Disruptive technologies spark energy revolution

Innovation is happening more rapidly than expected – and it will vastly improve energy efficiency in the next few years

THE world is approaching a tipping point in the development of technologies that could generate leaps in energy productivity on a scale not seen since the Industrial Revolution, McKinsey, a consultancy, predicts.

Many of the technologies that could prove disruptive in the very near future are familiar – including unconventional gas, solar power, lighting from light-emitting diodes (LEDs) and electric vehicles. Other less well-known emerging technologies that could affect energy productivity shortly after 2020 include grid-scale storage, digital power conversion, compressor-less air-conditioning and electrochromic windows (known as smart glass), clean coal, as well as biofuels and electrofuels.

Yet the mainstream view is that most of these technologies will not reach scale any time soon.

"The view rests on a misunderstanding of the nature of technological change," writes Matt Rogers, an energy specialist at McKinsey, in his report *Energy = innovation: 10 disruptive technologies*.

The pace of energy innovation means that some technologies will hit commercial viability much faster than most observers expect, Rogers claims.

Superior technology

As developing technologies are marginalised, they may remain uneconomical for a long period of time, even as leading innovators approach breakthroughs. This makes it all too easy for the establishment to dismiss them.

But once they reach that sweet spot – where technology delivers cost and performance that is materially superior to the status quo – they could well be adopted extensively.

"Such technologies can render existing ways of doing business untenable in less than a decade – the blink of an eye, in economic terms," says Rogers.

In a speech in Abu Dhabi earlier this year, US energy secretary Ernest Moniz highlighted the efficiency gains expected from technical innovations in wind and solar technology, LEDs for lighting, as well as advanced batteries for transport, among others.

Developing the technology to lower costs is essential in moving to scale, Moniz told his audience, adding that "sometimes we lose perspective on what has happened".

In just five years, the US, the world's second-largest energy consumer, has seen wind power generation double its deployment, making up half of all new capacity, with the remainder largely coming from gas. The cost of installed solar has fallen from $6 per kilowatt hour to $1/kWh, while the cost of LED lights is projected to hit $2 per thousand lumens by 2015, or an 85% drop from 2010. The cost of electric vehicle batteries has sunk 60% to around $500/kWh.

This does not necessarily mean that all of the technologies are right in the middle of the sweet spot for costs to scale, but their role is growing dramatically and they are preparing to be competitive, said Moniz.

Innovations in technology can transform industries and put societies on new paths to growth. Rogers points to the rise of wireless technology, which fundamentally altered telecommunications, adding that portable audio devices – starting with the Sony Walkman and continuing with the iPod – have radically transformed the way music is packaged and consumed.

Energy markets are on the verge of a similarly dramatic transformation, according to McKinsey. With prices of oil and other commodities hitting historic highs recently, energy technology innovators are taking advantage of developments in software and consumer electronics, semiconductors, even pharmaceuticals, to vastly improve how the world produces and consumes energy.

In fact, these emerging technologies, combined with potentially revolutionary distribution structures, could completely transform the energy system. A decentralised power system, for example, is possible. Decentralised energy, as the name suggests, is produced close to where it will be used, rather than at a large plant elsewhere and sent through the national grid. Of course, the utility industry is fighting hard to avoid that outcome, says Steve Sawyer, secretary general of the global wind energy council.

A couple of years ago, Jim Rogers, then chief executive of US utility Duke Energy, told an energy conference that "one of the biggest risks I see for companies in vertically integrated markets … is what I call disintermediation and what it really means is a Google comes in with an idea about improving the energy use in the home and the next thing you know demand drops 30%."

Google's spectacular acquisition of Nest – a high-technology home automation company – for $3.3 billion earlier this year highlights that risk. Nest, founded by former Apple engineers, is best known for its smart thermostat – it learns its owner's behavior to better control heating and cooling more efficiently. It can be managed remotely by a mobile device, as well as be tied into utilities' peak-load demand response programmes in the US to save consumers money. The next step, Nest co-founder (and Apple iPod designer) Tony Fadell told *Fast Company*, will be monthly budgeting, where consumers tell Nest how much they want to spend on energy each month, and the thermostat does the rest. Many see the move as Google's first step towards the connected home. In future, consumers will likely to be able to communicate with their refrigerator to gauge how much milk they have left or get statistics on how much energy their appliances are using each month.

But the process of disintermediation – the elimination of an intermediary in a transaction between two parties – is a threat to the established energy business. It happened in banking about 25 years ago when people moved their deposits to money market funds and it happened more recently in the music business.

"Distributed generation, electricity storage and energy management technologies are advancing rapidly and will eventually give large numbers of customers options to unplug from the grid," US-based clean-energy think tank Rocky Mountain Institute said in a study released last year.

In an interview with *Bloomberg News,* Rogers said that if

Disruptive technologies at a glance

Electric vehicle batteries: Over the past five years the cost of making advanced batteries for vehicles has fallen more than half to around $400-500 per kilowatt hour. The cost of batteries could reach total-cost-of-ownership parity with the internal combustion engine when the price hits $250/kWh, at which point the global market could expand to between 15 million and 20 million vehicles sold per year, from 1 million to 2 million now. Of course, it could still take up to five years from the time batteries become cheap for car-makers to incorporate them. But once the cars are rolled out the improved fuel economy could save consumers more than $500 billion every year in the near term, replacing oil with lower-cost domestic electricity, says McKinsey. Batteries could also become affordable back-up power supplies for the power industry if Tesla, a leader in electric cars, achieves its goal of lowering costs below $200/kWh.

Solar photovoltaics (PV): Solar costs are falling, and as the trend continues this should transform the face of the utility industry. In developing countries, distributed generation – in combination with inexpensive storage – could bring electricity to millions of poor people living in rural areas.

LED lighting: Software boosts the value of LEDs by adjusting their energy use based on needed lighting levels. The price of LED lighting fell substantially over the past decade and is expected to fall even further in the coming years. The US Department of Energy estimates that the price of LEDs will reach $2 per thousand lumens by 2015 – an 85% decrease from 2010 prices. The price decline would make LEDs cost-competitive with conventional lighting technologies in many regions. LED lighting makes up 5% of the global lighting market, but it could hit 80% by 2020. If LED lighting hits these levels, global consumers could save more than $100 billion every year by 2020, which would trigger a 1.5% fall in US electricity demand, the equivalent of more than 30 base-load power plants, says McKinsey.

Grid-scale storage: Numerous technologies are being developed to enable large-scale storage of electricity within electric-power grids, many of which are following an innovation pattern similar to auto batteries. Grid storage costs about $600-1000 per kilowatt hour and can only be used under certain conditions. But technical innovations could cut costs to $150-200/kWh by 2020, making it possible to offer storage in every major metropolitan market. It would significantly improve reliability and make solar, wind, nuclear, and coal much cheaper to deliver.

Digital power conversion: Large-scale, high-voltage transformers were invented in 1885 and triggered the widespread development of the electrical grid. Technologically, not much has changed since. A typical transformer costs $20,000, weighs 4,500 kgs, and takes up 250 cubic feet. But high-speed, extremely reliable digital switches have been developed for high-frequency power management by the military. They use 90% less energy, take up only about 1% as much space, and are more reliable and flexible than existing transformers. McKinsey predicts these digital transformers could begin to replace conventional technology at less than one-tenth the cost by 2020. China is particularly well positioned to benefit from the adoption of digital power electronics as its grid is set to expand on a large scale.

Compressor-less air-conditioning and electrochromic windows (smart glass): These expensive new technologies (smart glass controls the amount of light and thereby heat transmission) offer the potential to slash home and heating bills in half. By 2020 they could begin to cost half as much to install as start-of-the-art cooling and window technologies do today.

Biofuels and electrofuels: With oil prices hovering over $100 per barrel biofuels have rapidly expanded their market share, but their supply has been limited by demand for food. Genetic innovations that use cellulosic and algae-based biofuels can free producers from such constraints. Some innovative start-ups are creating high-margin specialty chemicals and blend stocks that are already generating cash, but could offer a pathway to delivering biofuels at $84/b or less by 2020. At the same time, biopharmaceutical researchers are developing electrofuels that feed carbon dioxide, water, and energy to enzymes to create long-chain carbon molecules that perform like fossil fuels at one-tenth of the cost of biofuels, says McKinsey. ●

(*Sources:* McKinsey, *Petroleum Economist*)

the cost of solar panels keeps coming down, if installation costs also drop, and if customers combine solar with affordable battery technology and a power management system – that balances energy demand with available supply – then utilities could end up being used as a back up.

Two or three decades from now distribution and transmission of energy, in other words, may look a little more like the internet. This will mean nodes with variable degrees of self-sufficiency and fat pipes connecting them to a wide variety of sources and consumers, Sawyer told *Petroleum Economist*.

He sees a sophisticated local system in which houses, offices and companies will be both producers as well as consumers at various times during the day. The so-called fat pipes will channel energy from large renewable producers, such as solar plants in the deserts, wind in the plains and offshore, as well as hydro, among others.

Sawyer is enthusiastic about a number of possible technical innovations, but most importantly the so-called "smart grid" – an electricity grid proponents claim is more resilient and cost-effective than the existing network – pooling supply, demand and storage. Nodes tied to fat pipes will more rationally match supply with demand, offering a pricing structure that would balance out the load in tune with supply.

"I am also intrigued by the possibility of low-voltage direct current (DC) to dramatically increase household and small office efficiency, especially with the shift to LED lighting," he adds.

Edison's comeback

Indeed, DC has been something of a poor relation in the electrical world since it lost out to alternating current (AC) over 100 years ago in a fierce battle between AC's champion Nikola Tesla and DC's proponent, Thomas Edison. AC won for a number of reasons, the most important one being that it provided a better system for transmitting and distributing electricity over long distances.

But AC, like any ageing system, is terribly inefficient. Its shortcomings started to become clear about 50 years ago

when semi-conductors, which need DC power, became a common component in a whole raft of electrical goods.

Nowadays, televisions, fridges and computers need to convert AC into DC. This is a nuisance because in doing so they lose a big chunk of power. Just feel the heat coming off the back of a fridge or a laptop's power pack. Many devices have a conversion efficiency of no better than 80%, with some low-end products rating as low as 65%.

In a typical US home, the losses from such conversions make up around 5% of all electricity used.

But now the humble USB (universal serial bus) cable, used to charge an array of electrical devices, could be part of a revolution that could help flip the energy system.

The big change coming this year will be a new USB PD (power delivery) standard, which will bring more flexibility and 10 times more power than the existing meagre 10 watts – barely enough to charge an iPad.

Moixa has pioneered a prototype souped-up USB socket that powers the UK-based technology company's laptops, monitors, printers and desktops. The office lighting, which uses low-voltage LED lamps, runs off the same circuit. Mains power is only for power-hungry fridges, kettles and the like.

This could "presage a much bigger shift, reviving the case of DC as the preferred way to power the growing number of low-voltage devices in homes and offices", argued a recent article in *The Economist*.

This is where USB cables come in, the magazine said. They carry direct current and also data, which will transform the way electricity is used in the long term, Paddy Padmanathan, chief executive of Saudi Arabia's ACWA Power, says. They can help establish priorities between devices that are supplying power and those consuming it. Take for instance, a computer charging a mobile phone. "The computer can say 'I need to start the hard disk now, so no charging for the next 10 seconds," Ajay Bhatt of Intel, the man who invented the USB, told *The Economist.* Effectively, one USB could help optimise power across a host of power-hungry electrical devices.

Aside from its greater power and variable voltage, the USB PD has another groundbreaking feature – power can flow in any direction. This means it can help directly channel DC power – from solar panels or hybrid cars – back into a smart grid, rather than running it into an AC system and converting it back to DC again.

If this shift, to smaller DC micro-grids, starts to happen, it will have a dramatic effect on how we create and consume power.

US-based Nextek Power Systems says using its DC smart-micro grid systems translates into energy savings of between 10-42% compared with conventional practices. In fact, the company claims, if these methods of energy creation and consumption were deployed across the entire US, the energy savings would be enough to power the state of California for a year.

It is hardly surprising, then, that large data centres are already tapping the energy and cost-saving opportunities offered by DC. Facebook, JPMorgan, Boeing and Bank of America have all built DC data centres.

A DC-powered data centre is 10% more efficient than a standard AC data centre because incoming electricity needs fewer conversions before it powers a server or storage system. It also costs 30% less than its AC counterpart and needs 25-40% less floor space. They will also work well with renewable technologies, such as wind and solar, which both produce DC power. SAP spent $128,000 retrofitting a data center at its offices in Palo Alto, California, to rely on DC power. In 2010 it cut SAP's energy bills by $24,000 per year.

These micro-grids work even better if the network has a biggish central battery tied into the mains grid, which can charge itself up at night when power is cheap.

Some futurists, such as Ad van Wijk, an entrepreneur and sustainability energy expert at Delft University in the Netherlands, believe that the fuel-cell car will be at the cutting edge of the energy and transport systems creating a decentralised smart energy system.

"Together with a fuel-cell car you can easily develop a small-scale, off-grid smart system to produce all the energy we need," he told *Petroleum Economist*.

Van Wijk visualises a world where fuel-cell cars, making electricity more efficiently from gas or biogas, would effectively become mini-power plants on wheels. Of course, the technology and infrastructure needed to make the model work faces numerous challenges, but the potential is mind blowing. Cars could even overtake the world's total power-system capacity of 5,000 gigawatts (GW). With consumers buying 80 million new vehicles every year – each with an engine capacity of at least 100 kilowatts – they represent a potential total power capacity of 8,000GW on the road every year, Wijk says.

Energy efficiency

He agrees that clean-energy technologies, especially solar, still have a long way to go, but believes individuals will eventually become their own producers of electricity – generating power close to their homes or offices, taking competition to another level. This means consumers will not only save on fuel costs, but also on taxes and transportation.

Today's energy demand forecasts, dominated by fossil fuels, assume no drastic technology or system changes in the near term. But today's technical innovations will help build an energy system that's more efficient, more electricity based, more flexible and certainly cleaner.

Soaring energy costs – about 9% of global gross domestic product was spent on energy in 2012 – are forcing the world's economies to find ways to lower expenses.

It's "simply not sustainable from a long-term perspective", Sarbjit Nahal, head of thematic investment strategy at Bank of America Merrill Lynch, said in an interview with the bank's *Advisor* magazine.

Gains could come through increasing reliance on non-fossil-fuel energy sources, or through improved efficiency, he said. Buildings, for example, make up 40% of energy use in terms of emissions worldwide. Yet residential and commercial buildings can use far less energy for heating, cooling and ventilation by adopting state-of-the-art methods.

Elsewhere, the sprawling data centres and server farms that power the internet consume as much as 7% of the electricity produced in the developed world. Information technology has now overtaken the airline industry as a source of emissions. As with automobiles, the next generation of IT equipment must be designed to cut energy use.

Indeed, were it not for the technological advances of the past 40 years, energy use would be as much as 60% higher than it is today. So it makes sense for this trend to continue, the investment bank added.

"The general rule of thumb is that for every dollar you invest in energy efficiency, you achieve $2-4 in terms of long-term cost savings," Nahal says, adding: "You may or may not believe in climate change, but energy efficiency is all about reducing costs. And it's hard to argue against economics."

Not every technology will come to fruition. But some will – and they will change energy markets dramatically and for good. **DE**