the extent the President determines such action is required for the national defense, the President shall encourage the development and appropriate conservation of domestic sources for materials determined pursuant to section 98b (a) of this title to be strategic and critical materials—***
>
> ***(1) by purchasing, or making a commitment to purchase, strategic and critical materials of domestic origin when such materials are needed for the stockpile; and***
>
> ***(2) by contracting with domestic facilities, or making a commitment to contract with domestic facilities, for the processing or refining of strategic and critical materials in the stockpile when processing or refining is necessary to convert such materials into a form more suitable for storage and subsequent disposition.***

The U.S. can no longer afford to leave this tool in the tool chest, and it should become a priority in terms of meaningful appropriations in the next budget cycle.

This authority can be used in a way that avoids "industrial policy," or "picking winners and losers," as a future commitment to purchase still requires a private company to raise capital in private markets to progress – a test that requires it to demonstrate market competitiveness. That the "winner" would have a willing purchaser in the form of the U.S. Government's National Defense Stockpile would still need to be leveraged into private-sector financing to make production possible. In this way, the U.S. Government could reasonably "encourage" multiple potential critical mineral suppliers, without anointing any one of them as a chosen provider.

Question 4: Our committee held a hearing in March on the United States' increasing dependence on foreign minerals. We discussed at length the threats posed by our foreign mineral dependence and ways to lessen that dependence. I've been calling attention to this issue for years and would like to make real progress on reversing our dependence.

a. I asked each of our witnesses in March, and I will ask you now, what can we do to call greater awareness to this issue? How can I make this issue relevant to more of my colleagues on Capitol Hill?

At the risk of adding to Committee workload, I would suggest calling for the establishment of an informal Resource Security Working Group, including subject-matter experts, and open to representatives of the HASC, SASC, and Homeland Security Committees, who live with the results of critical mineral shortfalls and potential embargoes – but can often be cut off from

the Energy & Natural Resources Committee deliberations that could well alleviate these strategic vulnerabilities.

Those of us who care about this critical issue must break down the silos that exist between the interested parties essential to crafting a sound and sustainable federal solution.

Questions from Senator Debbie Stabenow

Question: Thank you for raising the issue of resource security. I would like to hear your thoughts on the need for strong transportation infrastructure to successfully bring domestic metals and minerals to market.

According to the U.S. Army Corps, as much as 90% of the iron ore produced in the United States is shipped through the Soo Locks in Sault Ste. Marie, Michigan. According to a report from the Department of Homeland Security, an unplanned shutdown of this lock and dam would likely halt all North American production of mining equipment, automobiles, and appliances; leave 11 million people unemployed; and throw the North American economy into a severe recession.

How important is it to have well-functioning locks and dams, roads, bridges, and rails to achieve resource security?

Have you considered the implications of failures in transportation infrastructure on North American energy and resource security?

I have not in my research considered the specific risk associated with locks and dams, bridge and rail lines. I can, however, extrapolate from the U.S.'s deep and diverse dependency on key tech-metals and minerals – and the risk of "single point of failure" that these dependencies present – the same risk associated with a single path of transport and supply that carries commercial traffic critical to large swathes of the U.S. economy. While I cannot offer potential solutions for this vulnerability, I will note that the Soo Locks in this instance bear a resemblance to the Strait of Hormuz or Malacca or the Panama Canal in terms of resource security.

Question from Senator Steve Daines

Question: What many do not understand is that energy security is also mineral security. This committee and myself have spent considerable effort in expounding on the dangers of being too dependent on mineral imports and the dire consequences that can have. Critical minerals

play an important role in energy, including in turbines, batteries, power plants, and much more. Sadly, as you stated, the U.S. is 100% reliant on 20 minerals and metals, and 50% on 50 more. It is imperative the U.S. begin to expand our own mineral production and begin to distance ourselves from complete dependency. Not only is this an important step for energy security, but it is important because the U.S. has safer and cleaner mining practices. If one looks at the map of countries supplying much of the U.S.'s critical minerals, they are not known to be environmentally friendly and not known to have strong worker protections.

What legislation can we enact to begin to curb this dependency and promote greater mineral and energy security?

[I offer to Senator Daines the answer provided to Senator Murkowski above, on this issue.]

Clearly, the measures included in Subtitle D/Critical Minerals of the proposed Energy and Natural Resources Act of 2017 will be a strong step in the right direction, both in terms of a) creating a single methodology for determining a federal list of Critical Minerals, ranking criticality of those minerals and metals, and providing for periodic updates of that list, and b) establishing a permitting reform regime that will address the cumbersome and duplicative labyrinth of federal rules that have grown up around federal mine permitting, delaying the average process to the point that it among the world's lengthiest in comparison to the major mining nations, with no concomitant improvement in environmental and safety concerns.

Studies that show the U.S. permitting process routinely runs 7 to 10 years compare with fellow industrial democracies Canada and Australia that complete permitting reviews in a fraction of that time.

Especially in the context of Critical Minerals – where issues of national security turn on the timely availability of specific materials, for many of which the U.S. is presently 50, 75 and even 100% import-dependent, often from nations that are either unstable or that could in crisis circumstances withhold supply – the U.S. cannot continue to watch the permitting process become longer and less transparent. That is deeply irresponsible, and puts U.S. national Security needlessly at risk.

I also believe federal policy would benefit by amending the so-called FAST 41legislation to explicitly apply to critical minerals development, using the same list established under Subtitle D. This should be done, however, in a way that is consistent with Subtitle D permitting protocols – and not constitute yet another layer of federal regulation.

While the following points may fall beyond the purview of the Committee, I would also like to see existing legislation – passages in the long-established Defense Preparedness Act – "re-discovered" and used to advance all aspects of U.S. critical mineral production, from mining through refining/smelting, recycling and reclamation, and into advanced material production.

U.S. Senate Committee on Energy and Natural Resources
July 18, 2017 Hearing: The U.S. and North American Energy and Resource Security
Questions for the Record Submitted to Mr. Dan McGroarty

I am thinking specifically of 50 U.S. Code 98h-6, "Development of domestic sources" which in addition to authorizing purchases of strategic materials authorizes off-take contracts and other forward-based contractual commitments to encourage U.S. companies to enter production, see below, Section (2) (underlined passages added):

> ***(a) Purchase of materials of domestic origin; processing of materials in domestic facilities***
> ***Subject to subsection (c) of this section and to the extent the President determines such action is required for the national defense, the President shall encourage the development and appropriate conservation of domestic sources for materials determined pursuant to section 98b (a) of this title to be strategic and critical materials—***
>
> ***(1) by purchasing, or making a commitment to purchase, strategic and critical materials of domestic origin when such materials are needed for the stockpile; and***
>
> ***(2) by contracting with domestic facilities, or making a commitment to contract with domestic facilities, for the processing or refining of strategic and critical materials in the stockpile when processing or refining is necessary to convert such materials into a form more suitable for storage and subsequent disposition.***

The U.S. can no longer afford to leave this tool in the tool chest, and it should become a priority in terms of meaningful appropriations in the next budget cycle.

This authority can be used in a way that avoids "industrial policy," or "picking winners and losers," as a future commitment to purchase still requires a private company to raise capital in private markets to progress – a test that requires it to demonstrate market competitiveness. That the "winner" would have a willing purchaser in the form of the U.S. Government's National Defense Stockpile would still need to be leveraged into private-sector financing to make production possible. In this way, the U.S. Government could reasonably "encourage" multiple potential critical mineral suppliers, without anointing any one of them as a chosen provider.

Question from Senator Joe Manchin III

Question: I am working with a bipartisan group of elected officials on the concept of developing an Appalachian Storage Hub for natural gas liquids. When you consider the quad-state area of West Virginia, Ohio, Pennsylvania, and Kentucky, it is hard to avoid noticing the abundance of natural gas and natural gas liquids, expanding energy infrastructure and the naturally occurring geologic storage primed for receiving these products. These factors would make our region even more attractive to additional manufacturing investment. According to the Mid-Atlantic Technology Research & Innovation Center, about 20% of the value in the Marcellus Shale alone is ethane, propane and butane. So, the Hub would attract companies that need reliable affordable access to these products. But it would also provide the United States with access to supplies of these high value products in the event of an extreme weather event or other scenario that negatively affects the supply chain in the Gulf. With safety and the

environment top of mind, I'd like to see a regional storage hub move forward and that's why I introduced a bill making this type of project eligible for the Title XVII Innovative Technologies loan program at DOE.

Please provide your understanding of the energy security benefits that development of a regional storage hub in Appalachia would provide.

Senator Manchin, while I have no expertise on the natural gas storage hub issue you raise, I can say that the broad idea of resource reserves deserves serious attention from federal policymakers. Our economy and our defense industrial base are increasingly dependent on complex interrelationships at all points along the supply chain, with potential disruption at any one point creating the potential for gridlock and breakdown.

You reference the possible impact of an extreme weather event "or other scenario" creating a disruption – to the extent that U.S. resource abundance can provide an "insurance policy" against unforeseen events, whether triggered by Nature or other nations, storage hubs and stockpiles deserve serious consideration as public policy solutions.

Questions from Senator Catherine Cortez Masto

Question 1: Rare earth elements are critical for innovation in clean energy, consumer electronics, computer applications, and health care technologies. These minerals are crucial for Nevada's clean tech sector which includes members of your association, employs an estimated 21,800 jobs, and is driving economic growth. Can the federal government help manufacturers achieve lower-cost operations and promote industry growth with technology breakthroughs?

The federal government can certainly encourage advances in materials science – which is arguably the driving force in so many of the technology breakthroughs that are transforming clean tech, high-tech and many other industry sectors. Many of the metals and minerals discussed in the hearing for which the U.S. is presently in varied states of deep import-dependency are critical to advances in the sectors you mention in your question. Take the principal minerals and metals needed for EV Batteries of the type Nevada's GigaFactory is manufacturing: The U.S. is 100% dependent on foreign-sourced manganese; more than 70% dependent for cobalt; 100% dependent for graphite; and approximately 75% import-dependent for lithium. This is at best a potential bottleneck for U.S.-based EV Battery manufacturers in the event supply is interrupted, and at worst a magnet that will draw EV Battery production to nations closer to the raw materials supply – costing American jobs and undercutting the ability to experience the productivity gains of American innovation.

U.S. Senate Committee on Energy and Natural Resources
July 18, 2017 Hearing: The U.S. and North American Energy and Resource Security
Questions for the Record Submitted to Mr. Dan McGroarty

Question 2: Can technologies increase greater mineral supply chain awareness so that companies can more easily institute sustainability programs?

Increased mineral supply chain awareness – of the kind promoted by your Committee in its hearings and reports – is essential if the U.S. has hopes of aligning federal policy with the raw materials "inputs" required to feed American manufacturing.

As for sustainability programs, much more can be done at the federal level to encourage recycling of eWaste and other scrap for critical metals – which, unlike fossil fuels, are not consumed by their use (a "spent" EV Battery still contains lithium, manganese and cobalt that, extracted and re-processed, retain their initial characteristics and can be used in a new battery. More can be done to encourage reclamation – that is, the recovery of critical metals and minerals that lie in historic mine waste piles across the U.S. – metals and minerals that were simply not the target of the initial mining, as their properties for 21st Century applications were unknown. This is essentially a "treasure from trash" opportunity, which federal policy should find ways to encourage.

Question 3: What are the barriers that impede further domestic investment and development of critical minerals?

First and foremost, our near worst-in-the-world permitting process, which puts barriers in the way of the billions of dollars needed to develop major mining projects. Comparatively less prospective deposits – in Canada or Australia, for instance, fellow industrial democracies that balance environmental concern with an understanding of the importance of mining – attract capital that could otherwise have flowed to American projects. A graph of U.S. mining exploration and development "spend" versus the time to permit a mine would, over the past 20 years, show the "spend" is a prolonged decline, with time-to-permitting in a steep increase.

On the subject of permitting and other means of encouraging responsible resource development, please see my response to Question 5, below.

Question 4: How can advances in technologies improve the effectiveness of recycling electronic waste in order to access the critical minerals in them?

Market forces are driving interest and effort to more efficiently extract critical metals and minerals from eWaste and other sources. This is, however, "new science" – novel approaches to a task that has been more discussed than scientifically explored. Federal policy should acknowledge this trend – and encourage it through the methods discussed in my previous

answer. The idea would be to avoid mandating or micro-managing the methods of recycling, but to set a goal for recycled material (for example, to be bought into the National Defense Stockpile, or to receive production tax credits, etc.) and allow technologists and the private market to "discover" which methods work best.

Question 5: I have heard from several mining operations in my state about lengthy timelines for the permitting process. What are your recommendations for streamlining permitting?

On the subject of permitting and other means of encouraging responsible resource development, I will share the answer I provided to Senators Murkowski and Daines:

Clearly, the measures included in Subtitle D/Critical Minerals of the proposed Energy and Natural Resources Act of 2017 will be a strong step in the right direction, both in terms of a) creating a single methodology for determining a federal list of Critical Minerals, ranking criticality of those minerals and metals, and providing for periodic updates of that list, and b) establishing a permitting reform regime that will address the cumbersome and duplicative labyrinth of federal rules that have grown up around federal mine permitting, delaying the average process to the point that it among the world's lengthiest in comparison to the major mining nations, with no concomitant improvement in environmental and safety concerns.

Studies that show the U.S. permitting process routinely runs 7 to 10 years compare with fellow industrial democracies Canada and Australia that complete permitting reviews in a fraction of that time.

Especially in the context of Critical Minerals – where issues of national security turn on the timely availability of specific materials, for many of which the U.S. is presently 50, 75 and even 100% import-dependent, often from nations that are either unstable or that could in crisis circumstances withhold supply – the U.S. cannot continue to watch the permitting process become longer and less transparent. That is deeply irresponsible, and puts U.S. national
Security needlessly at risk.

I also believe federal policy would benefit by amending the so-called FAST 41legislation to explicitly apply to critical minerals development, using the same list established under Subtitle D. This should be done, however, in a way that is consistent with Subtitle D permitting protocols – and not constitute yet another layer of federal regulation.

While the following points may fall beyond the purview of the Committee, I would also like to see existing legislation – passages in the long-established Defense Preparedness Act – "re-discovered" and used to advance all aspects of U.S. critical mineral production, from mining through refining/smelting, recycling and reclamation, and into advanced material production.

I am thinking specifically of 50 U.S. Code 98h-6, "Development of domestic sources" which in addition to authorizing purchases of strategic materials authorizes off-take contracts and other forward-based

contractual commitments to encourage U.S. companies to enter production, see below, Section (2) (underlined passages added):

> ***(a) Purchase of materials of domestic origin; processing of materials in domestic facilities***
> ***Subject to subsection (c) of this section and to the extent the President determines such action is required for the national defense, the President shall encourage the development and appropriate conservation of domestic sources for materials determined pursuant to section 98b (a) of this title to be strategic and critical materials—***
>
> ***(1) by purchasing, or making a commitment to purchase, strategic and critical materials of domestic origin when such materials are needed for the stockpile; and***
>
> ***(2) by contracting with domestic facilities, or making a commitment to contract with domestic facilities, for the processing or refining of strategic and critical materials in the stockpile when processing or refining is necessary to convert such materials into a form more suitable for storage and subsequent disposition.***

The U.S. can no longer afford to leave this tool in the tool chest, and it should become a priority in terms of meaningful appropriations in the next budget cycle.

This authority can be used in a way that avoids "industrial policy," or "picking winners and losers," as a future commitment to purchase still requires a private company to raise capital in private markets to progress – a test that requires it to demonstrate market competitiveness. That the "winner" would have a willing purchaser in the form of the U.S. Government's National Defense Stockpile would still need to be leveraged into private-sector financing to make production possible. In this way, the U.S. Government could reasonably "encourage" multiple potential critical mineral suppliers, without anointing any one of them as a chosen provider.

Question 6: Do you believe that chronically underfunded and understaffed agencies affects permitting deadlines?

Underfunding and understaffing certainly contributes to the permitting delay problem. The Committee's proposed Energy Bill, and specifically Subtitle D/Critical Minerals, outlines several ways to expedite permitting without compromising its thoroughness.

Question 7: USGS's work on the Minerals Commodity Summaries and other minerals information and analysis work is critical information that helps inform economic forecasters. Do you believe stable funding is crucial for this agency to do an effective job in helping private industry?

In the case of USGS, the vital work being done by the Mineral Commodity Specialists is in my view significantly under-resourced. Each specialist is tasked with multiple metals and minerals, which in spite of their admirable efforts to track and report, needlessly stretches

their expertise over too many subjects. More resources in the hands of the critical minerals division at USGS would pay significant dividends, increasing U.S. information via mapping of known resources, accurate and expanded knowledge of critical minerals supply-and-demand, potential production shortfalls, and other key issues that would help guide private resource investment and policymakers alike.

On the specific issue of resource mapping, modern methods stand ready to greatly expand knowledge of the United States' potential resource wealth. An investment in mapping – done in collaboration with leading private sector exploration geologists – would be a strong first step towards addressing many of the minerals shortfalls that currently put the U.S. at risk to unstable or unwilling foreign minerals suppliers. A USGS Mapping "Moonshot" could set the pace for U.S. resource development for the remainder of the 21st Century, and would more than pay for itself in economic development, technology advancement – and contributions to our national security.

U.S. Senate Committee on Energy and Natural Resources
July 18, 2017 Hearing: The U.S. and North American Energy and Resource Security
Questions for the Record Submitted to Dr. Fatih Birol

Questions from Chairman Lisa Murkowski

Question 1: It has now been about 19 months since we lifted the domestic ban on crude oil exports, so this is a good time to look back and see how that decision is playing out. Despite some assertions that no one would want our oil, or that prices could skyrocket if anyone did buy it, we have instead seen prices stay moderate even as our exports topped one million barrels a day in some recent weeks.

a. Can you speak to the benefits that our ability to export energy, especially oil and natural gas, is providing both for the United States and for our allies?

The decision to end the crude oil export ban was a logical response to the significant increase in US crude oil production seen after 2008. Before the ban was lifted, rising production saw domestic crude oil stocks increase while logistical difficulties in terms of the configuration of pipelines and storage systems forced down the price of US oil versus other international benchmarks to very low levels. At one point US WTI was valued at nearly $30 a barrel below Brent.

Such low prices were good for refiners (and ultimately for end users) and inhibited to some extent investment in exploration and production, even though overall U.S. exploration and production were still impressive. Now that the export bottleneck has been removed, US oil companies are free to sell their production at international prices. This enables US companies to compete for a share in growth markets, which are mainly in Asia. The US benefits because export volumes and earnings increase. Customers of US oil also benefit from a greater diversity of suppliers, which improves their energy security. Energy security is important for all countries: the US is increasing its security via higher domestic production and its key allies/trade partners increase theirs by adding the US to their list of suppliers.

With respect to natural gas, the emergence of the US as a major exporter of liquefied natural gas (LNG) will be a catalyst for the major transformation of global gas markets with respect to pricing, gas security, and the environment. US LNG offers more flexible pricing and contracting arrangements than traditional LNG contracts, helping gas customers in Europe negotiate better prices from existing suppliers.

In Europe, where 40% of import contracts expire in the next four years, the option of US LNG strengthens the hand of European companies in negotiations with Russia and other exporters. The emergence of the US as one of the three major LNG exporters also bolsters global energy security by giving customers opportunities to diversify their supplies. Finally, competitively-priced LNG will encourage customers, particularly in Asia, to use natural gas in preference to coal. This provides not only energy security benefits through diversification, but also significant environmental benefits, especially with respect to the serious problem of urban air quality.

U.S. Senate Committee on Energy and Natural Resources
July 18, 2017 Hearing: The U.S. and North American Energy and Resource Security
Questions for the Record Submitted to Dr. Fatih Birol

Question 2: I appreciate all of the work that your agency, the International Energy Agency (IEA), does. One item that caught my attention was a report at the end of April, noting that "global oil discoveries and new projects fell to historic lows in 2016."

a. Can you put that in context – how low were discoveries, compared to previous years – and discuss the implications of that trend, going forward? What might it mean for a state like Alaska, which has prolific oil resources?

At the global level, according to our analysis only 2.6 billion barrels (bbls) of conventional oil were discovered in 2016, sharply down from an annual average of 9 bbls over the previous 15 years. Further along the value chain, the volume of conventional resources sanctioned for development last year fell 30% versus 2015, and the number of projects given the final development go-ahead fell to the lowest level since the 1940s. The picture in the US is very different. Investment in unconventional oil (i.e. shale resources), has increased sharply as costs have fallen and productivity has improved.

The IEA has regularly warned that unless the investment climate changes in the next year or so, we could, on the assumption that global oil demand increases for the next five years at the average annual rate of 1.2 mb/d forecast by the IEA, find that today's comfortable spare capacity cushion falls to a historically low level of less than 2% in 2022. This increases the risk of price spikes if market conditions suddenly change.

In the specific case of Alaska, there has recently been a revival in production with 2016 seeing the first year-on-year increase in oil production since 2002. Even so, production, at 490 kb/d in 2016, is still a long way below the peak of 2 mb/d seen in 1988. Alaska has very large unexploited resources of higher-cost, conventional crude oil but these cannot be developed without legislative and tax changes. The tax changes announced in 2013 went some way to addressing the latter issue, but this issue, as has been the case in the North Sea, should be regularly reviewed. Also, the outlook for oil prices is not currently sufficiently stable or attractive enough to encourage investment in many high-cost areas.

Question 3: As head of the International Energy Agency, you track developments in countries all around the world. Given that the United States shares both borders and an integrated energy market with Canada and Mexico, what do you believe are the most important energy-related trends in those countries right now? What should we be paying the most attention to in Canada and Mexico, and how will that affect our security and global markets in the years to come?

The strongly integrated oil and gas markets among the US, Canada and Mexico provide economic benefits and stability in a changing global energy market.

Canada is the fifth-largest crude oil producer globally, contributing to global energy security, and will remain one of the drivers of non-OPEC supply growth in the coming years, with its oil supply increasing to 5.3 mb/d in 2022. The United States derives 43% of its crude oil imports from Canada and the oil industry supply chains of both countries are well integrated, boosting

U.S. Senate Committee on Energy and Natural Resources
July 18, 2017 Hearing: The U.S. and North American Energy and Resource Security
Questions for the Record Submitted to Dr. Fatih Birol

employment opportunities, product markets, and technology progress in unconventional resource development. The oil export infrastructure from Canada is expanding, with several pipeline upgrades to be commissioned in the coming years. Canada also remains the top destination of US oil product exports (58%).

On natural gas, the US relationship with Canada is evolving: 96% of US gas imports are currently from Canada. However, import volumes have been in fast decline since 2007 (though a small increase has been seen since 2015) as Canada lost ground in the US gas market following the US shale gas revolution. Eastern Canada is now importing US gas (Ontario, Quebec), benefitting from low gas prices in the US and fostering Canadian energy security. Canadian gas production is expected to remain flat at 170 bcm per year, as the country has to find new markets (LNG) amid flat gas demand in Canada and the US. The IEA sees a slightly increasing role for natural gas in power generation as Canada phases out coal use by 2030. The Canadian government has responded to the increase in US production by encouraging the Canadian oil and gas sector to seek new markets.

On electricity, the US increasingly imports clean energy (hydro and uranium inputs for nuclear power) from Canada. In 2016, Canada exported a record of 70 TWh to the US, and imported less than 10 TWh. Uranium imported from Canada helps generate 6% of US electricity. With many more power lines being planned between Canada and several States, the US has an opportunity to increase the share of clean energy in the future and increase local power system flexibility thanks to Canadian hydro power.

In terms of energy efficiency, the introduction of common energy efficiency standards (e.g. Energy Star) agreed across the US and Canada drives energy efficiency progress (cars, appliances, products). There are large opportunities from an integrated North American market for clean energy technologies.

Moving on to Mexico, for the past decade Mexico has been on a trend of declining oil production, with production falling from 3.5 mb/d (2000) to 2.5 mb/d (2016). In the first half of 2017, Mexican oil production declined further to only 2.3 mb/d. However, this trend is poised to change. Since 2013, Mexico has undertaken one of the most comprehensive energy sector reforms ever, opening its oil sector to private investment for the first time in seven decades. The reform also fully liberalizes power generation and legally unbundles the former state monopoly CFE (electric utility).Thanks to the very determined implementation of the reform by the Mexican government in recent years, we see Mexico's oil production recovering to 3.4 mb/d by 2040. In the meantime, however, production will likely fall further, bottoming out at 2.2 mb/d in 2018 and 2019 before slowly climbing.

US refineries are well placed to process Mexican crude, add value, and export oil products (gasoline) back to Mexico. Mexican crude can help replace crude from less stable suppliers, improving security of US supply and -- by extension -- also contribute to supply security in the global oil market.

U.S. Senate Committee on Energy and Natural Resources
July 18, 2017 Hearing: The U.S. and North American Energy and Resource Security
Questions for the Record Submitted to Dr. Fatih Birol

US companies will have an important role to play in developing the deepwater oil resources on the so-far almost undeveloped Mexican side of the Gulf of Mexico. Companies with experience from the US side of the Gulf have an advantage vis-a-vis other players due to their great level of expertise operating in almost the same geological conditions. Similarly, once development of shale gas starts in Mexico, US players will be able to apply their experience from the US side of the same or similar shale gas plays.

Another key trend in Mexico is the growth of gas-fired power generation, not least due to a shift from coal and oil to natural gas use in power generation. In combination with the energy reform, which enables the building of new gas export pipelines to Mexico, this has made Mexico the main export destination for US shale gas, and we expect Mexico's imports from the US to continue to grow from today's 40 bcm/y to 45 bcm/y in 2022. Having Mexico as an export market is an important success factor in further developing the US shale gas industry.

Finally, the power sector reform in Mexico will enable more private investment in Mexico, allowing for additional international electricity interconnections to be built, thus enabling a more efficient utilization of energy resources. US-Mexico interconnections will also help balance the grid once more variable renewables are deployed, thus contributing to the stability of power supply.

Questions from Ranking Member Maria Cantwell

Question 1: Given the increasing intersection of digitization and energy, as you describe in your testimony, what lessons have you observed from Russian and other state actor cyberattacks globally that we can apply to ensure the energy security and national security of our country?

Digitalization is bringing smarter connection and integration of energy technologies and operations. This has many benefits, but it also opens doors to increasing risks. Cybersecurity and broader policies to manage digital risks and promote resilience in critical national energy infrastructures are of growing importance.

The disruption caused to energy supply by reported cyber-attacks to date has been small compared to major power outages resulting from storms or mechanical equipment failures (and to oil and natural gas supply disruptions due to geopolitical events). However, increased cyber vulnerabilities have been demonstrated, and there are credible scenarios for attacks that could shut down the electric grids of a major economic region for a period of days.

Complete prevention of cyber-attacks is impossible, but impacts can be limited if the targets are well prepared and have designed-in resilience – the ability to withstand shocks and to quickly recover to a desired level of stability, while preserving continuity of critical infrastructure operations. One factor that is important to resilience is choice of technology and system architecture. This means that cybersecurity and resilience need to be mainstreamed in energy research, development, and deployment.

Clarity about which aspects of security, preparedness and response are the responsibility of for-profit energy system operators and which belong with the government is also critical. Stronger regulatory requirements can help to improve the business investment case for cybersecurity

protections in personnel, technologies and procedures, for example, adding cybersecurity criteria to the rate-base for electricity grids.

IEA analysis and multi-party collaboration focus on the following aspects of digital security: training exercises for cyber preparedness; establishing the business case for utilities (e.g. costs of service interruption, insurance); mainstreaming of cybersecurity into smart technology development; and helping identify best practices and policies to ensure our grids of the future are digital resilient.

The IEA's work on energy security of supply is already raising awareness among our member and partner countries on new digital risks within a wider context of planning for resilience in the short-, medium- and long-term. Emergency Response Reviews of member countries ask energy policymakers and regulators to consider whether they have robust national governance arrangements for internal coordination and information-sharing on resilience, including undertaking preparedness exercises.

Question 2: Can you please share your perspective on the scale of action, innovation, and investment that is needed to avoid the worst consequences of climate change?

Under energy policies currently planned or implemented, global carbon dioxide (CO_2) emissions are projected to continue to increase, albeit at lower rates of growth than in the past. Conversely, low-carbon scenarios see global CO_2 emissions peak around 2020 then fall rapidly. This rapid reduction is associated with a shift in energy supply from unabated fossil fuels toward renewable energy, nuclear and fossil fuels equipped with carbon capture and storage (CCS). Natural gas also plays a transitional role in the coming decades. More efficient use of energy in buildings, industry and transport means that economic growth continues with little increase in energy demand in the low-carbon scenarios.

Incremental and breakthrough technology innovations, supported by policy and market design, would be needed across the energy system to achieve the results of the low-carbon scenarios. Some technologies like shale gas or wind power are now mature and in large-scale deployment, but several key technologies including CCS, advanced biofuels, new materials for efficiency, and new battery technologies still require substantial R&D efforts.

Given the assumption of continuing declining costs of some key clean energy technologies, IEA analysis shows the total investment needs of a low-carbon energy supply may be similar in magnitude to those of the "business as usual" case but with a different structure. In particular, there would need to be considerably higher investments required in clean energy technologies, which in turn would reduce the demand for and the investment need into the highest cost fossil fuel resources. Nevertheless, even with strong policies on clean energy and efficiency, some $700 billion per year in investment into conventional fuels would be required -- primarily oil and gas -- due to the need to replace depleting reservoirs.

There are also increased investment needs in the low-carbon scenarios to improve energy efficiency, but IEA analysis shows that this would be more than offset over time by fuel savings.

U.S. Senate Committee on Energy and Natural Resources
July 18, 2017 Hearing: The U.S. and North American Energy and Resource Security
Questions for the Record Submitted to Dr. Fatih Birol

More broadly, IEA analysis reveals that initial steps towards a low-carbon pathway can be taken at low cost. The IEA has outlined five key actions that can enable global greenhouse gas emissions to peak around 2020 without impacting GDP growth in any global region.

Question 3: Where do [you] see energy efficiency fitting into the issue of energy security?

Energy efficiency is a cheap, stable and abundant resource that does not depend directly on any resource endowment that a country may or may not have. It reduces the amount of energy needed to power the economy, lowering import requirements and freeing up more fuel for export. In the United States, improvements in energy efficiency since 2000 avoided $3.4 billion worth of imports of oil and natural gas in 2015. For many countries, energy efficiency is expected to make a larger contribution to greater energy independence than the supply side.

Energy efficiency also reduces the costs of maintaining the adequacy of electricity and natural gas networks. In the United States, key examples of this can be seen in electricity capacity market auctions run by independent system operators where energy efficiency resources, such as building refurbishments and efficient heating and cooling systems, compete with supply side resources. In 2016, 2.2 gigawatts of energy efficiency cleared the auction in New England for delivery in 2019/20 – 6% of the total. The digitalization of energy is providing new opportunities for businesses to better measure the impacts of energy efficiency and get rewarded for the services they can provide to systems operators, an issue the IEA will further discuss in a publication to be released in October 2017.

Energy efficiency, along with other conservation measures, can play a strong role in response to an emergency situation. Energy that is not consumed cannot be interrupted. In the aftermath of the Great East Japan Earthquake and tsunami, energy conservation measures, such as turning up thermostats in air conditioning systems and reducing lighting levels in buildings helped to reduce the amount of power needed to be sourced from other fuels following the removal of almost 300 terawatt hours of nuclear energy generation in 2011. By 2015, 45% of the lost Japanese nuclear generation was being replaced by demand-side measures, bigger than the contributions of natural gas, coal or renewable energy.

Energy efficiency remains a largely untapped resource. Less than one-third of total global energy use is subject to mandatory efficiency requirements, and IEA projections indicate that the majority of efficiency potential will remain untapped until new policies and measures are put in place.

Question from Senator Steve Daines

Question: In the written testimony provided to the committee you state that a pillar of energy security and modernization is the promotion of clean energy and that clean energy doesn't only include renewables, but energy efficiency, carbon capture and nuclear. In a state where we split the majority of our power between hydro and coal, this rings very true. It is important that we don't focus all our research and capital in just wind, or just solar, but instead expand our reach to

upgrading efficiency, expanding carbon capture, elevating hydropower and perfecting nuclear. Coming from Montana where an appreciation of outdoors runs in our blood, we all want clean energy and a healthy planet. We can do this by promoting an all-of-the-above energy portfolio while investing and researching new technologies that provide for cleaner energy.

Can you expand on how the U.S. can continue to be a leader in promoting clean technology, like CCUS, hydropower, and efficiency?

In CCUS, the US is a leading country, with the highest number of large-scale CCUS facilities worldwide, most of them related to CO_2-Enhanced Oil Recovery (EOR). In general, EOR is an attractive form of utilizing captured CO_2 even at current oil prices. The US has abundant geological potential to apply CO_2 based EOR and this should be regarded as a win-win for furthering domestic oil production and reducing emissions.

Federal financial policies such as credit guarantees have also played a major role to make CCUS projects bankable. Going forward, financial support can facilitate further expansion of CO_2-EOR / CCUS deployment.

The US Regional Partnerships, which aim to assess and develop large-scale CO_2 storage in different regions, can also be key enablers for CCUS deployment in the long term. US efforts to develop new generation CO_2 capture technologies, led by NETL and other national laboratories, have been important drivers for CCUS development. Finally, US leadership in international CCUS collaboration through key organizations such as the International Energy Agency (IEA), Mission Innovation, the Clean Energy Ministerial, and the Carbon Sequestration Leadership Forum (CSLF), has been essential to catalyze broader international support for CCUS development.

There is also considerable potential for the US to promote development of hydropower, which is one of the lowest cost sources of electricity supply but which currently represents only 5% of total power generation. This includes augmenting supply from the 100 GW of existing hydropower facilities, including upgrading and optimizing output using the latest turbine technology and installing power generating equipment at the country's considerable stock of non-powered dams. There is also large potential for new pumped-storage hydropower that would help to meet grid flexibility needs and support increased integration of variable generation resources, such as wind and solar. These methods would increase the contribution of hydropower while respecting social and environmental concerns about dam construction.

As regards energy efficiency, research and development has been crucial in developing new, more-efficient technologies, and then driving their costs down for large-scale deployment. Light-emitting diodes (LEDs) offer a recent example, where the price of a LED lightbulb has fallen by around 85% since 2010. The digitalization of energy is enabling US companies to take a lead in developing new technologies and business models building on the ability to measure and control, in a much more granular and timely manner, the energy consumption of industrial processes and buildings. Allowing energy efficiency to compete for funding through market-based instruments,

U.S. Senate Committee on Energy and Natural Resources
July 18, 2017 Hearing: The U.S. and North American Energy and Resource Security
Questions for the Record Submitted to Dr. Fatih Birol

such as the auctions carried out by the independent systems operator in New England, can also foster further innovation.

Questions from Senator Catherine Cortez Masto

Question 1: You mentioned that wind and solar have become the two fastest-growing sources of electricity around the world since 2010, largely in part to reductions in technology costs, innovation, and supportive policies. Do you believe the federal government has been a valuable partner in R&D investments as well as creating more opportunities for innovation?

The federal government has played an important role in promoting innovation and learning-by-doing across the energy sector, including in both clean and fossil fuel technologies. Given the long lifetimes and capital intensive nature of energy assets, stable and predictable policies for both innovation and deployment are crucial for realizing such benefits.

Technological innovation in the energy sector has often emerged from cross-cutting federal programs: solar panels have their origins in the space program, and gas turbines in military aviation. Federal funding has played a direct role in facilitating R&D in frontier energy technologies from shale fracking to electricity storage.

With over $6 billion of investment in 2015, the United States is the largest single government spender on R&D, though these expenditures have remained stable in recent years. The DOE innovation funding has generated strong private sector spillovers from the creation of new companies and funding from investors.

Federal government policies, combined with measures at the state level, have also been instrumental for bringing innovative technologies to market and attracting financing at scale.

Question 2: What do you believe the role for federal government should be with respect to innovation?

Governments have for many decades played a central role in energy innovation because their time horizons and social objectives allow them to accept risks that the private sector cannot.

The US has advantages that other countries lack. US universities and research labs are world-class; the interfaces between researchers and the corporate sector are well developed; the venture capital market is the world's most mature; and there is an appetite for high-risk, high-reward new ventures.

Governments can have the highest impact when they focus on portfolios of early-stage technologies that are not yet fully appreciated by the market or face the high risks of crossing the 'valley of death' between R&D and commercial deployment. Once the market is created,

U.S. Senate Committee on Energy and Natural Resources
July 18, 2017 Hearing: The U.S. and North American Energy and Resource Security
Questions for the Record Submitted to Dr. Fatih Birol

governments can maintain innovation momentum by ensuring that new and better technologies can compete on a fair basis. Finally, governments have a unique role to play in objectively assessing innovation progress and communicating needs and opportunities back to entrepreneurs.

This year, the IEA published a Special Focus on Tracking Clean Energy Innovation, which looks at the ways that the public sector can boost and track clean energy R&D, a topic that is often neglected in energy discussions.

Question 3: You mentioned that other countries already have much larger shares of wind and solar in their power system, in some cases up to six times higher than the United States. What lessons can the United States learn from other countries in integrating high shares of wind and solar in a reliable and cost-effective manner?

Countries such as Denmark, Ireland, Germany and the Iberian Peninsula (Portugal and Spain) have much higher shares of wind, or wind and solar, than the United States. These countries have managed to integrate wind and solar in a reliable and cost-effective manner through improved operation of the systems and the markets as well as making the power system more flexible.

IEA analysis has identified four resources that can increase the flexibility of power systems and facilitate the integration of large shares of wind and solar: 1) dispatchable power plants, 2) stronger grids and interconnections,3) affordable electricity storage (including hydro), and 4) demand side response. Stimulating these resources can require an integrated and well-designed market, policy and regulatory framework.

Question 4: How does market design play a role in successfully integrating renewables?

Market design plays a very important role in integrating wind and solar PV and an integrated and well-designed market, policy and regulatory framework is required to ensure successful integration of large amounts of generation from these technologies. As their shares of total power generation increase, market design needs to:

- *ensure efficient operation of the power system, which can be achieved through measures to unlock flexibility from all existing resources and improve dispatch practices by moving operational decisions closer to real time;*
- *ensure sufficient remuneration for providers of grid services and development of new flexibility resources;*
- *ensure "system-friendly" deployment of new renewable capacities such as generation of wind turbines with more regular output and higher capacity factor, and one-axis tracking of solar plants, or westward orientation of fixed-tilted solar modules;*
- *ensure electricity security of supply, including measures to ensure that generator revenues reflect their full contribution to system security; and*

U.S. Senate Committee on Energy and Natural Resources
July 18, 2017 Hearing: The U.S. and North American Energy and Resource Security
Questions for the Record Submitted to Dr. Fatih Birol

- *ensure sufficient investment in clean power generation, which can be achieved by providing sufficient investment certainty to attract low-cost financing for capital intensive investment projects through mechanisms such as a long-term power purchase agreement.*

A good example of a well-designed market in the US is ERCOT in Texas, which has managed to successfully integrate increasing amounts of variable renewable energy resources at costs that have generally been small-to-modest. ERCOT has put in place a number of mechanisms such as faster dispatch, ancillary service markets and scarcity pricing to ensure that wind is integrated into the system in a secure and cost effective manner. Crucially, Texas regulators also coupled these mechanisms with funding for $7 billion in large-scale transmission investment under the Competitive Renewable Energy Zone program, which supports the transport of nearly 20 GW of wind power from resource-rich West Texas to cities in the eastern part of the state.

Question 5: One of the major drivers of the clean energy sector is the rapid decline in battery prices with a roughly 80% decrease in prices since 2010. In what ways can the government expedite these falling battery costs?

There are two main applications of batteries in the energy sector: electric cars and stationary storage (either connected to the grid at the utility-scale or behind the electricity meter in homes and businesses). Our Global Electric Vehicle Outlook shows the number of batteries produced for electric cars will far outstrip those in stationary storage applications (by a factor of 10), so demand-pull policies facilitating the adoption of EVs will be the main driver for future battery cost reductions. In this sense, standards driving the overall efficiency of the car fleet and fiscal incentives helping the initial penetration of EVs can have significant impacts.

At the current state of EV technology, standards and tax incentives remain important, but as the technology matures the tax incentives will need to be progressively phased out towards less distortive policies that help increase the value proposition of driving electric, such as circulation incentives (e.g. dedicated parking, low emission zones, waivers from congestion charge, access to HOV lanes, etc.), as well as developing an appropriate re-charging infrastructure.

For stationary-storage applications, as the amount of electricity generated from wind and solar technology increases, the variability they bring will require the system to respond to changes at all levels of the electricity grid with greater flexibility. Because batteries can be sited anywhere and are quick to respond, batteries can be a good candidate for providing flexibility services in various applications.

The cost of the batteries themselves represent just below half of the total costs of grid-scale battery systems, with the rest due to local costs incurred as part of the process of installing the system and integrating it within networks. Market-pull policies are needed to drive down these 'soft' costs.

In electricity markets where policies are in place to reward system services and flexibility, grid-scale batteries are being built competitively today. Batteries compete with other flexibility

options such as gas turbines, hydro plants and decentralized demand response portfolios using e-business methods. The IEA advocates a flexible, technology-neutral policy enabling competition and innovation.

Especially with increased shares of variable wind and solar, there will be a greater need for storing energy over several days, which is not cost-effective with the current generation of commercial lithium-ion batteries. There is thus a need for other options, including investment in fundamental research into long-term storage technologies such as solid-state batteries and flow batteries, areas where the US is well positioned to innovate.