# Graphene proves its mettle in the energy industry


**It sounds like the stuff of science fiction. At one atom thick, graphene is the first two-dimensional material ever discovered – and it appears to have significant real-world applications in batteries and solar cells. *Sarah Gibbons* reports.**

With its thin sheet of atoms arranged in a honeycomb shape, the wonder material graphene is said to be stronger than diamond while still being flexible. Given that it also offers excellent thermal and electronic conductive properties, it's little surprise that materials scientists are exploring its applications in the energy sector. Analysts predict that almost one third of global graphene could be deployed in the service of energy storage within the next decade. Significant growth is forecast in the electric vehicle segment in particular, as graphene can be used as an electrode material in car batteries.

An April report from Allied Market Research predicted that the graphene-based battery industry would be worth almost $400mn by 2027 – up from $49mn last year. So-called 'nano platelets' of graphene have enabled the dramatic improvement of both portable electronic devices and EVs by providing a better means to store electricity. Plug-in vehicles therefore boast extended ranges and faster charging times, ultimately boosting sales and increasing consumer confidence.

According to Allied Market Research, graphene also has the potential to help realise supercapacitors with the energy density of batteries that can be recharged in seconds.

Lithium-ion batteries are notably flawed in that they can expand in volume leading to a loss of electrical connection between electrode particles and decomposition of the electrolyte. The end result is poor cycle life. Graphene helps by encasing the silicon, protecting against electrolyte degradation, and providing a network to help maintain electrical conductivity.

## Powering batteries

Jesus de la Fuente, CEO of Boston-based graphene producer Graphenea, told *Energy World* that several companies are working on novel graphene battery prototypes: 'These batteries could power electric vehicles, computers and phones requiring high energy density. With graphene, a very small amount has a huge impact.'

Graphene was first discovered in a lab in 2004
*Photo: Graphenea*

Graphene could also help with the commercialisation of new battery formulations. Sulphur-based batteries, for instance, have recyclability issues which could be resolved by adding graphene-based materials to improve the formulation of the battery and extend its life. 'It's very suitable for the circular economy,' de la Fuente adds. 'In the future, you could use graphene waste to make new graphene materials.'

The role played by graphene in super-capacitors is also important, helping reduce battery drainage during high charge surges, such as EV acceleration. Simon Savage, Managing Director at Ionic Industries, based in Melbourne, Australia, said activated carbon can be replaced in supercapacitors with graphene oxide to improve performance at a comparable cost – cheaper than pure graphene. 'The biggest improvement is in power density – a 20 to 50% increase,' he told *Energy World*, predicting that over the next five years there will be a rapid increase in the use of graphene supercapacitors to improve battery life.

'Draining and charging a battery takes its toll on the chemical reactions in a battery,' Savage explained. 'Supercapacitors store power in the electrodes so there is no chemical reaction. With EVs using both supercapacitors and batteries, when you accelerate it rapidly drains supercapacitors, which is fine, and then batteries will be used to slowly charge up the supercapacitor for the next charge. As you brake, it's the capacitor that trickle charges the battery, so there are significant performance and maintenance advantages using graphene.'

According to Savage, Internet of Things (IoT) devices increasingly rely on supercapacitors because transmitting data takes a lot of short bursts of power. 'Encrypted data needs even more power,' he said. 'Secure and long-range Wi-Fi need a lot of power – they're thirsty.' He believes that supercapacitors supporting batteries in a 'complete, complementary system' will be the hybrid system of the future.

Meanwhile Tallinn-based Skeleton Technologies uses curved graphene at the heart of its 'ultracapacitor' range. Arnaud

Castaignet, the firm's Head of Communications and Policy, told *Energy World* that the material acts like a piece of paper crumpled up to increase its surface area. 'It features finely-engineered, consistent pore size and a very large accessible surface area, which is a perfect match for the electrolyte ions,' a company note said, delivering twice as much energy storage capacity and five times higher power performance compared to other ultracapacitors.

The design allows for more than a million charge cycles or a 15-year lifespan, claims the company. 'Graphene has a high surface area and a higher surface area means you have better electrostatic charge storage,' Castaignet explained.

Skeleton's products are used across various industries, including major German car manufacturers and European train and tram systems. Working with one of America's leading medical suppliers, its ultracapacitors also power MRI scanners in hospitals to shave peaks of power and ensure consistent power density with the same energy standard.

The company is working alongside NanoMalaysia, a Malaysian outfit specialising in nanotechnology commercialisation and industrialisation, to develop the first fuel cell-powered EV for use in the motorsports industry. The NanoMalaysia-HyPER is set to be completed later this year.

It will use lithium-ion batteries, a graphene-based ultracapacitor and a fuel cell stack with on-board hydrogen generation, said a report from graphene information platform, Graphene Info. Using Skeleton's ultracapacitors allows for higher power density, and 'lightning-fast charging compared to conventional lithium-ion based vehicles', it said.

### Novelty to reality

Meanwhile, researchers at Rice University in Texas have turned laser-induced graphene (LIG) – a graphene foam produced when chemicals are heated on the surface of a polymer or other material with a laser – into small devices that generate electricity through movement such as walking.

Placing LIG composites in contact with other surfaces produces static electricity that can be used to power devices, Rice Professor James Tour told *Energy World*. 'This relies on the triboelectric effect, by which materials gather a charge through contact. When they are put together and then pulled apart, surface charges build up that can be channelled toward power generation.'

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A piece of LIG embedded within a flip-flop enabled a wearer to generate energy with every step, as the graphene composite's repeated contact with skin produced a current to charge a small capacitor. 'This could recharge small devices with the excess energy of heel strikes during walking, or swinging arm movements against the torso,' Tour said.

'The nanogenerator embedded within a flip-flop was able to store 0.22 millijoules of electrical energy on a capacitor after a 1-km walk,' said Rice postdoctoral researcher Michael Stanford. 'This rate of energy storage is enough to power wearable sensors and electronics with human movement.'

Further research is underway at Linköping University, in Sweden, exploring how combining energy from the sun and graphene applied to the surface of cubic silicon carbide can convert water and carbon dioxide to renewable energy, with graphene acting as a superconductor. 'We have now shown that it is possible to grow uniform graphene that consists of up to four layers in a controlled manner,' said Jianwu Sun of Linköping's Department of Physics, Chemistry and Biology.

In an article in the journal *Nano Letters*, Sun said multilayer graphene has 'extremely promising electrical properties that enable the material to be used as a superconductor, a material that conducts electrical current with zero electrical resistance.'

De la Fuente told *Energy World* that graphene can be added to solar cells to increase efficiency and could be much cheaper and easier to produce than silicon-based cells. 'It's a road the industry is exploring for use on buildings and large structures,' he said. 'It could be put on a flexible substrate making it easier to adapt for buildings.'

Graphene could help with the creation of new battery formulations
*Photo: Graphenea*

### Wi-Fi signals

Finally, scientists are looking at how graphene can use Wi-Fi signals as a power source. Devices that send out a Wi-Fi signal emit high frequency terahertz waves. Researchers at MIT say that, if harnessed, they could generate enough energy to power a small sensor, mobile phone or laptop. Graphene combined with boron nitride could be a material that absorbs these signals and turns then into power, said a note: 'Any incoming terahertz waves should 'shuttle' graphene's electrons, like so many tiny air traffic controllers, to flow through the material in a single direction, as a direct current.'

The researchers are working on a physical device that would generate power using this technology. 'We are surrounded by electromagnetic waves in the terahertz range,' said lead author Hiroki Isobe, a postdoctoral student at MIT's Materials Research Laboratory. 'If we can convert that energy into an energy source we can use for daily life, that would help to address the energy challenges we are facing right now.'

Given that it's a microscopically small material, graphene has the potential to have an outsized impact on the energy transition. Less than 20 years ago, scientists were unsure if it was even possible to slice graphite down to an atom-thin sheet. Now it looks as if graphene will become an integral building block of the energy transition. ●