Plumbing the oceans could bring limitless clean energy

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FOR a company whose business is rocket science Lockheed Martin has been paying unusual attention to plumbing of late. The aerospace giant has kept its engineers occupied for the past 12 months poring over designs for what amounts to a very long fibreglass pipe.

It is, of course, no ordinary pipe but an integral part of the technology behind Ocean Thermal Energy Conversion (OTEC), a clean, renewable energy source that has the potential to free many economies from their dependence on oil.

"This has the potential to become the biggest source of renewable energy in the world," says Robert Cohen, who headed the US federal ocean thermal energy programme in the early 1970s.

Exploiting the difference in temperature between seawater near the surface and deep down could supply the world with cheap green power (Image: Matthew Oldfield/SPL)

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As the price of fossil fuels soars, private companies from Hawaii to Japan are racing to build commercial OTEC plants. The trick is to exploit the difference in temperature between seawater near the surface and deep down (see diagram).

First, warm surface water heats a fluid with a low boiling point, such as ammonia or a mixture of ammonia and water. When this "working fluid" boils, the resulting gas creates enough pressure to drive a turbine that generates power. The gas is then cooled by passing it through cold water pumped up from the ocean depths via massive fibreglass tubes, perhaps 1000 metres long and 27 metres in diameter, that suck up cold water at a rate of 1000 tonnes per second. While the gas condenses back into a liquid that can be used again, the water is returned to the deep ocean. "It's just like a conventional power plant where you burn a fuel like coal to create steam," says Cohen.

The idea of tapping the ocean's different thermal layers to generate electricity was first proposed in 1881 by French physicist Jacques d'Arsonval but didn't receive much attention until the world oil crises of the 1970s. In 1979, a US government-backed partnership that included Lockheed Martin, lowered a cold water pipe from a barge off Hawaii that was part of an OTEC system generating 50 kilowatts of electricity. Two years later, a Japanese group built a pilot plant off the South Pacific island of Nauru capable of generating 120 kilowatts.

In the first flush of success, the US Department of Energy began planning a 40 megawatt test plant off Hawaii. Then in 1981, the funding for ocean thermal technologies began to dwindle. It dried up altogether in 1995 when the price of oil began to drop, eventually falling below $20 a barrel.

Now rising fuel costs have revived interest in this neglected technology. In September, the Department of Energy awarded its first grant for ocean thermal energy in more than a decade, giving Lockheed Martin $600,000 to develop a new generation of cold water pipes.

Cohen believes this could eventually lead to 500 MW OTEC plants on floating offshore platforms sending electricity to onshore grids via submarine cables, and factory ships "grazing" the open ocean for power.

Lockheed's first goal is to get a test facility up and running. The company has got together with Makai Ocean Engineering of Waimanalo, Hawaii, to build a 10 to 20 MW plant, most likely off Hawaii, that it hopes to have up and running in the next four to six years. The plant - including a 1000-metre pipe some 4 metres in diameter - would feed electricity to the island's energy grid via submarine cables.

While Lockheed gears up for its test facility, a plant for the US military could come online even sooner. OCEES International, based in Honolulu, is finishing designs for an ocean thermal facility to be built off the island of Diego Garcia in the Indian Ocean, which is home to a major US military base.

The plant would provide 8 MW of electricity and would also power the desalination of 1.25 million gallons of seawater per day. OCEES says it could be up and running by the end of 2011.

At the moment Diego Garcia is powered entirely by diesel fuel, and base commanders see ocean thermal as a means to energy independence. "It's a strategic military installation in the middle of the Indian Ocean," says Harry Jackson of OCEES. "They don't want to rely on others to provide their power."

"I think OTEC has the potential to develop sufficient power output much quicker than wave buoys or tidal power would," says Bill Tayler, director of the US navy's Shore Energy Office. "It would take a lot of buoys to produce 8 to 10 MW of power. We're looking at them all but have our hopes on OTEC."

Still, both teams will have to work out issues such as how to connect the floating, bobbing platforms to fixed submarine power lines. Heat exchangers will have to be designed in a way that prevents excessive buildup of algae, barnacles and other marine organisms that could clog the system.

If these test plants are a success, larger, commercial-scale plants could transform the energy equation on Hawaii, where nearly 77 per cent of electricity is generated by burning oil. "It will be the major energy game changer for our state and elsewhere in the world if we can get OTEC working well at the 100 MW level or larger," says Lockheed collaborator Reb Bellinger of Makai Ocean Engineering.

But scaling up won't be easy. "A 100 MW plant might have a pipe 30 feet in diameter suspended 3000 feet. That's not a small challenge. You've got this huge structure vertically suspended. You've got a lot of stresses and strains from current, from the movement of platform on the surface - how you are going to anchor it and install it?" asks Bellinger.

Smaller designs have already run into trouble. In 2003, Indian engineers building a 1 MW ocean thermal plant attempted to lower an 800-metre cold water pipe into the ocean from a barge in the Bay of Bengal only to lose the pipe in 1100 metres of water. A new pipe met the same fate the following year. "Both times there were some winch problems and it fell to the bottom of the sea," says Subramanian Kathiroli, director of India's National Institute of Ocean Technology. "I don't think we will ever be able to go beyond 5 to 10 MW with present knowledge," he says.

Yet the technology will have to be scaled up if OTEC is ever to make a significant impact on the green power market. Hans Krock, who has worked on OTEC designs for the University of Hawaii, the US Department of Energy and others since 1980, says he's tired of testing. "Pilot tests have been done," Krock says. "It's not a matter of design, it's a matter of getting the economics right."

Krock, who founded OCEES in 1988, recently left to start Energy Harvesting Systems, a firm with

ambitious plans to build a 100 MW OTEC plant off the coast of Indonesia. The electricity it generates will be used to produce hydrogen, a green fuel that could be used to power zero-emission vehicles. Krock says he has funding for the $800 million plant and it could be up and running within two years, once building contracts are finalised.

For Cohen, who has also waited decades for ocean thermal to come into its own, such a large plant seems overambitious, especially as it is coupled with the production of hydrogen, whose distribution structure is still largely undeveloped.

"Scaling up so quickly could be risky," warns Cohen. "I'd like to see us move fast on ocean thermal but I think we have to be careful."

Lake ontario helps toronto chill out

As governments and private companies around the world look to capitalise on ocean thermal energy, an offshoot of the technology is already up and running. Instead of trying to harness cold, deep water for electricity production, the city of Toronto in Canada uses water from the bottom of Lake Ontario to cool its buildings. Makai Ocean Engineering of Waimanalo, Hawaii, recently helped construct the city's cold-water air conditioning system that will save 60 megawatts of electricity when it is fully connected to buildings in the city's centre. The system works by pumping water at a temperature of 4 °C from a depth of 80 metres and then sending it to buildings within the city via three pipes, each5 kilometres long. The cold water is then used to cool air.Makai is working on a similar cold-water air conditioning system for Honolulu in Hawaii. "Ocean thermal energy is the big prize, but cold-water air conditioning can play a major role in cutting energy needs, and it can do it today," says Reb Bellinger of Makai.

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