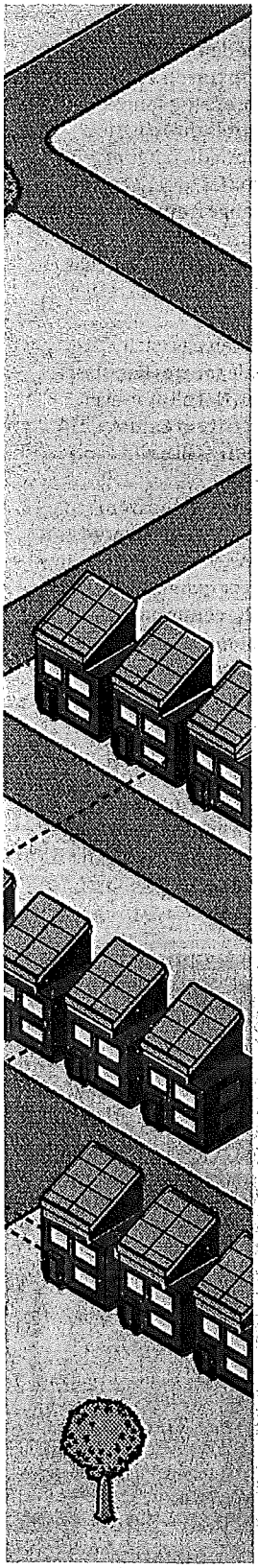


Electric Avenue

Could our power be locally sourced? Caroline Williams reports on the dawn of a community-based revolution

EVERY generation likes to blow the young 'uns' minds with tales of the bad old days. For today's 30-somethings, it is the era before cellphones and the internet, when people were sometimes out of contact for, like, hours at a time. For those a little older, it is when televisions were black and white, only had two channels, and few could afford one.

By the middle of the century, today's pre-schoolers will have their own tales to tell the kids: perhaps of a bleak time when electricity was piped to our homes from dirty great power stations, few people made their own electricity let alone stored it, and nobody had even thought of using the car to power the washing machine.

The kids of the 2060s will roll their eyes and get back to whatever kids spend their time doing by then. But they might be the beneficiaries of one of the biggest technological revolutions of the modern world. The electrical grid is in need of an overhaul, and there are competing ideas about how it will end up. One ambitious notion would involve taking apart our energy supply and rewiring it into a network of "community grids" – cleaner, greener and perhaps able to run entirely on renewable energy. It may sound far-fetched, and not everyone buys into this vision of the future, but if it is right, we could be at the start of the 21st-century electric revolution.

One thing is certain: the grid is ageing. Much of its infrastructure in Europe and North America is getting to the end of, or is already past, its planned life expectancy. According to a recent report by the European Commission, about $17 trillion of investment is needed, globally, by 2035 to bring the grid up to scratch. The US alone needs to invest $1 trillion: rumour has it that parts of its grid date back to Thomas Edison's time.

And if we are going to replace the grid, says Neil Fromer, who directs the Resnick Institute at the California Institute of Technology (Caltech) in Pasadena, we may as well update it. "We certainly don't want to put in the latest version of the same one-way, centrally controlled infrastructure we have now."

To be fair to the grid, that one-way system has done us proud for over a century. When you think about it, the fact that it works at all is mind-boggling: flick a switch, and the room lights up using electricity that was generated less than a second before at a power station tens or even hundreds of miles away and zipped to your home at just under the speed of light. The electricity flows from a few big, central power stations, radiating out along transmission and distribution lines to millions of people. Peaks and troughs in supply and demand are smoothed out by storage built into the generators themselves, along with manual tweaks from computer and human operators. This architecture makes the grid stable enough to keep us from plunging into darkness, whatever the demands placed on it.

By and large, it all works well – but times are changing. Most countries have plans to reduce emissions by increasing the proportion of their electricity provided by renewable energy (see diagram, p 41). Germany, for example, is aiming for over 80 per cent from renewables by 2050. In the US, no legislation prescribes overall targets but 39 states have goals ranging from 10 to 33 per cent by about 2025.

The good news is that renewable energy can provide enough electricity to get them there. The US National Renewable Energy Laboratory concluded last year that the technology available today – including wind, solar and hydropower – is "more than adequate" to allow the US to meet its targets. The trouble is that the locally intermittent nature of such energy sources means they can't be used to generate electricity continuously.

Ask Germany, which learned the hard way after phasing out its nuclear programme last year and pushing renewables to the fore. In ›

a cold snap last February, the grid couldn't handle the millisecond outages, causing temporary shutdowns in several factories.

To make matters worse, even as many countries try to boost use of their renewable resources, worldwide energy demand is set to rise, thanks in part to a growing population, always-on gadgets and electric cars. Predictions from both sides of the Atlantic suggest that the UK and US will need to be producing about 30 per cent more energy by the middle of this century to keep up with demand.

Meeting these demands is "one of the greatest technological challenges industrialized societies have undertaken", says a report published last year by researchers at Caltech.

In response, the system is already evolving. Governments and researchers have spent the past decade testing ways to update the grid. To replace big coal-fired power stations with more intermittent sources, it is crucial to predict accurately how much power people will use and when they will use it. So a raft of demonstration projects around the world have trialled "smart grids" that deal with electricity flowing in two directions – accommodating individuals selling power back to the utility company operating the system – on grids dotted with networked sensors called smart meters. These beam back real-time information on consumers' electricity use to the utility company.

"If countries are serious about sustainability and energy security, they need to deploy massive amounts of distributed energy"

The biggest of these projects, with 4.5 million smart meters, opened in late April in Florida, where frequent storms mean blackouts are commonplace. Initial figures suggest that allowing utility companies to remotely monitor homes in this way has shortened the duration of the average home's power outage by 2 hours, and allowed people to spot costly energy drains in their homes.

Although promising, this approach requires compromises from customers. Utility companies need be able to remotely tweak energy-hungry appliances to be turned down or off for a few minutes to prevent tripping the system when demand starts to outstrip supply.

Not everyone is happy with the idea of utility companies reaching into their home. A proposal to make these kinds of smart sensors mandatory in energy-hungry appliances such as fridges and freezers was submitted to the European Commission by a group of European energy regulators last month. So far there has been no decision, but headlines in the UK blared their preemptive dissent. One described a world of "sinister technology" where "big brother can switch off your fridge".

Power to the people

This isn't necessarily much to be concerned about, says Mani Chandy, a computer scientist at Caltech. Consumers always have the option to override the utility's command to switch an appliance off. "I see it as an opportunity," he says. "In California you can already reduce your rates if you give the utilities limited control over the devices that consume the most electricity – in California, the air conditioner, pool pump and washing machine."

Still, there are other issues. Smart appliances and meters can gather data on our personal energy use for their own ends. The European Union's data protection authority last year warned that smart meters could determine if you "are away on holiday, or use a specific medical device or a baby monitor".

The biggest problem, however, is hackers. Linking the entire grid to people's homes leaves both wide open. In 2009, Mike Davis of Seattle-based security firm IOActive warned that smart meters were vulnerable to computer worms and modelled how they could spread rapidly across large areas, turning off smart meters as they went. Ross Anderson at the University of Cambridge has shown that hackers could go through meters to bring down the entire grid.

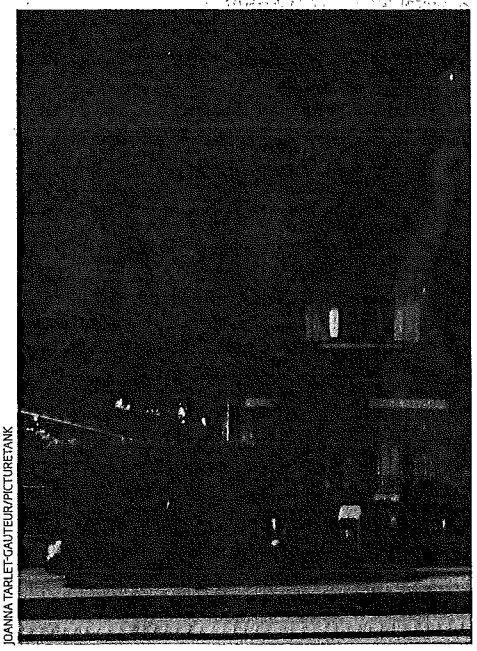
What's the alternative? For the individual, complete separation from the grid remains an expensive, unreliable option suited only to the very rich or to determined eco-warriors.

But a small group of energy researchers is arguing for a third possibility, which they say is emerging thanks to advances in sensing, local storage and small systems for tapping renewable energy such as rooftop solar panels and micro wind turbines. At its heart is a vision of "community grids" that rely mostly on local energy sources and storage. They buy energy from the larger national grid when necessary, but can also feed renewable energy into the national pot. Such a system, they argue, could reduce demand on the main grid, freeing it up to run on a higher percentage of renewable energy sources.

It started with small grids that have for decades successfully allowed a range of self-contained communities to generate their own electricity. These range from military bases, university campuses and jails to remote villages in Alaska, for example, that have found it too expensive to connect to the central grid.

Most of these derive their electricity largely from constantly available sources like diesel generators and batteries. Not all, however: a microgrid at the University of California in San Diego adds clean sources like wind and sun to the mix.

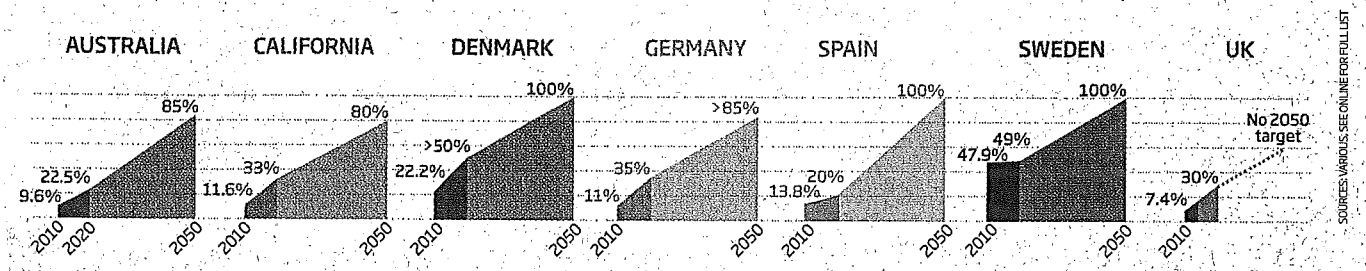
Such microgrids could graduate from speciality niches and become much more common. To do that, however, it would be necessary to find a way for individuals to store the electricity in the community. One source with great potential, says Willett Kempton of the University of Delaware in Newark, is the batteries of electric cars. In April, Kempton, working with the local grid operator and a utility company, unveiled a system to enable electric cars to supply energy to the grid as well as taking it. Car owners can then earn around $5 per day by selling energy, along with providing the grid with a back-up supply.



JOANNA TARLET-GAUTEUR/PICTURETANK

Clean by 2050?

Many countries have set ambitious targets to derive high percentages of their electricity from renewable sources by mid-century. Today's power grids will have to be drastically updated to accommodate the increased use of renewables and their storage

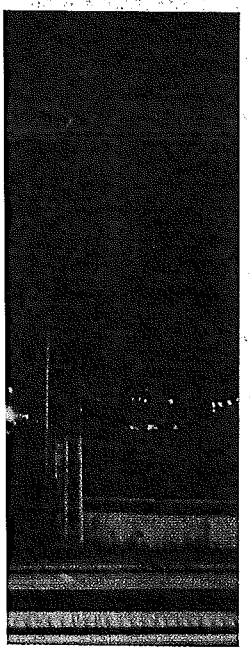


SOURCES: VARIOUS. SEE ONLINE FOR FULL LIST

In many ways, electric car batteries are the perfect storage medium for renewable energy. "The average US car is driven only 1 hour per day, the batteries are huge, and the times of use are fairly predictable," says Kempton.

When plugged in, the circuit queries the grid every 4 seconds and receives a signal telling it to either charge, discharge or do neither, depending on what the grid needs. Kempton recently compared this Grid Integrated Vehicle (GIV) system with warehouses full of batteries and hydrogen fuel cells. "All three work, but GIV is the least expensive way to do it," he says.

Of course the future for electric vehicles is by no means clear, but car batteries aren't the only way to store energy at home. Kempton recently suggested that batteries built into electric home-heating systems could do the same job (*Journal of Power Sources*, vol 225, p 60). Indeed, in theory, pretty much any device could do it. "If energy manufacturers start integrating energy storage into air conditioners and refrigerators, you'd buy a refrigerator with an energy-storage system and solar panel," says Ryan Wartena, co-founder of Growing Energy Labs in San Francisco. "You'd have little bits of energy storage everywhere, and now you're no longer a consumer but a little micro-utility."



Community grids could make central power stations a thing of the past

One issue with this vision is that the average person could not be expected to program their car battery to make decisions about whether to store the power from their solar panel or feed it into the grid. Programming such decisions requires the skills of a specialist. It's the same issue that delayed the mainstream adoption of cars and microcomputers. But as soon as a user-friendly interface made these accessible to the masses, they quickly became ubiquitous.

Rewiring the world

Wartena is working on just such a system for community grids. He and his team have created an operating system that links together every electrical device in the home, including smart sensors and storage batteries, and coordinates their activity with the grid. "We're developing the technology that allows everyone to be an energy operator and to be part of the system. And we'll automate it so you don't have to worry about the science behind it," he says.

A team at the Georgia Institute of Technology in Atlanta is working along the same lines. "It's a bit like an operating system, only a little more complex," says team leader Santiago Grijalva. He predicts that the future grid will consist of billions of networked storage and generation devices – "home appliances, buildings, motors, elevators, everything". To coordinate the interaction of all these pieces, Grijalva's team has created a system that can assign tasks autonomously so that users would not have to be bothered with figuring out where and when to divert power. This system could also help route around power fluctuations caused, for example, by a dead car battery or a cloudy, windless day.

Grijalva says that a system where energy is produced in small quantities from wind turbines, solar panels and other local sources, stored in many devices, and then traded by everyone, from individuals to companies and communities, puts us all in control of our energy supply. "If countries are serious about energy security and sustainability, they need to deploy massive amounts of distributed energy generation and storage," he says.

Granted, there is some resistance to the idea that this approach will change the world.

First, the idea of local storage may be more complicated than pioneers envision. "The cost-effectiveness of storage increases with scale," says Mark O'Malley, director of the Electricity Research Centre at University College Dublin in Ireland. "If you put storage in everything, it makes it incredibly expensive."

O'Malley agrees that the grid needs to be improved, but he thinks we should keep to large-scale systems. "The power grid is the most reliable thing we've ever done," he says. "It's there, it's fundamental to society, it's incredibly reliable. And this idea that a few dreamers can come in and because of IT will sort out the 'old and inefficient' grid is complete rubbish. The people who really understand it are the industry people."

Some industry people, however, see it coming and are rattled. In January, the Edison Electric Institute, the US utility trade association, warned that the rise of distributed electricity generation could threaten industry profits. And earlier this month, the UK's Department of Energy and Climate Change began a review of the carbon reduction potential of local, community-led energy projects. The grid will change; the only question is how radical the overhaul will be. And the enthusiastic newcomers to the energy world are unrepentant. "I'm dedicated to seeing this happen in my lifetime," says Wartena. "It's the way that everyone wants to see it. We have all the pieces, we have the strategy, the manufacturers want to do this, the utilities know that they need to make a move." After all, he says – "nothing beats a good plan except for a better plan". ■

Caroline Williams is a science writer based in Surrey, UK