

Opportunities for innovation

**The business opportunities
for SMEs in tackling the
causes of climate change**

October 2006

Executive summary

Introduction

The world has become increasingly aware of the need to tackle the threat of climate change. Over the next fifty years limiting the concentration of carbon emissions in the atmosphere means a reduction of greenhouse gases equivalent to between 2.2 and 3.7 trillion (million million) tonnes of carbon dioxide.

This provides a substantial opportunity for both small and large businesses to sell goods and services that reduce greenhouse gas emissions. Although the market opportunity is large, the cost of tackling climate change is not unaffordable for the UK economy. If the average UK business met the environmental damage of its greenhouse gas emissions it would amount to less than 0.8% of its value added.

This study estimates the size of the UK and global market opportunity for small and medium-sized enterprises (SMEs) in tackling the causes of climate change. The role of SMEs in tackling climate change is often not well understood, either by government or by SMEs themselves. This study aims to show that the size of the opportunity is substantial.

The role of small and medium sized enterprises and the opportunity for them

Small and medium sized companies will be able to seize the opportunity in a multiplicity of ways. In fact, there are virtually no areas of the market that are not open to them. Even large scale infrastructure projects often use SMEs as subcontractors, and use the innovations created by SMEs. SMEs are ideally placed to create radically new innovations that open up entirely new markets or revolutionise them.

Examples of areas where SMEs might be successful include the germination of new technologies or the application of pivotal combinations of existing technologies in novel ways, to fresh markets. They also include new methods of manufacturing, financing capital, trading commodities, sharing information and managing resources. Many of the prime opportunities lie in the extraction, supply, distribution and conversion of energy, but there is also fertile ground in the delivery of services through low-carbon means, the re-design of existing products, the management of energy demand, changing behaviour and the adaptation of existing infrastructure.

Opportunities from voluntary actions and compliance

In the short term there is a burgeoning market arising from individuals and companies voluntarily taking actions to reduce their impact on the environment. This market is growing rapidly with the increasingly common use of carbon trading in the form of projects to reduce carbon emissions from industry in developing countries. Many voluntary actions are difficult to measure because they are the result of private choices in markets that already exist and where the motivation for purchasing is unclear. However, in both the short term and long term the voluntary market appears to be outweighed by the compliance market. While the voluntary market is likely to be under-measured we estimate that 90% of the opportunity in 2010 will be due to government action.

Opportunities in the UK and global markets

On the basis of the UK Government's plans to tackle climate change (the compliance market) and the emerging voluntary market, the UK market opportunity alone will be worth £4 billion a year by 2010. The compliance market resulting from the UK Government's climate change programme over the next 10 years will be worth around £30 billion or more. The compliance market is growing primarily because the UK is tightening building standards, bringing forward renewable electricity and biofuel schemes, and tackling the energy efficiency of dwellings.

There will be significant markets of several hundred million pounds a year in each of several areas, such as road transport fuels through to building regulations. The expenditure rather than the carbon saving in each part of the market is the best indicator of market size. Energy efficiency offers the largest market opportunity because the capital-intensity of energy efficiency measures in buildings results in high spending, whereas emissions trading offers the largest emissions savings. SMEs looking for the largest opportunities should look at expenditure by a sector, not the emissions savings delivered by it.

UK consumers do not currently take a prominent role in tackling climate change by purchasing emission offsets. If they were to offset the emissions associated with 5% of their purchasing (roughly equivalent to the share of organic produce in the food market), the total emissions reduction would be about 12 million tonnes of carbon dioxide, worth about £40m per year. If businesses were to do the same, the reduction would be a further 20 million tonnes of carbon dioxide, worth around £60 million per year.

SMEs will also benefit from the opportunity presented by the far bigger global market for reducing greenhouse gas emissions. The scale of regulatory activity in California, other parts of the US, and across Europe is creating a market worth tens of billions of pounds. In addition, new research and development programmes of multi-national firms, which are both reactive to new regulation and pre-emptive of future regulation, in motor manufacturing, power generation and power systems, are now worth billions of pounds.

If we take an estimate of the cost of cutting emissions by one tonne of carbon dioxide emissions and apply it to the cuts that have to be made globally to achieve stabilisation of global temperatures, this gives us an estimate of future global expenditure, and hence market size. Assuming that the world does act, the annual expenditure on carbon emissions reduction will grow by between US\$10 and 100 billion per year for the next 45 years and total \$1 trillion over the first five years. Our central estimate is that this market would have to grow by \$70 billion a year for the next few decades, if greenhouse gas concentrations are to be stabilised.

What next

The stability of long term government policy is one of the key determinants of market opportunity. A clear regulatory framework reduces uncertainty and can stimulate action, leading to consumer and business demand in international and national markets.

In a country like the UK, where the public sector makes up 36% of the economy, public sector procurement can have a major impact.

Case studies of innovators and a study of the SME sector as a whole shows that drawing innovators' attention to finding solutions for particular technical problems and drawing innovators to the attention of potential customers could create substantial benefits. We propose a series of prizes to deliver these effects, modelled on the famous Longitude Prize established by Parliament in 1714.

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1. Introduction

Shell Springboard commissioned this report from Vivid Economics with the aims of gathering evidence on opportunities to tackle the causes of climate change for small and medium-sized enterprises (SMEs), exploring the size of the opportunities by market segment and using case studies as illustrations of entrepreneurs operating in this field.¹

Section 2 sets out some background on small businesses and climate change.

Section 3 investigates the special role of the climate change entrepreneur in bringing radical innovation to market and the challenges he or she faces.

Section 4 looks at the potential size of the market demand which entrepreneurs can tap into, the balance of segments in which it will occur and the drivers causing it.

Section 5 sums up the findings and offers a recommendation.

2. Background

One year ago, Shell Springboard and Ipsos MORI asked UK SMEs how much they knew about climate change. Although some were knowledgeable, 69% knew little or nothing about the consequences for their businesses.ⁱⁱⁱ

The number of firms showing concern over the causes of climate change is equally low. The average small business makes only a minute impression on global warming. If the average UK business met the environmental cost of its greenhouse gas emissions it would amount to less than 0.8% of its value added, using a common measure of the value of damage.^{iv} This is because three quarters of the UK's economy consists of services which consume little energy.^v

When a sample of businesses is asked for their views, it is unsurprising that cost pressures spring to mind first. The policies now in place to tackle the causes of climate change have pushed up the price of gas and electricity and are planned to raise the price of transport fuels.^{vi} In MORI's study, 49% of small and medium-sized enterprises saw climate change as a burden in the form of increased regulation, taxes or risk. However, there is a group of SMEs who stand to benefit, and in doing so, deliver benefits for the economy and for the environment.

3. The role of the small entrepreneur

3.1 Radical innovation

Small entrepreneurs have a critical role to play in tackling the causes of climate change.^{vii} We know this because of an impressive history of innovation by small businesses, particularly in the genesis of radical and disruptive technologies, processes and business models.^{viii} Examples include the telegraph, telephone, radio, personal computing, the internet dot coms, biotechnology and nano-technology.^{ix}

Start-ups and larger companies innovate in different ways. Start-ups can pioneer technologies that are revolutionary because they are freer from the inertia that can restrain more established firms for a number of reasons. Firstly the new entrant may be more motivated to innovate as a necessity of survival. Secondly more established companies may have to overcome handicaps such as an attachment to their past successes, an organisational culture focussed on existing products, a structure not well suited to research and development, and may be reassured by the loyalty of their current customers.^x The ability of new entrants to think anew is illustrated by HeliSwirl, a company with a radical new technology which emerged from university research.

There are also reported features of markets that focus managers' attention on short- and medium-term profits, rather than research and development which can take a long time to bear fruit. To try and overcome these challenges a large company will sometimes set up an SME within itself in the hope that it will behave differently to its parent. In comparison, small companies that are owned by their management may have the right incentives to look to the long-term, but will only do so if they have the financial resources to wait.

New entrants do not hold a monopoly on innovation. In addition to the radical technologies that incumbents do generate, such as Pilkington's float glass process, established firms have a formidable record in improving the performance and reducing the cost of existing products and processes.^{xi} Small entrepreneurs introduce radically new ideas and established companies build and improve on them.^{xii} Large companies are more likely to make major innovations by applying their existing competencies to new markets and activities.

HeliSwirl Technologies' founders continue the great tradition of inventors mimicking the natural world. Five hundred years ago, Leonardo da Vinci sketched the swirling flow mechanism that closes the valves in the heart's chambers. More recently, researchers at Imperial College found that nature also uses swirling flow in blood vessels and that this insight could be harnessed to reduce energy consumption in many industries.

The breakthrough observation that blood travels around the body in a spiral motion and the insight that this pattern of flow reduces friction, bubbles and clots, presented them with the challenge of how to replicate the flow at low cost in man-made pipes. In solving this problem, HeliSwirl's technology was born. The technology generates swirling flow, cutting friction in multi-phase flow in pipes. This reduces energy consumption, allows pumps to be downsized, lowers pipe friction and avoids the deposit of sediment which can block pipes. All of these benefits translate into cost savings and lower energy use.

The company was conceived at Imperial College, where the researchers were based. Spotting the potential application to industrial fluid handling, they sought to commercialise their ideas. The company expects to take the technology to potential customers including petroleum production, petrochemical processing, water distribution and the food industry.

Frequently, entrepreneurs bring an insight, cross-sector transfer of technology or application of research findings to the market for the first time. On other occasions, the innovation involves the specialisation of an existing technology, process or business model to suit a new market. For example, a boutique or niche provider can gain a high market share in a developing market while remaining small and tailoring its business to that market. Therefore, as demand to tackle the causes of climate change builds rapidly from a small base, it creates fast-expanding niches into which small companies are able to move.

Funding is an important issue. In a recent study for the Environmental Innovation Unit of the Department of Trade and Industry, funding for research and development and for commercialisation were mentioned most frequently as a challenge by 46 enterprises in the environmental field surveyed.^{xiii} However, these are not the only obstacles to overcome. Proving that the product is fit for purpose, which often involves quality verification, can also present a challenge, and provides another stage where external funding and appropriate testing and certification facilities can help.

The extraordinary strength of the composite panel at the heart of the Mantle® Building System® was discovered indirectly while trying to create something else. A programme of testing performed in 1999 at the Building Research Establishment near Watford was intended to determine the best load-bearing frame material for an engineered, water-resistant, carbon neutral, highly insulating building component used for walls and roofs.

Mantle Panel Ltd was founded in July 2001 with the aim of developing further and making best use of the technology. The ultra-high thermal insulation properties of the Mantle® Building System® lead the market, its performance abilities being far in excess of existing or envisaged building regulations in the UK or Europe. So airtight and insulated is a Mantle® building that most of the necessary heating is supplied by the occupants of the house. A mechanical Heating/Ventilation and Air Conditioning system fitted with a hypo-allergenic filter must be installed to control air circulation and humidity at a cost comparative to conventional central heating. In combination with other existing and simple technologies to generate power, a Mantle® house can be energy self-sufficient. In some cases it has been calculated it could even return energy to the National Grid.

The Mantle® system cuts carbon emissions by using partly recycled material and using fewer vehicles and lighter-weight transportation to get the material to a site because only just enough material to complete the build is needed. The smaller and lighter foundations also reduce carbon impact and the system will use far less energy when the building is inhabited. Richard Sexton, Director, says 'build it right and you do not need to depend on the occupier to do their bit, because the house that they live in does it for them. Shell Springboard gave us a big boost in public profile, and we are using Springboard funds to broaden our certification throughout Europe.'

In a country like the UK, where the public sector makes up 36% of the economy^{xiv} public sector procurement can have a major impact, providing customers for entrepreneurs with high value and environmentally-beneficial technologies. This has been recognised in the US where the Small Business Innovation and Research programmes have supported emerging technologies through to market readiness. In the UK, it is a role of the Greening Government initiative.

3.2 Funding and lead times

The effort involved in bringing innovations to market readiness can be surprisingly high. One example that shows just how long and expensive it can be is that of Kevlar fibre. Dupont spent \$5.7m on lab research, \$32m on pilot plant development, over \$300m on commercial plant construction, and another \$150m on marketing, sales and distribution.^{xv} Kevlar took 17 years to develop and another common material, Teflon, took 31 years. Furthermore, once the product is ready to take to market, sales may not follow immediately. The product lead time in automobile manufacture is around 3 years, but can be up to 30 years in aerospace. However, some companies manage to bring new technologies to market much faster. A company which envisages a short adoption period for its technology is Enecsys.

Enecsys is a pioneer in developing ways of connecting new energy sources such as solar, wind and fuel cells to the electricity grid. The power from solar panels needs to be converted to mains electricity while adapting to variations in sunshine levels. To maintain high efficiency when the power output from the solar panels is low is particularly challenging.

Market research clearly shows that the key requirements for photovoltaics are installation costs, scalability and reliability. In response, the company has designed its product to work with small solar systems and to be scalable to much larger systems. This will make it easier for small-scale domestic and commercial users to adopt local micro-generation of solar, wind and fuel cells. Enecsys aims to make renewable energy systems more reliable and cheaper, laying the basis for new forms of energy generation and distribution.

Once a company has been formed, it can tap into a further source of funding, i.e. awards and grants, aimed at helping to bring the product close to market readiness and the prospect of sales revenues. Grants are invaluable because they neither impose heavy interest charges on a company that still lacks revenues nor do they force entrepreneurs to sacrifice their ownership of an organisation before they are ready in order to obtain equity funding. These are available from organisations such as The Carbon Trust and the DTI, and can prove crucially important to the further development of products. At both of these early stages, entrepreneurs can approach technology incubators to act as midwife or mentor, advising on protection of intellectual property, business strategy, and funding, as ideas are taken from the research phase into the start-up–business phase. After incubation, the next stage is frequently funded by a mixture of venture capital and business angels and, at a later date, by public listing. The Carbon Trust operates in all these areas.

The problem of funding for SMEs is essentially a ‘chicken and egg’ problem of proving that an innovation is valuable before it has been widely used. Wide use in turn can only occur once funding has been secured. Funding may have to be secured not just once but several times as a company develops as the example of CMR shows.

In 2000, Michael Evans and Michael Priestnall, colleagues at the Generics Group in Cambridge in the UK, realised that the little-known mixed-reactant or single-chamber fuel cell (which has been known since the 1950s) could be modified to make a much cheaper fuel cell. The new company was founded to develop direct methanol fuel cells based on this idea and was incorporated as CMR in October 2003. CMR became one of a number of companies to branch off from Generics, which has a history of generating new companies.

In January 2004, CMR secured funds from Conduit Ventures, an energy technology venture capital firm specialising in fuel cells and related hydrogen technologies, with the Carbon Trust Investments and Scientific Generics as co-investors. In August 2004, John Halfpenny was recruited by CMR as Chief Executive. As a former director at ARM and Chief Executive of Splashpower, he had experience of new business models for commercialising technologies. This founding team then set out to accelerate product development and stack performance while at the same time securing funds to support development. In July 2005, CMR Fuel Cells completed a second private funding tranche from a syndicate of institutional and individual investors. Following the completion of the last round tranche of funding, in December 2005 the company successfully listed on the AIM market of the London Stock Exchange, raising £11.5 million in a private share placement.

CMR was selected for Red Herring’s Top 100 List, as Technology Pioneer for 2006 at the World Economic Forum and were further chosen by Harvard Business School as one of 25 companies ‘most likely to change our world by 2010’. CMR is now working with a number of electronic product original equipment manufacturers to develop fuel cell systems based on its technology for their products.

John Halfpenny, CEO of CMR, says: ‘there are two main things we have to do: create demand by showcasing the real-world commercial benefits of CMR technology, and to build a supply chain of component suppliers and system integrators which allows us to fulfill that demand.’

4. Market opportunities

4.1 Introduction

This section begins with a short review of the global trends to tackle climate change after which, the UK long-term emissions target is set out. Then, focussing on the UK, the section explores the market created by government-enforced compliance measures and the market for voluntary consumer action. Following this, the focus changes to a global perspective where the global emissions targets are explained before a commentary is set out revealing the markets created by global carbon trading and those that might develop in the future as a result of new compliance measures being introduced overseas.

4.2 Global trends

The first pointer to new opportunities is the simple arithmetic of quantities. The amount of greenhouse gases that can be accommodated in the atmosphere without what the UN convention describes as 'dangerous anthropogenic interference with the climate system' is much less than the amount that could be released by burning all the fossil fuel resources in the world.^{xvi} This means that the price of oil, gas and coal in the future is likely to be determined by rationing the amount of fuel that can be burnt, and the cost of reducing or sequestering greenhouse gases. This price increase will create new markets for substitutes to fossil fuels and for more efficient ways of using fossil fuels.^{xvii}

The second pointer to new opportunities is the global trends in demand and action to tackle climate change, which the World Business Council on Sustainable Development refers to as megatrends.^{xviii} These trends encompass five broad sectors: power generation, industry and manufacturing, mobility, buildings and consumer choices.

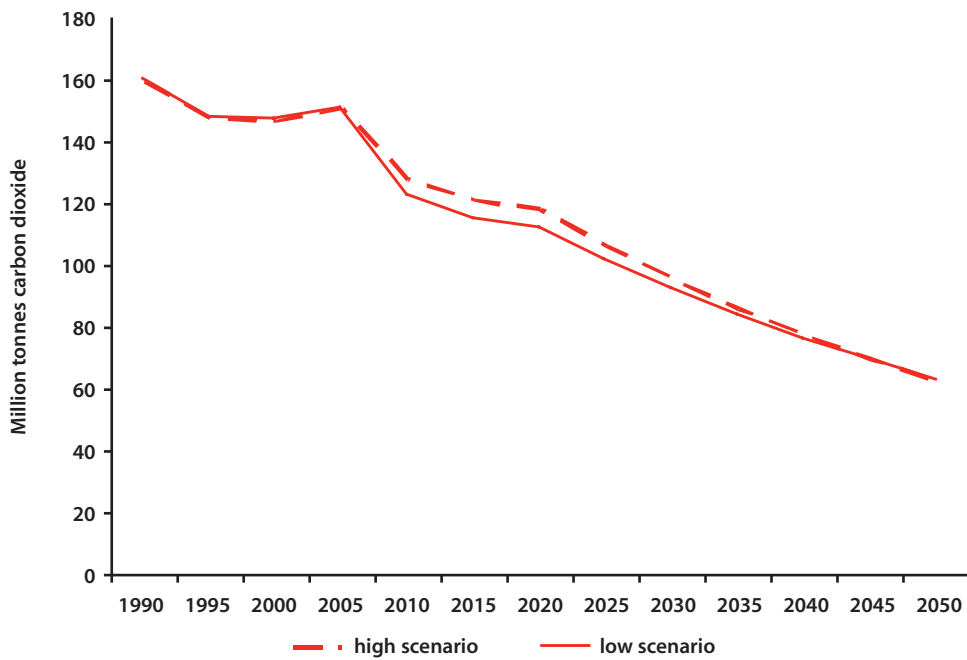
Each of these sectors offers opportunities for SMEs between the present date and 2050. For example, in power generation, the WBCSD anticipates a 160-fold increase in renewable electricity generation, with the fitting of carbon capture and storage technology to half of all coal-fired power generation, an expansion of the nuclear fleet, and the increasing consumption of energy in the form of electricity rather than other fuels. In industry, it expects substantial improvements in the energy efficiency of motors and the adoption of new carbon-efficient processes, involving the replacement of much of the current stock of manufacturing plant in some sectors. In mobility, the trend towards higher vehicle ownership and distance travelled would be counteracted by greater use of zero and low-emission vehicles, using hybrid, advanced diesel and hydrogen technologies as well as biomass fuels. In buildings, the WBCSD predicts demand for electricity for heating and cooling, lighting and appliances to increase, for the technologies to improve and to be augmented by solar energy, and for the design of the building to play a greater role in maintaining a comfortable and well-lit environment. Finally, the WBCSD sees the potential for significant action by individuals to change their energy-using habits and consumption of energy-intensive products. All of these involve innovation either in technology or in business models.

4.3 UK targets

The UK has emitted 6.3% of all anthropogenic greenhouse gas emissions since the industrial revolution and was the 6th largest emitter over that period.^{xix} It still ranks as a large world economy, but now only emits 2% of the world's carbon greenhouse gas emissions.

The UK has set itself an objective of reducing its GHG emissions from the level in 1990 to 40% of that level by 2050. This means an absolute reduction in emissions of just under 2% per year for the next 45 years, notwithstanding growth in the economy.^{xx} Figure 1 shows the emission reduction to be achieved by the UK in the future, together with the projected effect of the Climate Change Programme 2006.

Figure 1
The long-term emissions target for the UK, carbon dioxide only (excluding other greenhouse gases)

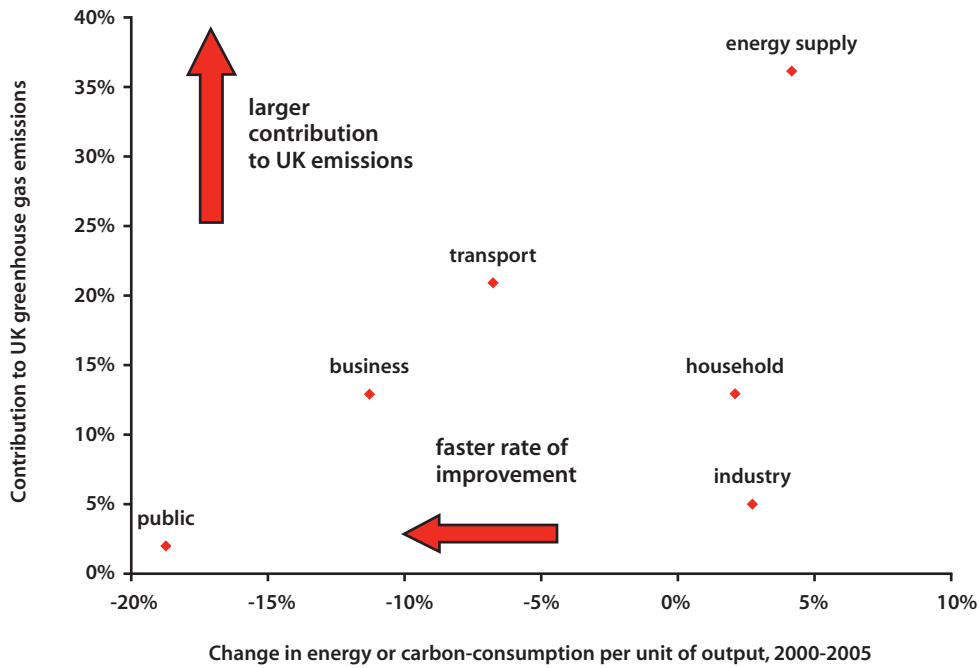


Source: Vivid Economics

This emissions target is equivalent to reducing by approximately 3 MtC the UK's emissions each year for the next few years. At current prices covering the range between emission offsetting and fuel-switching in power generation, the market size would be in the range £40–200 million per year, rising to £200–1,100 million per year in 2010.^{xxi} As will be shown, the UK is planning to spend much larger amounts over the next few years in order to bring forward renewable electricity and biofuel schemes, which are more expensive. The rationale for this higher expenditure is in part to secure future cost reductions in those technologies.

The sectors that present the greatest opportunity for entrepreneurs are those that have short lead-in times to adopt new technologies, are the target of regulation because of trailing emissions performance, and are responsible for a large share of emissions. Figure 2 shows that the sectors most likely to create market demand through regulation are energy supply, transport and households.

Figure 2
Trends in greenhouse gas intensity



Source: DTI energy statistics, Vivid Economics calculations.^{xxii}

4.4 UK compliance and voluntary market opportunities

There are two forces driving the creation of markets to reduce carbon emissions; consumers and government of which the latter is dominant. Most of the government's initiatives consist of compulsory changes through setting caps on emissions, taxation and regulation. Consumers exert a demand by pulling the market to produce new products to meet their preferences. Figure 3 illustrates the mix of drivers for the UK. Illustrating the power of regulation is a company whose products tackle both climate change and pollution of rivers and who, therefore, benefit from regulatory demand in two areas. It is Water Innovate.

In May 2005, Water Innovate split off from Water Sciences at Cranfield University with the goal of transferring new technologies out of the laboratory and into the water industry. It spotted a niche bridging the gap between research and industry, and moved into it, identifying, evaluating and exploiting routes to market for new water-related technologies. Innovate's products meet demand created by pollution controls on effluent discharges to rivers and the sea, they address the emissions of climate change-causing gases and reduce the energy use of wastewater treatment processes.

To achieve this, it set up a management team with a successful track record in both academic research and utilities management and added expertise in protecting and licensing intellectual property. For funding, it successfully approached the National Endowment for Science Technology and the Arts (NESTA), Oxford Technology 4 Venture Capital Trust, Cranfield Enterprises Limited, and a group of private investors, and raised over £0.5m. Then, earlier this year, it became a Shell Springboard Award winner with its product N-Tox®. The product is a clean technology which meets several needs simultaneously.

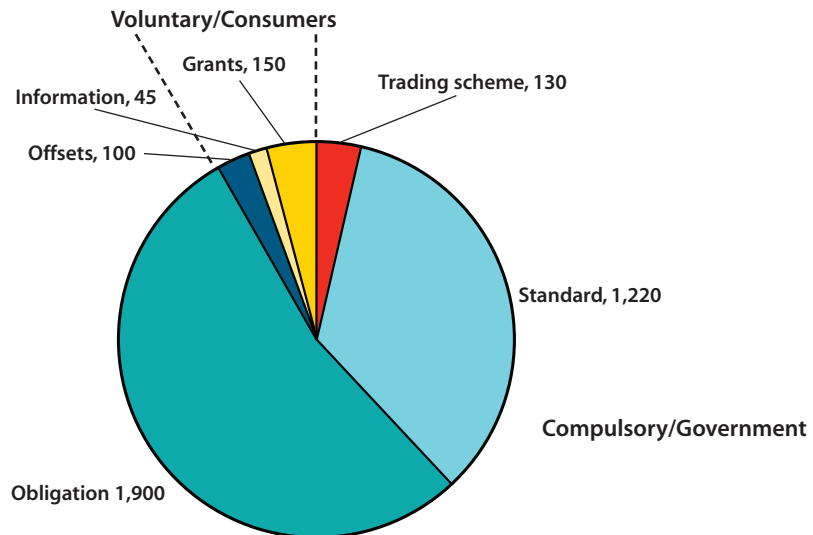
Ammonia, the same chemical as found in household cleaners, is discharged from wastewater treatment works, but has to be kept at low concentrations to avoid toxicity to aquatic plants and animals. The ammonia levels in effluent are kept down by a process which has a high potential to emit dinitrogen oxide, better known as laughing gas. Dinitrogen oxide gas is 300 times more powerful as a greenhouse gas than carbon dioxide.

N-Tox® measures the performance of the treatment process and warns if the process is becoming poisoned or over-loaded. It takes measurements by passing infra-red light through air, where it is absorbed by even tiny traces of gas, which triggers an alarm. This warning gives plant managers time to re-route flows around the treatment works or to adjust process conditions, well before there is a risk of breaching environmental safety limits or releasing climate change-causing gases. A twofold benefit for the environment. It finds similar applications in landfill leachate and pharmaceutical waste effluent treatment.

The company has identified an expanding market, with water companies continuously investing to reduce ammonia levels in their effluent, under the supervision of environment regulators, and the increasing pressure to tackle climate change.

Following the Shell Springboard Award, Water Innovate was able to benefit from further financial support through a DTI research and development grant from the East of England Development Agency (EEDA). It employed a new member of staff, tested the tool at a full-sized treatment works, and built a pilot plant so that in the future, customers will be offered a complete diagnostic service.

Figure 3
Drivers creating market opportunity in the UK, £m per year in 2010



Source: Vivid Economics estimates^{xxiii}

Notes: standard = a constraint on the performance or design of products licensed for sale, for example the energy efficiency of vehicles or domestic appliances; obligation = a duty or operating license condition placed upon traders or service providers, for example the Renewables Obligation and the Renewable Transport Fuels Obligation; trading scheme = compulsory imposition of tradable emission rights such as the EU Emissions Trading Scheme.

Increasing voluntary demand is about changes in attitudes and providing information, rather than providing incentives, which is what government regulation provides. The increasing public concern over climate change will be a major driver of voluntary demand, though action will be constrained by concerns over other people not pulling their weight. Some voluntary action will be driven by information, for instance when households become aware of the potential savings from increased energy efficiency. Finally, some changes in behaviour may occur without being easily observable. For instance fuel efficient driving is not directly observable but could have an impact on emissions. Voluntary demand will usually lead to demand for technologies and services which are very similar to those provided in response to regulation.

4.4.1 Compliance

Earlier this year, the Government launched its second climate change programme. This programme expands the size and number of schemes from the original 2000 version. Many of these schemes will be in place for ten years, allowing a medium-term forecast of compliance market size.

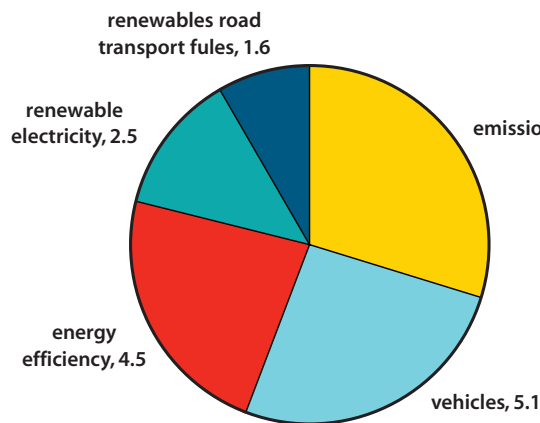
The largest created market is for improvements in the energy efficiency of commercial and industrial buildings. The next largest is the generation of renewable electricity, dominated by the construction and operation of wind turbines. This is followed by domestic energy efficiency, which consists mainly of the installation of cavity wall and loft insulation in private dwellings, together with high-efficiency lighting and domestic appliances. By 2010, as shown in Table 1, the whole market will be turning over about £3.5 billion per year, with over half being energy efficiency, one third being renewable energy and about 5% being emissions trading. The compliance market resulting from the UK Government's climate change programme over the next 10 years will be worth around £30 billion or more.

Table 1
Market size generated by UK Climate Change Programme schemes in 2010

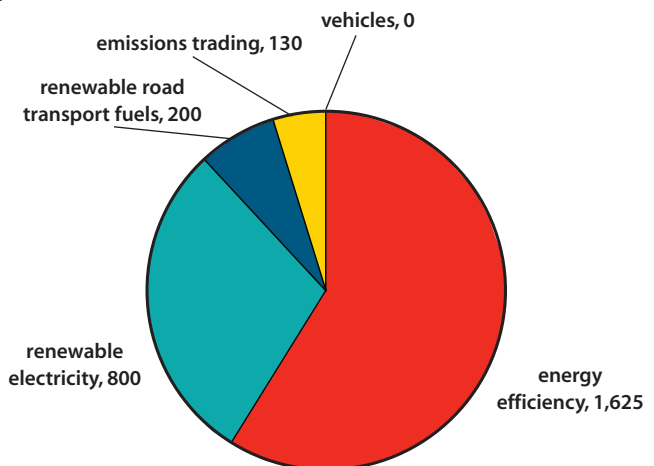
	Market size in 2010, £m per year
Building Regulations (commercial and industrial)	950
Renewable electricity	800
Domestic energy efficiency schemes	400
Building Regulations (households)	275
Climate Change Agreements	240
Renewable road transport fuels	500
Emissions trading	130
Vehicle manufacturers' voluntary agreement	n/a
Information and grants	200
Total	c. 3,500

It is notable that the carbon savings delivered in each part of the market is not a good indicator of market size, as shown in Figure 4. Energy efficiency offers the largest market opportunity because of the capital-intensity of energy efficiency measures in buildings, whereas emissions trading offers the largest emissions savings.

Figure 4
Reductions in emissions from government policies and associated market opportunity in 2010



Emissions savings, MtC per annum in 2010



Estimate of market size, £ million per annum in 2010

Note: no figures are available for vehicles sector market size. For second figure see endnotes for Figure 3. For first figure see Defra (2006), 'Climate Change: The UK Programme 2006', Chapter 10.^{xxiv}

In the transport sector, the market is being stimulated by two obligations, both operating Europe-wide. One requires car manufacturers to improve the fuel efficiency of the vehicles they sell, and the other demands a proportion of road fuel to be sourced renewably. The motor vehicle and fuel manufacturers have similar demands placed upon them in California, which sets ambitious targets. NetComposites illustrates how regulation on fuel efficiency can create demand for radically new components with no connection to fuel combustion.

NetComposites was formed in 2000 to bring to market new products and processes in the manufacture of composite materials. These combine strong fibres for reinforcement with resin. They can be made into many different shapes, with a variety of finishes and can be used in a wide range of environments. In addition, their levels of strength and stiffness, relative to weight, are such that they can out-perform metals.

NetComposites recognised the demand for recyclable and energy saving materials and made its strategic focus environmentally friendly, sustainable material technologies. This allows it to tap into demand for materials that are needed to satisfy a climate change, waste management regulation and the preferences of the final consumer. It used research for the DTI and discussions with leading manufacturers such as JCB, Caterpillar and Lotus, to build its vision.

Like many successful entrepreneurs before it, it combined that product vision with a novel business model, bringing together research, information distribution, consulting, new product innovation and manufacturing, under one roof.

The company won a Shell Springboard award in 2005 for LoPlas, a new process that takes a composite made from the marriage of plastic fibre reinforcement and a plastic matrix and converts it into parts for the automobile industry. These new materials have desirable properties of strength, lightness and impact performance, and they can be recycled. A material such as this is in demand in the automotive industry which is faced with tighter regulatory requirements to recycle vehicles and the need to meet fuel efficiency targets, while at the same time maintaining stringent safety demands.

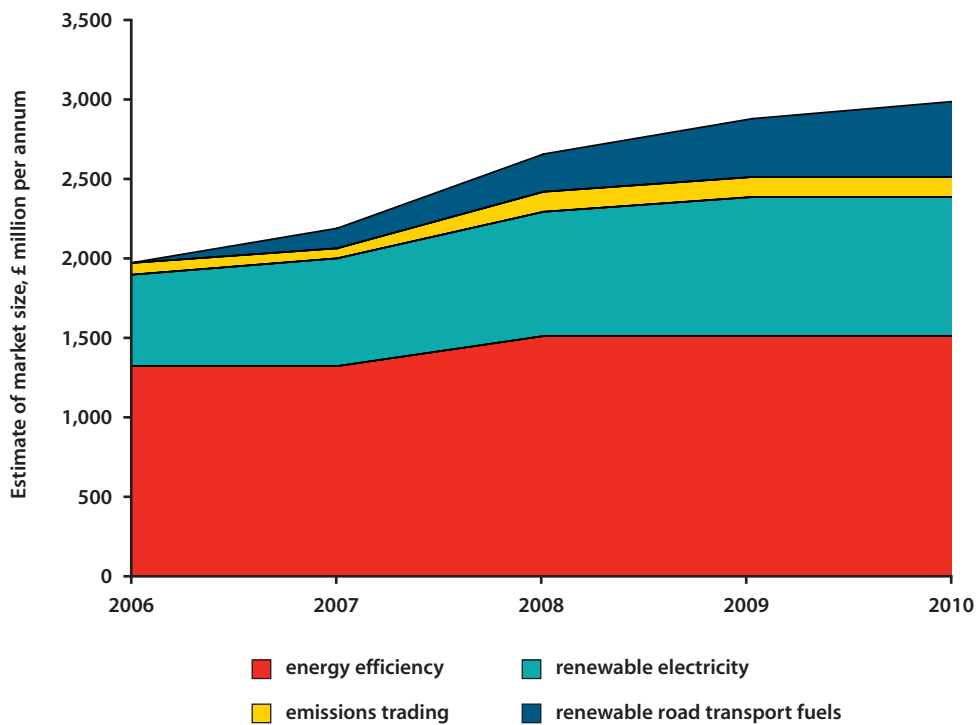
The company estimates that if a single panel on each car manufactured in Europe was to be made of the material, this alone would save 3 MtCO₂ per year through reduced fuel costs. The ultimate potential, worldwide and over many structural parts, is much higher.

Gordon Bishop, Managing Director, comments 'Winning the Shell Springboard Award was fantastic; it has given us the financial kick to take our unique products to market. The money has enabled us to develop more complex parts for the automotive industry for a wider range of vehicles. And it has also given us the confidence to press ahead with developing sustainable and recyclable products for commercial markets.'

A major new development is the EU Emissions Trading Scheme which covers half of all carbon dioxide emissions in Europe, and is having a marked impact on corporate strategy in the electricity generation sector. Finally, for business consumers of energy there is the Climate Change Levy, a tax on energy use.

These compliance markets are expected to grow as policy programmes expand to address rising targets, as shown in Figure 5.

Figure 5
Approximate change in market size for climate change action in the UK over the next five years



Note: for assumptions see endnote.^{xxxv}

In the area of housing, more stringent eco-targets imposed by the government are stimulating innovation, not only by large developers, but also by small firms. These create business opportunities for more environmentally friendly solutions, which need not be high tech. A case in point is Viridian Concepts.

Viridian is pioneering a new approach to solar hot water heating which aims to reduce costs dramatically. Solar water heating displaces around 50% of gas-fired hot water heating for a household over the course of a year. However, existing products take many years to pay back their investment.

Viridian Concepts was incorporated in January 2003. Having sold their previous business, Martin Davies and Stuart Elmes sat down at the drawing board to work out their ideas for a new activity. They saw new forms of energy as an area of increased business opportunity.

They looked for unmet market demand and technical challenges. It was clear that new forms of energy were being held back by cost. They chose solar hot water, the Cinderella technology to photo-voltaics. The solar thermal technology they aimed at was simple but crucially, it addressed the flaws in other current designs.

A further problem was that solar panels could be both unsightly and costly add-ons to a house. If panels were built into the roof as part of the structure, they could be more aesthetically acceptable and cheaper. This consideration pointed the designers to 'new build' as their market place. Firstly they had to check their ideas with the people who were building new houses.

They picked up the phone to find out what would be of interest to potential customers. To obtain valuable feedback from the experts, Viridian built up a Partnership Programme consisting of commercial house developers and social housing providers. 'First we asked for their time. Could they provide 40 hours of time over the next 12 months to attend workshops? We figured that this was a pretty good test of potential customer interest', says Stuart Elmes. The entrepreneurs learned that a major part of the price of current solar systems resulted from their lack of integration with house building schedules.

Viridian aimed at a payback of 8–15 years, ideally, their aim was to reduce the price to £600 for a home solar hot water system.

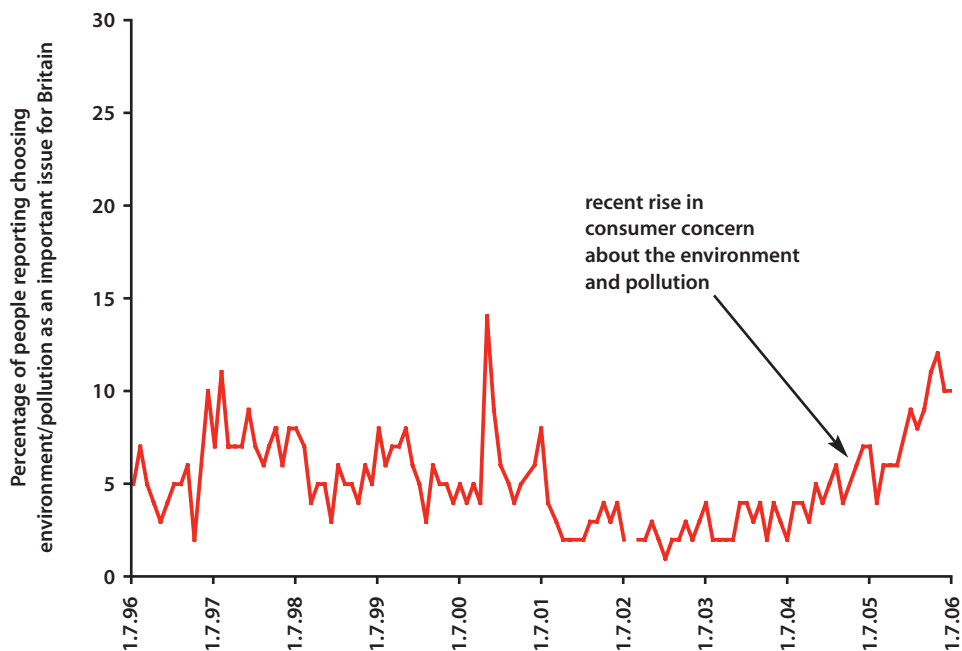
After watching roofers at work, they devised ways to avoid interrupting the order in which developers build houses. They filed patents (three to date) as their designs were improved, to make the product easy to install. The engineers also worked on design for fabrication, finding ways to cut cost without sacrificing performance.

Stuart Elmes, the CEO of Viridian believes that 'Small, pragmatic measures multiplied by large numbers of households are better than large showcases that cost a fortune and deliver little CO₂ reduction per pound'. He says that DTI and Carbon Trust R&D grants have been a big help to the business, but procurement from the public sector is no less important. 'Companies need customers!'

4.4.2 Voluntary

In the UK, almost everybody has heard of climate change or an associated term, and 90% of people believe that the climate is changing. Although the trends are not clear, one piece of evidence indicating that concern may be rising is the MORI monthly monitor which shows, see Figure 6, that the proportion of people saying that environmental pollution is an important domestic issue, which is typically under 5%, has risen to above 10% since the early summer this year.

Figure 6
Ipsos MORI monthly monitor of consumer attitudes, last ten years



Source: Ipsos MORI

Consumer concern does not necessarily translate directly into purchasing. For example, despite the growth in organic food production, retail sales still only amount to £1.6 billion, which is 1.3% of all retail food and drink sales. Yet, there are market niches where penetration is much higher, such as yoghurt.^{xvii}

Contracts for reductions in emissions at another location are growing rapidly. They usually involve projects that prevent the release of greenhouse gases, or reduce global warming potential, for example by burning methane. One difference between organic food production and carbon offsets is that the former typically increases the price of the product significantly, whereas offsets should only increase the price by a few per cent for most products, as shown in Table 2 if a damage cost of £70/tC is incorporated into the price. However, the cost of offsetting emissions is currently much lower than this figure, so the price rises could be much smaller still.

Table 2
The value of carbon damage as a percentage of value of sales

Agriculture	Food production	Tobacco	Textiles	Paper	Iron & steel	Cement	Construction	Retail	Hotel & restaurant	Air transport	Insurance
4.0%	1.7%	1.6%	1.4%	4.1%	7.0%	26%	1.4%	0.6%	0.7%	4.4%	0.6%

Source: National Statistics, Environmental Input-Output Tables, based on Blue Book 1996, i.e. 1993 data, and Vivid Economics calculations.

If consumers were to offset the emissions associated with 5% of their purchasing, i.e. similar to the take-up of organic food purchasing, the total emissions reduction would be about 12 million tonnes of carbon dioxide, for expenditure of about £40m per year. If businesses were to do the same, the total reduction would be 30 million tonnes of carbon dioxide, for expenditure of around £100m per year.^{xxvii}

The new businesses identified in this study are located across the UK. A survey for the Carbon Trust by Library House in 2005 identified clusters of clean technology entrepreneurs around Bristol, Cambridge, London, Oxford, Manchester, Newcastle and Southampton.

It is also possible to imagine regional specialisation occurring. For example, companies involved in marine renewable energy taking root near dockyards, companies involved in biomass fuels locating in Scotland, carbon sequestration expertise co-locating with the oil industry in Aberdeen, and financial firms setting up in the City of London.

4.5 Global targets

If we take estimates of the cost of cutting a tonne of carbon dioxide emissions and apply them to the cuts that have to be made globally to achieve stabilisation of global temperatures, we obtain an estimate of the future global market opportunity.

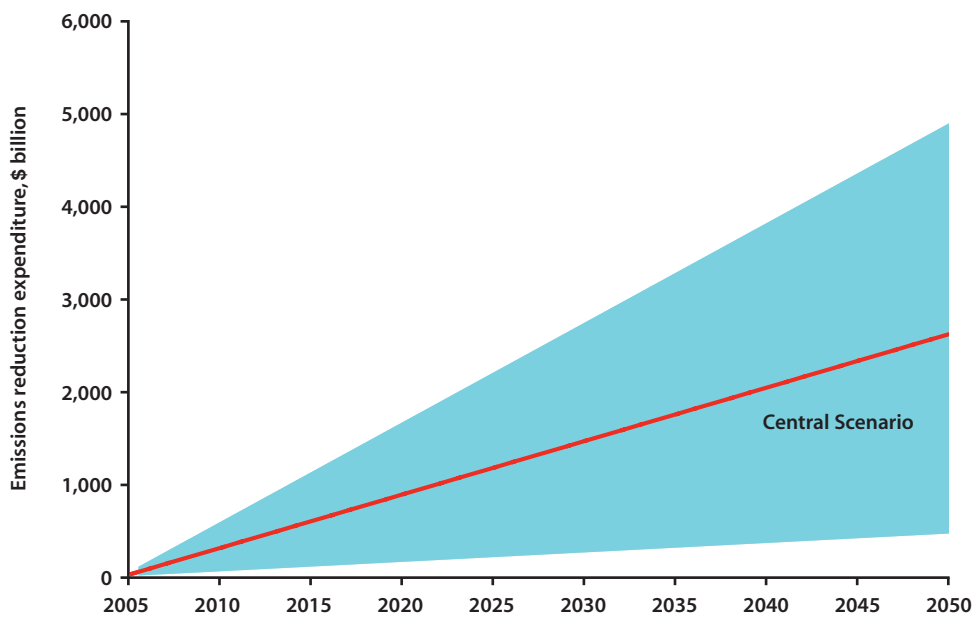
Climate scientists have attempted to calculate the concentration of carbon dioxide in the atmosphere that is consistent with a 2 degrees Celsius rise in global average temperature. Some estimates appear to be around 500 parts per million, although significant uncertainties remain, including the nature of the relationship between concentration and temperature. This concentration target could be achieved by capping cumulative greenhouse gas emissions from the industrial revolution to 2100 to the equivalent of 2.7 trillion tonnes of carbon dioxide.^{xxviii} However, without action to tackle emissions of greenhouse gases, the combined forces of population and economic growth would result in cumulative emissions equivalent to around 5.5 trillion tonnes of carbon dioxide by 2100.^{xxix} The exact figures are uncertain, but the calculation shows that to remedy climate change, the world must deliver a cumulative reduction against the prevailing scenario of between 2.2 and 3.7 trillion tonnes of carbon dioxide by 2050.^{xxx}

The cost of cutting emissions currently lies between US\$5/tCO₂ for projects in less developed countries and around US\$30/tCO₂ for substantial fuel switching in western power generation markets. Some renewable technologies, such as wind and solar, are above the top of this range at present, and some energy efficiency projects are claimed to be below the bottom end of the range. In order to generate an illustrative central estimate, we have used US\$20/tCO₂. Over time, the cheapest options will become exhausted, raising the average cost of abatement, while at the same time, this effect will be counteracted by economies of scale in abatement technologies.

To discover the total expenditure on carbon emissions reduction in the future, we take the total cumulative reduction that must be achieved, and work down towards that level by equal reductions every year between now and 2050. This may over-state the market size initially, because reductions may be back-loaded to allow for economic growth and improving technology, and because it assumes reductions made by 2050 with no slippage against the targets.

Using this crude calculation, and assuming that the world does act, the annual expenditure on carbon emissions reduction will grow by between US\$10 and 100 billion each year for the next 45 years, with an illustrative central estimate of US\$70 billion per year.^{xxxix} Over the first five years of a global effort to achieve stabilisation of greenhouse gas concentrations the market would cumulatively turnover \$1 trillion. The pattern is shown in Figure 7.

Figure 7
World expenditure required to address the causes of climate change, if the world acts



Source: Vivid Economics calculations.

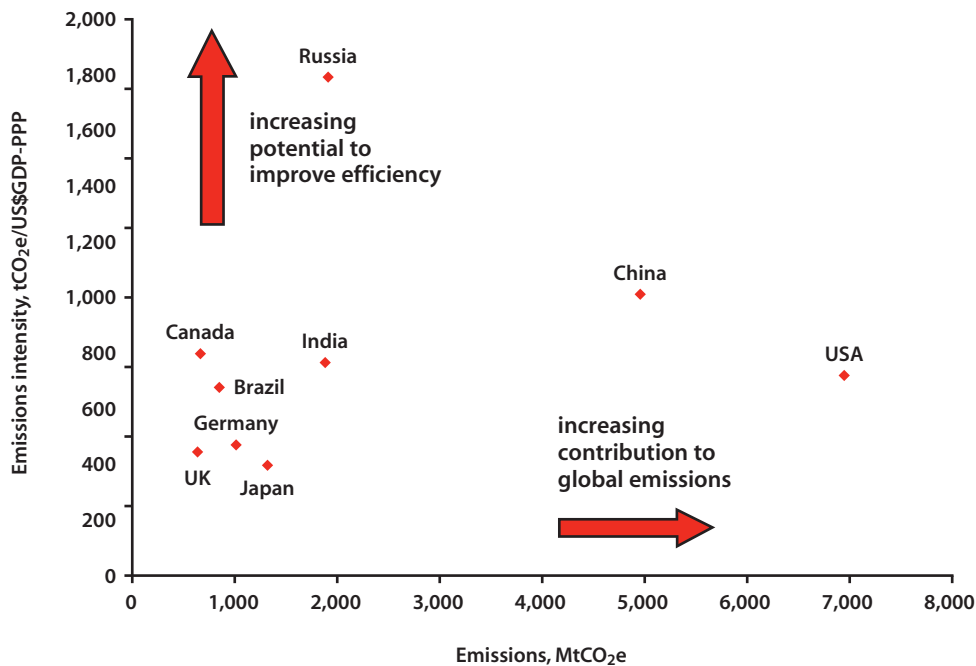
These are large potential markets for climate change technologies, services and finance, which provide substantial opportunities for entry and growth for SMEs.

4.6 Global carbon trading

Global action to avert climate change is also creating a large trading market, where action is taken in one country to avert emissions and the savings are traded. The World Bank reports that carbon markets were worth over US\$10 billion in 2005 and some expect them to be worth US\$25–30 billion in 2006.^{xxxix} One would expect the majority of that action to occur in the countries with the greatest share of emissions, and those with the highest carbon-intensity economies, which are Russia, China and the USA as shown in Figure 8. In addition, India already lays claim to being the largest source of emission reduction projects.^{xxxix}

A proportion of the obligation under the EU Emissions Trading Scheme may be met by Certified Emission Reductions (CERs), which are project credits from around the world. This is in large part responsible for the current trade in CERs, which the World Bank estimates at \$2.7 billion (£1.5 billion) in 2005, covering 374 million tonnes of carbon dioxide.^{xxxix} Since 25% of all CER projects worldwide involve the participation of UK firms, around 100 million tonnes of carbon dioxide per year of CERs are being traded with UK involvement.^{xxxix} This gives a UK market size of about £400m. These markets are expanding rapidly, although the exact size and trends are unclear.^{xxxix}

Figure 8
Carbon intensity and annual emissions by country



Source: based on data in Baumert K.A., Herzog T., Pershing J. (2005), 'Navigating the numbers: greenhouse gas data and international climate policy', World Resources Institute.

Notes: (1) 1 tCO₂e = an amount of greenhouse gas that has the same global warming effect as one tonne of carbon dioxide.
(2) GDP = gross domestic product and PPP is measured at purchasing power parity.

Metalysis offers an example of a generic technology with potential application globally.

Metalysis was founded in 2002 to exploit the opportunities created by the FCC (Fray, Farthing, Chen) process, a new electrochemical reduction process. Patented in 1998, the technology provides an innovative electrolytic method that produces metals at a fraction of the usual cost. Development work on production processes is already underway in South Yorkshire. As the founder, Dr. Fray explains: 'The patented technology is a one step process for the production of metals from oxides, and because the process is more energy efficient than traditional methods, we will also greatly reduce environmental impact.'

The FCC process lowers energy input and eliminates hazardous by-products. Conventional processes need to use hazardous and difficult reactants, such as liquid sodium, hydrogen fluoride and methyl isobutyl ketone. In contrast, the only reagent used in the FCC Cambridge process is a salt no more toxic than table salt. Conventional processes also yield hazardous by-products such as ammonium fluoride gas and magnesium fluoride. The only by-product of the FCC Cambridge process is oxygen.

The process is a generic innovation with applications for pure metals, metal alloys, carbides, foams and near-net shape products. For this reason the company has a hybrid business model that involves in-house manufacturing, acquisitions and licensing in order to fully exploit its technology.

In 2004, the company moved its facilities from Cambridge to South Yorkshire. It is now working with international partners to develop the process for a range of commercially significant metals and has successfully and consistently reduced a large number of different oxides to the metal powder with high levels of purity.

4.7 Global compliance markets

California often sets the trends for the rest of the western world to follow. It is the world's twelfth-largest economy and a centre of high technology enterprise. The latest news from California, under the governorship of Mr Arnold Schwarzenegger, is that climate change policies continue to expand and strengthen. In August this year, he signed legislation that aims to put solar power on a million roofs in California by 2018 and a bill to cap state-wide greenhouse gas emissions, returning them to 1990 levels by 2020.

Successful innovation often depends on a fortuitous combination of complementary technologies. A regulatory framework can help to synchronise related innovations, as the Californian emissions regulations did for the emergence of catalytic converters in the 1970s and 1980s. For example, today Proton Exchange Membranes (PEM) fuel cells, which could find a massive market in road vehicles, would benefit from further innovations in polymer membranes, catalysts and fuel cell stacks. This combination of technologies might be assisted by simultaneous regulation on electricity infrastructure standards and vehicle emissions performance, which would stimulate demand.

Another area in which synchronisation of technologies is required is bio-fuels, which is, in some respects, low tech. Here a whole new distribution infrastructure is required. Bio-diesel is a UK SME who was pioneering in this area well before extensive bio-fuel distribution facilities had been rolled out.

Martin Brook is a serial entrepreneur who saw waste vegetable oils as a resource that could be used to lower carbon emissions if its viscosity could be adjusted to the requirements of the internal combustion engine. He commissioned research by chemical engineers at Cambridge University, who produced a device capable of achieving this.

On a trip to Zimbabwe in 1983, Martin Brook saw buses standing idle because the country was too poor to afford sufficient imported petrol. He was to keep that image in his mind as he pursued his vision.

Back in the UK, Brook went into partnership with John Murray and Stephen Hall with the intention of making a contribution towards the reduction of carbon emissions by improving biofuel so that it could be used in standard vehicles in place of petroleum and diesel. As well as providing a lower carbon fuel source, it involved a less energy-intensive production method. Brook started out by exploring a niche, detecting the potential for using waste oil from school catering. Knowing from past experience the competitive edge that novel technology from researchers can provide, he turned to the University of Cambridge's Department of Chemical Engineering who had developed the Oscillatory Flow Reactor (OFR) and who were seeking applications for their discovery. The research at the university had shown that bio-diesel satisfying the current European standard could be produced from fresh rapeseed oil.

In 2002, the Government reduced the fuel duty on biodiesel making it a similar price to petrodiesel. Another significant economic driver has been an EU directive to proscribe the use of waste vegetable oil in animal feeds, the main market up to that date. This has led to the sources of supply of waste oil becoming much more freely available.

5. Conclusions

5.1 Conclusions for SMEs

The main conclusions for SMEs are as follows.

- The greatest opportunities for all businesses, including SMEs, lie in the compliance market. The UK has a compliance market worth £3.5 billion per year in 2010 and expanding rapidly. This part of the market is likely to be nearly ten times larger than the voluntary market in 2010.
- The main compliance opportunities in the UK are in meeting tighter building standards, the supply of biofuels for road vehicles and the generation of renewable electricity.
- To anticipate the future shape of compliance markets in the UK and Europe, SMEs can monitor developments in other countries, particularly California, which has a track record of setting trends in environmental policy and has an economy and technology sector large enough to influence world markets. They can also consider the global trends which commentators such as the World Business Council on Sustainable Development have summarised, with major changes expected in power generation, industry and manufacturing, mobility, buildings and consumer behaviour.
- The size of market opportunities is determined by the level of political will to tackle climate change. This is uncertain, and hence an awareness of policy trends is of vital importance in understanding future market opportunities. SMEs can take comfort from the fact that policies will need to strengthen and broaden in scope over time, if climate change targets are to be met.
- Those SMEs that bring innovation to the market are of strategic importance and can expect to receive more financial encouragement from government and financiers. SMEs with climate change related products already receive support in various ways from government and they have been attracting more attention from private investors in recent years. As markets expand and the value of SMEs' innovations grow, and awareness of their role increases, then the level of support may rise making it easier for new SMEs to launch themselves.
- Of all these new entrants, those which will be remembered in the future for the high value they created are most likely to be those that exhibit the typical strengths of innovative SMEs – the motivation to bring forward radical ideas and access to market-beating invention and research which will bring their vision to fruition.

5.2 Proposal for Government

It is clear from the case studies examined here that funding, understanding market demand, and identifying customers are all significant hurdles for SMEs. The funding requirements change as the company moves from research into sales. First, grants can provide a vital leg up to many early-stage ventures, and incubators and other mentors can help prepare a company for wider equity participation. The recently-announced Energy Technologies Institute will increase the availability of this support for climate and energy technology SMEs.

As Shell Springboard award winners have found, winning awards helps companies not only with their funding, but also to find their potential customers and to present their product to them. There is a means by which this help could be extended, because, of all the initiatives discussed in this report, none has included a mechanism for drawing innovators' attention to fixing particular technical problems. Neither do other schemes have the objective of drawing innovators to the attention of potential customers.

The prize for measuring longitude at sea, which was offered by Act of Parliament in 1714 and was famously won by John Harrison, with his clock 'H4', nearly 60 years later is an appropriate example.^{xxxvii} In addressing the problem of longitude, he made shipping safer and he produced innovative developments in clock-making and mechanics along the way. The safety of shipping was one of the most important problems of the eighteenth century. Consider also the commercial value of literary prizes such as the Booker, which draw customers' attention to newly-released novels.

We propose a series of prizes to address the obstacles to tackling the causes of climate change. The prizes would be offered and would stand until they were won. Entries for the prize would be judged by an independent board, and would gain recognition from having entered. Prize winners would gain reputation and interest from funders and customers for products that would be of great value in tackling climate change. The main value of the prize would not be in the prize money itself, but in having some of the most important problems addressed, and in helping the prize-winner to achieve a reward in recognition of his or her innovation. There might be several prizes in each of the categories of energy supply, industry, mobility, buildings and consumers, and every prize would focus on an obstacle to reducing carbon emissions.

6. Highlights of findings and new figures

If the average UK business paid for the environmental damage of its greenhouse gas emissions it would amount to less than 0.8% of its value added, using a common measure of the value of damage.

There are two forces driving the creation of markets to reduce carbon emissions; consumers and government. The government created market is dominant.

The equivalent calculation for the UK gives a value in the range of £40–200 million per year, rising to £200–1,100 million per year in 2010. However, the UK is planning to spend larger amounts, including on renewable electricity and biofuel schemes, giving total climate change programme and voluntary market opportunities of £4 billion a year or more in 2010.

If we can take estimates of the cost of cutting a tonne of carbon dioxide emissions and apply them to the cuts that have to be made globally to achieve stabilisation of global temperatures, this gives us an estimate of future global opportunity. The cost of cutting emissions currently lies between US\$5/tCO₂ for projects in less developed countries and around US\$30/tCO₂ for substantial fuel switching in western power generation markets. Assuming that the world does act, the annual expenditure on carbon emissions reduction will grow by between US\$10 and 100 billion each year for the next 45 years, giving a market size over the first five years of \$1 trillion.

The carbon saving delivered in each part of the market is not a good indicator of market size. Energy efficiency offers the largest market opportunity because of the capital-intensity of energy efficiency measures in buildings, whereas emissions trading offers the largest emissions savings. SMEs looking for indications of market size should look at the expenditure by a sector, not the savings expected to be delivered by it.

The UK is a major player in the origination and trading of Certified Emission Reductions (CERs), which are project credits from around the world. UK firms are involved in trading about 100 million tonnes of carbon dioxide per year through these projects, giving a UK market size of around £400 million per year. These markets are expanding rapidly.

Although consumers do not currently take a prominent role in tackling climate change by purchasing emission offsets, if they were to offset the emissions associated with 5% of their purchasing, the total emissions reduction would be about 12 million tonnes of carbon dioxide, involving expenditure of about £40m per year. If businesses were to do the same, the reduction would be increased by a further 20 million tonnes of carbon dioxide, involving expenditure of around £60m per year.

Appendix, endnotes and references

Appendix SMEs' innovation strengths and history

The differences in innovation between small and large companies are summarised in Table A1.

Table A1
A concise comparison of innovation strengths and weaknesses of small and large firms

SMEs	Large firms
Strengths	Strengths
openness to radical innovation	understanding existing markets
links to university research	access to funding and resources
ability to trial novel business models	ability to combine technologies
ability to target small and emerging markets	legal and commercial expertise
identifying new customer demand	ability to deliver projects and investments
motivation to innovate	ability to scale up manufacture
speed of prototype and early model manufacture	skill at performance improvements and cost reduction marketing capacity
Weaknesses	Weaknesses
knowing the current market	attachment to past successes
capacity to scale up	sunk costs to amortise
access to funding products	organisational culture focussed on existing structure not well suited to research and development
proving product performance	high existing customer satisfaction
combining technologies	shareholders' priorities
capacity to wait for revenues	
resources available to penetrate market	

Source: Vivid Economics and Freeman C. (1982), 'The Economics of Industrial Innovation', second edition, Table 6.5.

Table A2
Small innovators who became major players

Firm	Product
Marconi	radios
Ford	mass-produced car
Morris Austin	cheap cars in the UK
Genetech	biotech
Apple	personal computer
Microsoft	operating systems for personal computers
ARM	fabless chips for mobile devices
Google	internet search engine

Endnotes and references

- ⁱ There are 1.6 million SMEs with fewer than 250 employees in the UK. They operate throughout the economy and employ around 10.5 million people out of a total workforce of 29 million. The remainder work in 8,000 large enterprises. National Statistics (2005), 'Business Survey', Table B4.1.
- ⁱⁱ National Statistics (2005), 'Business Survey', Table B4.1.
- ⁱⁱⁱ Ipsos MORI, Shell Springboard Report, 'Small business attitudes to the opportunity of climate change', October 2005.
- ^{iv} The gross value added in the UK economy was £1,200 billion in 2005, National Statistics (2006), The Blue Book. The value of damages is the product of the total annual greenhouse gas emissions and unit cost of damages. The UK's greenhouse gas emissions totalled 153 MtC in 2005, Defra (2006), 'The UK's Fourth National Communication under the United Nations Framework Convention on Climate Change'. The most widely used estimate of the unit cost of damages from greenhouse gas emissions is £70/tC in 2000 prices or £85/tC adjusted to 2005 incomes and prices, see Clarkson R., Deyes K. (2002), 'Estimating the Social Cost of Carbon Emissions', Government Economic Service Working paper 140, HM Treasury and Defra, January. Note that the true figure of damages is uncertain and may be much lower or higher. Taking similar figures for SMEs gives 0.6%.
- ^v Gross value added at basic prices by industry in 2003.
- ^{vi} The main examples are the Climate Change Levy, Renewables Obligation, EU Emissions Trading Scheme and the Renewable Transport Fuels Obligation.
- ^{vii} We gratefully acknowledge valuable discussion and reference material on environmental enterprise provided by the Centre for Technology Management, University of Cambridge, and particularly by Dr Elizabeth Garnsey, see www.ifm.eng.cam.ac.uk/ctm.
- ^{viii} See for example, Freeman (1982), 'The Economics of Industrial Innovation', Frances Pinter Publishers Ltd, London, UK.
- ^{ix} See the appendix for examples of SMEs that became major market players.
- ^x Maine E., Garnsey E. (2006), 'Commercialising generic technology: the case of advanced materials ventures', Research Policy, Elsevier Science, forthcoming.
- ^{xi} Utterback J.M. (1994), 'Mastering the dynamics of innovation', Harvard Business School Press, Boston.
- ^{xii} Porter M. (1985), 'Competitive Advantage', Simon & Schuster.
- ^{xiii} Dee N., Ford S., Garnsey E. (2006), 'Clean Technology Ventures and Innovation', Working Paper No. 2006/01, Centre for Technology Management, Cambridge University, www.ifm.eng.cam.ac.uk/ctm.
- ^{xiv} Tax as a proportion of gross national income. National Statistics (2006), The Blue Book, Table 8.5.
- ^{xv} Maine E., Garnsey E. (2006), Commercializing Generic Technology: the case of advanced materials, Research Policy, 35 (3), 375–393.
- ^{xvi} United Nations (1992), 'United Nations Framework Convention on Climate Change', Article 2.
- ^{xvii} An example is General Electric's 'Ecomagination' range.
- ^{xviii} World Business Council on Sustainable Development (2005), 'Pathways to Energy and Climate Change', November.
- ^{xix} Baumert K.A., Herzog T., Pershing J. (2005), 'Navigating the numbers: greenhouse gas data and international climate policy', World Resources Institute.
- ^{xx} Over the last 30 years, the UK has experienced a fairly stable greenhouse gas emissions profile as a result of productivity improvements of around 2% per year, which have counterbalanced the effect of economic growth. This has been achieved by general improvements in productivity and energy efficiency, a structural shift in the economy away from industry and towards services, and fuel switching from coal to gas in the power generation sector. The economy has been switching from production to services over a period of decades and this trend cannot continue to the same extent. Hence, the underlying rate of improvement in carbon productivity may slow down. The figures above show an underlying trend that is half the rate of improvement required to keep pace with GHG reduction targets.
- ^{xxi} The UK has a 30-year trend of roughly stable CO₂ emissions, so carbon productivity improvements have been keeping pace with economic growth. However, to keep the UK on course for its 2050 target, it must cut its emissions by 1.9% each year. In 2010, 1.9% of 169 is 3.2 MtC. The average annual reduction required for the period 2010 to 2020 is 3.0 MtC each year. The cost is assumed to be between US\$5/tCO₂ if offsets are used and US\$30/tCO₂ if fuel switching in power generation is used. This gives additional costs each year of £35–210m/year in 2010. Over a five-year period the costs rise by just under five-fold.
- ^{xxii} The change in intensity shown in the chart = (index of intensity in 2005/index of intensity in 2000) – 1. The data is taken from DTI energy statistics available at www.dti.gov.uk. The contribution to UK emissions is taken from Defra (2006), 'The UK's Fourth National Communication under the United Nations Framework Convention on Climate Change'.

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- xxiii Trading scheme: $\text{£}130\text{m}/\text{year} = 5.5\text{MtC}/\text{year} * 44/12 * \text{?}15/\text{tCO}_2$ where 5.5MtC is the mid-point of the range of savings quoted for the EU Emissions Trading Scheme in the Climate Change Programme Review 2006, 44/12 is the ratio of the molecular and atomic weights of CO₂ and carbon, and ?15/tCO₂ reflects EU Emissions Trading Scheme allowance prices in 2005/06. Obligation: $\text{£}1,900\text{m}/\text{year} = \text{£}780\text{m}/\text{year} + \text{£}400\text{m}/\text{year} + \text{£}500\text{m}/\text{year}$. $\text{£}780\text{m}/\text{year}$ is the cost of the Renewables Obligation, see Department of Trade and Industry (2001), *New & Renewable Energy: Prospects for the 21st Century*. The Renewables Obligation Statutory Consultation, page 5. $\text{£}400\text{m}/\text{year}$ is the cost of the Energy Efficiency Commitment, see Defra (2004), *Energy Efficiency: The Government's Plan for Action*, Table 2, Annex 6, page 107, Cm 6168, April which states that capital investment is $\text{£}1,150\text{m}$ over a three or four year period between 2008 and 2011. $\text{£}500\text{m}/\text{year}$ is the cost of the Renewable Transport Fuels Obligation as estimated in *Climate Change Capital (2005)*, *Optimising the Design of the RTFO*, a study for the Department for Transport, July. Department for Transport (2005), *Partial RIA Biofuels*, November. Page 36 states a cost of around $\text{£}500\text{m}/\text{year}$ for a 5% obligation, and Tables 7 and A5.2 in the appendices confirm that the figure is an annual cost. Standards: $\text{£}1,220\text{m}/\text{year} =$ the sum of annual costs of components of building regulations given in Tables 3–5 and 7 of Office of the Deputy Prime Minister (2004), *The Building Act 1984*, *The Building Regulations 2000*, *Proposals for amending Part L of the Buildings Regulations and Implementing the Energy Performance of Buildings Directive*, A consultation document, July. This figure excludes standards for road vehicles, electrical and electronic appliances. Offsets: $\text{£}100\text{m}/\text{year} =$ total emissions of 169.2MtC taken from Defra (2006), 'The UK's Fourth National Communication under the United Nations Framework Convention on Climate Change' and multiplied by 5% to find the proportion that might be offset. The market size is found by multiplying this figure by $\text{US}\$5/\text{tCO}_2$, which is assumed to be the price of offsets, and an exchange rate of 1.6 US dollar per pound Sterling. Information: $\text{£}45\text{m}$. There is little information available on the size of information policies, but the Government spent $\text{£}90\text{m}$ on the Energy Saving Trust and The Carbon Trust in 2003/04 according to Defra (2004). Some of this money was spent on information and some on other initiatives. Using this as a guide, we have assumed that the market size for information is $\text{£}45\text{m}$. Grants: $\text{£}150\text{m}$. The Energy Technologies Institute will distribute $\text{£}100\text{m}/\text{year}$, some of which will be directed at climate change technologies, see DTI (2006), *Energy Technologies Institute Prospectus*, August. If the proportion were 50%, then it would amount to $\text{£}50\text{m}/\text{year}$. Between 2002 and 2008, the Government's capital grant programme for renewable and other technologies is around $\text{£}100\text{m}/\text{year}$, see Defra (2006). The CCPR does not state a total in 2010.
- xxiv Emissions trading = EU Emissions Trading Scheme + UK Emissions Trading Scheme. Vehicles is the whole transport sector. Energy efficiency is the whole of business and domestic energy efficiency measures except for Climate Change Agreements.
- xxv See also endnote for Figure 2. Energy efficiency = Energy Efficiency Commitment + building regulations. The renewable electricity profile reflects increases in the Renewables Obligation target between 2005 and 2010 and includes $\text{£}100\text{m}/\text{year}$ of capital grants. Emissions trading builds to an annual amount in 2008–2012, the phase two trading period. It is assumed to be half that amount in 2005 and 2006. Renewable road transport fuels reaches $\text{£}500\text{m}/\text{year}$ in 2010, with an assumption of a linear increase from 2007 to 2010.
- xxvi Soil Association (2006), 'Organic Market Report 2006'.
- xxvii Vivid Economics calculations.
- xxviii Emissions limits based on Intergovernmental Panel on Climate Change (2000), 'IPCC Special Report Emissions Scenarios: Summary for Policymakers, A special report of IPCC Working Group III'. 1 trillion tonnes = 1,000,000,000,000 tonnes = 1,000 Gigatonnes.
- xxix Global Commons Institute model, available at www.gci.org.uk.
- xxx To achieve 550 ppm CO₂, total emissions must be limited to 660 GtC according to the Global Commons Institute model. This is 840 GtC less than the business as usual projection. Similarly, to achieve 450 ppm, the total emissions must be limited to 440 GtC.
- xxxi To achieve a saving of 800 GtC over 45 years, a saving 36 GtC/year has to be made relative to business as usual by year 45. Assuming a linear increase in emission reductions, this gives the area under a triangle of $36\text{ GtC} * 45\text{ years} * 0.5 = 800\text{ GtC}$. Thus in year one, savings of between 0.6 and 1.0 GtC are required, at a cost of between $\text{US}\$10\text{ billion}$ for 0.6 GtC at $\text{US}\$5/\text{tCO}_2$ abated and $\text{US}\$100\text{ billion}$ at $\text{US}\$30/\text{tCO}_2$ abated.
- xxxii Capoor K., Ambrosi P. (2006), 'State and trends of the carbon market', The World Bank, Washington D.C.
- xxxiii Lecocq L., Capoor K. (2005), 'State and trends of the carbon market', International Emissions Trading Association, Washington DC.
- xxxiv Capoor and Ambrosi (2006).
- xxxv Defra (2006), 'EU Emissions Trading Scheme Phase II (2008–2012), Joint Implementation and Clean Development Mechanism credits. Partial Regulatory Impact Assessment', August.

Notes

About Vivid Economics

Working in close partnership with our clients we aim to bring about long-term benefit. Our approach is to apply sound economic principles with an emphasis on foresight, clear communication and follow through. In this way we help our clients achieve the best possible outcomes in relation to their critical business decisions, competitive advantage and public policy.

About Shell Springboard

Shell Springboard awards up to £40,000 to selected small businesses that have potentially successful commercial ideas for products and services that will contribute to combating climate change. Judging is carried out by three regional panels of independent experts. Up to two businesses from each region then meet a national panel of judges, as they compete to be named overall UK winner.

Awards will be made in early 2007 and the deadline for applications is 10 November 2006. The Chair of the national judging panel in this second year of Shell Springboard will be Lord Ron Oxburgh.



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