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Statement of the
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before the
Committee on Energy and Natural Resources
United States Senate
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Chairman Murkowski, Ranking Member Manchin and Members of the Senate Committee on Energy and Natural Resources --

Thank you for the opportunity to appear before you to discuss energy innovation and other potential solutions to help address climate change. It's an honor to return to the Committee. I've appeared here several times before to discuss electric vehicles, clean energy standards and other topics. Over the years I've observed the Committee's long tradition of constructive bipartisan dialogue. I wish you every success in continuing that tradition in the months and years ahead.

I have worked on energy innovation and climate change for many years -- as a member of the White House staff, an Assistant Secretary of State, an Assistant Secretary of Energy and Acting Under Secretary of Energy. Today I'm honored to be the Inaugural Fellow at the SIPA Center on Global Energy Policy at Columbia University. Our mission is to help public and private sector leaders as they make choices about the world's most pressing energy issues. I hope to be able to do that with today's testimony.

My testimony today will have four core points:

- First -- energy innovation is essential for fighting climate change.
- Second -- some energy innovations fight climate change. Some don't.
- Third – innovation alone won't solve climate change
- Fourth – as a nation, we should build on our strengths and address our weaknesses when it comes to energy innovation.

I'll discuss each of these in turn.

First -- energy innovation is essential for fighting climate change.

The energy sector (including power, transport, heating and more) produces roughly 75% of global greenhouse gas emissions. Significant reductions in energy sector emissions are essential in addressing climate change.

In the past decade, dramatic innovations have begun to change the energy sector, offering great promise in responding to climate change. Solar module costs have fallen by more than 80% since 2010. Wind turbine costs have fallen by half during the same period, with taller towers and larger blades greatly improving the ability to generate power from wind.

From Indiana to India, solar and wind power are now competing on the basis of cost with coal-fired power. Last year the Northern Indiana Public Service Co. found it could save customers more than $4 billion over 30 years by replacing its coal-fired power with solar power, wind power, energy storage and demand response. In 2016, Indian Energy Minister Piyush Goyal said "a new coal plant would give you costlier power than a solar plant" in India.

But more is needed. The scientific consensus is clear: the impacts of climate change are already here, and we must cut carbon emissions deeply in the decades ahead to avoid risk of catastrophic damages. The Paris Agreement, ratified by more than 180 nations, calls for net zero greenhouse gas emissions by the second half of this century. To reach safe levels of emissions, we will need energy innovation in many areas. The highest priorities include:

- **Energy storage.** Battery costs have fallen significantly in recent years. But further reductions in energy storage costs are needed for deep decarbonization of both the transport and power sectors. Vehicle electrification will proceed much more quickly once the purchase price of an electric vehicle is less than the purchase price of a comparable conventional vehicle. (Many experts believe that will happen by the mid-2020s.) Cheap large-scale, long-duration energy storage would make an enormous difference in integrating high volumes of solar and wind power into electric grids.
- **Floating offshore wind.** Offshore wind power costs have declined significantly in recent years. Here too more is needed. Cost-competitive floating offshore wind technology could dramatically expand areas available for production of wind power.
- **Industrial heat.** High temperatures are essential for the manufacture of many products including iron and steel, chemicals and cement. Today almost all that heat is generated from the combustion of fossil fuels – leading to roughly 15% of global emissions.

Finding ways to generate high temperatures for industrial purposes without greenhouse emissions is essential for deep decarbonization.

- **Heavy-duty road transport.** Trucks, buses and other heavy duty on-road vehicles are responsible for roughly 5% of global greenhouse gas emissions. Municipal bus fleets are starting to convert to electric drive trains (with more than 400,000 electric buses already on the roads in China), but decarbonization of long-haul transport may require innovations in hydrogen fuel cells and/or renewable liquid fuels.
- **Aviation.** Aviation is responsible for roughly 2% of global greenhouse gas emissions and growing fast. Powering most airplanes with electric motors and batteries is not possible with today's technology. Biofuels are a potential pathway for decarbonizing aviation, but building biofuel supply chains with net zero emissions at a scale sufficient for the global aviation industry will require innovation. Improvements in air traffic management could help reduce emissions growth in this sector.
- **Carbon capture, utilization and storage.** Carbon dioxide (CO_2) is currently being separated from the flue gas of coal-fired power plants and industrial facilities at several dozen sites around the world. CO_2 is being separated from the ambient air at several sites as well. Carbon capture technologies, when coupled with technologies that convert CO_2 into commercially useful products or permanently sequester CO_2 underground, have enormous potential to contribute to solutions to climate change. Innovations are needed to drive down the costs and improve performance of these technologies.
- **Cheap, passively safe nuclear reactors.** Nuclear energy provides more than half of the United States' carbon-free energy. However many reactors are nearing the end of their useful lives, even with life extensions. Replacing those reactors with new ones could help prevent emissions increases once those plants retire, however new nuclear power plants face at least two significant barriers: cost and public acceptance. Innovations to reduce the costs of new nuclear reactors while addressing public concerns (in part by ensuring that operator intervention is not needed for a safe shutdown) could make an enormous difference in fighting climate change.

Second -- some energy innovations fight climate change. Some don't.

Not all energy innovations help fight climate change.

For example, in recent decades advances in 3-D seismic, tension-leg platform and other technologies have dramatically enhanced the ability to produce oil from the deep ocean. Forty years ago, no oil rig in the Gulf of Mexico operated in water deeper than 2,000 feet. Today rigs can operate in 12,000 feet of water. The expansion of oil drilling into ultra-deep waters is the result of significant technological innovations. However those innovations do not contribute to the fight against climate change.

Another example: autonomous vehicles. The potential climate impacts of autonomous vehicles are quite uncertain:

- Autonomous vehicle technology could increase greenhouse gas emissions by lowering barriers to driving and increasing vehicle miles traveled.
- Autonomous vehicle technology could reduce greenhouse gas emissions by improving driving efficiency, facilitating vehicle platooning and reducing miles spent looking for parking spaces in urban areas.

Autonomous vehicles are hugely important innovations, with potentially far-reaching consequences, however on their own they do not necessarily contribute to the fight against climate change. Policies promoting the coupling of autonomous vehicle technology with electric drive trains may be essential to ensure that autonomous vehicles do not increase emissions.

Third -- innovation alone won't solve climate change.

Innovation is essential for fighting climate change. But it's not enough. The most innovative, low-carbon technologies won't help fight climate change unless they're deployed. And widespread deployment of low-carbon technologies often requires a range of policies.

The building sector offers a classic example. Many simple technologies for improving the energy efficiency of buildings are available but sit unused due to a combination of factors including split incentives between landlords and tenants, lack of information among architects and builders, and inattention to energy costs by buyers at the time of purchase. Policies such

as building codes and appliance efficiency standards can make a big difference in saving energy, cutting costs and reducing emissions.

Access to low-cost capital is especially important for innovative technologies to reach the market at scale. Historically this has been a significant challenge for many low-carbon technologies due to the amounts of capital needed, timeframes in which returns can be expected and risk aversion of debt markets. Without government intervention to guarantee loans, cover first loss risks or otherwise reduce capital costs, many innovative low-carbon technologies will never make it from the lab to marketplace. The growth of utility-scale solar power in the United States offers an example of the benefits of such tools.

A price on carbon offers an especially powerful tool for moving innovative low-carbon technologies from the lab to marketplace. Technologies that emit greenhouse gases receive an implicit subsidy when they are allowed to do so – imposing costs on others -- at no charge. (The IMF has estimated the value of this subsidy at more than $1 trillion globally.) Correcting this imbalance would make a big difference in addressing climate change. This can be done while promoting economic growth and putting more money in the pockets of most American taxpayers.

Finally, global engagement is also essential for solving climate change. Although the United States is the world's second largest emitter, and responsible for more greenhouse gases in the atmosphere than any other nation, last year the vast majority of global emissions came from outside our borders. Policies to promote the global deployment of low-carbon technologies are essential to meeting the challenge of climate change.

There is a virtuous cycle to many of the policies discussed above. These policies are essential complements to the innovation agenda. Without such policies, technological innovation will not provide climate solutions at the scale and speed needed. At the same time, many of these policies also promote innovation as one of their core features:

- Building codes that set performance standards for energy use per square foot encourage innovations in building energy efficiency.
- Loan guarantees that help an industry scale help drive down technology costs.
- A price on carbon encourages innovation in low-carbon technologies across the entire economy.

- Policies to promote global deployment of low-carbon technologies help those technologies scale, driving down costs.

Policies essential for innovative, low-carbon technologies to deliver real climate solutions often promote innovation as well.

Fourth – as a nation, we should build on our strengths and address our weaknesses when it comes to energy innovation.

The United States has an extraordinary record when it comes to energy innovation. Our universities, national labs, companies and others have played central roles in the development of solar power, wind power, energy storage, hydraulic fracturing, horizontal drilling, nuclear power, building energy efficiency technologies and much more. However that record of success does not guarantee future results. To retain our abilities and pre-eminence, we must regularly assess our strengths and weaknesses. We should build on the former and address the latter.

Three strengths stand out:

- *Our great universities*. The United States has an extraordinary system of higher education, with dozens of pre-eminent universities filled with superb research talent. Top students from around the world dream of coming to U.S. universities to study. The research and training underway in our universities provide an essential foundation for our nation's work on energy innovation.
- *Our national lab system.* U.S. Energy Secretary Rick Perry has called DOE's 17 national laboratories "the crown jewels of American science." These national labs are an extraordinary resource, with some of the world's best scientists, fastest computers and well-designed facilities for promoting energy innovation.
- *Our entrepreneurial culture.* We are a nation of strivers. We respect those who take risks to deliver results. From the earliest days of our republic, we have applauded and rewarded those who innovate in business and a range of endeavors.

At the same time, three weaknesses inhibit our ability to promote energy innovation:

- *Our broken politics.* US politics has always been rough. But in recent years polarization has become especially extreme. A former Senator told me recently how much less civil

this body is now than when he first knew it. That interferes with the ability to generate consensus around programs and policies that should command broad support. It creates risks that programs will be attacked due to their political sponsorship more than their potential or results.

- *Lack of respect for science.* It is ironic that, in a nation with such extraordinary universities and national laboratories, the envy of much of the world, science receives such little respect. Top leaders and significant minorities of the public reject scientific conclusions on topics as wide-ranging as climate change and vaccinations. In my travels in Asia and Europe I often encounter people deeply puzzled by this phenomenon. This undercuts political support for the work needed to promote energy innovation.
- *Short-term focus.* Several European governments set energy and emissions targets 10-15 years ahead and then adjust policies to implement those targets year after year. The Chinese government develops Five-Year Plans with energy and emissions targets that guide policymakers in the central government and provinces. In the United States, we struggle to pass one-year appropriations bills. I would not trade our governance system for that of any other nation, but we could learn a great deal from other countries about planning. In addition -- the payback period for many clean energy innovations is beyond the time horizons of many investors. That has limited access to capital in the sector.

What can we do to build on our strengths and address our weaknesses? That's a large topic, with many answers. I'll briefly suggest three steps:

- *Increase federal budgets for energy innovation.* For generations, U.S. government funding has played a central role in world-changing innovations. Among the innovations that grew directly from federal funding are the Internet, the Google search engine, GPS devices, DNA mapping, inexpensive mass data storage and even Teflon. Federal funding has played an important role in many energy innovations including solar power, wind power, hydraulic fracturing, horizontal drilling and nuclear power.

  Within the federal government, the U.S. Department of Energy plays an especially important role in energy innovation. The Office of Science, ARPA-E, the Office of Energy Efficiency and Renewable Energy, the Office of Fossil Energy, the Office of Nuclear Energy and other offices conduct vitally important research on energy technologies. These offices support work throughout the national lab system and in universities around the country. Their capacity to deliver results for the nation far exceeds their budgets.

The budgets for DOE and other federal offices that support energy innovation need substantial increases in the years ahead. I applaud Senator Lamar Alexander's call to double federal funding for clean energy research as part of his recent New Manhattan Project for Clean Energy.

- *Channel U.S. entrepreneurial spirit toward meeting the climate challenge.* Federal R&D spending for energy innovation is important. But most R&D in the United States is funded by the private sector. Most energy technologies in the United States are deployed by the private sector. The private sector is a powerful engine of progress.

  Policies that improve the returns businesses earn from deploying innovative energy technologies are among the most powerful tools available for promoting energy innovation. There are many examples, including tax credits (which have helped accelerate innovation in solar power, wind power, electric vehicles and carbon capture, use and storage) and performance standards (such as the renewable portfolio standards in effect in 29 states, which have helped accelerate innovation in solar and wind power). A federal carbon price or clean energy standard would each be powerful tools for accelerating clean energy innovation.

  Harnessing the power of the private sector to promote energy innovation is especially important for climate solutions.

- *Build long-term thinking into decision-making on energy innovation.* DOE should launch multi-year, multi-stakeholder planning processes with respect to clean energy innovation. Working with other federal agencies, national labs, universities, businesses and others, DOE should identify clean energy innovation goals, barriers to achieving to them and strategies for overcoming those barriers. In addition – building on the example of the Breakthrough Energy Coalition, institutional investors, philanthropies and other capital providers with long time horizons should increase their support for promising clean energy innovations.

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