A New Kind of Sea Power

Heat from ocean waters can be used to generate electricity and manufacture fuel

by PAMELA WEINTRAUB

Solar energy enthusiasts usually overlook the fact that most sunshine falls not on land but on the oceans, which cover more than 70 per cent of the earth's surface. The sun warms the water, which stores heat, making the oceans a vast reservoir of energy. But this has not escaped the notice of the United States Department of Energy. A technology called OTEC, the department says, will help free the United States from OPEC. Within a decade, Ocean Thermal Energy Conversion could provide electricity for Miami and other coastal cities in the tropics and subtropics. Later, OTEC plants could generate electricity for producing chemical products in factories far at sea, further reducing America's dependence on foreign oil.

The basic concept of OTEC was spelled out a century ago, when Arsène d'Arsonval, a French physicist, suggested that energy could be generated by exploiting the temperature difference between the ocean's sun-warmed surface and its chilly depths. But both the French, who experimented with the scheme at the end of the 19th century, and the Cubans, who tried it in 1929, found it to be impractical; available sources of energy were far less expensive. New technology and OPEC's price rises are beginning to change all that.

To operate efficiently, OTEC needs surface water at a temperature of about 80 degrees Fahrenheit. That is tepid compared with the several hundred degrees needed to vaporize water and produce the steam that drives conventional turbine power generators. But turbines can be turned by vapors other than steam, as was demonstrated in 1979 aboard a barge anchored just off the west coast of the island of Hawaii.

The vessel, named *Mini-OTEC* and operated by Lockheed, was equipped with a system that drew water from the surface of the ocean into a heat exchanger, or evaporator, containing liquid ammonia under pressure. The exchanger heated the liquid ammonia (which has a boiling point far lower than that of water), turning it into vapor that was directed against the blades of a turbine. The spinning turbine powered a generator that produced electricity. After the vapor passed through the turbine, it was funneled into another heat exchanger, or condenser, this one cooled by 40-degree water pumped up from about 2,000 feet below the ship. At this temperature the ammonia gas, under pressure, condensed back into a liquid, ready for another round in the cycle.

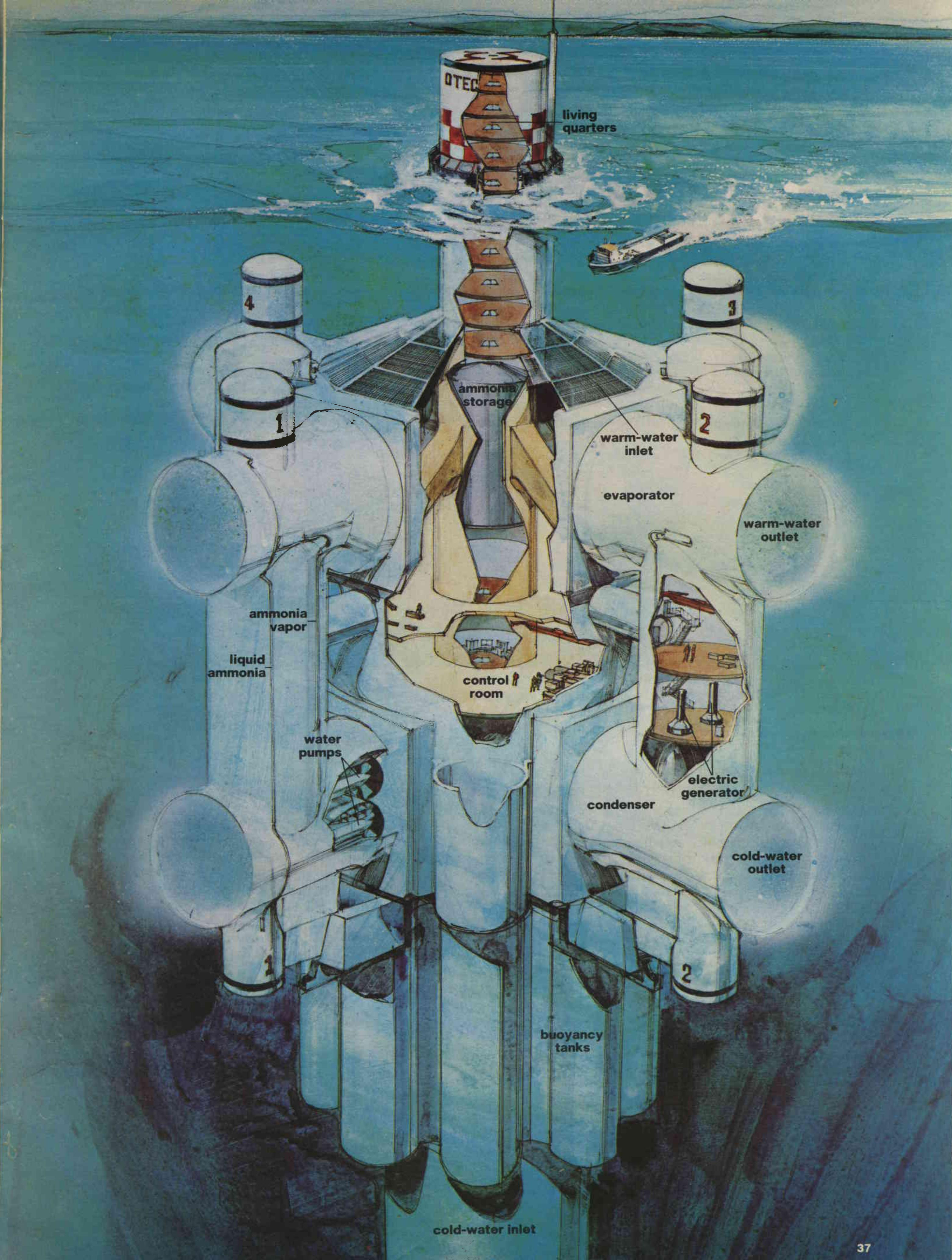
The *Mini-OTEC* plant produced a mere 50 kilowatts of electricity, just enough to run its own equipment and a few floodlights on board. But it convinced many skeptics that OTEC would work. Since then Congress has firmly committed itself to OTEC: recent legislation calls for 10,000 megawatts of OTEC power (enough to supply 10 million houses) by 1999, and sets up a $2 billion loan-guarantee program to make it possible. In November DOE completed the conversion of a Navy tanker dubbed *OTEC-1*, anchored 18 miles off Keahole Point in Hawaii, where it is testing the technology for the large pilot plants to follow.

"OTEC offers a source of energy that is simply enormous," says William Avery, head of the OTEC research group at Johns Hopkins University's Applied Physics Laboratory. "The fuel is ocean water—free, virtually unlimited, and nonpolluting. And the technology is basically ready to go." In fact, according to Avery, OTEC is one of the few forms of solar energy that will be both cheap enough and plentiful enough for widespread use within the next 20 years. OTEC power, he says, may soon cost less than electricity produced by nuclear energy or coal.

OTEC plants must be located where the difference in temperature between the water at the surface of the sea and the water half a mile below is at least 37 degrees—and that means in warm climates. American OTEC plants will

In this 260-megawatt OTEC plant, designed by the Lockheed Corporation, warm water drawn in through the grates surrounding the central core will be pumped to each of the four evaporators. There it will flow through tubes surrounded by liquid ammonia under pressure, heating it to vapor that will turn turbines to generate electricity. The vapor then moves down to the condensers to be cooled and reliquefied by water pumped up from 3,000 feet below. Cables will carry electricity to the shore. The plant's living quarters will house a crew of 30

ILLUSTRATION BY DENNIS LYALL


OTEC
living quarters
4
3
ammonia storage
1
2
warm-water inlet
evaporator
warm-water outlet
ammonia vapor
liquid ammonia
control room
water pumps
electric generator
condenser
cold-water outlet
1
2
buoyancy tanks
cold-water inlet

have to be built in deep water a mile or two off the coasts of such places as Hawaii, Puerto Rico, and the Virgin Islands, and at least a hundred miles south of the Gulf Coast. The power produced by these plants will be cabled to local utilities on shore. Kent Keith, of Hawaii's Office of Planning and Economic Development, predicts that OTEC will eventually supply his state with 80 per cent of its energy.

Other tropical and subtropical regions, especially those lacking fuel for industrial development, will also benefit from OTEC. As Lawrence Neuman, an expert on ocean economics and technology at the United Nations, told DISCOVER's Carol Truxal, France is once again examining OTEC, for possible use in Tahiti and Guadeloupe. The European Economic Community has offered to pay for feasibility studies on the Ivory Coast; the Swedes may build a plant off Jamaica; the Dutch are considering one for Curacao; and the island nation of Nauru, northeast of Australia, has been negotiating with the Japanese for a 100-kilowatt plant.

Not all of OTEC's energy will be supplied in the form of electricity. Because they need deep water to operate, many plants will have to be placed so far out at sea that it will not pay to transmit electricity to shore by cable. Some of these distant plants will function as factories, using power generated at sea and raw materials brought from the shore to make such products as aluminum, methanol, and synthetic crude oil.

Even more important, these plants could produce low-cost ammonia. As Evans Francis, an economist at Johns Hopkins, points out, ammonia is now produced by separating hydrogen from costly natural gas and combining it with nitrogen from the air. It is used largely in fertilizers. But ammonia could be produced at less expense by OTEC, which would use cheap electricity generated at sea to extract hydrogen from ocean water by electrolysis. This ammonia could be broken down once more into nitrogen and hydrogen. Liquid hydrogen could replace gasoline in automobiles, and could also power fuel cells that generate electricity.

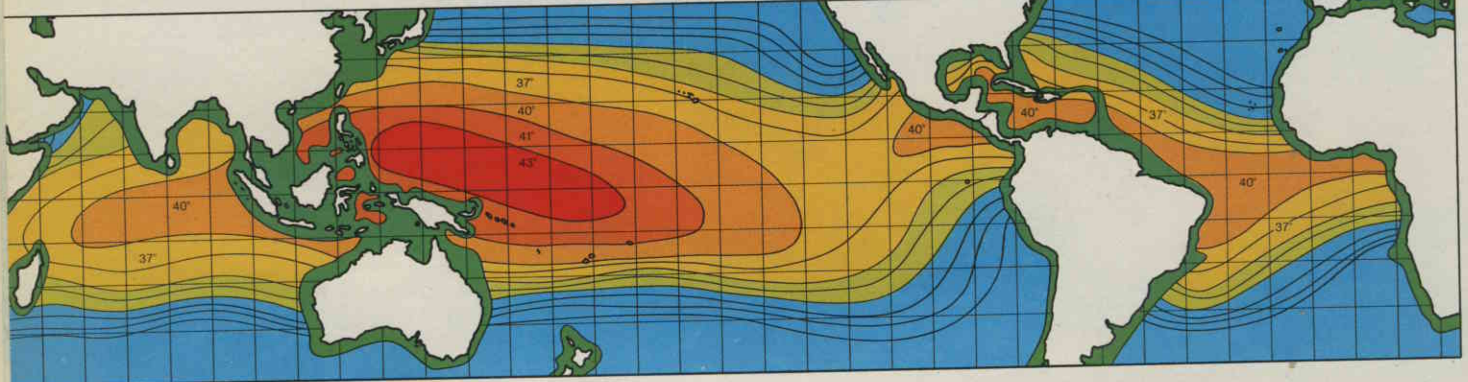
Still, designing and building full-scale OTEC plants is a formidable task. A 300-megawatt OTEC plant (which could provide electricity for 300,000 households) would need pumps that could move more water than flows in the Nile. The plant might look like a floating concrete platform the length of three football fields or like the giant "bobbin" shown on page 37. Either design would require a cold-water pipe some 3,000 feet long, five times the height of the Washington Monument, and big enough to enclose it.

Building the plants will be expensive. At today's prices, a pilot plant of 40 megawatts could cost $250 million. But according to engineer Frederick Naef, of Lockheed (which wants to build OTEC plants around the world), the fact that the fuel is free will eventually make up for the high building costs. "By the 1990s," he says, "OTEC will have become inexpensive enough for islands like Hawaii and Puerto Rico, and perhaps for the mainland. It will become even cheaper as petroleum prices go up, and as we gain experience in building the plants."

Other obstacles remain. Biochemist David White, of Florida State University in Tallahassee, predicts that one of the biggest will probably be "biofouling"—the growth of small marine organisms on underwater structures. Most marine animals live near the warm surface of the ocean. When they die, their carcasses sink to the depths, where they form a nutritious layer of protein. When OTEC pipes bring this cold, nutrient-filled water up to the plant and later discharge it near the surface, organisms around the plant will thrive on the food and begin to multiply rapidly. Drawn in with the warm surface water, they will coat heat exchangers and pipes and clog the pumps.

White suggests several ways of dealing with biofouling. Ultrasonic vibration could dislodge the organisms. Scrubbing with chlorine could dissolve the microbe plaque. And the pumps, pipes, and tubing can be designed without corners and crevices where organisms can lodge. "In the past year we've learned a lot about biofouling," White adds. "I can't say it will be easy, but we're working under the assumption that this problem can be licked."

MAP BY WILLIAM REDUTO



At the best sites for OTEC plants, colored red on the map above, the surface water is 43 degrees Fahrenheit warmer than the water 3,000 feet below. But the plants could also use cooler waters, shown in shades of orange, where the temperature difference is usually at least 37 degrees

Although the marine environment may damage OTEC power plants, the reverse is not as likely to occur. "OTEC's environmental problems are nowhere near as severe as those caused by coal and synthetic fuel or radioactive waste," says Lloyd Lewis, of DOE. In fact, the problems are so undramatic that "the environmental groups hardly come to our meetings." Nevertheless, there are a few concerns. Great care must be taken with any chlorine used in cleaning, so as not to harm marine life in the surrounding waters. OTEC plants will have to be far enough apart so that the water they discharge will not lower the temperature of the ocean enough to disturb the ecological balance.

In short, the obstacles to deriving energy from the sea seem surmountable. "So far there are no show stoppers," says DOE's Robert Cohen. "It's sort of like having an Erector set," says the U.N.'s Neuman. "We have all the pieces and we have a picture of what the thing should look like. It's just a question of putting it together." ■