

**PROSPECTS FOR GLOBAL ENERGY MARKETS,
INCLUDING THE ROLE OF THE UNITED STATES—
PERSPECTIVES FROM THE INTERNATIONAL
ENERGY AGENCY**

**HEARING
BEFORE THE
COMMITTEE ON
ENERGY AND NATURAL RESOURCES
UNITED STATES SENATE
ONE HUNDRED SIXTEENTH CONGRESS
FIRST SESSION**

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**PROSPECTS FOR GLOBAL ENERGY MARKETS,
INCLUDING THE ROLE OF THE UNITED
STATES—PERSPECTIVES FROM THE INTER-
NATIONAL ENERGY AGENCY**

THURSDAY, FEBRUARY 28, 2019

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

The Committee met, pursuant to notice, at 10:06 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.

This is the second hearing of the week, so we are moving along aggressively, which is a good thing. We are here this morning to consider the perspective of the International Energy Agency (IEA) on global energy markets.

It has been a busy couple of weeks here. We have done some scene-setting hearings. We have covered the energy and minerals sectors, we have discussed the outlook for domestic policy, we have looked to the future of innovation, and we have examined the very real and persistent cyber threats to our critical infrastructure.

This morning we are very, very pleased to welcome back to the Committee Dr. Fatih Birol, who is the Executive Director of the IEA. He has had an opportunity to be before this Committee on numerous occasions. I am always, always, very pleased with the opportunity that we have to ask you your views, your perspectives and for the information that you are able to provide to all of us for this global outlook for the year.

The IEA is one of the world's premier organizations for energy information, insight, and analysis. So, again, the opportunity to discuss the agency's new World Energy Outlook is greatly appreciated.

The good news for us right now is I think we are in a pretty good place. Over the past decade, the United States has transformed into a dominant player in global energy markets. Breakthroughs in hydraulic fracturing and horizontal drilling have allowed the United States to avoid building LNG import terminals up and down our coasts and instead export to our friends and our allies.

We ended the arbitrary prohibition on domestic crude oil exports a few years ago. Since then, we have watched our exports take off and OPEC's power start to decline, all while prices remained at low to moderate levels.

New technologies have substantially reduced our nation's greenhouse gas emission levels, and that points to our most reasonable path forward on climate change, which is lowering the cost of clean technologies—as opposed to burdensome new taxes, or endless regulations.

We have also continued our strong commitment to research and development which allows the United States to be a technology driver with an impact that reaches far beyond our borders. As more of the world electrifies, we have an opportunity to build a supply that is more resilient, more affordable, and more reliable.

I was pleased as I looked at the Outlook, Dr. Birol, that you take a very, very close look at the global power sector for these trends. And key to so much of this is the interconnectedness of our energy systems. No longer do we need to wonder what is happening on a pipeline or wind turbine in a remote part of the world. We have sensors that can provide its status almost instantly. And while this technology is remarkable and transformative, it is also critical to ensure that worldwide networks are protected against the evolving cyber threats and other vulnerabilities as interconnectedness grows in the energy sector.

I am certainly among those who look to the IEA on energy policy, and what I find, what I hear from IEA helps ensure that our policies here are well-considered. I appreciate that the agency has branched into sectors beyond oil and gas, which had been that focus historically. I would also note that IEA's membership has now grown to 30 countries, each with dynamic and diverse energy portfolios.

So again, Dr. Birol, it is wonderful to have you here, we appreciate your leadership. We all know that Paris is a long way away. We appreciate that you take the time to come here to Washington, DC, and particularly that you accept our invitation to speak before the Energy and Natural Resources Committee. You provide a very valuable perspective to the Committee. This is a hearing that I look forward to each year. And again, I welcome you.

With that, I turn to my colleague and Ranking Member, Senator Manchin.

**STATEMENT OF HON. JOE MANCHIN III,
U.S. SENATOR FROM WEST VIRGINIA**

Senator MANCHIN. Chair Murkowski, thank you for convening the Committee today, and Dr. Birol, thank you so much for joining us.

I have been so impressed with the energy scene-setting hearings we have held in recent weeks, and hearing your view from the International Energy Agency is a great way to round those out for us.

I also want to thank you for your focus on CCUS as an important part of our energy future. Both the Chairman and I come from energy producing states that have helped lead the U.S. to energy independence.

West Virginia's coal and coal miners have done a lot of the heavy lifting for this country's economy, and West Virginia continues to be an energy exporter. Additionally, the Marcellus and Utica shale plays in West Virginia and Appalachia, more generally, have been key drivers in our nation's ability to further establish ourselves as a global energy leader. Of course Alaska, in turn, has long been a leader in oil and gas production. So the Chairman and I both believe that the U.S. needs to continue to lead in sustainable energy production as well as develop the energy technologies that incentivize other nations to reduce emissions to address the climate crisis.

It has been some time since the Senate took a hard look at where we stand in terms of the power sector as it relates to climate change, so I am excited that Senator Murkowski and I will be holding a climate hearing next week to discuss where things stand here in the U.S. and globally. And this is most timely for you to be here today. Energy is often looked to as being at the heart of the climate debate, so I am very happy Dr. Birol is here to give us the global picture on energy needs.

As we have discussed at previous hearings, breakthrough technologies will help us reliably meet our energy needs in the future while decarbonizing our energy system, and that is an all-of-the-above conversation. It can't just be about one fuel type, renewables or otherwise. If we are being realistic, we need to pursue solutions across the board. And the United States as a leader in energy production has a unique role to play in developing and commercializing innovative technology solutions. We need to prioritize advancing technologies like carbon capture that we can employ both here at home and overseas.

According to the IEA in 2017, China and India used coal for 67 and 74 percent of their electricity, respectively. Under current policies, that will be 51 and 57 percent by 2040. While I understand both countries are taking steps to reduce emissions and add more renewable generation, fossil fuels are still a part of their future in all three of the scenarios that IEA models in its most recent report. In other words, no matter how you slice it, coal is going to be part of the energy mix for decades to come around the world. So innovation in carbon capture, advanced nuclear, storage, energy efficiency, and other technologies are going to be key.

I also want to touch on a topic that I believe you can speak to which concerns my colleagues and me deeply, that is the use of energy as a geo-political weapon by countries such as China and Russia.

Russia has for years relied on their energy resources to exert influence and exact concessions. Central and Eastern Europe are relying on Russia for approximately 75 percent of their gas import needs. Russia, in turn, uses that reliance for political coercion and influence, and that is why I oppose the Nord Stream 2 pipeline.

Meanwhile, China is buying up energy and natural resources around the world, from large parts of Africa, Latin America, to Asia, to right here in the United States. For certain commodities, China has become the price setter and exerts enormous influence. When it comes to using energy and natural resources for manipulation or influence, it sometimes feels like we are short-sighted while

Russia and, particularly, China are playing the long game. We have to get back in the game and lead in order to promote American energy independence and serve as a bulwark against Russia and China's aggression.

I very much appreciate you making the trip to be here today for your third annual visit to share your views on the global energy markets and the role of the United States.

With that, Chairman Murkowski, I look forward to hearing from our witness today.

The CHAIRMAN. Thank you, Senator Manchin.

I have introduced Dr. Birol as head of the IEA, the Executive Director. We all have a little bit of a background and a biography contained within our background memo, so I won't read it in detail.

But I do think that it is important to note that in addition to his tenure there at IEA, the background, the experience that he brings to these issues, not only before us in the Committee here, but really, around the world, Dr. Birol has been named by Forbes magazine as among the most influential people on the world's energy scene. He was recognized by the Financial Times in 2017 as Energy Personality of the Year. What a great title.

[Laughter.]

Energy Personality of the Year. We are honored, truly honored, to have you here again—your leadership at IEA and your willingness to share so much of it with us.

Typically, we ask our witnesses to try to limit their testimony to about five minutes, and their full statements are incorporated as part of the record. But because you are the sole witness this morning, we certainly give you discretion to share with us this morning the time that you need to present on the outlook for 2019 and then we will move to questions and your responses.

So, again, Dr. Birol, welcome.

**STATEMENT OF DR. FATIH BIROL, EXECUTIVE DIRECTOR,
INTERNATIONAL ENERGY AGENCY**

Dr. BIROL. Thank you very much, Madam Chair.

Chairman Murkowski, Ranking Member Manchin, distinguished members of the Committee, thank you very much for this great opportunity and honor for me and for my agency to appear in front of you.

I am since almost two decades with the International Energy Agency and I appear in front of this Committee as the Chief Economist before you have invited me, Madam Chair. But I am the head of the Agency since three years, almost, and then I had the pleasure to be here each of the past three years and to share with you our views. And I benefited from that discussion very much. Thank you very much, Madam Chair.

Perhaps more information about the IEA. This year is our 45th anniversary. We are 45 years old, and we were founded by Henry Kissinger in the State Department just over here with 16 other countries. In fact, after this very meeting I will go to the State Department for some celebration for our 45th birthday.

Now, I thought the following, Committee. First, I will share with you some of the trends in the global energy markets because even though the United States is perhaps the most important energy

country in the world, today no country is an energy island. So I want to highlight what's happening in the world. And second, some observations about the U.S. role in the global energy picture.

First of all, I start with general trends. We see that the global energy demand is growing strongly, mainly driven by Asia, but also Africa, Latin America with the increase in income levels, increase in population, urbanization, modernization because energy means better lives and energy means more comfort, more productivity. We see a growth across the world, and this is solid growth.

Particularly, natural gas is growing very, very strongly, driven by Asia. And when I say Asia, one country is very important here which is China. The China effect we have seen in the oil markets some ten years ago, we are seeing now in the natural gas markets. As we speak now, China is overtaking Japan as the largest gas importer of the world, and most of this gas imports will be in the form of LNG. So gas is growing and LNG will have a very important part of it.

Second, oil. We also see the global oil demand is growing very strong. Some observers look at the changes in the automotive sector and calling the end of the oil era which we believe is not right because, first of all, global oil demand growth is not driven by the cars, it is driven by trucks, aviation and petrochemical industry. And on top of that the share of cars in the world oil consumption is about 18 percent—82 percent everything else put together and cars are only 18 percent.

We also see that the increasing share of electric cars around the world, it is making some dent on the global oil demand growth but looking at other factors, it is going very strongly global oil demand, in any case, one million barrels per day.

Having said that, looking at the production side to that where the oil production come from. It will come in the U.S. part, the exclusive part of the United States, but I have one major concern, namely the growing geopolitical tensions around the world, especially in those countries where the significant amount of oil production is coming from.

I am, Madam Chair, since 13 years I am attending the Davos meetings at the World Economic Forum, and I have another hat. I am the Chair of the Energy Board of Davos World Economic Forum and this year I have never seen that the geopolitics, the overarching team on the energy sector. Geopolitical developments with Russia, with the trade tensions around the world, what's happening in the Middle East Gulf countries, some Gulf countries, Iran, Venezuela. When we look at all these issues, including Brexit, if I may say so, geopolitical tensions are everywhere and, as such, we think that the supply disruptions is a very important area that we need to pay attention to.

These geopolitical tensions plus the possible hurricanes and the others that we experience in this country and abroad tells us that the main thing in strategic oil stocks is still a critical issue, we believe. We have to think about the rainy days and not only looking at the current station.

A few things on the wind and solar. After gas and oil, wind and solar are growing everywhere across the world mainly because of the one particular reason—they are getting cheaper and cheaper

and they are also, in many cases, subsidized by the governments and their share are increasing.

And as a result of that, we are also having some benefits in terms of environmental benefits, but also some challenges because, as we all know, solar and wind are intermittent energy sources. If there is no sun, we don't have electricity. If there is no wind, we don't have electricity, if we do not take the necessary measures.

So therefore with the increasing share of renewables, we also need to pay attention to flexibility of our electricity systems, including those such as nuclear power, gas, coal and hydropower and others.

A few words on coal, Senator Manchin also mentioned, now many people say also, we came to the end of the coal age but when we look at the numbers, we don't see the same picture. In the last two years, leading scientists tip decline of coal globally. We have seen an increase in the global coal consumption. And China alone is very important in this equation because China, today, consumes half of the global coal. So about 50 percent of coal in the world is consumed by China, the other half, everybody else put together.

So to sum up the global picture—oil, gas, coal—they are all growing still in the global energy scene, but the renewables are making strong inroads, especially in the electricity generation.

A few words about the United States and starting from oil. We expect that, thanks to shale revolution, United States will be providing 70 percent, 7-0 percent of the global oil production growth between now and 2025. And the impact of this cannot be over-emphasized on the prices, on the energy security and on the geopolitics of finance which means about almost three-fourths, almost three-fourths of the global oil production will come from the United States only. And this is something very important to underline.

And in terms of natural gas, I mentioned to you that globally there is a demand for natural gas. We expect that the about one-third of the global gas production will come again from the United States.

Maybe more importantly, two-thirds, two-thirds of the LNG exports worldwide comes from the United States between now and 2025. This is extremely important.

Now, Madam Chair, some seven years ago when I was a Chief Economist, I had made the World Energy Outlook and made the international press release and in that seven years ago I said, "United States will overtake Saudi Arabia as the number one oil producer." My colleagues will give a copy of this. It was in the Wall Street Journal cover page.

[The information referred to follows:]

A look back at WEO-2012



"By around 2020, the United States is projected to become the largest global oil producer"

Quote from the launch presentation of WEO-2012, London, 12 November 2012
Fatih Birol, IEA Chief Economist



Dr. BIROL. And as we expected, as of next year, they are now, the U.S. is in the same level of production with Saudi Arabia and Russia. By 2020, U.S. is definitely, by far, the number one oil producer of the world. This is an incredible, incredible development as the IEA seven years ago was spot on said and it was a very daring expectation at that time.

But the most important message I want to give here to you and to the world is the following. Many people think that this is we now slow the impact of shale revolution. This is not exactly right. What I believe this is only the first wave of the shale revolution impact. The full impact of the shale revolution is yet to be seen.

It is now coming because the first wave of oil and gas shale was mainly used domestically to replace the imports for the petrochemical industry, for other power generation it is used there. And the second wave of production is going to be used to export U.S. oil and gas several nations around the world and this will have a major impact on the established oil and gas market order around the world. And I believe this impact will be not limited to energy only, it will go beyond energy.

A few other thoughts, Committee members, on renewables. I think the achievements of the United States in terms of renewables may be a bit behind the shadow of shale oil and shale gas. In the United States, the renewables are also growing very strongly. In the year 2010, the share of renewables in the U.S. electricity generation was 10 percent and as of today it is about 18 percent. There's very strong growth there mainly driven by wind and solar and this is very good news, but there is a lot of potential to increase even further.

We are also seeing that in the United States the electricity networks are also getting some attention from the policymakers as the transmission system in the United States is a bit segmented now and it results in some bottlenecks. And we hope that these bottlenecks will be treated appropriately by using the right technologies and there is more connection between the different parts of the United States.

Now, coal. It is, it will be very wrong not to see what is happening in the coal markets around the world. Coal is still the second largest energy carrier after oil in the world. And in terms of the power sector, it is number one source of electricity generation, especially big load is coming from Asia.

And more importantly, in United States or in Europe the coal plants, the power plants, are very old. They are about 40–42 years old. They are aged, so they are coming to the end of their lifetime, many of them.

But in Asia, there is a huge coal fleet and it is very young. It is 11 years old. So it means investments were made there and the utilities, the countries, would not change their plans before those investments are paid back. And it is across Asia, very young fleet. And of course, the question is how do we, how do we find the solution while they provide much needed electricity for the poor segments of the population there and providing input to the economic growth, how do we address their environmental impacts?

Now for me, the magic word here is carbon capture, utilization and storage (CCUS). If you ask me, Madam Chair, if I have to pick

out one technology, advanced technology, which is vital for our planet, it is difficult to choose. They are all very important, but for me, CCUS is extremely important, as in all of our expectations in the future, we see fossil fuels still have a large share and we can make use of CCUS.

The problem is not with, we don't have any problem with energy. We have a problem with emissions. And that is a very good thing. It brings us better lives, growth to our economies, but emissions is the problem and CCUS can definitely address this problem.

And here I would like to thank the U.S. Administration and your Committee and legislators for the 45Q business model that you came up with which provides a very nice business model in United States and also around the world.

I am traveling to many, many countries around the world. The critical importance of CCUS is more and more recognized and your leadership here would be extremely important pushing the 45Q that it may need some fine tuning here and there, but it's an extremely important model.

Now, to finish I wanted to talk another important technology for me, for the International Energy Agency, I believe and for the world which is nuclear power.

I believe nuclear power should be seen as a key asset in the United States. United States has been the leader of nuclear energy for almost 60 years together with Japan, France and other countries. However, I think we are at a very critical juncture of the nuclear industry in the United States now. If you do not change the policies as far as nuclear energy is concerned, our numbers show that in less than ten years of time, China will overtake the United States as the number one nuclear power in the world. This is very important for the electricity sector, but I think it may have well other implications beyond electricity sector as well.

Today, nuclear power generates about 20 percent, one-fifth, of the U.S. electricity, but if we do not change our policies in the United States this share will go down to seven percent only. And this will have implications for the electricity security as the nuclear power provides baseload electricity generation and very flexible, but also the carbon footprint of the U.S. electricity generation and therefore the change of the policies is very important.

And there, I'm sure, there are many measures that you and the Administration are thinking about. But for me, the very first priority would be extending the lifetimes of the existing nuclear power plants and to have them with us as long as the safety considerations allow.

And of course, in the longer-term looking at advanced nuclear technologies such as the SMRs, small modular reactors, will be of crucial importance to help the U.S. leadership continuing in the nuclear domain.

So, Madam Chair, these are some thoughts about the global energy picture, the U.S. success stories in oil and gas, also renewables, but some challenges in terms of the coal markets and at the same time, nuclear energy.

Thank you very much, Madam, for your kind consideration.

[The prepared statement of Mr. Birol follows:]

Written testimony
Hearing of the U.S. Senate Energy and Natural Resources Committee
Prospects for global energy markets, including the role of the United States

Dr Fatih Birol
Executive Director
International Energy Agency

10:00, 28 February 2019

Chairman Murkowski, Ranking Member Manchin and distinguished Members of the Committee, thank you for the opportunity to appear before you today and to present the International Energy Agency's view on global energy.

It has been my privilege to serve as the Executive Director of the International Energy Agency (IEA) for over three years. And it is my distinct pleasure to share with you our very latest views on prospects for global energy markets and in particular the role of the United States.

A brief overview of the IEA

But first I would like to give you a brief introduction to the IEA. Since the founding of the IEA almost 45 years ago, the United States has played a critically important role – US support has come not only from the Executive Branch, including the White House, Department of State and Department of Energy, but also very much from this Committee and from the Congress more generally. I've been privileged to appear before this Committee each of the past three years and have benefited from the perspectives, dialogue and guidance from Committee Members.

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. Since that time our Agency has evolved, growing to become the world's leading energy advisor across the entire energy mix, providing data, analysis and advice to governments and industry on all fuels and all technologies.

Today the IEA is made up of 30 member countries, and over the last three years, we have welcomed eight IEA Association partner countries: Brazil, China, India, Indonesia, Morocco, Singapore, South Africa and Thailand. This broader IEA family more accurately reflects the global nature of the energy system, accounting for almost 75% of the world's energy consumption compared to less than 40% in 2015.

Key global trends

Economic growth, urbanization and industrialization – primarily in Asia – are set to drive global energy consumption 25% higher by 2040 in the IEA's central scenario. This growth would be even more rapid without vital energy efficiency measures.

Air pollution concerns are increasingly motivating energy policy all across Asia. The result is massive new investment in cleaner energy sources, especially renewables and natural gas, for which Asian supply is increasingly coming from imported liquefied natural gas (LNG). The IEA has long emphasized

the role of China, India and other countries in Asia in driving global gas demand, but the recent upswing has exceeded even our expectations. Satisfying expected gas demand growth in Asia would require additional supply equal to building one new average-sized US LNG project every 5 months.

Economic growth is also driving oil demand, with the vast majority of growth coming from trucks, aviation and petrochemicals where oil is very likely to stay dominant in the foreseeable future. Even though we are increasingly optimistic about electric cars, we have also recently raised our expectation for oil demand in 2025 by 2 million barrels per day given the strong dynamism of oil demand growth especially in petrochemicals and aviation. The efficiency measures currently implemented only slow down the growth of global oil demand, which we expect to reach 106 million barrels/day by 2040.

Yet in parallel with global oil demand growth, in the absence of additional investment, existing conventional oil production in ageing fields is set to decline on average by around 3 million barrels per day, every year. In addition, it appears that a host of geopolitical risks will continue to affect oil supply. As a result, robust upstream investment, infrastructure development and collective preparedness for supply security remains as important as ever. Even if domestic supplies in the United States surpass domestic demand, the country would still be vulnerable to the consequences of a global oil supply disruption. A spike in oil prices can result in higher gasoline prices for consumers all around the world, including the United States. Large disruptions can also result in serious negative consequences for the global economy.

This is one of the fundamental reasons IEA member countries maintain strategic oil stocks, to be collectively pledged to markets when a disruption occurs. The United States, together with Japan, Korea and Europe are the central pillars of this system. We are now considering how we might begin to involve other large consumers, from the emerging economies, more closely in this system. US strategic stocks have proved themselves useful not only during cases of global oil disruptions but also during domestic disruptions, such as during the hurricane seasons of 2005 and 2008 and as recently as 2017 in the aftermath of hurricane Harvey.

The rate at which the world uses electricity is growing twice as fast as growth in overall energy consumption – that is, a higher and higher proportion of energy demand is being met with electricity. Despite the popular narrative of the age of electric vehicles, the largest drivers of electricity demand are actually electric motors in industry and air conditioners in emerging markets. As industrialization creates wealth, the emerging middle class buys new electric appliances. The electricity consumption of the digital economy is also increasing.

As a result, electricity has bypassed oil as the largest target for energy investment. Within electricity, wind and solar are increasing their shares of new investment. While wind and solar provide only 6% of global power generation today, together they will account for half of the growth in electricity generation over the next two decades.

This growth in wind and solar, driven by improving technology and reductions in cost, is an unprecedented opportunity – one that will require the electricity system to become much more flexible. Flexibility refers to the ability of the electricity system to react to changes in supply and demand. Dispatchable power plants – namely hydro, gas, coal and nuclear – can be key flexible resources; involving consumers in flexible demand response and electricity storage are also growing in importance.

The unique leadership role of the United States – oil and gas

We forecast that around 70% of the growth of world oil production to 2025 will come from the United States. In fact, the United States has essentially compensated for recent production shortfalls in Venezuela and Iran, and, in the process, stabilized oil prices at a level conducive for global economic growth.

The importance of the US shale industry for the global economy cannot be overemphasized. And shale oil is not the only contribution from the United States; we are increasingly optimistic about the impact of cost declines, technological improvements and modular development approaches on offshore investment in the Gulf of Mexico. In addition, major new discoveries in Alaska have confirmed the quality of the resource base. If shale oil in the Permian is the superstar of the team, these other regional opportunities are key supporting players.

The United States continues to break records in natural gas as well. Last year US gas production increased by 12%, adding almost 10 bcf/d, the highest recorded production increase in absolute terms by any country, ever. US LNG has already played a major role in expanding supply, improving security and creating more efficient markets. Whether it is increasing energy security and diversity in Poland or compensating for the disruption of Turkmen supplies in China, American LNG could step into the gap.

We think a further wave is coming. Over the period to 2040, our projections suggest that North America could account for one-third of the increase in global LNG trade, helping to improve market efficiency and supply security. While the pacific coast of Canada is also attracting investment, the large majority of investment will be in the United States. Along with Australia and Qatar, we expect US LNG to play a growing role in meeting market demand in Europe, India, Japan, China and elsewhere in Asia.

However, there are energy security and sustainability challenges to overcome. In particular, the Northeastern United States needs more robust gas pipeline infrastructure to maintain supply security. In addition, more progress needs to be made in reducing methane leakage, a major concern for efforts to address climate change. For years, the IEA has highlighted the need to reduce methane emissions from oil and gas operations, and we are working with countries and leading companies on how to achieve this.

The unique role of the United States – electricity

The United States is also a world leader in technological, policy and business innovation for transforming the electricity system. The share of wind and solar in US power generation is over 8% and growing by 1% per year. 13 states already have a higher share of wind and solar generation than the European average.

The United States is leading innovation in terms of technology and system integration – that is, how to ensure that the power generated by these variable sources is used efficiently and effectively. For example, an average new wind turbine in the United States generates up to twice as much electricity as the global average.

Texas is a notable success story. In the past decade, wind generation tripled while the proportion of curtailed renewable production has been reduced to less than one-tenth. This was a result of policy

reforms, infrastructure investment and better technology. The United States also has a strong manufacturing capability for wind.

In addition, the United States is playing a major role in both regulatory and business model innovation. At both federal and state levels, regulators have pioneered policies that ensure that the electricity grid performs as efficiently and effectively as possible. Last but not least, the wind and solar industries have created a substantial number of jobs, especially in blue collar installation and maintenance.

Nevertheless, the transformation of the electricity system is an unfinished journey. First, the United States needs to continue to build upon successful regulatory and market reforms that have enabled efficient integration of wind and solar. The United States can take advantage of its abundant wind and solar resources. However, doing this in a cost-effective manner and without compromising electricity security will require enhancing power system flexibility.

Addressing this flexibility issue requires a broad portfolio approach including more flexible operation of conventional power plants, continued electricity market integration, and an appropriate regulatory framework that engages consumers in demand response and encourages investment in storage. In addition, renewable producers should be exposed to market signals according to the value and system cost associated with their production.

There are several additional policy challenges that need to be overcome. For example, the US transmission system is segmented, resulting in a number of bottlenecks. There are promising initiatives for new transmission to remove these bottlenecks, including the use of innovative direct current technology, as well as expansion of transmission lines from Canada, but permitting is usually slow and burdensome. Policymakers need to ensure that infrastructure investment is financially attractive and is not hindered by undue administrative burdens. Finally, there is also a need to adopt regulatory models that are adapted to decentralized, bottom-up electricity generation.

The unique role of the United States – other key energy technologies

I believe that one of the greatest strengths of the IEA is that we are an all-fuels, all-technologies agency. We track trends throughout all energy sectors with our detailed, global data, and we use rigorous analytical tools that provide actionable insights to key global actors. With this in mind, let me share some other data and insights I thought you might find useful.

Coal is the second largest energy source in the world after oil, and while demand actually grew slightly over the past two years, our expectation is that demand worldwide will continue to plateau. Most future coal demand will be driven by power generation in emerging Asian countries.

75% of the current global coal-fired power fleet is in Asia, and Asian coal plants are only 12 years old on average. This is much younger than those in the United States, where coal plants are 45 years old on average. Given this young Asian fleet, technology innovations will be critical to balance the future of coal with environmental sustainability concerns.

The United States has made major progress on **carbon capture, utilisation and storage** (CCUS), especially with the passage of the 45Q tax credit legislation. We believe this vital legislation – and congratulations to all who were involved in its passage – will create a viable business model for various CCUS opportunities. Let me add – including from my co-chairing recent CCUS summits (one of which I

had the privilege to co-chair with Secretary Perry) – that we are optimistic about the investment appetite for CCUS projects. In short, we applaud the new policy design and US leadership.

Previous approaches to CCUS around the world have tended to be top-down and focused on handpicked projects. 45Q puts a value on this important clean technology and helps unleash the innovation and business savvy of the private sector. No doubt, there will be a continued need for fine tuning, but in this field the United States has clearly taken a strong global leadership role.

This kind of innovation will be crucial to reducing emissions in both the United States and worldwide. The good news is that since 2000, the United States has cut emissions by 800 Mt – the largest decline in the world by any country in absolute terms. While there was a 3% increase in emissions in 2018, our analysis shows that weather conditions – an unusually cold winter and hot summer – accounted for a large part of this increase.

I also believe that **nuclear** should be seen as a key asset in the United States. The United States has been a leader in nuclear power generation technology for 60 years, alongside France, Japan and Russia. The new leader is set to be China, if US policies don't change.

China has rapidly developed nuclear power over the past two decades, increasing from just 3 operating reactors in 2000 to 46 at the end of last year. Nuclear capacity in China is set to overtake that of the United States within ten years.

Nuclear still generates twice as much low-carbon electricity in the United States as wind and solar combined. The baseload capacity of nuclear power plants also plays a major role in maintaining electricity security. This is especially true in the Northern regions of the United States which experience spikes in electricity and gas demand during extreme cold spells like the recent polar vortex – times when solar production can be challenged. Nuclear plants also provide frequency control and other system services as well.

There is today significant international appetite for innovative approaches to nuclear power, including small modular reactors (SMRs). SMRs can offer significant benefits, such as factory fabrication, flexibility in where they can be deployed and lower upfront investment. This is yet another opportunity for American innovation to play a leading role.

That all said, nuclear in the United States is facing major challenges. Without effective policy action the United States will be on track to lose a substantial proportion of its capacity. From my vantage point, this would be detrimental to both energy security and clean energy objectives.

A first priority should be to safeguard the existing fleet. Nuclear plant lifetimes should be extended as long as safety considerations allow. In large parts of the United States this presents a challenge, as wholesale markets don't value the energy security and clean energy contribution of nuclear. In order to safeguard the long term contribution of nuclear, the United States also needs to continue to accelerate innovation in new nuclear technologies, including SMRs.

Chairman Murkowski, Ranking Member Manchin and distinguished Members of the Committee, thank you again for the opportunity to appear before you today and, even more importantly, thank you for your continued support on behalf of the International Energy Agency.

The CHAIRMAN. Thank you, Dr. Birol.

Again, very, very, very interesting. There is so much to ask about. So many good conversations here. So let me begin.

Your observations here as they relate to oil where the United States is in terms of meeting that growing global demand there. Your comment that the U.S. will be providing 70 percent of the oil production growth between now and 2025. I guess the question to you is, in anticipating that, are we seeing the level of investment that we need to have here in the United States in order to be able to meet that?

From a policy perspective, obviously what we did several years ago in lifting the oil export ban, that has had a significant impact on what we have seen with increased production and our participant on that world market. So, specific to the adequacy of the investment and then from a policy perspective, is there more that we should be doing here?

Obviously from Alaska's perspective we are trying to do as much as we can in meeting the demand with increased opportunities within the federal lands, within the National Petroleum Reserve. And then just last year, in moving forward on the 1002 area in the coastal plain. That is still a long way out from production. We won't have that online by 2025. So can you speak to those aspects, please?

Dr. BIROL. Thank you very much, Madam Chair.

The U.S. oil production is becoming more and more cost-effective as a result of improvements in the technology. It is now cheaper and easier to produce compared to, for example, five, seven years ago. So therefore, with the current prices, we don't see any major problem that the U.S. oil production will be profitable in most of the provinces in the United States.

Where is the challenge? In my view, the challenge will be how do we bring the oil to the international markets, namely the pipeline capacity? This is extremely important. We are aware that there is a lot of efforts now to improve, to enhance, the pipeline capacity to bring the oil to the international markets. And if those efforts are successful, it will increase the U.S. oil industry's ability to respond to the changes in the international oil markets because to produce oil is important but it is one thing.

The second thing is to send for the other nations that they need that oil and for that you need the pipeline capacity to increase. There's a lot of effort there but these efforts need to be, in our view, enhanced and the bureaucratic hurdles, in our view, need to be softened, eased in order to give licenses for those efforts.

Other than that, we don't see any major risk to observe substantial increase of U.S. oil coming to the markets.

When it comes to Alaska, Madam Chair, 2025 is too short to see substantial amount of oil coming from Alaska to the markets, but we know that there are huge resources there and with the improving of technology one may well expect beyond those dates the Alaskan oil goes to the customers as well.

I'm a believer of the economic facts. The economic facts are stubborn. The oil resources are there. Oil demand is going worldwide. I am sure, sooner or later, that oil will go to the customers around the world from Alaska.

The CHAIRMAN. Well, we are working on it as quickly as we can. I appreciate that.

I've got many, many more questions, but I am going to respect colleagues here and move to Senator Manchin.

Senator MANCHIN. Thank you, Madam Chairman. Very quickly, thank you so much again and your enlightening statement, the opening statement. So many things are going on.

We are trying to decarbonize, if you will, by using everything in a pragmatic way. You are telling me that no matter what we do in the United States of America, Asia has a younger coal fleet. They are going to basically run that coal fleet out for a minimum of 20 to 30 years. Is that the timeframe?

I would ask first of all: Most of the coal fleet we have left in the United States has used scrubbers, low NO_x boilers, and baghouses for mercury. We have taken most of the particulates and the harmful effects of the particulates out. CO₂ is what we have not been able to perfect through CCUS.

The coal fleets that are young and new over in Asia, do they have at least what we have been striving for with sulfur, NO_x and MATS? Have they—so all the China and India fleet coming on. So, they are building new, young, new fleets. Are they using this technology?

Mr. BIROL. Thank you very much, sir.

First of all, yes, efforts are, of course, very, very important to get efforts coming from, hopefully, from the rest of the world. But you're completely right, we have in the world, about 2,000 gigawatts of coal fleet and the bulk of it is in Asia today.

Senator MANCHIN. Right.

Dr. BIROL. And it is being—every day.

And to be honest with you, not all the countries building coal plants have their scrubbers, the so-called, the filters and on top of that, perhaps more subtle but maybe more importantly, some of them, even though they don't have the scrubbers, they don't use them during the generation of the electricity. For some reasons which is not well known to us to build it to equip the power plant to something to use it during the electricity generation something, yes. So this is what we are seeing.

Senator MANCHIN. But they are not using the scrubbers or—

Dr. BIROL. Not all the time.

Senator MANCHIN. Because of the cost, right?

Dr. BIROL. Exactly. Cost issues is—

Senator MANCHIN. So this is what I have a hard time with.

We have a global climate concern. We should have an alarming concern, but unless we get the rest of the globe to participate, how do we incentivize them? How, as the IEA, are you able to raise the flag that they should be participating? All these new coal-fired plants should use the latest in technology. For us to use carbon capture and sequestration, we have to do something because the cost is prohibitive right now if you don't have any enhanced revenue coming out of the ground when you sequester.

Dr. BIROL. Yes.

So we are talking with all these governments from Indonesia to China, China to India and for them the first thing, very important, is the cost of electricity. Then they think and they make a point

that because they are developing nations, but the obligations of our planet is definitely nothing to compromise there.

Senator MANCHIN. Right.

Dr. BIROL. So the scrubbers are very important for the aid of pollution in those cities and many of the major problems in those countries——

Senator MANCHIN. Well, the air that we see in China. And the other thing I would say is that storage is important as far as our renewables.

Is our wind and solar more efficient than China's and other places around the world? Do we have a more efficient renewable energy than others? And how close are we to the storage? As we know, it is intermittent.

Dr. BIROL. Yes.

Senator MANCHIN. And when the wind blows, we have electricity. When the sun shines, we have electricity. When it doesn't, we don't.

If we are overproducing in net periods of time, do you see storage coming on to where we will be able to be more efficient in those arenas?

Dr. BIROL. Yes.

First of all, you are right, the U.S. wind generation is much more efficient than the global averages, you're completely right there. But in terms of storage being commercially viable and used in a large scale, we are not yet there but there's a lot of R&D, research and development, coming around the world to make it commercially viable and use it in large scale. Because without the storage the benefits of solar and wind are not fully utilized. As you rightly mention, they are intermittent and they have a major challenge.

Senator MANCHIN. Finally, my last question.

If the United States wants to be a leader in reducing its carbon footprint, should it not use its trade policies, or so-called tariffs that we use in different types of opportunities that come to our markets, as an incentive to use the technology that we develop?

Dr. BIROL. The United States, today, is the leader of the global energy technology research and development. You have wonderful national laboratories around this country, and I believe there may be different ways of incentivizing them. It can move from putting tariffs or the value like you did, like the 45Q which is recent——

Senator MANCHIN. Right.

Dr. BIROL. ——to some regulations that can change from technology to technology.

But wherever I go, Mr. Senator, I give the 45Q as a gold star example to the rest of the world how the fossil fuel—of a country can marry with the environmental objectives in a market friendly way. So there are some examples.

Senator MANCHIN. Thank you.

Thank you, Madam Chairman.

The CHAIRMAN. Thank you.

Senator Cassidy.

Senator CASSIDY. Dr. Birol, I always enjoy your conversations.

What do you foresee for deepwater oil production? I am from Louisiana, so the Outer Continental Shelf is very important.

Dr. BIROL. It is definitely very important. I talk about the shale today as it is the big news around the world but also, of course, the offshore with the decreasing cost of deepwater, offshore technologies it will be growing world both for the United States and beyond, including Louisiana.

Senator CASSIDY. Have we reached that price point now where it is profitable to resume or to et cetera?

Dr. BIROL. I think we need to see that either the cost needs to go down, maybe tomorrow, or the process remain a little bit higher levels in order have a very decent profits there. But we are almost there. We are close to the break-even points.

Senator CASSIDY. Now you hear about energy but you spoke a lot about carbon. One thing that seems to empirically have occurred when the EU began their cap and trade system and we began to regulate greenhouse gas emissions, there appears to be a lot of carbon leakage to China and India.

You are nodding your head, yes.

Dr. BIROL. Yes.

Senator CASSIDY. And when you speak about their energy growth, it suggests to me that there will continue to be some carbon leakage, i.e., energy intensive manufacturing moving to China. Any thoughts on that?

Dr. BIROL. Yes, definitely.

The EU is putting climate change as a top priority in their energy and maybe economic policies and they are making a lot of efforts to reduce their CO₂ emissions, but the CO₂ emissions coming from, I don't know, from Paris or from Jakarta or from Ipswich or from Ottawa it is the same impact on everybody—

Senator CASSIDY. Now if they are not using—according to Mr. Manchin's question—if the coal-fired plants in China and India are not using scrubbers, whereas in Germany they are, it suggests to me that if we have carbon leakage from the EU, the United States to China, we actually end up with more global greenhouse gas emissions than we would if the industry stayed resident in the country of origin. Is that a fair statement?

Dr. BIROL. Yeah, I think it is going in the right direction. But what I mean is the following, we should do whatever we can do. But whatever we can do in Germany or the United States is not enough to reduce the CO₂ emissions at the appropriate level.

Senator CASSIDY. No, I realize that. But my question is if we put in a policy that merely causes a company to move energy intensive enterprises to China, it sounds from your statements, that we will end up net worse, globally, because China does not use the same environmental standards/techniques as do we.

Dr. BIROL. It may well be the case but I should tell you that India, China, Indonesia, they are also trying to reduce emissions but the main driver there comes from, not from their concern about the climate change. They're concerned about the local pollution in the cities which at the end of the day may have to reduce the CO₂ emissions as well.

But in any case, we have seen, for example last year, global CO₂ emissions once again increased and the main driver of that increase came from Asia.

Senator CASSIDY. And again, carbon leakage would contribute somewhat to that. Just the point I——

Dr. BIROL. Definitely.

Senator CASSIDY. Definitely.

Dr. BIROL. Oh, yeah.

Senator CASSIDY. Let's see if I have any more time. I sure do.

Next, you mentioned as well the CC, the carbon capture and sequestration. Do you see any use of captured CO₂ being economic, any use of it being economically viable in the short- or medium-term?

Dr. BIROL. Yeah. First of all, I believe carbon capture, utilization and storage is perhaps the most critical technology we have now if we want to find a peaceful marriage between the global fossil fuel resources and our environmental objectives. And here we can both do two things, to capture the carbon and store it or use the carbon.

Many countries are working to get money using carbon. There's a lot of research and development going there to put money on carbon, to make money out of carbon.

Senator CASSIDY. Do you see anything that is close to bearing fruit?

Dr. BIROL. It is not yet there to be very frank, but there's a lot of work going on.

But I should also highlight that the scrubbers are mainly used to reduce the local pollution and the CCUS is used to reduce the carbon, the so-called CO₂ emissions. So there are two important technologies addressing two important and long-term problems.

Senator CASSIDY. Real quickly.

So I am also gathering the degree to which the United States increases LNG exports to China allowing them to use cleaner burning LNG is the degree to which we can have a positive impact upon their global greenhouse gas emissions. Again, is that a fair statement?

Dr. BIROL. Exactly.

So what we have seen in the United States, for example, a big chunk of the major achievement of the United States in terms of historical drop-off CO₂ emissions was due to using a lot of——

Senator CASSIDY. And that is despite methane leakage because you mention methane leakage.

Dr. BIROL. Yes. It can happen also in China as well if the U.S. LNG replaces China's coal which is very, very likely. But the pure condition here is, as I mentioned, is the methane issue.

So it is very important that we produce natural gas in a responsible way to minimize, if not nullify, the methane venting and flaring, and the United States and other countries are taking measures in order to minimize the methane emissions there.

Senator CASSIDY. I am a minute over. I thank you, Madam Chair.

The CHAIRMAN. Thank you, Senator Cassidy.

Senator King.

Senator KING. My first question will surprise you, Madam Chairman.

The CHAIRMAN. Go ahead.

Senator KING. Thank you very much. I apologize for being late. I was in an Armed Services Committee meeting.

Are we headed for a place where natural gas, because of exports and the technology of LNG, is a worldwide commodity like oil? And if so, what does that imply for the domestic prices of natural gas here in this country where it is produced in great quantities?

Dr. BIROL. So, Mr. Senator, we are seeing natural gas is entering a golden age in the United States and globally because not only from the United States, but also from Australia, from Qatar, substantial amount from Canada, I just came from Canada, substantial amount of natural gas is coming to the markets.

And this is having two types of impacts. Number one, it is providing flexibility to the customers around the world. They can choose whatever the exporters they have, which conditions and this brings the prices down. Second, increasing natural gas production in the United States and elsewhere also puts downward pressure on the natural gas prices which is also very good news which is good for the heating bills of the families for electricity cost. So therefore, natural gas is good news overall, except for the countries who are pipeline exporters today.

Senator KING. My concern is—and maybe you just said that in your last phrase, I am not sure.

My concern is if we get to a place where we are exporting natural gas in much larger quantities than we are today, and it becomes a worldwide commodity. China increases its utilization, which could be almost infinite. Doesn't that inevitably put pressure, upward pressure, on prices which would reflect themselves in domestic prices?

What I am getting at is I am afraid of exports affecting the low price in the U.S., which is one of our few advantages in terms of things like manufacturing.

Dr. BIROL. I don't expect this to happen in a big manner, Mr. Senator. That may be different, some fluctuations, but the U.S. gas resources are so huge that even the prices we are talking about now it is enough to increase the production. There's a lot of resources now.

Senator KING. So it is supply and demand. You believe that the supply is so large that—

Dr. BIROL. I can give you one example, sir.

When the shale gas revolution started, we hit a lot of shale gas resources. And in the last ten years we used a lot from those resources, normally should go down because we use from those resources, but we have discovered in the United States also, a lot of resources. And now, as of today, the shale gas resources in the United States are seven times higher than 2010. So even though we also use because we have discovered with the new technologies, more resources.

So we have huge resources and I wouldn't worry of the shale or natural gas price spikes in the United States. That may be volatility, but the increase of the price is because of the exports.

Please do not forget that the exports, the revenues coming from exports will also inject U.S. dollars to the country's economy as well.

Senator KING. Well, I hope you are right. And I think what I hear you saying is that in the short- and medium-term, you do not see a risk to domestic prices.

But didn't that happen in Australia? I thought I had seen data that Australia's domestic prices went way up when they significantly increased their exports.

Dr. BIROL. The main reason there is some of the shale gas resource states in Australia put a ban on the shale gas production because of, as they said, environmental——

Senator KING. So they restricted the supply?

Dr. BIROL. Exactly, exactly.

And the ban because of environmental reasons, they say, didn't allow them to produce gas there.

Senator KING. Quick question.

We tend to think of ourselves as being the repository of all the research and work that is going on. I believe in your previous discussion you talked about the importance of storage.

Dr. BIROL. Yes.

Senator KING. In terms of developing solar and wind and other renewables, is significant research going on in other parts of the world on storage? It seems to me that is the greatest energy question we face right now.

Dr. BIROL. Everywhere, sir.

It is ranging from the United States to China, China to Europe, Europe to Japan. Everybody is after to find the economic solution to storage that can be used at the large scale so that we can address the limitations of wind and solar. But if you ask me whether or not we are there today that it is economically viable at the large scale, we are not yet there.

Senator KING. Give me a timeframe. Five years?

Dr. BIROL. Five years, it would be reasonable, but I would say between five and ten years.

Senator KING. So we are looking at technological breakthroughs.

Dr. BIROL. Exactly, technology breakthroughs, especially to bring the cost down because the cost issue today because we have also a lot of alternative technologies, established technologies such as the gas, such as the coal, such as others in order to make them competitive needing to bring the cost down and address the other challenges.

Senator KING. Thank you.

Thank you, Madam Chair.

The CHAIRMAN. Thank you, Senator King. Always good questions, we appreciate it.

Senator McSally.

Senator MCSALLY. Thank you, Madam Chair.

Dr. Birol, I served in the military, deployed to the Middle East five times. For many reasons I have long been an advocate for our energy security and energy independence to also be a part of our national security, because it is not just about energy prices and energy security is so much part of the geopolitical environment and where our reliance comes from related to these issues. So I think these last years have been so significant for us in America and in North America in the larger context of the geopolitical dynamics in the world.

You mentioned in your testimony on page three that there are energy security and sustainability challenges we still have to overcome. In particular, the Northeastern United States needs a more robust gas pipeline infrastructure to maintain supply security. I want to talk about this a little bit.

In 2016, it is my understanding that Massachusetts and New Hampshire blocked funding for the Access Northeast Pipeline. And in the cold snap of last year, it was reported that they, in fact, because of the challenges there, had an import from Novatek, a Russian oil company that was actually sanctioned by the Obama Administration and there was increased reliance on coal during the cold snap last year in the Northeast because of their ability to be resilient and provide and fill those gaps.

It just seems like there is potentially some activism or ideological views that are causing policymaking decisions in the Northeast that maybe do not have good outcomes related to our energy security, national security or other elements.

Could you just comment on that and what else needs to be done in order to better secure our energy security and issues related to this?

Dr. BIROL. Thank you very much for your question.

Before answering your question, if I may, since you worked in the Middle East and you follow, I guess, the Middle East issues, I would like to make the following point. I mentioned that the U.S. is set to become the number one oil producers of the world but this is different than the very fact that, for example, Saudi Arabia is still the number one oil exporter of the world.

So a lot of exports are still going from the Middle East to the rest of the world, especially to Asia where the economic growth comes from. Therefore, the oil security is still an issue because a price spike——

Senator MCSALLY. Right.

Dr. BIROL. If it happens, it will affect, including United States, all of us.

Senator MCSALLY. Right.

Dr. BIROL. Therefore, once again, I want to underline the critical importance of the strategic stocks we have in this country, also, of course, in Japan, Korea and Europe.

Coming back to your question. I, of course, I don't want to intervene in the internal discussions of this very nation, but not to have given permission to the pipelines to bring the gas from Point A to Point B is, in my view, economically, it doesn't make any sense. It doesn't make any sense because natural gas is one of the cleanest fuels we ever have and it is good for the United States, good for the United States' neighbors, U.S. partners around the world. But once again, I believe the economic facts are stubborn and at the end of the day those problems will be solved.

As I said, I came from Canada here. It was a problem in Canada, but now Canadians are pushing the Canadian LNG and the Canadian LNG is now meeting the Asian customers and they solved these pipeline problems. I believe it to be the same case across the United States because this is where the international is and it is every fuel has its own disadvantages or challenges. We have to see that. But we do need energy for our daily lives, for our economies.

Senator MCSALLY. Right, thank you.

I agree with you. I just think to summarize, it is important for us to have the pipelines to access the energy that we have here.

Dr. BIROL. Exactly.

Senator MCSALLY. And choosing not to do that, having states like Massachusetts rely on Russian imports, does not make any sense geopolitically.

And then also the reliance on coal which is an important, resilient factor—

Dr. BIROL. Exactly.

Senator MCSALLY. —for our energy is also the result of that.

So, let's not—let's do the right thing for our country, for our energy security and for the economic opportunities for people. Let's have that drive our decisions and not other factors.

Dr. BIROL. I completely agree, madam.

Senator MCSALLY. Great. Thank you.

Thank you, Madam Chair.

The CHAIRMAN. Thank you, Senator McSally.

Senator Cortez Masto.

Senator CORTEZ MASTO. Thank you, welcome, thank you so much.

I apologize I was not here earlier; I was in a Banking Committee hearing going on at the same time. We seem to do that here.

Let me talk a little bit about electrification of industries. We know that electrification can bring countless benefits, notably by reducing local pollution, but it requires additional measures to decarbonize the power supply in order to unlock its full potential. And furthermore, the World Energy Outlook for 2018 mentions that some significant parts of the energy system, such as long distance road freight shipping and aviation, are not electric ready with today's technology.

Doctor, you have previously stated that in order to decarbonize the whole energy system, we are going to have to start getting large amounts of wind and other renewables into heating, transport, and industrial processes. From your perspective, what research needs to be done to ensure that these three sectors catch up to the future of electrification?

Dr. BIROL. So thank you very much for this question as well.

I mentioned it to renewable energies, solar and wind, are penetrating the energy markets. This is true. But they are almost exclusively concentrating on the electricity systems, power systems. But we use energy also in the industry sector to produce, to manufacture, a lot of goods or we use energy also for the heating at home. We use energy for the transportation sector. The renewables are very little, if any use here.

So what are we going to do? So we can do at least two things. One, the bulk of the energy use in the industry sector are coal or gas and we have to, Mr. Manchin also highlighted, the CCUS, carbon capture, utilization and storage is a critical technology here and more research and development in this country is already being made, but outside as well would be very helpful. This is number one.

Number two. Another way of that, in addition to using the fossil fuels in a long-term way to CCUS, we can also see that the storage

is another thing also highlighted, storage, development of storage, making research and development there to bring the cost down and making renewables also used in the industry sector would be of crucial importance. Therefore, if I have to pick up two technologies that I would be very happy to see more research and development efforts go to, CCUS and the storage will be two candidates from my side.

Senator CORTEZ MASTO. So what potential do hydrogen fuel cells have for the industry?

Dr. BIROL. Hydrogen will also play a very important role, especially in the context of, we call that hard to abate sectors. Hard to abate meaning mainly the industrial, the iron steel sector, the petrochemical sector and others and, in fact, this year Japan is chairing the G20 meetings and the Prime Minister Abe asked the International Energy Agency to prepare a report on hydrogen, how it can help to decarbonize our energy system. And we are working very hard on that.

Hydro energy is also a very promising option. It was done many years ago, but it is coming back as a result of the lower cost of solar and wind and also diversification of our energy mix.

Senator CORTEZ MASTO. Thank you.

Recycling of critical minerals has not been economically viable to date. It is less expensive to mine raw minerals than to recycle with current technology, but mining these materials is highly complex and hazardous to both workers and the environment. With the demand of these materials growing throughout the world, what is your outlook on the potential for recycling these critical minerals to meet our manufacturing needs?

Dr. BIROL. With the current energy path we don't see a major problem with the current level of rare earths we have now. The problem is it is concentrated on a few countries around the world and it may well be again a secular energy supply question.

But in terms of availabilities, economic availability, we don't see a major challenge at the moment.

Senator CORTEZ MASTO. Thank you.

Thank you, Madam Chair.

The CHAIRMAN. Thank you, Senator Cortez Masto.

I am going to defer to my colleague here for a question. I think he is going to have to leave the Committee.

Senator MANCHIN. Really quick, I have to go to another committee, but Dr. Birol, thank you so much for being here. We look forward to staying in touch with you.

To follow up on Senator Cortez Masto's question on spent fuel—nuclear, right now—and you have showed that nuclear, the utilization of nuclear power in the United States, is reducing.

Dr. BIROL. Yeah.

Senator MANCHIN. And you think that is harming us as far as decarbonizing.

Dr. BIROL. Yes, sir.

Senator MANCHIN. You said that in your opening statements.

Is the reason for that because of our inability to dispose safely of the waste? Is that what is holding us back or is it basically that we are just not promoting it because of cost ineffectiveness of new nuclear reactors, if you will?

Dr. BIROL. I would say the second one, Mr. Senator.

You have lots of very tough regulations in this country. It's very good to have safety concerns. It's very good to have prepared measures.

But it is mainly the cost issue today and gas is very cheap, natural gas. The renewables are becoming also cheaper and cheaper and we have difficulties under the very heavy pressure of those existing regulations for the nuclear to be profitable. So, therefore, my plea is that we need to find ways to appreciate the contribution nuclear has for our electricity security and also for the environmental challenges and find some ways to——

Senator MANCHIN. Your opening statement was very enlightening in saying that basically, on a global basis, fossil is going to be used and depended upon and not always in the cleanest fashion to decarbonize.

Dr. BIROL. Exactly.

Senator MANCHIN. So no matter what the United States does, we are not making a dent in the atmosphere.

Dr. BIROL. Yeah.

Senator MANCHIN. It is basically coming from Asia right now. We can't get them up to speed.

But for us, basically not having our nuclear facilities online or coming up, you said, the number one thing if you want to decarbonize is carbon capture and utilization. And if the world would adapt technology that we could develop and basically perfect, that would be the number one source of decarbonizing.

Dr. BIROL. Exactly.

Senator MANCHIN. And then nuclear would be the number two source to rapidly decarbonize?

Dr. BIROL. Yeah.

Senator MANCHIN. As we develop technology for storage and using our renewables or hydrogen coming on, that is something in the future, but you are talking right now to stop the global warming that is going on. Is that accurate?

Dr. BIROL. Exactly. This is, we have so big challenges in terms of emissions because every time there comes a report or a government statement, government target, that we need to reduce emissions immediately, but when we look at the numbers, we see that the emissions are increasing.

There is a growing disconnect between those targets and what is happening in the real life. And this disconnect is very, very worrying and to be honest with you, we are not in a position to pick up our favorite technology today. We need all these technologies, renewables, CCUS, nuclear power, energy efficiency, if we are serious to address those challenges.

But the renewables are only making good inroads, but I believe it is CCUS and nuclear in the United States that need special attention if you want nuclear as a part of the U.S. power generation mix, which I believe, very important for the electricity security of the United States and also for the leadership of the United States globally.

Senator MANCHIN. Thank you.

The CHAIRMAN. I appreciate that, agree.

Senator Hoeven.

Senator HOEVEN. Thank you, Madam Chairman.

Greetings, Dr. Birol.

One of the things that I would like to get your input on is how we get natural gas to markets. In North Dakota we drill for oil, in the Bakken and other shale plays and so forth.

Today, we produce 1.4 million barrels a day of oil, 1.4 million barrels a day, and that is going up. And so, we don't drill for natural gas. We are not actively trying to produce natural gas, but every time we drill another oil well, we produce more natural gas.

So our challenge is capturing it and, you know, either processing it locally or shipping it off to markets, but our problem is getting it to markets. For example, whether it is Asia or the European market, we are constrained because of the difficulty of building LNG facilities on the West Coast—California, Oregon, Washington State, British Columbia—or getting a pipeline to the West Coast to move it most efficiently.

We are in a situation where we are producing more and more natural gas, but our challenge is to get it to market. So it is, you know, it would be very low cost. It would be a tremendous opportunity for us to export and get value. It is not only a very good economic proposition for the United States and for states like mine, but it is also a national security, geopolitical security issue, right? In other words, us selling energy to our allies rather than our adversaries, be that Russia or somebody else, right?

What can we do to convince people that we need to have access for pipelines and other means to export our natural gas? It is in the national interest of our country, the national economic interest and the national security interests of our country.

Dr. BIROL. Yes.

Senator HOEVEN. How do we do that?

Dr. BIROL. Thank you very much, Mr. Senator.

I think your problem is many countries around the world would consider as a "sweet problem" because many countries are dying to have natural gas for their energy mix. You have natural gas, but you are not able to export it.

Senator HOEVEN. Correct.

Dr. BIROL. So this is really such a pity because, as I said in the beginning, Asia is gas hungry. Asia is gas hungry and the amount of gas they need is huge, large amounts. There's a huge market out there and that market will be desperate to look for the U.S. natural gas in terms of LNG.

I think the missing link between you and Asian gas markets is the pipeline capacity. So this is what needs to be done is the, to have the right investment framework there and to tell the investors how lucrative those returns would be and to tell them that there's a huge amount of demand for your natural gas waiting in Asia.

Senator HOEVEN. It is not an investor issue. I think the investors—I know the investors would step up right now and build the infrastructure. The challenge is the approval process. How do we win the argument so we can get approval to build? The capital is there. I mean, the price of natural gas in our state, it is not zero, it is probably negative because what do they do with it?

Dr. BIROL. It comes anyway.

Senator HOEVEN. They can't flare it off. They have to capture it. There is a cost to it. And if they can't market it, what do they do with it?

There is, I think, any number of investors that would build, put the investment forward right now to build the pipelines. The problem is getting the approvals.

Dr. BIROL. Yeah.

When I said the investment framework was essential I also meant the, all these administrative processes which are sometimes too slow and it makes the investors losing their appetite for the steps they are going to make. And it is the case in many countries around the world, but maybe a bit too much in some other parts of the world which would lead to a loss of money, loss of economic value in the exporting countries.

And when you think about what is being lost, it's not only the money, but U.S. providing the security, energy security, around the world.

Senator HOEVEN. Right.

Dr. BIROL. In terms of providing flexibility in the gas markets, it is not only losing money, but losing from the energy security in the world.

Senator HOEVEN. Right.

How do we convince people that this is a winning proposition? It is a winning proposition as we are talking about economically, it is a winning proposition in terms of national security and our global security interests, and it is a winning issue from an environmental standpoint, you know, with natural gas.

Dr. BIROL. Exactly.

Senator HOEVEN. And the infrastructure to move it most efficiently, cost-effectively, is also the most environmentally sound.

Dr. BIROL. Yeah.

And definitely, we're talking about the CO₂ emissions in the world and when I said Asia is waiting for the U.S. natural gas, it is in most cases, it will end up with reducing the global CO₂ emissions which is a net benefit for the world.

But of course, what needs to be done is to find ways to ease up those administrative steps and bureaucratic hurdles through administrative measures.

Senator HOEVEN. Well, absolutely.

I mean, if you are going to commit to billions in capital it takes to build that kind of pipeline, you probably want to know that you are going to be able to build it, don't you?

Dr. BIROL. Exactly. Definitely, definitely.

The CHAIRMAN. Thank you, Senator Hoeven.

We are talking about, when you say that the missing link here in addressing the Asian market is pipeline capacity—

Dr. BIROL. Yes.

The CHAIRMAN. —there are some who are not bothering with that, and I want to talk about Russia here for a moment. I am glad that my colleague and co-chair of the Arctic Caucus is with me today, because it is an issue that I think we are just closing our eyes to here in the United States and that is what is going on with Russia and how Russia is working to meet the Asian demand for natural gas.

There is a lot of discussion. I think everybody over here, Senator Manchin just mentioned his opposition to the Nord Stream 2 pipeline, we focus a lot on the sanctions against Russia in these, you know, asking our European friends and allies to join us with this. Again, a lot of discussion there.

Well, up in the top, up in the Yamal Peninsula right now, Russia is going “hucklety-buckle” and they are producing in a way, bringing on these resources that I think has really been quite remarkable. And they are not building a pipeline across Siberia. What they are doing is they are putting that natural gas into LNG tankers. These are tankers that are being built by South Korea. They are ice strengthened, so they can go through the Northern Sea. They are going down—they are coming right through the Bering Strait, you know, 20, 30, 40 miles from Alaska—going down and meeting the demand in Korea. They are working with Japan to supply Japan with natural gas. Nobody is raising the hue and cry about well, wait a minute, where are the Russian sanctions when it comes to oil over here?

In Alaska, we are still quite a few years away. We have been struggling to get an agreement for a pipeline through Alaska that could take our natural gas to Tidewater and supply that Asian market. Our market has never been in the Lower 48. It has always been Asia. Well, we are working to gain these partnerships. We have made good headway, not only with Korea, Japan, Vietnam, Russia, certainly with Russia with the past Administration.

But if you can, give me some of your observations here. You mentioned a little bit about Russia’s role, but how has the stepped-up activity in Russia, particularly coming off the Yamal Peninsula, how has the increased LNG production in the Arctic impacted the global energy markets as well as the Russian sanctions here? Because I am trying to get some attention to the Arctic issues.

Dr. BIROL. Yes.

The CHAIRMAN. And I think we just, kind of, have a tendency to either stick our head in the sand or stick our head in the snow on this one. And Russia is not sitting around waiting, and neither are some of our other Arctic neighbors. In fact, our non-Arctic neighbors—China, Japan, Korea—are having discussions about this as we speak. They are more involved in the Arctic right now than we are.

Dr. BIROL. This is an excellent, excellent question. Thank you very much, Madam Chair.

Let me put it this way, there are two important current and possible customers of Russia—Europe and Asia. In Europe, many countries since long time came to the conclusion that they need to reduce the Russian gas imports because of the energy security. But what is happening is just opposite. At the end of 2018 the share of Russian gas in the European gas consumption reached a record high, about close to 40 percent mainly in addition to pipelines, as you mentioned LNG coming from Russia to you. It is a very important trend. Forty percent of the European gas, close to 40 percent, comes from Russian pipelines and now with LNG.

This is—Russia or in other countries political intentions for any business to rely on one single partner is, in my view, a risky way to go.

Plus, European domestic gas production is in a decline now. There are a couple of fields which are in a decline. Therefore, European gas imports will increase very rapidly.

Now the question is, new imports will come from, again, from Russia or from other countries. This is a historical moment. It is the reason why I tried to say in the beginning of my remarks, in my view, if the U.S. Government, U.S. Administration, uses in a wise way, we may well see the full impact of shale starting now. And how we see it, we see that the U.S. shale comes to the markets in a big time and also competes with the Russian and other gas exporters.

Some people say that the U.S. gas, U.S. LNG, is more expensive than the Russian pipe, but I say the following. We have calculated, Madam Chair, let's assume one major European economy who has no LNG facility. If this country decides to build an LNG facility, it will give this country a very important negotiation power with the contracts they have with the partner exporter, such as Russia. And because they will say, if you don't bring the prices down, I have LNG for sale, I will import LNG. And we have calculated that if they improve their LNG contracts only one percent of the gas prices as a result of having another option in their hand, it would be enough to finance a major LNG facility for 30 years. So therefore, to have the LNG facility there would be very important to negotiate with Russia and others to bring the prices down. This is number one.

Number two. Many countries, some OPEC members and Russia wants to bring the oil prices up higher levels. If the oil prices go up, most of those contracts to Europe are indexed oil prices. Those gas prices will go up and in the United States, as one of the Senators mentioned here, most of the gas in the United States is associated gas. Since the oil prices go up, oil production will go up. Therefore, the shale production, shale gas production, will go up and the prices of gas will go down. So the difference between the contracted oil/gas to oil index gas prices will go up, U.S. shale prices will go down, and economically it will be much more visible.

Coming back to Asia. I have a completely different picture. I see a huge opportunity U.S. LNG making major, major, having a major market share in Asia, especially replacing inefficient coal plants because the biggest headache today in China, India, Thailand in those countries is the air pollution in the cities, local pollution in the cities. And natural gas may well be the key solution to all of those countries, and they are building LNG terminals. China built, only in the last five years, 13 new LNG terminals. And United States together with Australia is a very good candidate to bring LNG there, also to India, also to Japan, of course, to Korea, the other countries in the southeast Asia region of the world.

So there will be a very harsh competition between the established exporters such as Russia and the U.S. LNG. And I see many great opportunities for the U.S. LNG to have good competition, bringing more flexibility to the markets because U.S. LNG is much more flexible and much more optional and I see that it will be bringing more, make the gas markets much more fluid than it is today. And it is the reason many countries are now building LNG terminals.

When we look at the next ten years, we see that the LNG trade is at least three times faster developing competitive pipeline gas trade. There's a big growth there. And U.S. is the number one candidate to fill that gap, Madam.

The CHAIRMAN. I am going to come back to the Arctic, because I am still curious about how you see Russia's LNG in Asian countries and impacting them. But I didn't stop you, because I think what you have outlined is so key to all of these discussions.

I want to have a little more follow-on there, but let me turn to Senator King.

Senator KING. First, Madam Chair, I just want to compliment you on the passage of the Lands package. I often think we don't celebrate enough around here. We always focus on the next problem. This Committee and you, as the Chair, had one of the most significant legislative achievements in decades in the last two weeks, and I just think we ought to take a minute and say this is something that was well done and will be important for the country for generations.

The CHAIRMAN. And if we were 16, we would all go like this. [Snapping fingers.]

[Laughter.]

But thank you, I appreciate that.

Senator KING. So I do want to thank you.

And thank you for your testimony, Doctor. It has been very, very illuminating.

I will just share one little thought which you could put in your rhetorical tool box. We are always looking for a silver bullet, something that will solve the problem with one solution. I have a good friend in Maine who says there is rarely a silver bullet; there is often silver buckshot.

Dr. BIROL. Yes.

Senator KING. A lot of solutions.

And I think one of the things we take from your testimony today is that the world energy situation is not subject to a silver bullet, although natural gas has an important role to play, as you say. But there are all kinds of other pieces of this puzzle, and I think that is one of the things that we have learned today. And we have to work on all of them.

Dr. BIROL. Exactly.

Senator KING. And I think that is important.

An example is the Senator from Arizona. It was heartening, by the way, to have a Senator from Arizona expressing sympathy with the weather plight of New England.

[Laughter.]

But the interesting part about that issue which I have been very involved with for some years, is that it is a short-term problem. And the economic and energy issue is, do you develop a billion dollars' worth of pipeline for a two-week problem or is that a storage issue, and what other kinds of options are there? LNG may be one of the options, storage in the region in order to meet the demand that comes in a few week period, usually in January.

It is a very serious problem. It is very serious, because it gets priced into our electric rates and we are now 50 percent dependent upon natural gas.

So, I don't expect an answer to that, but I think this is another kind of storage. It is not day-to-day storage, but it is a longer period storage to meet a shortfall.

Maybe the pipeline capacity is the answer, but it is at least worth discussing what is the exact nature of the risk and what is the most cost-effective way to solve it?

If you have any thoughts, I—

Dr. BIROL. Thank you very much, Mr. Senator.

First of all, if I can wholeheartedly agree with you that in the world of energy, unfortunately, we don't have this silver bullet. We work on all the fuels, all the technologies since 45 years but we have not yet discovered the back door to paradise, if I may say so. It's definitely a big challenge.

But we are, we need to improve the technologies which are promising and which needs more help such as CCUS, such as the electricity storage you mentioned a few minutes ago. I think it will be a combination of all these technologies working together to have a more sustainable and secure energy system.

But it can change from one country to another. Some countries, for some reason, don't want to have nuclear. It is their choice. Some countries don't want to use renewables. It is their choice. But we believe at the IEA we have to make use of all of them because there is not even one perfect solution. Even natural gas, you say, in fact natural gas is an excellent, excellent fuel in terms of addressing the, reducing the local pollution, be plant available pressure not so high but natural gas, if not produced sustainably, it has some impact on the environment as that so both methane leakage going into the atmosphere—

Senator KING. And there is a concern. We have the concern, and I have the concern in New England. We are now 50 percent dependent upon natural gas for our electricity supply. That was maybe five percent 20 years ago.

Dr. BIROL. Yes.

Senator KING. There is a danger, as you pointed out, when you have one customer.

Dr. BIROL. Yeah.

Senator KING. When you have one energy source, particularly if it is a fossil fuel that we have no control whatsoever about the price, it is a commodity. There is a risk there where, again, diversity of sources seems to me is the best policy.

Dr. BIROL. Exactly.

And if, I agree with you that there is no silver bullet but if there's a magic word in the energy world for me it is the diversification. Diversification is always good for the energy sources, for your customers, your importers, your exporters.

Coming back to your question on natural gas. Of course, the gas storage is very important to have enough amount of gas storage and the adequate level of pipeline capacity answers to the problem. But of course, I didn't study your case very carefully, but 50 percent reliance on natural gas may be on the high side.

Senator KING. Thank you.

Thank you, Madam Chair.

The CHAIRMAN. Senator Cortez Masto.

Senator CORTEZ MASTO. Thank you.

Let me shift gears for a little bit. I am curious. I am from a Western state and in the West, water is a very precious commodity. So much so I think there is a famous quote that says, "Whiskey is for drinking, water is for fighting." And I understand, for the first time, the World Energy Outlook incorporates a water dimension in the sustainable development scenario——

Dr. BIROL. Yes.

Senator CORTEZ MASTO. —illustrating how water constraints can affect future fuel and technology choices. I also understand a sustainable development scenario details the energy required to provide universal access to clean water and sanitation for countries around the world.

I am curious, how is the IEA compensating for changes in water availability and the potential declining supply of water as you conduct your reports and analysis?

Dr. BIROL. Now, first of all, water is extremely important for the energy sector. We need water, for example, we talk about the shale gas and we need water for shale gas for LNG. We need water for biofuels. We need water also when we're talking about the power plants, coal plants, nuclear plants. You need water to cool down the towers of those power plants. It is a very important element for the energy system.

But we see that the availability of water is becoming a question in many places around the world, including the United States. Therefore, now water this time comes to energy because now energy is used and will be used more and more to desalinate the water, desalination of water and use it as tap water, useable water. So not only the energy sector needs water but to get, to make water, drinkable water and also to be useable water, we need energy to desalinate the seawater and make use of it.

But if I look at the trends, the availability of water will be a question, at least for the energy sector, for many years to come. Not a big problem in the United States, but a growing problem, especially in Middle East and Africa.

Senator CORTEZ MASTO. Well, in the Western states we know this, and I appreciate your comments because I think we have looked at desalination, and it just does not pencil out right now. I think Israel does an incredible job with desalination.

Dr. BIROL. Yes.

Senator CORTEZ MASTO. But in the Western states, particularly those along the border of the Colorado, we are in a drought mode. Water is precious. And utilization of that water, how we manage that water amongst the states, is important moving forward.

And so, I appreciate the thought now that as we incorporate and move forward and look at, not only future fuel in our energy portfolio and those technologies, but also water and how it is incorporated into this is going to be important whether we can move forward or not, particularly whether you are a Western state or an Eastern state.

Dr. BIROL. Exactly.

Senator CORTEZ MASTO. So, thank you, I appreciate that.

Dr. BIROL. Thank you very much.

The CHAIRMAN. Thank you, Senator. I always appreciate when we are able to bring back the issue of water.

In our Energy 2020 that we laid down some years ago, we had a little chapter there on the energy water nexus. It was really the first time we had had conversation about this and the key, as you have mentioned, Dr. Birol, you can't produce energy without water and you can't have water without energy. And so, understanding that and how it all fits in is so, so key. So the fact that you have included it as well.

I want to ask about a couple different policy initiatives that are coming our way in the very short-term.

The first one is this IMO 2020. The International Maritime Organization (IMO) regulation that is going to go into effect, literally overnight, capping the amount of sulfur in the marine fuel.

What is your best estimate in terms of the impact that this regulation is going to have on the middle distillate market? What are we going to see with regards to diesel fuel, jet fuel prices? Are we going to see a jump up with that?

There has not been a lot of discussion about it, and it is one of these things where I am afraid we are going to wake up on January 1st and people are going to be saying, what just happened there? Yet, theoretically, we have been planning for it for years now. But your observations, please.

Dr. BIROL. Thank you very much.

I would be happy to mention this, but also one point on the Arctic, I will comment on that, if you don't mind.

For that, you are right, these regulations from the IMO are very serious and there was, in the beginning, a bit of a type of panic in the oil industry. But what we are seeing now with all of the oil industry around the world, the refineries are adjusting themselves to these regulations.

There may be some temporary price spikes for diesel, jet fuel prices, but we think that the market will adjust and we don't expect those price spikes will be long lasting and big. There will be some adjustment period but refineries are now, today, being configured according to the IMO rules around the world and the U.S. is one of the leaders.

The CHAIRMAN. So, you don't think that it would potentially be necessary to have, kind of, a phase in period just to avoid any potential for price spikes? It sounds like you think that we are preparing for this and will be ready.

Dr. BIROL. Definitely. We are preparing around the world. There may be some price spikes, but it will be temporary and it will not be big.

In terms of Arctic, I think you are completely right from your perspective. Russia is making substantial efforts in terms of the LNG from Yamal, but the volumes are not yet that big, but they are working on that.

But in my view, this is a signal for the United States that if the U.S. wants to get the market share, to put the market share in its pocket, it should move very fast in order to get that market share because the volumes might not be very big today, but tomorrow it may be bigger and they will be a much tougher competitor.

The CHAIRMAN. So you see that as an area of growth for Russia. Do you factor that in as you are looking then to where the demand

for natural gas is coming from? Do you see the production in this very remote part of Russia as coming on in a significant way?

Dr. BIROL. Yes.

The CHAIRMAN. Or what does your analysis show you at this point?

Dr. BIROL. Currently, Madam Chair, not big volumes but I can't exclude that it will grow in the future. My advice would be to take this challenge seriously and the U.S. LNG should, I think, be ready to compete with the possible growth coming from Yamal LNG which is small today but may be bigger tomorrow.

The issues that some of the Senators mentioned today, not having enough licenses for building the pipeline capacity, I think those decision-makers should see those facts and perhaps make their decisions accordingly.

The CHAIRMAN. I appreciate that.

I thank you for your focus on nuclear and a recognition that when it comes to nuclear and leadership, the United States had a very, very, very key role and we are standing, almost standing, down on that. And I do not, I hesitate to use that terminology because it makes it sound pretty dismal, but to know that right now 20 percent here in the United States comes from nuclear but we are headed down to 7 percent.

Dr. BIROL. Yes.

The CHAIRMAN. Again, when we want to talk about ways that we can be meaningfully reducing our emissions in this country and around the world, in my view, nuclear energy is that source that we should be looking to and making those investments in an aggressive way toward the advanced technologies in dealing with our waste issues but really being aggressive rather than, kind of, pulling back on that now. I am more than a little bit concerned that we are placing less value on nuclear here.

I have been trying to take point on this and move us out, but when you look around the world, you mentioned that China is moving more aggressively with nuclear. What other nations are stepping up? I mean, there have been some very political reasons where countries have drawn back after the horrible incident in Fukushima, Japan, but we saw some of the European nations really pulling back. Do you see that turning at all where there is now renewed interest in nuclear? Speak a little bit more to your long-term view.

Dr. BIROL. Right.

Thank you very much for this opportunity.

Now we see that not only in the U.S. but also in Europe, the share of nuclear will go down if there is no policy change. And there are two countries going in the other direction, China and Russia. China and Russia are building nuclear power plants and what will happen if the policies do not change? At least two things. One, the U.S. and Europe will lose major technological advantage because many countries around the world would like to import nuclear technology and China and Russia by learning by doing, they are bringing the cost of nuclear down. And therefore, they will have more advantage compared to U.S. or the European countries to sell their nuclear technology.

So this is because cost is a major issue and the United States, we have, or in Europe, we don't build any nuclear power plants, perhaps just a few and we are even the opposite of learning by doing, forgetting by not doing. So we are forgetting how to do these technologies.

The CHAIRMAN. Yes.

Dr. BIROL. So, therefore, it is, you know, the second one is, in my view, you rightly mention, again, Madam Chair, the emissions. Nuclear is a technology which reduces the emissions in a very, very radical way.

And in the absence of nuclear, the reaching our environmental goals will be much, much tougher. And when we look at today, we talk about the United States being also a successful country in terms of renewables, but in nuclear generating electricity as much as all the other renewable sources put together in the United States today. Losing this would be, in my view, not a very wise policy.

So this would be another negative implication and, of course, I am only talking about here energy and environment, not U.S. but other countries being together on nuclear capacity may well have other implications beyond energy and environment.

The CHAIRMAN. You had made the comment that most notably in places like Russia, certainly India, while environmental concerns are important that affordability, access to electricity—

Dr. BIROL. Yeah.

The CHAIRMAN. —these are the things that are really driving, as they are working to build out these countries here.

Do you think we get to a point with nuclear where it is viewed as, not only the environmental choice, but from the perspective of the cost and a stability of cost that we are going to see greater investments? Obviously China is taking that step, but in other countries as well.

I just see the focus, the global focus on what we are dealing with with our emissions, recognizing that, and I noted in my opening comments, we were on a pretty good trend here in the United States with reducing our emissions. But you know, we have bumped back up here. I want to think that that is just a temporary bump, and we are going to work to keep reducing them.

But is this global dialogue about how we reduce our emissions, will that begin to have an impact on some of the investment and policy decisions or is it still always going to be about, what does it cost me to stay warm, to stay cool, to keep my lights on?

Dr. BIROL. First, about the nuclear, I think the challenge for current nuclear technologies, the first down payment is very, very high cost but operation costs are very cheap.

Since a big chunk of this new investment needs to be done in the emerging countries whose the financial means are a little limited, it may not be a mushrooming technology in those countries.

Having said that, advanced nuclear technology such as small modular reactors (SMRs) can be a very good fit for those countries and in the United States and other parts of the world there's a lot of work going there. And if we see the commercial success in the SMRs, it can be definitely one of the favorite options.

Now, the investments today are going for renewables but at the same time for oil, at the same time for gas and coal. It is very difficult to say that there is a clear winner today.

But when we look at the last year, for example, more than 50 percent of the new power capacity came in the world was solar only. Solar was 50 percent, everything else put again, another 50 percent and the renewables are getting a lot of attention from investment community as well.

The CHAIRMAN. One last question, and it is something that nobody has really hit on today. In your outlook you mention that the electricity sector, star of the show, is experiencing its most dramatic transformation since its creation more than a century ago, a lot of focus and attention on that as well and acknowledgement that our electricity grid is increasingly becoming more digitalized. This allows us to be clearly smarter, much more efficient which, again, is important for a more flexible grid.

But it then presents issues that make us realize how vulnerable our grid can be to any level of cyberattack. Your thoughts on how we balance the real benefits of this digitization of our electric sector versus the vulnerabilities that are then created. And are there any good examples worldwide where some nations are really aggressively taking this on in a way that you see is making a difference?

I know that here this is an issue that we talk about in every single committee that I am on, but it is almost like this is so big we don't know how to start taking a bite at this elephant. And so, looking to others who might be able to show some progress here would be interesting to learn from.

Dr. BIROL. This is an extremely important point, Madam Chair.

In the '70s when the IEA was founded, oil security was a key issue and it still is. There is no change there. But electricity security is becoming a major issue as well for two reasons.

One, the share of solar and wind, they are increasing in our electricity system and if we do not take the necessary measures, in the absence of solar and wind, we may see blackouts. For examples, we have seen one in Australia recently. The share of renewables was more than 50 percent in that day, there was no electricity and blackout in our country like Australia. So this is one electricity security issue.

The second one is the cybersecurity and this is an area which needs the utmost attention of not the energy people, but also security people and the necessary measures and the backup technologies and backup the security measures need to be taken in an area, that again, we are working very hard with the regulators, system operators and also security forces so that we are prepared for cybersecurity attacks.

To be very frank with you, we have 30 member countries and, if you ask me if any of those countries are fully equipped vis-à-vis such cyberattacks, I would have hesitations to say yes to you for any country we have. It's a major issue and we all know that without electricity, hospitals, lifts, nothing will work and our system will be completely paralyzed.

As such, we have as IEA, in addition to oil security we are working now on the electricity security as a major issue for us too.

The CHAIRMAN. Good.

Well, next year we will anxiously await your report to see what progress you have made on that. It is certainly key.

Senator Cortez Masto, did you have any other comments or questions that you wanted to ask?

Senator CORTEZ MASTO. No, thank you.

The CHAIRMAN. I want to thank you, Dr. Birol. You have been, again, very informative. It has been a very important discussion.

I always leave these hearings taking my notes with me and finding myself referring to them throughout the year. But you have given us some good reminders here when you start off with just the reminder that, you know, no country is an energy island. We sure got that.

But a reminder, too, that the role that the United States is playing when it comes to oil and natural gas is not only important for us, it is important globally, it is important to our partners, to our allies.

And we have a lot of good news that is there. We have some policy considerations that we need to address that relate to a limitation of our own capacity here that we can address that and help ourselves and help others. I think that that is significant.

You know, we always ask, are there any, whether it is silver bullets or silver buckshot, as Senator King reminded us, but you have given us some specifics where the United States is leading.

You mentioned the 45Q as a business model out there. You have clearly reminded us that if we want to truly work toward a diversified portfolio that helps us reduce our emissions, in addition to what we are doing with renewables, that nuclear and particularly, advanced nuclear, has got to be so much of our calculus here.

We have no shortage of issues to deal with before the Committee, but I think as we move forward and lay down our priorities here, what you have given us this morning and what the agency has provided us with—just the background and the factual analysis—is good, it is solid and it allows us to be better informed as we move forward with our policies.

So, again, I thank you in so many ways for your leadership on this. And again, thank you for coming to the Energy Committee this morning.

With that, the Committee stands adjourned.

[Whereupon, at 11:56 a.m. the hearing was adjourned.]

APPENDIX MATERIAL SUBMITTED

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Questions from Chairman Lisa Murkowski

Question 1: You note that Asia is a primary driver of the projected 25 percent growth in global energy consumption by 2040, and that air pollution is motivating energy policy across that continent. As China, India, and other countries in Asia look to increase investments in cleaner energy sources like renewables and natural gas, will that be enough to negate any emissions uptick associated with the significant increase in energy consumption?

Under the IEA's New Policies Scenario, developing Asia is projected to see an increase in energy demand of 50% through to 2040 – two-thirds of the projected global increase. Significant investment in natural gas and renewable energy technologies will allow most Asian countries to reduce the CO2 emissions intensity of energy demand.

In China, this shift in the energy mix is sufficient to see a peak in emissions in the next decade, with emissions falling below today's level by 2040, despite a 26% increase in energy demand. However, this is not the case across the rest of developing Asia, where energy demand is projected to increase by almost 90% to 2040, while emissions nearly double.

Question 2: Your testimony noted that U.S. supply increases have provided stability and promoted global growth at a time when the market is seeing events—like the uncertainty in both Venezuela and Iran—that could have caused significant price shocks. In addition to its abundant domestic benefits, our development is providing international benefits. However, you also noted that international oil supplies are seeing significant natural declines, and the world will need large new investments in oil exploration and development to maintain supplies at even flat levels in the years ahead.

- Either domestically or internationally, where do you see investment flowing to make up this shortfall? Do our international competitors have significant existing spare capacity without new investment?

There is considerable investment planned in the US, particularly in the shale regions, but also in the Gulf of Mexico. We also see a major expansion of the domestic pipeline system and capacity at export terminals. As a result, we expect to see the US contribute growing volumes of crude oil and products to international markets in the years to come. Elsewhere, our analysis shows that as a result of investments, some of which have had a long lead time, production will increase in several other countries led by Brazil, Canada, Iraq, Norway, UAE and newcomer Guyana. There are smaller increases elsewhere. Even in countries where projects were considered to be “long cycle”, the time taken to bring new discoveries to first production has been reduced.

On the question of spare capacity, only OPEC countries have any significant volumes at about 2.5 mb/d, more than half of which is in Saudi Arabia. Unless there is investment, the spare capacity cushion will dwindle to very low levels. This means that in the event of a sudden emergency there is a risk of a de-stabilising price spike. Our estimate of the current spare capacity does not include volumes for Iran, Venezuela or the Neutral Zone. In these cases, barrels are not available due to political or operational reasons.

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- How do the domestic options compare to international competitors?

The US is very attractive for oil investment for several reasons. Compared to most other countries, it is relatively easy to develop resources and take them to market. This is particularly so since the lifting of the crude oil export ban. There is also minimal political risk in the US. The international oil companies have been major investors in the Gulf of Mexico, and they are gaining a larger foothold in the shale sector. However, they are active in many other countries where resources might be closer to growth markets. It is not an issue of the US or elsewhere. Oil is used in every country and international oil companies will always hold a territorially-balanced portfolio to maximise their market opportunities.

Question 3: You mentioned burgeoning Asian gas demand, and that it would take annual supply increases equivalent to multiple new average-sized U.S. LNG facilities to satisfy this demand growth.

- How does this compare with the significant number of LNG projects currently under review by FERC? Are we on our way to meeting this need?

The Asia Pacific region is forecast to account for half of global natural gas consumption growth for the coming five years – mainly driven by China which alone comprises almost 40% of the total increase. India contributes 7% to global growth and the rest of the region 11%. Asia Pacific is expected to add over 200 billion cubic meters of natural gas consumption between 2017 and 2023, while the region's production is expected to grow by less than 100 bcm over the same period. New LNG projects will therefore account for most of the growing supply demand gap, the United States being the single largest contributor to LNG trade growth based on LNG export capacity with final investment decision as of today.

- How long does IEA expect this growth to continue? Will it be sustained over several years? Over a decade?

Asia Pacific's natural gas consumption is expected to grow at an average 4% per year between 2017 and 2023 – this structural trend is assumed to last through the longer term with our New Policies Scenarios showing an average 3% per year growth rate to 2040.

- Who are our primary competitors for meeting this demand?

Australia is currently on the verge of becoming the largest exporter of LNG, with capacity ramping up from its latest projects, but no additional export capacity is planned as of today.

Qatar has announced its intention to expand its existing export infrastructures from 77 to 110 million tonnes per annum (mtpa) by 2024 and will see a sizeable share of its existing contracts expiring in the next decade, thus freeing up additional volumes for potential sale to emerging markets.

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Russia's Novatek recently raised its 2030 LNG export objective to 70 mtpa while incumbent Gazprom is also planning to develop new export projects.

New exporters such as Mozambique or Argentina have also great ambitions in terms of medium to longer term development, while Canada's first export project is scheduled for 2025.

Question 4: During the hearing, we discussed the International Maritime Organization's upcoming "IMO 2020" regulation and potential price impacts from its implementation. You highlighted that refineries are adjusting and that IEA does not believe a price spike will be "long-lasting." How long do you project that prices will remain higher as a result of this regulation?

Any price increase is unlikely to last beyond 2020. The IEA does not forecast prices as such, but we needed to make assumptions in our models regarding the possible price impact on diesel markets resulting from the IMO switch. Our balances indicated that, when analysing the respective diesel needs for inland uses, marine gasoil and blending, there will be an initial shortfall. We therefore think that diesel prices will have to increase in 2020 to rebalance the market, by increasing supply and reducing demand. Markets should, however, rapidly adjust.

Questions from Ranking Member Joe Manchin III

Question 1: As you mentioned in your testimony, most future coal demand growth will be driven by power generation in emerging Asian countries, and the average age of Asian coal plants is less than 15 years old. Based on current policies, coal will make up 51% and 57% of China and India's generation mix in 2040, respectively. And in all of the scenarios presented in the World Energy Outlook, coal remains an important part of the energy mix. As a result, technologies like carbon capture, utilization, and storage (CCUS) are going to be critical to decarbonizing the power sector. The U.S. must lead in this space in order to incentivize China and India to clean up their use of fossil fuels. Right now there are only two large-scale CCUS power generation projects in operation, including one in the U.S. What role do you see CCUS playing in the coming decades?

CCUS technologies will be critically important in meeting globally-agreed climate and energy goals. CCUS is the only technology solution able to deliver the deep emissions reductions needed across key industrial processes such as steel, cement and chemicals manufacturing, all of which will remain vital building blocks of modern society. In the power sector, CCUS can support near-zero emissions from coal and gas power generation and provide greater diversity in generation options. CCUS technologies also provide the foundation for negative emissions or carbon removal, a likely requirement for achieving net zero emissions globally.

The ability to retrofit CCUS to power and industrial facilities is significant when considering the potential lock-in of emissions from existing infrastructure. IEA analysis has highlighted that today's energy-using infrastructure would absorb more than 90% of the allowable CO₂ emissions to 2040 in a pathway consistent with climate goals (the IEA's Sustainable Development Scenario). For example, coal-fired power plants could account for one-third of these "locked-in" emissions, with three-quarters of the global coal fleet located in Asia where the average plant

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age is just 11 years, compared with more than 40 years in Europe and the US. Retrofitting of CCUS can bridge the practical reality of these existing and long-lived investments and the need for rapid emissions reductions.

How does current investment in CCUS stack up against investment in other technologies, and where does it need to be?

Investment in large-scale CCUS facilities has been limited and in recent years has represented less than 0.1% of global investment in low-carbon energy. This reflects a lack of public support for CCUS investment in most jurisdictions relative to other low emission technologies. Globally, the level of public funding support flowing to large-scale CCUS projects over the past decade is equivalent to 3% of the subsidies received by renewable energy in 2016 alone.

Investment in CCUS would need to rapidly scale-up to be consistent with the level of deployment seen in the IEA's Sustainable Development Scenario. Today's CO₂ capture rates represents less than 4% of that required by 2030 in the SDS.

What have you seen as a barrier to CCUS deployment globally?

The key barrier to CCUS deployment is no longer technical, but commercial. The scale of the commercial barrier can vary considerably across CCUS applications: global analysis by the IEA has found that as much as 450 MtCO₂ could be captured for use or storage each year with an incentive of less than USD 40 per tonne. This highlights that there are lower-cost opportunities for CCUS investment, most often involving industrial processes that produce a relatively pure stream of CO₂ and where revenue for CO₂-EOR may be available. Yet in most jurisdictions, there is limited or no incentive to undertake this investment.

The United States has taken a very significant step to support the commercial deployment of CCUS, with the expansion of "45Q" tax credits. Initial IEA analysis suggests that this incentive could trigger the largest surge in CCUS investment of any policy instrument to date, with potential for USD 1 billion in capital investment and an increase of as much as 30 Mtpa in CO₂ captured, which would almost double today's global CO₂ capture rate.

Question 2: In your statement you mentioned the importance of maintaining the current nuclear fleet production capacity while also supporting innovation in advanced nuclear power technology. The IEA report indicates that electricity generated by nuclear is the second-largest source of low-carbon electricity in the world yet production has stagnated over the past two decades, with new reactors coming online in only 2 countries - Pakistan and China. Globally, due to phase-out policies and financial challenges, 30 gigawatts will be lost by 2025. Without license extensions, a total of over 55 gigawatts will be retired by 2030. Nuclear is a critical component to reducing and eliminating carbon output. But, it seems to me the U.S. has taken a backseat to China, Russia, and South Korea. I think it is critical to reverse the trend of nuclear plant retirements while also reinstating the U.S. as a leader in nuclear. Domestically, what can be done to ensure the current reactor fleet can become more economically competitive while also supporting the development of advanced reactor concepts?

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US nuclear plants – as a fleet – already perform at a high level but face stiff competition from natural gas generation and the growing shares of generation from wind and solar power. The US enjoys the advantage of inexpensive natural gas, particularly compared to Europe and Japan – a situation that is likely to persist and thus make it more difficult for US nuclear power to compete.

The key economic question is recognising the value of carbon-free generation. Renewable generation has benefited from both federal and state-level support in part because of the recognition of its carbon-free nature. Similar programs for nuclear power, such as the Zero Emissions Credits programs offered by some states, is one way to do this – to provide support in order to keep nuclear plants operating and total emissions down.

While such supports can postpone nuclear retirement decisions, eventually today's plants will close. Given the changes in the power markets in the US and other advanced economies, with little load growth and the continuing expansion and falling costs of renewables, new approaches will be needed if new nuclear plants are to make a significant contribution to tomorrow's clean energy systems.

And internationally, how can the U.S. maintain a leadership role in nuclear technology?

The private sector in the US is already a leader in new nuclear innovation, with government programs to support moving promising technologies forward. International cooperation represents an opportunity for the US to learn from the best practices other countries, and to make others aware of the latest US developments. The NICE Future initiative, led by the US along with Japan and Canada is a good example of this cooperation.

Question 3: The electric sector is experiencing a dramatic transformation and, even though demand is flat in advanced economies, massive investment is required for this transformation. For example, grid operators need to upgrade power lines, software, and power controls and improve cyber protections, not to mention the need for investment in technologies like energy storage and carbon capture. You mention in your testimony that the U.S. is leading the world in innovation in energy technology as well as system integration. U.S. leadership in system integration is making our power sector more efficient because we're managing the flow of electrons better – you give the example that new wind turbines in the U.S. generate up to twice as much electricity compared to the rest of the globe. But you also noted that what the modern grid needs is more flexibility, and that will take not only technology innovation but also regulatory innovation and market reforms. How can we keep U.S. companies at the forefront of energy innovation while expanding business opportunities in other countries?

The private sector needs to understand the complex system integration challenges that countries are facing since these challenges are context specific. These challenges depend not only on the share of renewables but also the flexibility of the system. IEA analysis has shown that many countries will require an unprecedented degree of flexibility at such a large share.

This need for flexibility calls for reforms to deliver investment in flexibility options: power plants, storage and grid infrastructure and unlock demand-side response. Cost reductions are a key factor that have in the past led to increased attention in advanced technologies, particularly electric batteries and EVs. These technologies can have an important role in providing flexibility with the increasing share of wind and solar PV.

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Question 4: Your report notes that buildings are a key sector in achieving energy efficiency targets because buildings consume 40% of energy produced in the U.S. and in Europe. That's far more than either the transportation or industry sectors. I agree and think that energy efficiency is low-hanging fruit and that we should pursue greater energy efficiency across the economy. According to the report, European countries are focused on increasing energy productivity in buildings both in new buildings and in retrofits.

What policies do you see as being most effective?

There are a number of policy measures that will help realise greater efficiency gains across both commercial and residential buildings. Regulatory approaches have been highly effective at driving efficiency gains. Key measures include building codes, for both new and existing buildings, along with performance standards for energy using appliances and equipment. These measures form the basis of policy action in the building sector, and the IEA emphasizes the need to update and strengthen these policies on a continual basis to account for changes in technology or market conditions. Recent updates to the European Union's Energy Performance of Buildings Directive (EPBD) provide an example of how existing buildings policy measures have been updated to drive greater levels of efficiency.

While regulatory approaches ensure a minimum level of performance, for greater efficiency gains it is desirable to encourage consumers to purchase high efficiency appliances and upgrade existing buildings to improve performance. Financial mechanisms are important to unlock the great potential for economic gains in buildings that are inhibited by high upfront investment requirements. Fiscal or financial incentives can encourage consumers to move beyond minimum performance levels towards higher levels of efficiency. Measures include grants or rebates for the purchase of efficient appliances and equipment, and low interest rate loans to fund building upgrades. Market-based instruments, such as the energy efficiency resource standards in place across many US states, have also helped to incentivise utilities to increase the deployment of energy efficient appliances and equipment.

Information and capacity building measures are an important complement to regulation and incentives in the buildings sector, as they seek to improve consumer understanding and enhance the ability of the market to deliver greater levels of efficiency. Labels for appliances and equipment, information about building performance and practitioner training are examples of effective measures. These need to be tailored to suit consumer preferences and adapted over time, particularly to leverage the capacity of increased data availability and new methods of providing information to consumers.

Are there any new approaches we should be considering as we work to promote efficiency in buildings?

Digitalization is and will continue to create opportunities for greater efficiency gains in the buildings sector. An increase in the number of 'smart' appliances and equipment is providing consumers with more information about how they are using energy and what can be done to improve efficiency. This can also lead to innovation in how energy efficiency is delivered to consumers and business models that recognise the value of efficiency as an energy resource, improving its value to the wider energy system. Thus gains can be made not just in terms of end-use efficiency, but also in overall system efficiency. This is an area that the IEA is currently studying in detail.

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Government policy will play an important role in maximising the benefits from digitalization. Innovation in terms of energy market design that recognises the value of the energy efficiency will provide further incentive for deployment. However, the amount of energy use data created and shared as a result of digitalization also means that government policy will need to provide for the appropriate protection and use of consumer energy data.

Question 5: Russia's pattern of using its energy resources for political coercion continues to put our allies at risk. For example, Russia supplies 98% of NATO-member Bulgaria's natural gas, dominates the Bulgarian nuclear sector, owns the country's only oil refinery, and owns over 50% of the wholesale fuels markets. In other words, the Bulgarian energy sector is under the Kremlin's thumb. Some observers note that Russia has "weaponized" its energy holdings in Bulgaria to further its influence in the country, and to grow its energy reach to other parts of Europe. The IEA reports that the EU currently imports 74% of its natural gas with the largest supply coming from Russia. However, the report also notes that while the EU's import dependence will rise, Russia's leverage is set to decrease as several European countries are building LNG import terminals to diversify their supply. U.S. LNG currently comprises a very small percentage of Europe's overall imports, but the IEA reports it will significantly increase. There was a recent New York Times story about Poland's LNG import strategy, which increasingly includes buying U.S. LNG.

What is the import capacity of Europe for LNG over the next 5 and 10 years, and where do you expect those imports to come from?

Europe has currently almost 250 bcm of LNG import capacity (or about 45% of its total consumption equivalent) but it is underused (with 68 bcm imported in 2018). This receiving capacity is currently concentrated in the northwest and southwest of the continent, regions where the share of Russian gas is the lowest in Europe – thanks to the contributions of LNG imports and domestic production. The decline of domestic production will call for additional imports and for a higher share of LNG, with increasing competition from traditional suppliers and new sources.

How do you view U.S. LNG exports as part of the EU LNG supply?

Europe's traditional LNG suppliers are Qatar, Nigeria and Algeria, which altogether accounted for almost 70% of the region's imports in 2018. Most of the supply contracts from these traditional suppliers are due to expire in the coming decade, which creates additional opportunities for competition among suppliers on top of the widening supply demand gap caused by the diminution of domestic production. The United States will become one of the leading LNG exporters in the near future and will as such contribute to improving Europe's diversity and security of natural gas supply.

Question 6: In the IEA's New Policies Scenario, natural gas is the fastest growing fossil fuel, becoming the second largest source of energy after oil. China's gas demand triples by 2040, and moves from being roughly half of current European Union demand to 75% higher than the European Union in 2040. The import picture is even more interesting. China will import as much gas as the entire EU by 2040. This reflects what we've seen already, with China overtaking Korea in 2017 as the world's second-largest LNG importer, second only to Japan. And the scenarios note China will overtake Japan in the coming years. Conversely, the U.S. is the largest gas producer today, and remains so through 2040. Where are the most important LNG import markets in the next 5 to 10 years?

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China and other fast growing Asian economies are forecast to account for over 90% of LNG import growth between 2017 and 2023. Asia will remain the primary destination for rising LNG imports in the longer term – our New Policies Scenarios assumes that China and India account for over half of the growth in net LNG imports in the period to 2040.

In that same timeframe, how much U.S. LNG do you see heading to Asian markets, specifically China, Japan, and South Korea? Where else do you anticipate China will purchase LNG from?

US LNG flows were equally balanced between the Atlantic and Pacific basins in 2017 (and almost in 2018) owing to the preponderance of Mexico. LNG exports to Mexico are expected to decline as they will be replaced by US pipeline flows as additional capacity is being commissioned.

Although Europe will remain an attractive market for US LNG, flows will shift eastward to the Pacific Basin driven by higher demand growth and margins and account for around two-thirds of US LNG exports by 2023.

On top of its short term procurement, China is building a strong and diversified portfolio of long-term LNG import contracts sourced from global portfolio players and national oil companies from the Middle East and Asia.

Does the speed and volume of a single country importing one commodity so fully concern you?

China has been one of the key drivers of LNG trade growth and is likely to play a major role in future LNG trade growth. However, it is not the only source of LNG trade development as other Asian economies will face strong energy import needs (such as India, Pakistan or Bangladesh) due to strong economic growth, or will need additional LNG to compensate for nuclear or coal phase outs such as Korea. These different components contribute to improving the dynamics of LNG trade and enhancing competition from the point of view of both suppliers and consumers.

Question 7: Your testimony highlights the United States' position as a world leader in technological innovation transforming the electricity system. And I have repeatedly said that this committee and the U.S. Department of Energy (DOE) have to double down on supporting investment in R&D and innovation to ensure that we remain a global leader in this space. Advances in the natural gas technology that helped lead the U.S. to the current energy revolution were supported early on by DOE funding. That is why I was especially disappointed to learn of reports that a U.S. energy company moved manufacturing operations to Asia. This company has breakthrough solar power technology conceived of by an MIT professor, staffed by MIT students, backed by investors, and received clean energy grants from the DOE. The company had even applied for a loan from the DOE Loan Programs Office, which has approximately \$40 billion left in loan authority. Unfortunately, the company reversed course and moved their manufacturing operations to Malaysia.

What policies should the U.S. consider to incentivize technology leaders to stay in the country?

Continued support is needed for a well-functioning and coherent innovation system that balances demand-pull and market-creating instruments that drive investments in energy and manufacturing infrastructure, with technology-push incentives that continues to generate world-class knowledge and innovation. The suite of

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demand-pull policies should be aligned with overall energy policy goals and send strong signals of policy priorities in technology areas where the US has strong leadership and stewardship role.

A broad range of policies that push for new energy technologies also can serve as a strong incentive for technology leaders. Through targeted support for innovation, governments also give a strong signal on which activities they value as important. Innovation activity supported by governments can help make corrections to markets that encourage local innovation, while at the same time creating new markets.

In particular, energy sector infrastructure is capital intensive and long-lived. For new technologies to succeed long-term, patient support is required to move technologies from lab to market, and governments are a vital source of this kind of finance. Much innovation by technology leaders in the private sector builds on publicly funded programmes for early-stage, higher-risk research, so continued support for these programmes enhances the innovation capabilities of technology leaders.

Governments can also send strong signals to technology leaders and attract other sources of funds through the pursuit of long-term strategic missions. Policy instruments can be used to enable access to finance for risky projects, and experience in a number of countries has shown that the commercial results of public energy RD&D investments can be dramatic.

What incentives do other countries offer to support commercializing breakthrough technologies?

The US has a world-class innovation system, and the most mature and effective venture capital system. Other countries are currently rushing to catch up using a range of instruments similar to the US like tax credits, field trials, standardization, financial incentives for deployment or fuel economy standards, but the US still has the largest and most diverse set of instruments to support innovation.

Experience in other countries has shown that support for breakthrough technologies needs to take into account the varied and specific characteristics energy technologies have in the field. For example, technologies with a high cost of demonstration need more capital to be put at risk in early stages of innovation to realise their ‘breakthrough’ potential. Public support also has a key role when a technology with significant potential edges closer to commercialisation, by identifying and lifting potential barriers to commercialisation. Corporate innovation tends to prioritize investments that deliver short-term returns and build incrementally on existing capacities, so creating an encouraging environment for investors with longer-term perspectives and philanthropic organisations has also shown promise.

Positive results have also been seen from measures that create environments to test and experiment with new technologies at scale. The energy sector is among the most highly regulated in the economy, so demonstrating new technologies can work within existing systems is key to gain acceptance and accelerate deployment. Sandboxes (where new technologies and business models can be tested in a real world environment shielded from certain rules), testbeds and incubators are delivering, and are particularly valuable for energy technologies related to intelligent transportation, smart grids and smart homes. The US has world-leading potential to capitalise from the interaction between innovators in these areas where the digital and energy sectors interface.

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In these areas in particular, the nature of innovation is changing and technologies with breakthrough potential may need new kinds of support. Digital technologies have shorter innovation cycles and can be brought to the market quicker. They require less investment or equipment, and prototypes can be built and tested much faster than traditional energy infrastructure. Innovation in this area can be greatly accelerated through open innovation and facilitating platforms that encourage cross-collaboration between customers, technology suppliers, energy companies and regulators. These emerging technologies often struggle to operate and scale up within legacy systems and practices, which are often designed with large companies in mind. Setting clear and transparent rules, standards and interoperability requirements reduces risks and helps these technologies be brought to the market quickly.

International cooperation and networking can increase effectiveness of innovation efforts and accelerate the development of technologies with breakthrough potential. Participation in international agenda-setting initiatives like Mission Innovation can help raise ambition, exchange analysis and maximise synergies with innovation efforts elsewhere. For decades, the US has used with success the IEA Technology Collaboration Programmes (TCPs), as a mechanism to accelerate innovation across 36 key technology areas – the largest participation of any country worldwide.

Finally, important returns to innovation can be gained from maintaining robust databases on the status of public and private investments in innovation, that also track the performance and innovation support system in place for a broad range of energy technologies. There is a gap currently for collecting information on what incentives exist in different jurisdictions and how much is being spent, an area where the IEA is working to improve. These performance metrics can aid innovation managers in governments and the private sector to track the status of potential breakthrough technologies in priority areas, and in turn, help national policy makers to identify gaps and to enhance efficiency of public finance allocation. At the international level, multi-lateral initiatives like Mission Innovation, where the US has made a commitment to double clean energy R&D spending, can also be aided by such data collection.

Question 8: The world's demand for reliable affordable energy is growing – you expect global energy demand to increase by more than 25% by 2040 but you make the point that this increase could double if improvements to energy efficiency do not continue. As you have discussed, economic growth will continue to drive the demand for oil in particular as growth coming from trucks, aviation, and petrochemicals where oil will likely stay dominant in the foreseeable future. You also discussed geopolitical risks that will continue to affect oil supply and could result in serious negative consequences for the global economy. You note in your report that increasing efficiency and electrification in the transportation sector and continuing displacement of oil in the power and buildings sector puts downward pressure on global oil demand. Although efficiency measures and fuel switching can't protect us from supply risks overnight, it seems that you're suggesting that energy efficiency measures can mitigate some of this risk.

Do you look at energy efficiency as a way to improve energy security in your analysis?

Yes, the IEA does analyse the impact on energy security from improvements in energy efficiency. The focus of this analysis is the imports of coal, oil and gas that are avoided because of improvements in energy efficiency, which enhances energy security. In major economies covering three quarters of global energy use, including all IEA

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member countries, improvements in energy efficiency since 2000 avoided the need for 20% more fossil fuel imports in 2017. In IEA member countries, the avoided oil imports alone were worth over USD 30 billion, which benefits both energy security and trade balances.

Energy efficiency will continue to play an important role in enhancing energy security and improving trade balances. The IEA's Efficient World Scenario, presented in the Energy Efficiency 2018 report, highlights the benefits that the increased adoption of cost-effective energy efficiency measures could bring between now and 2040. For energy security the benefits are substantial. The European Union, China and India could avoid over USD 700 billion in energy imports in 2040, greatly benefitting trade balances in these countries and reducing reliance on imported energy.

In 2017, the IEA also published analysis highlighting the benefits of energy efficiency for short-term gas security in Europe and emergency response in Japan. Without improvements in energy efficiency, particularly for heating in buildings, the United Kingdom and France would have needed nearly 250 million cubic metres of additional daily gas supply capacity to meet the European Union's short term gas security requirements. Following the great East Japan Earthquake and Fukushima Daiichi nuclear accident, the Japanese government instituted a series of energy conservation measures, which transitioned into sustained efficiency improvements. The energy savings from these measures replaced 39% of Japan's nuclear power generation capacity that was shutdown following the earthquake, the single largest contribution of any fuel source, ensuring continued security of Japanese electricity supply.

What efficiency measures should we focus on to mitigate those risks?

To maximise the potential of energy efficiency and mitigate the impact of economic growth on energy demand, the IEA continues to emphasize the importance of a comprehensive suite of energy efficiency policies, across all energy-using sectors. Key actions being taken by Governments around the world include:

- Implementing and strengthening mandatory energy efficiency policies, which push the performance of appliances, equipment and vehicles towards best available technologies.
- Providing targeted and appropriate fiscal or financial incentives to encourage energy-users to pursue greater levels of energy efficiency.
- Leveraging the power of the market, through implementation of market-based mechanisms, to deliver energy efficiency improvements at least cost.
- Providing targeted and high quality information and capacity building measures, to maximise market readiness to deliver higher levels of energy efficiency.

Current innovations, many of which have started in the United States, provide a glimpse of what is possible, with digital technologies creating opportunities for new innovations that unlock efficiency gains. The IEA has commenced a new programme entitled Modernising Efficiency through Digitalization. This is examining how new digital technologies such as advanced monitoring and control, artificial intelligence and data analytics, can further enhance overall systems efficiency.

Questions from Senator Steve Daines

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Question 1: In the World Energy Outlook 2018, the IEA outlines that Carbon Capture, Utilization and Storage (CCUS) should play a significant role in emissions reduction stating that Coal plants with high capture rates “could generate near-zero or (if co-firing with bioenergy) even negative-emissions electricity.” However, CCUS technology has been slow in coming to market. The U.S. has made some progress with two coal-fired plants with CCUS and the passage of the 45Q CCUS tax credit, which I strongly supported and thank you for your support, but we still have much to do. What other reforms, legislation, or investments do you think the U.S. and the world need to pass to get more CCUS in the market and thus reduce global emissions?

Supportive policies will be important for scaling-up investment in CCUS globally. The United States has already taken a very significant step with the expansion of the 45Q tax credits. Other policy mechanisms available to governments, depending on national circumstances and preferences, could include grant funding, feed-in tariffs (for the power sector), public procurement, low-carbon product incentives and CCUS certificates. Carbon pricing can also play a role, but is unlikely to support a rapid scale-up of CCUS investment in the near-term. Government leadership will also be necessary to ensure adequate legal and regulatory frameworks for CO₂ storage and to facilitate investment in CO₂ transport infrastructure.

Question 2: The World Energy Outlook also outlines the importance of CCUS for Enhanced Oil Recovery (EOR). The use of captured carbon from facilities with enhanced oil recovery will not only make CCUS technology more cost effective it can help reduce emission from the oil and gas industry. I have worked with Senator Hoeven to update the 45Q tax credit to allow for more investment in CCUS-EOR. What reforms, legislation, or investments do you think the U.S. and the world need to pass to get more CCUS for enhanced oil recovery in the market and thus reduce global emissions?

The use of CO₂ for enhanced oil recovery (EOR) has been a major driver for investment in CCUS, particularly in North America and more recently in China and the Middle East. CO₂-EOR can deliver net climate benefits where the CO₂ is from anthropogenic sources, even when accounting for the combustion of the recovered oil, as almost all of the injected CO₂ is ultimately retained in the reservoir. Policies that recognise the climate benefits of oil produced with CO₂-EOR can encourage an expansion of this practice – a recent example being the Californian Low Carbon Fuel Standard CCS protocol. Policies can also be designed to increase the climate benefits of CO₂-EOR by encouraging operators to maximise the quantity of CO₂ injected and ultimately stored for each barrel of oil produced. As with CO₂ storage, appropriate legal and regulatory frameworks will be necessary to support investment in CO₂-EOR.

Question 3: In the World Energy Outlook 2018, the IEA projects increased global demand for oil and gas, and even a slight increase in global coal demand through 2040. It also projects that the U.S. will be a net exporter of oil, gas and coal through 2040. If the U.S. were to enact the policies in the Green New Deal and completely cease energy exports, what countries would you predict would fill in the gap if the U.S. leaves the market?

The IEA’s New Policies Scenario from the World Energy Outlook explores the implications for energy of policies in place as well as the policy ambitions announced by governments around the world. Our Sustainable Development Scenario explores how the world might get on track to achieve the objectives of the Paris Agreement and other sustainable development goals related to energy access and air quality. In the Sustainable Development Scenario all countries accelerate deployment of a wide range of clean and efficient energy technologies, in order to achieve

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an early peak and rapid subsequent decline in global emissions. Primarily because of much lower consumption levels, but also because of the cost advantages that the United States has in oil and gas production, the US continues to export oil and gas in this scenario through to 2040 (albeit at lower levels than in the New Policies Scenario). We have not examined the implications of a Green New Deal either for the US or for global markets.

Question 4: In particular on coal exports, Japan has expressed extreme interest in more U.S. coal imports. According to the World Energy Outlook, Japan and Korea will remain 100% reliant on foreign coal imports through 2040. Much of their coal is currently coming from Australia or Indonesia (where it must pass through the South China Sea) and Russia. Due to foreign policy concerns, Japan would like to diversify their portfolio to include more U.S. coal. However, our current export capabilities are at capacity and we are struggling to get more throughput permitting in Washington State. If the U.S. cannot service the demand in Japan and in others like South Korea, what countries do you suspect would fill the gap in coal exports?

The seaborne coal trade works quite efficiently but is not very diversified, as six countries account for more than 90% of the global seaborne thermal coal trade, and coking coal is even more concentrated.

Therefore, if US cannot service demand in Japan and South Korea, the global flows will change in order to balance the market, with higher cost exporters here and there filling the gap. Australia, Indonesia and Russia will concentrate the supply to Japan and South Korea, and Colombia and South Africa will focus on Europe and the Mediterranean region. Regarding coking coal, Mongolia (as a Chinese captive exporter) and Mozambique can react to higher prices and increase supply, but mainly Australia, and to a lesser extent, Russia and Canada, will supply the bulk of the market.

Question 5: If the U.S. enacted the policies of the Green New Deal and immediately ceased energy exports, how would that affect global energy markets, prices, and jobs?

See answer to Question 3.

Question from Senator Bill Cassidy

Refiners in my state are telling me that the United States is prepared to meet the United Nation's 2020 requirement to reduce the amount of sulphur contained in bunker fuel. The US Energy Information Administration, in their January 2019 Short-Term Energy Outlook, found that, with IMO in force, the cost of gasoline, diesel, and heating oil *will be lower in 2020 than in 2018*.

"Refinery wholesale gasoline margins in the United States (the difference between the wholesale price of gasoline and the price of Brent crude oil) averaged 13 cents/gal in December. This level was lower than the 19 cents/gal average in December 2017 and 8 cents/gal lower than the fiveyear (2013–17) average for December. Refinery wholesale gasoline margins averaged 28 cents/gal in 2018, which was 12 cents/gal lower than the 2017 level and 8 cents/gal lower than the five-year average. EIA expects refinery wholesale gasoline margin to average 29 cents/gal in 2019 and 33 cents/gal in 2020.

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The diesel fuel retail price averaged \$3.18/gal in 2018, which was 53 cents/gal higher than the average in 2017. EIA forecasts that the diesel price will average \$2.94/gal in 2019 and \$3.13/gal in 2020. The rising prices from 2019 to 2020 reflect a forecast increase in crude oil prices, tight distillate fuel inventory levels, and increasing diesel refinery margins driven by impending IMO 2020 regulations. EIA expects that low-sulfur IMO regulations set to begin in 2020 will drive global demand for U.S. ultra-low sulfur diesel volumes and contribute to gradually increasing diesel refinery margins. Diesel refinery margins based on Brent crude oil, which averaged 43 cents/gal in 2018, are expected to average 48 cents/gal in 2019 and 65 cents/gal in 2020.”
 – EIA January 2019 Short Term Energy Outlook

Question: What are IEA’s thoughts on how this transition will impact gasoline prices, the maritime industry and refiners?

Gasoline markets are currently oversupplied as demand growth has slowed markedly in the last few years. The gasoline margins earned by refiners have mainly been negative this winter. While the US summer driving season will offer some support, overall we see oversupply lasting for the next several years. This is why we do not foresee a significant impact on gasoline prices from the IMO 2020 regulations.

Refiners will try to maximise diesel yields and very low sulphur fuel oil yields. The growing availability of light sweet crudes (US shale, mostly) is very helpful in these circumstances. Another important way in which the US shale revolution is helping the global refining industry to meet the new regulations is through increased production of natural gas (refineries need natural gas to produce hydrogen to remove sulphur from final products). Natural gas prices in the US have halved compared to a decade ago, just ahead of the shale revolution.

Many forecasts of IMO-related spikes in oil product prices are based on comparisons with the 2007-2008 oil market, when European regulations for ultra-low sulphur diesel drove diesel margins and crude prices to very high levels. Back then, light, sweet oil output was declining, not increasing as it is today, and natural gas prices were higher. Taking into account changes in crude supply, the slowdown in traditional diesel demand sectors, and the slowdown in gasoline demand, we think the markets are much better placed to meet the new regulations.

On the other hand, the maritime industry will definitely see a price impact. Currently they are using high sulphur fuel oil, the lowest quality and cheapest oil product. Regulations will see them moving to higher quality products, which are inherently costlier to make. Therefore, their fuel costs will have to increase.

