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

It has been my privilege to serve as the Executive Director of the International Energy Agency (IEA) for slightly more than two years now. And it is my distinct pleasure to share with you our very latest market outlook.

Let me start by wishing you all a Happy New Year. For the IEA, 2017 was a year of growth and continued transformation. In particular, our Ministerial Meeting held last November was a remarkable success, in no small part thanks to contributions made by the U.S. I would like to particularly thank Secretary of Energy Rick Perry for his personal engagement, including for co-chairing a Carbon Capture, Utilization and Storage Summit on the side-lines of the Ministerial, which included the participation of many other ministers and CEOs of some of the world's leading energy companies.

A brief overview of the IEA

The strong relationship between the United States and the International Energy Agency goes back to the founding of the IEA in 1974. Throughout these more than 40 years, the United States has played an absolutely critical leadership role in the IEA. And, U.S. leadership and support has not only come 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 know that you, Madam Chair, and many of your colleagues know very well what the IEA does, but I also appreciate that not everyone here will be fully familiar with the exciting recent developments at your IEA.

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. As the world has evolved, so has the IEA. While energy security remains a core part of our mandate, the IEA has also grown to become the world's leading energy-policy advisor across the entire energy mix, providing data, analysis and solutions to governments and industry on all fuels and technologies.

During our 2017 Ministerial Meeting, our members reaffirmed your commitment to the IEA's modernization strategy, which is based on three pillars.

The first is opening the IEA's doors to emerging economies. Over the last two years, we have welcomed seven new IEA Association members – China, India, Brazil, Indonesia, Thailand, Morocco and Singapore – reflecting more accurately the global nature of the energy system.

Our Association countries are now developing closer relations with the Agency, participating in meetings of IEA committees and standing groups, working with us closely on improving energy data and statistics, strengthening energy security relationships, undertaking energy policy studies, and cooperating more closely with the Agency on their energy policies. We have also recently welcomed Mexico as our newest member. As a result, our expanded IEA family is now much more global, accounting for 70% of the world's energy use, up from under 40% in 2015.

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

The third modernization pillar is to strengthen the IEA's role as a leader in clean energy, including building a global hub for energy efficiency. Specifically, we help our Members to cost-effectively achieve their own clean energy objectives, which can include renewables and efficiency, as well as carbon capture, utilization and storage (CCUS) and nuclear power. One key aspect of this approach is our work with around 40 IEA Technology Collaboration Programs (TCPs), which are made up of 6,000 research analysts from around the world. The United States is represented in almost all of these TCPs – more than any other country – across a range of sectors and technologies from transport and electricity, to fossil fuels, renewables and other clean energy technologies.

These three pillars represent the future of the IEA as a truly global energy institution covering the full range of the energy mix.

Looking over the horizon

In my last written testimony to this Committee, I focused on energy security, recent developments in oil, gas and renewables, and the medium-term outlook for the range of fuels covered by the IEA. Today, I would like to take the opportunity to look further ahead, and focus on the forward looking scenarios that define the IEA's flagship publication – the *World Energy Outlook*.

While we produce a range of scenarios, I will focus on the outlook in our central scenario, which describes where existing policies and announced intentions might lead the energy system by 2040. We produce this scenario to inform decision-makers about the impact of their existing and planned policies as they seek to improve on this outcome.

Four large-scale shifts in the global energy system set the scene for the coming decades: 1) the U.S. becoming the undisputed global oil and gas leader; 2) the rapid deployment and falling costs of clean-energy technologies; 3) the shift to a more services-oriented economy and a cleaner energy mix in China; and 4) the growing electrification of energy.

With regard to the rapid deployment of **clean-energy technologies**, in 2016 the growth in solar photovoltaics (PV) capacity was larger than for any other form of generation. Since 2010, costs of new solar PV have fallen by 70%, while wind costs have dropped by 25% and battery costs by 40%. This trend is set to continue, signalling the coming new age of renewables.

Under our central scenario, renewables capture two-thirds of global investment in power plants to 2040 as they become, for many countries, the least-cost source of new generation. Rapid deployment of solar PV, led by China, India and the United States, helps solar become the largest source of low-carbon capacity by 2040. In the European Union, renewables account for 80% of all new capacity and wind power becomes the leading source of electricity generation. By 2040, the share of all renewables in global total power generation reaches 40%.

In the United States after 2020, use of renewables-based electricity grows faster than the use of renewables for heat and transport combined. However, in our central scenario, the annual rate of growth of renewables in the United States slows from 3.5% per year to 2.5% per year after 2025.

Policies are still needed to support the deployment of renewable electricity worldwide, increasingly through competitive auctions rather than feed-in tariffs and by ensuring that power systems operate with sufficient flexibility to accommodate rising shares of solar and wind power. The transformation of the power sector is amplified by millions of households, communities and businesses investing directly in distributed solar PV.

Of course, clean-energy technologies include far more than renewables. In particular, energy efficiency will be key to reducing demand across all sectors. Energy efficiency is central to the achievement of a range of policy goals, including energy security, economic growth and environmental sustainability.

The progress on energy efficiency over the past few years has been remarkable, with global energy intensity – measured as the amount of primary energy demand needed to produce one unit of gross domestic product (GDP) – declining at an average rate of 2.1% per year. This is a significant improvement over the average rate of 1.3% between 1970 and 2010. Lower energy intensity was responsible for offsetting three-quarters of the increase in greenhouse gas (GHG) emissions due to GDP growth, with the shift to renewables and other low-emission fuels offsetting the other quarter.

However, in contrast with previous years, nearly all the increase in 2016 in the share of world final energy use covered by policies that mandate energy efficiency improvements was due to the continuing impact of existing policies, as old energy-using equipment was replaced. Just 1% of the increase was due to newly enacted policies – marking an historic low that deserves specific attention from policy makers.

Stronger policy development and implementation is essential if the current level of efficiency gains is to be maintained or accelerated over the coming decades. In our central scenario, improvements in efficiency play a huge role in taking the strain off the supply side to 2040. Without these improvements, the projected rise in final energy use would more than double. If the world's policy ambitions are to be met, governments must recognise the importance of developing and putting into force new and more ambitious efficiency policies.

The second major theme, which is very much related to the growth in clean-energy technologies, is how **electricity** will play a rapidly expanding role in the energy sector.

Electricity is the rising force among worldwide end-uses of energy, making up 40% of the rise in final consumption to 2040. This is the same share of growth that oil took for the last 25 years. Global rising incomes mean that many millions of households add electrical appliances and install cooling systems. With total electricity demand growing at 2% per year from 2016 to 2040 – nearly twice the rate of final energy

demand – electricity experiences more growth than all other fuels, meeting over 37% of additional final energy demand.

Electricity also makes inroads in supplying heat and mobility, allowing its share of final consumption to rise to nearly a quarter. A strengthening tide of industry initiatives and policy support pushes our projection for the global electric car fleet up to 280 million by 2040, from 2 million today.

The scale of future electricity needs and the challenge of decarbonising power supply help to explain why global investment in electricity overtook that of oil and gas for the first time in 2016 and why electricity security is moving firmly up the policy agenda.

This does not come without significant challenges. For example, because wind and solar PV are variable renewable resources and their input cannot be fully forecast and programmed, the so-called system integration of these variable renewable sources has emerged as a major economic and policy challenge.

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

The U.S. already boasts a number of power system flexibility resources, including more flexible thermal power plants (mainly gas, but possibly also coal), multiple storage options, and demand-side response. In addition to these flexible resources, market design also has a very important role to play in successfully integrating renewables.

Existing and emerging digital technologies will also play a major role in power systems, providing opportunities for not only integrating variable renewables, but also smart demand response, smart charging of electric vehicles, and small-scale distributed electricity resources. However, digitalization of the energy sector can facilitate this positive change only if policy makers undertake efforts to understand, channel and harness digitalization's impacts and to minimise its risks – for example taking steps to ensure our power systems are resilient to cyber-attacks.

Speaking of the third major global trend, the direction that **China** takes over the coming decades will shape all of these trends. President Xi Jinping's call for an "energy revolution", the "fight against pollution" and the transition towards a more services-based economic model is moving the energy sector in a new direction. The emphasis in energy policy is now firmly set on electricity, natural gas and cleaner, high-efficiency and digital technologies.

The scale of China's clean energy deployment, technology exports and investment makes it a key determinant of momentum behind the overall global low-carbon transition: one-third of the world's new wind power and solar PV is installed in China to 2040 in our central scenario, and China also accounts for more than 40% of global investment in electric vehicles (EVs).

China also provides a quarter of the projected rise in global gas demand with projected imports of 280 billion cubic metres (bcm) in 2040. This is second only to those of the European Union, making China a linchpin of global gas trade.

China remains a towering presence in coal markets, but our projections suggest that coal use peaked in 2013 and is set to decline by almost 15% over the period to 2040.

In addition, China overtakes the United States as the largest oil consumer around 2030, and its net imports reach 13 million barrels per day (mb/d) in 2040. But stringent fuel-efficiency measures for cars and trucks, and a shift which sees one-in-four cars being electric by 2040, means that China is no longer the main driving force behind global oil use – demand growth is larger in India post-2025.

In fact, India is the largest contributor to demand growth to 2040 – almost 30% of total growth – as its share of global energy use rises to 11%. Southeast Asia is another rising heavyweight in global energy, with demand growing at twice the pace of China. Overall, developing countries in Asia account for two-thirds of global energy growth, with the rest coming mainly from the Middle East, Africa and Latin America.

The United States: the undisputed global oil and gas leader

Finally, with regard to the fourth major global trend, I would like to speak about the noteworthy resilience of shale gas and tight oil here in the United States, and the future of oil. The remarkable ability of producers to unlock new resources cost-effectively pushes the combined United States oil and gas output in 2040 to a level 50% higher than any other country has ever managed. This is an impressive feat, which cannot be overstated. This makes the United States the undisputed oil and gas producer in the world over the next several decades.

In our projections, the 8 mb/d rise in US tight oil output from 2010 to 2025 would match the highest sustained period of oil output growth by a single country in the history of oil markets. A 630 bcm increase in US shale gas production over the 15 years from 2008 would also comfortably exceed the previous record for gas.

Expansion on this scale is already having wide-ranging impacts within North America, fuelling major investments in petrochemicals and other energy-intensive industries. It is also reordering international trade flows and challenging incumbent suppliers and business models.

By the mid-2020s, the United States also becomes the world's largest liquefied natural gas (LNG) exporter and a few years later a net exporter of oil – assuming increasingly stringent fuel economy standards are enacted. Your country remains a major importer of heavier crudes that suit the configuration of your refineries, but at the same time a larger exporter of light crude and refined products.

As such, with the United States accounting for 80% of the increase in global oil supply to 2025 and maintaining near-term downward pressure on prices, our projections suggest that the world's consumers are not yet ready to say goodbye to the era of oil.

Up until the mid-2020s, oil-demand growth remains robust in our central scenario, but slows markedly thereafter as greater efficiency and fuel switching bring down oil use for passenger vehicles (even though the global car fleet doubles from today to reach 2 billion by 2040).

Yet, demand from other sectors is enough to keep overall oil demand on a modest rising trajectory to 105 mb/d by 2040. Oil use to produce petrochemicals is the largest source of growth, closely followed by rising consumption for trucks, for aviation and for shipping.

However, despite these positive developments, it is worth noting that this central scenario falls short on a range of important goals, namely: universal access to modern energy services and clean cooking facilities, improvements in air quality and the reduction of greenhouse gas emissions. In 2017 the IEA produced, for the first time, a Sustainable Development Scenario as an alternative point of reference in which these objectives are met. It is noteworthy that under this scenario we find that meeting global climate goals does not in fact impede efforts to provide universal access and improve energy security.

Conclusions

The last few years have seen an acceleration in the evolution of the global energy system, with the centers of gravity for both demand and supply shifting dramatically. The United States is a key player in this evolution, and will no doubt continue to help shape the energy system over the coming years.

As we have done over the past 40 years, the IEA looks forward to continue working with all of our partners in the United States and with our other Member Countries, and we stand ready to offer our analysis, advice and support as you oversee your nation's energy policies.

On behalf of everyone at the IEA, I wish to once again thank you for inviting me before your Committee. I am happy to answer any questions.