Technology in emerging economies

Of internet cafés and power cuts

Emerging economies are better at adopting new technologies than at putting them into widespread use

WITHIN a few months China will overtake America as the country with the world's largest number of internet users. Even when you factor in China's size and its astonishing rate of GDP growth, this will be a remarkable achievement for what remains a poor economy. For the past three years China has also been the world's largest exporter of information and communications technology (ICT). It already has the same number of mobile-phone users (500m) as the whole of Europe.

China is by no means the only emerging economy in which new technology is being eagerly embraced. In frenetic Mumbai, everyone seems to be jabbering non-stop on their mobile phones: according to India's telecoms regulator, half of all urban dwellers have mobile- or fixed-telephone subscriptions and the number is growing by 8m a month. The India of internet cafés and internet tycoons produces more engineering graduates than America, makes software for racing cars and jet engines and is one of the top four pharmaceutical producers in the world. In a different manifestation of technological progress, the country's largest private enterprise, Tata, recently unveiled the “one lakh car”; priced at the equivalent of $2,500, it is the world's cheapest. Meanwhile, in Africa, people who live in mud huts use mobile phones to pay bills or to check fish prices and find the best market for their catch.

Yet this picture of emerging-market technarcadia is belied by parallel accounts of misery and incompetence. Last year ants ate the hard drive of a photographer in Thailand. Last week internet usage from Cairo to Kolkata was disrupted after something—probably an earthquake—sliced through two undersea cables. Personal computers have spread slowly in most emerging economies: three-quarters of low-income countries have fewer than 15 PCs per 1,000 people—and many of those computers are gathering dust.

And the feting of prominent technology projects in emerging economies is sometimes premature. Nicholas Negroponte, of the Massachusetts Institute of Technology, has long been championing a $100 laptop computer, presented with most fanfare at the World

Economic Forum in Davos two years ago. The laptop was supposed to sweep through poor countries, scattering knowledge and connectivity all around. But the project is behind schedule, the computer does not work properly and one prominent backer, Intel, a chipmaker, has pulled out.

So how well are emerging economies using new technology, really? Hitherto, judgments have had to be based largely on anecdotes. Now the World Bank has supplemented the snapshot evidence with more comprehensive measures.

Take-off to tomorrow, and to yesterday

The bank has drawn up indices based on the usual array of numbers: computers and mobile phones per head, patents and scientific papers published; imports of high-tech and capital goods. In addition, it uses things such as the number of hours of electricity per day and airline take-offs to capture the absorption of 19th- and 20th-century technologies. It tops this off with measures of educational standards and financial structure, which show whether technology companies can get qualified workers and enough capital. The results, laid out last month in the bank's annual Global Economic Prospects report, measure technological progress in its broadest sense: as the spread of ideas, techniques and new forms of business organisation.

Technology so defined is fundamental to economic advance. Without it, growth would be limited to the contributions of increases in the size of the labour force and the capital stock. With it, labour and capital can be used and combined far more effectively. So it is good news that the bank finds that the use of modern technology in emerging economies is coming on in leaps and bounds.

Between the early 1990s and the early 2000s, the index that summarises the indicators rose by 160% in poor countries (with incomes per person of less than about $900 a year at current exchange rates) and by 100% in middle-income ones ($900-11,000). The index went up by only 77% in industrialised countries (with average incomes above $11,000), where technology was more advanced to start with. Poor and middle-income nations, the bank concludes, are catching up with the West.

The main channels through which technology is diffused in emerging economies are foreign trade (buying equipment and new ideas directly); foreign investment (having foreign firms bring them to you); and emigrants in the West, who keep families and firms in their countries of origin abreast of new ideas. All are going great guns.

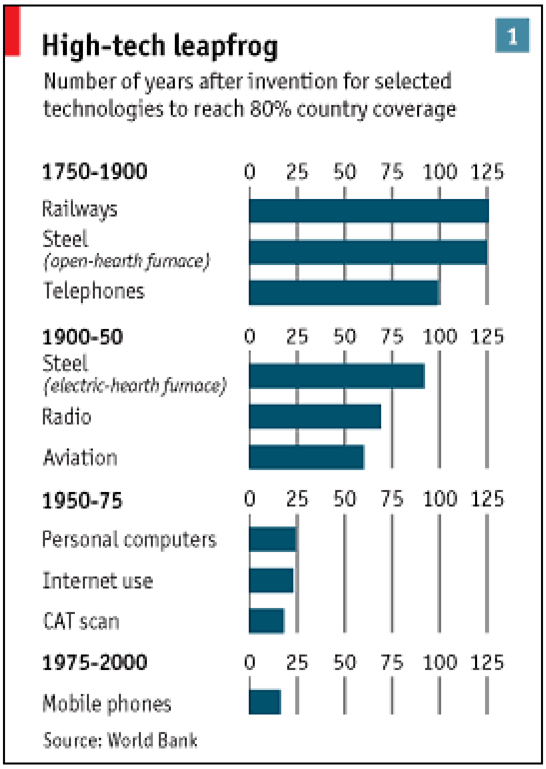
To me, to you, to me, to you

Start with trade. In the past ten years the ratio of poor countries' imports of high-tech products to their GDPs has risen by more than 50%. The ratio in middle-income countries has increased by over 70%. Capital goods (mainly industrial machinery) often embody new technology, and imports of these have increased faster in middle-income countries than in rich ones.

The gain in high-tech exports has been more striking still: emerging economies' share of global trade in such goods rose by 140% between the mid-1990s and the mid-2000s. Some of the world's fastest-growing multinationals have sprung from such countries. These include Brazil's Petrobras, owner of some of the world's best deep-sea oil-drilling technology, and Mittal, a company of Indian origin that is now the world's largest steelmaker.

Relative to GDP, inflows of foreign direct investment to developing economies have increased sevenfold since the 1980s. In some countries, such as Hungary and Brazil, foreign firms account for half or more of all R&D spending by companies. This has had dramatic demonstration effects. Local French-language call centres in Morocco and Tunisia got going only after French operators began outsourcing to the Maghreb. A quarter of Czech managers said they learned about new technologies by watching foreign companies in the Czech Republic.

Emigrants are arguably the most important source of new ideas and capital. Granted, emigration can be costly: computer engineers, scientists and doctors, trained at public expense at home, go to work abroad. But money and skills flow back. Nearly half the $40 billion-worth of foreign direct investment in China in 2000 came from Chinese abroad. Remittances have doubled in the past ten years and now account for roughly 2% of developing countries'GDPs—more than foreign aid. An émigré banker returned to set up Bangladesh's Grameenphone banking network last year; it now has 15m customers. Bata, a Czech shoemaker, has been saved twice by foreign connections. Facing bankruptcy in the early 1900s, Tomas Bata went to America to learn about mass production. He came back and established branches from India to Poland. After the second world war his son fled to Canada to escape the communists. He returned in 1989 and used late-20th-century know-how to expand in eastern Europe and open factories in China and India.



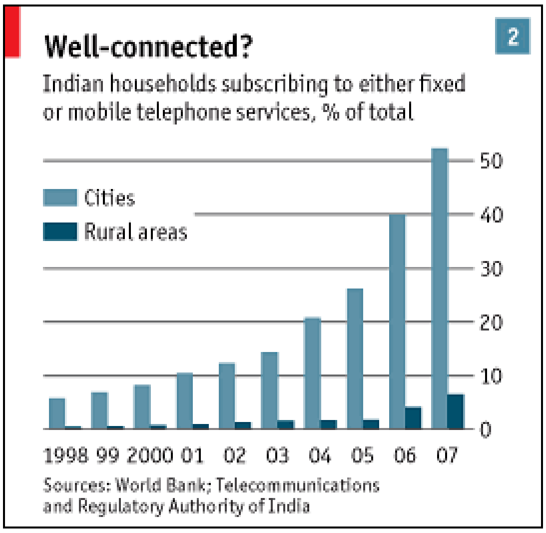
The upshot is that technology is spreading to emerging markets faster than it has ever done anywhere. The World Bank looked at how much time elapsed between the invention of something and its widespread adoption (defined as when 80% of countries that use a technology first report it; see chart 1). For 19th-century technologies the gap was long: 120 years for trains and open-hearth steel furnaces, 100 years for the telephone. For aviation and radio, invented in the early 20th century, the lag was 60 years. But for the PC and CAT scans the gap was around 20 years and for mobile phones just 16. In most countries, most technologies are available in some degree.

But the degree varies widely. In almost all industrialised countries, once a technology is adopted it goes on to achieve mass-market scale, reaching 25% of the market for that particular device. Usually it hits 50%. In the World Bank's (admittedly incomplete) database, there are 28 examples of a new technology reaching 5% of the market in a rich country; of those, 23 went on to achieve over 50%. In other words, if something gets a foothold in a rich country, it usually spreads widely.

In emerging markets this is not necessarily so. The bank has 67 examples of a technology reaching 5% of the market in developing countries—but only six went on to capture half the national market. Where it did catch on, it usually spread as quickly as in the West. But the more striking finding is that the spread was so rare. Developing countries have been good at getting access to technology—and much less good at putting it to widespread use.

As a result, technology use in developing countries is highly concentrated. Almost three-quarters of China's high-tech trade comes from just four regions on the coast. More than two-thirds of the stock of foreign investment in Russia in 2000 was in Moscow and its surroundings. Whereas half of India's city-dwellers have telephones, little more than one-twentieth of people in the countryside do.

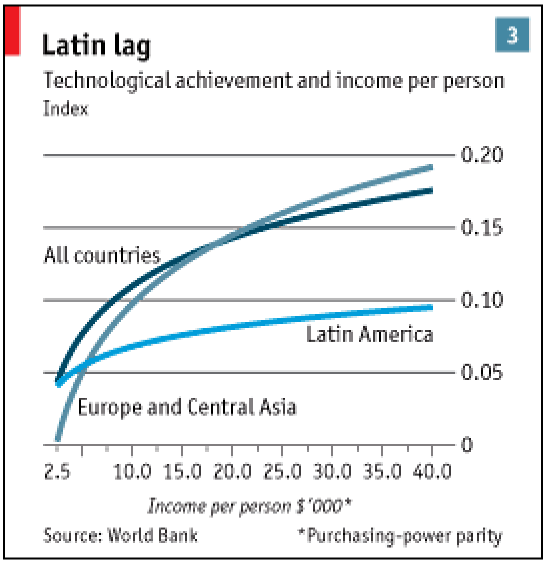
Not only is there a technology gap between emerging economies and the West, and another within emerging economies: there are also surprising differences between apparently comparable emerging economies. For example, China imports and exports far more high-tech goods than India does and its exports are as technologically advanced as a country three times as rich. India and Bangladesh are neighbours with comparable levels of GDP per head. But electricity losses in India are about 30% of output; in Bangladesh, they are below 10%. And although Africa as a whole has low levels of mobile-phone use, in six countries (Botswana, Gabon, Mauritius, the Seychelles, Sierra Leone and South Africa) more than 30% of the population uses them.



The question is how much this unevenness matters. It is tempting to say, not much. What really counts, say techno-optimists, is that technology should get a toehold. Once it does, its grip will strengthen. So although only 6% of India's rural poor have phones, urban folk were at the same stage in 1998—and look what happened (see chart 2). Optimism about diffusion seems all the more plausible because of leapfrogging. Technologies such as mobile phones can be dropped into developing countries without the slog of building expensive infrastructure (such as land lines) and can circumvent the failings of old 19th- and 20th-technology. Poor countries will leapfrog into the next generation.

Fast or forget it

But this view—essentially, that technological diffusion is a problem that will take care of itself—may be too sanguine. The evidence from successful emerging markets is that if they absorb a new technology they usually do so fairly quickly. The corollary is that if a technology is not diffused promptly, it may at best be diffused only slowly and incompletely.



Judging by the World Bank's index, that is what seems to be happening in some places. As a general rule, technological achievement rises fastest in poor and middle-income countries and then levels off as these countries approach Western living standards (see chart 3). But now compare Latin America and Europe. Eastern Europe is following the path taken by America and western Europe a few years before. But in Latin America the slope flattens at lower levels than elsewhere.

The region has less installed bandwidth and fewer broadband subscribers than poorer East Asia, and not many more internet users or PCs. High-tech exports account for less than 7% of the total in Argentina and Colombia, against one-third in East Asia. In Chile and Brazil less than 2% of the business workforce is in ICT. This relative technophobia probably reflects years of inward-looking economic policies, import substitution and disappointing education systems. Here, slow technological dispersal may not be just the result of a time lag. It may be evidence of more fundamental problems.

Broadly, two sets of obstacles stand in the way of technological progress in emerging economies. The first is their technological inheritance. Most advances are based on the labours of previous generations: you need electricity to run computers and reliable communications for modern health care, for instance. So countries that failed to adopt old technologies are at a disadvantage when it comes to new ones. Mobile phones, which require no wires, are a prominent exception.

The adoption of older technologies varies widely among countries at apparently similar stages of development. Soviet central planners loved to build electricity lines everywhere;

the result is that ex-communist countries enjoy near-universal access to electricity (an extremely rare example of a beneficial legacy from communism). Latin American countries had no such background and as a result consume only about half as much electricity per person as eastern Europe and central Asia.

This partly explains the patchiness in countries' technological achievements overall. Call centres in Kenya, for example, pay more than ten times as much per unit of bandwidth as do rivals in India, because India's fibre-optic cable system is far better and cheaper. So sometimes you cannot leapfrog. As countries get richer, older technology constraints do not always fall away. It depends in part on how governments organise basic infrastructure like transport and communications.

The other set of problems has to do with the intangible things that affect a country's capacity to absorb technology: education; R&D; financial systems; the quality of government. In general, developing countries' educational levels have soared in the past decade or so. Middle-income countries have achieved universal primary-school enrolment and poor countries have increased the number of children completing primary school dramatically. Even so, illiteracy still bedevils some middle-income countries and many poor ones.

A similar pattern can be seen with R&D. Emerging economies spend less on R&D than rich ones: rich countries spend 2.3% of GDP on R&D, East Asians 1.4%, and Latin America 0.6%. Also important, though, is who spends the money; and this also varies considerably. East Asia's pattern is similar to the West's: companies spend most of the money and do most of the research. In eastern Europe and Latin America, by contrast, the government is the largest source of finance, and in Latin America universities do the largest share of the work. Sometimes government-supported research is fine: it triggered South Korea's technology boom in the 1980s. But in general, companies tend to be the most efficient and effective promoters of technology (mobile phones are a case in point).

And in rich countries, high-tech-firms get money from banks, stockmarkets and venture capitalists in ways that emerging-market entrepreneurs can only dream of. Here, and in government policy towards technology firms—meaning everything from trade openness to product standards—there has been little catch-up with the West. In Kenya, flower-growing counts as a technology-improving activity because it requires fertilisers, irrigation, greenhouses and just-in-time delivery. The damage wrought by political chaos (see article) is a reminder that technology is far more fragile in poor countries than in the West.

Yet it would be wrong to be gloomy about the technological outlook of emerging economies. The channels of technology transfer have widened enormously over the past ten years. Technological literacy has risen, especially among the young. But all this has helped emerging economies mainly in the first stage: absorption. The second stage—diffusion—has so far proved much more testing.

Demography and genetics

Kissing cousins, missing children

A wider choice of mates reduces people's reproductive output. That may explain why families in rich countries are smaller than those in poor ones

ONE of the biggest paradoxes in human biology is that as societies grow richer, people have fewer children. In most species, such an increase in available resources leads in the opposite reproductive direction. What makes the demographic transition, as this phenomenon is known, even more paradoxical is that in less developed times and places, the rich do not have smaller families than the poor.

Most explanations of the demographic transition are social. One school of thought emphasises reduced child mortality, suggesting this means that fewer “spares” need be generated to be sure that some children reach adulthood. Another points out that elderly people in rich countries do not depend on their children to look after them. A third suggests that as people are presented with more choices about how to spend their resources, they more often choose to consume things and experiences other than the joys and tribulations of parenthood. A fourth, somewhat more biological, posits that lavishing time and money on a few children, rather than spreading it around amongst many, produces adults who do better in the next-generation reproductive stakes. None of these ideas, though, is really satisfactory.

Now yet another explanation has been added to the pot. This is that the mixing-up of people caused by the urbanisation which normally accompanies development is, itself, partly responsible. That is because it breaks up optimal mating patterns. The demographic transition is thus, in part, a pure accident.

Love thy neighbour?

This suggestion is the corollary of a paper published in this week's Science by Agnar Helgason and his colleagues at deCODE Genetics, a firm based in Reykjavik. DeCODE's business depends on a unique resource—the entire population of Iceland, living and dead. The country's records since its founding by a few, intrepid Vikings are so good that the antecedents of today's inhabitants (apart from a handful of recent immigrants) are known with precision. On top of this, its medical records are also good, and most Icelanders have willingly given genetic samples to an endeavour which is seen to be beneficial to the country's economy as whole.

DeCODE hopes to translate this knowledge into money by understanding the genetic underpinning of diseases and hence developing diagnostic tools and drugs. On the way, however, it is generating a lot of additional scientific knowledge—of which this study is one example.

The study's principal finding is that the most fecund marriages are between distant cousins. Using Iceland's genealogical records, which allow the degree of relatedness between husband and wife to be calculated with great precision, Dr Helgason showed the optimum degree of outbreeding (measured in terms of the number of children and grandchildren produced) lay somewhere between cousins of the third and fourth degrees.

Probably, the reason is that marriages between close relatives risk inbreeding depression (caused by individuals receiving two copies of broken genes from the same ancestor, but by different paths—one maternal and the other paternal). Outbreeding means this is unlikely to happen, and at least one functional copy of each gene will be received. But outbreed too far and other difficulties arise as genetic incompatibilities between the parents make reproduction harder. (A well-known example is the case of rhesus blood groups, when the mother's immune system may reject a fetus because of its father's genes.)

The optimal degree of outbreeding remained the same in every 25-year generation since 1800, although the overall number of children from marriages of every degree of relatedness did drop gradually over time—an observation that accounts for part of Iceland's demographic transition, and which probably has a social explanation. However, the level of outbreeding in Iceland has also increased markedly over that period, and Dr Helgason's findings suggest that this, too, drives down average family size measured over the whole population by reducing the number of third and fourth cousin marriages.

The strong relationship between kinship and fertility was so unexpected that the researchers have not yet calculated exactly how much it contributes to the demographic transition. But even from the figures they present, it is clearly an important factor, and one that is likely to apply in other parts of the world where the records needed to prove it are not so good. Even in poor countries, birth rates are now falling fast. An important part of the explanation may simply be the additional choice of mates that development and urbanisation bring with them.

Evolution

Human races or human race?

Genetically, people still look pretty much alike

SOME light was shone this week on the vexed question of the genetics of race in humans. Lluís Quintana-Murci and his colleagues at the Pasteur Institute, in Paris, published a study in Nature Genetics that looked at which genes have undergone recent natural selection at different rates in different parts of the world, and might thus contribute to any biological differences between races.

Given the fraught nature of the subject, the results are gratifyingly uncontroversial. Several of the differences Dr Quintana-Murci detected are in genes for the superficial racial markers of skin colour and hair form. Most of the others whose functions are known are connected either with diet or with resistance to disease.

Dr Quintana-Murci's data were drawn from a project called HapMap, which catalogues what are known as single-nucleotide polymorphisms, or SNPs. These are places where individual human genomes routinely differ from one another by a single genetic "letter". If such a variation happens inside a gene, as opposed to occurring in part of the "junk" DNA that pads the genome out, the result can be a change of function of the gene in question—the raw material of evolution.

Applying various statistical techniques to the 2.8m SNPs so far catalogued by HapMap, Dr Quintana-Murci found 55 genes that showed evidence of having undergone significant localised evolution. Six controlled skin pigment and hair development. Four helped the immune system combat disease-causing organisms, such as malarial parasites, that are a problem in some places, but absent from others. A further six regulated metabolism in various ways, probably in response to the different diets enjoyed by different people. (Some of these genes are of wider interest as they are involved in obesity, diabetes and hypertension.) Nine others had various other jobs that were also of no political significance. All in all, the school of thought which holds that humans, for all their outward variety, are a pretty homogenous species received a boost.

There were, however, 30 locally selected genes whose functions are as yet unknown. And it is possible that others have been overlooked. This result promotes the brotherhood of man. But it is probably not the last word on the matter.

Seismology

Plumbing the depths

A new generation of mermaids looks at oceanic earthquakes

LIKE bats bouncing their shrieks off insect prey, geologists use the echoes of earthquakes to understand what the inside of the Earth is like. However, the ears they employ—known as seismometers—are mostly on dry land. And dry land is a mere third of the Earth's surface. To complete the picture, especially at the shallowest levels of the Earth's crust, it would help to have a network of seismometers at sea as well.

That is what Frederik Simons of Princeton University and his colleagues are proposing to create. To do so, they have designed and are now testing a device that they whimsically call a Mermaid (Mobile Earthquake Recorder in Marine Areas by Independent Divers).

Dr Simons's Mermaids would not, however, have sex-starved sailors leaping overboard to embrace them. They are torpedo-shaped machines packed with equipment intended to listen for the type of low-frequency sound waves that are generated by earthquakes.

To do that, they need to float near the sea floor, since most of an earthquake's energy travels through the rock rather than the water. So a Mermaid can operate at a depth of up to 1,500 metres (about a mile). When she hears something that might be pertinent, she runs the signal through her on-board computer to decide just how significant it really is. If it does turn out to be significant, she surfaces by pumping air into a bladder and makes contact with a satellite that has been co-opted into the project. Once she has delivered her message, the air is sucked back out of the bladder and she returns to her gloomy underwater station.

The main engineering problem Dr Simons faces—apart from making something that will work reliably in the salty ocean depths—is energy conservation. When a Mermaid runs out of power, she dies. That power is provided by lithium-ion batteries and is reckoned sufficient for between 50 and 100 surfacings.

One of the ways Dr Simons saves power is in the computer. The decision to surface is made by an algorithm that depends on a mathematical function called a wavelet. This divides an earthquake wave into separate components which can be studied independently. That allows the computer to restrict energy-intensive high-resolution analyses to those sections of the waves that really need it. The other sections receive a more cursory (and thus less power-consuming) glance.

At $15,000 a pop, a Mermaid is not outrageously expensive. A few million dollars would buy a network that could cover an ocean. That would unlock many of the Earth's secrets, including how much heat is transferred from the inside of the planet to the outside and exactly how mid-ocean volcanoes like those in Hawaii are formed. Such knowledge may not be everyone's idea of sunken treasure, but it would have great value to those who struggle to understand how earthquakes are caused.

Self-generated energy

Power from the people

Now you can recharge things just by walking around

IN THE early 1990s, an inventor called Trevor Baylis came up with an idea that provoked the sort of smirking disbelief journalists usually reserve for those who have spent too long in their garden sheds. But the smirkers were wrong. Mr Baylis's clockwork radio turned out to be a great success in places where batteries are expensive and mains electricity is non-existent. In the latest versions, the crank charges a battery directly, rather than winding up a spring which then turns a small dynamo. A few minutes' handle-turning can provide an hour's reception.

Wind-up radios have turned into consumer products in rich countries too, along with wind-up torches, wind-up mobile-phone chargers and wind-up music players. But all these gadgets rely on people having to do some specific work in return for their entertainment. Hence the appeal of finding a way of extracting power from everyday activities without the user noticing what was going on—rather like an old-fashioned self-winding watch, but on a grander scale. There have been several attempts to do this in the past, from trainers that absorb power from the pounding of a foot on a pavement to backpacks that generate it from the bobbing motion of the load while the wearer walks. None, though, has really taken off. But the latest idea might, as it is a human version of a popular idea in car design—regenerative braking.

The “energy harvester” that Max Donelan of Simon Fraser University and his colleagues describe in this week's Science looks like an orthopaedic knee-brace. It tucks behind its wearer's knee and has extensions that strap around the front of his calf and his thigh.

When the wearer walks, the knee's motion drives a set of gears which turn a small generator.

On the face of it, that sounds like a recipe for making walking difficult. Surprisingly, it is not. Although the leg muscles perform “positive” work when they accelerate the leg forward to begin a step, when the leg straightens at the end of the step they perform “negative” work as they slow the leg down. If the generator in the harvester were connected during the accelerating phase the process would, indeed, be expected to increase the load on the muscles. But if it were connected only during the decelerating phase it would impose no load. It might even make things easier.

To test this idea, Dr Donelan recruited six volunteers, attached harvesters to their knees and put them on a treadmill. With the generators in the harvesters engaged all the time, walking produced seven watts of power. When the generators were engaged only during deceleration, however, they produced almost five watts (enough to power ten mobile phones simultaneously). Moreover, in that second case, the amount of extra energy used by walkers wearing the harvesters was insignificant, since the harvesters were absorbing energy that would otherwise be dissipated as heat—which is exactly the principle used by regenerative braking in a petrol-electric hybrid car.

One use for the harvesters, if they could be made cheaply (and people could be persuaded to wear them routinely), would be to charge up batteries. But Dr Donelan also has more sophisticated applications in mind. He thinks energy harvesters could be used to power robotic artificial joints and might even, one day, be implanted within muscles for that purpose.

A green light

Even the quotidian uses of an energy harvester like Dr Donelan's will, however, be enhanced by other advances in the field. Rechargeable batteries are getting smaller, lighter and more powerful. They may eventually be replaced in some applications by ultracapacitors that can charge up and discharge even faster than a battery. More efficient cranking systems and generators are also under development. And the miniaturisation of electronics continues to reduce power demands.

One of the biggest changes has been the use of light-emitting diodes (LEDs). This has transformed wind-up lighting products, says Rory Stear, chairman of Freeplay Energy, which specialises in such “self-powered” devices. The company's Indigo lantern, for instance, can provide up to two hours of light from just one minute of winding. LEDs also last for a long time: those in the Indigo are rated for 100,000 hours, whereas a filament bulb might burn out after 16 hours.

Such products can make a huge difference to power-starved people. Freeplay's charitable foundation reckons that the use of kerosene, candles and firewood for lighting absorbs 10-15% of monthly household incomes in sub-Saharan Africa. It is planning to test a range of wind-up LED lanterns in Kenya and South Africa this year. These, it hopes, will allow people to do things like studying at night, increasing their security and coping better with medical emergencies. Freeplay Energy is also developing self-powered medical equipment, including a fetal-heart monitor.

Mr Stear says people in poor countries are prepared to work hard for their energy, with wind-up lanterns often passed among family members to help power them. That bodes well for Dr Donelan's idea, if it can be mass-produced. But the ability of such devices to save on batteries and to serve as reliable standby devices could make them popular even in Western markets as their performance gets better. Save the planet by walking to work and powering up your iPod at the same time. What more could a Green want?