A long-dismissed form of clean energy is resurgent, thanks to some unexpected allies.
Helen Knight reports

IF ANY energy source is worthy of the name "steampunk", it is surely ocean thermal energy conversion. Victorian-era science fiction? Check: Jules Verne mused about its potential in *Twenty Thousand Leagues Under the Sea* in 1870. Mechanical, vaguely 19th-century technology? Check. Compelling candidate for renewable energy in a post-apocalyptic future? Tick that box as well.

Claims for it have certainly been grandiose. In theory, ocean thermal energy conversion (OTEC) could provide 4000 times the world's energy needs in any given year, with neither pollution nor greenhouse gases to show for it. In the real world, however,

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it has long been written off as impractical.

This year, a surprising number of projects are getting under way around the world, helmed not by quixotic visionaries but by hard-nosed pragmatists such as those at aerospace giant Lockheed Martin. So what's changed?

It's possible that Verne dreamed up the idea for OTEC to help out Captain Nemo, the protagonist of Verne's deep-sea yarn who needed electricity to power his submarine, the Nautilus – it is the first written mention of the idea. "By establishing a circuit between two wires plunged to different depths, [it should be possible] to obtain electricity by the difference of temperature to which they would have been exposed," Nemo told his shipmate. Eleven years after the book was published, French physicist Jacques-Arsène d'Arsonval proposed the first practical design for a power plant that does exactly that. Instead of using wires, he used pipes to exploit the temperature difference between the cold deep ocean and the warm surface waters to generate steam energy.

The idea is brilliant. The ocean is a massive and constantly replenished storage medium for solar energy. Most of that heat is stored in the top 100 metres of the ocean, while the water 1000 metres below – fed by the polar regions – remains at a fairly constant 4 to 5 °C.

To make energy from that heat difference, modern-day systems pump warm surface water past pipes containing a liquid with a low boiling point, such as ammonia. The ammonia boils and the steam is used to power a turbine, generating electricity. Cold deep-ocean water is then piped through the steam, causing the ammonia to condense back into a liquid, ready to begin the cycle again (see diagram, page 51). Steam-powered turbines drive nearly every coal and nuclear power plant in the world, but their steam is produced by burning polluting coal or generating long-lived nuclear waste. OTEC, by contrast, provides steam in a clean and theoretically limitless way.

Electric ocean

That's in an ideal world. In reality, what the ocean's thermal gradient gives, the equipment takes away. The main problem is accessing the cold deep water: pumping the vast amounts of water needed requires 1000-metre-long pipes that are wide enough and strong enough to handle several cubic metres of seawater per second for every megawatt of electricity produced. Tally all the inefficiencies in the process and the theoretical efficiency of an OTEC plant drops to a dismal 4 to 6 per cent.

Thanks to this and other factors, the process needs a temperature difference of at least 20 °C between the surface and deep water to work. Such conditions exist in a relatively narrow band around Earth's equator that includes the tropics and subtropics (see map, page 50).

Despite these constraints, the 20th century was filled with fitful efforts to make OTEC work. The most ambitious of these, in the 1970s, was sparked by an oil crisis, after which the US president Jimmy Carter signed into law the production of 10,000 megawatts of electricity using the technology by 1999. However, the price of oil then fell again, and alternatives to petroleum sank once more to the bottom of the to-do list.

So when Lockheed Martin last year announced that it would begin construction on a 10-megawatt plant off the coast of southern China, the news was met with a marked lack of interest. We had been here before.

"Jules Verne mused about getting energy from stored heat in the ocean in 1870"

A closer look, however, reveals that the project may signal a sea change for OTEC. The time may finally have come for this 19th-century technology to become part of the 21st century's renewable energy mix, thanks to a strange partnership of other renewables, the oil industry – and perhaps even climate change.

Many calculations are changing. OTEC's efficiency may be low, but since it uses seawater, which is abundant and free, it still makes economic sense if done on a large-enough scale. Oil prices are unstable and climate change is becoming an increasingly urgent driver of alternative energy sources. The shortcomings of intermittent renewables such as wind and solar energy, which only produce electricity when the sun is shining or the wind is blowing, are still keeping these on the margins. By contrast, OTEC plants can operate 24 hours a day, says Ted Johnson of Ocean Thermal Energy Corporation, which plans to commercialise the technology. Round-the-clock power means an OTEC plant could simply be plugged directly into a municipal grid to replace fossil fuel power plants, without the adjustments and balances necessary to integrate unpredictable solar and wind power.

But what use is that power if the equipment needed to harness it costs more than the electricity it provides? Here, too, advances have been made. Lockheed Martin borrowed techniques from bridge and wind-turbine manufacturing – both of which use advanced fibreglass and resin composites to make their ultra-light, ultra-strong materials – to design a cheap pipe that is strong and flexible enough to withstand the stresses and strains of ›