Stanford | Natural Gas Initiative
*School of Earth, Energy & Environmental Sciences and Precourt Institute for Energy*

# NATURAL GAS *brief*

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*Climate change is a serious global threat with impacts that are already being felt. In response, a growing number of environmentalists are taking the position that there should be no new energy developments that involve fossil fuels in any form.*

## The costs of fossil-free development

By Mark C. Thurber

The activist group 350.org pushes institutions to divest from all fossil fuel holdings and has galvanized university student opinion against the use of fossil fuels. The Sierra Club has focused for a number of years on blocking coal power plants in the United States and around the world, but there were reports in the run-up to the 2016 presidential election in the U.S. that it planned to start opposing new gas-fired units as well. This is despite the fact that natural gas plants burn cleanly and emit only about half the $CO_2$ emissions of coal plants, and coal-to-gas switching has been responsible for substantial greenhouse gas emissions reductions in the U.S.

These and other environmental organizations are not limiting their “fossil-free” advocacy to rich nations. They are pushing to eliminate all fossil fuel use in developing countries as well. It’s true that developing countries will be responsible for the lion’s share of future growth in greenhouse gas emissions, but this approach raises a stark question: What would ruling out all fossil fuels mean for efforts to reduce poverty? The International Energy Agency (IEA) estimates that 1.2 billion people lack access to electricity and 2.7 billion people still cook with solid biomass. These figures are associated with very real harms. Lack of electricity diminishes productivity and quality of life. ▸

### ABOUT THE AUTHOR

**Mark C. Thurber** is associate director of the Program on Energy and Sustainable Development (PESD) at Stanford University. He edited and contributed to *The Global Coal Market: Supplying the Major Fuel for Emerging Economies*. This 2015 book examines how policies toward coal in the most important coal producing, consuming, and exporting countries—China, India, Indonesia, Australia, South Africa, and the United States—affect economic and environmental outcomes. Dr. Thurber also co-edited the 2012 book *Oil and Governance: State-owned Enterprises and the World Energy Supply*, co-authoring chapters on the Norwegian and Nigerian national oil companies and on how the need to manage risk has shaped the global oil and gas industry.

Dr. Thurber teaches a course on energy markets and policy in the Graduate School of Business at Stanford, in which he runs a classroom simulation of energy and carbon markets. He also oversees PESD’s work on business models for distributed solar generation in sub-Saharan Africa. Dr. Thurber has experience working in the high-tech industry, with a focus on manufacturing operations in Mexico (where he lived for several years), China, and Malaysia. He holds a Ph.D. from Stanford University and a B.S.E. from Princeton University.

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Indoor air pollution from traditional biomass cooking causes over 4 million premature deaths a year from respiratory and other diseases, according to the World Health Organization.

Are development goals and climate goals fundamentally incompatible? Is it possible to give everyone access to modern energy-using amenities and hold the rise in global temperature to a safe level? To the extent environmental advocates address this question at all, they tend to argue that intermittent renewables are already cost competitive with fossil fuels (a highly dubious contention when the need for storage or backup power is taken into account), so a renewable future for poor countries is both cheaper and more environmentally sound. Cooking can be done with improved biomass cookstoves. Electricity can be provided by solar home systems, renewable mini-grids, or central grids powered by renewables.

This brief critically evaluates the idea that eliminating all fossil fuel use need have no downside when it comes to reducing energy poverty. It considers three principal questions: What are the implications of ruling out fossil fuels in cooking? Can distributed renewable electricity provide a sufficient solution to energy poverty? And can high-quality, affordable energy be delivered reliably through a centralized grid without the use of fossil fuels? The brief concludes with a short discussion of how climate and development goals might be balanced.

## ARE FOSSIL FUELS NEEDED FOR COOKING?

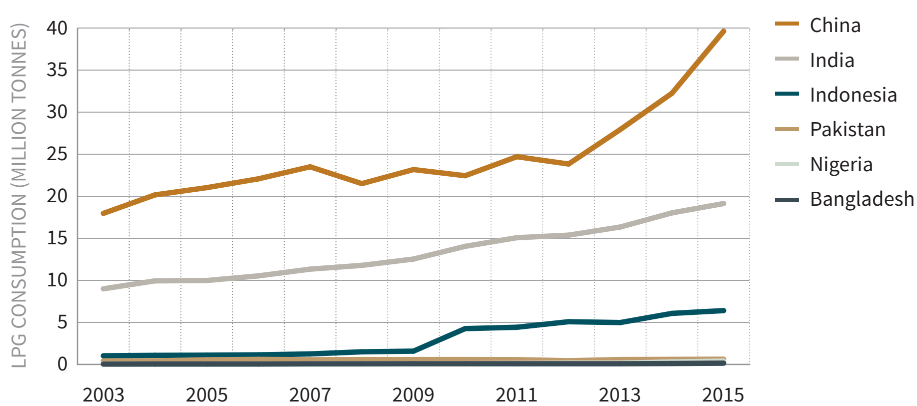
One possible solution to the problem of indoor air pollution is replacement of traditional biomass for cooking with liquefied petroleum gas (LPG), a safe, convenient, and clean-burning fuel that is produced as a byproduct of oil refining or natural gas processing. Another major option is distribution of "improved cookstoves" that burn available biomass more cleanly. A third alternative in theory is use of electricity for cooking, but in practice this is only feasible in homes with grid electricity, and in any case cooking with electricity is less efficient than cooking with gas.

Governments, nonprofit organizations, and academic researchers have devoted significant effort over the last several decades to developing and distributing clean cookstoves. Unfortunately, these stoves have mostly failed to take hold among consumers. They are simply not perceived as offering significant benefits relative to traditional cooking methods.

Even where there has been significant penetration of improved biomass cookstoves into the market, as in the case of a government program in China that distributed more than 180 million stoves over two decades, it is not clear these stoves have done much to reduce the disease burden from biomass cooking. Sometimes the stoves are only used for a limited share of meals, or they aren't durable over time. Emissions in actual household use may turn out to be higher than emissions measured in the laboratory. And even when the stoves perform as expected, the dose-response curves for respiratory disease as a function of emissions appear to be highly non-linear, suggesting that drastic rather than incremental emissions reductions are needed. ▶

**Figure 1**

LPG consumption for six countries with largest populations cooking with traditional biomass. Data source: WLPGA Statistical Review of Global LPG 2014-2016.



By contrast, the expansion of LPG use is a clear success story, though a still-incomplete one, when it comes to reducing dependence on unhealthy cooking methods. Figure 1 shows growth in LPG consumption in the six countries that together account for 64% of the people still cooking with traditional biomass. Most of the LPG consumption in these countries—for example, about 60% in China and 90% in India in 2015—is for domestic use, which is almost entirely cooking in the home. Figure 2 shows estimates of the number of people whose households cook with traditional biomass and the number whose households cook with LPG. If LPG consumption in India and China had not grown as it did over the last 10 years, it is likely there would be millions more people still cooking with traditional biomass. (LPG does not always displace biomass; Indonesia's huge step up in LPG use was the result of a very successful program to replace kerosene for cooking, which has its own problems.)

Continued barriers to LPG use include its cost, especially in rural locations where biomass can be gathered for free, as well as the sometimes limited reach of LPG distribution networks outside cities. Creative policymaking can play a role in overcoming these barriers. India's government has had surprising success with a recent program that encourages well-off households to give up their LPG subsidies so that the government can subsidize poorer households without incurring an undue budgetary burden. If LPG is made more accessible to domestic users in countries like Pakistan and Bangladesh, the health and welfare benefits could be enormous (see Figures 1 and 2).

Global LPG production is expanding. The United States, already the world's largest producer, saw annual output rise by over 20 million tonnes between 2010 and 2015, according to the World LPG Association. This incremental LPG supply is a byproduct of growth in oil and gas production. Policymakers should do everything they can to leverage this additional gas to displace unhealthy biomass cooking around the world. It is important that dreams of a completely fossil-free world not interfere with efforts to do so.

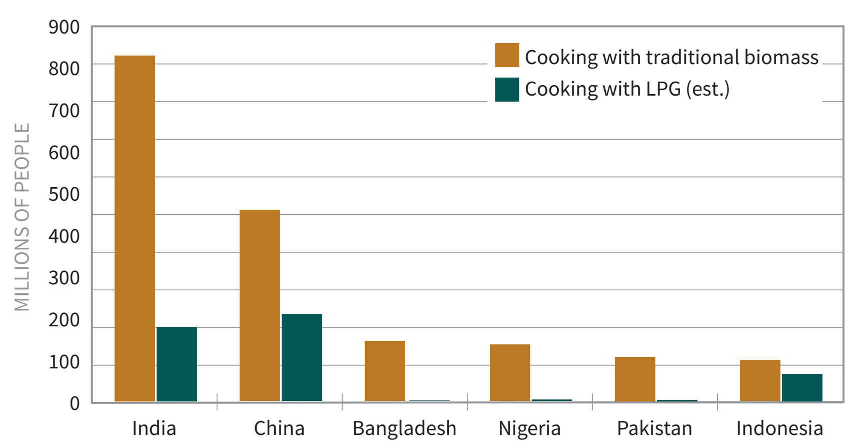
## CAN DISTRIBUTED RENEWABLE GENERATION SOLVE THE ELECTRICITY ACCESS PROBLEM?

Limited access to electricity is a problem in many of the same parts of the world where people cook with traditional biomass, especially sub-Saharan Africa and developing Asia. The electric grid often doesn't reach remote rural areas, and even in cities or rural areas where electricity is available, service quality is typically low, with frequent outages. Lack of electricity can leave households without even basic services such as lighting. It also inhibits commercial and industrial activity that provides livelihoods and boosts the economy.

Distributed renewables are having a positive impact in providing basic energy services in areas where ▶

**Figure 2**

Estimated populations cooking with traditional biomass and with LPG in 2014. Data sources: IEA Energy Access Database 2016 (traditional biomass); WLPGA Statistical Review of Global LPG 2015 (LPG).




Notes: Author's estimates for million people cooking with LPG assume household size of four and daily LPG use of 1 kg per household (2 meals at 0.5 kg of LPG per meal). In practice, some households may use a mix of LPG and other fuels, but this calculation approach should give a rough estimate of total "people" covered by LPG, where one "person" could, for example, represent one person whose meals are all cooked with LPG or two people who each use LPG for half of their meals.

> *"Solar home systems... will never support the kinds of high-power appliances developed country consumers take for granted..."*

the grid doesn't reach, but can they eliminate the need for fossil fuels altogether? The off-grid solar lighting sector has certainly grown rapidly in recent years, to the point where solar lights are now available and affordable in much of the world. A report by the Global Off-Grid Lighting Association (GOGLA) and the World Bank's Lighting Global program estimated that over 36 million people worldwide were meeting their basic lighting needs with solar products as of June 2016.

There is also growing availability of small solar home systems (SHSs) that can run multiple lights as well as basic appliances such as radios or low-power televisions. However, the reach of SHSs remains limited; they represented only 5% of the off-grid solar products sold in the first half of 2016, according to GOGLA/Lighting Global. Moreover, the relatively modest power output of even large, expensive systems means they are unlikely to ever be a true substitute for grid-based electricity. Solar home systems are good at providing light, charging phones, and powering basic entertainment appliances like radios or low-power TVs. They will never support the kinds of high-power appliances developed country consumers take for granted: air conditioners, larger refrigerators, electric irons, electric cooking appliances, and so on.

In the language of the multi-tier framework for energy access proposed by the World Bank in 2015, solar home systems can readily provide Tier 2 electricity supply (at least 50 watts of power, 200 watt-hours of energy generation, and 4 hours of availability per day) and conceivably Tier 3 in the case of large systems (at least 200 watts, 1 kilowatt-hour, and 8 hours per day). However, it is unrealistic to expect them to provide electricity access at Tier 4 (at least 800 watts, 3.4 kilowatt-hours, and 16 hours per day) or Tier 5 (at least 2 kilowatts, 8.2 kilowatt-hours, and 23 hours per day) levels. For this, a standalone diesel generator or grid power of some sort is required. Even as solar cost per unit *energy* comes down, solar is simply not well-equipped to run high-*power* appliances like electric irons or stoves, even for short times. The solar panels and batteries required are prohibitively expensive.

Diesel generators remain by far the most widespread energy source for applications that require significant power in off-grid areas. They also provide backup for businesses or affluent households with unreliable grid electricity. Worldwide, there are at least several hundred gigawatts of capacity from diesel generators. In some places, informal businesses have sprung up that use diesel generators to charge car batteries for household power supply. These batteries are used by households to power lights and perhaps even a television. Diesel generators can also supply power to a larger set of customers via mini-grids. According to a 2015 working paper by the International Renewable Energy Agency, diesel is second only to small hydro as an energy source for mini-grids around the world.

In some cases, wind and/or solar generators have been added to diesel mini-grids to save on diesel fuel costs, which can be substantial in remote areas, and reduce emissions. The IRENA working paper mentioned above estimates there are fewer than 10,000 diesel-solar hybrid mini-grids and under 1,000 diesel-wind hybrids around the world, as compared with 50,000 to 100,000 purely diesel-based mini-grids. (An estimated 1,000 to 2,000 mini-grids use biomass for power.)

Can solar and wind, alone or in combination, stand on their own as a power source for mini-grids delivering higher tiers of electricity access? There are certainly some high-profile demonstrations of renewable-plus-battery systems. India's Sagar Island featured early demonstrations of solar and wind mini-grids. Solar City and Tesla recently deployed a mini-grid with 1.4 megawatts of solar PV capacity and 6 megawatt-hours of battery storage to power the island of Ta'ū in American Samoa. ▶

So far, though, systems like this remain expensive and few in number. They have usually been implemented as part of generous aid programs. It has not yet been demonstrated that they can be economically viable on their own in a typical developing country context. When no special financial incentives are available, diesel almost always outcompetes pure solar or wind options.

## WHAT ARE THE PROSPECTS FOR FULLY RENEWABLE GRIDS IN DEVELOPING COUNTRIES?

A centralized grid remains the proven way to deliver large quantities of power over large areas, so reliable centralized grid power should be the development goal for most countries. Environmental activists sometimes concede this point in theory while failing to offer realistic suggestions for how countries should build reliable centralized grids without any fossil fuels.

The very poorest countries usually have limited electricity supply, and their most common energy source is hydropower. Over half of the countries classified as "low income" by the World Bank (and tracked individually by the IEA) generated the majority of their electricity in 2014 from hydro, with oil being the second most common energy source. This reflects the fact that readily available hydro resources tend to be tapped first. Unfortunately, hydro resources are limited. Moreover, an over-reliance on hydro (29% of the "low income" countries obtained more than 90% of their electricity from hydro) severely impacts electricity availability when there are droughts.

Could countries with limited electricity supply today leapfrog ahead and generate almost all of their new electricity with intermittent renewables like wind and solar instead of fossil fuels?

So far, grid-scale renewables are disproportionately found in rich countries, and even there they account for a small fraction of overall generation. Figure 3(a) shows the "average" energy supply mix by country income classification, and Figure 3(b) shows the energy supply mix for the country in each category (for countries with >3 terawatt-hour total generation) with the highest fraction of intermittent renewables.

Rich countries have important advantages when it comes to renewable energy. First, they can afford the significant financial incentives that in most cases are still needed to make renewables competitive. Second, they have access to significant dispatchable generation to help keep the lights on when the intermittent resources are not available. These dispatchable units may be within the country in question or in neighboring countries interconnected by transmission lines. Denmark could not as easily generate over 40% of its power with wind if it did not have access to the larger Nord Pool market, which benefits from significant hydro and nuclear generation from Norway, Sweden, and Finland.

Low-income countries with significant hydro may be able to benefit from adding intermittent renewables, just as Ethiopia has with wind, which accounted for close to 4% of generation in 2014. However, this strategy only works as long as intermittent renewable energy capacity remains a fraction of overall capacity. In the absence of other dispatchable generation, the intermittency of the renewables becomes the limiting factor for electricity reliability.

Cost and reliability considerations have led developing countries that want to significantly expand their electricity supply to rely on fossil fuels. What this most often means is coal. Burning coal is a serious contributor to local air pollution and climate change, but its wide availability and low cost lead to the perception that it is the most energy-secure fuel. China and India, notably, use coal to generate over 70% of their electricity.

Multilateral development banks like the World Bank and Asian Development Bank have become less willing to finance coal power plants due to the climate concerns of their member countries. ►

*"Rich countries have important advantages when it comes to renewable energy."*

It remains to be seen whether the China-led Asian Infrastructure Investment Bank (AIIB) will follow suit. Bilateral deals to finance coal plants are important too, with Japan playing a leading role, though the OECD countries agreed in 2015 to phase out public financing for all but the highest-efficiency coal plants.

Whatever happens with financing from major multilaterals, it is virtually certain that financing of some kind will continue to be available for coal power projects, and that they will remain an important contributor to power capacity growth in developing countries. There just aren't enough viable alternatives. Nuclear power has a significant public acceptance problem in most countries, hydro sites are too limited (and have environmental issues of their own), and natural gas needs expensive transport infrastructure and suffers from the perception that it will always be more expensive that coal.

Expecting poor countries to expand their electricity grids without fossil fuels is more than just unrealistic. It asks them to take on a heavier burden of climate change mitigation than developed countries have and to achieve levels of renewable energy penetration that developed countries have not yet achieved. A more constructive approach is to recognize that fossil fuels will remain important for emerging economies and then seek leverage points to help shift their fossil fuel generation in a less polluting, less carbon-intensive direction.

One possible source of cost-effective emissions reductions is substitution of coal with natural gas. Gas-fired power plants emit only about half the $CO_2$ per unit energy output of coal plants and far less local pollution. The biggest challenge is convincing investors and governments that a new natural gas power plant can be economically competitive with a new coal plant. With significant new LNG capacity coming online in Australia and North America, and continued success tapping unconventional supplies in both places, delivered LNG prices around $7/MMBtu seem plausible over the longer term. Even at this relatively modest gas price, however, a carbon price of $20–30/tonne

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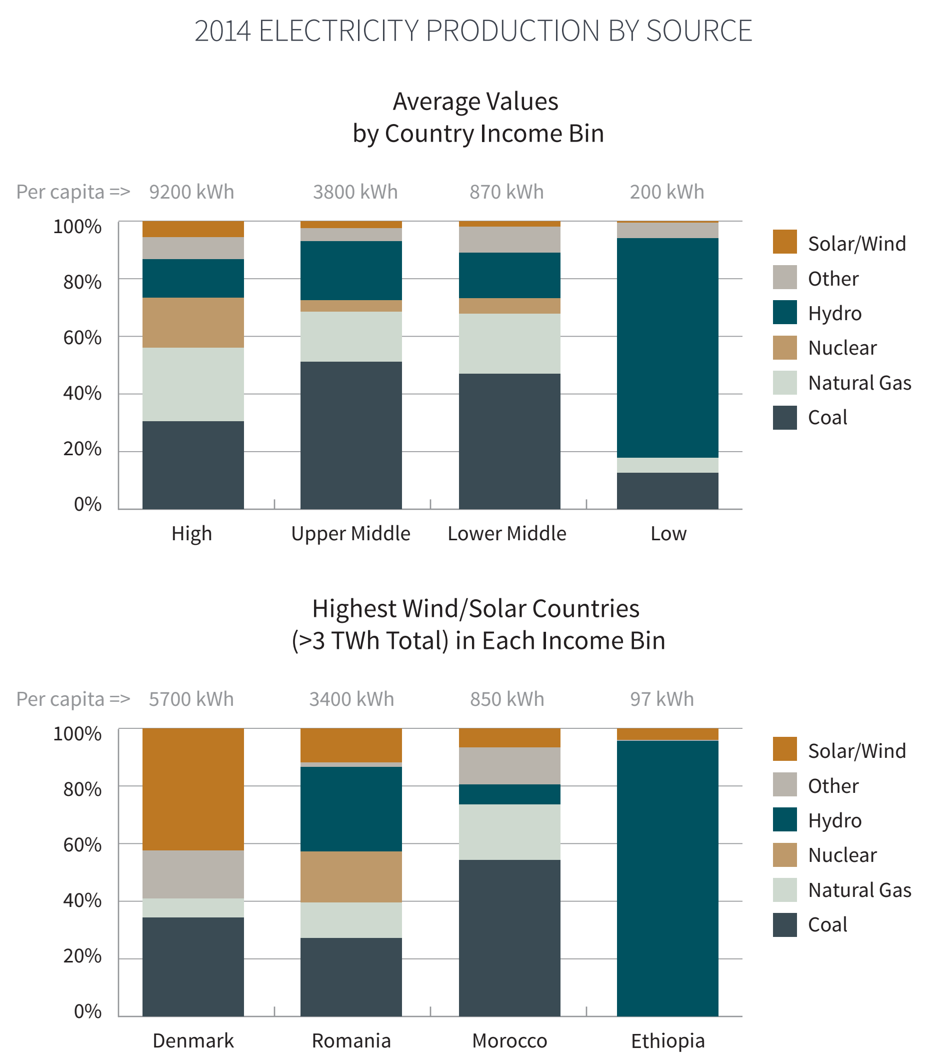
**Figure 3**

Electricity mix by country income classification. Data sources: IEA Electricity Information 2016; World Bank Lending Classifications 2016.



of $CO_2$ is probably necessary to make gas competitive with coal in Asia. (Exploitation of shale gas at scale in Asia could change this calculus.) Poor countries are justifiably disinclined to impose a carbon price on themselves, so developed countries need to find policy mechanisms through which to shoulder the burden. For example, new gas plants in places like India could be paid a carbon price times the avoided emissions from using gas instead of coal for every megawatt-hour of electricity generated.

## SUPPORTING DEVELOPMENT *AND* ENVIRONMENTAL GOALS

The reality is that there are—*and should be*—genuine tensions between development and environmental goals. It simply isn't possible to deal with the climate change problem without finding ways for poor countries to grow less carbon-intensively than rich countries have. At the same time, it is unacceptable to deny poor countries access to the modern amenities that rich countries enjoy. Both problems must be tackled at once. Doing this will be difficult and expensive enough without rigid ideologies that unnecessarily close off options. The idea that no new energy should come from fossil fuels is one such inflexible ideology.

Literal elimination of fossil fuels would cut off millions of households from LPG, the fuel with the best chance of easing the massive health problems associated with traditional biomass cooking. It would put an end to most commercial and industrial activity in off-grid areas by ruling out diesel. It would block the vitally important build-out of reliable central grids in countries without them.

Any environmental group claiming to be against all fossil fuels in all geographies should think carefully about what this would actually mean for the poor of the world, just as any organization trying to justify inaction on greenhouse gas emissions should consider what a catastrophe unchecked climate change would be for vulnerable populations.

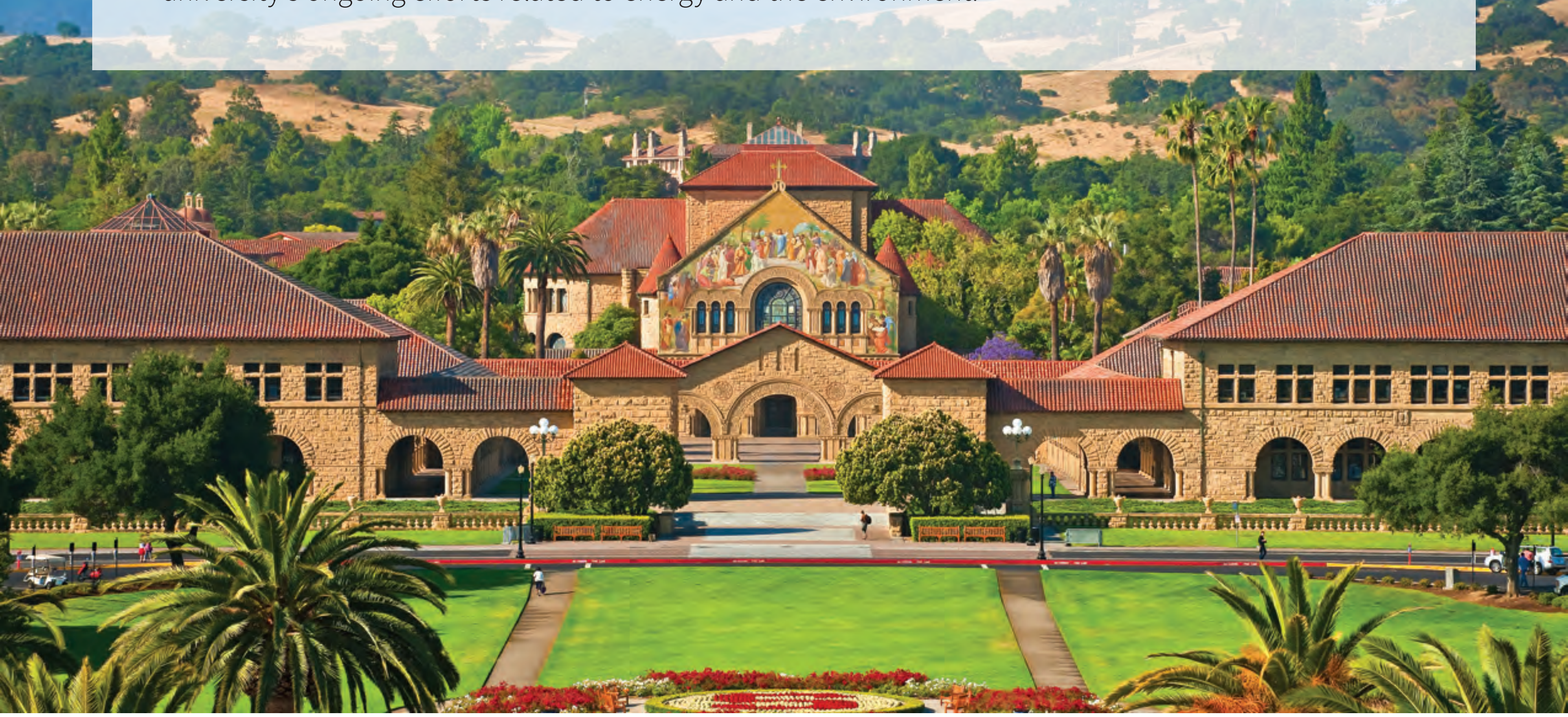
Fossil fuels will continue to play a major role in developing countries whether we like it or not. Even withdrawal of World Bank and other international financing is unlikely to do much on its own to slow the advance of coal. By engaging with this reality and treating fossil fuels in a transparent and balanced way, we can work to maximize the gains and minimize the harms from their use. Key priorities should be to make sure that LPG gets to as many households as possible and that environmental policies properly account for the climate and local pollution impacts of power generation, which will help gas compete with coal on a fairer playing ground. ▲

## THE NATURAL GAS INITIATIVE AT STANFORD

Major advances in natural gas production and growth of natural gas resources and infrastructure globally have fundamentally changed the energy outlook in the United States and much of the world. These changes have impacted U.S. and global energy markets, and influenced decisions about energy systems and the use of natural gas, coal, and other fuels. This natural gas revolution has led to beneficial outcomes, like falling U.S. carbon dioxide emissions as a result of coal to gas fuel switching in electrical generation, opportunities for lower-cost energy, rejuvenated manufacturing, and environmental benefits worldwide, but has also raised concerns about global energy, the world economy, and the environment.

The Natural Gas Initiative (NGI) at Stanford brings together the university's scientists, engineers, and social scientists to advance research, discussion, and understanding of natural gas. The initiative spans from the development of natural gas resources to the ultimate uses of natural gas, and includes focus on the environmental, climate, and social impacts of natural gas use and development, as well as work on energy markets, commercial structures, and policies that influence choices about natural gas.

The objective of the Stanford Natural Gas Initiative is to ensure that natural gas is developed and used in ways that are economically, environmentally, and socially 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.



## Join NGI

The Stanford Natural Gas Initiative develops relationships with other organizations to ensure that the work of the university's researchers is focused on important problems and has immediate impact. Organizations that are interested in supporting the initiative and cooperating with Stanford University in this area are invited to join the corporate affiliates program of the Natural Gas Initiative or contact us to discuss other ways to become involved. More information about NGI is available at ngi.stanford.edu or by contacting the managing director of the initiative, Bradley Ritts, at ritts@stanford.edu.