Testimony of
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"Geopolitics of U.S. Oil and Gas Competitiveness"

Preface: Gas Technology Institute (GTI) is an independent 501(c)(3) research organization, established as an Illinois not-for-profit corporation. GTI has a 75-year history that stems from two predecessor organizations—the Institute of Gas Technology (IGT) established in 1941 as an education and research performing organization, and Gas Research Institute (GRI), created in 1976 to manage a cooperative research and development (R&D) program on natural gas. Based on a settlement between FERC and the gas industry in 1998, the traditional GRI RD&D program—and the mandatory funding to support it—ended in 2004. Today GTI is a voluntarily funded organization developing technology-based solutions for consumers, industry, and government.

Chairman Poe, Ranking Member Keating, and Members of the Subcommittee, on behalf the employees of the Gas Technology Institute (GTI), I thank you for this opportunity to testify before you today regarding U.S. Oil and Gas Competitiveness and the Geopolitical Implications.

My name is David Carroll, President and Chief Executive Officer at GTI. I oversee GTI's entire staff and operations, which focus on enhancing unconventional gas supply, energy conversion, natural gas delivery, and improved efficiency in end use markets. Prior to joining GTI in 2001, I held various technical and commercial positions in the global chemical industry with Air Products and Chemicals, Inc. and Praxair, Inc.

GTI is a leading non-profit research, development, and training organization, and our mission is to turn raw technology into practical energy solutions that have meaningful impacts on the economy and the environment. We celebrated our 75th anniversary as an institute in 2016 and have spent the last seven decades creating innovative solutions to critical challenges along the entire gas value chain, improving the ways of producing, transporting, converting and using energy to benefit the general public.

We cover a robust spectrum of initiatives. In addition to reducing the environmental footprint of shale gas production, which you'll hear more about, GTI's focus includes:

- Expanding the supply of natural gas and renewable energy
- Developing cleaner and renewable alternatives to petroleum-based transportation fuels and chemicals
- Enhancing the integrity of our nation's vast pipeline infrastructure
- Reducing methane emissions across the value chain
- Promoting energy efficiency by developing and demonstrating high-efficiency technologies
- Advancing clean, low-cost power production from all of our energy resources

With more than 360 employees across the nation, GTI engineers and scientists are developing innovative new tools, technologies, and methodologies, and delivering science-based factual data that helps guide informed decision-making and enlightened policy development.

GTI and its predecessor organizations, the Institute of Gas Technology (IGT) and the Gas Research Institute (GRI) have a storied history rich in meaningful Public-Private Partnerships on

various energy related topics, especially in the development of our country's unconventional oil and gas resources.

I currently have the additional honor of serving as President of the International Gas Union or IGU. This global association spans 91 countries, representing 97% of the world's production and use of natural gas. IGU is a non-profit based in Barcelona, Spain, and its member associations and companies are dedicated to enhancing the operational, technical and economic performance of the global gas industry and improving the quality of life for our fellow citizens through natural gas. The American Gas Association is the U.S. charter member of the IGU as are its global counterparts.

IGU is the owner of the World Gas Conference, a massive triennial event that takes place next month at the Walter E. Washington Convention Center right here in Washington. This conference and exhibition has not been held in the U.S. since 1988, so I hope that you will have the opportunity to join thousands of energy professionals, government leaders and policy makers from around the world.

U.S. Shale Development: Revolution or Evolution?

While shale development seems like an overnight occurrence to most, decades of research underpin the technical understanding and complexities of producing this almost seemingly impermeable resource. GRI and DOE conducted a focused research program addressing fracturing and production of shale formations during the 1980s and 1990s, investing more than $100 million.

Much of what now is considered seminal research was conducted in a series of field experiments that took place in eastern U.S. shales. Researchers from industry, national labs, and universities studied the data sets from empirical field tests of these wells and successfully built important fracture models and other innovations that have accelerated shale production over time. It is of interest to note that this research was criticized by much of industry at the time, with some large exploration and production companies describing the research as a "waste of money". Two men, former GRI President Dr. Henry Linden and George Mitchell, CEO of Mitchell Energy who served on the GRI Board of Directors at that time, fortunately did not share this sentiment.

Mitchell expressed support for shale research, but recommended moving the research program to new geologic basins. In 1991 GRI worked with Mitchell Energy to drill the Stella Young well in the Barnett Shale in Texas — a horizontal well stimulated with new technology that produced three times more gas than any other well up to that time. This was a pivotal point in the U.S. shale gas evolution that transformed the energy industry.

Impact of Upstream Development - Shale by the Numbers:

In addition to the research and technology underpinning that occurred over decades, the U.S. has a unique alignment of factors that no other country in the world enjoys that has made shale development such an astounding success:

- Incredible, vast resource of brittle shale
- Mineral rights ownership by landowners

- Great access to capital
- Tremendous pipeline infrastructure
- Robust service sector
- Entrepreneurial spirit of the independent producer
- Public policy that provides incentives for development

Fast forward to today, oil and gas production from U.S. shale formations has become what most consider the world's "swing supply", a truly amazing success and likely the biggest energy breakthrough of the last 50 years. While the oil and gas sector is responsible for an estimated $1.2 trillion in GDP and 9.3 million U.S. jobs, one of the most meaningful and visible impacts of shale gas is lower utility bills for consumers, putting $1,372 back into the pockets of the average American family, according to a Perryman Group study. Since shale gas is used to heat homes and produce electricity, consumers are seeing the impacts in both natural gas and electricity bills. The increased use of natural gas in electricity generation has also produced significant reductions in CO2 from the power sector – 27.8% from 2005 to 2017, according to EIA.

Net energy imports have decreased from 30 Quadrillion Btus (Quads) in 2005 – over 30% of our total energy needs in that year – to only 7.4 Quads in 2017 and just 7.6% of our domestic energy needs. With continued expansion of domestic energy production from multiple sources – natural gas, oil, biomass, wind, and solar – and steady strides in energy efficiency, we are heading closer to full net energy independence.

Liquefied Natural Gas - Imports to Exports

In addition to the myriad benefits to the U.S. economy, shale gas has given our country the opportunity to participate more broadly in the global gas trade, both through pipeline gas to Mexico and through exports of liquefied natural gas, or LNG, to more distant markets.

At next month's World Gas Conference, IGU will release the latest edition of its much anticipated World LNG Report, which highlights recent trends and statistics in the global LNG market. I've provided below some excerpts from this report to give you a sense of the vibrancy of this global market in which the U.S. now vigorously competes.

"International trade in liquefied natural gas (LNG) continues to be one of the most vibrant segments of the world's natural gas value chain, growing in 2017 by 35.2 million tonnes (MT), or 45.8 billion cubic meters, of natural gas, to 293.1 MT in global trade. That represents growth of over 10% and comes as projects in Australia and the U.S. bring new capacity on line and Asian markets continue to grow. China and South Korea led Asian growth with additional demand of 12.7 MT and 4.9 MT, respectively. China has focused on aggregate energy demand toward natural gas and away from coal in its fight against air pollution.

In 2017, more traditional European trade patterns returned, including a move away from LNG re-loading due to overall supply increases and stable demand. Spain, Italy, Portugal and France returned to more traditional LNG uptake. In North America, Mexican imports of LNG were up, as additional low-cost U.S. shale gas imports were unavailable due to pipeline delays. Unlike

2016, the increases in world trade occurred without new major entrants to the world LNG market.

Qatar continued to be the world's leading exporter of LNG, with 2017 liquefaction reaching 81.0 million tonnes per annum (MTPA), followed by Australia, Malaysia, Nigeria, Indonesia, and the U.S. Australia and the U.S. led in growth of exports by increases over 2016 of 11.9 MTPA and 10.2 MTPA, respectively. There are 92 MTPA of liquefaction capacity under construction world-wide, and we expect about one-third to come online this year in far-reaching locations of Australia, Cameroon, Indonesia, Malaysia, Russia, and the United States.

Thus far, the global market is absorbing new supply with minimal distortion, as new buyers and existing markets alike demonstrate a high need for natural gas to meet growing energy demand. The need for cleaner fuels that are available on-demand is a key part of this trend. Non-long-term trade (which includes "spot market" activity) increased yet again, reaching over 88 MT in 2017.

U.S. shale gas continues to moderate North American natural gas prices through technology and efficiency improvements, which translates into lower U.S. feedstock costs. Global LNG prices have seen a rebound as dictated by the international supply/demand balance. Average Northeast Asian spot prices have increased $1.33/MMBtu from 2016 to 2017, and averaged $9.88/MMBtu in January 2018, which is the highest price point in three years. Incremental supply during 2018 will impact the balance and may moderate prices."

As you can see from the above, U.S. LNG is participating in a fast growing, dynamic marketplace with an increasing number of producers and consumers. The U.S. is emerging as a major exporter and will solidify that position as additional liquefaction facilities come on line over the next couple of years.

But our success as an exporter is not assured. It's a competitive market, and the competitors are not standing still, so continued efforts to enhance productivity and reduce costs in our upstream production, transportation network and liquefaction processes will be necessary to keep pace.

U.S. LNG has its advantages, from relatively low cost supply, to flexible contracting and business models, to transparent pricing, to competent reliable producers with access to gas resources and capital. But we have some disadvantages also, not the least of which are higher transportation costs to the growth markets of Asia and Africa. Again, diligent efforts to bring innovation to the LNG value chain will help the U.S. emerge as a leader in this attractive global market.

India – A Strategic Partner Building a Gas Based Economy

Now a few words about the global demand for gas. The International Energy Agency (IEA) expects roughly 70% of demand growth over the next twenty years to take place in non OECD countries. We're seeing this today, as developing countries in Asia, Africa and the Middle East look to fuel growing economies, sustain ever growing, urbanizing populations and address the acute problem of poor urban air quality. Natural gas is helping these economies meet these challenges effectively and in a way that doesn't break the bank.

While the examples are many, let me focus on India to illustrate the important role of natural gas. Prime Minister Modi, Energy Minister Pradhan and other authorities have established a goal of increasing the share of gas in their direct energy mix from 6% to 15% over the next 15 years, a massive challenge in a growing economy. LNG will play a role in India's gas supply, as will enhanced domestic production, pipeline infrastructure development and city gas distribution network buildout. Helping India succeed in this initiative, enhancing their energy security, fueling their economic development all the while improving their environment is in the U.S. interests in many ways.

Our government sees this clearly and has responded accordingly. In June of 2017, President Trump and Prime Minister Modi announced the U.S.-India Strategic Energy Partnership (SEP), affirming the strategic importance of our bilateral relationship against the backdrop of one of the most critical and fundamental sectors: energy. Last month, Secretary Perry traveled to New Delhi where he and Petroleum Minister Pradhan co-chaired the inaugural meeting of the US-India Strategic Energy Partnership. SEP has four primary pillars, including one on oil and natural gas, and the goals are simple, yet aspirational: universal energy access, strengthened energy security and increased energy efficiency. The Partnership will create opportunities for advancing favorable policies and commercial sector investment in their emerging gas market. While India's goals and ambitions are bold, they lack much of the necessary infrastructure to bring gas into the country, and to distribute it throughout India. The Partnership should help.

GTI has similarly responded to help India build its capacity to embrace natural gas. As GTI's CEO I've been in India three times over the last 18 months, meeting with government and industry leaders to explore areas of potential cooperation. Earlier this month, GTI signed Memoranda of Understanding to formerly cooperate with two institutions, Pandit Deendayal Petroleum University (PDPU) and LNG importer Petronet LNG, Ltd. Much of our early focus will be to train and develop India's energy workforce, from engineering students, to plant operators and technicians, to mid-career technical and management professionals. Under the Prime Minister Modi's leadership, these are exciting times for natural gas in India.

It's interesting to note that while I was India three weeks ago, a shipment of LNG exited the Cove Point, Maryland LNG facility enroute to Petronet's receiving terminal in Dahej Terminal. India is now the world's fourth largest LNG importer and growing, behind only Japan, China and South Korea. The future is bright for LNG, and natural gas more broadly, in India. The U.S. should continue its efforts to support the development of energy supply, infrastructure, and markets of this important strategic partner.

How Do We Expand our Competitive Position and Expand our Global Reach

In the past decade, the U.S. has gone from high oil and gas prices, scarcity and planned import terminals to sustained low prices, 100+ year supplies and an increasing number of export facilities. U.S. shale development has turned the energy landscape upside down.

As we examine the global energy landscape, the U.S. has two things that separate us from everyone else: abundant natural resources and a robust infrastructure. We are fortunate enough to

have 2.5 million miles of pipelines that deliver these critical assets across the country. However, the U.S. is not the lowest cost exporting producer of natural gas even with our expansive shale reserves, and only better recovery factors through continued technology advancement can change this paradigm. The most proven path to broadly enhance results in the subsurface is via Public-Private Partnerships, as demonstrated in the following example.

The Permian Project: GTI's Hydraulic Fracturing Test Site (HFTS):

Our goal is simple – substantially advance the hydraulic fracturing process to optimize well spacing so that fewer wells are needed to effectively improve resource recovery and reduce the environmental footprint of production.

The problem is multifaceted – subsurface completion science has the greatest uncertainty and variability of the shale development process. Yet, even as hydraulic fracturing is in wide use, it continues to be a complex and controversial process with many variables that affect the locations at which the fractures propagate, their dimensions, and their ability to enhance production of hydrocarbons. The actual internal architectures of the fractures created along the horizontal holes that are drilled during each stage are not well understood. While we know that the fractures form a complex three-dimensional pattern, direct and reliable data is still needed about the size, shape, and distance of hydraulic fracturing propagation.

Solving this complicated problem requires input from scientific, engineering, and operating subject matter experts from across the industry (operators and service providers), universities, national laboratories, and other research institutes, and the only realistic way to do this is via a Public-Private Partnership. So with the assistance of a cooperative agreement in the amount of $7.4MM from U.S. DOE Fossil Energy, GTI was able to attract:

- A **host site partner** in Laredo Petroleum that provided an eleven horizontal well test bed in the Permian, pertinent micro-seismic and other background data with an approximate value of $100MM, and approximately 25 engineers and operations staff for the experiment.
- A **Joint Industry Partnership** (JIP) of service companies, independent producers, and integrated majors that sponsored the additional $16MM of research work and also provided subject matter experts to technically contribute to the program. (JIP participants are Chevron, ConocoPhillips, Core Laboratories, Devon, Discovery Natural Resources, Encana, Energen, ExxonMobil, Halliburton, Shell, and TOTAL.)
- A team of **leading researchers** at the University of Texas (UT) Petroleum Engineering Department, at the UT Bureau of Economic Geology, and at the National Energy Testing Laboratory.

The key differentiator of this field experiment is the 600 feet of unique core that was obtained by drilling a one-of-a-kind core well through created hydraulic fractures at the test site. Extracting core of this magnitude is an expensive and risky undertaking, but all participants agreed in advance that this ground truth evidence is paramount to understanding fractures, validating and developing models, and to consider if and how big data and predictive analytics can improve the process.

The analysis of fracture properties as impacted by reservoir rock conditions will help researchers develop a cause-and-effect relationship between fracturing parameters and reservoir rock to measure the consequences of fracturing—results that can be applied to other locations and plays. Important data about subsurface fracture propagation and proppant transport dynamics will lead to the design of optimal fracture treatments and, ultimately, ideal well spacing. Many of the findings will likely be transferrable to other basins, but shale is a heterogeneous resource so much more work needs to be done.

Conclusion:

In conclusion, innovation in the natural gas sector over the last couple of decades has given our nation tremendous opportunities to enhance the competitiveness of our economy, create jobs, save consumers money and engage more broadly in global trade. Developing this abundant domestic resource has enhanced our nation's energy security and provided more flexibility in dealing with strategic partners around the world.

It's important to remember that this success in natural gas didn't happen overnight and it didn't happen by accident. And sustaining our progress will require continued investments in research to enhance well productivity, reduce costs and minimize the overall environmental impacts of production, transportation and use. We also need continued investments in pipeline infrastructure to get this affordable, cleaner energy to market.

There are many stakeholders in the natural gas space: employees, customers, consumers, investors, national and local governments, regulators, environmental groups and others. Our industry is working hard to constructively engage these stakeholder groups to stress the benefits from gas that accrue to our broader economy. Reinforcement of these benefits by our national leaders and policy makers to stakeholders of all demographics would help ensure that we realize the full economic, strategic and environmental benefits of natural gas for decades to come.

Thank you for the opportunity to provide this testimony.

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