An audio interview with Dr. David Cutler is available at NEJM.org

it only more difficult to weigh the complex trade-offs of any reform. Yet if anything unites Americans when it comes to their health care, it's that once they have it, they don't want to let it go.

Disclosure forms provided by the author are available at NEJM.org.

Dr. Rosenbaum is a national correspondent for the *Journal*.

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The False Promise of Natural Gas

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Production of natural gas has grown by nearly 400% in the United States since 1950, and gas is now the country's second-largest energy source. The main driver of this increase has been the wide-scale adoption of hydraulic fracturing ("fracking"). During the fracking process, large volumes of water, sand, and chemicals are injected deep underground at high pressure to fracture shale deposits and sand and coal beds to release trapped gas. The world's largest gas-transmission network — with more than 300,000 miles of interstate and intrastate transmission pipelines, 2.1 million miles of local distribution lines, and more than 1000 compressor stations — brings this gas to the market. The ready availability of gas has reduced dependence on coal and oil, enables the United States to ship gas overseas, and will make the country a net energy exporter by 2020.[1] It has also made gas an important feedstock for the chemical, pesticide, and plastics-manufacturing industries.

Natural gas, composed principally of methane, has been hailed as a clean "transition" fuel — a bridge from the coal and oil of the past to the clean energy sources of the future. This claim is partially true. Gas combustion produces only negligible quantities of sulfur dioxide, mercury, and particulates. It is thus less polluting than combustion of coal or oil, and this benefits health.[2] Gas combustion also generates less carbon dioxide per unit of energy than combustion of coal or oil.

But beneath this rosy narrative lies a more complex story. Gas is associated with health and environmental hazards and reduced social welfare at every stage of its life cycle.[2] Fracking is linked to contamination of ground and surface water, air pollution, noise and light pollution, radiation releases, ecosystem damage, and earthquakes (see table). Transmission and storage of gas result in fires and explosions. The pipeline network is aging, inadequately maintained, and infrequently inspected. One or more pipeline explosions occur every year in the United States. In September 2018, a series of pipeline explosions in the Merrimack Valley in Massachusetts caused more than 80 fires and explosions, damaged 131 homes, forced the evacuation of 30,000 people, injured 25 people, including two firefighters, and killed an 18-year-old boy. Gas compressor stations emit toxic and carcinogenic chemicals such as benzene, 1,3-butadiene, and formaldehyde. Wells, pipelines, and compressor stations are disproportionately located in low-income, minority, and marginalized communities, where they may leak gas, generate noise, endanger health, and contribute to environmental injustice while producing no local benefits. Gas combustion generates oxides of nitrogen that increase asthma risk and aggravate chronic obstructive pulmonary disease.

Compounding these hazards are the grave dangers that gas extraction and use pose to the global climate.[3] Gas is a much more powerful driver of climate change than is generally recognized. As much as 4% of all gas

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Health and Environmental Hazards of Natural Gas.*

Category	Pathways and Mechanisms	Established and Potential Health Hazards
Local hazards		
Water contamination	Ground and surface water at gas wells is contaminated with fracking chemicals.	Many fracking chemicals are toxic: 25% are carcinogens; 75% are dermal, ocular, respiratory, and gastrointestinal toxins; 40 to 50% have toxic nervous, immune, cardiovascular, and renal effects; 30 to 40% are endocrine disrupters
Air pollution	Heavy trucks, construction equipment, and drill rigs emit diesel exhaust, oxides of nitrogen, and particulates; sand piles release silica dust; gas venting and flaring produce volatile organic compounds (benzene, 1,3-butadiene, and formaldehyde).	Exacerbation of asthma and COPD; increased risk of cardiovascular disease and diabetes; increased risk of prematurity and low birth weight; volatile organic compounds increase risk for leukemia and lymphoma
Noise pollution	Heavy equipment and gas flaring generate nearly continuous noise; sound levels can reach 70 A-weighted decibels, which exceeds EPA community guidelines.	Sleep disturbance; stress (associated with increased cardiovascular disease risk); cognitive deficits in children
Light pollution	High-intensity illumination and gas flaring generate bright light day and night	Sleep disturbance; stress
Radionuclide releases	Some shale formations contain naturally occurring radionuclides such as radon, principally in Pennsylvania and Texas.	Cancers, chiefly lung cancer
Earthquakes	Seismic activity is increased near fracking sites and up to 30 miles away.	Injuries; anxiety; loss of property value
Community disruption	Poor and minority communities are disproportionately exposed to noise, toxic chemicals, and explosion hazards.	Mental health problems; substance abuse; sexually transmitted diseases
Regional hazards		
Fires and explosions	Pipeline explosions occur every year in the United States and recently occurred in Armada Township, MI; Refugio, TX; Salem, PA; Watford City, ND; and Merrimack Valley, MA.	Injury; death
Air pollution from gas combustion	Gas combustion in stoves, boilers, and furnaces generates oxides of nitrogen.	Increased asthma risk; exacerbation of COPD and cardiovascular disease
Global hazards		
Contributions to climate change	Use of natural gas causes methane leakage and gas combustion generates carbon dioxide.	Heat waves; extreme weather events; droughts; floods; wildfires; expanded ranges of vectorborne diseases; compromised food supplies resulting in famine, migration, conflict, and mental distress

* COPD denotes chronic obstructive pulmonary disease, and EPA Environmental Protection Agency. Sources of information are listed in the Supplementary Appendix, available at NEJM.org.

produced by fracking is lost to leakage, and these releases appear to have contributed to recent sharp increases in atmospheric methane.[4] Methane is a potent contributor to global warming, with a heat-trapping potential 30 times greater than that of carbon dioxide over a 100-year span and 85 times greater over a 20-year span. Gas burned in stoves and boilers additionally contributes to global warming by generating carbon dioxide. Together, this evidence suggests that the purported advantage of gas over coal and oil has been greatly overstated.

Despite growing recognition of the dangers associated with gas and recent exponential increases in the production of electricity from renewables, new gas wells continue to be drilled and new pipelines built. The U.S. Energy Information Administration projects that daily natural-gas pro-

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duction in the United States will increase by 10 billion cubic feet in the next year and that under current federal policy, more electricity will be generated from gas than from renewables each year from now through 2050.[1] This expansion of the gas infrastructure is supported by government subsidies and tax breaks that benefit the fossil-fuel industry and artificially depress gas prices.[5] State subsidies provide additional support for fossil fuels.

As physicians deeply concerned about climate change and pollution and their consequences, we consider expansion of the natural-gas infrastructure to be a grave hazard to human health. All reasonable analyses indicate that we must leave nearly all remaining fossil fuels in the ground if we are to hold the extent of global warming below 1.5°C, the target set by the Intergovernmental Panel on Climate Change, and thus mitigate the health and environmental consequences of climate change.

A further argument against investment in gas is that it is economically reckless. Such investment ignores the reality that the cost of producing electricity from renewables is falling rapidly and that energy prices are approaching a “tipping point” after which it will become cheaper to generate electricity from solar and wind sources than from gas. The Energy Information Administration estimates that by 2023 it will cost $36.60 per megawatt-hour to produce electricity from wind and $37.60 to produce solar energy, versus $40.20 to produce energy from gas. Any investment in gas is thus at risk of failing to yield an economic return and becoming a stranded asset. This risk could increase if federal subsidies for gas were to be cut.

We believe that investment in gas is also shortsighted. States that provide subsidies for gas and permit construction of new pipelines and compressor stations will lock in dependence on gas for years to come while missing opportunities to invest in renewables. The real problem with fracking, then, is that it perpetuates the carbon-based energy system and delays the transition to a carbon-free economy.

To address this problem, we recommend that state and federal subsidies for natural gas be reduced over the next 2 years and then eliminated. The International Monetary Fund has made similar recommendations. We also recommend that new residential or commercial gas hookups not be permitted, new gas appliances be removed from the market, further gas exploration on federal lands be banned, and all new or planned construction of gas infrastructure be halted. We believe an ill-conceived proposal announced recently by the Environmental Protection Agency to roll back limits on methane pollution needs to be blocked. At the same time, we call for the creation of new tax structures, subsidies, and incentives such as carbon pricing that favor wind, solar power, and other nonpolluting, renewable energy sources and policies that support energy conservation, clean vehicles, and expansion of public transit.

Implementation of these recommendations will require courageous political leadership and face fierce resistance. But wide-scale transition to renewables would yield enormous benefit for the United States. It would reduce air pollution and therefore prevent disease, extend life expectancy, and reduce health care costs. It would free up the billions of public dollars now spent on fossil-fuel subsidies, and it would protect our planet.

Models exist for effective climate action. In July 2019, New York State enacted comprehensive energy and climate legislation and pledged to reduce greenhouse-gas emissions by 85% by 2050. To meet this target, New York is developing the country’s largest wind farm and collaborating with Ireland and Denmark to improve its electric power grid. It has also created economic incentives for clean vehicles, including trucks and buses, and tax incentives for energy conservation. Idaho Power, the largest utility in a deeply conservative state, has pledged to produce 100% of its electricity from renewable sources by 2045. The United Kingdom has committed to net zero carbon emissions by 2050. New York, Idaho, and the United Kingdom are creating new, high-paying jobs in the wind and solar energy industries.

Natural gas has been portrayed as a bridge to the future. The data now show that it is only a tether to the past. We believe it’s time to reject the false promise of gas.

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The Patient-Scientist's Mandate

Sonia M. Vallabh, Ph.D.

Eight years ago, at the age of 27, I learned that I had inherited a fatal genetic mutation in the prion protein gene (*PRNP*). Pathogenic mutations in this gene cause genetic prion disease, a rare adult-onset neurodegenerative disease that is rapidly fatal once it strikes. The mutation I carry, which stole my mother's life when she was 52, makes me nearly certain to die of this disease if no preventive measure is developed.

In response, my husband, Eric Minikel, and I left our previous careers in law and transportation engineering to retrain in biomedicine. Starting in night classes and entry-level laboratory jobs, we earned our Ph.D.s in biomedical research from Harvard in the spring of 2019. In the process, we found our scientific home at the Broad Institute at MIT and Harvard, where we have now established our own laboratory focused on the development of therapies for prion disease.

There is a proud tradition of activated patients driving science. Fellow travelers of this path may be familiar with the kinds of questions we fielded from day one: whether it was wise to pursue genetic testing for a currently incurable disease; how we would weather the setbacks inherent in the drug-development process; whether it was appropriate for patients to work on their own disease. But we were fortunate to find mentors willing to fight alongside us, and together we forged a plan to tackle prion disease.

My goal is prevention: to preserve at-risk brains, including mine, in full health. Prion disease advances exceptionally swiftly: the average patient dies within 6 months after first having a symptom. Previous clinical trials have involved symptomatic patients and used a survival end point, accepting that many such patients are already profoundly debilitated at enrollment. But predictive genetic testing provides an opportunity, and arguably a mandate, to aim for a higher goal: preservation of full quality of life.

Because the onset of genetic prion disease is not preceded by an established molecular prodrome, testing drugs in healthy carriers will require a primary prevention strategy based on genetic risk. This realization has defined our priorities for the past 5 years,[1-3] leading us to focus on a drug target present in healthy people (normal prion protein, or PrP); a biomarker that can reflect drug activity absent a clinical phenotype (PrP in cerebrospinal fluid); tools for quantifying risk; appropriate recruitment infrastructure; the presymptomatic natural history of the disease; and proactive engagement with the Food and Drug Administration. As this list suggests, redefining the aims of drug development to encompass prevention leads to many new research goals. In the area of genetic prion disease, it took a patient-scientist to drive this shift. Perhaps there is something peculiarly clarifying about defining success by honestly answering the question "What would you want for your own brain?"

Since genetics provides an opportunity for prevention in only a subset of cases of prion disease, symptomatic-stage intervention will remain an important goal.

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