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A global natural gas boom alone won't slow c change

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The ongoing shale gas revolution (http://www.rff.org/RFF/Documents/RFF-Rpt-NaturalGasRevolution.pdf) in the United States, dubbed a "game changer" by many experts, is the result of a surge of innovation that is extracting huge amounts of natural gas from shale deposits once thought to be inaccessible. It has reversed a decade of declining domestic gas production and brought enormous economic benefits to American consumers and businesses: natural gas prices that dropped by two-thirds within 12 months after widespread fracking began and have risen only slightly since then, hundreds of thousands of new jobs, a renaissance of investment in new manufacturing capacities, and improved energy security. The rise of shale gas has had an environmental benefit as well—greatly reduced carbon dioxide emissions, because generating electricity by burning natural gas emits less than half as much carbon dioxide as burning coal.

The US success story has stimulated the interest of numerous countries around the world. After all, shale is the mos abundant form of sedimentary rock on Earth. Global energy assessments (http://www.globalenergyassessment.org/) report quantities of shale gas several times that of "conventional" gas—which can be extracted with standard drilling alone. Although the extent of the US experience is unlikely to be replicated (http://www.foreignaffairs.com/articles/141203/robert-a-hefner-iii/the-united-states-of-gas) elsev economically recoverable quantities remain a matter of debate, shale gas (http://press.nature.com/pdf/press_fil /NewsFeat_Fracking.pdf) has the potential to become a widely accessible global fuel.

What would that mean for Earth's climate? A study that my colleagues and I recently conducted suggests that abunc lead to substantial reductions in coal use. But without a price on carbon emissions, gas could also edge out nuclear a —increasing overall emissions.

Unconventional gas. Shale gas belongs to the category known as "unconventional" gas resources. Conventional g sediments covered by an impermeable cap rock. Drilled wells relieve the natural pressure, which produces a steady f quantities. Unconventional gas deposits have much lower porosity and permeability, and drilling alone is insufficier rates. Gas flow requires artificial pathways within the rock formation.

Unconventional gas extraction is technically more challenging and economically less attractive, unless, of course, in challenges. In the case of shale gas, innovation came in the form of horizontal drilling and hydraulic fracturing, also sand, and chemicals injected into horizontal boreholes at very high pressure fracture the shale rocks and release the

Some of the other categories of unconventional gas—tight gas, coal bed methane, aquifer gas, and gas hydrates—dwa hydrates, in particular, exist in unfathomable quantities that could fuel global energy needs for centuries to come. G like substances consisting of water and gas molecules held within a cage-like structure. They are found under sedim Arctic permafrost sediments.

To date, gas hydrates and other unconventional gas resources are technically inaccessible and probably will remain s the large volumes of conventional gas and the increasing availability of shale gas. But the constellation that brought —dwindling production, high prices, and energy security concerns—could result in a similar surge of innovation tha non-shale unconventional gas resources.

Blessing or curse? Experts have both welcomed and rued the prospect of abundant natural gas. Where gas replac and low-cost climate mitigation strategy. Two-thirds of the US reductions in carbon dioxide emissions (http://www /emissions/carbon/) since 2005 are attributable to fuel-switching, and one-third to growth in low-carbon generati technologies such as wind and solar energy. Unconventional gas, proponents argue, can act as a "bridge" fuel, curbin energy sources such as renewables and nuclear energy are ramped up.

The curse? Abundant gas gives fossil fuels a new lease on life. Cheap gas may replace coal in many industrial applica generation, or even penetrate markets traditionally served by oil, such as transportation. But a global gas boom wou rationale suggests that gas would also encroach on investments in renewable energy, nuclear energy, and energy effi to $5 per million British thermal units, gas-fired electricity holds a definite competitive advantage over new nuclear renewables. Indeed, only four out of more than two dozen applications for new nuclear power plants have begun con federal license to do so. Two dozen other nuclear plant applications (http://www.nrc.gov/reactors/new-reactors/ withdrawn, suspended, or are still under review. All four reactors are being constructed in deregulated electricity ma overruns can be passed on to ratepayers.

Cheap gas has even put the economic viability of some existing nuclear plants in doubt, especially plants operating i utilities cannot recover costs through regulated cost-of-service rates. Despite being licensed to operate until 2033, D Station in Wisconsin was forced to close in May 2013 solely due to economics. This is somewhat surprising, as one o advantages is its low operating cost. Ten additional nuclear plants are considered to be at risk of closure (http://ww /info/Country-Profiles/Countries-T-Z/USA--Nuclear-Power/), all but one located in deregulated states. While c eroding the profitability of nuclear energy, it is the straw that is breaking the camel's back.

Moreover, if cheap gas provides an easier route to a lower-carbon economy than high-cost renewables and nuclear p destination fuel. But natural gas is still a fossil fuel that emits carbon dioxide. A much higher share of natural gas in eventually raise emissions again, especially if gas not only displaces coal but also non-fossil energy sources. Moreove component of natural gas, is itself a heat-trapping greenhouse gas with 25 times the warming effect of carbon dioxid (http://www.pnas.org/content/109/17/6435.full)—from drilling through end use—is greater than about 4 percen climate benefits of switching from coal and oil to gas (http://www.eeb.cornell.edu/howarth/publications /Howarth_2014_ESE_methane_emissions.pdf).

Modeling the boom. I was part of a group of 13 researchers from the United States, Australia, Austria, Germany, published a paper in the journal *Nature* tackling the question of how a global gas boom alone would affect carbon di (http://www.nature.com/nature/journal/v514/n7523/full/nature13837.html#close) between now and 2050. U "integrated assessment models" that account for economic activity, energy demand and supply, and the Earth's clim I explored two alternative assumptions about future gas availability: a "conventional gas" scenario reflecting extract before the shale gas revolution, and an "abundant gas" scenario reflecting a global abundance of natural gas and sub costs.

The findings were stark: By 2050, market-driven gas use was greater in the abundant-gas scenario by 82 percent on emissions varied only from a minor drop of 2 percent to an increase of 11 percent. Accounting for the climate impact eliminated all climate mitigation benefits.

Clearly, abundant gas not only displaced coal but also nuclear power and renewables. Nuclear electricity was reduce renewables by 24 percent. Moreover, cheaper gas and electricity prices increased overall energy demand and raised efficiency improvements.

We concluded that, if left to market forces alone, cheap and abundant gas would not help mitigate climate change. It carbonization of the global energy system by eliminating economic incentives for ramping up virtually-carbon-free r The study, however, showed that prices can make an enormous difference, here to the detriment of climate stability. imposed on carbon dioxide emissions in the models, climate change mitigation is induced, as shown in the Fifth Ass Intergovernmental Panel on Climate Change. (http://www.ipcc.ch/pdf/assessment-report/ar5/wg3/ipcc_wg3_ fuel with the lowest carbon dioxide intensity, gas displaces coal and oil, but the costs of its own carbon dioxide emiss

With climate policies that put a price on carbon emissions and recognize low-carbon energy sources, natural gas wo renewables and nuclear energy, offering backup for intermittency and peaking for baseload. Then abundant gas cou and become a major player on the global energy scene without unduly restraining nuclear power and renewables—a