creased dependence on imported uranium and capital. It is thus all the more irrational to suggest that, without nuclear power, nations must war over oil.

As several thousand pages of critiques and responses on the soft-energy-path thesis show (*13, 19*), this is not the first time someone has decried "soft numbers" before verifying references. May I renew my earlier plea (Letters, 24 June 1977, p. 1384) that analysts get on with substantive refinement, extension, and application of soft-path concepts?

AMORY B. LOVINS
Energy and Resources Program, University of California, Berkeley 94720

References and Notes

1. A. B. Lovins, *Soft Energy Paths: Toward a Durable Peace* (Friends of the Earth and Ballinger, Cambridge, Mass., 1977), especially chaps. 3, 6, and 8.
2. ———, "Re-examining the nature of the ECE energy problem" [ECE(XXXIII)/2/I.G., U.N. Economic Commission for Europe, Geneva, 1978]; "Soft Energy Technologies," *Annu. Rev. Energy* **3**, 477 (1978).
3. M. Carasso *et al.*, *The Energy Supply Planning Model* (Report to the National Science Foundation, Bechtel Corp., San Francisco, 1975), two volumes, acquisition Nos. PB-245 382 and PB-245 383 available from the National Technical Information Service, Springfield, Va.; facility data sheets and updates from M. Carasso and J. M. Gallagher, personal communications, 1976.
4. D. Sternlight (Chief Economist, Atlantic Richfield Corp., Los Angeles), personal communication (1978) of a detailed Arco estimate that the total present-valued investment (exploration, field cost, pipeline, Valdez terminal, and new tankers delivering to existing West Coast terminals), including interest, is about $17,500/bpd (1978 dollars) for the Sadlerochit field (lifetime ~30 years). I have deflated this estimate at 7 percent per year to 1976 dollars and added $4621/bpd for storage, refining, and distribution, all treated as marginal costs [Bechtel data (*1, 3*) converted to 1976 dollars with the Marshall and Stevens index (*6*)].
5. For illustration, if 30 percent of system investment were at the wellhead and 70 percent downstream, with respective lifetimes of 13 and 30 years, the present value of the stream of original plus replacement investments over 40 years, at a 5 percent per year real discount rate, would be only 30 percent above the total investment if all lifetimes were 40 years.
6. For a 1.1-GWe PWR, $585 per net installed kWe (1974 dollars) is converted to $929/kWe (1976 dollars) using the 1.26 per year index from a 35-plant multiple regression ($r^2 = 0.71$) by I. C. Bupp and R. Treitel, "The economics of nuclear power: De omnibus dubitandum" (Harvard Business School, Cambridge, Mass., 1976). For T & D—respectively $69 and $420 (1974 dollars) per net kWe of installed marginal generating capacity, taking into account supply diversity—the conversion to 1976 dollars is made with the 1.25 Marshall and Stevens Equipment Cost Index.
7. This is highly conservative. For example, a regression ($r^2 = 0.76$) on the 39 U.S. light water reactors (LWR's) completed through May 1977 reveals that, with each successive year of construction permit issuance (1967–1971), controlling for all other significant variables, real plant cost rose $141/kWe. If this kept up, a 1.1-GWe PWR ordered in 1976 (25th unit built by the architect-engineer, outside the northeast region, with a cooling tower) would cost ~$1474/kWe. Both these figures have been converted to 1976 construction dollars with the Handy-Whitman steam-plant construction cost deflator, and would be higher if they were in 1976 GNP dollars [W. E. Mooz, "Cost analysis of light water reactor power plants" (Report R-2304-DOE, Rand Corp., Santa Monica, Calif., 1978].
8. The assumed LWR cost is also probably too low. For example, the California Energy Commission's draft report to the state legislature on Assembly Bill 1852 [R. Knecht *et al.*, *Comparative Generation Costs* (California Energy Commission, January 1978), appendix 19] estimates $1027/kWe for the Sundesert plant, ordered in January 1976 (neglecting dedicated transmission and deflating to 1976 dollars at 6.5 percent per year). The August 1978 final draft (in press) estimates $1185/kWe.
9. The empirical average for all U.S. LWR's through 1977 was 60 percent (58 percent if weighted by unit size), 53 percent for units over 0.8 GWe. Exhaustive regressions on the entire U.S. data base lead to a predicted average, levelized over the first 10 years of operation of a new 1.1-GWe PWR, of 60 percent, taking account of a new vintage correlation that emerged during 1977 (55 percent without it). See C. Komanoff, *Nuclear Plant Performance Update 2* (Komanoff Energy Associates, New York, 1978). Komanoff and V. Taylor have also prepared an improved analysis of the Mooz data (*7*).
10. Also assumed are Bechtel's (*3*) $61/kWe for marginal fuel-cycle facilities—probably ~ 3 to 5 times too low—updated to 1976 dollars and ordering with the Marshall and Stevens index (*6*), and $100/kWe, calculated (*1*) in 1976 dollars, for the initial core.
11. Bechtel (*3*) assumes 16.4 percent at the margin.
12. The omitted terms are: real escalation after 1976 ordering; marginal investment in reserve margin, land, future services such as waste management and decommissioning, and past or present services such as federal R & D, regulation, and security services; and the ~ 6½ to 8 percent of electric output currently needed to run the fuel cycle. Terms omitted from both the $3495/kWe and the ~$5000/kWe totals include costs of end-use devices, externalities, dynamic net-energy considerations, and any "miscellaneous" items.
13. U.S. House of Representatives, Committee on Government Operations, Subcommittee on Environment, Energy and Natural Resources, *Nuclear Power Costs* (Government Printing Office, Washington, D.C., 1978), part 2, pp. 1103–1115.
14. For example, if one uses Bechtel data (*3*), a 0.8-GWe coal-electric system with a scrubber but no fuel cycle would cost $2200/kWe delivered (1976 dollars) at 0.62 capacity factor (*1, 9*). If James's oil-fired plant cost the same, an oil-system cost of $30,000/bpd (capital charge at 0.12 per year = $9.9/b, too much to clear the market), divided by 0.46 First Law plant efficiency, would imply a system cost of $3172/kWe—generously assigning the whole oil-system cost to the residual rather than the light fractions (*15*).
15. J. Harding, in (*13*), part 2, pp. 1778–1802. The rationale for considering such a combined-cycle plant at the margin is that California is to have an embarrassing glut of residual oil from refining Alaskan crude oil extracted for its light fractions. Saving residual oil (nearly all of the 15 percent of California oil now burned in power stations) would probably not save crude oil; the residual oil is a by-product, not a motive. California is also considering gasifying residual oil.
16. The ratio of present electricity supply to electricity-specific needs approaches 2 in the United States today, and may exceed 3 after long-run end-use efficiency improvements.
17. J. Carter, remarks to Opening Conference, International Nuclear Fuel Cycle Evaluation, Washington, D.C., 19 October 1977.
18. V. Taylor (Pan Heuristics, Los Angeles), personal communication, May 1978. The proportional import reduction would be greatest in the United States, not in Europe or Japan.
19. U.S. Senate, Select Committee on Small Business and Committee on Interior and Insular Affairs, *Alternative Long-Range Energy Strategies* (Government Printing Office, Washington, D.C., 1977), two volumes [this contains all published critiques and responses except the exchange with Forbes in (*13*)].

Light on the Shroud?

Sindonologists may find the following paragraphs (*1*) of interest.

To make a reinforced plastic that will last for thousands of years, soak a strip of linen in oil of lavender that contains Syrian asphalt and let the fabric dry in the sun. Light will cause chemical bonds to form between adjacent molecules of the tar, converting the sticky

mass into a durable solid. The reaction would be regarded by organic chemists as an example of photocrosslinking, but to the artisans of ancient Egypt it was merely a way to make good mummy wrappings. Syrian asphalt, which is also known as bitumen of Judea, is a naturally occurring mineral tar of high molecular weight that, according to the Bible, was used for caulking both Noah's ark and the rush basket of the infant Moses.

Other experiments can be made with the material. For example, in 1824 Joseph Nicéphore Niepce, a French physicist and amateur Egyptologist, coated a glass plate with the same mixture of oil and tar and exposed it to a brightly lighted scene with a camera obscura that he constructed according to the design of Leonardo da Vinci. When Niepce subsequently washed the plate with oil of lavender, the unexposed tar dissolved but the light-struck portions, which were photocross-linked, adhered to the glass, forming an image of the scene. The plastic film served as a lithographic surface for greasy links, thus yielding the first permanent photograph.

Such an image is three-dimensional, with a thickness proportional to the intensity and duration of the incident light; it may appear as either a photographic positive or negative depending upon the lighting and the nature of the surface material.

ROBERT A. GORKIN

Department of Pharmacology, Mayo Foundation, Rochester, Minnesota 55901

References and Notes

1. C. L. Strong, *Sci. Am.* **221**, 128 (December 1969).

Solar Energy: Ignored Predictions

In News and Comment coverage of the recent Council on Environmental Quality report, which projected that an accelerated development of solar energy technologies could result in their contributing 20 to 30 quadrillion Btu's per year by the year 2000 (12 May, p. 627), it is stated that "No federal agency has ever previously held out even the possibility of so rapid a growth of solar energy. . . ."

As a matter of fact, 4 years ago, the extensively documented but largely ignored Project Independence Task Force on Solar Energy suggested that accelerated solar technology implementation would yield almost exactly this amount of energy by the year 2000 (*1*).

BRUCE L. WELCH

Welch Associates, One Investment Place, Baltimore, Maryland 21204

References and Notes

1. Federal Energy Administration, *Project Independence Blueprint, Final Task Force Report: Solar Energy* (Government Printing Office, Washington, D.C., 1974).