raise steam and drive turbines and generators, just like a conventional power station. Solar heat can be stored in melted salt or other substances so that electricity generation can continue through the night or on cloudy days. This technology has been generating electricity successfully in California since 1985, and it currently provides electricity for 100 000 homes. Plants are being planned or built in many parts of the world.

The CSP technology works best in hot deserts. But with transmission losses at only about 3% per 1000 km, transmitting solar electricity throughout the US is entirely feasible and economical with the use of highly efficient, high-voltage direct-current (HVDC) transmission lines.

Waste heat from electricity generation in a CSP plant can be used to desalinate seawater—a useful endeavor in arid regions.

The report *Trans-Mediterranean Interconnection for Concentrating Solar Power*, commissioned by the German government (available at http://www.trec-uk.org.uk/reports.htm), predicts that CSP plants in North Africa and the Middle East will become one of the cheapest sources of electricity for Europe, including the cost of transmission. A large-scale HVDC transmission grid has also been proposed by the wind energy company Airtricity to optimize the use of wind power throughout Europe.

For more information about CSP, see http://www.trec-uk.org.uk.

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Robock replies: I agree with William Morse that fossil fuels produce lots of pollution, particularly CO_2. This is why renewable sources are needed, but nuclear power is not the answer.

The first five nuclear weapons states—the US, the Soviet Union, the UK, France, and China—tried to prevent nuclear proliferation by promoting civilian nuclear power through the nuclear nonproliferation treaty. But the reactors produce plutonium, which can be used to make weapons. Therefore, while telling other countries they could not have nuclear weapons, those five nations gave them the means to do so.[1] Israel developed nuclear weapons with assistance from France. The UK, the US, and Canada helped India build its first reactor. China, the Soviet Union, and European nations aided Pakistan. Pakistan and other countries helped Iran and North Korea.

Richard Wilson is wrong in saying that the nuclear waste disposal problem is just political. Opposition is based on the legitimate concerns of neighbors who do not want the waste nearby without assurance that they will be safe, and the proposed site of Yucca Mountain has geological problems that render it unsafe.[1]

Wallace Manheimer is correct that energy is needed to provide a more comfortable life. But it can come from sources that do not emit greenhouse gases. And through regulation of the industry and a tax on carbon emissions, energy can be used much more efficiently than in the past. Coal with carbon sequestration is part of the solution; an abundant energy source is used but not allowed to produce global warming. Gerry Wolff illustrates an innovative way that solar power can be part of the solution.

We currently use the atmosphere as a sewer without paying the costs. Fossil-fuel and nuclear industries in the US are heavily subsidized by the federal government. Changes in government policy—for example, vehicle mileage standards—and allocation of resources to support efficiency; solar, wind, tidal, and wave power; cellulosic ethanol and biodiesel; and clean coal technology (with carbon sequestration) will allow us to maintain sources of energy for comfortable lives and still limit the environmental damages of global warming. Such developments will also stimulate new businesses and technologies that we can export and will reverse the US's appalling lack of environmental leadership and global concern. That is how a superpower should behave.

Reference

1. H. Caldicott, *Nuclear Power Is Not the Answer*, New Press, New York (2006).

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Scheider replies: William Morse and Wallace Manheimer deal with future energy needs and whether there will really be no better alternative than the nuclear option. While relevant, that is beyond the scope of my original letter, which was about the legacy of the Three Mile Island accident. Scholarly works in 2004 suggest that a better grasp of why people still reflect on TMI some 28 years later might be useful in understanding, for example, Morse's reference to politicians who closed the nuclear power plant at Shoreham. Undoubtedly, their constituents' TMI-induced distrust of the industry's concern for safety outweighed their appreciation of technological fixes implemented since 1979.

Richard Wilson rightly includes the Soviet Union with my observation that the bottom line of nuclear management appears to place greater value on getting it running than on making it safe. At Chernobyl, as at TMI, the frontline crews played roulette, taking risks for the sake of what they took to be their industry superiors' priorities, to make it go and hope for the best. How else can the public interpret the failure to find the cause of a relief valve's first observed failure (at TMI) that resulted in its unrecognized failure again in the moment of crisis? One can hope that the new organizations cited by Wilson and new "safety targets and guidelines" will change the industry's maintenance ethic, but one should not be surprised if the public remains skeptical.

It's a chump's choice between the release of toxic fossil-fuel waste and the risk of a catastrophic nuclear accident. Who will give odds on the risk? The best objective hint is the periodic descent of the nuclear lobby upon Congress every time the Price-Anderson legislation by which your taxes insure the industry against liability exceeding $9 billion comes up for renewal.

I deny Wallace Manheimer's claim that I reject nuclear power. I reject systemic risks of nuclear accidents. I like Carlo Rubbia's simple and nearly foolproof thorium-fueled, proton-beam-primed reactor.[1] Why is the industry proposing, instead, to mix thorium in conventional reactors where it is primed by excess reactivity of uranium or plutonium? Because the money isn't there to develop Rubbia's idea. Nor, equally regrettably, is money flowing to Gerry Wolff's proposal and others like it.

Reference

1. R. L. Garwin, G. Charpak, *Megawatts and Megatons: The Future of Nuclear Power and Nuclear Weapons*, Knopf, New York (2001), p. 153. See also the article from the April/May 1995 issue of the CERN Courier, http://einstein.unh.edu/FWHersman/energy_amplifier.html.

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Unwired energy questions asked, answered

The "Unwired Energy" Update item (PHYSICS TODAY, January 2007, page 26) reports a wireless energy-transmission system working over a few meters, proposed by Marin Soljačić, Aristeidis Karalis, and John Joannopoulos of MIT.

The item concludes with the statement that "Soljačić and his MIT colleagues are now working on demonstrating the technology in practice." I strongly recommend that they consult with the MIT Radio Society and the Federal Communications Commission (FCC) before testing anything, since simple calculations show that their system would be a terrible and illegal electromagnetic polluter.

The system proposed by the researchers uses conducting wire rings that are series-resonated with capacitors and that operate at a frequency of 6.4 MHz. Practical examples of these resonated rings for 7.0 MHz are sold by various vendors.

The proposed system provides 4 watts of output from the receiving ring, at a cost of 11 W dissipated as heat in the transmitting ring and 1.5 W of power radiated from the system. Simple calculation shows that the 1.5 W exceeds the FCC's radiated-emission power limit by a factor of 800 000.

As most amateur radio operators know, 1.5 W of radiated power at 7.0 MHz is enough for worldwide radio communications under good conditions, and indeed some of the resonated rings available for purchase are marketed as radio antennas.

The 3- to 30-MHz frequency range is intensively used for long-distance radio communications and broadcasting even today, because it is the only channel that provides long-distance communications with no transmission infrastructure at all.

I consider it deeply unwise to pollute this unique channel for the sake of short-range systems.

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I was somewhat bewildered by the "Unwired Energy" Physics Update.

Energy transfer using electromagnetic resonance is used today in thousands of locations around the world—door locks, toll roads, and many more upcoming applications such as airport luggage tracing and supermarket checkouts. All RFID (radio-frequency identification) tags are powered with LC resonant circuits.

Actually, nearly 50 years ago, when I was in primary school, I built a diode radio receiver that drew operating energy from a circuit tuned to a radio-station frequency. A diode was used to detect the signal that drove an earphone. No battery was involved.

I don't think the MIT work is really new physics but rather an attempt at improved engineering for, say, transferring sufficient energy to drive laptops. Radiating hundreds of watts of RF in a room or several thousand watts in a coffee shop seems to me to be too risky for people and will not be accepted.

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Karalis, Kurs, Joannopoulos, and Soljačić reply: The results presented in our theoretical work[1] are relatively simple examples of how to implement our proposed scheme for wireless energy transfer. In practice, the system could be designed to operate at frequencies outside the ham radio band, to perform much better than Peter Anderson states (see, for example, section 4 of reference 1) by improving on the materials and geometries used, and to radiate below general safety and interference limits—for example, the IEEE (Institute of Electrical and Electronics Engineers, Inc) standards for general public exposure.[2] Safety and interference issues are very important and will have to be thoroughly investigated before any product development.

The physics of electromagnetic resonance and its use for transferring energy wirelessly has long been known and used to provide relatively low levels of power to various applications, as Herzel Laor states. Existing resonant-electromagnetic-induction technology has been inadequate to efficiently power, over mid-range distances, devices that require on the order of tens of watts of power or more. Our work demonstrates that it is the physics of strong coupling, for which resonance is a prerequisite, that enables the efficient wireless energy transfer needed for larger power applications.[1] The principles of this physical concept will certainly lead to improved engineering in designing actual systems.

In addition, strong coupling implies that the scheme is not radiative but rather uses the near stationary field; therefore, "hundreds of watts of RF" are *not* being radiated by our method, as numerical examples in reference 1 demonstrate.

References

1. A. Karalis, J. D. Joannopoulos, M. Soljačić, *Ann. Phys.* (in press); preprint at http://arxiv.org/abs/physics/0611063.
2. For a detailed analysis, see the supporting online material with A. Kurs, A. Karalis, R. Moffatt, J. D. Joannopoulos, P. Fisher, M. Soljačić, *Science* **317**, 83 (2007).

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