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LETTERS

Moving Toward Decarbonization

Concentrated Solar Thermal (CST) energy, such as that used at the SEGS solar energy plants, is not new. What appears to be new is R. Shinnar and F. Citro's suggestion that oil at a temperature of >800°F can be stored for hours or days before being used to generate steam ("A road map to U.S. decarbonization," Policy Forum, 1 Sept. 2006, p. 1243).

Tucson, Arizona, at 32°N latitude has average daily solar insolation of 2,000 Btu/feet^2. This is the highest level in the United States and occurs only in the southern half of Arizona and a small part of New Mexico. During the peak summer periods, the rate of solar energy falling on a given land area is more than five times the rate in winter. Further, about 60% of the solar energy comes between 10 a.m. and 2 p.m.

Consequently much of the oil would be heated to >800°F during midday in summer and stored for use in the winter. The amount of hot oil storage required to provide 50% of U.S. energy consumption is enormous and impractical.

Howard Hayden describes part of the SEGS operation as follows (1): "The optical efficiency varies from 71% (units I and II) to 80% (units VIII and IX). That is, between 71% and 80% of the sunlight that strikes the mirrors is actually reflected to the pipes containing the therminol. They achieve this high efficiency by washing the mirrors every five or so days, and with a high pressure wash every ten-to-twenty days. Let's repeat that: they wash the several million square meters of mirror--much more than the 2.3 million m2 of aperture--about 25 times a year!"

The storage and cleaning problems render this CST project nonviable. A third problem is that of finding 15,000 square miles of land suitable for SEGS systems that can be made available.

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Reference

1. H. Hayden, *The Solar Fraud--Why Solar Energy Won't Run The World* (Vales Lake Publishing, Pueblo West, CO, 2005), p. 189.

Moving toward a decarbonized energy system is an essential element of any strategy to mitigate climate change. In their Policy Forum "A road map to U.S. decarbonization" (1 Sept. 2006, p. 1243), R. Shinnar and F. Citro have outlined one possible technological road map to achieve U.S. decarbonization, in large part by using extensive concentrated solar thermal technology for large-scale, carbon-free electricity generation. Although we fully support studies that explore the potential of technology to "solve the climate problem" (1), we are of the opinion that strong policy analysis is needed to reinforce the findings of such work and that policy research in support of this or other technological futures should adhere to common research standards (2). Policies--or lack thereof--are probably the most profound barrier to successful implementation of technological climate change mitigation measures.

Shinnar and Citro have used an engineering cost-effectiveness calculation to estimate that the investment in carbon-free energy technology would cost $45 to $50 per ton of CO_2 reduced. They state that this figure is the appropriate value for a CO_2 tax, but cite no previous policy research or new analyses to support this. Rather than a single policy solving the climate mitigation problem, a policy analysis might reveal that a portfolio of policies, implemented at different levels of government, introduced over different time scales, and aimed at different parts of the energy system, will be required to make decarbonization a reality. In addition to pollution taxes (a price instrument), there are many other empirically validated policy approaches (3, 4), such as "cap and trade" quantity limits, financial incentives or subsidies, and emission standards. A full consideration of all options through rigorous policy research is critical to overcome the "political hurdles" mentioned at the end of the Policy Forum.

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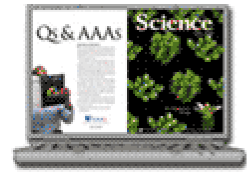
Response

Lightfoot seems to confuse solar cells with concentrating solar power (CSP). CSP plants constructed by Luz have been operating in the Mojave Desert for 20 years (1, 2). The interval required for cleaning the collectors is not considered to be an impediment to their operation (1, 3). The storage capability of these plants was an important technical breakthrough that, if properly designed, can allow solar energy to become a major source of electric power in countries with large desert areas.



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Lightfoot is not correct when he says that the use of a high-temperature heat transfer fluid for energy storage is "new." It was an essential part in the initial Luz design that provided storage for two hours. This capability, which is not feasible for solar cells, is the critical concept that makes large-scale use of solar energy via CSP possible. Our Policy Forum also shows that, with simple design changes, CSP with storage can provide a load-following capability that can stabilize the grid and increase the usefulness of solar cells.

One of Lightfoot's main arguments is the assertion that the solar irradiance ratio in Tucson, Arizona, between summer and winter is larger than 5. Figure S1 (4) shows that the measured monthly solar irradiance ratio, averaged over a period of 30 years, for Tucson and two other places is less that 1.8 (1.7 for Tucson), and that the difference from the average is less than 30%.

As rainy or cloudy days do occur even in the desert (less than 25 days a year), the ability to store energy and to use fossil fuel as backup gives CSP a critical edge over any other renewable energy with variable output. In our plan, the excess electricity generated will be used to obtain the hydrogen to produce hydrocarbons as well as storable fuels for backup.

Regarding Lightfoot's concern about available space, extensive studies by the U.S. Department of Energy have identified four Southwest states (Arizona, California, Nevada, and New Mexico) with deserts large enough to generate 4000 GW (5), more than twice the output needed for our plan. Larger deserts with stronger and more even solar irradiance are available in nearby Mexico.

We fully agree with Reynolds and Mazzi that dealing with the decarbonization of the economy requires a complete systems analysis. Political problems, costs, and the economic constraints on implementation must be taken into account, as well as time factors and competing priorities. But the methodology they recommend requires quantitative data on risks, penalties, and costs that cannot be clearly defined. When guesses replace hard numbers, the results can be highly misleading. The only sensible response when faced with a calamitous risk is to do everything feasible and affordable to prevent it.

Our Policy Forum did not deal with a complete systems analysis. We accepted the conclusions of previous analysts that the risk of any of the three problems--peaking of oil and gas reserves, energy independence, and global warming--we discussed is unacceptable (6). Instead, we identified the technological options available and focused solely on proven technology that we can start to implement now. We demonstrated that a totally decarbonized economy can be realized with existing technology at an affordable cost. Furthermore, as each of the problems mentioned has unbearable consequences, we showed that it is cheaper and more effective to treat them simultaneously, which our plan tries to achieve. We estimated a cost of $200 billion a year, but this is the total investment required; the cost to society would be significantly less, probably reduced by one-third, by the income realized from the investment. The reduction of imported oil and gas alone would free up between $200 and $300 billion a year.

We agree with Reynolds and Mazzi that there can be many ways to help implement our plan and that a CO_2 tax is only one possible example. But no risk analysis can lead to positive results unless we acknowledge that the problems we face are ominous and that no foreseeable research will provide a "silver bullet" that will make the solution pain-free.

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5. See **www.solargenix.com/pdf/Southwest.pdf**.
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The editors suggest the following Related Resources on *Science* sites:

In *Science* Magazine

POLICY FORUM
ENERGY: Enhanced: A Road Map to U.S. Decarbonization
Reuel Shinnar and Francesco Citro (1 September 2006)
Science **313** (5791), 1243. [DOI: 10.1126/science.1130338]
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