Cleaning up

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Business is getting down to cutting carbon, but needs more incentives to make much difference to climate change, argues Emma Duncan

WHEN the notion of global warming first seeped into public consciousness in the 1980s, business took a dim view of it. Admitting that human activity was changing the climate would involve accepting some responsibility, which was likely to mean coughing up cash. So, in 1989, shortly after the establishment of the Intergovernmental Panel on Climate Change, the body set up under UN auspices to establish a scientific consensus on the issue, the big carbon emitters set up the Global Climate Coalition (GCC). It cast doubt on the science and campaigned against greenhouse-gas reductions.

The GCC folded in 2002. Its line of argument enjoyed a final flowering last year, in a startlingly inane television commercial put out by the business-funded Competitive Enterprise Institute (CEI). It showed pictures of trees (breathing in carbon dioxide) and a happy little girl blowing dandelion seeds (breathing out carbon dioxide). The punchline was: "Carbon dioxide: they call it pollution; we call it life."

These days very few serious businessmen will say publicly either that climate change is not happening or that it is not worth tackling. Even Exxon Mobil, bête noire of the climate-change activists, has now withdrawn funding from the CEI and appears to accept the need for controls on carbon emissions.

Businesses in every sector boast about their greenness. Annual reports elaborate on investments to offset companies' emissions. Of course the companies that do this tend to be those with few emissions, such as banks and retailers. Some oil companies do it too, but they offset only the greenhouse gases that they emit in producing petrol, not the emissions from the petrol itself. Power generators, which emit CO_2 on a huge scale, do not do it.

Yet the corporate world's sudden conversion to greenery is not just fluff. Big emitters are beginning to price carbon into their investment plans, and to alter them accordingly. As a result, wind and solar energy are getting an enormous boost, the price of electricity produced from renewable sources is dropping fast and a flurry of projects to sequester carbon emissions from power generation is beginning to get under way. On the transport side, money is flowing into biofuels and electric cars.

Energy has become the hot new area for venture capitalists and universities. MIT's president, Susan Hockfield, has started an "energy initiative" to promote research into alternative sources, storage and cleaning up conventional sources; and student enrolment into energy-related courses has tripled over the past five years. In 2003, the most recent year for which figures are available, America's power-generation industry spent less on R&D as a proportion of turnover than did the country's pet-food industry, which suggests there is scope for more investment.

What is driving this shift towards cleaner energy? First, moral pressure. ▸▸

Al Gore, in the eye of the storm

Thanks to a potent combination of science, Hurricane Katrina, a heatwave in Europe, Al Gore's admonitions and starving polar bears, the fight against global warming has acquired the force of a religion enhanced by celebrity endorsement. Climate change has gone from being dull and marginal to cool and core. Businessmen, like everybody else, want to be seen to be doing the right thing, and self-interest points in the same direction. Firms that seem to be on the right side of the argument have a better chance of pulling in clever, idealistic young people to work for them.

Second, there is economic pressure. Governments increasingly accept the need to put a price on the damage carbon does, and make polluters pay that price. Fears about energy security mostly push in the same direction as those about climate change. Many governments are keen to reduce dependence on Middle Eastern and Russian oil and gas. That means encouraging energy efficiency and promoting domestic energy sources—which, aside from coal, tend to be the clean sort, such as solar, wind and biomass.

Europe already puts a price on carbon, through its Emissions-Trading System. The chances of a similar scheme being adopted in America rise with every passing hurricane. There is a plethora of subsidies on both sides of the Atlantic for clean-energy alternatives. Direct controls on emissions, for instance through vehicle fuel-efficiency standards, are being tightened around the world.

Yet emissions keep on rising. If greenhouse-gas concentrations are to be stabilised, then the carbon price or the support mechanisms for clean energy, or both, will have to rise or be adopted worldwide, or both. And if that happens, the returns on clean-energy investments will increase even further and the companies that have already invested in such businesses will have a head start over those that have not.

Moral and economic pressures have become intertwined, driving investors to push managers to go for cleaner investments. The Carbon Disclosure Project allows companies to report their emissions—and thus allows investors to see which companies don't. A group of investors, organised by Ceres and the Investor Network on Climate Risk, wielding $4 trillion and including powerful funds such as CalPERS, the Californian public employees' pension fund, and CalSTERS, the Californian teachers' pension fund, discriminates in favour of cleaner firms. The recent buy-out of TXU, Texas's main power-generator, led the company to abandon eight out of 11 planned coal-fired power stations because the private equity firm concerned, Texas Pacific, wanted to square the environmental movement.

Yet the shift towards greenery is also driven by more positive factors. For some huge firms, such as GE, Alstom and Siemens, a move towards clean energy spells opportunity. They sell power-generation equipment and aircraft and train engines. New regulations requiring companies to adopt cleaner processes will mean that capital equipment is replaced more quickly, to the benefit of such companies.

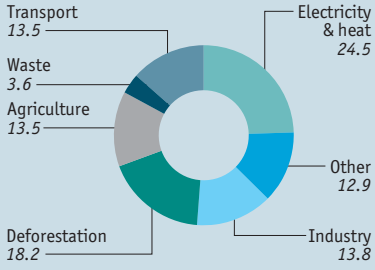
Even their customers increasingly realise that although climate change may push up their costs, it will also provide new opportunities—new markets, new technologies, new businesses and new money to be made. This could be disruptive. If carbon controls are tightened, the companies that will flourish are those that have positioned themselves well. In power generation that means companies such as Exelon and Pacific Gas & Electric, which have invested heavily in nuclear or renewable energy, whereas coal-heavy ones such as AEP will suffer. In the petroleum business, the winners will include BP, with its enthusiasm for renewables, and the losers Exxon Mobil. In the automotive industry, producers of fuel-efficient cars, such as Toyota, are more likely to do well out of carbon constraints than companies such as BMW.

Technological change may also allow some parts of the energy and transport business to invade each other's turf. The power utilities hope to gain from the enthusiasm for plug-in electric cars, which could spell trouble for the oil companies. Biofuels, too, are a potential threat to them, not only because every farmer and forester may build a cellulosic ethanol plant in his backyard, but also because companies such as DuPont may prove better at making the fuels of the future. The power utilities, in turn, may suffer if fuel-cell technology turns cars into net producers, rather than consumers, of electricity. But these things will happen only if carbon constraints are tightened.

This special report will examine how climate change is affecting business, and how business can affect climate change. It will concentrate on industrial emissions rather than on agriculture and deforestation (which produce lots of carbon dioxide without involving business much) but will leave out air travel, on which this newspaper will publish a special report in two weeks' time. It will examine what is driving change in the sectors responsible for most emissions, the nature and extent of that change, and its likely impact. It will argue that business has changed nothing like enough to have a chance of averting global warming—but that, given the right incentives, it can. Whether that happens or not will be largely determined in America. ■

Something to work on 1

World greenhouse-gas emissions by sector
2000, %



Source: World Resources Institute

Everybody's green now

How America's big companies got environmentalism

MEETINGS of the Edison Electric Institute, the trade association for the American power utilities, do not normally make waves. But the one that took place at Scottsdale, Arizona, on January 10th of this year was different.

Up until then, the EEI had been split between the companies arguing for carbon constraints—usually those, like Exelon, PG&E and Entergy, with more gas and nuclear energy than coal—and those arguing against—usually those, like TXU and Southern, with lots of coal. Since coal provides 50% of America's power, the coal utilities had mostly had the upper hand, and the organisation had advocated only voluntary restraint.

But this year the new chairman, Jim Rogers of Duke Energy, asked each of the 50 chief executives present what they thought the government should do about carbon. "It was pretty clear going round the table that the vast majority wanted to move on," says Mr Rogers. Afterwards the EEI announced that it was calling for "regulation". It balked at the word "mandatory", but the implication hung in the air.

Power generation is the biggest source of CO_2 in America. America is the biggest source of CO_2 in the world. If America continues to refuse to control its carbon-dioxide emissions at the federal level, there is no chance that countries such as China and India, whose emissions will soon overtake America's, will control theirs. The EEI's turnaround was therefore significant.

Similar things have been going on in other industries. Companies that once pooh-poohed the idea of climate change have gone quiet; others have come out loudly in support of emissions controls. The shift culminated, in January this year, in the establishment of the United States Climate Action Partnership calling for "strong" federal action to combat climate change. The initiative was launched by ten blue-chip companies, along with four NGOs. Membership has now doubled, and includes GM, GE, BP, Alcan and Alcoa.

Attitudes in corporate America have changed in part because a federal system of controls has come to look like the lesser of two evils. America's states have already started to legislate to cut emissions. California is leading the charge. Last September it passed Assembly Bill 32, under which carbon emissions are to be cut to 1990 levels by 2020 and to 80% below 1990 levels by 2050. It will probably be implemented through a European-style cap-and-trade scheme. And California has adopted a low-carbon fuel standard that will require oil companies to cut the carbon content of their petrol. Other state governments have been watching California's initiative carefully and seem likely to follow its lead.

For companies, a diverse patchwork of state-wide systems is much harder to cope with than a single nationwide system. According to Ken Cohen, vice-president of public affairs at Exxon Mobil, "we need a uniform and predictable system. If the states are left to their own devices, we won't get that. It needs to be a federal system." And since the Democrats took over Congress last November, the chances of America adopting federal controls have risen sharply. Bills are proliferating. Dan Kammen, of the Energy and Resources Group at the University of California at Berkeley, says he has never had so many calls along the lines of: "I'm Congressman X and I need to write a high-profile bill on climate change. What should it say?"

But in accepting the idea of federal regulation, companies are not just bowing to the inevitable. There is money in it, too. If the American government adopts a cap-and-trade system (see next article), it will hand out permits to pollute. They are, in effect, cash. According to Paul Bledsoe of the National Commission on Energy Policy, those allowances are likely to be worth in the region of $40 billion. Companies therefore want to be involved in designing those regulations. As Mr Rogers explains: "There's a saying in Washington: if you're not at the table, you're on the menu."

The process has become self-reinforcing. In order to be seen to be green, companies have to lobby for emissions controls. That increases the pressure for emissions controls, which in turn increases the need to be seen to be green.

The more that American businessmen examine the European system, the less alarming the prospect of carbon constraints begins to look. Not only has it resulted in a lot of cash being handed over, but it has also created a whole new business: the carbon market. ■

Power and positive thinking

Trading thin air

The carbon market is working, but not bringing forth as much innovation as had been hoped

EVERY year the average sow and her piglets produce 9.2 tonnes of carbon-dioxide equivalent through the methane emissions from their effluent. In the past, that has been a problem both for the environment and for pig-farmers. In developing countries the pig-effluent collects in open lagoons which smell bad and get infested with flies. Sometimes it flows straight into nearby water systems.

Now this problem has become an opportunity. Bunge, an agricultural-commodities business based in America, builds lined and enclosed pools to collect the effluent and captures the methane that it emits. The farmer can use the gas to generate electricity. By preventing methane from escaping into the atmosphere, Bunge creates a credit which it can sell on the carbon market. The farmer gets to keep 20-30% of the value. Bunge has 40 such projects operating in Brazil and is planning to expand into Mexico, Guatemala, Peru and the Philippines.

The carbon market is truly innovative. Although it works like any commodity market, what is being bought and sold does not exist. The trade is not actually in carbon, but in not-carbon: in certificates establishing that so many tonnes of carbon dioxide (or the equivalent in other greenhouse gases) have not been emitted by the seller and may therefore be emitted by the buyer.

The purpose of setting up the market was, first, to establish a price for carbon and, second, to encourage efficient emissions reductions by allowing companies which would find it expensive to cut emissions to buy credits more cheaply. It has had some success on both counts—some would argue too much on the second.

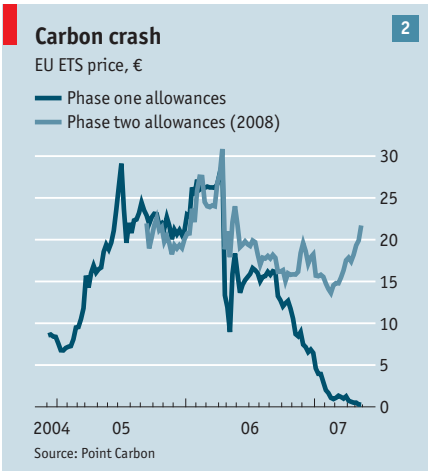
A carbon price now exists, established by the European Emissions-Trading Scheme (ETS). In its first phase it has been volatile (see chart 2) because information about Europe's industrial emissions was poor, so the market got a shock in early 2006 when it emerged that the European Commission had been too generous with the allowances it handed out to industry. Phase one allowances (2005-08) are now virtually worthless. But the commission has learnt its lesson and got meaner with allowances, thus pushing up the price in phase two.

The supply of carbon credits comes principally from two sources. The first is the allowances given to companies in the five dirty industries covered by the ETS (electricity, oil, metals, building materials and paper). The second source of carbon dioxide lies outside Europe. The European Commission linked the ETS to the "clean-development mechanism" (CDM) set up under the Kyoto protocol. This provides for emissions reductions in developing countries—such as those on the Latin American pig farms—to be certified by the UN. Such "certified emissions reductions" (CER) can then be sold.

The demand for carbon credits comes mostly from within the ETS, from polluters who need certificates allowing them to emit carbon. There is some demand from Japan, which has a voluntary scheme, and from companies and individuals elsewhere in the world who want to offset their emissions for moral reasons, or to make themselves look good.

The trade is now sizeable. Some €22.5 billion-worth ($30.4 billion) of allowances were traded last year, according to Point Carbon, a data-provider, representing 1.6 billion tonnes of CO_2—a huge increase on the €9.4 billion traded in 2005. Europe's ETS made up about 80% of the total value.

Developing-country CERs accounted for about €4 billion of last year's trade:



562m tonnes of CO_2. According to New Carbon Finance, a research company, carbon funds worth $11.8 billion have been raised so far. Half of that total is managed from London. Climate Change Capital, a niche investment bank, raised $130m for its first carbon fund, launched in July 2005; its second, launched a year later, is now worth around $1 billion. According to Tony White of Climate Change Capital, all the money for the first came from hedge funds, which like risk. By the time the second fund was established, more cautious investors, such as pension funds and banks, were prepared to put money into it.

The money has gone mostly into projects in developing countries to produce CERs. Bunge's Brazilian pig-farmers are making CERs out of their animals' effluent. But the bulk of the investment has gone into greenhouse-gas capture in China.

Cheap and cheerful

The most potent greenhouse gas is HFC-23, a by-product of HCFC-22, a chemical used in, among other things, fridges. It is now mostly banned in the developed world. Its global-warming effect is, tonne for tonne, 11,700 times greater than that of carbon dioxide, so it is good to get rid of it, and cheap, too; capturing it and burning it off costs less than €1 for the equivalent of one tonne of carbon dioxide. These days China produces most of the world's HFC-23. That—along with the fact that the Chinese government is efficient to deal with—explains why 53% of the total volume of CDM projects in 2006—worth around €3.5 billion in total—went to China.

The very cheapness of cutting emissions of HFC-23 makes the trade controversial. Credits costing less than €1 to produce have been sold on the market for up to €11. Factories have found that their damaging by-product, HFC-23, can be more valuable than their main output. The Chinese government, realising how much money there is in this business, has imposed a tax of 65% on revenues from it, and in February this year it launched its own $2 billion CDM fund. So European consumers, who are paying for greenhouse-gas abatement through their electricity and other bills, are contributing billions of dollars to the Chi-

nese government's coffers via the CDM.

Easy options—HFC-23 and other fabulously dirty (ie, profitable) industrial gases—will soon run out. Guy Turner at New Carbon Finance reckons that the days of the CER that costs less than €1 to produce are over, and that the range is now more like €1-5. But there is plenty of scope at that level. China's industrialisation is a fast and dirty business, and there will be no shortage of greenhouse gases produced there for rich-country money to clean up.

That is part of the problem. Of the 65% of companies surveyed by Point Carbon earlier this year which claimed that the ETS had led them to abate their emissions (up from 15% the previous year), most were planning to buy credits rather than cut their own emissions. Yet the ETS was intended to cut European emissions as well as Chinese ones.

This is happening on a small scale. At times the carbon price has made it worth power companies' while to switch from dirty fuels to cleaner gas. "We massively reduced our lignite production when the CO_2 price was at its height," says Alfred

Irrational incandescence

People can't be bothered to make easy energy savings

SOME ways of cutting carbon are cheaper than others. So, at different carbon prices, different sorts of methods of abatement become worthwhile. Vattenfall, a Swedish power utility, has tried to quantify which ones would be worth undertaking at what price (see chart 3).

The result is a testament to economic irrationality. The measures below the horizontal line have a negative abatement cost—in other words, by carrying them out, people and companies could both cut emissions and save money. At a macroeconomic level they would boost, rather than reduce, economic growth.

Lighting, for instance, accounts for some 19% of the world's electricity use. A standard incandescent light bulb costs around €1, says Theo van Deursen, chief executive of Philips Lighting, and uses €15-worth of electricity a year. A low-energy one costs €5-6 and uses €3-worth. The payback on investing in a compact fluorescent bulb, therefore, is less than a year. Yet low-energy lighting makes up only 30% of Philips's sales. Mr van Deursen admits to being disappointed. Sales are rising faster in the developing world: there, people pay more attention to electricity bills than they do in the rich world.

Economists trying to explain this apparent irrationality suggest that the savings are too small and the effort involved in change too large. People find their electricity bills too boring to think about; within companies, those responsible for keeping bills down may not have the authority to spend the necessary capital. Another explanation is the agency problem: that the developer who would have to pay higher capital costs up front will not be forking out for the electricity bills. Besides, people buy houses not because they have good insulation but because they have pretty views.

Compared with pursuing greater energy efficiency, the abatement measures into which so much money is now being poured look rather expensive. Carbon capture and storage and wind and solar power, for instance, all have positive, and relatively high, abatement costs.

But the cheapest sources of abatement are difficult for policymakers to get at. Billions of different actors are involved. They cannot be targeted in the way that a few hundred factories can. What is more, a moderate carbon price is not likely to be effective, since people clearly do not care enough about cost.

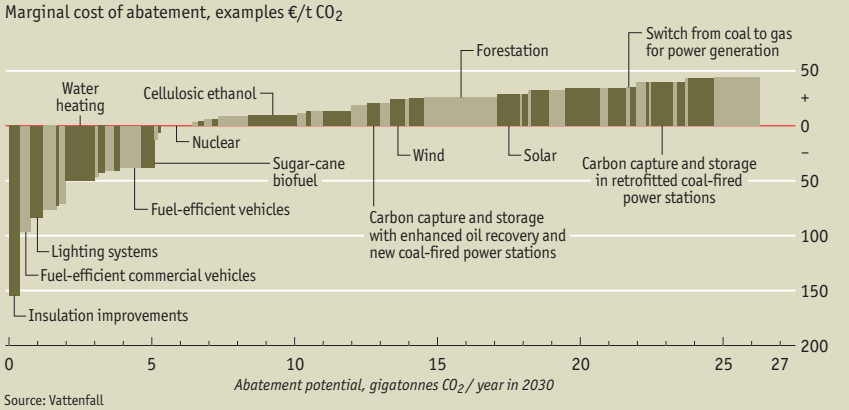
One policy option is to decouple the utilities' revenues from the amount of electricity they sell. That gives them an incentive to increase the efficiency of power usage rather than to produce and sell extra power. California is already doing this, which is presumably why electricity prices there are among the highest in America, while consumption is relatively low.

Energy-efficiency standards, such as building regulations, are another option. Economists generally prefer to avoid rules that specify what companies can produce and how, because they require governments, rather than markets, to allocate resources, and markets tend to do a better job. But if, as in this case, a public as well as a private good is involved, and the market does not seem to be doing its job properly, there is an argument for governments giving it a nudge.

There are lots of energy-efficiency regulations in place already, and they are being tightened. Incandescent light bulbs are the top target at the moment. Both the European Union and Australia said earlier this year that they are planning to ban them. But the man in the vanguard of this green revolution is Fidel Castro, who started phasing them out two years ago.

The cost of cutting carbon in different ways 3

Marginal cost of abatement, examples €/t CO_2



Source: Vattenfall

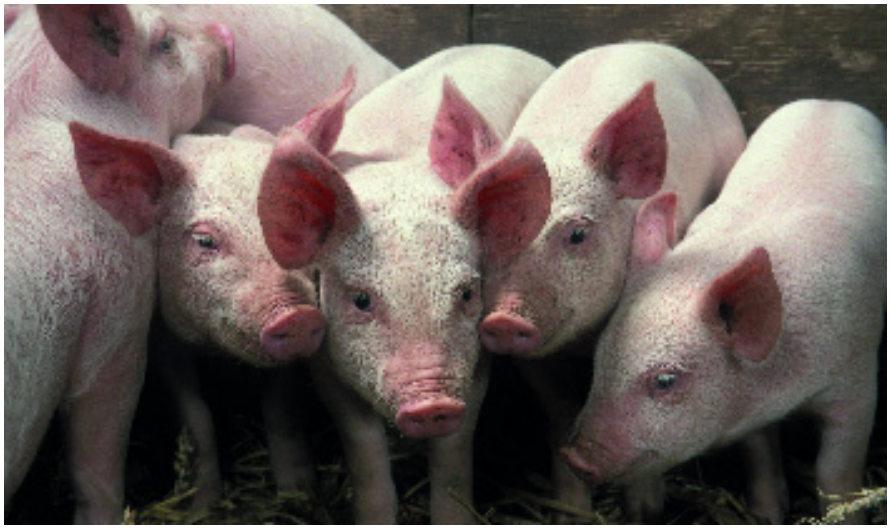
Hoffmann, head of portfolio management in Scandinavia and Germany for Vattenfall, a Swedish power company. Lignite is dirtier than black coal. But then gas prices rose, making switching less attractive.

The carbon price has delivered some of the innovation that it was supposed to generate. Shell, for instance, is pumping CO_2 from a refinery in the Botlek area of the Netherlands into 500 greenhouses producing fruit and vegetables, thus avoiding emissions of 170,000 tonnes of CO_2 a year and saving the greenhouse owners from having to burn 95m cubic metres of gas to produce the CO_2 they need.

Alcan, an aluminium company, is planning to use the heat from one of its smelters to increase the efficiency of its power-generation plant at Lynemouth in Northumberland in Britain. Wyn Jones, managing director of Alcan's British smelting and power-generation operations, says this will save 150,000 tonnes of CO_2 a year (€3m if the price of CO_2 is around €20 a tonne, as Alcan expects) and 60,000 tonnes of coal (£2.1m, or $4.2m, at around £35 a tonne). He is not sure how much the project will cost, but is reckoning on a payback period of around five years.

But European emissions overall are not falling, which suggests there may not be as much switching out of coal, or as much technological innovation, as had been hoped. Chinese CERs are too cheap and the carbon price is too low and too volatile. Even when it was bouncing around at €15-25, it did not seem to encourage much new investment. According to Bjoern Urdal of Sustainable Asset Management, who took a detailed look at the effects of the carbon price on the German electricity market last year, replacing old coal-fired power stations with gas-fired ones became worthwhile only at a carbon price of €33. He has not done the sums since last November, when the European Commission chucked out Germany's "transfer rule" (which would have exempted new coal-fired stations from the ETS for 14 years), but reckons the break-even point will have come down to more like €25.

That helped raise the carbon price. So did the commission's decision to slash national governments' planned allocations to industry for the period 2008-12. The price of phase two allowances has risen to a level high enough to get some power generators to switch from coal to gas at the margin when the gas price is moderate; but not high enough to get them to replace coal-fired power stations with gas-fired ones—nor to encourage much of the innovation that carbon trading had been expected to spawn. ■



Bringing home the methane

Fairfield v the valley

Two competing models for the clean-energy business

TWO men represent two very different models of the clean-energy business. One is Vinod Khosla, chief executive of Khosla Ventures, a company headquartered in Menlo Park, California, which employs ten people. The other is Jeff Immelt, chief executive of GE, a company headquartered in Fairfield, Connecticut, which employs 300,000 people.

Mr Khosla, formerly of Sun Microsystems and Kleiner Perkins Caufield & Byers, the venture-capital firm that launched many of the big names of the internet boom, is now the most visible venture capitalist in the clean-energy business. There is plenty of competition. Silicon Valley is piling into the business. John Doerr, the valley's best-known venture capitalist and one of Mr Khosla's former partners at Kleiner Perkins, also invests in clean-energy start-ups, sometimes alongside Mr Khosla. Larry Page and Sergey Brin, the founders of Google, have invested in Nanosolar, a company using solar thin-film technology. Microsoft's Bill Gates has invested in Pacific Ethanol, a company building bio-refineries in California.

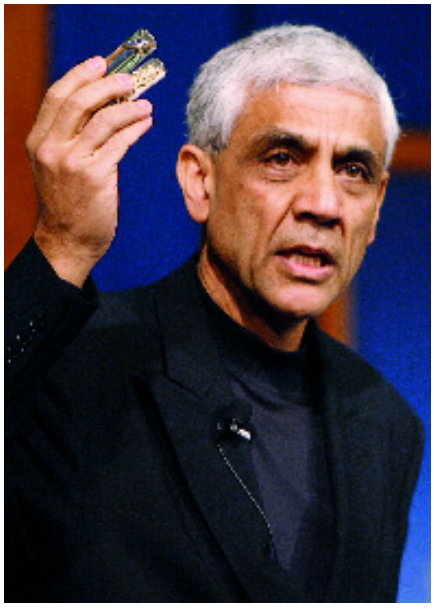
California is buzzing with clean-technology projects: breakthrough energy-storage systems; devices for making electricity grids more intelligent; enzymes that chomp their way through lignin to make ethanol; algae that can be turned into fuel. As the home of some of America's best universities, it is a natural place for such ideas to flourish. The notion of man-made climate change has been accepted for years in most universities, and the climatologists' work has influenced other academic departments. Stanford and the University of California at Berkeley both have big clean-energy programmes.

California's tough energy-efficiency and emissions regulations have given its businesses an interest in investing in clean energy. And some of the state's VCs are keen to spend the cash they made from the internet on improving the world. Not that they plan to lose money on it: investing in clean energy promises to satisfy both idealism and greed. ▸▸

Mr Khosla is backing some 27 companies in four clean-energy areas: replacing oil, replacing coal, developing new materials and energy efficiency. His model is the usual one: he finds an inventor or a good piece of intellectual property, adds some money and an experienced manager and waits for it to flourish or fail.

Bud Klepper, for instance, had been working for years on a process to make cellulosic ethanol without anybody paying much attention. But then he met Mr Khosla, who liked his scheme, introduced him to Mitch Mandich, a former Apple employee, added some money and stirred. In February the resulting company, Range Fuels, announced that it would build a commercial-scale cellulosic ethanol plant in Georgia, using the state's abundant wood offcuts as feedstock.

The VCs who used this model to transform the computer business reckon that they can do the same for the energy business. "The investments we're making are like those we made in the internet," says Mr Doerr. "They're based on technological and scientific innovation, they're driven by entrepreneurs, and they're distributed, in the way that the internet was distributed." The VCs also reckon that they can topple incumbents, as they did in the information and communications business. "Look at voice telephony," says Mr Khosla. "These days, it's basically free. Ten years ago, people told me that would never happen. AT&T believed that—and look what happened to them."



Khosla thinks small

At the other end of the scale is Mr Immelt. "When I was looking at the growth potential of our businesses three years ago," he says, "I saw an emphasis on clean energy and energy efficiency, on scarcity and the rise of regulatory pressure. And I thought—we've got something here." And so he developed the theme, making GE the big company best known for espousing greenness. "Green is green" has become a company mantra. And GE was among the ten companies that launched the United States Climate Action Partnership.

Green synergies

The vehicle that Mr Immelt settled on for promoting green products was Ecomagination. This brings together products from GE's different businesses that are either intrinsically green—like wind turbines—or have been certified as being more competitive and producing fewer emissions than whatever else of that sort is on the market. Not all GE's products get through. The GEnx aero engine, which powers Boeing 747s and 787s, did, but the new-generation CFM engine for narrow-bodied jets did not, because its emission levels are no lower than the competition's. Ecomagination's sales have been rising slightly faster than GE's, by 12% a year rather than 9%. Its energy products have been rattling along.

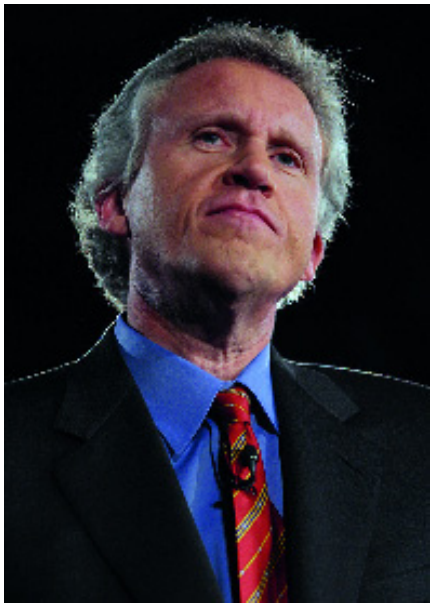
To a large extent, Ecomagination is a marketing device. GE was selling all those aero and power-generation engines long before Ecomagination was invented, and "fuel efficiency has always been the number one criterion for airline-engine economics," says Tom Brisken, general manager of the GEnx programme. But Mr Immelt has also made sizeable clean-energy investments. He bought Enron's wind-turbine business out of bankruptcy for $358m. Sales rose from $200m in 2002 to around $4 billion last year. His purchase of Chevron's integrated gasification combined-cycle technology—a potentially cleaner but costlier coal-burning technology for power stations—has still to prove itself, because GE has not yet sold a plant.

GE's enthusiasm for greenery is informing its R&D effort. The company is, for instance, looking at radical ways of making aero engines cleaner. "Suppose we used a totally different fuel. Suppose we used a bio-derived fuel." says Sanjay Correa, GE's global technology leader for energy and propulsion. Biofuels are widely believed to be out of the question for aero engines because they are less energy-intensive, so more is needed to travel the same distance. But Mr Correa points out that aeroplanes these days have such a long range that they can cross the Atlantic with their tanks only one-third full. "We've done tests. We've studied this pretty hard. It works."

So who is best placed to win in the clean-energy stakes: the VC who helped transform the computer business or the chief executive of one of the great incumbents? The VCs point out that the energy business is becoming more friendly to small companies. Electricity generation is becoming more distributed as wind farms and solar panels feed into grids. Ethanol can be produced in backyard plants.

True; but that is happening at the margin. The big companies still dominate. According to Michael Liebreich of New Energy Finance, only around $2 billion of the $71 billion that went into the clean-energy investment last year was VC money.

The VC model is an excellent way of generating innovation, and fine for the early stages of clean-energy companies, but ultimately does not suit the energy business as well as it suits computing. Moving molecules around takes far more capital investment than moving bits of information around. Shipping fuel from refineries to petrol stations and running electricity grids are operations best done at scale; and the energy business's hunger for capital ensures a measure of protection for incumbents. Mr Khosla may very well produce some exciting new technologies and thus generate some valuable intellectual property; but it is Mr Immelt who will exploit them. ■



Immelt thinks big

Sunlit uplands

Wind and solar power are flourishing, thanks to subsidies

LAST year Shi Zhengrong, a Chinese solar engineer, gave a new-year's party for his 3,500 employees in a sports stadium in Wuxi, in eastern China. He had much to celebrate. The company he started in 2001, Suntech, is now the world's third-largest manufacturer of solar cells, after Sharp and Q-cells. It is listed on the New York Stock Exchange and is worth around $5.5 billion. Mr Shi, aged 44, owns 40% of it. He was the richest man in mainland China last year, but according to *Forbes* magazine has been superseded by Wong Kwong Yu, an electrical retailer.

Renewable sources currently provide 13% of the world's energy needs. The main sources of renewable energy at present are geothermal and hydro-electric power and biomass. Scope for increasing the contribution of the first two is limited by geology. Scope for private-sector involvement is limited because building dams means turfing people out of their homes, so large-scale hydro-electric projects are undertaken only by governments.

Biomass provides 10% of the world's primary energy needs, mostly in developing countries, where villagers burn cow dung on basic stoves. There are a few niches in developed markets: in Britain, for instance, local councils increasingly require new developments to get 10-20% of their energy needs from renewable sources. Putting a biomass water-heater in the basement tends to be easier than sticking a windmill on the roof.

But the technology for producing electricity from biomass has not changed much in recent years, and shipping manure and woodchips over long distances is expensive. That leaves wind and solar power as the main sources of growth. Stirring figures are bandied about. According to the US Department of Energy, for instance, America could supply its entire energy needs by covering a mere 1.6% of its land area with solar cells.

Wind and solar energy already play an important part in a few countries. Around 20% of Denmark's electricity comes from wind and about 80% of China's hot water from solar energy. But worldwide those two energy sources barely register.

In the past they have flourished when oil crises pushed subsidies and investment their way. At other times they have survived in a tiny niche, providing power to isolated communities. But now they are enjoying their biggest boom ever. Solar photovoltaic power has grown by an average of 41% a year over the past three years; wind has grown by 18% a year.

The supply side offers part of the explanation. During the wind boom of the 1970s turbine blades were around 5-10 metres long, and turbines produced no more than 200-300kW of energy each. The energy they produced cost around $2 per kWh. Now the blades are up to 40 metres long and turbines produce up to 2.5MW each at a cost of 5-8 cents per kWh, depending on location (coal-fired electricity, depending on the plant, costs 2-4 cents per kWh). And there are even 5MW prototypes in existence, with 62-metre blades.

Much the same has happened to solar photovoltaic cells. The efficiency with which they convert sunlight to electricity has increased from 6% when they were first developed to 15% now. Their cost has dropped from around $20 per watt of production capacity in the 1970s to $2.70 in 2004 (though a silicon shortage has pushed prices up since).

Making hay while the sun shines

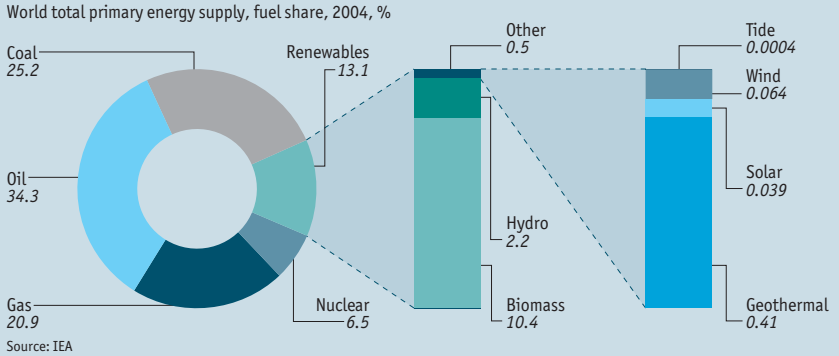
Increased demand has fuelled the boom. Power companies are getting more interested in renewables. Electricity generation is particularly vulnerable to a carbon price, and the size of companies' emissions would determine how hard they would be hit by it (see chart 5, next page). Coal-heavy companies such as American Electric Power and Southern Company would suffer more; companies such as PG&E and Exelon, which generate a larger proportion of their output from nuclear and renewables, would do better.

Many governments (see table 6, next page) have set targets for the proportion of their country's energy that should come from renewable sources. Subsidies are one way to try to meet those targets. There are, broadly, three systems in operation: the expensive and effective (Germany's and France's feed-in tariffs), the complex and ineffective (Britain's and Italy's quota-and-trade system), and the unpredictable (America's production tax credit).

Germany's and France's feed-in tariffs give generators a fixed payment for the electricity they provide. Wind and solar energy have both grown fast in Germany, but the guaranteed price for solar energy is especially generous (54-57 cents per kWh against 8.4 cents for wind). According to Julie Blunden of SunPower, an American solar-cell manufacturer and distributor, Germany's feed-in tariff means that, as a generator of solar power, "you sell power to the utility at 50 cents and you buy it from the utility at 20 cents. You're clearing 30 cents." According to Jerry Stokes, president of Suntech Europe, the payback period for a solar panel is eight or nine years, whereas the price for the electricity it generates is guaranteed for 20. Germany is the

Not much clean stuff 4

World total primary energy supply, fuel share, 2004, %



Source: IEA

Who's vulnerable 5

Top US power companies, by turnover, 2005

	Emissions disclosed tonnes, m	Cost of 25% cut in emissions at $22.57* $m	% of turnover
Constellation Energy	22.09	124.64	0.73
Exelon	12.61	71.15	0.46
Southern Company	137.00	773.02	5.70
Public Service Enterprise Group	24.81	139.97	1.13
American Electric Power	146.47	826.43	6.82
FirstEnergy	45.36	255.94	2.13
FPL Group	47.35	267.17	2.26
PG&E	0.54	3.02	0.03
TXU	50.00	282.13	2.70
Progress Energy	58.06	327.60	3.24

Source: Trucost *CO_2 price per tonne

principal source of Mr Shi's wealth: in 2004 it was buying 90% of his output. The main customers are farmers who put panels on the roofs of their barns.

One consequence is a silicon shortage which has pushed up the price of solar panels, making them harder to afford in countries sunnier than Germany that could use them more effectively. Many panel-makers have signed long-term contracts with silicon producers at exorbitant prices. The boom has spurred investment in silicon production which is likely to lead to a lot of new capacity in a couple of years, and some of those cell producers are likely to be in trouble. Another consequence is a big bill for taxpayers and electricity consumers. Germany's feed-in tariff may cost consumers an extra €2 billion-2.9 billion a year in higher energy prices.

Under Britain's Renewables Obligation, a set proportion of the electricity that power distributors buy must come from renewable sources; if they fail to meet their obligation, they must put money into a pot to be shared among the renewables providers. The system is complex and the resulting price uncertain; which, along with planning constraints, explains why so much capacity has been planned and so little built. One consequence is that the pot of money is divided between few developments, which are therefore highly profitable (see chart 7, next page). Another is that Britain will not meet its target of producing 10% of its electricity from renewables by 2010. That's one reason why, in its energy white paper published on May 23rd, the government promised a radical revision of the scheme.

America's production tax credit gives renewable-energy producers 1.9 cents per kWh, enough to encourage plenty of investment in wind, since in breezy places it is already competitive with some coal and gas generation. But the government has failed to renew it in some years, so investment in the business has slumped. Steve Bolze, GE's vice-president of power generation, says that uncertainty about the future of the production tax credit caused their turbine sales to halve between 2003 and 2004; sales then tripled, to 1,500 in 2005, when customers were once more confident of the subsidy.

Governments are using sticks as well as carrots to push investment in renewables, requiring a proportion of the energy sold to come from renewable sources. In America, for instance, 21 states have renewable portfolio standards requiring a certain proportion of power sold—20% by 2017 in California, for instance—to come from renewable sources. But it is in China that government fiat is having the most dramatic effect. The country currently meets 7.7% of its energy needs from renewable sources (including large-scale hydro). In 2005 it announced that the figure would rise to 15% by 2020. That has led to a huge rise in demand for wind turbines.

China's turbine market, says Paulo Soares, a Brazilian who runs the Chinese operations of Suzlon Energy, India's biggest wind company, has increased sevenfold in two years. Suzlon has just opened the world's biggest turbine factory in China. All the big foreign makers—Spain's Gamesa, Denmark's Vestas, GE and Suzlon—have piled in, along with a lot of smaller ones. But the Chinese government is determined to build a local industry, demanding that 70% of parts should be locally produced. There are now nine Chinese turbine-makers.

Despite the current boom, there are constraints to the growth of renewables. One of the reasons why wind power has developed so slowly in Britain is the proliferation of little local battles over planned developments. Scotland, which is empty and windy, sounds like a good bet, but most of the demand is in England, so the electricity would have to travel a long way. Highlands Before Pylons is a pressure group that campaigns against the aesthetic consequences of long-distance transmis-

Off target 6

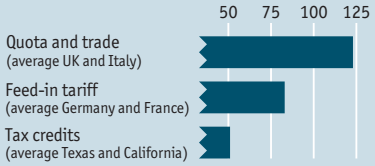
Green electricity

	Current proportion	Target proportion	Likelihood of success
Britain	4.1%*	10.4% by 2010. Nonbinding national target of 20% by 2020	No chance in 2010. 2020 target achievable only with offshore wind
Germany	10.4%*	12.5% by 2010. 20% by 2020	Likely
France	11.0%*	21% by 2010 No national target for 2020	Slow permitting set to miss target by over 50%
Spain	17.2%*	29.4% by 2010 No national target for 2020	On track until wind tariffs changed 2006-07. 22% likely
Italy	16.5%*	25% by 2010 No national target for 2020	Low because of slow permitting process, 20% likely
United States	10.0%*, >5.0% excl	No national target but binding renewable portfolio standards in 21 states	Fair depending on continuing build out of transmission capacity and political will
China	7.7%* of TPES†	15% of TPES by 2020	Likely overshoots as wind, solar, biomass and hydro industries surge
Japan	3.0% incl hydro and geothermal, 2.0% excl	3% by 2010 (no geo or hydro) 7% by 2010 (with geo & hydro)	High

Source: New Energy Finance *Including large hydro †Total primary energy supply including fuel transportation

Where wind makes money 7

Revenues from wind-power support schemes*
€/MWh



Source: New Energy Finance
*All tariffs normalised over a 20-year period

sion. Such groups, not wanting to appear hostile to a virtuous power source, tend to argue in favour of offshore wind farms, but these are considerably more expensive than onshore ones.

Despite the difficulties, however, money is flowing in (see chart 8). The NEX represents pure-play clean-energy companies, some of which have grown big. Denmark's Vestas, for instance, with a market capitalisation of $12.5 billion, is the world's biggest turbine producer. In wind energy, GE is playing catch-up.

The beauty of being big

But, for the big energy companies, catching up may not be all that hard. BP, for instance, has been producing solar cells, in a small way, for 30 years. Now it is investing heavily, in its much-vaunted determination to look Beyond Petroleum. In a joint venture with India's Tata, for instance, it expects to produce 300MW of solar cells a year by 2010; and in March this year it announced that it will also build a 300MW factory in Spain. Through a joint venture with Clipper, an American turbine manufacturer, it plans to turn itself into a significant wind-power generator.

BP has two advantages in the renewables business. It knows about energy, and it is big. Next year it will devote a mere 4% of its capital expenditure to renewables. But that adds up to $800m which, for most renewables companies, is a lot of money.

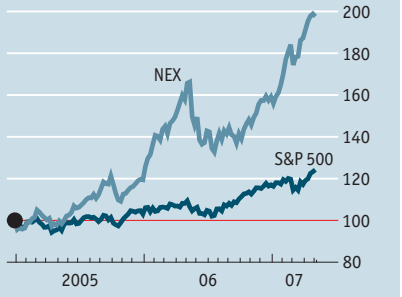
Is it money well spent? Some do not think so. "Exxon was a big investor in solar in the 1970s," says Ken Cohen, Exxon Mobil's head of public affairs. "We got out of it because we couldn't make money out of it. We bring nothing unique to solar, wind or nuclear. But we certainly bring much that's unique to the world's petroleum business. That's a full-time job."

Technology will in part determine who is right. If renewable energy goes on getting cheaper, it will get more attractive. Vlatko Vlatkovic, head of GE's renewable energy research, reckons that wind power is heading towards 3-4 cents per kWh. To achieve that, he says, the length of turbine blades needs to increase to 90 metres. The weight of the central cell, positioned between the blades, is a problem. "At the moment the cell weighs 300 tonnes. That's sitting 100 metres up in the air. Just scaling up is not viable. All the stuff in the cell has to get lighter, so the way we build these generators has to change."

But wind is now so big—it is approaching the size of GE's gas- and steam-turbine business—that companies are investing seriously. Up to now, says Mr Vlatkovic, turbines have been made from different technologies spliced together: propulsion equipment developed for ships and standard variable-speed drives used in pumps and conveyor belts. "Now the business is so big that we can design equipment specifically for wind."

Greener, cleaner investors 8

Share prices, December 31st 2004=100



Sources: Thomson Datastream; New Energy Finance

There is an upside to the silicon shortage: it has accelerated investment in thin-film technologies that use much less silicon. Silicon Valley is particularly interested in these developments. Two of the most advanced thin-film companies are Miasole and Nanosolar. John Doerr has invested in the first and Larry Page and Sergey Brin in the second.

Politics will also help determine renewable energy's future. If the carbon price and subsidies rise, its prospects should be good. But wind and solar are not as vulnerable to politics as the carbon-free technology that, in many ways, has the most potential to free the planet from fossil fuels: nuclear power. ■

Boom

As security and climate concerns rise, nuclear power may be coming back

JAPAN STEEL WORKS is in an enviable position. The core of a nuclear power plant demands huge steel forgings that weigh up to 240 tonnes. With the nuclear industry in the West in decline for nearly three decades, Japan Steel Works is one of the few companies left that can do the work. According to Yoshitaka Sato, who is in charge of the company's exports of forgings and castings, orders have doubled over the past two years. Capacity has just been expanded, but slots are now fully booked to the end of 2010 and further capacity may be added.

The nuclear industry has been chugging along in Asia, but in the West safety worries have caused it to stall. Nuclear power stations are, therefore, ageing. They contribute a sizeable chunk of electricity in the rich world—18% in Britain, 19% in America and 80% in France—so if they are replaced by coal-fired stations, CO_2 emissions will rise swiftly. Hence the recent revival of interest in nuclear power.

In Europe, this has so far been modest. Finland is building a reactor, and France, which never lost its enthusiasm for the technology, has placed a firm order for one. Britain intends to speed up the planning process for nuclear plants, and nervousness in Germany about energy security has led to a heated debate about a law requiring the phase-out of nuclear power.

It is developments in America, which has 104 of the world's 443 nuclear plants, that excite the industry. No new plants have been ordered there since the accident at Three Mile Island in Pennsylvania in 1979 (when radioactive gas escaped from a nuclear power plant), though some that were being built were completed. Many proved a burden. In 1988, Public Service

Company of New Hampshire became the first American utility since the Depression to go bankrupt, mostly because of the unexpected costs of a nuclear plant.

Since then, three things have changed. First, the approvals process was reformed in the 1990s. An application alone can cost $20m-100m, so that matters. "The intention was to offer a degree of comfort to Wall Street," says Jeff Merrifield, one of America's five nuclear commissioners.

Second, there was global warming. "Our recognition that carbon was a problem was a tipping-point in the decision-making," says Jim Rogers, chief executive of Duke Energy, which already has seven nuclear plants and is planning to build another. "You wouldn't take such a big risk if you weren't going to be in a carbon-constrained world."

Third came the Energy Policy Act of 2005, which gave the industry a production tax credit worth 1.8 cents per kWh, provided $1.25 billion for innovative technologies and made available $2 billion in insurance against regulatory delays. For a plant to be eligible, the application has to be in by the end of next year, so the race is on: 22 companies have told the Nuclear Regulatory Commission (NRC) that they are planning a total of 32 new reactors.

Suppliers are gearing up. "We have been pouring in money and people," says Andy White, president of GE Nuclear Energy. "We're making a big bet on nuclear." Last year Areva, the big French nuclear-construction company that is building the Finnish plant, bought Sfarsteel, a loss-making company which produces some of the large steel forgings needed. Toshiba bought Westinghouse, which has bounced among owners over the past decade. Now Mitsubishi Heavy Industries and others are trying to get designs certified for the American market.

Rising again?

But three tricky issues remain. The first is waste. The Department of Energy has spent $9 billion on studying the main proposed burial site, Yucca Mountain, without coming to a decision. But the absence of a long-term burial site may be less of a problem than it seems. The NRC reckons that waste can be kept safely in dry-storage casks surrounded by inert gas for 100 years while a solution is pursued.

Second, there is terrorism. The NRC's Mr Merrifield says that nuclear plants, with three-foot-thick concrete walls, are robust enough to withstand most forms of attack; but given the modern terrorist's proven ability to surprise, not everybody will be satisfied by such reassurances.

Third, there is cost. A study by MIT put the cost of nuclear electricity at 6.7 cents per kWh, against 4.2 cents per kWh for pulverised coal. Suppliers say it would be wrong to judge nuclear power on the basis of past performance, since better technology coming on to the market will cut costs significantly; but the cost overruns at Areva's new Finnish reactor do not inspire confidence.

New plants are needed to show whether they can be more cost-effective than the previous lot. And it looks as though America may build them. ■

Dirty king coal

Scrubbing carbon from coal-fired power stations is possible but pricey

THERE are two remarkable things about Sleipner T, a gas rig in the middle of the North Sea owned by Norway's state-owned oil company, Statoil. One is the working conditions. Technicians get around NKr600,000 ($100,000) a year, private rooms with televisions and ensuite bathrooms, and work two weeks out of every six. That is what you get when social democracy meets oil wealth.

The other unusual thing about Sleipner T is that the CO_2 which has to be extracted before the gas can be sold does not contribute to global warming. Instead of being pumped into the atmosphere it is reinjected into the ground, 1,000 metres below the seabed. That is what you get when an innovative company meets a carbon tax.

Statoil started capturing and storing its carbon dioxide in 1997, five years after Norway introduced a carbon tax. Nobody paid much attention then, but these days Statoil gets a regular stream of visitors because carbon capture and storage (CCS), also known as carbon sequestration, is widely seen as a possible quick fix for global warming.

It is the abundance, cheapness and dirtiness of coal that makes CCS so appealing. Coal produces 50% of America's electricity, 70% of India's and 80% of China's. It is widely distributed around the globe, which enhances its attractions at a time of concern about energy security. Burning coal is the cheapest way of generating electricity. And coal produces around 40% of the CO_2 emissions from energy use.

High gas prices have meant that coal has been enjoying a revival in recent years. In America some 150 new coal-fired power stations are on the drawing board. In China, two 500MW coal-fired power plants are starting up every week, and each year the country's coal-fired power-generating capacity increases by the equi-

valent of the entire British grid. So anything that offers the prospect of cleaning it up is attracting a great deal of interest.

Standard pulverised-coal (PC) generation can be made a bit cleaner by burning the fuel at higher temperatures. "Ultrasupercritical" generation can cut CO_2 emissions by a fifth. But if demand goes on increasing, that is not enough. Hence the interest in CCS.

CCS is being done in three places—at Sleipner; at In Salah in Algeria, where the CO_2 removed from gas produced by a joint venture between BP, Statoil and Sonatrach, Algeria's state-owned energy company, is stored in the desert; and at the Weyburn oil field in Saskatchewan, Canada, where the CO_2 produced by a coal gasification plant in North Dakota is piped across the border and used to increase the pressure in a partly depleted oil field. This process, known as enhanced oil recovery (EOR), is in use in 70 oil fields around the world, but at Weyburn, unusually, some of the CO_2 remains underground.

Most of the operations involved in CCS are familiar. First, the CO_2 must be separated from other gases. At Sleipner, for instance, the CO_2 content of the gas that emerges from the oil field is 9%. That has to be reduced to 2%, which is done by passing the gas through amines (nitrogen-based chemicals). Second, the CO_2 is moved along in pipelines. That is commonly done in EOR, as is the third stage—injecting it into the ground.

The fourth stage is the least familiar. When CO_2 is being used for EOR, it returns to the surface (except at Weyburn). For sequestration, however, the CO_2 must be stored underground, probably in depleted oil and gas fields or in porous briny rock. Statoil has been doing this for a decade at Sleipner, and there is no sign of the stuff bubbling up again. Scientists say that within decades or centuries it will dissolve, and within centuries or millennia it will react with elements in the rock and form new minerals. But this part of the process needs more study.

The challenge is to put all those technologies together and deploy them at a reasonable cost, and on a scale that can make some impact on emissions. That will take some doing. If 60% of the 1.5 billion tonnes of CO_2 that America produces every year from coal-fired power stations were liquefied for storage, it would take up the same amount of space as all the oil the country consumes.

Coal-fired power stations are the likeliest candidates for CCS because they are dirty and numerous. But there is a difficulty with PC plants: they spew out a huge volume of flue gas, of which CO_2 is only a small part. Separating it from other gases is expensive. The main alternative is to turn coal into gas before using it to generate electricity. The resulting CO_2 and hydrogen are then separated, the hydrogen used to generate electricity and the CO_2 stored. A few such integrated gasification combined-cycle (IGCC) plants have been built.

Every which way

Now that power utilities are beginning to accept that they will have to do something about carbon, the big question is what. GE has bought Chevron's IGCC technology. The cost of generating electricity from it, according to GE's Steve Bolze, is 20-25% more than a PC plant, but Mr Bolze believes that, once the cost of separating carbon is taken into account as well, IGCC may be cheaper.

Philippe Joubert, president of power systems at Alstom, which in March announced a joint venture with American Electric Power, America's biggest coal-fired generator, rejects the idea that IGCC is cheaper, even with CCS. "This is clearly not true. We should know. We are in IGCC as well as PC. It's clearly 10% more expensive. All serious academics realise that it is more expensive." A study by MIT published in March tends to side with Mr Bolze. Generating electricity from an IGCC plant with carbon capture, it maintains, is 35% more expensive than PC without CCS; but PC with CCS is 60% more expensive than PC without.

Sending carbon back where it came from

Plans for IGCC plants are proliferating. In America, at least, that says more about subsidies than about faith in the technology's future. George Bush announced a $2 billion clean-coal initiative in 2002, and the 2005 Energy Policy Act, notorious for its pork content, included $1.6 billion-worth of subsidies for coal gasification.

According to the International Energy Agency, around 15 power plants with CCS are being planned and another seven CCS projects are on the drawing board. Most make economic sense either because of direct subsidy or because of their particular economic circumstances. Statoil and Shell are planning to sequester CO_2 from a Statoil power plant on the Norwegian mainland under Shell's Draugen platform. The investment is justified by Norway's carbon tax, currently about €50 per tonne. BP is planning a petroleum-coke-fuelled power plant in California, where electricity is particularly expensive and the petroleum coke for the power plant comes as a by-product of oil refining; the project is a joint venture with Edison International, an electricity company.

One big company that is making a sizeable punt on CCS is Vattenfall, which is building a 30MW plant in Germany. "I'm totally convinced", says Lars Josefsson, Vattenfall's chief executive, "that the issue of carbon sequestration will change the way we do business in the long term. I believe the companies that realise that soonest will be the winners."

If CCS is to take off, the rules on CO_2 storage need sorting out. The 1996 London protocol on dumping waste at sea was amended earlier this year to allow CCS at sea. But rules on land need attending to, for promoters of CCS worry that it will become as contentious as nuclear waste.

And, as always, there is the problem of cost. At present, academics reckon that it would take a carbon price of around $30 to make sequestration economic—below the peak that the ETS hit briefly in 2006, and way above the $10 safety valve in the only carbon bill in Washington, DC, to mention a figure. But the cost may come down, because that is generally what happens as technologies are commercialised.

Despite the tricky economics, the sheer abundance of coal is an argument for pursuing CCS. And if it can be made to work, it has a certain poetic circularity: the carbon extracted from the earth as fossil fuel shall return unto the earth whence it came. ■

The drive for low emissions

Car and fuel companies are investing in clean transport

KEN LIVINGSTONE, the mayor of London, last year caused a mild panic among drivers who cruise the city's narrow streets in "Chelsea tractors" (SUVs to the rest of the world). He announced that he was planning to charge cars emitting more than 225g of CO_2 per kilometre £25 a day to go into the centre of London rather than the standard £8. "Red Ken" has always enjoyed stirring it among the rich, so he was probably quite happy at the stink he caused.

Worldwide car ownership is growing around 5% a year, so if emissions from cars are to be cut, engines will have to become dramatically more efficient, or there will have to be a technological breakthrough to replace petrol with a clean fuel. Now that governments seem to be getting serious about emissions, car and fuel companies are getting serious about finding less polluting alternatives.

Fuel-efficiency regulations of varying kinds already exist in all the countries that matter, but in America, where they were fairly tough during the oil crises of the 1970s and 1980s, they have lost their bite. Improvements in engine efficiency have been used not to reduce fuel consumption but to weigh cars down with gizmos. And car companies have carried the burden of those regulations. Fuel companies, so far, have got off scot-free.

That seems to be changing. Mr Livingstone's initiative is only one of many new measures that have been proposed around the world to cut vehicle emissions. California is trying to impose greenhouse-gas emissions standards on cars, though the motor manufacturers have taken the state to court on the ground that this is federal-government business. In his most recent state-of-the-union address, George Bush's big concession to the greens was to propose a 4% a year tightening in fuel-efficiency rules.

The EU has had a long-standing voluntary deal with the carmakers under which they would aim to reduce the average CO_2 emissions of their fleets to 120g/km by 2012. But thanks to consumers' growing enthusiasm for high-power, high-emissions cars, that seemed unlikely to happen, so this year the European Commission decided to impose a mandatory standard. There was a big row, but the commission got most of what it wanted.

And now governments are taking aim at fuel companies too. In January California announced that by 2020 it will require a 10% reduction in the carbon emissions that a fuel emits over its life cycle. That has implications for "unconventional oil"—petrol made from oil shale and tar sands. Although CO_2 emissions from the resulting fuel are the same as those from conventional sources, producing it is a filthy business, so such rules will discourage its use. Europe is planning to follow California. That is not necessarily a coincidence. There is a lot of traffic between Brussels and Sacramento on green issues.

Tighter regulation will not hit all companies equally (see chart 9). German car firms are particularly vulnerable, which was why they made the most fuss about the commission turning the voluntary target into a mandatory one. The French and the Italians were smugly silent.

A corny idea

"This industry is 98% dependent on petroleum. GM has concluded that that's not sustainable," says Larry Burns, GM's vice-president of R&D and strategic planning. "It's all about displacing petroleum."

The Prius's success—390,000 Americans own one—is a testament to Toyota's vision and marketing. But it is not clear how much potential there is in the hybrid market. Bill Ford announced in 2005 that his company would be building 250,000 hybrids by 2010, but it no longer seems to be aiming for that. Anyway, hybrids are not a solution to global warming. Their somewhat greater fuel efficiency will soon be offset by the increase in global car ownership. More radical technological changes are needed.

Ethanol is one possibility, because although burning it emits CO_2, growing the crops needed to produce it absorbs the stuff, at least in theory. The farming lobby has been pushing it as a new source of revenue. The car industry is keen on it: if the fuel changes, then the cars don't have to. GM has been running a "live green, go yellow" campaign to promote it.

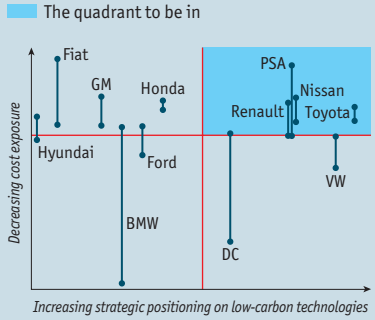
Ethanol currently accounts for only 3.5% of American fuel consumption, but thanks to heavy subsidies its use is growing by 25% a year, says Matt Drinkwater of New Energy Finance. When oil prices were at their peak, the payback period on an ethanol plant was 11 months. Not surprisingly, they have sprung up all over the Midwest. Soaring demand for maize for ethanol caused the sharp rise in the corn price which led to "tortilla riots" in Mexico.

There are three problems with corn ethanol. First, the market is limited. At present, any car can take E10 fuel (10% ethanol) but only 6m out of America's 237m cars and trucks are "flex-fuel" vehicles that can take E85 (85% ethanol). Converting a car costs only around $200, but invalidates the guarantee. Detroit has promised that half of its output will be "flex-fuel" by 2012.

Second, corn ethanol is expensive. At the pump it is competitive with gasoline; but according to the International Institute for Sustainable Development, America's subsidy costs taxpayers somewhere between $5.5 billion and $7.3 billion a year. And high tariffs keep out imports of cheap Brazilian ethanol made from sugar cane.

Third, corn ethanol is not very green. Some people think that corn ethanol is responsible for more emissions than it saves, because so much energy is used in growing the corn. Dan Kammen and Alex Farrell of the University of California at Berkeley reviewed six studies on the issue ▸▸

How car companies fare in a cleaner-energy future 9



Source: WRI and SAM Research

Length of car-company line represents the range of cost exposures

and concluded that, gallon for gallon, ethanol is probably 10-15% better than petrol for emissions of greenhouse gases. That is a help, but no panacea.

A better bet may be cellulosic ethanol—ethanol that can be made out of straw, switchgrass, wood chips—pretty much anything with cellulose in it. Mr Bush, keen on a technological quick fix for global warming, has offered $385m in government subsidies to bring cellulosic ethanol to market.

A lot of people are trying. Vinod Khosla's company, Range Fuels, is planning to build a commercial-scale ethanol plant in Georgia. Using woodchips as a feedstock, it employs heat and chemicals to break down the tough bonds in cellulose molecules. Up to $76m of subsidy will help it on its way. Many companies are working on suitable enzymes to break down those bonds. One such is Iogen, in which Goldman Sachs and Shell have taken stakes. It will be getting up to $80m from the government.

One further problem with ethanol is that it is less energy-intensive than petrol, so you get fewer miles per gallon. That is one reason why BP is putting its money into a different fuel, biobutanol, which is more energy-intensive than ethanol. BP is developing it in a joint venture with DuPont, for which biobutanol offers a possible way into the fuel business.

And then there is the electric car—not the hybrid car that uses electricity for pottering about in the city and switches to its combustion engine at speed, but the fully electric sort that uses either a hydrogen fuel cell to produce electricity or a battery to store it.

Hydrogen is an attractive way of powering a vehicle because it can be made from all the sources that electricity can. But hydrogen fuel cells have been just around the corner for a long time. GM has been working on them since the 1960s, and reckons that so far it has spent $1 billion. The technology's appeal is obvious, for it could revolutionise not only the car: if the hydrogen fuel cell can produce electricity to power a vehicle, why not a house as well?

There was a bubble of excitement about fuel cells in the late 1990s, and shares in companies such as Ballard Power Systems rocketed. But hopes that a fuel-cell car would be on the market early this decade were disappointed. The fuel cell, says Shell's Duncan Macleod, was "overpriced and over-promised at the front end".

Still, fuel-cell vehicles are getting onto the roads. London ran three buses for a three-year trial and is now planning to buy ten. There are around 60-80 hydrogen buses and 200 cars on the road worldwide, and a few filling stations. Shell, which is taking hydrogen seriously, is about to open its first filling station in California. It has one already, in Washington, DC, to service ten cars, and another in Iceland, for three buses. It is an expensive business. London's three-year, three-bus trial cost £4.5m. Hydrogen cars cost around $1m each to build, according to Mr Macleod. At the pump the hydrogen costs $5 a kilo—about the same, in terms of mileage, as current petrol prices. How much does it cost Shell to make? "A lot more than $5," says Mr Macleod, laughing.

GM is also working on battery technology. At this year's Detroit motor show it unveiled the Chevrolet Volt, which has both a battery and a combustion engine. The technology got generally good reviews, but GM has not said when it will start producing the car commercially.

Meanwhile, rushing up on the inside lane are those disruptive people from Silicon Valley. Last year Elon Musk, a South-African-born entrepreneur who started PayPal, an online payments system, unveiled the Tesla, an electric sports car. It plugs into the wall and stores the energy in a lithium-ion battery—the sort used in laptop computers, only with 6,831 cells. And it's a pretty, and nippy, little car. "A Porsche can accelerate from 0-60 in 4.7 seconds," says Mr Musk with understandable pride. "The Tesla can do it in four seconds."

It has a few disadvantages. The first is cost. Mr Musk has pre-sold the first 350—the first 120 of those for $100,000 apiece. "The average net worth of the first 120 customers is over $1 billion," he says. However, he plans to start work on a budget version next year. The second is range. The Tesla's maximum is 250 miles. If there are other downsides, they may become clear in August or September this year, when the first production models should slip silently off the production lines and onto America's roads.

Clean-energy entrepreneurs may find the transport business harder to crack than power generation, because the existing infrastructure of pipelines and service stations is dedicated to petrol. Yet Brazil, where sugar ethanol now accounts for 40% of fuel used by cars, shows that it can be done. Now that governments are beginning to lean on big oil as well as on the car companies, the drive towards cleaner transport is likely to pick up speed. ■

The final cut

Business can do it, with governments' help

THESE days business is full of enthusiasm for combating climate change. That is a good thing, but there are risks.

One lies in the very voguishness of the issue. Climate change is fashionable, and although fashion has the virtue of being able to transform the dull and worthy into the hip and happening, it is, by definition, transitory. Hollywood stars will probably get bored of their Priuses, and executives may become weary of mouthing green platitudes and move on to whatever branch of corporate social responsibility next catches the popular imagination.

A second risk lies in the volatility of the oil price. The higher it goes, the better the prospects for constraining carbon. Shares in clean-energy companies rose with the oil price in 2004-05 and dipped last year; but the oil price remains historically high, thus supporting the current optimism about green business. In the long term the oil price is expected to be above $50, which would be good for clean energy. But should it crash, those who had invested heavily in renewables and other alternatives to fossil fuels would look silly.

The third risk is political. Companies investing in energy efficiency and alternatives are banking on incentives to provide them with decent returns on their investments. But unless those incentives rise, the clean-energy boom is likely to turn to bust.

Consumers are not likely to provide companies with the incentive to go green. They may like the warm glow they get

It's getting unbearable

from buying ethically sound products, but there is little sign that they are prepared to spend more money on them. Not even 1% of passengers have taken up BA's very reasonably priced offer to offset the carbon emissions of their flights (£5 for London-Madrid, £13.50 for London-Johannesburg). That may be because people are selfish—or it may be because they are rational enough to know that their individual economic choices are not going to make a blind bit of difference to the future of the planet. Nobody is going to save a polar bear by turning off the lights.

As voters, however, people can make a difference. Climate change is a collective problem, which can be dealt with only collectively. Voters can encourage that by electing governments committed to changing the rules to encourage companies to behave differently.

There are three ways for governments to persuade companies to constrain carbon: subsidies, standards and a carbon price. Subsidies are popular with recipient companies; with greens, who reckon that any money used to combat climate change is well spent; and with governments, which like handing out taxpayers' money. Taxpayers tend not to notice. Some economists also advocate subsidies to particular technologies because they need a kick-start to get them to market. That may be true in the case of big, risky processes such as CCS. But subsidies tend to be inefficient because they require governments to pick technologies. And, once in place, they are hard to abolish.

A second way for governments to discourage emissions is by setting standards for products and processes (such as imposing energy-efficiency requirements for buildings, or banning incandescent lightbulbs). Such standards are usually a bad idea, for they require governments to tell the private sector how to allocate resources, and the private sector tends to be better at that than governments are. But given the market's inability to eliminate energy waste from buildings, and society's interest in doing so, they are probably worth having in this case.

Still, a carbon price is likely to be the best way to cut emissions. That can be established through either a tax or a cap-and-trade system of the sort Europe has.

A tax would be the better option. Unlike a cap-and-trade system, which stipulates the amount of CO_2 that may be emitted and allows the price to vary, a tax sets a price and lets it determine the quantity emitted. The volatility of the carbon price in Europe, which has variously risen above €30 and dropped to close to zero, is blamed in part for the lack of investment in clean energy, so there is a lot to be said for setting a price. But the prospects for a tax are not good. Business—particularly in America—is allergic to the very word; and the allowances which companies tend to be handed in the early stages of a cap-and-trade system have an obvious appeal to companies concerned about rising costs.

Whichever way a carbon price is established, the big question remains: can it be set at a level high enough to make a difference to climate change without derailing the world economy?

Probably. According to Richard Newell of Duke University, economists' estimates of the carbon price needed to stabilise CO_2 concentrations at 550 parts per million (widely reckoned to be a safeish level) range from $5 to $30 per tonne by 2025 and from $20 to $80 per tonne by 2050. The Intergovernmental Panel on Climate Change came out with fairly similar figures in its fourth report earlier this year—$20-50 per tonne by 2020-30. Mr Newell reckons that, in America, $20 per tonne would raise petrol prices by an average of 18 cents (or 6%) per gallon, and electricity prices by 14%. A $50 price would raise petrol prices by an average of 45 cents (or 15%), and electricity prices by 35%.

At the bottom end of the range these costs are not huge. Even at the top end they are manageable. The IPCC's estimates of what a $20-50 carbon price would do to world GDP by 2050 range from a slight increase on what it otherwise would have been to 4% less. The average is 1.3% less, which would mean that average annual growth would be around 0.1% lower than it might otherwise have been.

Those prices assume that the entire world adopts a carbon price. That is a heroic assumption. Persuading developing countries to do so will be very hard.

It cannot be done unless all rich countries take the first step. They need to set an effective carbon price, and show the developing world that they can do so without ruining their economies. It wouldn't be a solution to climate change, but it would be a start. ■