The Economist

Engineering a fix to climate change

Simulating the sense of touch

The web's creator watches it grow up

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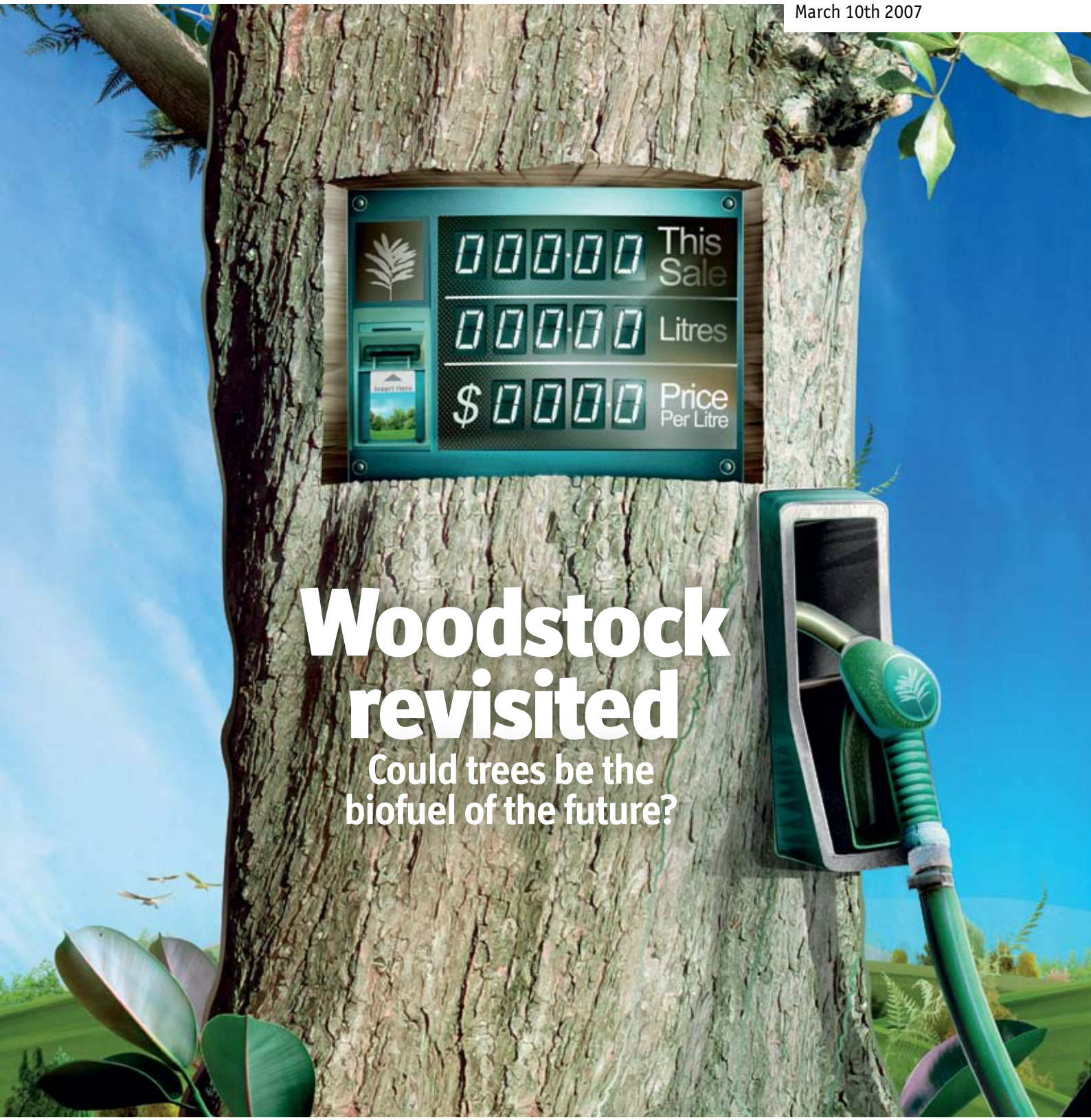

Woodstock revisited

Could trees be the biofuel of the future?

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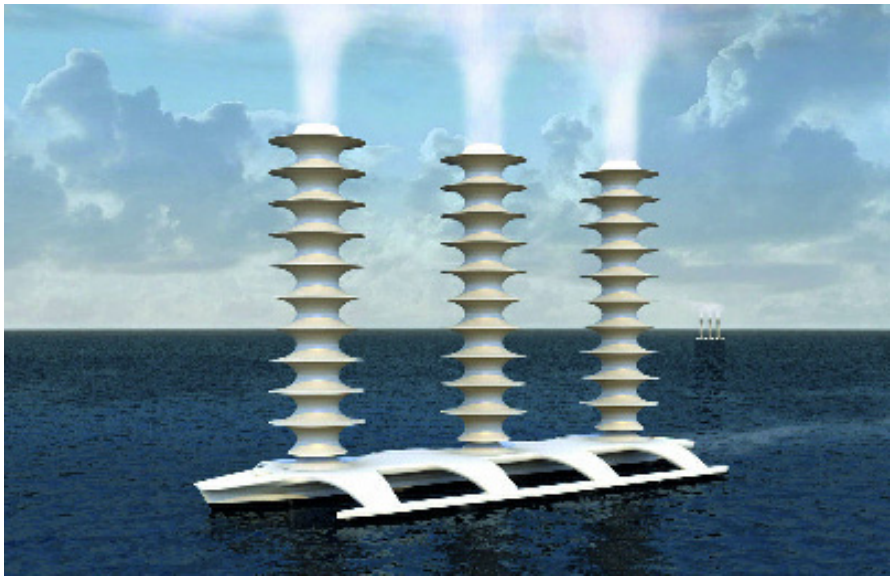
It could give "tree hugging" a whole new meaning. Rather than making ethanol from corn or sugar cane, why not make it from trees? The technology is not quite ready and needs refinement. But the rise of "treethanol" could give wood, mankind's oldest fuel, a new lease of life



Plan B for global warming?

Environment: "Geo-engineering" is the direct use of technology to counteract climate change. The idea is highly controversial

IF MAN is inadvertently capable of heating the entire planet, surely it is not beyond his wit to cool it down as well? Although most climate scientists do not like to talk about it, cutting greenhouse-gas emissions is not, strictly speaking, the only way to solve the problem of climate change. Just as technology caused the problem, it might also be able to help reverse it. The use of planetary-scale engineering to counteract climate change is known as "geo-engineering".

The idea has been around for years. When a report on climate change was submitted to President Lyndon Johnson in 1965, the authors did not even bother to consider the idea of reducing carbon-dioxide emissions. Instead, the report suggested spreading "very small reflecting particles" across the ocean surface to reflect light and heat back into space.

Since then most campaigners and policymakers have focused on cutting emissions, but the idea of deliberately cooling the Earth has never gone away. Most people think cutting emissions is the more sensible path. But global emissions are still rising, and seem likely to do so for years to come, so some scientists believe it might be worth thinking about a second line of defence, if only as an insurance policy.

The idea has gained new currency in recent months. *Climate Change*, a scientific journal, published a series of papers on geo-engineering last August, including one by Paul Crutzen, a Nobel prize-winning atmospheric chemist. In November the Carnegie Institution and America's space agency, NASA, held a conference on the topic. And American officials have lobbied for geo-engineering research to be included among the recommendations of the Intergovernmental Panel on Climate Change's latest report on climate-change mitigation.

Of all the schemes proposed, the most ambitious (and expensive) idea would be to place a giant sunshade in space at the inner Lagrange point, the position on the line between the Earth and the sun where the combination of centripetal and gravitational forces allows an object to maintain a constant position between the two. If the object is big enough, it could block out enough of the sun's rays to cool the Earth. Roger Angel, an astronomer at the University of Arizona, has suggested assembling a cloud of millions of small, reflecting spacecraft less than a metre across at this point, where together they would block out 1.8% of the sun's rays.

Dr Angel estimates that the total mass of the sunshade required would be around 20m tonnes. The shade would consist of individual craft around one metre across, put into position using a combination of magnetic launchers and

ion propulsion. He believes the total cost of the project would be a few trillion dollars, or less than 0.5% of world GDP. Dr Angel admits that this is a somewhat far-fetched solution, and does not believe it would be attempted unless all other options had failed. But he has been given a small grant by NASA to explore the idea.

A less exotic approach, endorsed by Dr Crutzen, would be to spread tiny particles in the upper atmosphere to reflect the sun's rays. This effect has already been shown to work in nature: fine sulphate particles, called aerosols, ejected by large volcanic eruptions like that of Mount Pinatubo in 1991, have produced periods of global cooling. And sulphate pollution from industry had similar consequences, helping to balance the warming effects of carbon dioxide until the 1990s, when pollution controls in many regions had the perverse effect of increasing warming.

Ken Caldeira, a scientist at the Carnegie Institution, suggests that this idea might be more suited to local rather than global application, at least at first. The Arctic, for example, is among the regions most affected by global warming, and keeping the polar sea-ice frozen would be a good thing: white ice reflects more heat back into space than dark ocean, and the scheme would also save a few polar bears from drowning.

The most down-to-earth idea is that proposed by John Latham, a scientist at the National Centre for Atmospheric Research in Colorado. He suggests that blasting tiny droplets of seawater into the air would stimulate the formation of highly reflective, low-lying marine cloud. Simulations suggest this would have a substantial cooling effect. The question is how to do it economically. Stephen Salter of the University of Edinburgh has designed an unmanned vessel which would produce these clouds using wind power. Just 50 vessels, he reckons, each costing a few million dollars and spraying around 10kg (22lb) of water per second, could cancel out a year's worth of global carbon-dioxide emissions—though another 50 vessels would be needed every year until carbon-dioxide emissions were under control.

Dr Salter's ships would be much more precise than other geo-engineering schemes—"like an artist's paintbrush", as he puts it. They could be deployed to the North Atlantic to cool the Greenland ice sheet during the northern summer and then migrate to Antarctica for the southern summer. Dr Caldeira even suggests that by cooling the sea, these ships could be used to combat hurricanes, since high sea-surface temperatures are linked to hurricane formation.

Other proposals include seeding the oceans to get them to absorb more carbon dioxide and building huge reflectors in desert regions to reflect sunlight back into space. This latter idea is impractical, says Dr Caldeira, who reckons that half the world's deserts would have to be covered. Indeed, most geo-engineering schemes sound half-crazy and tend to have both technical and aesthetic complications. Deliberately polluting the stratosphere would make the sky less blue, although sunsets would probably be prettier. Blocking out the sun would help to cool the planet, but it would do little to address other nasty side-effects of high carbon-dioxide levels, such as the acidification of the oceans.

Many greens oppose the whole idea in principle. Ralph Cicerone, president of America's National Academy of Sciences, has said that geo-engineering inspires opposition for "various and sincere reasons that are not wholly scientific". But it does seem reasonable to worry that the illusory hope of a scientific fix might undermine the adoption of policy solutions, such as carbon caps and carbon quotas, designed to address the underlying cause of the problem. And then there is the danger of unintended consequences. Climate change is arguably an experiment which mankind has unwittingly found itself performing on the planet. To start a second experiment in the hopes of counteracting the first would be risky, to put it mildly. ■

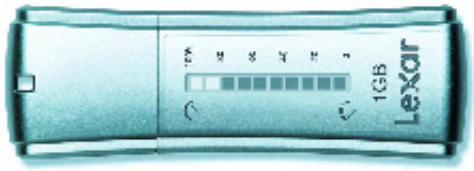
Displays to keep an eye on

Consumer electronics: New displays are starting to appear in consumer devices, offering advantages over today's liquid-crystal screens

FROM tiny mobile phones to enormous flat-panel televisions, liquid-crystal displays (LCDs) are everywhere. The technology is cheap, even for large panels—witness the tumbling price of LCD televisions—and can brilliantly display text and graphics. LCDs have made notebook computers possible and have pushed aside the bulky computer monitors of a few years ago. They make it possible to show films on aeroplane seats-backs, play video games on the train and see digital photos right away on the back of a camera.

But LCDs are not perfect.

The displays they are a-changin'



A flash drive with a fuel gauge

They can be power hungry, tend to produce washed-out images in bright sunlight and are often thick and inflexible. As a result, several other display technologies, each with benefits and drawbacks of their own, are starting to appear in consumer-electronics devices. Some of them could give the LCD a run for its money, at least in some areas, by offering crisper images, brighter colours, thinner screens and lower power consumption.

Electronic-paper displays, first developed in the 1970s, are finally making their way into a number of products. Appropriately enough, Sony and several other manufacturers are using the technology in portable "e-book" devices intended to replace books and newspapers. Colour LCDs are grids of tiny shutters, each of which decides how much light to let through from a "backlight" behind the screen. Electronic paper, conversely, relies on ambient light from the surroundings, just like ink on paper—so electronic-paper displays are sharp and easy to read in bright sunlight. Better still, once the screen has been set to display a page of text, no electrical power is needed to keep it there; power is consumed only when the screen is updated, which can extend the battery life of mobile devices.

The technology is also easy on the eye, says Nico Verplancke of IBBT, a Flemish research institute. Last year he oversaw a trial of electronic-paper technology carried out by *De Tijd*, a Belgian newspaper. The newspaper asked 200 readers to evaluate an electronic edition displayed on the iLiad, a device made by iRex Technologies of Eindhoven, in the Netherlands. Their responses to the display were favourable. "The reading experience was pretty amazing," says Mr Verplancke. "It was very close to reading normal paper."

Sony has developed a similar device called the Reader, which went on sale in America last autumn. Like the iLiad, it uses electronic-paper technology from E Ink, based in Cambridge, Massachusetts. E Ink's technology has also been used in the Motofone, Motorola's low-cost mobile phone for the de-

veloping world, a Seiko wristwatch, a weather-station and a flash-memory stick. And it will appear in a new mobile device with a five-inch (13cm) roll-up display that will be introduced in Italy later this year. The "Librofonino", an e-book reader with a cellular connection for receiving information, was developed by Polymer Vision, based in the Netherlands, and will be sold by Telecom Italia.

A second emerging technology is based on organic light-emitting diodes (OLEDs). Such displays, which are based on the electroluminescence of organic compounds, are said to be thinner and brighter than LCDs, and offer wider viewing angles. Since they emit light directly, OLED displays do not need a backlight. So far OLED displays have appeared mostly in small devices such as music players and as the secondary display on the outside of mobile phones. Sales of OLED displays in 2006 reached $615m, says Vinita Jakhanwal of iSuppli, a market-research firm. But the technology is improving and annual sales will grow to around $3 billion in 2012, she predicts.

The technology's main drawback is that OLED displays only have a lifetime of around 20,000 hours, or a little over two years in continuous use, so they are not yet suitable for use in laptops or TVs. But those working on the technology are optimistic that this problem can be solved. "Every year, the R&D team is making strides," says Dave Das of Samsung. The South Korean electronics giant is one of the biggest backers of OLED displays.

The firm is already using the technology in some of its mobile phones and music players, and introduced a prototype TV with a 40-inch OLED screen in 2005. Samsung is one of the biggest manufacturers of LCD TVs, but OLED technology could offer better brightness and contrast, and faster response. "It's better at displaying fast-moving images, for example a football game," says Mr Das.

Another emerging technology, called iMoD, is being developed by Qualcomm, an American firm that developed the CDMA technology that underpins modern mobile phones. The idea is to exploit microscopic mechanical structures that reflect light in such a way that specific wavelengths interfere with each other to create vivid colours, like those of a butterfly's wings. (The name is derived from "interferometric modulator display".)

Qualcomm says this approach can produce pure, bright colours using very little power. It has demonstrated the technology in prototype form and hopes to license it to handset-makers. Marlene Bourne, an analyst who covers the field of "micro-electromechanical systems", says iMoD is an impressive technology. As with electronic paper and OLEDs, it is certainly worth keeping an eye on. ■

Let's get physical

Video games: "Exergaming", which combines on-screen action with physical exercise, shows that gamers need not be couch potatoes

IN THE heart of Silicon Valley, not far from Google's headquarters, a new gym aimed at a teenage clientele opened its doors last September. As befits its location, it is an unusually high-tech establishment. As well as the weights and cardiovascular exercise gear, Overtime Fitness has "exergaming" equipment that combines video games with physical exercise. One controller allows ordinary Xbox games to be played using full-body movements: players exert pressure on a padded metal bar, rather than pushing buttons on a plastic controller. With another system, players stand in front of a screen and wear a belt equipped with motion sensors, controlling on-screen action with real-world movements.

The gym's founder is Patrick Ferrell, a veteran of the video-games industry and the man behind both *GamePro* magazine and E3, a long-running gaming trade-show. As a volunteer sports coach and the father of three teenagers, Mr Ferrell thinks the combination of gaming and exercise has huge potential. "It breaks up the monotony of exercise," he says.

The origins of exergaming can be traced back to 1989, when Nintendo released two accessories for its Nintendo Entertainment System. The Power Pad was a large plastic platform that plugged into the console and contained 12 pressure sensors on which gamers could step or jump to play sports games such as "World Class Track Meet". The Power Glove was a glove-like controller that translated various gestures into on-screen movements. Neither sold well.

Then in 1998 Konami, another Japanese games company, released an arcade game called "Dance Dance Revolution" in which players had to dance on an electronic platform, placing their feet as instructed in pre-determined patterns. The game proved very popular and over 90 versions of it have been produced, including versions for home video-game consoles. Playing the game is so physically demanding that it is now being taken seriously as a means of keeping fit.

A study by researchers at the Mayo Clinic in Rochester, Minnesota, published in the journal *Pediatrics* in December, found that exergaming more than doubled players' energy expenditure compared with sedentary gaming, and suggested that it "might be considered for obesity prevention and treatment". In another study researchers at West Virginia University found that children who played "Dance Dance Revolution" showed "significant improvement in arterial function and fitness levels".

It is no surprise to find one of the game's many imitators, "In the Groove 2", in the gaming corner at Overtime Fitness. And nearby is another of Konami's pioneering exergames: "MoCap Boxing", launched in 2001, in which players shadow-box against an on-screen opponent. (The player's movements are detected using infra-red "motion capture" sensors, which give the game its name.)

In the past few months a similar boxing game has made its way into millions of living rooms, following the introduc- ▸▸

tion of the Wii, Nintendo's latest games console. "Wii Boxing", like other Wii games, does away with button-pushing and instead incorporates physical movements directly into the gameplay, using the Wii's motion-sensitive wireless controllers. Holding a controller in each hand, players throw punches into the air to control the on-screen action. Similarly, the Wii's tennis, bowling, golf and baseball games require players to act out the physical movements involved in each of those sports, though they do not require as much physical exertion as the boxing game. Some Wii users claim to have lost weight simply through regular playing of its sports games, without otherwise changing their routines.

Michael Pachter, a video-games analyst at Wedbush Morgan Securities, predicts that the Wii will spawn a whole new generation of fitness and calisthenics games, going far beyond existing titles that use dance mats or video cameras (such as the EyeToy, which works with PlayStation consoles) to detect players' actions. The Wii's controller, which can detect far more subtle and complex movements, could be used to record and analyse them too, he suggests.

Not everyone is convinced that the Wii, or gaming set-ups like those found at Overtime Fitness, can have long-term benefits. Susan Zieff, an associate professor of kinesiology at San Francisco State University, says that limited movement and "sporadic kinds of jumping" are no substitute for a real workout. Still, some exercise must be better than none at all. ■

Call and response

Computing: Nobody enjoys telephoning a call centre. Could "chatbot" technology make the experience less painful?

WITH their irritating menu trees and endless holding for the next available operator, call centres are one of the bugbears of modern life. Could a dose of software make the experience of dealing with one less painful? Researchers working on conversational software programs, or chatbots, certainly hope so. They aim to supplement and even replace human operators with software that can understand ordinary conversational language, and thus deal with calls more efficiently.

IBM, for example, has developed a "speech analytics" system that listens in to a call-centre conversation and spots keywords and phrases to help the operator handle the caller's query. One of the limiting factors in dealing with a query is how fast the agent can match the caller's problem to a "knowledge base" of thousands of possible solutions, says David Nahamoo, chief technology officer for speech technology at IBM's T.J. Watson Research Centre in Yorktown Heights, New York. The keywords are used to search the knowledge base and quietly make suggestions to the operator, so speeding things up.

Another system developed at IBM, called Sensei, helps to ensure that the caller and operator can understand each other properly by assessing a potential operator's pronunciation, grammar and comprehension. The system has been used to help select candidates for call-centre positions in India, and to train them once they have got the job, says Dr Nahamoo. By assessing and improving operators' ability to speak a second language, Sensei ensures that operators are easy to understand and can deal with callers efficiently. And although the prospect of being interviewed for a job by a piece of software might sound dehumanising, feedback from candidates has in fact been very encouraging, he says. Both of these systems are part of a more general long-term trend towards automating call centres, says Dr Nahamoo. "More and more of the low-level functions are going to be automated," he suggests.

Rollo Carpenter, a chatbot programmer, hopes to automate the high-level functions too, by developing software that can directly replace human operators. Chatbots have already been used by some companies to provide customer support online via typed conversations. Their understanding of natural language is somewhat limited, but they can answer basic queries. Mr Carpenter wants to combine the flexibility of chatbots with the voice-driven "interactive voice-response" systems used in many call centres to create a chatbot that can hold spoken conversations with callers, at least within a limited field of expertise such as car insurance.

This is an ambitious goal, but Mr Carpenter has the right credentials: he is the winner of the two most recent Loebner prizes, awarded in an annual competition in which human judges try to distinguish between other humans and chatbots in a series of typed conversations. His chatbot, called Jabberwacky, has been trained by analysing over 10m typed conversations held online with visitors to its website (see jabberwacky.com). But for a chatbot to pass itself off as a human agent, more than ten times this number of conversations will be needed, says Mr Carpenter. And where better to get a large volume of conversations to analyse than from a call centre?

Mr Carpenter is now working with a large Japanese call-centre company to develop a chatbot operator. Initially he is using transcripts of conversations to train his software, but once it is able to handle queries reliably, he plans to add speech-recognition and speech-synthesis systems to handle the input and output. Since call-centre conversations tend to be about very specific subjects, this is a far less daunting task than creating a system able to hold arbitrary conversations.

That said, there is more to handling call-centre queries than simply understanding language and looking things up in databases. Sheryl Brahnam, a researcher at Missouri State University in Springfield, suggests that it will also be necessary to program chatbots to deal with verbal abuse. In some cases, she says, companies that have used chatbots to handle online queries have found that when confronted by verbal abuse or sexual innuendo, the chatbots were programmed to respond inappropriately in kind, with insults of their own.

Dr Brahnam has also found that the appearance of the chatbot's on-screen persona, or avatar, has a significant impact on how much abuse is levelled at it. "My study showed that you get more abuse and sexual comments with a white female compared with a white male," she says. Black female avatars were the most abused of all. This leads Dr Brahnam to question how effective IBM's electronic-elocution lessons will prove to be. Even if two operators are using the same script, she says, some callers may respond differently (or even abusively) depending on the operator's gender or accent.

Never mind the philosophical question of whether it is wrong to insult a machine. To neutralise such situations,

chatbots must be able to handle verbal abuse constructively, says Dr Brahnam. She is now devising ways to program chatbots with the sorts of rules that human operators use. There are two broad approaches. The first is a "three strikes and you're out" approach in which the chatbot repeatedly warns the customer to stop being abusive, and eventually hangs up or passes the call over to a human manager. The second approach is more psychological. Giving some ground to customers and acknowledging that they have been wronged, and that their frustration is legitimate and understandable, can help to restore calm and allow the call to proceed.

Chatbots may well be able to speed up the handling of call-centre enquiries. But the same technology could also make things worse, if it is unable to understand callers or gives inappropriate responses. Dr Nahamoo says he doubts that call centres will ever be completely automated, because there will always be some queries that demand human intervention. "There's a balance between cost and customer experience," he suggests, somewhat diplomatically. ■

Working the crowd

Online advertising: New business models let communities of internet users control how their personal information is bought and sold

WIKINOMICS? Crowdsourcing? Mass collaboration? "Long tail" marketing? Nobody is quite sure what to call it, but lots of people are interested in the way the internet makes it possible for people to organise themselves according to their preferences and habits into tiny niches, access to which can then be bought and sold.

This is unquestionably a huge market—it is, after all, what Google does. Users of the internet giant's search engine and e-mail service provide information about their interests in the form of search terms and e-mail messages. Google is then able to gather up the handful of people who express an interest in an obscure term and provide advertisers with a way to reach them. In effect, Google users trade personal information in return for free use of Google's online services.

But some people think this is a bad deal. They think the personal information is worth far more than the services that Google and others offer in return. Seth Goldstein, a serial entrepreneur based in San Francisco, believes that the personal information contained in users' click trails, online chats and transactions is something they ought to take hold of and sell themselves, generating direct payback. "Attention is a valuable resource, and we're getting to the point where it can be parsed in real time," he says. So he has co-founded a new venture called AttentionTrust.

Its approach is to turn the tables on Google and other big aggregators of personal information. Instead, users amass their own traffic patterns and preferences using a piece of "plug-in" software that runs inside a web browser. The resulting profile can then be deposited in an online vault, where interested parties can pay to see it. Prices can be structured on a sliding scale, depending on whether an advertiser or company wants to contact individuals or analyse demographic slices—graduates of the same age from the same university who share an interest, for example.

This type of grassroots self-marketing is also the idea behind GestureBank, another anonymised data-aggregation tool started by Steve Gillmor, an American technology commentator. Users will be able to make "a hell of a lot of money," Mr Gillmor predicts, by deciding which aspects of their behavioural data go into a central pool. He imagines such services will initially take hold among bloggers, who love analysing how many readers they have, who they are, and how their readership compares with that of other bloggers. Before long, he hopes, advertisers will follow with their chequebooks.

Yet another example, established by a group of Stanford graduates, is Agloco. "Advertisers, search providers and online retailers are paying billions to reach you while you surf," says its website. "How much of that money are you getting? You deserve a piece of the action." Like AttentionTrust, Agloco is based on a browser plug-in that tracks users' online activity and then uses this information to allow advertisers to target people with specific interests. Agloco promises to return 90% of ad revenue, sales commissions and other income to its users. In a further twist, those who recruit other users get a cut of the revenue, too. Akshay Mavani of Agloco says the firm is on target to sign up 10m users by July.

A related approach sets out to address the problem of junk e-mail. Rather than using blacklists and filters to stop unwanted messages reaching their in-boxes, why not charge advertisers for permission to send promotional messages? That is the philosophy behind Boxbe, a start-up based in San Francisco that recently secured funding from Draper Fisher Jurvetson, a renowned venture-capital firm, for its "negotiated e-mail delivery" service. It works rather like an automatic tollbooth between the internet and your in-box, deciding which traffic to let through, and how much to charge.

Boxbe suggests that users set a price of $0.15-0.25 per message to allow companies to contact them. (The start-up takes a 25% cut.) Users fill out a personal profile and the idea is that Boxbe will be able to sign up enough users to offer a critical mass to advertisers, who will then pay to send messages to the users most likely to be interested in them. Advertisers can target messages more easily and users receive fewer irrelevant e-mails. They also get paid. An average user could make over $100 a year, reckons Thede Loder, Boxbe's founder. "It's like picking up a quarter from the sidewalk. Even rich people do it, and it adds up," he says. The idea for Boxbe grew out of his graduate research into the economics of communications, and of spam in particular.

All of these models enable online groups of users to organise themselves into niches and charge advertisers for access to them. But sometimes the transactions can take place within the groups

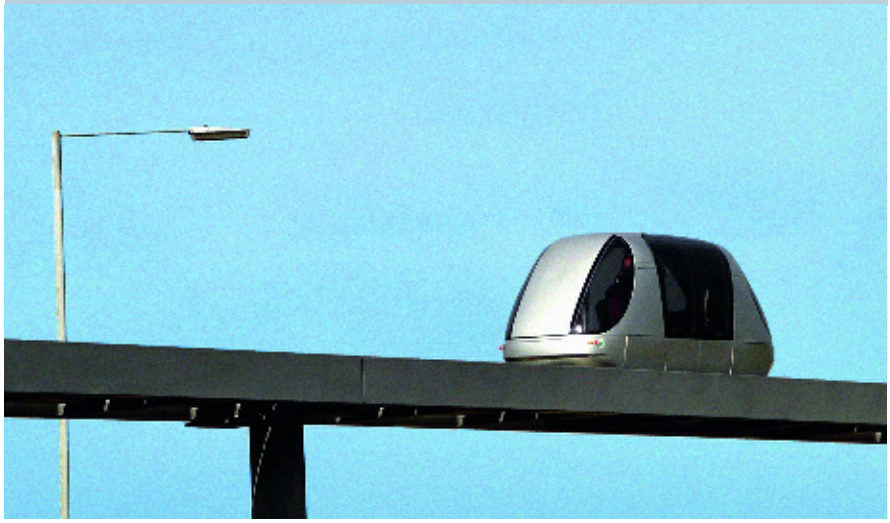
They want their share

themselves. That is how eBay works: it brings together people so that they can buy and sell things, with the online-auction giant taking a cut of each transaction. Once again, new bottom-up models are emerging that do similar things.

A good example is Threadless, an online T-shirt firm based in Chicago. It sees itself as a community in which members can upload T-shirt art, vote for the most promising designs and order them. The company has about half a million registered users and receives 600 submissions for new T-shirts a week. Each week's winning design wins a $2,000 prize, and several thousand people end up ordering it. As the community grows, so the size of the prize, which initially started at $50, will continue to grow too, says Jeffrey Kalmikoff of Threadless. The firm is considering rewarding the thousands of members who vote each week as well, because they provide valuable insights into market trends that help the company with research and planning. This model could work in any industry, Mr Kalmikoff believes. "I am convinced Detroit could use it for designing cars," he says.

But big firms seem to be reluctant to share control, and rewards, with the masses. Two researchers at Microsoft, for instance, created a stir recently with a scientific paper describing a scheme in which owners of portable music-players could share songs wirelessly with strangers, earning a small commission if such sharing prompted others to buy the music for themselves. Music fans could thus become promoters and micro-resellers for their favourite artists.

Rumour had it that this scheme would be included in Microsoft's Zune music-player, but it was not (though the Zune does allow person-to-person sharing within limits). Nor does Microsoft allow the researchers to elaborate on their vision for a "long tail" alive with the sound of music and money. ■



Beyond the stagecoach

Transport: Fans of "personal rapid transport" claim that nifty individual pods are the future of public transport—again

THE fundamentals of public transport, complains Martin Lowson, an academic and entrepreneur, have not changed very much since the era of the stagecoach. Passengers wait at an arranged point for a large vehicle to arrive. It then carries them, along with a crowd of strangers, along a fixed route. The meandering course and frequent stops make the trip far slower than it would be in a private vehicle and the odd-looking person sitting opposite makes it less pleasant. But Dr Lowson's firm, Advanced Transport Systems, thinks it knows how to overcome all this—and give public transport its biggest overhaul in three centuries—using a concept known as personal rapid transit, or PRT.

PRT still involves stations, but they would be smaller and more closely spaced than in traditional transit systems. Instead of big trains or buses, passengers would board small, driverless pods, for one to four people, which would travel along narrow tracks or elevated rails. The stations would not lie on the main line, but on bypasses, allowing pods to proceed directly to their final destination without any stops. It is the stuff of science-fiction films: carefree passengers whizzing effortlessly around in gleaming, automated capsules, without any fear of traffic jams, pickpockets or breakdowns.

In theory, such a system could carry as many people as a more conventional light-rail network or bus service, at lower cost. Since the pods would be much smaller and lighter than trains, they could run on flimsier rails, which would be cheaper to construct. Since they are automated, they could travel much closer together than manually driven vehicles and so get lots of people moving quickly. And since the pods operate only on demand, no money would be wasted on under-used or redundant services.

Since the 1950s, visionaries (or dreamers, depending on your point of view) have been touting PRT as the most efficient way to move people around smallish cities and big public spaces such as airports and fairgrounds. In 1972 Richard Nixon insisted that if American ingenuity could transport three men 200,000 miles to the moon, it could also find a better way to transport 200,000 men three miles to work. The answer, he thought, was PRT. To prove it, he pushed through the construction of a demonstration system at the University of West Virginia. French, German and Japanese firms also built prototypes.

But in the end the model project in West Virginia was the only system to get up and running. The cost of construction, originally estimated at $14m, ballooned to $126m. Rising costs and subsiding political support sank all the other projects. In the 1990s, for example, Raytheon, an American military engineering firm, had to scrap a proposed PRT scheme near Chicago when the projected costs topped $30m per kilometre.

Dr Lowson argues that things are different now, thanks to advances in engineering and computing. Almost all the elements needed for a PRT scheme can be bought off the shelf, he argues, and relatively cheaply too. He estimates costs for Advanced Transport Systems' PRT scheme, called ULTra, at just £3m-5m ($6m-10m) per kilometre, in part because it runs at ground level where possible. That is comparable, he says, to the cost of building a dedicated bus lane. The operating costs are 40% lower than those of a bus service, since there are no drivers. What is more, ULTra, with its narrow rails and compact pods, takes up much less space than a bus lane or train track does.

BAA, the firm that operates Heathrow and several other British airports, is convinced. It has not only ordered a PRT system to carry passengers between Heathrow's new terminal and the sur-

Three wheels good?

Is it the next snowmobile—or the next Segway? Bombardier Recreational Products, based in Quebec, has spent C$225m ($195m) over 11 years developing the Can-Am Spyder Roadster, a three-wheeled motor vehicle. When it goes on sale later this year the $15,000 Spyder will be aimed at baby-boomers who like the idea of riding al fresco but do not feel comfortable on a two-wheeler, says Jose Boisjoli, BRP's boss. The Y-shaped wheel layout ensures greater stability, and the Spyder is loaded with high-tech features, such as stability control and electronic brake-force distribution, that are usually found in luxury cars. It is fun to drive, though it is too wide to squeeze between lanes in traffic and guzzles more fuel than a motorbike. Mr Boisjoli admits that his firm has no idea how much demand there will be for the Spyder. But BRP has a good record, having previously developed breakthrough products including the Ski-doo snowmobile and the Sea-doo "personal watercraft". Even so, as the Segway shows, pioneering a new type of vehicle can be risky.

rounding car parks, but has also bought a 25% stake in Advanced Transport Systems. The project, due to start operating next year, will have five stations and carry 250,000 people a year. If it proves a success, BAA might expand the service throughout the airport, to carry as many as 3m people a year.

Meanwhile, various other schemes are gaining momentum. Vectus, a division of POSCO, a Korean steelmaker, is building a test track for its PRT system in Sweden. A Dutch firm called 2getthere operates automated PRT-like buses in a suburb of Rotterdam and at Schiphol airport near Amsterdam, although PRT purists dislike them since they run on ordinary roads rather than dedicated tracks. Half a dozen other firms are marketing variants on the same theme.

There are still plenty of sceptics, however. Some argue that it would be dangerous to run pods close enough together, at high enough speeds, to eke enough capacity out of each line. The expense of buying rights of way in busy towns could push up costs. Other critics contend that the tracks will be eyesores, especially if they are elevated.

The local politicians who have the final say on most proposals certainly seem to worry that PRT will not live up to its promise. The European Commission has studied four potential schemes, and concluded that hesitant local authorities are the only significant obstacle. As Dr Lowson puts it, "No one ever got fired for proposing a bus system." ■

Big Brother just wants to help

Software: The use of data mining by governments need not be sinister, and could help to deliver public services more efficiently

WHEN you order books from an online bookstore or buy groceries from a supermarket's website, the personalised book suggestions that pop up, and the reminder that you normally buy milk, are generated by data-mining software that analyses buying habits. The use of such technology by retailers is commonplace. But now governments are adopting it too, in fields from education to tax collection, in order to plan, implement and assess new policies. "Not only do firms like Tesco have good operational systems that control their costs, but they understand their customers and can offer particular product mixes which are attractive to certain groups," says Peter Dorrington of SAS, one of the biggest providers of data-mining and analysis software. Why, he asks, shouldn't governments do the same?

After all, government policies, like a supermarket's special offers, are designed to meet the needs of particular subsets of the population. Using data-mining tools, it is possible to spot trends and optimise processes. Take, for example, the British government's efforts to encourage more people from poor backgrounds to go to university. The government gives universities extra funds if they recruit and retain students from poor backgrounds. The Universities and Careers Admission Service (UCAS) categorises the 2m university applications it processes each year by age, gender, ethnic origin, parental occupation, domicile, and the desired institution and course. Universities use this data when selecting candidates and the government uses it to see how its policy is working and to assess the effects of changes in policy.

Last year UCAS tested the use of data-mining software from SAS to evaluate applicants' suitability for courses based on their personal statements and references. For a set of applicants—those who had applied for medical school in recent years—the text from these documents was analysed to look for keywords such as "patient", "experience", "hospital" and "team" that might indicate that applicants had relevant experience and other signs of commitment. Data-mining software then looked for links between the occurrence of these keywords and outcomes, such as whether an applicant was accepted on a course or whether that applicant completed the course. If such links can be reliably identified, it would enable universities to select students who are most likely to complete a given course irrespective of their socio-econ-

omic backgrounds. That could help to reduce discrimination against poorer applicants, who may be regarded as bad risks by universities.

Similarly, a number of school districts in American states including Iowa, New York, Alabama, Colorado and Minnesota are using data-mining tools from SPSS, another software firm, to analyse students' records and spot trends in order to meet the requirements of the No Child Left Behind Act. These are relatively small projects so far, but could easily be scaled up. Big commercial users of SPSS's software, such as telecoms firms, use it to analyse databases of over 40m customers, says Colin Shearer of SPSS. So there is no technical reason why large government databases cannot be mined for insights.

One of the largest government systems to employ data mining is Centrelink, Australia's benefits agency, which deals with over 6.4m claimants and carries out more than 5 billion computerised transactions a year. Centrelink already has a predictive model, called the Job Seekers' Classification Instrument, which evaluates benefit claimants and assesses the risk that they will become long-term unemployed. Claimants thought to be at high risk are then given more help in finding a new job. The agency is now planning a scheme to test the use of data mining to identify fraudulent claimants. The inspiration comes from insurance companies, which use predictive risk models (developed from thousands of claim histories) to analyse claims. Low-risk claims are paid quickly, and high-risk claims are investigated further. Similarly, Centrelink plans to use data mining to identify claimants for whom further investigation is merited.

Tax agencies around the world already mine data to look for possible fraud. But a more recent trend is text-mining to help taxpayers avoid errors. Sweden's tax authority is using SPSS's software to analyse the patterns of mistakes in tax returns so as to provide better guidance and improve the design of tax forms. And Australia's tax office is employing SAS tools to sort queries from taxpayers who are uncertain whether the rules apply to them or not. The office can then supply taxpayers with the right information—and learn which parts of the tax code are causing the most confusion. Data-mining software is also used by Denmark's National Board of Health, France's benefits agency, the South African treasury and Belgium's finance ministry for performance measurement and policy planning.

All of these schemes use data mining in an effort to improve the delivery of public services. But despite the good intentions, the collection and analysis of personal data by governments inevitably raises Big Brotherish concerns over civil liberties. In Britain, for example, the National Health Service is establishing a national database so that the most important data about patients can be called up by any hospital in the country. But many family doctors are refusing to hand over records, which are now kept in local surgeries, because to do so would break patient confidentiality. Liberty, a human-rights campaign group, worries that data collected by one arm of government will be made available to others.

Another worry is that data mining could prove counterproductive. "Those at the more vulnerable end of the social scale are likely to stop seeking advice and help if they know that the information will be noted and generally available," says Gareth Crossman of Liberty. Yet another concern is that data-mining and classification schemes can get things wrong. The America Civil Liberties Union, for example, is worried about the Automated Tracking System, an American security scheme that uses data mining to assign a risk score to anyone who enters the country. If a model labels someone as high-risk, there is no way to find out why or to challenge the label.

Dr Paul Henman from the University of Queensland, who has written extensively on the subject, raises a rather more philosophical objection to government data-mining: that the technology starts to transform the nature of government itself, so that the population is seen as a collection of sub-populations with different risk profiles—based on factors such as education, health, ethnic origin, gender and so on—rather than a single social body. He worries that this undermines social cohesion. "A key principle in liberal democracies is that we are all peers and equal before the law," he says. But for proponents of the technology, such segmentation is the whole point: policies, like supermarket special offers, are often aimed at groups—and the more accurately they can be targeted, the better. ■

The slow death of dial-up

The internet: The spread of broadband connections heralds the demise of dial-up access. But it will take a long time to die

"WHO would have thought that the distorted screams of two modems introducing themselves would come to symbolise the dawn of the greatest communications medium ever invented?" muses Sky Dayton, who founded EarthLink, an internet-access provider, in 1994. In the early days of the internet, only a lucky few in business, government and academia enjoyed permanent access to the network; most people, including Mr Dayton's customers at the time, had to put up with slow, temporary links via dial-up modems.

The rise of broadband connections in recent years means that such modems are now in retreat. South Korea was the first country in which broadband subscribers exceeded dial-up users, back in 2000, says Taylor Reynolds, an analyst at the OECD. Broadband overtook dial-up within OECD countries, and probably worldwide, in 2005. According to the International Telecommunication Union, broadband accounted for 56% of global internet subscriptions by the end of 2005.

But even though the dial-up modem is clearly on the way out, it will take a long time to die. "The rumour of dial-up's death has been greatly exaggerated," says Bernd Lienhard of Conexant, a company that is the leading supplier of analogue modem components. He would say that. But his firm will ship its billionth set of modem chips this year, a milestone that highlights the modem's continued role in keeping the world connected. Dial-up has life in it as a lowest common denominator and will linger on, even in the de-

veloped world, particularly among the rural, the elderly and the contrary—those too far from telephone exchanges for broadband, too timid to change, or all too happy with dial-up's limited speed.

For internet users in rural areas, dial-up may be the only affordable way to get online. (Satellite-based broadband access tends to be much more expensive, and coverage of terrestrial wireless-broadband technologies, such as WiMax, is still very limited.) For their part, elderly users who rely on dial-up access may see little reason to upgrade to broadband. "By dint of their behavioural patterns, they don't have big demands for extra speed," says John Horrigan, the associate director of the Pew Internet & American Life Project, a non-profit research body.

That could change as broadband access is increasingly bundled together with telephone service at little or no extra cost, says Steve Weller of uSwitch, a British service-comparison website. In Britain, for example, combined telephone and broadband bundles are now available for as little as £11 ($21) per month. As broadband is bundled and becomes even cheaper than dial-up, he expects more older surfers to switch.

Contrary users may choose to remain on dial-up simply because the slow speed and intermittent connection provides a bulwark against the fast-moving online world. "There is a sizeable minority that stubbornly clings to dial-up," says John Navas, who maintains an extensive list of "frequently asked questions" about modems with corresponding answers on the web (see modemfaq.home.att.net). In yet another sign of the dial-up modem's inexorable decline, Mr Navas says that the traffic to this site has fallen from around 1.5m to 150,000 page views per year over the past four years.

Some people also prefer dial-up because they are not comfortable with the idea of an always-on broadband connection, says Daryle Brown of US Robotics, a maker of modems and other peripherals. They worry about people being able to "hack in through the ether," he says. Using a dial-up link certainly makes it less likely that a computer will be compromised. But it also makes downloading of multi-megabyte security patches and software updates almost impossible.

As with the AK47 rifle and the Jeep, resiliency is one of the dial-up modem's saving graces. Even the worst phone line can be enough to maintain a meagre but consistent data connection, sometimes at rates as low as 300 baud (bits per second)—a term that is unknown to most people under 30. Modems are also incredibly cheap, costing $2-5 to build into a computer. That highlights another area where dial-up will live on, at least for a while: among those who venture off the beaten track (in other words, to hotels without broadband, Wi-Fi, or a nearby internet café). "It's still the most ubiquitous offering that's out there," says Ken Denman, the boss of iPass, a firm that provides dial-up and Wi-Fi links for millions of corporate road warriors.

The high-pitched shrieking of dial-up modems, once the herald of a new digital age, now increasingly evokes a bygone era. It may even make some users feel nostalgic. But only up to a point. "It's not likely that you're ever going to see dial-up hobbyist clubs," says Dr Horrigan. ■

Bright sparks

Innovation Awards: We invite nominations for our annual prizes recognising innovators

THE *Economist*'s sixth annual Innovation Summit will take place in London on October 19th. Speakers from industry and academia will examine the latest trends in the management of innovation, from the laboratory to the marketplace. At an awards ceremony on October 18th, we will also honour successful innovators in a range of fields.

Accordingly, readers are invited to nominate outstanding innovators in seven categories: bioscience; energy and the environment; computing and telecoms; "no boundaries" (which includes materials science, nanotechnology and other emerging fields); consumer products; business processes; and social and economic innovation, a category that recognises individuals who have pioneered novel technologies and business models that improve everyday lives.

Nominees should be people, not companies, who are responsible for an innovation that has been a proven success in the past decade. Please e-mail nominations to innovation@economist.com, giving the nominee's name, current affiliation and contact information, and a 100-word summary explaining why the nominee deserves to win the award in a particular category. The submissions will be judged by a panel of technology and business experts, including several previous winners. The deadline for nominations is April 10th.

Woodstock revisited

Energy: Could new techniques for producing ethanol make old-fashioned trees the biofuel of the future?

MANKIND has used trees as a source of fuel for thousands of years. But now the notion of exploiting trees for fuel is being updated with a high-tech twist. The idea is to make ethanol, a biofuel that usually comes from maize (corn) or sugar cane, from trees instead. Politicians and environmentalists are embracing ethanol for a number of reasons. Unlike oil, ethanol is renewable: to make more of it, you grow more crops. And blending ethanol into ordinary petrol, or burning it directly in special "flex-fuel" engines, reduces greenhouse-gas emissions.

Why use trees, rather than maize or sugar cane, as a feedstock for ethanol? Because "treethanol" has the potential to be much more energy efficient. The ratio of the energy yielded by a given amount of ethanol to the energy needed to produce it is called the "energy balance". The energy balance for ethanol made from maize is the subject of much controversy, but America's energy department puts it at 1.3; in other words, the ethanol yields 30% more energy than was needed to produce it. For ethanol made from sugar cane in Brazil, the energy balance is 8.3, according to the International Energy Agency.

But for ethanol made from trees, grasses and other types of biomass which contain a lot of cellulose, the energy balance can be as high as 16, at least in theory. In practice the problem is that producing such "cellulosic" ethanol is much more difficult and expensive than producing it from other crops. But the science, technology and economics of treethanol are changing fast. Researchers are racing to develop ways to chip, ferment, distil and refine wood quickly and cheaply.

Interest in cellulosic ethanol is growing as the drawbacks of making ethanol from maize and sugar become apparent. Both are important food crops, and as ethanol production is stepped up around the world, greater demand is driving up the prices of everything from animal feed to cola and biscuits. The price of a bushel of corn rose by 70% between September 2006 and January 2007 to reach its highest level in a decade. Mexico's president, Felipe Calderón, even capped the price of corn tortillas in January as America's fast-growing ethanol industry caused prices to rocket. There are clear signs of a backlash against ethanol made from food crops. Supply is struggling to keep up, and as more governments introduce schemes to promote biofuels and cut greenhouse-gas emissions, the tension between food and fuel will only intensify.

Growing maize requires a lot of land, water and agrichemicals, so environmental groups such as America's Natural Resources Defence Council argue that it is merely a short-term, first-generation approach to making ethanol. Most energy experts reckon that using maize-based ethanol as a substitute for petrol can reduce America's demand for petrol by 10-15% at best. As for sugar, its growing value as a biofuel feedstock means that in Brazil, which is now one of the world's largest producers and exporters of ethanol, there is pressure to flatten rainforests to make more room for sugar production. One green objective (reducing dependency on fossil fuels) thus conflicts with another (preserving the environment).

Trees to the rescue

Cellulosic ethanol would address many of these problems. Writing in the *Wall Street Journal* recently, Vinod Khosla—a Silicon Valley venture capitalist who has made a fortune by spotting opportunities in fields from biotechnology to software—argued that America needs "cellulosic biofuels to win the war on oil…we must encourage research on biomass feedstocks, tomorrow's energy crops."

Trees are a particularly promising feedstock because they grow all year round, require vastly less fertiliser and water and contain far more carbohydrates (the ▸▸

"Treethanol has particular appeal in countries that have a lot of trees and import a lot of fossil fuel, such as New Zealand and Sweden."

chemical precursors of ethanol) than food crops do. Ethanol is the result of the fermentation of sugars, which is why it can be so simply and efficiently made from sugar cane. Making ethanol from maize is a bit more complicated: the kernels are ground into flour and mixed with water, and enzymes are added to break the carbohydrates from the maize down into sugars, which can then be fermented into ethanol. Making ethanol from cellulosic feedstocks is harder still, however, since it involves breaking down the tough, winding chains of cellulose and hemicellulose from the walls of plant cells to liberate the sugars. This can be done using a cocktail of five or six enzymes, says Edward Shonsey, the boss of Diversa, a biotech firm based in San Diego. The problem is that although such enzymes exist, they are expensive. It is no use being able to produce ethanol from trees if it costs $5 a gallon.

The lure of bioprospecting

So if cellulosic ethanol is to live up to its promise, researchers will have to find cheaper and more efficient enzymes. Grass, trees and other biomass feedstocks consist of a mixture of cellulose, hemicellulose and lignin, a tough material that helps plants keep their shape. Two large producers of industrial enzymes—Genencor, an American firm, and Novozymes, from Denmark—are working to reduce the cost of cellulase enzymes, which can break down cellulose, to below $0.10 per gallon of ethanol. For its part, Diversa is developing enzymes capable of breaking down hemicellulose. One approach, says Mr Shonsey, is to tweak the structure of existing enzymes to try to make them work better. Another approach is "bioprospecting"—looking for natural enzymes in unusual places, such as in the stomachs of wood-eating termites.

Treethanol has particular appeal in countries that have a lot of trees and import a lot of fossil fuel. Top of the list is New Zealand: in 2005 the country exported lumber worth NZ$411m ($290m) and imported fossil fuel costing NZ$4.5 billion. In January two of New Zealand's Crown Research Institutes, Scion and AgResearch, announced a research partnership with Diversa. The aim is to investigate the feasibility of producing enough ethanol from trees to fuel all the vehicles on New Zealand's roads without fossil-fuel imports—in other words, to make the country self-sufficient in energy.

BioJoule, a start-up based in Auckland, New Zealand, is planning to build a pilot plant to produce ethanol from a type of willow. The idea, says James Watson, BioJoule's co-founder, is that farmers would grow coppiced willow trees which could be processed into wood chips and then transported to a conversion plant to be turned into ethanol. The process would produce two useful by-products: unsulphonated lignin, a commercially valuable polymer, and xylose, a type of wood sugar used in dyeing and in foods for diabetics. Selling these by-products, Mr Watson calculates, means his plant should be able to produce ethanol for a direct cost of $1.13 per gallon, which compares favourably with ethanol from American maize ($1.44) and is not much more than Brazilian sugar-cane ($0.95).

Because willows are fast-growing and can thrive even on nutrient-poor soils, BioJoule's technology could also be used in other parts of the world where there is strong demand for energy, but the soil is not suitable for food crops. Mr Watson thinks China and India look promising.

Another country keen on cellulosic ethanol is Sweden, which is relying heavily upon wood-based solid and liquid biofuels as part of its plan to wean itself off oil by 2020. But where New Zealanders favour willows, the Swedes prefer poplars, since they are abundant and their biology is well understood, says Mats Johnson of SweTree Technologies, based in Umea in northern Sweden.

Even if the right cocktails of enzymes can be found, sceptics say treethanol will still have several problems to overcome. In particular, trees take much longer to grow than grass or food crops—so it might make more sense to make cellulosic ethanol from fast-growing grasses, or the left-over biomass from food crops. Some environmentalists worry that having struggled for years to protect forests from overexploitation, demand for biofuels could undermine their efforts.

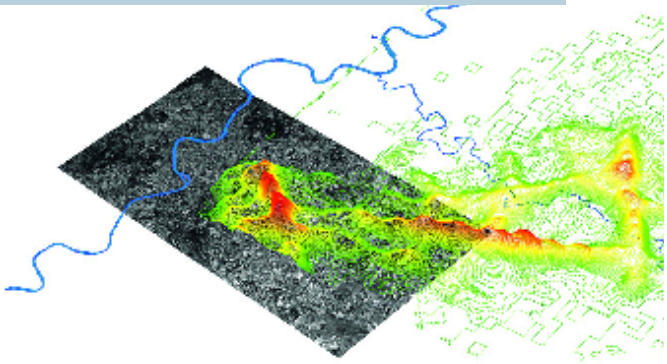
And now for Frankentreethanol

One idea is to create new, fast-growing trees to address this problem, either through careful breeding or genetic modification. A team led by Vincent Chiang, a biologist at North Carolina State University, is investigating the production of ethanol from genetically modified trees, with funding from America's Department of Agriculture. "Our preliminary results clearly point out that transgenic wood can drastically improve ethanol-production economics," says Dr Chiang.

A tree's rate of growth is limited by its lignin structure, which is what determines the tree's strength and form. Trees containing less lignin and more cellulose would both grow faster and also produce more ethanol. Some transgenic trees of this kind are being tested in America. Dr Chiang and his colleagues are also looking at ways to modulate the genes that determine the structure of a tree's sugar-containing hemicelluloses in order to make the breakdown and fermentation processes more efficient.

But Steven Strauss, a forest biologist at Oregon State University, says that because of the great genetic variation in willows and poplars, genetic modification may not be necessary. By screening existing varieties it ought to be possible to identify those well suited to ethanol production. Conventional breeding and cloning are very efficient when there is such a variety of species and hybrids to choose from, he says, and the tight regulation of genetically modified organisms makes using the technology expensive and time consuming.

Hundreds of thousands of years ago, when man first gained mastery over fire, wood was his primary fuel. In the past few centuries fossil fuels have risen to prominence, with calamitous consequences for the world's climate. A diversity of new fuels and energy sources seems the most likely future. It would be fitting if humanity's portfolio of new energy technologies had a place for wood, the oldest of them all. ■



Go with the flow

Visualisation: Data from mobile-phone networks can create maps that show how people are moving around

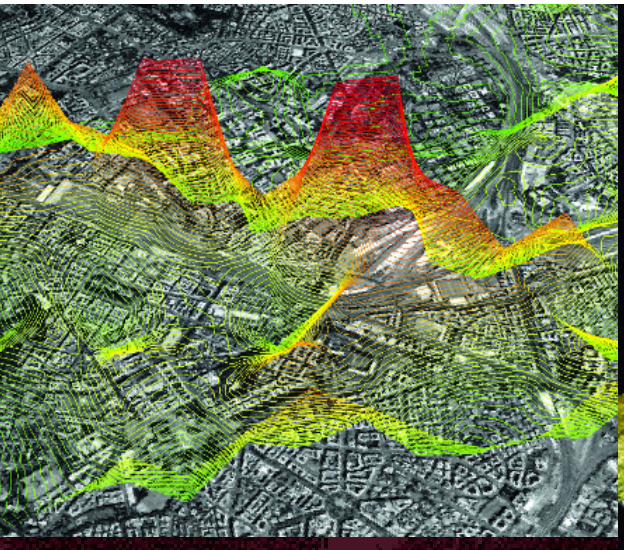
WHERE is everybody? Being able to monitor the flow of people around a city in real time would provide invaluable information to urban planners, transport authorities, traffic engineers and even some businesses. Bus timetables could take account of hourly or daily variations; advertisers would be able to tell which billboards were most valuable. Such information can be collected via traffic helicopters, roadside cameras, police patrols, sensors embedded in roads, tracking units in vehicles, data from public-transport turnstiles and surveys. But the resulting picture is often inadequate, expensive—or both.

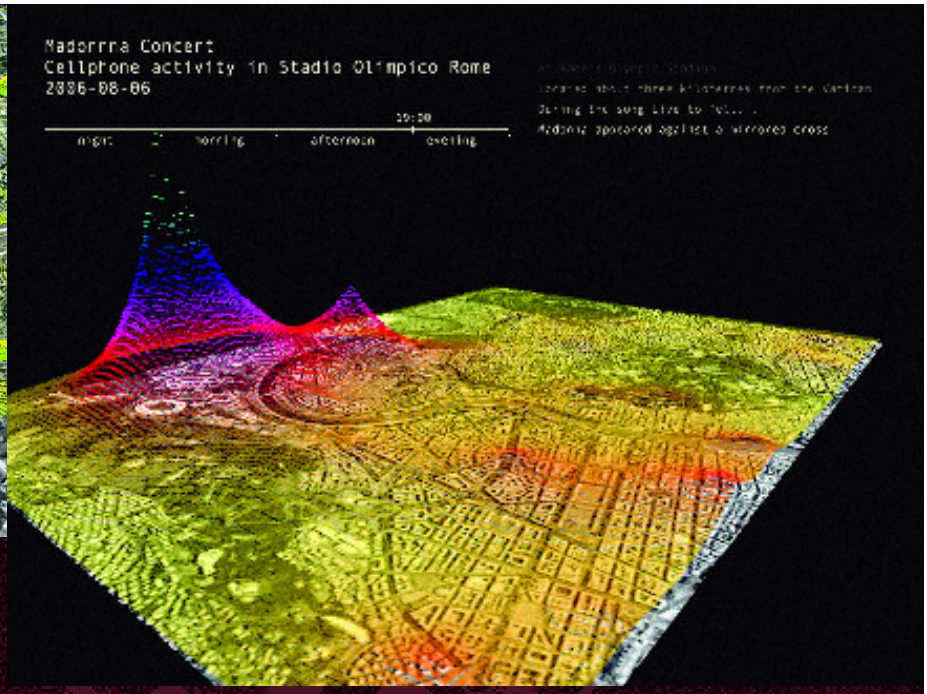
A new scheme devised by researchers at Massachusetts Institute of Technology (MIT) takes a different approach. Given that almost everyone in the developed world now carries a mobile phone, why not use the data from mobile-phone networks? Such networks have to keep track of where subscribers are, as they roam from cell to cell, in order to route calls and text messages. The MIT researchers have been testing the idea using anonymised data from two European operators, Telecom Italia and Mobilkom Austria, to analyse where mobile phones (and therefore people) are at any given moment.

The results take the form of luminous maps adorned with moving and colour-coded arrows, dots and patches of light that indicate the speed and population density of people in the city in question, with an accuracy down to a dozen or so metres. "You see how the city is pulsating," says Carlo Ratti, who is leading the research as head of the SENSEable City Laboratory at MIT.

The new approach has a number of advantages over other methods. Sensors embedded in streets can accurately count vehicles, for example, but cannot count passengers or detect pedestrians and cyclists. Sensors and cameras also fail to provide "origin-destination" (OD) statistics—jargon for information about where people are travelling to and from, and how long their journeys take. Such information is usually collated using surveys, which are very expensive to carry out. Using data from phone networks promises to be much cheaper. "It's pretty simple: you just need a digital map and you show the data," says Hannes Ametsreiter, head of marketing at Mobilkom Austria, which is working with MIT to map the city of Graz. "This could be an opportunity for us."

With markets becoming saturated and mobile operators' revenue-growth slowing—there are already 112 mobile devices for every 100 Austrians, for example—providing information about travel patterns could be a lucrative opportunity for tele-





Above: Map showing the distribution of mobile-phone users (and hence people) around Rome's Termini station.
Right: A large crowd assembles at Rome's Olympic stadium for a Madonna concert

"People-movement maps could lead to improvements in transport planning, traffic-light placement, signage and road layout."

coms firms. One potential customer is Seat, a firm based in Milan that provides real-time traffic maps that drivers keen to avoid traffic jams can call up on the internet before setting out. The company gathers information from roadside cameras, Italy's national toll-road operator, the police, and satellite-tracking systems installed in more than 220,000 vehicles across Italy. All this costs a lot of money and provides only a partial picture of the state of Italy's roads.

Paolo Cellini, the head of Seat's internet division, says using data from mobile-phone networks instead would dramatically improve the service. He estimates that within two years Seat will sell subscriptions to onboard navigation systems updated in real time with information on traffic levels and average speeds. After that, Seat will provide traffic forecasts produced by correlating past traffic patterns with variables including weather, the date and nearby events, says Mr Cellini. He expects to pay telecoms operators more than €30m ($40m) a year for access to their location data.

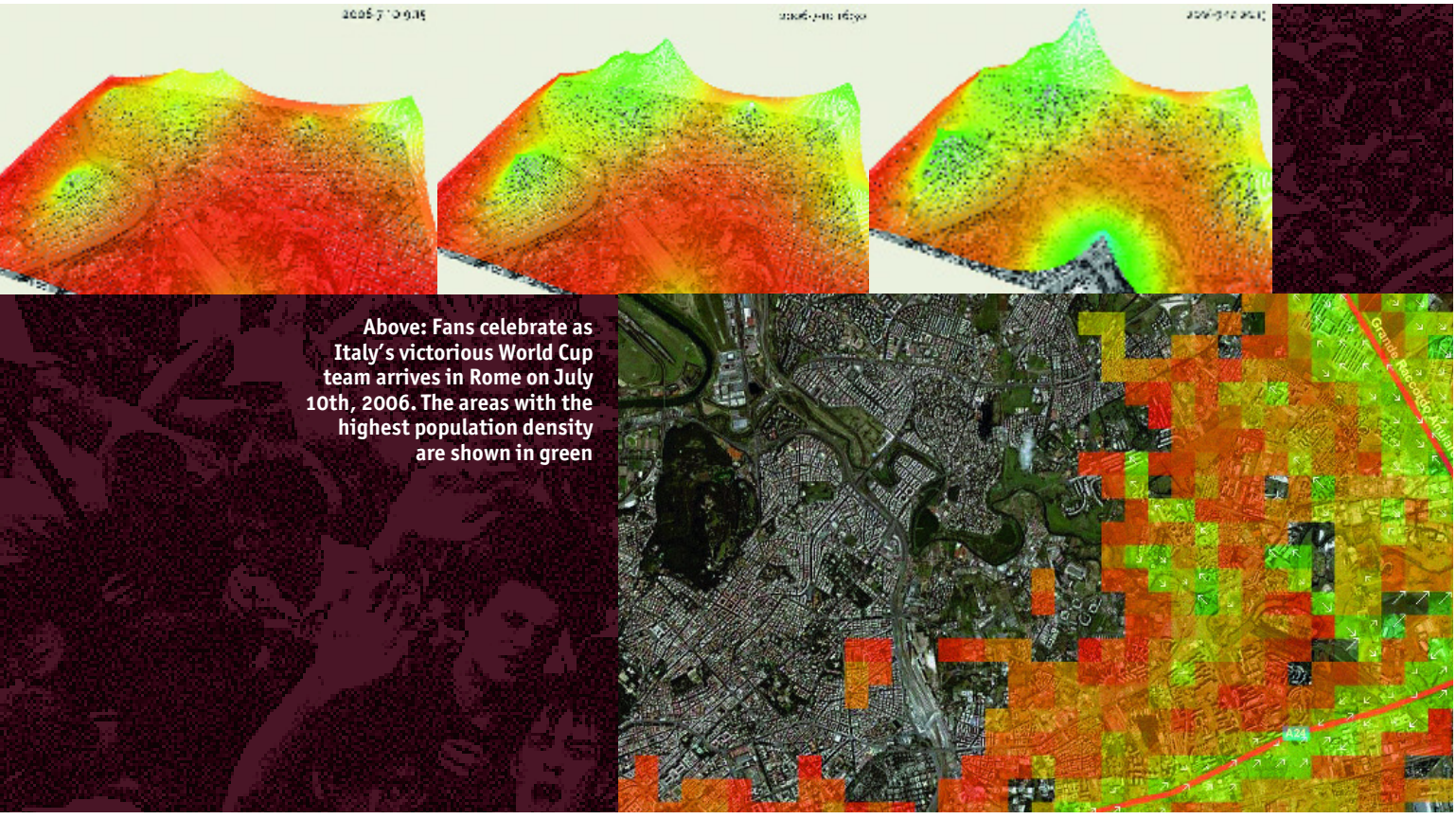
City-planning departments offer another important market, says Ricky Burdett, architecture adviser to the Mayor of London and the director of last year's Venice Architecture Biennale, at which MIT displayed a prototype real-time map of Rome (see picture). London is preparing for a projected additional 1m inhabitants in the next 15 years, and people-movement maps "will be invaluable" in planning housing and transport. Politicians will take to the technology because it can provide solid statistical backing for politically unpopular planning decisions.

Follow the people

It is not hard to think of other uses for the technology. Estate agents, for example, might be better able to appraise commercial property by determining how many pedestrians pass a given storefront. Advertisers would appreciate knowing how many eyeballs pass a hoarding and how those numbers vary between weekdays and weekends. And tourism authorities might change their promotional campaigns abroad after noting which nationalities (identified by their home networks) spend most time in town and which prefer to lie on the beach.

Rome will probably be the first city with commercially available people-movement maps. When MIT presented its project, called Real Time Rome, to Telecom Italia last year, the top management at the Italian telecoms giant gave the scheme its backing. So did Rome's mayor, Walter Veltroni, and the city's transport authority, ATAC. Fulvio Vento, the director of ATAC, says the new system will allow him to scrap an expensive annual OD survey of 2,000 people, which costs more than €60 per respondent to carry out. Mr Vento says the maps will give his planners extraordinary and unprecedented power to shuffle the schedules of Rome's 2,100 buses as demand shifts throughout the day. It could also lead to improvements in traffic-light placement, signage and road layout. Roma Metropolitane, the city authority for Rome's expanding subway network, also says the maps will be a boon to planners.

Samarcanda, a taxi firm based in Rome, is providing free consulting services to the project in return for access to the data. The company's boss, Giovanni Coco, says his drivers still choose their routes based on habit and experience. "It's a disaster," he says, "we need help." Transport planning will provide a ready market, in short, but plenty of other potential uses for the technology are waiting to be discovered. People-movement maps would appear to have a colourful and pulsating future. ■



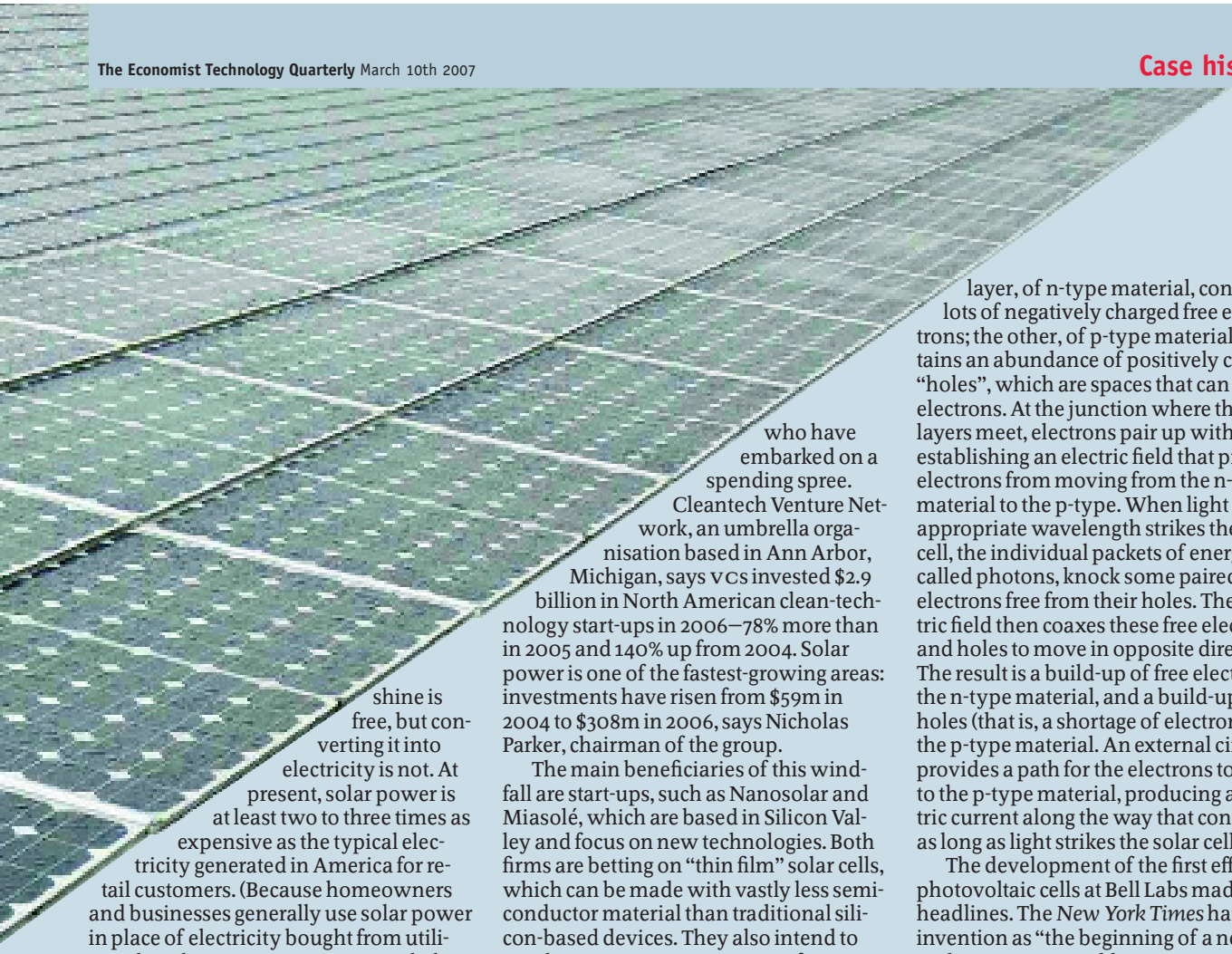
Above: Fans celebrate as Italy's victorious World Cup team arrives in Rome on July 10th, 2006. The areas with the highest population density are shown in green

Bright prospects

Energy: Solar power is in the ascendant. But despite its rapid growth it will not provide a significant share of the world's electricity for decades

LAST year Microsoft outfitted its campus in Silicon Valley with a solar system from SunPower, a local company that makes high-efficiency (and, some say, the world's best-looking) solar panels. A few months later Microsoft's arch-rival, Google, began building something on an even grander scale—one of the largest corporate solar installations to date. But all of this may yet be topped by Wal-Mart. In December the retail giant solicited bids for placing solar systems on the roofs of many of its supermarkets. Besides producing favourable publicity, the appeal of using solar power is obvious. Unlike fossil fuels, which produce significant amounts of pollution and enormous amounts of greenhouse gases, the sun's energy is clean and its supply virtually limitless. In just one hour the Earth receives more energy from the sun than human beings consume during an entire year. According to America's Department of Energy, solar panels could, if placed on about 0.5% of the country's mainland landmass, provide for all of its current electricity needs.

Yet since they were first invented more than five decades ago, photovoltaic solar cells—devices made of semiconductor materials that convert light into electricity—have generated much publicity but little energy. In 2006 photovoltaic systems produced 0.04% of the world's electricity, according to the International Energy Agency. The thing that has held back the widespread deployment of solar panels is their price. Sun- ▸▸



shine is free, but converting it into electricity is not. At present, solar power is at least two to three times as expensive as the typical electricity generated in America for retail customers. (Because homeowners and businesses generally use solar power in place of electricity bought from utilities, the relevant comparison is with the price of retail electricity, not the lower wholesale prices from power plants.)

Even so, many people believe the prospects for solar energy have never looked brighter. Decades of research have improved the efficiency of silicon-based solar cells from 6% to an average of 15% today, whereas improvements in manufacturing have reduced the price of modules from about $200 per watt in the 1950s to $2.70 in 2004. Within three to eight years, many in the industry expect the price of solar power to be cost-competitive with electricity from the grid.

In the meantime, some European countries and parts of America have instituted subsidies to support the adoption of solar power. California's "Million Solar Roofs" initiative, for example, will hand out about $3 billion in rebates and other incentives over a decade to encourage the installation of solar panels. In Europe Germany offers producers of solar power generous feed-in tariffs, which have made it the largest market for photovoltaics in the world. As a result of such incentives, the market for solar power has grown by about 40% a year for the past five years, reaching about $11 billion in 2005. In a matter of a few years, solar power has become a big business.

This development has not gone unnoticed by America's venture capitalists, who have embarked on a spending spree. Cleantech Venture Network, an umbrella organisation based in Ann Arbor, Michigan, says VCs invested $2.9 billion in North American clean-technology start-ups in 2006—78% more than in 2005 and 140% up from 2004. Solar power is one of the fastest-growing areas: investments have risen from $59m in 2004 to $308m in 2006, says Nicholas Parker, chairman of the group.

The main beneficiaries of this windfall are start-ups, such as Nanosolar and Miasolé, which are based in Silicon Valley and focus on new technologies. Both firms are betting on "thin film" solar cells, which can be made with vastly less semiconductor material than traditional silicon-based devices. They also intend to employ new, continuous manufacturing processes that promise to reduce the cost of solar panels very quickly in future.

Dawn of a new technology

Humans have always depended on energy from the sun, though it was exploited mostly indirectly for thousands of years. The photoelectric effect was not discovered until 1839, when Alexandre Becquerel, a French physicist, observed that light could generate an electric current between two metal electrodes immersed in a conductive liquid. About 40 years later Charles Fritts, an American inventor, built the first solar cell. Made with selenium and a thin layer of gold, the device was less than 1% efficient.

At the birthplace of the transistor, the now legendary Bell Laboratories, a team of scientists invented the first practical solar cell in 1954. The core of the invention was a semiconductor device made of thin strips of crystalline silicon that boasted a conversion efficiency of 6%. During one of the first public demonstrations of the "Bell Solar Battery" the device powered a small radio transmitter, carrying both speech and music.

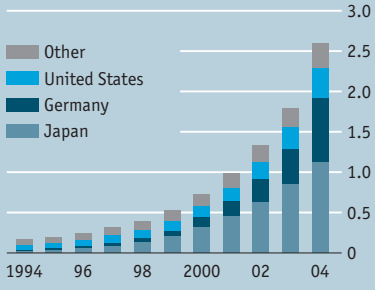
Since then, the basic structure of a solar cell has changed little. It is composed of two layers of semiconductor material, typically silicon, that are sandwiched together between metal contacts. One layer, of n-type material, contains lots of negatively charged free electrons; the other, of p-type material, contains an abundance of positively charged "holes", which are spaces that can accept electrons. At the junction where the two layers meet, electrons pair up with holes, establishing an electric field that prevents electrons from moving from the n-type material to the p-type. When light of an appropriate wavelength strikes the solar cell, the individual packets of energy, called photons, knock some paired-up electrons free from their holes. The electric field then coaxes these free electrons and holes to move in opposite directions. The result is a build-up of free electrons in the n-type material, and a build-up of holes (that is, a shortage of electrons) in the p-type material. An external circuit provides a path for the electrons to return to the p-type material, producing an electric current along the way that continues as long as light strikes the solar cell.

The development of the first efficient photovoltaic cells at Bell Labs made headlines. The *New York Times* hailed the invention as "the beginning of a new era" and *US News & World Report* suggested that solar cells "may provide more power than all the world's coal, oil and uranium." But although the "solar battery" received lots of publicity, the high cost—about $200 per watt—made commercialisation unfeasible.

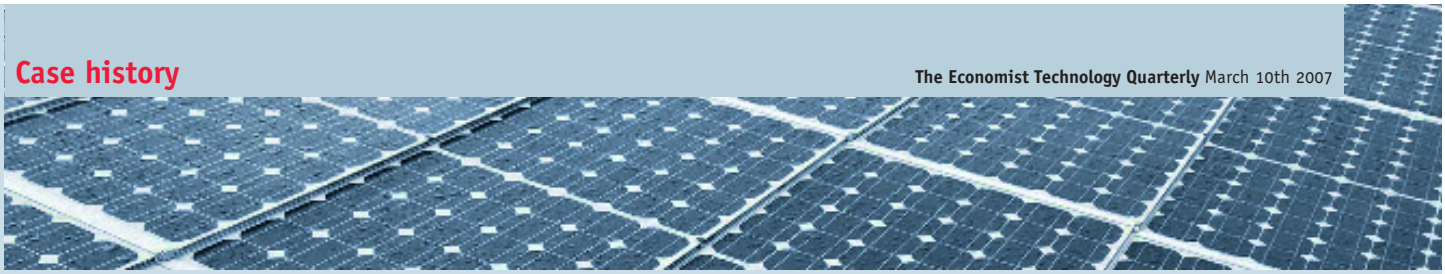
Fortunately, a few years later both America and the Soviet Union became interested in using solar power in space, where its advantages became apparent very quickly. In 1957 the Soviet Union launched *Sputnik I*, the first artificial satellite. But it stopped transmitting data after only a few weeks because its batteries ran out. In 1958 America fired the first solar-powered satellite into orbit. The batteries

Rising sun

Cumulative installed solar power, gigawatts



Source: BP



of *Vanguard I* also ran out after several weeks, but its solar panels powered the on-board transmitter for years to come.

The ensuing competition between America and the Soviet Union funnelled billions of dollars into the development of space technologies, and that included solar cells. Besides efficiency, durability and reliability, the most important requirement for solar cells was how much power they could generate per unit of weight. Cost considerations, at that time, were far less important. Solar cells back then were made much like jewellery, recalls Bill Yerkes, an industry veteran who is now the chief technologist at Solaicx, a start-up dedicated to reducing the price of silicon wafers for the solar industry.

The man who helped bring solar power down to earth was Elliot Berman. He realised that for photovoltaics to succeed in terrestrial applications, reducing their cost was vital. At his company, Solar Power Corporation, he pioneered a number of manufacturing changes. Among other things, he decided to buy cheap silicon wafers that had been cast aside by the semiconductor industry. The wafers he bought were also larger in size, which made it possible to increase the diameter of the individual cells, which in turn reduced the number of cells needed to make a module. As a result he was able to produce far less expensive solar panels, reducing the selling price from $100 per watt in 1970 to $20 per watt in 1973.

The first terrestrial solar cells were used for off-grid applications in remote locations where placing conventional power lines was not possible or economical. Among the earliest buyers of solar panels were gas and oil companies, which began to use solar power in the mid-1970s to protect wellheads and underground pipelines from corrosion and to power navigational aids on offshore oil rigs. In the 1980s America's Coast Guard began using solar panels to supply electricity to buoys. By the early 1990s solar cells powered hundreds of diverse off-grid applications including telecoms equipment, emergency roadside phone boxes, and consumer devices such as calculators and watches.

Although solar cells had now penetrated numerous niche markets, the cost of making them still priced them out of the market for grid-connected electricity. That changed in 1994, when Japan began a subsidy programme. By the time the subsidies were phased out in 2005, the programme had achieved its goal. In Japan, where electricity is expensive, solar power is now fully cost-competitive with power from the grid, says Paul Maycock of PV Energy Systems, a consultancy based in Virginia.

Over the years the solar industry has been able continuously to reduce the cost of silicon-based solar panels. For every doubling in cumulative production volume, the cost of modules has declined by about 20%. That translates to an annual reduction in manufacturing costs of about 5%. A variety of factors has contributed to this, including making the wafers thinner, increasing the efficiency of the cells, and taking advantage of economies of scale by building bigger and more automated factories.

Fifty-three years after their invention, silicon-based solar cells still make up more than 90% of the market. In 2008 the solar industry is even expected to surpass chipmaking in its appetite for silicon feedstock. The extent of the demand has caused a global silicon shortage, limiting sales growth for the solar industry to less than 20% in 2006, says Jesse Pichel, an analyst at Piper Jaffray. As prices for silicon have gone up, so have prices of solar modules. After decades of steady decline, prices increased from a low of $2.70 per watt in 2004 to about $4 per watt in the spring of 2006.

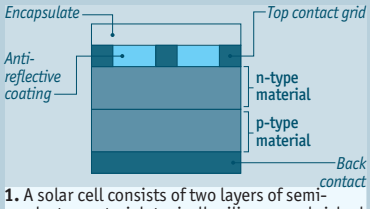
That has increased the opportunity for "thin film" solar cells, which use little or no silicon. Because thin-film cells are very efficient at absorbing photons, they require less than 1% of the semiconductor material needed by their conventional counterparts. At the moment, about 40% of the cost of a conventional module goes on silicon. "If you're making a thin-film module, much of that cost will go away," says John Benner, a group manager at the National Centre for Photovoltaics, a division of America's National Renewable Energy Laboratory. Thin-film technology also offers the potential for faster manufacturing processes and higher levels of automation, which cut costs.

For those reasons, people have wanted to move towards thin-film cells for a long time. But cadmium sulphide, an early thin-film technology that was pursued in the 1960s and 1970s in many research laboratories, did not live up to expectations. In the 1980s most scientists finally abandoned the material, since they were unable to make it stable. Even in newer thin-film technologies, high-volume production has been difficult.

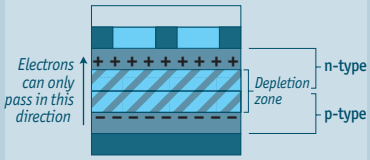
Cells based on amorphous silicon, for example, have been in development for several decades. Unlike the silicon in conventional solar cells, which is arranged using expensive manufacturing processes into a uniform crystalline structure, amorphous silicon is highly disordered and can therefore be made more cheaply. But its efficiency tends to degrade when exposed to sunlight. That problem, however, has now been largely eliminated, says Terence Parker of United Solar Ovonic, one of the firms making amorphous-silicon cells. Its triple-junction solar cells, which can absorb light of different wavelengths, are so popular

Sandwich in the sun

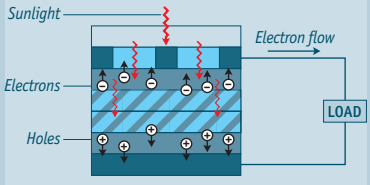
How a solar cell works



1. A solar cell consists of two layers of semiconductor material, typically silicon, sandwiched together between metal contacts. One layer, of n-type material, contains lots of negatively charged free electrons; the other, of p-type material, contains an abundance of positively charged "holes", which are spaces that can accept electrons.

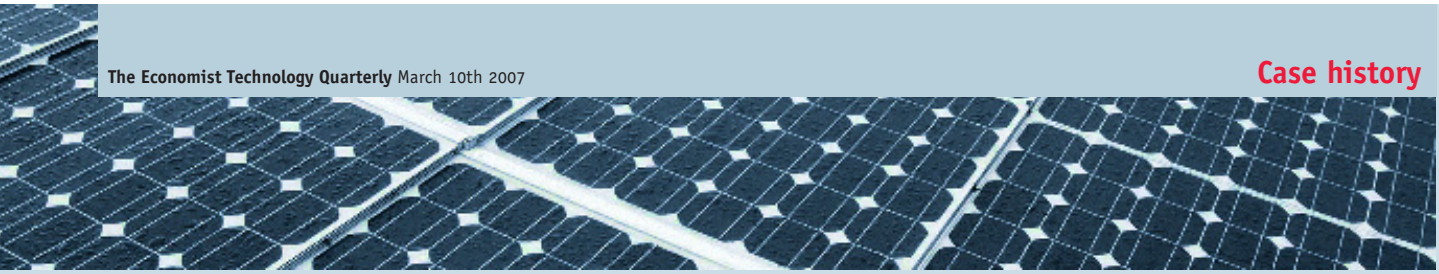


2. At the junction where the two layers meet, electrons pair up with holes, establishing an electric field that prevents electrons from moving from the n-type material to the p-type.



3. When light of an appropriate wavelength strikes the solar cell, the individual packets of energy, called photons, knock some paired-up electrons free from their holes. The electric field then coaxes these free electrons and holes to move in opposite directions. The result is a build-up of free electrons in the n-type material, and a build-up of holes (that is, a shortage of electrons) in the p-type material. An external circuit provides a path for the electrons to return to the p-type material, producing an electric current along the way that continues as long as light strikes the solar cell.

Source: *The Economist*



that the firm has become one of the largest thin-film manufacturers in the world.

Another promising thin-film outfit is First Solar, based in Arizona. Besides completing a successful stockmarket flotation last November, in which it raised $400m, it is the first company to produce large quantities of cadmium telluride-based solar panels. Although the efficiency of the modules is only 9%—far less than the 13% of an average crystalline-silicon module—the manufacturing cost is also much lower, and works out at about $1.40 per watt. That is about a dollar cheaper than conventional silicon-based modules, and has led to strong demand for the company's panels.

But the lower efficiency of thin films means they need more space: more efficient cells can squeeze more electricity out of a given area. "There is an additional cost at the systems level if the module efficiency is lower," acknowledges First Solar's boss, Michael Ahearn. His company focuses on ground-based and large commercial systems, which are cheaper and easier to install than residential roof-based systems.

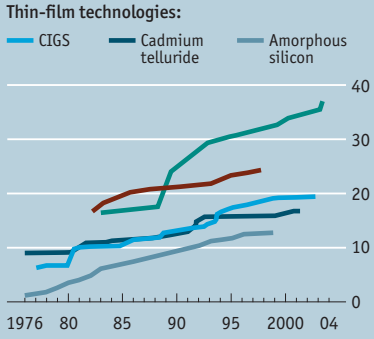
A competing thin-film technology is CIGS, which is short for copper indium gallium diselenide. The current efficiency record for this technology is 19.5%, which is why many start-ups, such as Nanosolar and Miasolé, are pursuing it. CIGS promises to combine low cost with efficiencies comparable to silicon, says Mr Benner.

But producing CIGS-based solar modules is not easy. They are composed of four different materials, which must be uniformly deposited on a backing material, or substrate. This is relatively easy when covering a small area, but it is difficult to maintain the uniformity, and thus the efficiency, of the cells over large areas. Nanosolar, which has raised $100m—more funding than any other solar start-up—believes it has found a cheap and effective solution to the problem. It mixes small precursor particles of the different materials to create a "nanoparticle ink" that is continuously coated onto metal foil and then heated so that the particles assemble correctly.

Miasolé, which is backed by Kleiner Perkins, a big Silicon Valley venture-capital firm, is also developing CIGS-based solar cells. Its approach is to deposit the CIGS layer using a sputtering process borrowed from the disk-storage industry. David Pearce, Miasolé's boss, says the firm is also developing flexible encapsulants for its solar cells, which will make it easier to integrate them into roofing materials and produce custom modules of arbitrary sizes. "It could literally be like roll-out carpet," he says.

Getting better

Conversion efficiency, %



Source: National Renewable Energy Laboratory

Others are taking yet another approach. By using lenses and mirrors to concentrate sunlight onto high-efficiency solar cells, start-ups such as SolFocus, in Palo Alto, are trying to reduce the cost per watt of solar systems. SolFocus's cell technology comes from Spectrolab, a subsidiary of Boeing, which is one of the largest suppliers of solar panels for use in space. David Lillington, Spectrolab's president, says its triple-junction cells have achieved record-breaking efficiencies of over 40% under concentrated sunlight.

These approaches may be very different, but they are all pursuing the same goal—cost-competitiveness with power from the grid. America's Department of Energy aims to get there by 2015. To many in the field this is a conservative target, especially for thin films. With additional gains in cell efficiency and by optimising its manufacturing processes, First Solar hopes to get there in 2010. Nanosolar's boss, Martin Roscheisen, boasts that his company will reach grid parity this year, as soon as its panels hit the market.

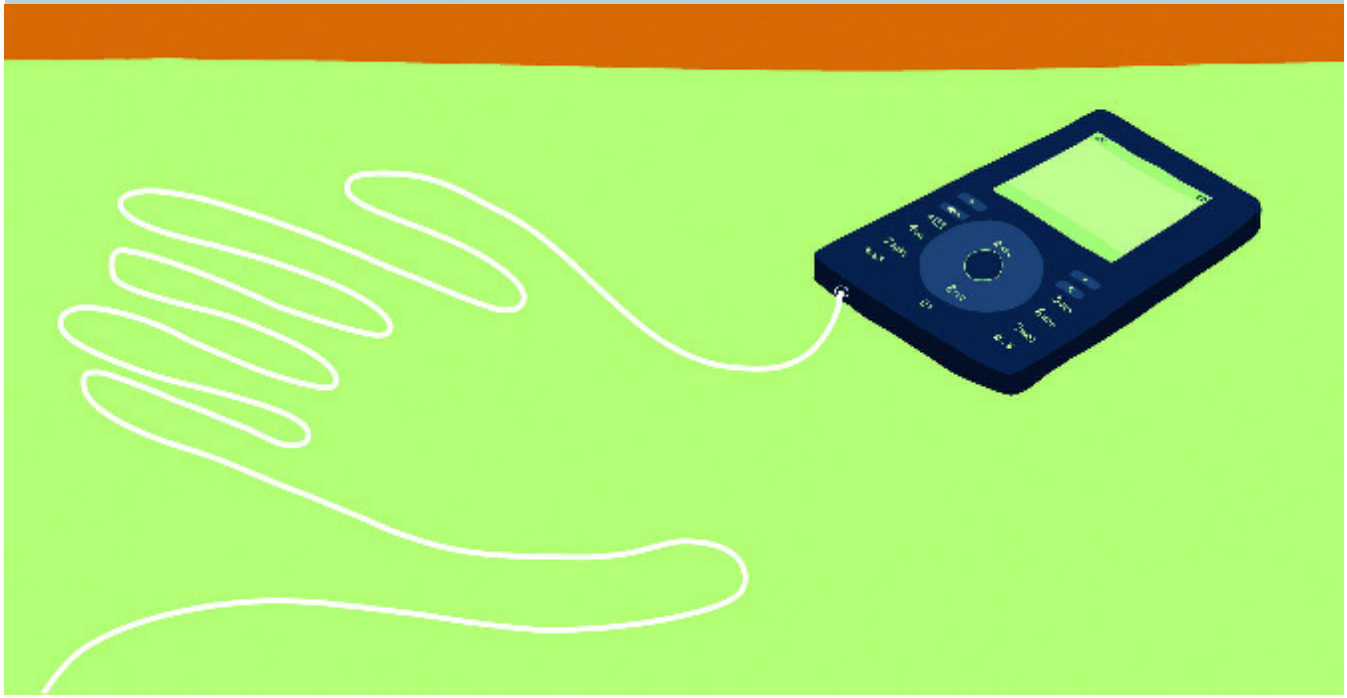
Catching some rays

Not everyone is convinced. "The introduction of any new technology is going to have all sorts of speed bumps," says Mr Benner. The bright prospects for thin-film companies could dim in 2008, when more silicon will reach the market and the much-lamented shortage is expected to end. Some experts even foresee a glut of silicon on the horizon, so that prices for modules could fall considerably. Start-ups will have to ramp up production quickly to compete with cheaper silicon modules. "There will definitely be some shakeout, both in terms of companies and technologies," says Joel Makower, principal of Clean Edge, a research and consulting firm based in San Francisco.

Slow sunrise

The solar industry has in the past profited from the manufacturing improvements of chipmakers, and is now finding ways to benefit from innovations in other high-tech fields. "I think of the silicon solar-cell industry as a marriage between the semiconductor industry, where it gets its base technology, and the CD industry, which is very high volume," says Richard Swanson, SunPower's president and technology chief. Applied Materials, a leading maker of chipmaking gear, recently decided to apply its expertise in making flat-panel displays to thin-film solar panels.

But despite the growing infusion of capital, innovation and talent, solar power will provide only a tiny fraction of the world's electricity needs for the foreseeable future. Even if the industry continues to grow at the same torrid pace that it has for the past few years, it will not be able to supply more than 1% or so of the world's electricity needs for at least another decade. That may sound like a gloomy forecast, but some regard it as a huge opportunity. It means there is a lot of room for growth, says Mr Roscheisen, Nanosolar's irreverent boss. His company generated an enormous amount of buzz last year when it announced plans to build the world's largest solar factory, in California. But, says Mr Roscheisen, "a couple of years from now this factory is not going to look that big." ■



How touching

Computing: "Haptic" technology is gradually bringing the neglected sense of touch into the digital realm

THE smooth, touch-screen display on Apple's snazzy new iPhone, unveiled in January and due to go on sale in June, has gadget fans salivating. In place of the usual keypad, the iPhone uses the screen as an input device, displaying different buttons and icons depending on the task at hand. Rival devices from other handset-makers, including LG and Samsung of South Korea, take a similar approach. Replacing physical buttons with virtual ones certainly makes for greater flexibility—but might it make the phone trickier to use? You can tell when you've pressed a real button because you can feel the subtle "click". But typing on the iPhone, in contrast, is said to be rather fiddly, because there is no such tactile feedback with a touch screen.

That is why Samsung's touch-screen phone, despite being less well known than Apple's device, is worth watching. The SCH-W559 handset, which is so far available only in China, fools the user's sense of touch and mimics the feeling of pressing a mechanical button, even though the surface is actually completely flat. It is the latest example of a new breed of "haptic" technologies that do for the sense of touch what lifelike colour displays and hi-fi sound do for eyes and ears.

Haptics is the science of simulating pressure, texture, vibration and other sensations related to touch. The term is derived from a Greek word meaning "able to lay hold of". Devices that exploit haptics have been around for decades: many modern aeroplanes, for example, have haptic control columns that shake or vibrate to warn the pilot of an approaching stall. The technology has also found its way into video-game consoles, where it adds an extra layer of realism. Players can feel when they are veering off course in a driving game, or when they have been hit in a shooting game. Force-feedback technology, another offshoot of haptics, is used in robotic telesurgery and in surgical simulators to enable surgeons to feel resistance as they move their surgical instruments around, just as they would in conventional surgery.

Even the "vibrate" mode on a mobile phone, which discreetly alerts the user to an incoming call or text message, is an example of haptics. But today's technology fails to take full advantage of the sense of touch. It has particular potential in relaying information to people when their other senses are occupied, as when walking or driving, says Karon MacLean, a researcher at the University of British Columbia in Vancouver, Canada.

Vic Viegas, the boss of Immersion, a company based in San Jose, California, agrees. His firm owns important patents in the field of haptics, and the touch-screen feedback in Samsung's new phone relies on the latest incarnation of Immersion's VibeTonz technology. In previous handsets, the technology was used to provide force-feedback effects when playing games and to provide "vibrotactile feedback" when playing music. "It feels like a sub-woofer," says Mr Viegas.

Feel the force

The new phone goes much further, using very precise actuations of its built-in motors to produce realistic, button-like clicks whenever an onscreen button is pressed. "Using a touch-screen, you normally lose the tactile confirmation you get from pressing a button," says Mr Viegas. But with haptic feedback, on-screen buttons can be made to feel real and are easier to use. "You get the feeling that you have somehow really touched this object on the screen," says Tapani Ryhänen, head of strategic research at Nokia, the world's biggest handset-maker, who has been investigating the idea of adding haptics to Nokia's phones as well.

Most of today's haptic devices rely on motors that either prod or vibrate the skin, but a new technology is emerging that is an even more flexible and effective means of stimulating the sense of touch: skin stretch. By laterally stretching the surface of the skin (without pushing or pok-

"The ultimate aim of haptics research is to find ways to simulate the feeling of any shape, texture or tactile sensation."

ing into it) it is possible to mimic the feeling of complex shapes and sensations. This is because the sense of touch seems to depend far more on the way in which the skin is deformed and stretched than it does on the degree of pressure applied. So it should be possible to recreate sensations purely by stretching skin, says Vincent Hayward, a researcher who first developed such a device at the Centre for Intelligent Machines at McGill University in Montreal, Canada.

"It's analogous to watching a TV screen," he says. The human eye can be tricked into seeing a range of colours on a video display, even though it really only consists of tiny red, green and blue dots. In much the same way the sense of touch can be fooled into feeling shapes and textures that are not there, says Dr Hayward. In one dramatic example Mexican and Italian researchers showed that a flat surface could be made to feel sharp. The effect was so realistic that subjects were able to match different configurations of simulated sharp edges to corresponding images, says Gabriel Robles-De-La-Torre, a neuroscientist and computer engineer based in Mexico City who carried out the experiment and is the founder of the International Society for Haptics.

What a feeling

When someone moves a finger over a sharp surface, typically both vertical and lateral forces are applied to the skin, says Dr Robles-De-La-Torre. Using a haptic interface called GRAB, which was developed by Carlo Alberto Avizzano and his colleagues at the Scuola Superiore Sant'Anna in Pisa, Italy, the researchers showed that a realistic sensation can be created using skin-stretch alone, and leaving out the vertical forces. The device consists of a thimble on a motorised arm. Using the motors to apply short bursts of very precise resistance it applies slight lateral stretches to the skin of a fingertip passing over the thimble, giving the impression of a sharp edge.

The ultimate aim of this sort of research would be to find ways to simulate any kind of shape, sensation or texture, says Dr Robles-De-La-Torre. "The holy grail for me is to do fur," says Dr MacLean. There is a long way to go, but it should eventually be feasible, she says. One of the difficulties of simulating textures, says Dr Hayward, is that the sensation of texture depends on the interaction between the surface and tiny ridges in the skin at the fingertips. In theory, it should be possible to stimulate these ridges individually using micro-electromechanical systems (MEMS) technology, but so far nobody has tried, says Dr MacLean.

For his part, Dr Hayward has been experimenting with other uses for skin stretch, and has developed a new type of haptic switch for use in mobile devices. The THMB (pronounced "thumb") takes the form of a sliding button on the side of a handheld computer or mobile phone, like those used to adjust the volume or scroll through a list of contacts. But the THMB can also communicate information back to the user, since its surface consists of an array of 64 tiny rods, each of which can be moved in relation to its neighbours. When a thumb is placed on the device, the rods are computer controlled to move and stretch the skin just enough to fool the nervous system into feeling various sensations.

Dr Hayward's idea is that such switches could be used to convey information to the user without the need to look at the device. Skin stretch could be used to present the tactile equivalent of icons to the user, rather like a simple form of Braille. So far Dr Hayward has shown that people can indeed learn to recognise symbols through touch, though it is unclear how many symbols they can accurately distinguish between. Nokia has been following the research closely, says Dr Ryhänen. It might, for example, someday be possible to tell who is calling your phone just by reaching into your pocket or bag and touching it, he says.

Exactly what haptic devices will be used for is still unclear, but they seem destined to become more widespread in future. In the short term, one trend in particular will drive adoption, Mr Viegas predicts. "The world is rapidly moving towards having touch screens in most devices," he says. The launch of the iPhone will accelerate this trend, since it is bound to spawn many imitations. "It's going to have a huge impact," says Mr Viegas. Strategy Analytics, a consultancy, predicts that 40% of new mobile phones could have touch screens by 2012—though if haptics takes hold, perhaps "touchy-feely" screens would be a better description. ■

What's in a name?

Computing: Intelligence agencies are using new software to handle the arcane business of comparing lists of names

IN 1990 a Pakistani named Mir Aimal Kansi used an alternative transliteration of his Urdu family name, Kasi, to obtain a visa at the American consulate in Karachi. He entered America, overstayed his one-month visa and then went to the Pakistani embassy in Washington, DC, and obtained a new Pakistani passport, this time with the "n" reinserted in his surname. Using this new identity, he obtained working papers and a driving licence, bought a gun and went on to shoot five CIA employees, killing two, outside the agency's headquarters. (Kansi spent four years on the Federal Bureau of Investigation's Ten Most Wanted list before being captured, and was executed in 2002.)

This case shows how the apparently humdrum process of transliterating names from one language to another can be exploited by criminals. According to the FBI, Kansi also used the names Mir Aimal Kanci, Mir Aman Qazi, Amial Khan and Mohammed Alam Kasi. That last name introduces a further twist: there are more than 15 accepted ways to transliterate "Mohammed" from Arabic into English, and when you count the ways the name is written in the other 160-plus languages that use the Roman alphabet, the figure jumps to more than 200 correct spellings. Transposing words or names from one language or alphabet into another is evidently an inexact science.

In Indonesia, where single names are common, what appears to be just part of a name may in fact be the whole name. Chinese and Korean surnames are often mistakenly written last by Westerners, but some Chinese and Koreans are now adopting the Western convention. And then there is the problem of spelling variants. The Chinese family name Zhou, for example, may be written by English speakers as Jhou, Joe, Chou or Chow. Jafari, the common English transliteration of an Iranian family name, is rendered in German as Djafari or Dschafari. Shahram, the standard English spelling of an Iranian first name, becomes Scharam in German (and Chahram in French).

Such ambiguities cause huge problems for intelligence analysts trying to monitor and prevent terrorist activity. In an effort to avoid being picked out by computer watch-lists, many terrorists use alternative (but linguistically legitimate) transliterations of their names. "It's extremely commonplace, particularly with Islamic names," says Dennis Lormel, former director of the FBI's Terrorist Financing Operations Section, who is now an intelligence consultant at Corporate Risk International, near Washington, DC. "There are just so many variations of a name and they know that, so they can just flip-flop their name around," he says.

But companies in a fast-growing corner of the software industry have developed name-matching programs that can take into account the thousands of possible transliterations of a particular name—say, Mohammed bin Abdul Aziz bin Abdul Rahman Al-Khalifa—as they scan through watch-lists and databases looking for a match. The industry was flooded with investment in 2004 when the 9/11 Commission noted that the terrorists who attacked New York and Washington, DC, on September 11th 2001 defeated watch-lists by using different transliterations of their names. The commission urged the government "to close the long-standing holes in our border security that are caused by the US government's ineffective name-handling software." In-Q-Tel, the investment arm of the Central Intelligence Agency (CIA), began pouring money into name-matching software developers, according to a former official who chose which firms to finance. He says the technology is now becoming "pretty solid, robust stuff".

A name by any other name

"One of our biggest problems has always been variations of names," says Michael Scheuer, who was the head of the CIA's Osama bin Laden Unit from 1996 to 1999. Mr Scheuer says analysis was "back-breaking", especially for Arabic names, because it involved manually compiling lists of variations deemed worthy of tracing. This included positing names with or without titles such as bin ("son of", also written as ben or ibn), abu ("father of", also written as abou), sheikh (tribal leader, also written as sheik, shaikh, shaykh, cheik and cheikh) or haji (Mecca pilgrim, also written as hajj, hajji, hadj, haaji, haajj, haajji and haadj). The article al (also written as el) may be attached to

"Name-matching can play a crucial role in counterterrorism by enabling analysts to piece together snippets of intelligence."

surnames directly, separated from surnames with a hyphen or a space, or omitted altogether. Some variants do not even look similar. Sheikh can be written as jeque in Spanish. Wled, one English transliteration of an Arabic first (and last) name, is often written as Ould in French.

To make matters worse, many bureaucracies tolerate name abbreviations and short forms. The result is that intelligence analysts, no matter how expert, are often plagued by doubts. Has a Russian-speaking intelligence officer in Moscow transliterated into Cyrillic the name of a Nepalese suspect in exactly the same way as a Russian-speaking Uzbek field officer? Has an Italian analyst working with Russian intelligence caught and corrected the error, or passed it along?

Name-matching difficulties actually worsened when counterterrorism activity increased in late 2001. Analysts were granted greater access to databases kept by foreign agencies—but locating relevant files proved hard. A Portuguese case officer, for example, might have difficulty taking advantage of Dutch intelligence on, say, Nepalese Maoist extremists, if he is unfamiliar with Dutch conventions for the transliterations of Nepalese names. The number of people gathering and handling intelligence also increased suddenly, and many newcomers had little language training or were unsure how to transliterate names from spoken sources. Information on suspects increased, but spelling variations—due both to terrorist subterfuge and intelligence shortcomings—made it harder to interpret.

Mr Scheuer says that by late 2004, when he left the CIA, name-matching software was beginning to perform well, and American agencies were investing heavily in the latest technology—with one glaring exception. Computer systems at the State Department, according to Mr Scheuer, were "archaic compared to the rest of the intelligence community". That was a grave weakness, considering that the State Department issues passports and visas for travel to the United States.

If someone fears that the Romanised version of his name has been flagged, he can choose a new (but linguistically correct) transliteration, and then establish that spelling gradually by using it on low-level documents such as a gym membership card or a lease agreement. These "feeder documents" are used to obtain progressively higher-level identity documents, such as a city-issued residence card, a driving licence or a certified birth-certificate translation. These documents, in turn, are presented at consulates to obtain the ultimate prize—passports and visas using the new variation of the name.

"It's a very tough set of problems," says Philip Zelikow, executive director of the now-dissolved 9/11 Commission. The group's research turned up numerous cases of transliteration fraud. Mr Zelikow notes, however, that the American government is now doing a better job handling names. Other experts affirm that the State Department has dramatically upgraded its name-matching software.

There are no firm estimates of how much name-matching software is being sold worldwide. Government agencies generally decline to release figures, and software firms shy from discussing hard numbers. Those in the industry, however, claim that growth is spectacular. Sam Kharoba of First Capital Technologies, based in Baton Rouge, Louisiana, says his firm's sales have doubled in each of the past three years. Its clients include America's Defence Department and over 20 other government agencies. Around 25 companies are working in the field in America, and a handful are in Europe.

As watch-lists multiply beyond the realms of intelligence and international travel, demand for such software is likely to grow. Increasingly, watch-lists are used to restrict access to training and education, and to stop people buying property, guns, chemicals and other things that can be made into weapons. Many postal services rely on name-matching software to pick out packages for inspection.

The financial services industry is also adopting the technology, which is often required by central banks and monetary authorities. In America, the Treasury's Office of Foreign Assets Control is one of the world's largest users of name-matching technology. It uses it to compile watch-lists that are sent to thousands of banks worldwide. Credit-card companies use the software to spot recidivists applying for new cards under modified names. (Names are cross-referenced with addresses, dates of birth and other data.) Developers and users are hesitant to discuss costs. But OMS Services, a British software firm, says government agencies pay a lot more than commercial users, who pay about $50,000 for its Namex programme.

Name-matching software is also becoming more sophisticated and performing other functions. The name-matching software made by Identity Systems, based in Old Greenwich, Connecticut, is used by more than 200 government agencies around the world. As well as flagging names on watch-lists, it also sifts historical records to reveal hidden relationships: if two men have entered a country several times on the same plane, sitting apart from each other, might one be a money-runner and the other his overseer?

Names and numbers

GNR, a software firm owned by IBM, makes software that "enriches" names by annotating them with inferred cultural information, scored according to probabilities derived from demographic data. Given a particular name it can, for example, say how likely someone is to have a particular place of birth. Names and titles can also provide clues as to birth order, occupation, deaths of spouses and immigration history. GNR also repairs names that are "damaged" by transliteration because the original non-Roman script is lost. The software generates possible original spellings and provides accuracy probabilities for each one. This helps spooks starting with the Romanised versions of, say, Pushtu names, to gather intelligence on those individuals in their native Afghanistan. GNR sells its software to law-enforcement and intelligence agencies—those in Australia, Israel and Singapore are particularly big spenders.

Name-matching software is just one small item in the counterterrorism toolbox. But it can play a crucial role by enabling analysts to piece together snippets of intelligence. What's in a name? The answer, in some cases, is a surprising amount of valuable information. ■

Watching the web grow up

Tim Berners-Lee created the web in 1991. Now people are talking about Web 2.0—but he is more excited by other things

IN 1994, when Tim Berners-Lee left CERN, the particle physics laboratory near Geneva where he created the world wide web, to move to the Massachusetts Institute of Technology (MIT), his children were toddlers—just like the fledgling information-sharing system he had released onto the internet three years earlier. Since then the web has grown up fast, expanding from around 10,000 websites in the world at the end of 1994 to over 100m today. After this rapid growth spurt the web is now, like Sir Tim's children, in its teenage years. The painfully self-conscious "Web 2.0" movement—a label which encompasses a range of technologies such as blogs, wikis and podcasts—represents the web's adolescence. It has all the hallmarks of youthful rebellion against the conventional social order, and is making many traditional media companies tremble.

Sir Tim ought to be thrilled. After all, his original vision was for the web to be a two-way medium, in which writing information was just as simple as reading it—but as the web took off in the late 1990s, publishing tools failed to keep up with web browsers in ease of use, and it is only with the rise of blogs and wikis that the balance has been redressed. Yet Sir Tim is less excited by all this than you might expect. He regards Web 2.0 as just a fancy name for some useful, if still rather basic, web-publishing tools, and was not at all surprised by the emergence of "user-generated content"—since that was what he had intended all along. "The web was designed so every user could be a contributor," he says. "That sort of participation was the whole idea and was there from the start."

Although he is somewhat sceptical of the hype around Web 2.0, Sir Tim is excited by three other areas of the web's development: its spread to millions of new users via mobile devices, the growing interest in the technology's social and political impact and the "semantic" web, in which information is labelled so that it makes sense to machines as well as people. "If you look at the number of internet-capable mobile phones, PDAs and so on, they are rapidly outnumbering the things we think of as computers," he says. "As the price of these devices falls, large parts of the developing world will get web access. When you have a large mass of new users, you will get many new applications, written by people with other needs."

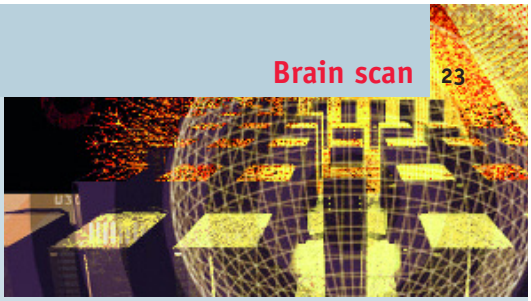
The number of internet users reached 1 billion in 2005. But although about 70% of the population now has access to the internet in North America, the figure is just 11% in Asia and less than 4% in Africa. To the jaundiced observer who remembers the disappointment of WAP, the first attempt to bring the internet to mobile phones, Sir Tim's enthusiasm for mobile-internet access may sound like déjà vu. But he insists that there are crucial differences. "WAP was not based on standard internet protocols, there was no competition for browsers, and operators had a stranglehold on access," he says.

Going mobile

All of this stifled innovation. The trick now is to bring the web, rather than some limited, cut-down version of it, to mobile devices. "The point of the web is that it is open, and anyone can create a new resource, instantly get feedback, and rapidly have a money stream flowing," he says. Under Sir Tim's leadership, the W3C—the web-standards body at MIT that he has headed since 1994—has launched a mobile-web initiative to adapt web standards so that information can be more easily accessed via mobile devices. Such standards will, he hopes, help to make the riches of the web available to the next billion users.

That should help to extend the benefits of the web to more of the world's population. But it will also help to spread what critics regard as the web's negative aspects. "Clearly, any technology can be used for good or for bad. That's always been the case," says Sir Tim. "But in general, more communication is a good thing." It can, he notes, build bridges between cultures, boost commerce and accelerate scientific progress. The web can be used by criminals and racists—but it can also be used to counter them. Totalitarian regimes can filter content on the web and use it to track dissidents, but human ingenuity means that attempts to block the flow of information altogether are doomed to fail.

Sir Tim is credited with creating the web's technical underpinnings—such as HTML and HTTP, the protocols used to encode web pages and transmit them



"The semantic web aims to allow computers to extract useful information from data on the net."

across the internet—but he has always argued, with characteristic humility, that the web is as much a social creation as a technical one. In fact, its social and technical aspects are intertwined, and understanding how the networks of people and computers that make up the web interact and reinforce each other has given rise to "web science", a nascent field that blends sociology with computer science.

To encourage this line of enquiry, Sir Tim last year helped to establish the Web Science Research Initiative (WSRI), a collaboration between MIT and the University of Southampton. "Web science looks at the web as a large system which depends on the laws of behaviour between people, like copyright law, as well as the protocols that govern how computers communicate with each other," he says. Such laws and protocols are drawn up in the hope of producing a large-scale effect, such as creating the blogosphere or facilitating scientific publishing. The point of web science is "to understand how these large-scale effects depend on the underlying laws and protocols".

An analogy can be drawn with the way that a few simple chemical interactions between atoms define how they bond together to form molecules, and that in turn specifies how proteins interact and DNA can copy itself, all of which ultimately determines the properties of immensely complex systems such as the human brain. Understanding how such "emergent phenomena" can result from simple laws has been all the rage in physics circles for over a decade, though in the web's case the basic rules are man-made, rather than being laws of nature.

Why bother studying any of this? Sir Tim is optimistic that analysis of the web will be followed by synthesis of this understanding into technical proposals that can encourage and support new social trends. Ultimately, he hopes the WSRI will produce recommendations for improvements to the web that can be fed into the technical agenda of the W3C. Understanding the interaction between technical protocols and social rules ought to make it possible to use the web more effectively in society, he thinks.

Analogies between the web and the brain have long played a profound role in Sir Tim's thinking. He is the son of two mathematicians who worked on the team that developed the world's first commercial, stored-program computer, the Manchester University Mark 1, which was commercialised by Ferranti, a British company, in the 1950s. He remembers his father reading books on the brain, looking for ways to make computers able to identify connections between things, as the brain does.

This line of thought has stuck with Sir Tim and is at the core of one of his most enduring passions, the semantic web. Whereas the web today provides links between documents which humans read and extract meaning from, the semantic web aims to provide computers with the means to extract useful information from data accessible on the internet, be it on web pages, in calendars or inside spreadsheets. Such data—much of it stored in databases that can be queried by humans via the web—is part of what is referred to as the "deep web", and cannot be accessed by the web-crawler programs used by most search engines.

No one knows exactly how much information is in the deep web, but estimates range from hundreds to thousands of times more than in the "surface web" that search engines currently index, which is thought to contain over 10 billion pages. If semantic-web technology can help computers access even a fraction of this hidden data, and make sense of it, it could make possible new forms of searching and would even allow software to retrieve information and make deductions from it.

A matter of semantics

The semantic web has been a work in progress for over a decade—indeed, Sir Tim has said that he has been working on it since he started work on the web. A few detractors have argued that it is simply not feasible in practice to expect people to apply labels to all the information sitting on the internet so that machines can make sense of it. But Sir Tim remains optimistic. He points to solid steps forward, including XML, a language which provides a basic syntax for sharing data and has been widely adopted. The key building block is the Resource Description Framework (RDF), which provides a way to refer to different objects (such as sets of data) and the relationships between them—the underlying semantics of documents and data. Then there is the Web Ontology Language (OWL), which provides a way to characterise objects.

"There's a thriving community working on the semantic web," says Sir Tim. The basic standards are in place, a query language called SPARQL is about to be launched, and the first semantic-web browsers are being prototyped. These are far more complex than web browsers, says Sir Tim. "You have to be able to display the data, draw graphs and so on. This is still very much at the research stage," he says.

When pressed for examples of applications of the semantic web that common mortals might appreciate, Sir Tim enthuses about "friend-of-a-friend" networks, where individuals in online communities provide data in the form of links between themselves and their colleagues and friends. The semantic web could help to visualise such complex networks and organise them to allow a deeper understanding of the community's structure. He also sees semantic-web technology playing a role in syndicating useful data, such as weather information, in the same way that RSS feeds are now used to syndicate news items and blog postings on the web. And just as the web was first embraced by particle physicists, the semantic web may well take root in the life sciences, where it could allow separate genomic databases to be linked, searched and compared in novel ways.

These examples may not sound like a revolution in the making. But doubters would do well to remember the web's own humble origins. In 1989 Sir Tim submitted a rather impenetrable document to his superiors at CERN, entitled "Information Management: A Proposal", describing what would later become the web. "Vague but exciting" was the comment his boss, the late Mike Sendall, scribbled in the margin. The semantic web may seem equally vague today, but it could prove just as exciting. ■