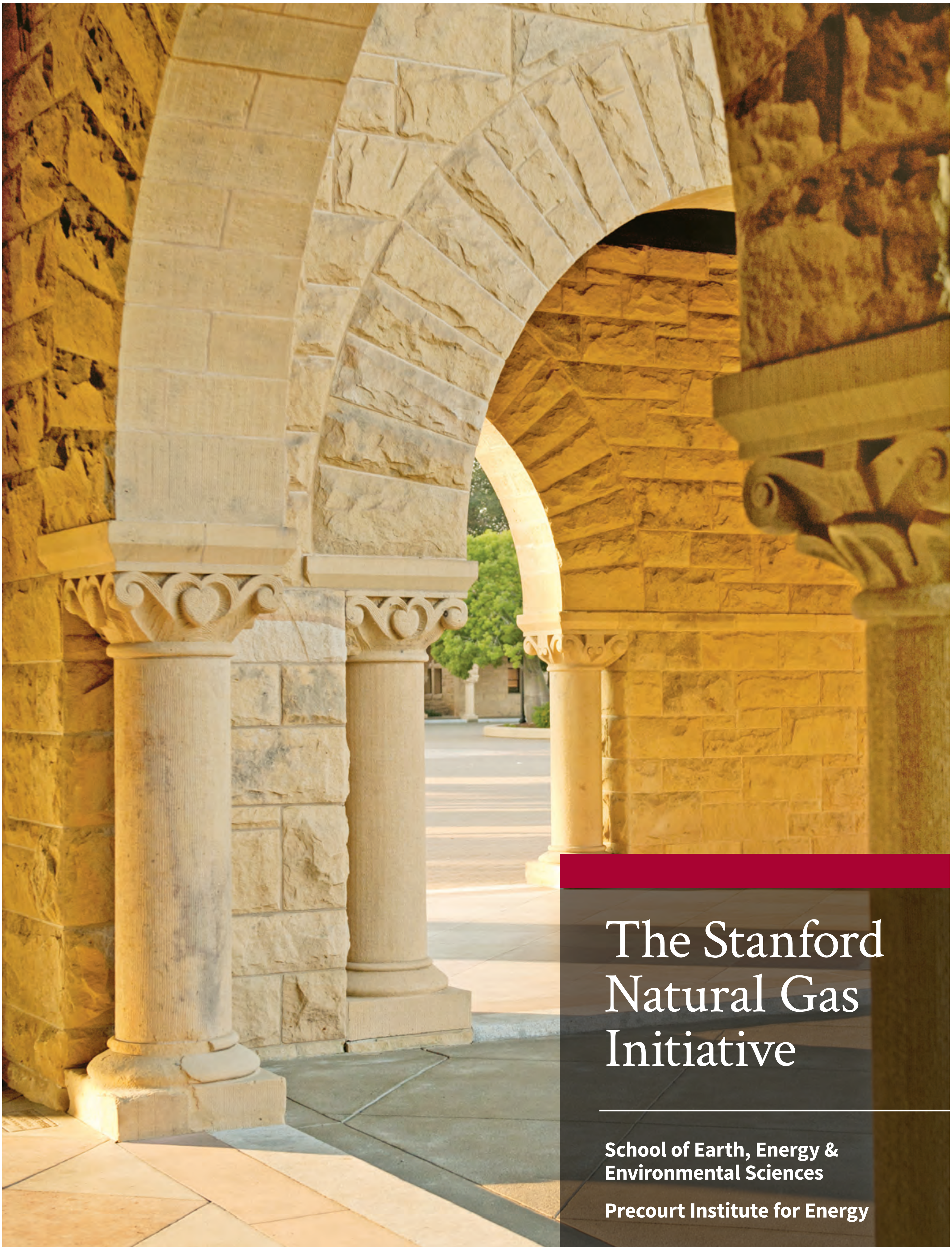
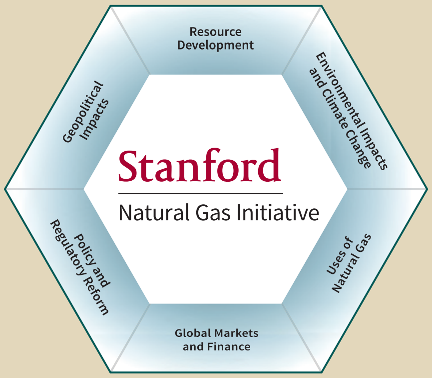


# The Stanford Natural Gas Initiative

School of Earth, Energy & Environmental Sciences

Precourt Institute for Energy

***Mark Zoback,*** *Director of the* ***Natural Gas Initiative****, is the Benjamin M. Page Professor in the Department of Geophysics in Stanford's School of Earth, Energy & Environmental Sciences. An acclaimed expert on reservoir geomechanics, Zoback is the author/co-author of more than 300 scientific papers and has advised industry and government leaders worldwide on shale gas development and environmental protection.*




"If developed in an environmentally sustainable manner, globally abundant natural gas resources will enable large-scale fuel switching for electrical power generation. This will dramatically reduce greenhouse gas emissions and air pollution in many countries, while enhancing energy security and economic growth.

"In this context, natural gas can play a critically important role as a transition fuel on the path to a decarbonized energy future."

**— Mark Zoback**
**Director**
**Stanford Natural Gas Initiative**

Stanford | SCHOOL OF EARTH, ENERGY & ENVIRONMENTAL SCIENCES

***Stephan Graham***
*Chester Naramore Dean,*
*School of Earth, Energy & Environmental Sciences;*
*Welton Joseph and Maud L'Anphere Crook Professor*

**Mission:** To create and effectively disseminate fundamental knowledge about Earth, its resources, and the processes by which it changes; to train students and future leaders, and educate the broader public in the Earth and environmental sciences; to integrate, synthesize, and apply scientific and engineering knowledge to societal problems, such as the sustainable use of energy and water resources, the identification and mitigation of risks posed by natural hazards, and the consequences of human activities on the environment.

Stanford | Precourt Institute for Energy

***Sally Benson***
*Co-Director, Precourt Institute for Energy;*
*Professor of Energy Resources Engineering*

**Mission:** The Precourt Institute for Energy at Stanford (PIE) serves as the hub of a broad and deep network of experts from various science, technology, behavioral, and policy disciplines who are working independently and collaboratively to solve the world's most pressing energy problems. PIE's mission is to advance the goal of major and rapid energy transformations. PIE provides funding and associated support for cutting-edge energy research, creates and maintains avenues for effective communication and intellectual exchange among scholars and others seeking energy solutions, and develops energy-literate leaders and communities through educational programs and the dissemination of research results.

***Bradley Ritts,*** *Managing Director of the* ***Natural Gas Initiative****, is an expert on oil and gas exploration and the upstream petroleum industry. Prior to joining Stanford, he held a variety of technical and management positions with Chevron in California and Singapore and was on the faculty of Indiana and Utah State universities. Ritts earned a doctorate in geological and environmental sciences at Stanford. He can be contacted at ritts@stanford.edu.*

**ngi.stanford.edu**

# Stanford | Natural Gas Initiative

*School of Earth, Energy & Environmental Sciences and Precourt Institute for Energy*

Major advances in natural gas production have fundamentally changed the energy outlook in the United States and much of the world. A decade ago in the U.S., natural gas supplies were declining, liquefied natural gas (LNG) import terminals were expanding, and the heavy reliance on coal for electrical power generation seemed impenetrable. The revolution in natural gas production has thrust this resource into the global spotlight as a potential bridge to a cleaner energy future. This development has raised hopes, along with concerns and complex questions about global energy, the world economy, and the environment.

Stanford faculty, students, and researchers are world-renowned experts in research and discovery related to energy resources, with a particular focus on producing resources efficiently and with as few negative consequences as possible. No one is better positioned to address the complex global questions surrounding the development and utilization of natural gas in a climate-constrained and increasingly energy-intensive world.

The new **Natural Gas Initiative (NGI)** at Stanford, hosted by the School of Earth, Energy & Environmental Sciences and the Precourt Institute for Energy, engages faculty across the university to carry out the many types of research needed to ensure that natural gas is developed and used in ways that are economically, environmentally, and societally optimal. In the context of Stanford's innovative and entrepreneurial culture, the initiative supports, improves, and extends the university's ongoing efforts related to energy and the environment.

Today there appears to be a technically recoverable global supply of natural gas to cover projected needs for the next 200 years. In the U.S., idle import terminals are being retooled to export LNG and utilities have been switching from coal to gas to produce electricity. This is contributing to the lowest $CO_2$ emissions in the U.S. since 1994, and low natural gas prices have revitalized industry.

These dramatic changes raise urgent, complex questions to be considered across the globe as we address energy, the economy, and the environment:

- What new technologies will enable the supplies and uses of natural gas to continue to expand with minimal impacts on communities and ecosystems?
- How is the shale gas revolution affecting the development and adoption of renewable energy technologies and the cleantech industry?
- How should North America export natural gas, and natural gas technologies, for maximum benefit?
- How can natural gas be utilized in conjunction with renewable sources to achieve the maximum benefit?
- Can accelerated fuel-switching to natural gas from coal help abate the extremely serious air pollution problems now affecting many cities in China, India, and other regions?
- What are the best uses for natural gas, and what policies can foster those uses?
- How will plentiful and broadly distributed gas resources affect economies around the world?
- What will be the geopolitical impacts of the coming natural gas revolution?

The **Natural Gas Initiative** examines the dynamic, multifaceted questions raised by the tremendous growth in natural gas production by focusing the efforts of Stanford's faculty, researchers, and students in six key areas:

- Resource development
- Environmental impacts and climate change
- Uses of natural gas
- Global markets and finance
- Policy and regulatory reform
- Geopolitical impacts

The natural gas industry is complex, requiring an integrated, comprehensive approach like that brought by the **Natural Gas Initiative.** Its many aspects, from production to processing, transmission, distribution, storage, and end-use are subject to vastly differing and evolving state and federal regulatory structures.

These factors present a spectrum of inter-related issues that need to be addressed to fully realize the potential of the apparent abundance of this resource. How the opportunity provided by natural gas is managed could mean the difference between tremendous benefits and significant harm for decades to come.


**STANFORD UNIVERSITY**
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Graduate School of
**BUSINESS**

School of
**EARTH, ENERGY & ENVIRONMENTAL SCIENCES**

School of
**ENGINEERING**

School of
**HUMANITIES & SCIENCES**

School of
**LAW**

**PRECOURT INSTITUTE FOR ENERGY**

**STEYER-TAYLOR CENTER FOR ENERGY POLICY & FINANCE**

**STANFORD WOODS INSTITUTE FOR THE ENVIRONMENT**

HOOVER INSTITUTION
**SHULTZ-STEPHENSON TASK FORCE ON ENERGY POLICY**

**NGI research on resource development focuses on creating:**

- Innovative new technologies for doubling recovery in unconventional shale reservoirs
- Practical alternatives to current hydraulic fracturing procedures
- A new generation of techniques for reservoir simulation and production modeling
- Novel techniques for producing natural gas from offshore methane hydrates
- Better methodologies for producing sour gas, $CO_2$ rich gas and other challenges of natural gas reservoirs

Large-scale production of natural gas from unconventional, organic-rich shale has emerged only in the past decade through the use of horizontal drilling and multi-stage hydraulic fracturing. Shale and other "tight" formations have permeabilities about a million times smaller than conventional reservoirs, and many fundamental scientific and practical engineering questions remain unanswered about how to develop these abundant resources for maximum production.

Currently, a typical recovery factor from unconventional shale gas reservoirs is about 25%. Only 5% of liquid hydrocarbons are typically recovered from shale reservoirs. Because these geologic formations are diverse and complex, an uncommon level of interdisciplinary integration will be required to answer the fundamental questions that need to be addressed to dramatically improve recovery. Combining expertise in Earth science, petroleum engineering, chemical engineering, computational science, and related disciplines can help create new production and resource management technologies and practices.

Gas flow mechanisms in the shales also include sorption to organic matter that varies with pressure and free gas flow through fractures. In addition, the presence of water in fractures leads to multiphase flow and potentially reduces the injectivity and producibility of methane. NGI investigators will develop models to integrate the roles played by various physical attributes and mechanisms that control production. New methods for reservoir characterization and modeling will improve production and make better use of geophysical imaging to guide exploration, provide information for decisions during field development, and manage depletion. Research will take place in the laboratory and in the field, and large-scale simulations across the various length scales will provide a basis for sound reservoir management.

***Eric M. Dunham**, Associate Professor of Geophysics and affiliated faculty member of the Institute for Computational and Mathematical Engineering, uses waves to image hydraulic fractures.*

*An expert on the multiphase flow of oil, water, and gas in porous media, **Tony Kovscek** is a Professor of Energy Resources Engineering and Co-Director of the Stanford Center for Carbon Storage.*

**NGI research on environmental impacts and climate change aims to:**

- Carry out the fundamental science needed to reduce fresh water use in hydraulic fracturing operations and contaminated flow-back water disposal through improved treatment and recycling technologies
- Analyze how increased natural gas usage will impact climate change efforts, including the transition to a decarbonized energy future
- Develop methodologies for managing and reducing the risk of earthquakes triggered by wastewater injection or hydraulic fracturing
- Develop new geochemical techniques to fingerprint the origin of natural gas when apparent leakage is detected
- Advance technologies to separate $CO_2$ from natural gas
- Improve techniques to reduce threats to health and safety of those associated with, and affected by, shale gas development

Done properly, the development of unconventional gas resources can reduce the carbon footprint of this industry—as measured by air pollution, greenhouse gas emissions, and even water use—relative to other fossil fuels and nuclear energy. Done poorly, it could release toxic chemicals into water and air. It could also push the world toward aggravated climate change if methane leakage from wells, pipelines, and compressor plants offsets the marked reduction of $CO_2$ emissions through burning gas for electrical power generation instead of coal, oil, or diesel, or if the increased use of natural gas delays a worldwide transition to a decarbonized future. Understanding the impact of increased gas usage on carbon reduction goals is critical.

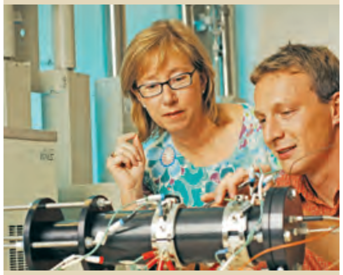
How we develop these resources today will affect future generations. It is they who will benefit most from the long-term enhanced utilization of natural gas and bear the costs of unintended consequences and environmental impacts.

Considerable potential exists for synergies among natural gas, renewable energy sources, and natural gas used to power low emission fuel cells. For example, natural gas-fired electrical power generation can help address the intermittency of solar and wind power, while renewables can help dampen the price volatility of gas. Also, hydraulic fracturing technologies developed for shale gas production could aid in the development of significant new geothermal resources. At the same time, more research is needed to understand how greater usage of natural gas for electricity production affects long-term carbon emissions-reduction goals and the best approaches to integrating increased gas usage with significantly higher levels of renewable power.

Public concerns about the environmental impacts of hydraulic fracturing include the potential for ground and surface water pollution, local air quality degradation, fugitive greenhouse gas emissions, induced seismicity, ecosystem fragmentation, and community impacts. These concerns arise from a mix of information and misinformation, and many are not unique to unconventional oil and gas production. However, the scale of hydraulic fracturing operations is much larger than in the past, with industrial development occurring in areas with little or no previous development, sometimes literally in people's backyards.

Like our nation's bridges and water mains, our natural gas pipelines date back almost to the Civil War in places and are often located in heavily populated areas. The pipeline outside the apartment building in Harlem that exploded in March 2014 was about 125 years old. The Allentown, Pennsylvania, explosion in 2011 was caused by leaks from an 83-year-old cast-iron pipe, and the San Bruno, California, explosion in 2010 was likely due to pipe installed in 1956 with faulty welds. Similar—and often more serious—infrastructure challenges are present in developing countries. Developing methodologies and technologies to reduce pipeline leaks through better detection will save money and lives while helping to preserve the environment.

*An expert on carbon, water, and nutrient cycling,* ***Rob Jackson*** *(right) is the Kevin and Michelle Douglas Professor of Environment and Energy and a fellow of the Woods Institute for the Environment and the Precourt Institute for Energy.* ***Adam Brandt*** *(left), an Assistant Professor of Energy Resources Engineering and Fellow of the Precourt Institute, studies greenhouse gas emissions from fossil energy sources.*



*A groundwater hydrologist and reservoir engineer who studies technologies and pathways to reduce greenhouse gas emissions,* ***Sally Benson*** *(left) is Professor of Energy Resources Engineering and Director of the Precourt Institute for Energy.*

**NGI research on the uses of natural gas aims to:**

- Develop novel processes that can convert methane to readily transportable products
- Develop advanced fuel cells and other devices for producing electricity from methane
- Develop new uses for methane in the petrochemical and manufacturing industries
- Create technologies to capture and beneficially utilize natural gas associated with drilling and well completion as an alternative to flaring
- Investigate how natural gas resources can be used in an optimal manner for electrical power generation and transportation
- Understand how can we best capture and utilize $CO_2$ emitted from natural gas-fueled power plants

Methane is used widely as a feedstock for the production of industrial chemicals, ammonia-based fertilizers, and liquid fuels, but natural gas resources are often located in remote areas. New processes that can convert methane to readily transportable products, including methanol or liquid hydrocarbons such as gasoline, could be more energy efficient and less costly than processes available today. Enhanced production of methane adds value, allows for more cost-effective transportation, and provides chemical feedstocks that can be readily converted to other important targets such as gasoline, diesel, and plastics.

Stanford has a strong team of scientists and engineers who work in the areas of chemical catalysis, with major research focused on understanding reaction chemistry at the atomic scale to facilitate the development of improved catalysts and chemical processes. A focused effort would be sure to produce new insights on a direct pathway for methane conversion.

Developing new means to produce electricity from methane for distributed power in smaller-scale mobile and stationary applications is also of great interest and of military importance. Expertise across several disciplines requiring advanced technical resources is needed to create new technologies in this domain, particularly the development of economic fuel cells that can directly utilize methane or natural gas as a fuel.

*A solid state physicist by training,* ***Friedrich Prinz*** *(left) is the Finmeccanica Professor of Engineering, the Bosch Chair of Mechanical Engineering, Professor of Materials Science and Engineering, and Senior Fellow at the Precourt Institute for Energy.*

*Combining chemistry and materials science principles,* ***Matteo Cargnello****, an assistant professor in Chemical Engineering, and his group are looking into catalytic processes that selectively activate the C-H bond in methane at lower temperatures, in order to reduce its emissions in the atmosphere and to produce useful chemicals and liquid fuels.*

## GLOBAL MARKETS AND FINANCE

**NGI research on global markets and finance aims to:**

- Develop a new modeling framework for advanced analysis of the global gas market
- Investigate the opportunities and impacts of exporting U.S. gas to Europe as an alternative to Russian gas and to Asia and Latin America as an alternative to coal
- Evaluate the implications of exporting U.S. shale gas and U.S. gas extraction technologies
- Explore the new flows of capital required to both develop new systems and renovate existing systems increasingly fueled by natural gas
- Examine the resilience of sectors dependent on natural gas in light of potential price volatility
- Investigate how to utilize available sources of capital that will assure expansion of both natural gas and renewable energy systems

To date, the direct economic impact of shale gas has been felt almost exclusively in North America. However, a number of LNG export facilities are slated to begin operation in the next few years in the U.S. and an increasing number of U.S. companies are employing hydraulic fracturing and horizontal drilling technologies both domestically and abroad in joint ventures with foreign oil and gas companies.

Mexico has an ambitious plan to expand its current pipelines and build new ones to import natural gas from the U.S. How will the export of U.S. shale gas to Mexico compete with the option of exporting U.S. extraction technology to facilitate production from Mexican shale gas reserves?

Globally, will a significant amount of LNG move from producing regions to consuming regions, making it a truly global commodity? Or, will natural gas markets remain segmented into different regions as defined by interconnected pipeline networks? Factors that may influence decisions about exporting natural gas may include resource costs, approval of LNG terminal siting, Russian natural gas strategy and demand from the European Union, Asian nuclear capacity and coal retirements, new developments in Latin American countries with rich natural gas reservoirs, energy reforms in Mexico and Argentina, and climate change policies in developed and developing countries around the world.

It is clear that a new modeling framework is needed for the global gas market. Policy makers need to be presented with potential paths forward that are robust to various types of uncertainty.

Improving the infrastructure to produce, transport, and store natural gas, while also addressing increasingly severe natural and man-made threats, will be costly and complicated. It will require significant new public- and private-sector investment and additional regulatory oversight. Competition for capital from other energy sources and investment sectors is growing. The Natural Gas Initiative will contribute to a better understanding of these large economic and regulatory challenges and help develop new approaches to address them.

*Former U.S. Assistant Secretary of Energy* ***Dan Reicher*** *directs the Steyer-Taylor Center for Energy Policy and Finance and is a faculty member of the business and law schools.*

***Frank Wolak*** *is the Holbrook Working Professor of Commodity Price Studies in the Department of Economics, Director of the Program on Energy and Sustainable Development in the Freeman Spogli Institute for International Studies, and a Fellow of the Precourt Institute for Energy.*

## POLICY AND REGULATORY REFORM

**NGI research supports policy and regulatory reform by contributing to the development of the following:**

- Effective federal, state, and local regulatory systems for conventional and unconventional gas resources
- Systems strategies for the utilization of natural gas in conjunction with renewable energy sources
- New policies and regulations to minimize leakage during natural gas transmission and distribution
- New national policies to address the numerous geopolitical impacts of the availability, distribution, and use of global natural gas resources
- A national survey of distribution system losses
- A national survey of federal and state regulations of gas distribution systems and cost recovery
- Assessment of new challenges as electric power systems in many countries around the world place greater reliance on gas
- Assessment of the extent to which natural gas as a transportation fuel should be supported

***Michael Wara,*** *Associate Professor of Law, brings his background as a geochemist and climate scientist to his study of energy and environmental law.*

How and at what level of government should air quality and water resource issues be addressed? How can leakage be minimized in a cost-effective and environmentally responsible manner at all points in the system? How will increased reliance on natural gas in the electric power sector be balanced against the need to ensure power system reliability during extreme weather events like the recent polar vortex and affect state or other carbon emission reduction goals? To the extent that new pipelines or other interstate infrastructure may be needed, are current regulatory systems sufficient regarding planning, permitting, and cost recovery? Such questions highlight the need for new governance strategies at local, state, and federal levels. To the fullest extent possible, solutions ought to preserve the attributes of the regulatory environment that made it a locus of technological innovation and economic growth. Crafting regulatory regimes with adequate enforcement appears to be a key challenge in the context of poorly financed institutions.

Deep expertise in the mix of institutional, legal, and regulatory contexts at the local, state, and federal levels will be essential to creating a new scholarship on natural gas regulation that addresses the changing landscape of natural gas. This scholarship will both learn from and inform policymaking in managing the impacts of shale gas. New and innovative thinking into the governance of natural gas development is needed to assure the sustainable utilization of this transformative resource.

It is important to achieve a better understanding of natural gas leakage in utility distribution systems and to develop incentive-based regulations to motivate distribution utilities to identify and remediate leaks. It is equally important to take steps to ensure effective oversight by regulators. National surveys are needed of both utility distribution system loss and regulation of gas distribution systems and cost recovery. It is important to identify which utilities operate the tightest systems and why. Ultimately, it is important to document the variations in leakage rates and outline a policy agenda for regulatory reforms at the local, state, and national level that would cut the leakage rate in a manner that is consistent with other priorities such as safety, reliability, and affordability. This initiative will work closely with policymakers, utilities, and trade associations to ensure a robust research effort to develop effective policies.

To some degree the recent availability of large supplies of inexpensive natural gas may have lessened support for research on truly transformative, low-carbon technologies. Historically, when the price of hydrocarbons for energy goes up, interest in alternatives rises, and when the price goes down interest wanes. Governments and industry could be tempted to decide that with plentiful and low-cost natural gas, they can ease up on the support for low-carbon energy technologies. Current research and development spending on no- and low-carbon alternatives is not large, but is making reasonable strides and holds great promise.

## AFFILIATED FACULTY AND RESEARCH STAFF

Jeffrey Ball, STC
Sally Benson, ERE, GCEP, PIE
Adam Brandt, ERE, PIE
Ken Caldeira, Carnegie, EESS
Matteo Cargnello, ChemE
Jeremy Carl, Hoover, SSTF
William Chueh, MSE, PIE
Eric Dunham, GP, ICME
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Chris Edwards, ME, PIE
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Tiziana Vanorio, GP
Xiaolin Zheng, ME
Mark Zoback, GP, PIE

| | |
|---|---|
| CEE | Civil & Environmental Engineering |
| ChemE | Chemical Engineering |
| EESS | Environmental Earth System Science |
| ERE | Energy Resources Engineering |
| FSI | Freeman Spogli Institute for Int'l Studies |
| GCEP | Global Climate and Energy Project |
| GES | Geological and Environmental Sciences |
| GP | Geophysics |
| GSB | Graduate School of Business |
| ICME | Institute for Computational & Mathematical Engineering |
| ME | Mechanical Engineering |
| MS&E | Management Science & Engineering |
| MSE | Materials Science & Engineering |
| PEEC | Precourt Energy Efficiency Center |
| PESD | Program on Energy and Sustainable Development |
| PIE | Precourt Institute for Energy |
| SEEES | School of Earth, Energy & Environmental Sciences |
| SIEPR | Institute for Economic Policy Research |
| SSTF | Shultz–Stephenson Task Force |
| STC | Steyer Taylor Center for Energy Policy and Finance |

# GEOPOLITICAL IMPACTS

**Geopolitical challenges and opportunities that NGI seeks to illuminate:**

- Shifts in the balance of economic power and energy security
- Governmental and diplomatic issues in developing economies
- The impact of new global supplies of natural gas on countries highly dependent on natural gas imports
- The potential regional and global impact of Mexico's efforts to develop its rich and untapped shale gas (and deep water oil) resources.

Lower cost methods for providing ample natural gas resources could significantly transform the geopolitical landscape. New supply sources for gas-poor countries will weaken the market power of Russian and other traditional sources, which have not always been secure. The pivotal role that natural gas plays in Crimea and the Ukraine has influenced recent military intervention and raised international tension, for example.

Expanding supplies could make natural gas markets more liquid financially and lead to a growing natural gas trade. If the United States becomes a major exporter of natural gas, hydraulic fracturing technology, or both, the U.S. economy would incur new vulnerabilities as well as benefits. Furthermore, Mexico's push to develop its rich shale gas resources could unleash important changes and economic benefits for Mexico and for North America as a region. This development could also have important geopolitical consequences for the U.S. and other countries.

In the developing economies of China, India, Mexico, and others, more abundant natural gas resources could provide a less expensive path for reducing greenhouse gas emissions by replacing coal in industry and the power sector. Such developments, however, would depend on lowering or eliminating barriers to the development of unconventional natural gas resources in these countries. For example, property rights for promoting multinational engagement would need to be clarified, and economic reforms to promote competition would need to be instituted.

*Former U.S. Secretary of State* ***George P. Shultz*** *is Thomas W. and Susan B. Ford Distinguished Fellow at the Hoover Institution. He directs the Shultz–Stephenson Task Force on Energy Policy and is Chair of the Precourt Institute Energy Advisory Council.*

# NATURAL GAS LANDSCAPE

### RESOURCE DEVELOPMENT

**Resource Development**
Assessment
Production optimization
Long-term resource management
$CO_2$ capture and storage

**Infrastructure Development**
Pipelines
Rail
Financing

### ENVIRONMENTAL IMPACTS AND CLIMATE CHANGE

**Environmental Benefits**
Bridge to a decarbonized energy future
Reduced GHG emissions
Reduced air pollution

**Power Plants**
Coal to gas switching
Displacing or firming renewables?

**Environmental Challenges**
Greenhouse gases
Potential water and air pollution
Earthquake triggering

### USES OF NATURAL GAS

**Electrical Power**

**Industrial**
Fertilizer
Petrochemicals
Catalysis
Manufacturing

**Transport Fuel**
LNG and CNG for trucks
Gas to liquids

**Integration with Renewables**

### GLOBAL MARKETS AND FINANCE

**Gas and Energy Microeconomics**
Prices
Regional balances
Substitution effects
Investment flows and profits

**Resilience**

**Macroeconomics**
Growth
Trade balance
Productivity

**Exports**
Global gas markets & prices
Infrastructure
Transport risk

### POLICY AND REGULATORY REFORM

**Regulation**
Environmental Safety and Health
Licensing
Enforcement

**Greenhouse Gas Policy**
$CO_2$
Methane

**Trade Policy**
Liquid natural gas
Exports

**Fuel Switching**
Subsidies and incentives

**Research & Development Funding**

### GEOPOLITICAL IMPACTS

**National Priorities**
National security
Competitiveness
Energy security
Climate negotiations

# Corporate Affiliates Program

The corporate affiliate program of the **Natural Gas Initiative** (NGI) engages leading companies and institutions in the work of the outstanding team of faculty and researchers from across Stanford University.

We bring together a wide range of Stanford faculty and researchers interested in examining the dynamic, multifaceted questions raised by the tremendous opportunities associated with increased production and use of natural gas.

## THE NGI AFFILIATE PROGRAM

The **NGI affiliate program** offers a three-tier membership structure and provides the following benefits of membership, depending on membership level.

**Basic members** ($35,000 per year) receive the following benefits:

- Participation the annual affiliate meeting
- Access to informed research from inception to outcome
- Meetings with professors who enable in-depth investigations of specific topics

**Corporate members** ($75,000 per year) receive the benefits listed above in addition to the following benefits:

- Participation in research conferences, workshops, short courses and other events
- Facilitated access to complementary programs at Stanford in energy and the environment
- Direct access to student recruitment and diversity initiatives at the school level

**Sustaining members** ($250,000 per year) receive all of the benefits listed above in addition to the following benefits:

- Membership on the governance board of the Natural Gas Initiative to help establish initiative priorities and strategic direction
- Research-in-Progress Program: Teams of advanced PhD students and Stanford faculty will visit affiliated partner company sites to give technical presentations and interact with industrial colleagues on the research being carried out under the Natural Gas Initiative. The site presentations and all information, data and results arising from such visitation interactions will be shared with all members and the public
- Industrial Visiting Scholar Program: Short-term residencies at Stanford for industrial researchers in accordance with Stanford's Visting Scholar policies.
- Fellow/Mentor/Advisor Program: This program helps forge stronger connections between Stanford graduate students, their faculty advisors, and outstanding researchers from member companies
- Membership in one additional industrial affiliate program (limited to programs with membership fee of $75,000 or less)

The Stanford University **Natural Gas Initiative** is a collaboration between the School of Earth, Energy & Environmental Sciences and the Precourt Institute for Energy. For more information, contact Bradley Ritts, Managing Director of the Natural Gas Initiative, at ritts@stanford.edu

Stanford Industrial Affiliates Programs and the terms and conditions that govern research at Stanford are described at: https://industrialaffiliates.stanford.edu

## A NEW ENTERPRISE FOR A NEW ERA IN ENERGY

The opportunities and challenges presented by transformative technological developments in natural gas are broad and deep. The profound economic, environmental, and political changes the United States has begun to experience over the past five years could multiply for decades as economic natural gas supplies become increasingly abundant around the world, and as further technological advances harness the production and use of shale gas.

We must not lose sight of the importance of continuing to invest in research and development to enable the transition to a low-carbon, secure, and affordable energy future. Energy research on a portfolio of technologies has grown tremendously in the past decade. Natural gas is part of the solution, not the whole solution. But with this newfound energy abundance, we are better able to develop cleaner and more affordable energy services to power economic growth, improve the air we breathe, and sustain the climate system we rely upon.

The **Natural Gas Initiative** expects to make vital contributions to the world's ability to make the most of global natural gas resources, leveraging Stanford's traditions and strengths to assume a leadership role at the state, federal, and international level on the many issues associated with the environmentally responsible development and use of natural gas resources.

## WAYS TO ENGAGE

# Giving Opportunties

Your support for the **Natural Gas Initiative** will help ensure Stanford's research leadership on emerging questions about the development and use of global natural gas resources and their impact on the global energy system, economy, and environment.

### GIVING OPPORTUNITIES

**Endowed Professorship**
A new, incremental faculty chair will allow Stanford to recruit a top caliber expert on land use planning in the context of unconventional resource development. Based in the School of Earth, Energy & Environmental Sciences and working with faculty throughout the university, the chair holder will play a key role in NGI research and outreach across the initiative's six focal areas.

**Nanocharacterization Lab**
This gift opportunity is for laboratory instrumentation dedicated to the characterization of extremely impermeable unconventional reservoir rocks. X-ray microtomography allows unprecedented, nondestructive, three-dimensional detail about the microstructure of these rocks. Such information is vital to research on effective resource development and can only be collected effectively in a specialized laboratory facility. Data generated by this apparatus will play a critical role in refining modeling and production approaches.

**Mobile Natural Gas Leakage Laboratory**
Leakage from natural gas pipelines and distribution systems is the biggest source of methane emissions from human activities in the United States. This mobile laboratory will integrate novel ground- and air-based sensors to locate, quantify, and ultimately help reduce hydrocarbon leaks and emissions. The technology will target natural gas leaks both upstream, associated with drilling and production, and downstream through the gas distribution system.

**Seed Grants**
Awarded by a faculty selection committee and administered by the Precourt Institute for Energy, NGI seed funding will support innovative, multidisciplinary research projects in the initiative's six focal areas.

To discuss these and other opportunities to support the **Natural Gas Initiative**, please contact naturalgasinitiative@stanford.edu

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