Energy: the U.S. at the crossroads

In late 1973, when the effects of the petroleum embargo were beginning to make themselves felt, the federal administration called for U.S. energy independence by 1980. There was also considerable talk about a concerted energy policy. This led to the formation of a Federal Energy Office, later to become the Federal Energy Administration (FEA), and other ambitious deeds, plans, and hopes.

In fact, as *ES&T* 's Marty Malin pointed out (in a Special Report, May 1973, p 392), the U.S. had (and apparently still has) a *de facto* policy which "boils down to a basic goal—unlimited cheap energy." Escalating electricity prices, for example, have shown how effective this policy has been. To be sure, some legislators, including Sen. Jennings Randolph (D–W.Va.) and Sen. Henry Jackson (D–Wash.), warned that this goal was impossible. They also explained why rational programs of source diversification, conservation, and efficient energy use were of the essence, but not many took heed of these warnings. Now that one embargo has come and gone, and fuel prices have spiraled, a polite hearing seems, once again, to be given to pleas for conservation and diversification.

Meanwhile, one no longer thinks in terms of energy independence by 1980, or, for that matter, by 1985. Indeed, achieving a fairly embargo-invulnerable position by 1985 would be quite a feat. Dependence on petroleum imports has increased to more than 40% from perhaps 25–30% in pre-embargo mid-197[illegible] Conservation policy is largely ill-defin[illegible] although, to be sure, many governme[illegible] and private institutions and compani[illegible] and public-spirited people, are volunta[illegible] undertaking vigorous conservation me[illegible] sures. On balance, the U.S. effort to c[illegible] to cut back its energy appetite can be s[illegible] not to have made great progress.

Reduction of motor fuel use helps to clean the air.

Here's how well that worked in the Washington, D.C., area, so far, if one judges by air quality:

Year	Number of air pollution alerts [b]
1970 [a]	1
1971 [a]	1
1972	4
1973	6
Embargo	
1974	1
1975	4
1976 [c]	5

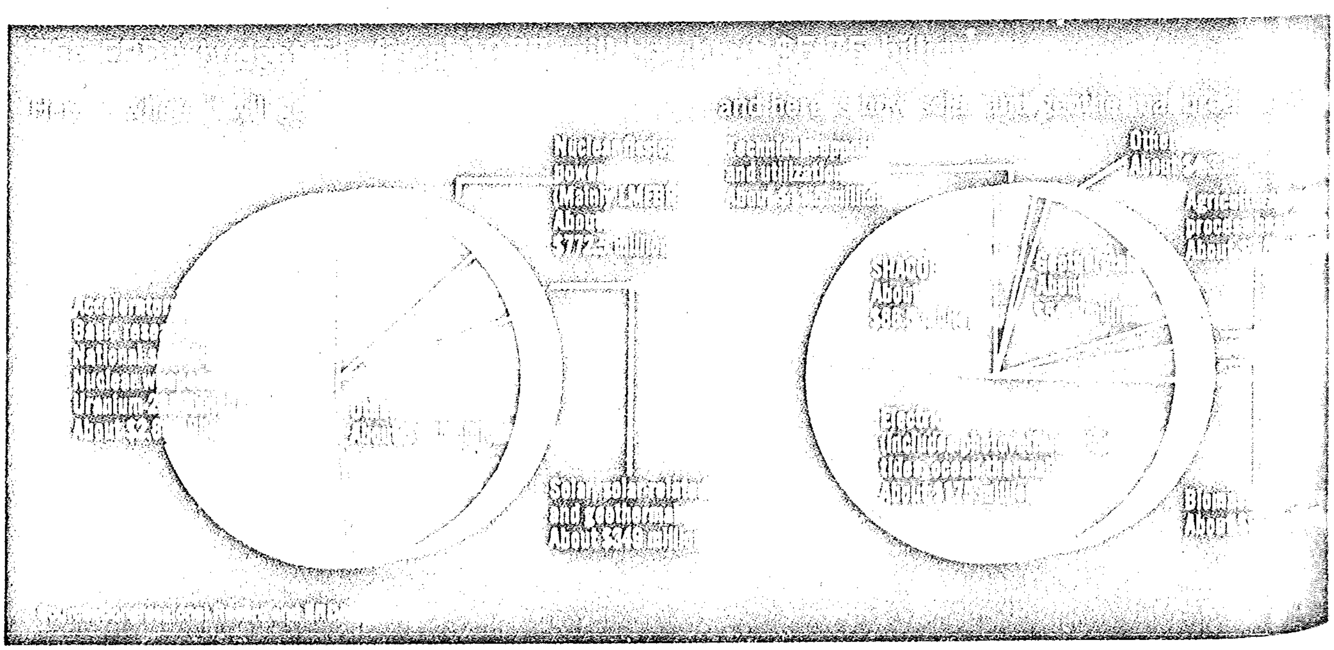
[a] Records were sketchy. [b] Compilation of air quality index figures began in 1973. [c] Through August 6. Note: Pollution around Washington is almost entirely of automotive origin. Source: Metropolitan Washington Council of Governments.

A "quick-fix" approach

The real essence of the present ener[illegible] situation is economic; more specifica[illegible] it is found in the billions of dollars the U[illegible] must export annually to pay its oil b[illegible] These dollars, if not exported, might, [illegible] part, have formed capital to create ne[illegible] products and jobs, to improve the en[illegible] ronment, or to retire outstanding debts. [illegible] other words, the amount of cash a[illegible] credit exported impoverishes the natio[illegible] by that much.

Is there a "quick-fix" way of alleviati[illegible] this situation? The answer is a guard[illegible] "yes," if one is not overly fussy abo[illegible] what time frame he may wish to assign [illegible] "quick-fix," and if one is prepared to a[illegible] cept certain sharp changes in life st[illegible] and all that these changes imply.

This "quick-fix" approach is simply t[illegible] type of industrial, residential, a[illegible]



ES&T's Julian Josephson takes a look at what is going on under the sun about "renewable" sources of energy. They show promise, but have many problems, and much technology still needs to be proved

transportational energy conservation measures one normally associates with wartime austerity. Such measures could be justified by the notion that, because of the 1973–1974 embargo and subsequent cartel prices, the U.S. is engaged in a form of economic war with certain oil exporting countries. Unfortunately, aside from the various dislocations they may cause, draconian austerity measures can lead to bureaucratic bumbling, inequities in their imposition, and other well-known problems. A countervailing argument might be that mandatory austerity produces results more quickly and completely than does voluntary austerity. However, those who have lived through tight austerity periods often take issue with this latter argument, citing personal experience as their basis.

Actually, the measures just discussed involve what Charles Coutant of the Oak Ridge (Tenn.) National Laboratory (this issue, p 868) calls reductive energy conservation (car pooling, rationing or high taxes, and the like). True, with this type of conservation, less domestic and imported fuel is consumed per time unit. The U.S. balance of payments could be improved, and, as a bonus, air quality, for instance, may be enhanced. However, Coutant notes that reductive conservation may only momentarily slow energy use, without much affecting the long-term upward trend. He calls for rounding out the picture with *productive* energy conservation with which partially spent energy is put to further use.

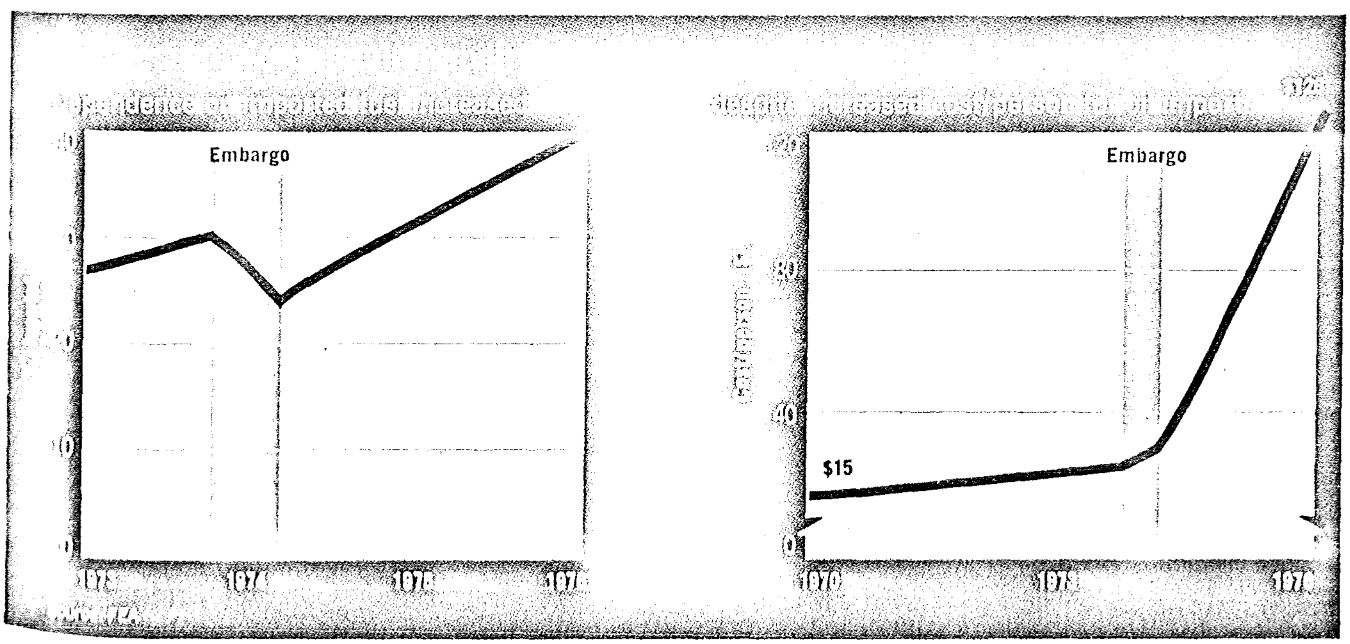
Nevertheless, conservation is the "quick-fix" (and non-polluting) approach, if one indeed exists, and probably the only one right now. There is a great deal heard about the environmentally acceptable, large-scale development of coal and nuclear power—much of which involves non-renewable energy sources. For an idea of how well that is going, one might consider that it is now estimated that even by 1985, for example, "clean" liquid fuels from coal will have no appreciable impact, according to the U.S. General Accounting Office. Original expectations were for a 2.5 million-bbl/d equivalent by then.

Time slippages, cost overruns, and other setbacks are also being experienced in the quest for oil from "far-out" sources, and in nuclear development. The Alaska pipeline and the Clinch River (Tenn.) liquid metal fast breeder reactor (LMFBR) are among the more notable cases in point. Still, it can be reasonably projected that the main thrust of energy source development will entail non-renewable petroleum, coal, and fissionable nuclear material, and that most of the renewable sources, with the possible exception of solar and perhaps geothermal, will be the subject of many more books and articles than of large-scale, practical engineering and commercialization.

Renewables

In a sense, there is no infinitely renewable source of energy. After all, the sun itself might cease to provide energy some billions of years from now. Nevertheless, there are very long-term sources. Plutonium breeding, for instance, is at least a multi-thousand-year source. Deuterium-deuterium fusion, if it ever proves feasible, can be seen as a billion-year source. Geothermal would be available as long as the earth's heat lasts; and solar energy and its derivatives, such as wind, ocean thermal gradients, waves and tides, biomass, and the like, should last as long as the sun itself.

If severe economic displacements are not to be experienced, additional non-renewable fossil and nuclear sources need to be developed with all due speed and safeguards. However, accelerated



efforts should be made to bring the renewables to a state of high technology:

- to provide the most diversified mix possible, so that dependence upon one or two sources is no longer lopsided
- to obviate the unpleasant economic situation that would arise when non-renewables are exhausted.

And, unless the U.S. and world economy undergoes some very unforeseen changes, or some radical technological breakthrough occurs, exhaustion of the non-renewables is almost as sure as the proverbial death and taxes.

The know-how is here

In "Energy Earth and Everyone" (Books, *ES&T*, January 1976, p 86), the author, Medard Gabel, who led the World Game Workshop that helped to put that book together, characterizes non-renewables as "capital energy sources," and renewables as "income energy sources." In the foreword, R. Buckminster Fuller, one of the elder statesmen of environment and clean energy, asserts that the knowhow to harness the "income energy sources" by 1985 exists now. Fuller also says that use of these sources will afford mankind a higher standard of living and greater degree of freedom than ever previously experienced. All this can be attained even though further use or development of fossil, fission, and fusion energies is phased out by 1985, he noted.

Perhaps Fuller's view reflects a great deal of optimism. A contrasting view was expressed by W. Donham Crawford, president of the Edison Electric Institute (EEI, New York, N.Y.) at a Bermuda meeting of the Industrial Gas Cleaning Institute (IGCI) held earlier this year. Crawford said that the energy base of the U.S. is in a "transition period" from fossil to renewable resources (in which he included fusion). However, he told the IGCI meeting that such new energy sources will not play any significant role until after the turn of the century. In the meantime, coal and nuclear power must be used to sustain the U.S. through this period of change, he said.

In hot water

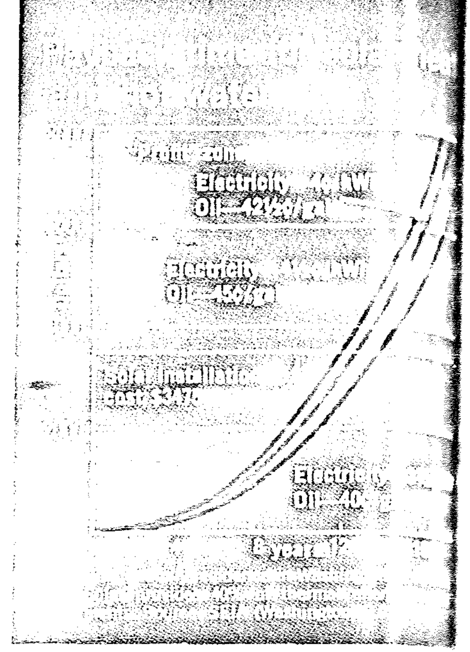
At least one "income source" seems to offer more than a ray of hope. When solar energy pioneer George Löf of Colorado State University received the $25 000 Lyndon Baines Johnson Foundation Award in February (*ES&T*, April 1976, p 315), he said that the use of solar energy for heating and cooling is "now a commercial reality." At least a reasonable facsimile of commercial reality exists, if one is to judge from the 45 exhibitors at the Second Annual Meeting of the Solar Energy Industries Association (SEIA, Washington, D.C.), held in Washington in mid-June. These exhibitors included large companies such as Ametek, GE, Grumman, Olin, PPG Industries, Revere Copper & Brass, and Westinghouse. Smaller firms with "track records," were also represented—InterTechnology Corp. (Warrenton, Va.) and Thomason Solar Homes (District Heights, Md.), to name a couple.

Products and systems on exhibit included collectors, heaters, photovoltaic cells, portable cookstoves, and publications. For example, Grumman (Bethpage, N.Y.) displayed its "Sunstream" domesticated hot water system. GE (Philadelphia, Pa.) had a solar-assisted heat pump. Ying Manufacturing Corp. (Gardena, Calif.) showed a patented solar heating/cooling system, and Ametek, Inc. (Hatfield, Pa.) offered a high-performance solar collector. Total Environmental Action (Harrisville, N.H.) was one of the book and solar component exhibitors, while Sam Nakhleh, president of Intercontinental Enterprises Corp. (Eastchester, N.Y.) was cooking French toast and "hot dogs" on a portable folding solar stove that accumulated energy from a floodlight, since the show was indoors.

Solar energy for heat and hot water, and even for cooling, is now available. For a U.S. first, Ametek provided 270 solar collectors (6500 ft^2) for heating and cooling of the $1 million Santa Clara (Calif.) community recreation center. The solar system itself cost about $500 000. About 40% of that cost is for monitoring equipment for the system and testing of the collectors. An additional $300 000, or so, will pay for a 1-yr monitoring program, as well as engineering and legal studies. The system will use a 140-gpm water flow for heating/cooling, a 10 000-gal hot-water reservoir, and a 50 000-gal cold-water reservoir.

Grumman's hot water system will be found in some homes on Long Island, (N.Y.). Solaron Corp. (Denver, Colo.), of which George Löf is vice president, had a $500 000 order backlog earlier this year, and was installing systems on 60 buildings in 12 states, as of the first quarter of this year. Thomason Solar Homes is licensing the "Solaris" system which, according to Harry Thomason, the company's president, provides material cost advantages in solar-heated/cooled home building and retrofitting, especially because of its design. For example, he explained how a solar heated/cooled home of his design would cost $42 000, while a competing home, with solar heating only, might cost $50 000.

Almost every day, one hears of a house, school, hamburger "joint," pro-



fessional building, or other establishment "going solar." As Löf observed, solar is commercial. However, he predicted—and the present situation seems to bear his prediction out—that initial commercial use of solar energy will be found in heating, hot water, and cooling. Large-scale use of direct solar energy for electricity generation and mechanical applications will probably come about in the 21st century, barring some unexpected technological breakthrough.

The sun industry

Sheldon Butt, SEIA president, observed, as Löf had previously, that solar energy is here now and not down the road. While it is not red hot yet, it is warming up, and is not just in a research and development situation. Butt, who is also director of market research and planning for Olin Brass, Olin Corp. (East Alton, Ill.), provided a cash flow analysis for heat and hot water for a single-family residence in Washington, D.C. This residence would total 1500 ft^2, have 40% of its thermal energy requirements furnished by solar energy, and be amortized over 20 yrs. The installation cost is estimated at $3475; back-up hot water requirements are provided by electricity, and heating by oil. "Payback" from installation of this solar energy system could be 12–14 yrs, depending on the price of electricity and oil; after these time periods, the projection shows a "profit."

George Szego, president of InterTechnology Corp., and secretary of SEIA, reminded *ES&T* that three days of sunshine provide the world energy equal of all known fossil reserves. He projected oil equivalent savings of 1 million bbl/d, equivalent to $5 billion/yr, within 10–15 yrs, if a crash program in accelerated solar energy development were initiated now. Other benefits Szego foresaw were new jobs and export markets, and less-and needs for fuel imports and public utility capacity. He also said that "typical" solar installations could provide 60% of SHACOB (*solar heating and cooling of buildings*) needs. Finally, Szego noted the existence of a double anti-pollution benefit that solar provides. First of all, solar does not pollute; secondly, pollution is obviated because other fuels, which would normally be used, are not used.

This anti-pollution benefit is especially important when one thinks of excess carbon dioxide (CO_2), with its "greenhouse effect," as a product when fossil fuels are burned. This is a controversial point; however, Szego observed that atmospheric CO_2 concentration averages 325 ppm worldwide. At present rates of fossil fuel combustion, this average could go to 650 ppm in 25 yrs; in 35 yrs, the earth's average temperature would rise 1 °C, and in 75 yrs, 3 °C. This increase could bring about wholesale changes in climate, food production, and ocean level. He brought up this potential CO_2 threat as a principal reason why solar becomes necessary. The large coal deposits, he said, cannot all be used, whether raw, refined, gasified, or liquefied, under known technology, without raising world CO_2 levels beyond the danger point.

Thus, accelerated solar energy application is vital. For quicker SHACOB use of solar, SEIA is calling for tax incentives and loan guarantees. For example, a homeowner might have a tax credit of 40% of the first $2000, and 25% of the next $6000 invested in solar equipment that meets standards under development by the National Bureau of Standards, or to be developed by the American National Standards Institute. Other tax credit and rapid amortization plans were proposed for commercial/industrial organizations and non-profit institutions. A start in this direction has been made. California has granted a state income tax credit of 10% for solar equipment purchase/installation costs, to a maximum of $1000.

"Sunpower"

The SEIA meeting and other events and activities emphasize SHACOB for the immediate future. But what about the use of solar energy to generate electricity? Piet Bos, solar program manager for the Electric Power Research Institute (EPRI, Palo Alto, Calif.) does not foresee large-scale sunpower for this century. Even as far as total energy is concerned, U.S. Energy Research and Development Administration (ERDA) officials see solar as supplying only about 7% of U.S. energy needs by the year 2000, and maybe 15% by 2020.

Nevertheless, some effort for sunpower is here. One project involves the use of 320 large mirrors to reflect sunlight onto a boiler atop a 200-ft concrete tower. Sandia Laboratories (Albuquerque, N.Mex.) will pilot-test this "heliostat" boiler/generator for ERDA as a means of producing electricity. If results are favorable, ERDA hopes to complete a similar solar tower. An example of indirect or "secondary" use of solar for power, that tower would produce 10 MW—enough for a community of 10 000 people.

Solar cells convert sunlight directly to electricity ("primary" solar use). Unfortunately, ERDA estimates power generated by this means at $20/W. This cost must come down to 50¢/W if solar cells are to be competitive with other sources. ERDA's plans are to achieve that 50¢ figure by 1985. Joseph Lindmayer, president of Solarex Corp. (Rockville, Md.), a solar cell manufacturer, believes that by 1985, these cells will be commercially available for house and building rooftop electricity generation.

A principal stumbling block in solar cells, up to now, has been the expense of their manufacture. Basically, they must be

SHACOB at work

Where it is used	*Who is doing it*
Homes in Mass., N.H., and R.I.	**New England Electric System**
Homes on Long Island, N.Y.	**Grumman (Bethpage, N.Y.)**
Barefoot Mailman resort hotel, Broward County, Fla.	**High Plumbing (Pompano Beach, Fla.) and Solar Dynamics, Inc. (Hialeah, Fla.)**
Burger King, Voorhees, N.J.	**Northrup, Inc. and Arkla-Servel**
Burger King, Tallahassee, Fla.	**Aerocell Pollution Control, Inc. (Tallahassee)**
Dental clinic, Indianapolis, Ind.	**Solar Energy Products, Inc. (Avon Lake, Ohio)**
"Decade 80" solar house, Tucson, Ariz.	**Copper Development Association, Inc. (New York, N.Y.)**

Problems with "renewables"

[illegible]

made of highly refined silicon, which is then "doped" with impurities such as boron, which is necessary to impart photovoltaic characteristics to the cell. Each cell must then be hand-cut and shaped to prescribed sizes and forms, and arranged in a predetermined pattern. However, Mobil-Tyco Solar Energy Corp. is working on a method to mass-produce and cut the time necessary to make cells—from silicon purification and "doping" to the formation and arrangement of the cells. Apparently promising alternatives to silicon cells, such as gallium arsenide (Ga-As) and cadmium sulfide (CdS) cells are subjects of federally funded R&D.

Sandia tried the approach of using a lens to focus sunlight on a silicon cell 2 in. in diameter. This procedure apparently raised the cell output from $\frac{1}{5}$ W to 10 W. A system of 150 lenses and 150 cells could produce 1 kW of electric power, and that goal is what Sandia was aiming for this summer.

Another possibility is the concentration of solar heat from concave aluminum reflectors on a system containing a fluid such as toluene. The toluene is vaporized and drives a turbine to generate electricity; spent vapor recondenses, and the cycle is repeated. Sandia is also trying this method with about twenty 9 by 12 ft reflectors to provide the necessary heat.

Another stumbling block for sunpower is energy storage, so that power can be provided by night, or during periods when the sun does not shine. This storage could be in the form of batteries or heat, and the technology still needs developing. For example, for the Sandia 10-MW heliostat system, Honeywell Inc., Martin Marietta Corp., and McDonnell Douglas Corp., are working on heat storage systems good for 4–6 h. At present, according to ERDA consensus spokesmen, attempts to increase this storage time would raise the costs "out of sight."

Finally, cell conversion efficiency needs to be perfected. Generally, photovoltaic efficiency runs 10–12%. This year, higher efficiencies—perhaps up to 20%—have been reported. A main objective of solar R&D is to improve cell efficiency. The Sandia conversion/heat technique may be one answer; cells of different chemical compositions may be another.

Blow ye winds, heigh-ho!

Wind may be regarded as a form of solar energy, since the sun's action on the atmosphere is the ultimate cause of winds. Its use as a power source is not exactly new; for example, at Grandpa's Knob, Vt., in 1941, a wind turbine, 175 ft in diameter, produced 1.25 MW at a cost (1945 dollars) of 3 mils/kW vs. 2.5–6 mils/kW for fossil-fueled power plants. The energy from wind at Oklahoma City, for example, averages 18.5 W/ft^2 of area perpendicular to the wind, approximately equivalent to the solar energy/ft^2 of land in that area.

Near Sandusky, Ohio, NASA's Lewis Research Center (Cleveland) is experimenting with a wind turbine generator (WTG) that can produce up to 100 kW with an 18-mph wind. Blade diameter is 125 ft; there are two 62.5-ft blades, each of which weigh 2000 lbs. Cost is estimated at $5500/kW; follow-on 200-kW systems may run $2340/kW. Also, vertical-axis systems are under development by NASA, Sandia, and others.

Do you want to be the first in your neighborhood with a wind energy conversion system (WECS)? Enertech (Norwich, Vt.), one of several firms, carriers WECS and auxiliary equipment for the home, farm, and business needing an alternate energy source. One system, priced at $16 200 with inverter, will produce 200–310 kWh in an 8-mph wind, and 600–930 kWh in 16-mph wind. It provides 115 VAC, and comes with a 40-ft galvanized steel tower and 115-VDC, 450-amp-h batteries.

Some electric utilities are interested in wind energy. Indeed, ERDA has asked [illegible] of them to monitor wind in their respective areas. The results of this monitoring should lead to four or five being selected for further work in development of wind energy as a power source.

Some "renewables" projects

[illegible]	Activity or approach	Agency/company
Ocean thermal	Floating power plant study	ERDA/Lockheed Missiles and Space Co. (Sunnyvale, Calif.)
Ocean thermal	Floating power plant study	ERDA/TRW, Inc. (Redondo Beach, Calif.)
Tides	Study, 9 mos., Passamaquoddy Bay, Me., and Cook Inlet, [illegible]	ERDA/Stone & Webster (Boston, Mass.)
Wind	Wind turbine generator, 100 kW, Sandusky, Ohio	NASA/LeRC (Cleveland, Ohio)
	Wind-power generator, vertical axis	ERDA/Sandia Laboratories (Albuquerque, N.Mex.)

Ups and downs

In a number of places tides range 20 ft and more. These include the Bay of Fundy (Me., and Canada), western France and England, the Yellow Sea coast of Korea and the U.S.S.R.'s White Sea.

The best-known use of tidal power is at La Rance, France, where tides help to generate 240 MW of power. At Mezen, on the U.S.S.R.'s White Sea, a 1.5-MW plant, the initial phase of a network that would generate 6 MW, is being built. There is also much talk about an 800-MW tidal plant for the Severn River, England, and about large-scale use of tidal power at Passamaquoddy Bay, Me. So far, these plants are still mainly in the talk stage. However, in April, ERDA did allocate $168 733 for a 9-mo study of tidal power at Passamaquoddy Bay, and Cook Inlet, Alaska. Stone and Webster (Boston, Mass.) is doing that study.

Great Britain may be placing a bet on wave energy with a Department of Industry grant equivalent to about $114 000 to test out "Salter's ducks." These are a string of vanes, devised by Stephen Salter of Edinburgh University, which are shaped to extract a high percentage of sea wave energy. Engineer Eric Wood has designed a means by which not only would the vane string array not be broken by the waves, but energy extraction would be level.

The British Department of Energy is also supporting wave-energy projects. That department estimates that 10 years must pass before a 10-MW prototype ocean-wave electric generator is operational, and that a 1000-MW station could not come on line before 1996. However, Salter, who is also with Sea Energy Associates, a part of Ready Mixed Concrete Ltd. (also supporting the "duck" project) believes that his system could actually be making money in five years.

On a small scale, the use of temperature differences between the warm ocean surface in tropical waters, and the colder depths have been used as power sources. Cuba (40 kW, 1930) and the Ivory Coast, Africa (7 MW, 1950s) were the sites. Essentially, this approach used a fluid such as ammonia or propane that vaporizes

industry," by Carolyn Pesko
Science Publishers, Inc.
1425
MI 48106
lists "who does or makes what"
industry.

Energy for Heating and Cooling of
" by Arthur R. Patton

Energy from the Sea," by Ar-

Corp.
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state-of-the-art reviews in their
fields.

Machines," by Frank R. Eldridge
number 038-000-00272-4
Superintendent of Documents
Government Printing Office
DC 20402
past and present, are de-
prospects are discussed.

to warmer depths to drive a turbine, and then condenses in the colder depths, 2000–3000 ft, for example.

For fiscal 1974, the National Science Foundation (NSF) awarded $500 000 for ocean-thermal work; NSF funding was $2 million in fiscal 1975. For fiscal 1977, ocean-thermal is included in ERDA's $175 million solar/electric funding. The Johns Hopkins University Applied Physics Laboratory pegged total costs of developing a 100-MW demonstration ocean-thermal plant at $96 million (*ES&T,* February 1975, p 104).

A head of steam

Geothermal power first came into service at Larderello, Italy, in 1904. Now, the Larderello plant is almost 406 MW, and contributes materially to powering the (Italian railroad). In California, at "The Geysers," Pacific Gas and Electric Co. (PG&E) uses dry geothermal steam to provide 502 MW (ultimate capacity could approach 2000 MW) for 5% of the needs of PG&E's 3 million customers in northern and central California. Other geothermal sites are in use or under construction in France, Iceland, Japan, Mexico, New Zealand, and the U.S.S.R., or are being planned or contemplated in those countries, as well as El Salvador (UN project), and in California, Idaho, Oregon, and Texas.

Ideally, a geothermal source would be dry, clean steam. Hot water, however, could also be a source. The latter will be looked to increasingly, since it is more abundant. Unfortunately, much of this water is mineral-rich, and corrosive, abrasive, and hard on equipment. There is also potential for release of ammonia and sulfurous gases. Nevertheless, "teakettle power" (*ES&T,* August 1973, p 680) is plentiful, and if 13% of its total heat were converted to electricity, about 10 times the world's present power output (580 trillion kWh) could theoretically be produced.

On a lighter note . . .

Amid the energy hubbub, there are papers and conversations concerning possible conversion from fossil to hydrogen (H_2) fuel (*ES&T,* February 1975, p 102). And why not? In principle, H_2 burns cleanly, with water as its combustion product. H_2 abounds on earth. True, H_2 is hazardous, but so is natural gas if improperly stored, transmitted, and used. Hydrogen might be stored as a gas under pressure, as a cryogenic liquid, or as hydrides.

H_2 systems were the central topic of the 1st World Hydrogen Energy Conference, held in early March at Miami Beach, Fla. This conference was sponsored by ERDA and the University of Miami (UM), and chaired by UM professor T. Nejat Veziroğlu. Among topics discussed were nuclear, solar, fossil-fuel, and other approaches to H_2 production; conversion to an H_2 economy; and H_2 applications, some of which are quite advanced in concept. For example, Roger Billings of Billings Energy Research Corp. (Provo, Utah) proposes an H_2-fueled mass transit system using 21-passenger buses. Fuel storage would involve metal-hydride containers made of an iron-titanium alloy.

Other H_2 applications described involved conversion of a U.S. Postal Service mail truck to this fuel at the University of California (Los Angeles), and its good safety record despite an overturn at 20 mph. The fuel source was liquid H_2. The 3-volume Conference Proceedings (*ES&T,* May 1976, p 498) provides an insight into how far theoretical and practical work in H_2 energy has progressed.

Audacious prophecies

The foregoing discussion, at a very fast gallop, indicates some options that the U.S. has in its transition from non-renewables to renewables. It did not include fusion, solid waste, methanol, or other sources which, it was felt, are appropriate for other articles. Also not included are sources whose technology is in such a state of infancy as not to constitute a plausible option at this time. This category would include use of ocean currents, deep ocean pressure, and phase transformation.

Concerning the "transition period" of EEI's Crawford, *ES&T* makes the audacious prophecy that this period will be a very long one—well into the next century. Perhaps, clean, renewable sources will be part of an energy mix as this century draws to a close, but they will have the smaller share of this mix. The main thrust of energy development will remain fossil and nuclear.

For the nearer term, 5–10 yrs, *ES&T* brazenly prophesizes that U.S. vulnerability to the effects of a petroleum embargo will not lessen appreciably. Despite all the "pep talks" and "hoopla," this vulnerability could still exist in 1985 though, perhaps, less in degree by then.

Concerning a new embargo, hopefully, somewhere in Washington, there exist countermeasure plans. These plans should be based on the assumption that it will be long, widespread, complete, and efficiently policed by its perpetrators; and that the much-touted international plans to combat it will come unglued in an every-nation-for-itself scenario. As for renewable energy sources, there needs to be much more accelerated development, not only as a hedge against embargoes, but also to provide a rational, highly competitive and diversified energy source mix, and to husband carefully the finite and decreasingly accessible resources that exist on Spaceship Earth.

Some more audacious prophecies

- *Many more energy conservation programs will be in the industrial and commercial areas, rather than in the transportation sector. Indeed, conservation in the transportation sector will continue to lag far behind that of the other areas.*
- *There will be another oil embargo. Moreover, it will be more widespread and "leak-resistant" than the 1973–1974 embargo was, and it will last for a considerable time after its underlying political cause has ended. Its end will not be an abrupt lifting, but rather, an irregularly-staged phaseout. Hopefully, this prediction is dead wrong, and equally hopefully, there will be national plans made as though this prediction were right "on target."*