**Subcommittee on Energy**
**Committee on Science, Space and Technology**
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**Testimony of Dr. Erik K. Webb**
**Sandia National Laboratories**[1]

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Chairman Lamb, Ranking Member Weber, and distinguished members of the Committee, I want to thank you for the opportunity to testify today regarding the importance of Fossil Energy Research.

## SUMMARY

With this opportunity, I want to make four points:

1. Subsurface Science is extremely complex and requires integration of both basic and applied research
2. Science that helps understand and control the subsurface is applicable across multiple national needs
3. The complexity of Earth systems motivates and facilitates advances in cutting edge research
4. The Nation benefits from utilization of the whole of the national laboratory technical capabilities

## MOTIVATION

The research done in fossil energy subsurface and surface infrastructure systems has been essential to our Nation's move toward energy security, sustainability, and stabilizing carbon emissions. The vast majority of the energy currently used by our Nation is derived from the earth's subsurface. In 2017, our domestic oil production was equal to about 90% of our energy consumption.[2] Finding and effectively withdrawing those resources, while mitigating potential adverse effects to the environment can seem, at times, like a daunting challenge; but it is a challenge well suited to Federally Funded Research & Development Centers such as the Department of Energy's National Laboratories. The National Energy Technology Laboratory has a primary role in leading this research, but the complexity and scope of Fossil Energy research challenges require the expertise of not only Sandia, but all national labs in the DOE complex working together to find solutions.

Current research in this area addresses nationally relevant themes including: understanding and expanding the total scale of US recoverable reserves, thus allowing appropriate leasing structures on Federal lands, optimizing US companies and US-based exploration and production in order to reduce the surface footprint of the industry, reducing environmental impacts including surface infrastructure leaks and the threat of well bore integrity failures, induced seismicity, produced water impacts and utilization, and pipeline safety and environmental management.

For the purposes of today I will primarily focus on subsurface research but would be pleased to provide information on surface and engineering research at the Committee's discretion.

## SANDIA NATIONAL LABORATORIES ROLE

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[1] Sandia National Laboratories is a multi-mission laboratory managed and operated by National Technology and Engineering Solutions of Sandia LLC, a wholly owned subsidiary of Honeywell International Inc. for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525. SAND2019-6788

[2] https://www.eia.gov/energyexplained/?page=us_energy_home

While Sandia is not the lead Department of Energy Laboratory for Fossil Energy, we fill an important role with unique capabilities and projects that include serving as lead for the subsurface science and sustainment of the Strategic Petroleum Reserve and understanding the fire safety of crude oil transportation by rail.

Additionally, we utilize the extensive investment in engineering science funded by the National Nuclear Security Administration to expand the Nation's energy security to augment the capabilities and leadership of the National Energy Technology Laboratory (NETL) and other DOE Laboratories.

Sandia has developed seven cross-laboratory technical capabilities, known as research foundations, which are of particular importance in maintaining cutting edge research on Earth Science, Bioscience, Computing and Information Science, Engineering Science, Materials Science, Nanodevices and Microsystems and Radiation Effects and High Energy Density Science.

Our use of these foundational technical capabilities have been applied for fossil energy applications in several ways. For example:

Carbon Capture Technologies:

Sandia partnered with the University of New Mexico to develop an ultra-thin enzymatic bubble-like membrane that can efficiently separate and capture $CO_2$ from coal-fired and gas-fired power plants. The patented technology, referred to as Memzyme, has been tested at the lab scale and is both 100 times faster in passing flue gas than other membranes on the market, and 10-100 times more selective for $CO_2$ over nitrogen, the main component of flue gas. This work was sponsored internally by Sandia's Laboratory Directed Research and Development (LDRD) program.

Carbon Storage Validation and Testing:

Geological carbon storage (GCS) technology requires the injection of large volumes of $CO_2$ into subsurface storage reservoirs. Current challenges include: (i) sustaining large storage rates; (ii) using pore space with unprecedented efficiency, and (iii) controlling undesired or unexpected behavior. Sandia has been involved in addressing these challenges through its work within the Center for Frontiers in Subsurface Energy Security (CFSES) in partnership with the University Texas under funding by the Department of Energy's Office of Science Energy Frontier Research Centers (EFRC) Program.

Sandia is part of a long-standing Southwest Partnership led by the University of Utah and the New Mexico Institute of Mining and Technology funded by the DOE Office of Fossil Energy Carbon Storage program. This team-based project has completed an initial study exploring the potential to store $CO_2$ in geologic conditions. Current work is underway at the Farnsworth Unit in Texas as part of an enhanced oil recovery site using $CO_2$ captured from ethanol and fertilizer plants that is injected into the underground oil reservoir. Sandia has also conducted investigations relevant to the geomechanics of $CO_2$ Reservoir Seals. An in-situ fracture tester was developed to examine the effects of $CO_2$ injection on caprock integrity by measuring the effects of different solutions and their concentrations on fracture velocities.

Sandia developed techniques to ensure $CO_2$ remains in place once injected under a project titled Nanoparticle Injection Technology for Remediating Leaks of $CO_2$ Storage Formation. This project, which involved a partnership with the University of Colorado – Boulder, focused on the development of advanced materials and methods that can prevent/remediate leaks in complicated environments under a variety of pressure, temperature, and chemical conditions to ensure $CO_2$ permanence within the storage formation. The DOE Office of Fossil Energy funded this work.

Advanced Energy Systems

Sandia is currently developing a scaled demonstration version of the Supercritical Carbon Dioxide Closed Brayton Cycle. Brayton Cycles have the potential to achieve higher energy conversion efficiencies at 1/10th the cost of comparable steam Rankine cycles. The technology is demonstrated in Sandia's Nuclear Energy Systems laboratory/Brayton lab under joint funding from the DOE's Office of Nuclear Energy and the Office of Fossil Energy.

The Institute for the Design of Advanced Energy Systems (IDAES) project specializes in the identification, synthesis, optimization, and analysis of innovative advanced energy systems at scales ranging from process to system to market. Sandia provides the optimization algorithms that help balance design options. Our work is made possible through previous investments made by both the National Nuclear Security Administration (NNSA) and Laboratory Directed Research and Development (LDRD) funding. IDAES is led by the National Energy Technology Laboratory (NETL), in partnership with Sandia, Lawrence Berkeley National Laboratory (LBNL), Carnegie Mellon University, and West Virginia University.

Rare Earth Element Extraction

Rare earth elements are critical for energy and national security, and the development of novel separation approaches impacts both. Sandia is in the process of patenting a novel separation technique for individual Rare Earth Elements developed at the lab-scale under LDRD- based funding and anticipate the use of this technology in future DOE and Industry applications testing.

Carbon Removal from the air

In partnership with Lawrence Livermore National Laboratory, Sandia now utilizes an "algal racetrack," at our site in Livermore, California to study the biological and environmental conditions and resilience of algal communities for $CO_2$ extraction from the atmosphere. This project has the potential to remove toxic metals such as selenium from water, and to develop feedstocks for other industrial processes. The Department of Energy's Office of Fossil Energy sponsored this work.

Monitoring and Accounting for Carbon Management and Removal

The largest source of methane (natural gas) emissions, as seen at the Aliso Canyon natural gas leak, are the result of emissions from the natural gas transmission system during petroleum and natural gas production. The detection, mitigation, and response to methane leaks requires an understanding of the sensors, systems, wellbore integrity, concrete, and the ability to provide emergency response when big leaks occur at or below the surface. For ten years, Sandia has invested internal funding to develop and test new highly sensitive systems and sensors coupled with complex modeling that enable us to determine the attribution of specific emitters and emission types (e.g., combustion verses agriculture). We have also invested in optimization tools for stationary placement and moving monitoring tools to ensure the best configurations for a given cost burden. This work has primarily been pursued under LDRD investments but also in partnership with Lawrence Livermore National Laboratory, via projects funded by the DOE Office of Science, Basic and Environmental Research, and the power plant safety monitoring industry.

Waste gas utilization and conversation to useful products at the well head

Sandia researchers developed a modular, scalable chemical reactor platform, known as the Bayonet Reactor, that is capable of producing hydrogen and fertilizer products including ammonia and urea. It works by first producing hydrogen from methane using a patented energy efficient steam methane reforming process. The hydrogen can then be used as a product or further reacted to produce ammonia (NH3) or urea (NH2CONH2). This technology resulted in a start-up company that could allow chemical companies to produce fuel and fertilizer in the same location as its intended uses such as farms or filling stations for hydrogen-powered vehicles.[3]

Related research that strengthens the nation's fossil energy related science includes:

Sandia has engaged in research related to deep geologic storage of various forms of nuclear waste for more than 30 years in our role as science lead for both the Waste Isolation Pilot Plant (WIPP) and the Yucca Mountain Project. The ability to characterize the subsurface, identify and mitigate risk, understand and communicate environmental and regulatory needs, and evaluate drilling and deep subsurface access, has expanded through this research with focus on multiple types of rock environments. Again, this broad set of research has fundamentally strengthened our ability to solve subsurface fossil energy challenges, understand wellbore integrity and induced seismicity, and support the Strategic Petroleum Reserve. Sandia continues to lead in developing the scientific and engineering basis for deep geologic disposal, and advancement of salt as a potential permanent disposal medium. Sandia is also a lead for enhanced geothermal energy production within the DOE laboratory system. In partnership with Lawrence Berkeley National Laboratory (LBNL) and other partners, we are pursuing deep crystalline rock fracking experiments at the Homestake Mine in South Dakota, which holds the promise of bettering our understanding of both geothermal and fossil energy control mechanisms.

## SUBSURFACE SCIENCE IS COMPLEX AND REQUIRES INTEGRATION ACROSS BASIC AND APPLIED RESEARCH

Subsurface science deals with a wide zone from the Earth's Surface to nearly 10 KM below the surface and must address the coupled thermal, chemical, biological, hydrological, physical, energy propagation, and mechanical behavior of naturally occurring, significantly heterogeneous, and dynamic materials, ensuring integrated understanding and information across scales ranging from nanometers to hundreds of kilometers.

As we venture into this highly heterogeneous system, the most challenging problem is getting accurate in-situ data. In this case, in-situ means very high temperatures and pressures, often found in complex, inaccessible, and expensive environments. One of the key enabling technologies is material science and micro-electronics research to develop materials leading to sensors that can withstand these environments. Basic research focused on material science, additive manufacture, molecular scale water-rock interactions, metal and natural material interfaces and similar research pursued by the DOE Office of Science Basic Energy Sciences lays the foundation for the ability to capture the essential information to advance applied data collection tools.

Due to the critical importance these Earth systems play in all of Sandia's missions, Sandia has developed key capabilities to address and link these complex systems of systems with world-leading capabilities in geomechanical testing from nano to macro scales, subsurface access and sensing including microsystems, electromagnetic-seismic-infrasound sensing and interpretation, robotics and downhole tools, data structures, high performance computing moving toward exascale computing, and risk based decision making.

The efficiency, safety, and mitigation of environmental consequences will increasingly depend on highly skilled application of integrated sensing, analysis, and control tools. Sandia's approach to developing this next generation set of capabilities will be described later.

[3] https://www.abqjournal.com/1221553/bayotech-builds-its-first-modular-hydrogen-plant.html

## SCIENCE THAT HELPS UNDERSTAND AND CONTROL THE SUBSURFACE IS APPLICABLE ACROSS MULTIPLE NATIONAL NEEDS

Subsurface research that is applicable to Oil and Gas production is equally valuable to enhanced geothermal production, understanding and implementing $CO_2$ sequestration, nuclear waste disposal, environmental restoration, basic research in geosciences, water resource management, and multiple national security needs.

> For example, the vast majority of the oil and gas we use comes from wells drilled using drill bits that incorporate synthetic diamond cutters known as polycrystalline diamond compacts (PDC). PDCs were invented in the 1970s and the promise of using this new material in drill bits was recognized by Sandia. With funding primarily from the DOE Geothermal Program and its federal predecessors, Sandia engaged in fundamental research, testing, and industrial partnerships to help develop a new bit for drilling through rock. Sandia's efforts catalyzed the commercial development of these faster drilling, longer lasting, advanced bits. Today, PDC drill bits are used in many subsurface applications including energy extraction, civil development, and mining. The shale revolution, the potential for enhanced geothermal energy and our science-driven deep-drilling programs would not have happened without the PDC drill bit.
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> Studies have shown that Enhanced Geothermal Systems have the potential to unlock 100 Gigawatts (which could meet nearly 10% of U.S electrical need) of sustainable, electrical power capacity.[4] Sandia is one of nine national labs and numerous academic and industry partners working together on a DOE-EERE funded project called EGS Collab that will provide critical information needed to inform site selection for future large-scale geothermal facilities that can contribute toward US energy independence.
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> The objective of the project is to perform small-scale reservoir model prediction and field validation experiments to understand the basic relationships between stress, seismicity, and permeability which form the critical technical barriers to achieving commercial EGS deployment.

It has been Sandia's objective to use knowledge gained in any one of these endeavors to benefit others and thus support our broad energy and national security programs/mandates. When the leadership of the Department of Energy works to integrate across these programs it greatly enhances technical cross-fertilization and results in game-changing solutions

The research pursued for fossil energy or geothermal purposes has benefited from and provides benefits to national security applications including combat drilling, Global Nuclear Test Detection, and understanding of nuclear weapons effects.

Additionally, this research helps our nation prepare for and respond to national emergencies. A few examples, from the recent past include:

> 2010 Deepwater Horizon: At the behest of then Secretary of Energy, Steven Chu, former Sandia Laboratory Director, Tom Hunter, was asked to lead a multi-lab team comprised of researchers and scientists from Sandia, Lawrence Livermore National Laboratory and Los Alamos National Laboratory. Hunter and the multi-lab team were asked to quickly stand-up a temporary laboratory to provide on-site support to BP and Secretary Chu as they wrestled, around the clock, to overcome the immense technical challenges required to stop the flow of oil in to the

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4 Massachusetts Institute of Technology (MIT). 2006. The future of geothermal energy. Cambridge, Massachusetts. Available: http://geothermal.inel.gov/publications/future_of_geothermal_energy.pdf.

Gulf of Mexico and to understand and mitigate the cascading effects of the explosion which tragically killed 11 people.
2015 Aliso Canyon Natural Gas Storage Methane Release: Sandia, Lawrence Livermore and Lawrence Berkeley National Labs were enlisted by the State of California to assist in dealing with the 2015 natural gas leak after a failed well resulted in the release of about 200 million pounds of methane into the atmosphere. Sandia and our partner laboratories worked together to support the State in evaluating options to stop flow from the well and, in the aftermath of the leak, to evaluate standards to mitigate future risks associated with natural gas storage. The Aliso Canyon event spurred a DOE-supported effort that examined well integrity associated with natural gas storage in aquifers and depleted reservoirs. This work was led by the National Energy Technology Laboratory and involved Sandia, Lawrence Berkeley and Lawrence Livermore National Labs.

An emerging national challenge is wellbore integrity detection, prevention, and remediation. Sandia has an established role as a leader in the field of wellbore integrity. In addition to managing the US Strategic Petroleum Reserve, for the last decade Sandia has developed a thriving R&D program in wellbore integrity that has produced novel materials to repair damaged wellbore seals, as well as new state-of-the-art predictive tools to identify "problem wellbores" prior to failure.

## THE COMPLEXITY OF EARTH SYSTEMS MOTIVATES AND FACILITATES ADVANCES IN CUTTING EDGE RESEARCH

The Earth is our largest and most complex data set. While it is currently an analog data set motivating the strong "observational science" approach of most geoscience education programs, we are rapidly working to digitize or convert what we see into a numerical representation. For example, NASA's Earth Observing Data and Information System (EOSDIS) consists of a collection of data which is currently 22 petabytes (just over 16 billion floppy disks) in size. NASA estimates the volume of data in this one archive will increase to almost 247 PB by 2025. [5] This data volume represents just one Earth Science data set; however, there are several others. Big Data in many scientific fields is creating a new paradigm in which novel scientific discoveries are being made through the analysis of large data sets. As access to data increases and a digital view of the earth emerges, we will have the need and the opportunity to use all forms of data analytics, artificial intelligence, and physics-based computing to decipher its processes and value.

To this end, SNL is investing in a program known as Real-Time Subsurface Event Assessment and Detection (RESEAD) to enable a step-change in real-time, continuous monitoring connected to the analysis and decision-based management of the subsurface. This Smart Subsurface Sensing System will work with any subsurface access point, including new and retrofitted existing wells. We believe this will lead to "Real-Time" characterization and production data, controls and decisions, machine learning data analytics, advanced math, and utilize Exascale models.

## THE NATION BENEFITS FROM UTILIZATION OF THE WHOLE OF THE NATIONAL LABORATORY TECHNICAL CAPABILITIES

The nation needs to utilize the full technical capabilities and investments embodied in the national laboratories.

The national laboratories in the Department of Energy complex are vital, agile, centers of knowledge and R&D excellence. We are honest and prescient stewards of scientific information in the interest of the nation. It is the primary goal of the national labs to undertake research that is in the national

[5] https://earthdata.nasa.gov/eosdis-cumulus-project

interest and that fills the critical gap of early stage research that is of such high risk industry is unwilling to pursue it, or where universities don't have the ability to effectively integrate across multiple disciplines. Thus, National Laboratory-led research should be focused on large, national scale research projects that require innovative, game-changing thinking and broad integration. Of greatest importance and the area where the support of committee members is most needed, is the urgent need to establish a mechanism that connects the capabilities across the whole of the National Laboratories, academia and industry to unleash the greatest of US technical power. The technical expertise and innovation required to tackle our nation's energy challenges will take the efforts and collaboration of ***all*** of the DOE's national labs. We encourage and invite the Department of Energy to continue to leverage not only Sandia but our sister laboratories to solve these complex challenges.

A recent example of the positive outcomes achieved through lab partnership was the Department of Energy's Subsurface Technology and Engineering Research, Development, and Demonstration (SubTER) Cross-cut. Under this program Sandia and several laboratory partners received funding through the Energy Efficiency and Renewable Energy (EERE)-Geothermal Technologies Office and the Office of Fossil Energy as national laboratory teams to work on cross-cutting topics relating to subsurface challenges identified across DOE programs. Adaptive Control of Subsurface Fractures and Fluid Flow was identified as the cross-cutting theme for the initiative. Another example is the Geothermal Technologies funded Collab research mentioned above.

By providing opportunities for the national laboratories to collaborate and work jointly with industry and academia on challenges relevant to both the nation and the Department of Energy, precious intellectual capital, which typically resides in the individual national laboratories in a siloed manner, were harnessed in a very effective way.

## CONCLUSION

In conclusion, thank you again for the opportunity to provide testimony on the importance of Fossil Energy Research continuation. The research sponsored by the Department of Energy and in partnership with commercial industry and academia establishes the foundation for the US to remain energy independent, facilitates both our current use and expanded environmental management of fossil resources, and integrates our national security, renewable portfolio and basic science foundation. Sandia National Laboratories is proud of our heritage and the investments we have made to sustain our nation's subsurface energy science capabilities. We are energized by the challenge and complexity this field of science affords. It is essential our nation fully utilizes the capabilities and investments embodied in the national laboratories to meet these challenges.

Thank you for convening this hearing, and I look forward to your questions.