More Options Offered for Long-Term Energy Solutions

Before one adopts Albert Bartlett's thesis that population growth must be included in addressing issues of energy shortages and carbon dioxide emissions ("Thoughts on Long-Term Energy Supplies: Scientists and the Silent Lie," PHYSICS TODAY, July 2004, page 53), it may be instructive to consider the other side of the energy coin. Perhaps more important than population growth is individual energy consumption. According to Paul Weisz's article in that same issue (page 47), an average American today consumes 10^8 kcal of energy per year, about 10 times more than an individual from a developing nation; the same factor holds for CO_2 emission. It makes one ask, Is our energy consumption in the developed world, and especially in the US, really necessary to maintain our quality of life? Neither Bartlett nor Weisz addresses this question.

If all of Earth's population is to expect the same energy consumption as present-day America, clearly the world is in for real problems. In that case, there will always be wars and suffering as one country increases its population and its energy requirements at the expense of the nonrenewable resources of another nation. The recent war in Iraq is a case in point. Unfortunately, Earth's population is already being controlled by these energy-related forces. For example, Iraq's population is 2.5 million less than it would otherwise have been, largely due to a fivefold increase in child mortality there since the implementation of the United Nations–sponsored embargo.[1]

I suggest that it is much more effective, and more just, to ask educated individuals in developed nations to give up their sport utility vehicles and turn off the lights when leaving a room than to ask that illiterate farmers in developing nations give up their natural desire for children—or even worse, to bomb them.

The solution to the short-term energy supply may not be as problematic as Bartlett implies if one considers improvements in efficiency and conservation. Worldwide, the present population growth rate is 1.2% per year and the rate is decreasing by 3% per year. If this continues, Earth's population will reach a stable maximum of about 8.9×10^9 in about 250 years. If the developed world—say, one-sixth of the world's population—reduces its individual energy consumption by half and the developing world increases its individual consumption to one-fourth that of the US (Japan's individual consumption is presently half that of America's), so that on average each individual in the world consumes 0.225×10^8 kcal/year, then the worldwide energy demand will not grow, and Weisz's graphs for the estimated reserves of oil, natural gas, and coal indicate that we could live happily for at least another 100 years before having to look for alternative energy resources.

Of course, satisfying this stable population in the long term would depend on our ability to eliminate our reliance on nonrenewable resources such as petroleum and uranium by improving our ability to harvest the Sun directly. I believe that physicists should turn their short-term efforts to improving energy efficiency and, like the farmer, their long-term efforts to making better use of solar energy. Let's leave population control to the social workers and politicians, who actually are doing a good job. A physicist who still feels the urge toward social action could preach energy conservation to the developed world.

On a final, perhaps philosophical note, the fundamental purpose of any life on Earth is to dissipate the free energy incident from the Sun. It is a thermodynamic requirement from which we cannot escape. Whether we do our share by increasing our population or by increasing our individual energy consumption is probably thermodynamically irrelevant, since we are still a long way away from dissipating the 10^{22} kcal per year Earth receives from the Sun. Perhaps the only real silent lie we physicists are perpetuating is to sometimes neglect this thermodynamic imperative. The inescapable good news, however, is that society will continue to invest at ever increasing rates in science and scientists toward the quickest possible dissipation of that free energy.

Reference

1. See, for example, N. A. Nasheit, *J. Matern. Fetal Neonatal Med.* **13**, 64 (2003).

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The debate on energy resources and population clearly includes thoughtful and concerned people on all sides. Responses appear to be based on one of two different models.

In one model, population growth is slowing and will soon stabilize at a level at which both birth rate and death rate are low. Technological innovation and resource substitution will ensure that the Malthusian scenario of food and energy shortages, and their resultant malnutrition, disease, and wars need not occur.

The error in this model is that it only applies to countries where women have access to education and employment and need not depend on childbearing for status and security. But much of the developing world has a rapid population growth rate, due to the application of medical technology that limits infant mortality, without the application of contraceptive technology that limits the birth rate. Rapid population growth limits the use of resources to those needed for survival, with little left for education and job training, especially for women. They have no alternative to childbearing as a way of ensuring for themselves a respectable place in society.

In the other model, a high level of education and participation of women in the work force has stabilized the population in the developed countries. They have a low birth rate that balances a low death rate. But that is not happening in underdeveloped countries. In fact the frequent news reports of famines and local wars imply that unsustainable growth is occurring that will result in the Malthusian scenario in which population stability is achieved only with a high death rate to balance the high birth rate.

The error in the second model is that the present situation need not perpetuate itself. Provided globalization continues and productive capacity and resource control shift from the minority to the majority, the Malthusian scenario for the majority could be avoided. This option would also require that women worldwide be given access to family planning technology. It is also essential that women receive education and job training so that they have an attractive alternative in life to that of continual childbearing.

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Readers who responded in the November 2004 issue of PHYSICS TODAY to the earlier articles on energy and population seem to fall into two main categories: those who believe the population problem is already solved through declining birth rates and those who believe the energy problem is already solved because we have nuclear power and continuing energy efficiency improvements. Both views are falsely optimistic and minimize the tremendous technology development problem we face: to provide sufficient energy for a prosperous world in the 21st century and beyond.

Even with the most dramatic conceivable drop in birth rate, the only way population will decrease sufficiently in coming decades is with a correspondingly dramatic increase in death rate. I am surprised so many physicists seem willing to accept that option.

Nuclear energy has four basic obstacles that may prevent it from ever being scaled up by the factor of 20 to 50 needed to address world energy needs: cost, incompetence, corruption, and waste. No breeder reactor, a technology necessary for nuclear fission to be a long-term solution, has ever been successful in the marketplace. Because each plant has such enormous energy content, staff incompetence, even at reactors billed as inherently safe, can lead to much more serious disasters than for other energy sources. A world filled with breeder reactors would necessarily include large-scale traffic in plutonium; just one criminal in the supply chain could trigger a nuclear catastrophe. And the long-lived accumulative character of nuclear waste justifiably frightens many educated members of the public. Billions of dollars have been spent on nuclear energy research, with little progress on resolving any of these issues at the scale that would be needed.

Energy efficiency improvements can only slightly mitigate the continued growth in world energy demand as developing countries advance. The energy problem we face is immense: In coming decades, trillions of dollars of energy infrastructure will need to be replaced with alternatives of some sort. All the renewable energy options face cost issues, both in production and in transmission and storage, that put them beyond large-scale deployment, at least until significant research investment brings those costs lower. The problem is on the scale of the cold war, but policymakers and the general public are not treating it as such. It is past time that the US Secretary of Energy should be given the same respect, and a comparable budget, as the Secretary of Defense, and be charged with resolving this critical problem for the nation.

Chemistry Nobel laureate Richard Smalley has been speaking on the energy problem around the country; I heard him recently at Brookhaven National Laboratory. His specific suggestion is a "nickel and dime" solution: a gasoline tax of \$0.05/gallon and perhaps similar carbon taxes on other fossil fuels, to raise about \$10 billion per year for alternative energy research. That's the scale we need, not the miserly \$80 million solar energy gets in the current US budget. And physicists and engineers must energetically tackle the critical problems, just as they did 60 years ago for the Manhattan Project. Every year of delay in developing these alternatives further threatens the future well-being of humanity.

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Paul Weisz considers transforming America's energy economy using approximately 1000 square meters of solar cells per capita. That amounts to macroengineering; covering roughly 2.7% of the nation's area would alter radiative equilibrium and could effect climate change.

Earth's albedo is modest, but efficient solar cells reflect even less solar energy than the land they shade, a radiative forcing that can amount to hundreds of watts per square meter. Many cell designs also retard nighttime cooling. Weisz proposes 650 000 km^2 of photovoltaics in 11 nations alone. Add the rest, and the total is millions. Multiplying hundreds of watts per square meter over millions of square kilometers yields approximately 10^{14} W, rivaling the present anthropogenic CO_2 forcing.

This dark side of solar power competes with local efforts, like Los Angeles's Cool Cities Initiative, to limit the heat island effect of simmering expanses of asphalt by making sunlit surfaces lighter, not darker. Pale paving and roofing grow attractively cheaper as oil, electricity, and asphalt prices rise. Few Americans can swing a mortgage on 1000 m^2 of silicon, but whitewash is universally affordable. Even Senator John Kerry parks his sport utility vehicle on a brilliant white-shell Nantucket driveway, admirably offsetting the albedo deficit of the solar cells atop his yacht.

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In his comments, Paul Weisz concludes that our best hope is for solar cells and advanced nuclear energy. He dismisses wind energy with the assertion that "energy losses due to transmission, supply, and demand fluctuation or conversion to other energies will reduce the actual contribution" from his estimated maximum potential of 3–22 quads of energy per year, which is much less than the 100 Q required to sustain the US lifestyle. I find Weisz's statement illogical because the solar cells and nuclear sources will also require transmission, supply-to-load matching, storage, and conversion. More wind farms are being built than any other electricity-generation facilities because they are now the lowest-cost option. In its last quarterly report, Florida Power and Light noted that its profits from wind energy are enough to cover its losses from nuclear energy. Given that 2% of all solar energy reaching Earth is converted to wind energy,[1] the maximum potential at 30% conversion efficiency is 22 000 Q/yr.

Weisz also dismisses agricultural fuel production on the ground that agriculture currently provides barely more energy than it consumes. How-