Power of the future

New technologies are emerging that will transform the way we make and consume energy

The future is now: Toyota's Mirai hydrogen fuel cell vehicle

FROM space-based solar power and fusion electricity to hydrogen vehicles, there is a dazzling array of technologies that could offer the world clean, sustainable sources of energy.

It may have been the stuff of science fiction for decades, but space-based solar power could become a reality. That's if a push by the Japanese to develop a 1-gigawatt (GW) commercial system – about the same output as a typical nuclear power plant – makes headway. The US, China and India are also studying the technology's potential.

With no atmosphere, cloudy weather or even night, space is a perfect place to build solar power stations to harvest uninterrupted sunshine. On top of this, there is 10 times the amount of solar energy available in space as on earth, according to the Japan Aerospace Exploration Agency (Jaxa).

Studies from Nasa and the US department of energy in the late 1970s show there is nothing wrong with the physics, but the real question is economics. The price tag for the first space-based solar power station, which would beam power to earth via laser or microwaves, could be as high as $20 billion by some estimates.

No doubt it would be difficult and expensive, but the payoff would be immense, and not just in economic terms, says Susumu Sasaki, a professor emeritus at Jaxa. Sasaki has spent much of his 41-year career researching space-based solar power systems.

The best-case scenario for this technology, he wrote in an article published by the Institute of Electrical and Electronics Engineers (IEEE) called *It's always sunny in space**, is a global "paradigm shift" in which nations stop competing for energy resources on the ground, and instead work together to build grand orbital power stations that beam clean energy down to earth.

Still according to Paul Jaffe, spacecraft engineer at the US Naval Research Laboratory "without the similar research base that we have in the US for, say, fusion energy, it's unlikely to make meaningful progress.

"If the Japanese make progress in the next five years, people might start to notice and say why aren't we doing that here," he told CNN.

Ultimately, Jaffe said, space-based solar energy is like most novel ideas. "It's hard to tell if it is nuts until you've actually tried."

Cracking the fusion conundrum

Coming back down to earth, the potential for fusion electricity, which, if it proves viable, could yield limitless clean energy, would be enormous.

Unlike nuclear power, fusion uses low atomic weight raw materials that are relatively cheap and abundant. It has minimal waste because fusion reaction only creates helium, like that found in a party balloon, and a neutron, as well as massive amounts of energy.

Last December, US aerospace and defence giant Lockheed Martin announced it had figured out a way to build compact fusion within a decade.

Dubbed the compact fusion reactor, the device is conceptually safer, cleaner and more powerful than much larger, nuclear systems presently operating that rely on fission, the process of splitting atoms to release energy, said the company.

Crucially, by being compact, Lockheed believes its

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scalable concept will also be practical enough for applications ranging from interplanetary spacecraft and commercial ships to city power stations. It could even revive the concept of large, nuclear-powered aircraft that virtually never require refueling – ideas of the kind that were largely abandoned more than 50 years ago because of the dangers and complexities involved with nuclear fission reactors.

Howard Hornfeld of Swiss-based Fusion Advocates says the beauty of fusion electricity, if successful, is that it could provide base-load quantities of electricity, which no other non-fossil fuel system can. "It has the potential to push coal out of the energy mix," Hornfeld, who is preparing to build a $7 billion pilot plant backed by equity crowd sourcing from a Geneva-based financial institution, told *Petroleum Economist*.

For decades, fusion electricity was the plaything of academics and was long considered the fuel of the future. "But it has to be done now. The future is not what it used to be. The future is now," said Hornfeld, whose enthusiasm for fusion is infectious. It could also be the solution for the billions of new consumers that will need access to electricity supplies in the next 30 years.

More so, 100 kg of fusion fuel will produce the heat equivalent of 1 million tonnes of coal. There are no toxic materials, no possibility of explosions or meltdowns, and no greenhouse gas emissions, he added.

Low key approach

An advanced fusion reactor, the International Thermonuclear Experimental Reactor (Iter), being built in Cadarache, France, is expected to eventually generate 500 megawatts – enough to power 250,000 US homes. However, the $16 billion scheme, a sum three times the initial estimate, is only aiming to start piloting fusion power in 2028.

But Wal van Lierop, co-founder of Vancouver-based Chrysalix Energy Venture Capital, believes one of at least half a dozen smaller commercial fusion projects, which are much further ahead, will make a breakthrough in the next two to three years.

He reckons the international community should consider spreading part of the budget from Iter around, rather than concentrating most of its efforts in the south of France. This would open up more options, he says.

Very often these large government-backed projects, like Iter, don't succeed. It was the same a century ago when government-backed institutions were seeking a big break in aviation. In the end, the Wright brothers succeeded, making the first flight in an aeroplane built in their garage. "I think it will be the same with fusion," Lierop, who specialises in clean-tech energy start-ups, told *Petroleum Economist*.

Low-carbon nuclear power could make a comeback in the form of micro-nuclear reactors. They cost a fraction of full-scale nuclear plants and are much safer and easier to operate.

Micro-reactors would have a capacity of 5-10 MW – enough to serve 2,500-5,000 homes in a US city – and cost less than $100 million, compared with major projects that come in at over 1,000 MW and cost billions of dollars.

"There is a challenge for the nuclear industry to see whether we can come up with a plug-and-play device that is foolproof, inherently safe, and not too complex to be positioned in countries that have an increasing demand for electricity," Helmut Engelbrecht, chief executive of nuclear company Urenco, told Reuters.

Smaller reactors, with capacities of between 200 and 400 MW, are already being developed in the US and Russia, but these would be too complex for many developing nations.

Micro-reactors could also find demand in industrialised countries where companies are shy of large capital commitments.

Urenco, the second biggest producer of nuclear fuel, commissioned a study at universities in the UK and the Netherlands, that resulted in the "U-Battery" micro-reactor design based on high temperature reactor technology already available in Europe. It is designed to be plugged in and switched on and off, like a battery.

The key advantages of the U-Battery micro-reactor are that it would be self-contained, need minimal human intervention and designed not to melt down in case of a sudden shutdown.

"This thing is designed so that if something breaks, you don't need to do anything (in terms of emergency response). It won't work again until somebody comes and fixes it. It's like a windmill," said Engelbrecht, who is seeking support to build a prototype and remains convinced micro-reactors will be developed within 20 years.

"You see that a nuclear device is driving the Mars robot, that a nuclear battery was sitting on the moon and operating for 40 years," said Engelbrecht.

"Why the hell can't we do it small on earth? This kind of discussion needs to be had and needs some political support."

The nuclear industry, he insists, can be small. With its low-carbon credentials and ability to provide base load power, it makes an ideal provider of electricity to nations with less infrastructure.

Meanwhile, wind farms of the future could be under water. The UK may seem like an unlikely place for a renewable revolution, as it doesn't get much sunshine nor does it have plenty of space for wind farms. But given it does have thousands of kilometres of coastline with powerful tides that ebb and flow, it could become a major test bed for tidal power, if pilot projects succeed.

Seawater is 832 times denser than air, which means turbines powered by rising and falling tides can be smaller, yet still produce a similar amount of energy to a wind turbine on land. The force of these tides also means the turbines can be placed closer together, using less space on the seabed than an equivalent wind farm on land.

Marine turbines also have the great advantage of tapping an energy source that does not rely on the weather. Other renewables such as wind, wave, solar and even hydroelectricity depend in large part on seasons and climate. Tidal turbines are guaranteed two regular tide changes a day.

The energy source has the potential to produce 1.2 GW – roughly the equivalent of two average-sized nuclear power plants – from leases around Scotland.

The industrial internet, a term coined by General Electric (GE), is not an energy source in itself, but harnessing its

power to drive dramatic improvements in resource productivity has the potential to drastically cut energy demand growth over the coming decades.

The industrial internet is essentially the integration of complex physical machinery with networked sensors and software. It draws together fields such as machine learning, big data, the Internet of things and machine-to-machine communication to ingest data from machines, analyse it (often in real time), and use it to adjust operations.

And the industrial internet highlights the role efficiency, dubbed by the International Energy Agency as the world's most important fuel – a "hidden fuel yet hiding in plain sight" – can play in solving the world's energy and climate conundrum.

Over the past decade, advances in hardware efficiency and energy productivity have improved at a rate of 1% per year. At this rate, global industrial energy consumption – making up roughly half of all final energy use – will expand 54% from 270 quadrillion British thermal units (Btu) in 2013 to 416 quadrillion Btu in 2030. But if energy productivity were doubled to 2% per year, estimates GE, global industrial energy consumption would be held at 346 quadrillion Btu in 2030. Avoiding those 70 quadrillion Btu equates to saving more than a third of the world's yearly oil consumption.

Integration

Companies like GE are already working on productivity solutions by integrating efficient hardware with internet-enabled software. Since 2012, GE has released 40 industrial-internet apps, including an aviation-navigation service, which analyses flight data to design more efficient flight routes and cut fuel burn. Brazilian airline Gol Linhas Aereas Inteligentes saved $100 million over five years using the flight efficiency app.

GE's PowerUp product, which essentially adds a digital layer on top of a wind farm, analyses tens of thousands of data points each second to fine-tune performance and boost output. Since European utility E.ON applied PowerUp to its 469 wind turbines, power output jumped 4.1%, the equivalent of adding 19 turbines to its fleet.

Software can also enable better grid integration and management of solar assets, as well as improvements in oil and gas production.

Last year, German carmaker BMW began selling its sleek, new electric sports car, the i3, which can go 80 to 100 miles on a single three-hour charge. Priced at around $41,000 in the US, its sales are outpacing those of rival Tesla, which costs at least twice as much.

Meanwhile, French-based Airbus has started test flights of a prototype battery-powered aircraft. It aims to begin selling the two-seater in late 2017 for pilot training and is eyeing the eventual debut of a plane with space for four passengers.

In Abu Dhabi a solar-powered plane, Solar Impulse 2, is preparing to start circumnavigating the world for the first time ever with plans to take off by March. It will be the only aeroplane of perpetual endurance, able to fly day and night on solar power without a drop of fuel.

And the once-distant promise of clean, affordable hydrogen-powered cars is beginning to take shape.

The cost of making the critical components of hydrogen vehicles, which emit only water and heat, has fallen 95% since 2008, when a prototype fuel-cell system cost $1 million to make, said Toyota.

The Japanese automaker's first mass-produced hydrogen car – known as the Mirai or future in Japanese – will sell for around $57,000 in the US before incentives when it debuts this year. By 2020, the cost of fuel-cell vehicles will be closer to that of a plug-in hybrid vehicle and cheaper than an electric car, predicts Toyota.

Hydrogen vehicles could play an important role, along with electric vehicles, in lowering emissions of carbon dioxide and other pollutants responsible for climate change.

Instead of an engine that burns oil, cars like Toyota's Mirai have fuel cells that combine hydrogen with oxygen from the air to generate electricity that powers the vehicle's motor.

Most hydrogen is made from natural gas in a process that generates carbon dioxide. But it emits less than burning fossil fuels. And scientists say hydrogen could be created in a cleaner process by using solar or wind or other renewable sources, such as sewage or animal waste.

So-called sustainable or low-carbon liquid fuels will be crucial to the low-carbon transition, considering combustion engines will remain part of the technological landscape for many years.

Joule, a renewable energy firm, is working on industrialising its reverse combustion technique to make liquid-ready fuels, such as diesel, ethane and gasoline directly from sunshine, carbon dioxide and saline water via photosynthesis. Its industrialised method produces usable fuels as a direct product, as opposed to the natural method that makes plants (biomass) grow.

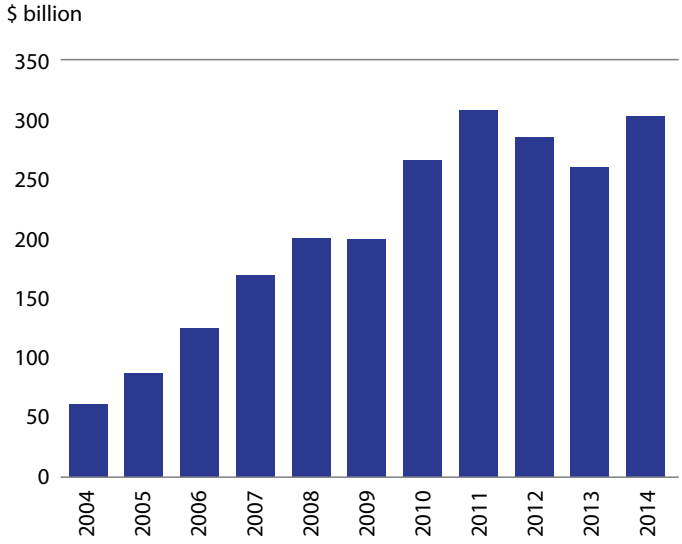
To boot, it helps cut emissions by sucking in carbon dioxide from industrial emitters.

In partnership with German carmaker Audi, Joule is getting ready to commercialise its technology, which it says is already competitive with fossil fuels at a cost of $50-80 per barrel.

Even the shipping industry, which has been hit hard by rising oil prices in recent years, and is one of the heaviest carbon emitters in the transport sector, is considering low-carbon liquid fuels, such as those pioneered by Joule and others.

It's hardly surprising then, given the increasingly unpredictable and volatile price swings in conventional energy markets that interest and investment in new technologies is accelerating. And there is little doubt the world will need many transformative technologies to deal with climate change. **DE** ●

Figure 1: New investment in clean energy



Source: Bloomberg, New Energy Finance