

help. Unfortunately, although they describe fracking and its impact carefully, the authors don't mention the controversy now raging about wind, solar, and other alternative fuel technologies, including modern nuclear technology. If Marder and coauthors want to stimulate constructive progress for humanity, they should help readers to think about fuels that have real promise of outlasting oil and gas.

The article cannot be the end of the discussion. The world drastically needs to overhaul its energy production scheme to use truly sustainable, modern, and safe nuclear reactors, while utilizing the vast existing infrastructure of turbines and generators for electricity production. Despite media portrayals to the contrary, nuclear energy is the safest power system known to man.¹ In the late 1960s, the Sierra Club's motto was "Atoms, not dams," and Ansel Adams, who was on the club's board of directors for 37 years, said, "Nuclear energy is the only practical alternative that we have to destroying the environment with oil and coal."

Consider the following facts about molten-salt reactors (MSRs), which were demonstrated in 1965–70 at Oak Ridge National Laboratory.

- MSRs require no expensive containment since they operate close to atmospheric pressure.²
- MSRs can eliminate the need for Yucca Mountain storage by consuming existing nuclear wastes.
- MSRs consume close to 100% of their fuel, compared with 3% for older reactors with solid uranium fuel.
- Thorium fluoride molten fuel for MSRs is of no weapons value.
- Thorium fuel is more abundant and cheaper than uranium.

The time is now to replace the current infatuation with solar and wind, which are illusions at best. When the sun doesn't shine or the wind doesn't blow, the power generation stops, so they are not equal to the demand of modern society for energy availability 100% of the time. Germany is demonstrating that removal of nuclear energy in favor of wind and solar results in more carbon emissions, not less.³ Nor is energy storage even close to meeting the need when those alternatives fail. For this nation and the world to succeed without drowning itself in a flood of carbon diox-

ide in the next few decades, we need to follow the advice of Glenn Seaborg in 1962:

The overall objective of the [Atomic Energy] Commission's nuclear power program should be to foster and support the growing use of nuclear energy and . . . make possible the exploitation of the vast energy resources latent in the fertile materials, uranium-238 and thorium.⁴

I thank Alex Cannara for assistance in preparing this letter.

References

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The article "Physics, fracking, fuel, and the future" had many crucial omissions and misleading statements and thus failed to give a clear idea of where we are and where we are headed with regard to fossil fuels in general, renewable energy, and energy technologies. For example, climate change, the main driver in the push to reduce fossil-fuel consumption, was not mentioned in the article.

Moreover, the authors do not seem to realize that the movement away from fossil fuels is already well under way. The Energiewende (Energy Transition), Germany's program to change to low-carbon, nonnuclear energy sources, is never mentioned, and that Germany, Spain, and Italy already obtain more than 20% of their electricity from renewable resources is ignored. The authors seem unaware of California's goal to generate, without nuclear power, 30% of its electricity from renewable resources by 2020 and 50% by 2030.

The authors attempt to discuss petroleum extraction modeling: Their figure 2 shows a plot of US crude-oil production and results from M. King Hubbert's model. Inexplicably, the strong decrease

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in US petroleum production in the past year is omitted. That decrease is not due to resource limits but rather to the unprofitability of shale-oil production at oil prices of about \$45 a barrel. Fracking has indeed opened up a significant new source of oil, but just like conventional oil it is a finite resource and production will peak based on economics and other factors.

Hubbert crafted an econometric model with political constraints.¹ The key role of economics is obvious: If oil is too expensive, demand and extraction will drop, as it did in 1973; if too cheap, companies will go bankrupt and supplies will drop, as they have in 2016. The role politics plays is less obvious than that of economics since regulations passed to restrict production and increase prices are unpopular and thus not widely debated. For example, in 1932 the US Congress established a tariff on oil imports to protect the US oil industry from cheaper foreign petroleum.

If US producers had been forced to compete with oil first from Venezuela

and then from the Middle East, US production would have peaked in the mid 1950s. Understanding how the oil market functions is crucial if oil production is to be modeled properly. Since 1973 the market has been divided between OPEC and non-OPEC producers, with OPEC adjusting production to obtain prices it deems appropriate based on economic and geopolitical considerations.²

In 2004 Exxon Mobil used that understanding and Hubbert's model to project a peak in non-OPEC conventional crude-oil production by about 2010, at which point OPEC would have complete control of the market. Based on that projection, Exxon Mobil declared that it would build no new oil refineries in the US³ since increased supplies of oil for them could not be guaranteed. In fact, non-OPEC conventional crude-oil production peaked in 2005, and OPEC raised prices rather than increase production.

Finally, the authors seem unable to imagine a world with much reduced fossil-fuel consumption (see the caption of the article's figure 1). My house in

Princeton, New Jersey, demonstrates that such reduced consumption is certainly possible. We insulate heavily, use high-efficiency windows, appliances, and lighting, and buy renewable wind electricity off the grid; a geothermal heat pump heats and cools our home; a heat-pump water heater supplies hot water; a photovoltaic array on our roof adds some renewable electricity to our grid. We also use an electric car for local travel.

Alternatives to fossil fuels and technologies, including energy efficiency and conservation, are actually widely available and affordable both in the developing and developed world, but may not be as cheap as fossil-fuel technologies. All of us should adopt the new (and old) high-efficiency technologies and work to inform the public that alternatives are available and that we can live quite comfortably without much fossil-fuel consumption at all.

References

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In the July article by Michael Marder, Tadeusz Patzek, and Scott Tinker, I found no reference to greenhouse gases, global warming, fugitive methane emissions, drought, pollution, ocean acidification, coral bleaching, overpopulation, sea-level rise, energy efficiency, energy conservation, nonpolluting energy sources, overfishing, and other concerns that many scientists, technical people, politicians, and citizens are dealing with. There is a growing realization today that we may suffer a catastrophe if we use all the fossil fuels we are able to extract. How do the authors view my concerns?

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[Editor's note: *PHYSICS TODAY* received several letters raising the same concerns as Richard LaRosa's.]

► **Marder, Patzek, and Tinker reply:**

David Cornell points out that we did not discuss wind, solar, and nuclear energy. Our purpose was to spur debate on the involvement of the physics community in research and education into energy by focusing on recent developments in hydrocarbon extraction, not to provide a comprehensive overview of potential solutions to the global energy problem. One of us (Tinker), through the Switch Energy Project (switchenergyproject.com), has provided a broad overview of advantages and disadvantages of various energy sources.

Alfred Cavallo brings up too many points for us to respond to all of them. He asks why we omitted the strong decrease in US petroleum production in the past year. According to the US Energy Information Administration, for the first nine months of each of the past six years US petroleum production has

been 1.5, 1.7, 1.9, 2.3, 2.5, and 2.4 million barrels. There has not been a strong decrease.

Cavallo also presents the virtues of energy-efficient homes. We note that one of us owns a home that runs off solar panels, has only electric appliances, uses only electricity for heating and cooling, and exports many megawatt hours of power each year to the electric grid. He also disconnected the city water supply and uses only rainwater gathered in three large tanks. Another of us invested heavily in home energy efficiency, including additional insulation, radiant barrier, water heaters, and beyond. The third reinsulated his home, gave up his parking permit, and has biked to work every day for more than 15 years. Such conservation measures are needed, but they cannot by themselves solve the problems we raised.

Richard LaRosa asks for our thoughts on the environmental dangers of using fossil fuels. His concerns are valid, and we share them. Yet to stop using fossil fuels precipitously and without a plan

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