For the Warwick University Policy Briefing, Wednesday February 9th 2005
Embargoed until midnight on the 9th

Energy and Travel in the Future

Andrew Oswald

Professor of Economics, University of Warwick
Research website: www.oswald.co.uk
Tel: 02476 523510
Email: andrew.oswald@warwick.ac.uk

Summary

This briefing paper makes four points.

1. The reason that global warming is hard to solve is because the unborn babies of the future are not yet here to vote. To save the planet, they need somehow to be empowered. This paper suggests a way to do this with a new kind of long-dated Global Warming Bond. These government bonds would be designed to start paying out in, say, the year 2045 (hence funded by future taxpayers). Yet the bonds would be valuable immediately and could be given -- as an incentive -- to those people and firms who reduce their emissions today. In this way, a generation of unborn babies can pay to solve global warming.

2. The UK is not serious about renewable energy. Crucially, our citizens need to understand that enormous land areas will have to be given over to the production of green energy.

3. We ought to have road pricing throughout the whole country.

4. We must now do something about UK air transport emissions. The air industry is the fastest-rising source of greenhouse gas emissions.

Energy and Travel in the Future

Andrew Oswald

Petroleum runs through the veins of modern society. Last year the planet consumed 30 billion barrels of it. Yet Earth's dependence on oil grows increasingly dangerous.

In this lecture I want to look ahead. I want to ask how we can switch away from oil and other fossil fuels, and more generally to speculate on energy and travel in the future. Economics has an important role to play in solving our worsening energy and travel problems. Innovative mechanisms for altering people's behaviour have to be found.

On my reading of the scientific evidence, global warming is the central problem of our age. In order to solve it, western society must change how it acts. There are other reasons to move away from petroleum. First, a reliance on oil is dangerous when so much of it lies buried in politically unstable countries. Second, at some point in the future, oil supplies will run sufficiently dry that to rely on oil will be too expensive.

The Kyoto agreement -- more formally, the Kyoto Protocol to the United Nations Framework Convention on Climate Change -- was designed to be a legally binding agreement under which industrialized countries reduce their emissions of greenhouse gases by 5.2% compared to the year 1990. It comes into force on February 16th of 2005.

Idea 1: Global Warming Bonds: A New Kind of Financial Incentive to Tackle Climate Change

Standard solutions to global warming miss the central point. The key intellectual issue is how to make unborn babies pay for us to clean up the world by reducing emissions. Unborn babies are the ones who will benefit. Yet they are not around to appear on television, to go to rallies, or to daub slogans on our profligate SUVs.

So how do you go about negotiating with a generation of people who have yet to be born? Of course you cannot. But we are able, in fact, to act as though they were already on the other side of the bargaining table.

I believe that the problem of climate change is best tackled by inventing a new kind of long-dated government bond (a certificate that would pay out cash in the future) and giving those out as incentives to people who today reduce their emissions. To my knowledge, this idea is not in policy-makers' minds. I think it should be.

Carbon dioxide emissions now get more attention than a decade ago. Unfortunately, the focus has been on getting lots of countries to attend meetings and sign up to rules and treaties. This is useful in its way but is unlikely ever to

make dramatic headway (and the extraordinary nature of American oil consumption is one reason). Yet what is really required is a way to get different generations to agree on a financial compensation strategy with sharp incentives for people in 2005 to alter their behaviour.

The voters of the next century do not have the same preferences as us. We like old MG sports cars and oil-fired central heating. They want us to have small new Saabs and use solar panels.

Earth's headache is this: the people who today inhabit the globe will receive almost no benefit from cutting back on greenhouse gases. All they get out of global-warming policies is inconvenience.

To solve climate-change, therefore, the world has to come up with some new incentive. It needs to find a way to allow the future citizens of the planet to persuade our generation to do things differently. Pounds make good persuaders: we should use financial incentives not complicated restrictions and rules.

Here is a workable strategy that would solve much of the problem of global warming.

Step one: the world's nations should each agree to issue a new kind of government bond. These certificates would pay a steady stream of income that would begin around the year 2045 and end in 2100 (or perhaps even 3000). Of course the year 2045 is not crucial; the point is that the certificates would start paying one full generation away from today. The costs of printing would be negligible and, as with other kinds of government bonds, the risk of default would be extremely low. This latter point is important. Payment from the certificates would have to be assured.

Step two: firms, people and nations that cut back their emissions today would be compensated by being given these bonds. The payment schedule would have to be worked out using the kind of data discussed in Kyoto and since. In other words, it would be necessary to make a scientific judgment about the size of reduction in carbon dioxide emission that is needed, and the size of the marginal reward (in the form of the number of bonds in exchange for each unit reduction of carbon dioxide) then could be calculated. A mixture of physical science, environmental science and economic science would be required here.

Step three: these Global Warming Bonds, like other government securities, would be allowed to be bought and sold. Because they would guarantee a flow of income in the future, the bonds would have immediate value. Recipients of them would mostly promptly sell up for cash.

Many bonds would be purchased by pension funds and other organizations interested in long-term returns (the bonds would not, of course, start paying out

until the year 2045). The money from these bond sales would thus compensate the current inhabitants of Earth for a change in their behaviour.

Final step: how the bonds were distributed and managed would be important. It seems natural to require all nations to deposit a stock of bonds with a world agency, which would be charged with giving out the bonds in a systematic way to reward those companies and individuals that demonstrated a drop in emissions. A multi-national agency of this sort would certainly lead to difficulties; it is not ideal. But some kind of independent inspectorate will probably be necessary under almost any form of strategy to control global warming.

Because of their long-dated design, the flow of income from these new sorts of government bonds would be paid for, ultimately, by the future citizens of the planet. In return for a cooler globe, our offsprings' offspring would pay more tax to the governments of their era.

That is sensible and efficient. The next generation of babies pass us down their money; in return we pass them up our low temperature. All generations then gain. And this would be fair, because, after all, those great great grandchildren of ours are going to be richer than we are, and they want us to alter our actions to help them.

If we think ahead, and use long-dated bonds as rewards, global warming is a solvable problem. It avoids the problem of requiring countries to cut emissions today without any pressing current incentive.

In a sense, this scheme allows our great grandchildren to vote today.

Idea 2: We Need to Take Decisions Today about the Enormous Amount of Land Needed for Renewable Energy Tomorrow

The sheer enormity of the UK's future energy problem is not widely understood.

Energy use in the UK falls into four main categories. The largest, at one third of all energy used in this country, is transport. It consumes approximately 55 million tonnes of oil per year. Next at a little under 50 million tonnes of oil-equivalent per annum comes domestic household use – for things like heat and light. Then comes energy used in the Industry sector. It totals around 35 million tonnes. Finally, approximately 20 million tonnes a year of oil-equivalent are consumed in Services.

As the Figures show, since 1970 these proportions have altered. While industrial energy consumption has dropped, the rise of the car in our society has seen energy use on the roads almost triple. Hence the key long-term issue is how to replace the fossil fuel that is currently burned in car engines.

In the year 2005, there is much talk of running motor vehicles in a green way -- powered by hydrogen. The Liberal Democrats have, in fact, called for subsidies for cars of this sort.

What is not widely appreciated is that hydrogen is not a source of energy. It is a carrier of energy.

Yes, cars can, and should, be made to run on hydrogen fuel. But, to be clean, the hydrogen has to be made with renewables-based electricity. Today, hydrogen is made from fossil fuel, which defeats the purpose.

What would it take to run all of Britain's road transport, in a truly green way, with hydrogen? It is possible to do an illustrative calculation (see the Appendix)*.

The answer is disturbing. What is required is approximately 100,000 new wind turbines. If sited off-shore, this would mean an approximately 20-kilometre-deep strip of wind turbines encircling the entire coastline of the British Isles. If sited on-shore, each citizen of our nation would have to be prepared to see wind-turbines from their bedrooms, or have a giant wind farm covering more than the area of Wales. And this would power only vehicles. Other measures would be needed for energy uses such as domestic heating.

We should also consider solar power and bio-fuels. Having a variety of green energy sources is sensible. But the important fact that most British citizens (and indeed world citizens) have not grasped is that green energy sources require huge land masses to be feasible. We are going to have to give over large tranches of our island, one way or another, if we are to switch from petroleum.

With technology as it stands, there is one obvious non-fossil-fuel alternative that should be mentioned -- nuclear power. Although that leads to other long run concerns (particularly how to deal with radioactive waste), nuclear power stations could in principle provide the necessary green electricity to produce the hydrogen to fuel the UK's transport needs.

However, again the number is striking. As the appendix shows, it would require 100 new nuclear power stations.

Transport is the single biggest energy user in the UK. On average, we all consume one tonne of oil in this way every year. To replace this with cars that run on hydrogen -- powered without any fossil fuel -- would take a revolution in society.

In short, the British are going to have to accept that big land areas must be given over to the production of green energy. This is likely to take a considerable amount of public persuasion.

Idea 3: Country-wide Road Pricing is Required, Not Just Congestion Charging in London

Since the 1950s, traffic has grown ten-fold. As the mayor of London has recognised, road pricing is the future. At the time of writing, Edinburgh, too, is about to vote on a version of congestion-charging.

Road pricing makes sense. We need more of it. This will be a hard lesson for Britain, and the whole of western society, to learn. But learn it we must because traffice jams will worsen and because cars will be our single-largest source of carbon emissions in the future.

Roads are a commodity -- just like roofing tiles and roller-skates -- and to have an efficient economy, and most especially to avoid the wasteful queues of socialist countries, commodities need prices.

Congestion-charging works by making drivers pay a toll. The toll is set deliberately high at peak times; when the roads are quiet it is set low. Road use is then sold in a rational way. People buy what they need. Crucially, by adjusting the tolls, a busy road can be made to flow, so that the decision by one driver to take his car does not contribute to bad 'externalities' -- traffic jams -- upon others.

As cities like Singapore and Trondheim showed even before London, this is not a theoretical dream, nor is it any longer necessary to have physical tolls booths where drivers throw coins into a plastic chute. New electronic methods keep down the costs of employing staff in toll booths and the inconvenience of having to slow down. Some methods rely on electronic transponders that follow a vehicle as it passes points in a highway; others use satellite global positioning systems.

The barrier is now primarily psychological. Our generation has grown up thinking that roads are 'free', that traffic jams are acceptable, and that the amazing rise in UK traffic volume since the 1950s is part of the inevitable wallpaper of civilisation. It is time to support the campaign to bring congestion charging throughout the country. By reducing the jams that plague life, the UK would be transformed.

Road pricing is working elsewhere. East Coast Parkway in Singapore is probably the world's most advanced electronic toll road. The peak toll applies between 8:00 and 9:00am, when the number of commuters into the cordon is at its greatest. On each entry to the city, car owners have to pay approximately a pound, which is deducted from pre-paid smartcards. A toll of around half that amount is set to apply for 30 minutes before and after the peak hour. Mini-buses and trucks are charged at a separate rate; the system is advanced enough to recognise the type of vehicle.

Trondheim functions in the same general way. Toll charges are levied on each vehicle coming into the city. A peak rate of approximately one pound applies between 6:00am and 10:00am in the morning. A charge of roughly half that is deducted between 10:00 a.m. and 6:00 p.m. Larger vehicles pay bigger tolls.

What has happened to traffic flow? Despite the low charges -- compared to the 5 pounds for London – most observers agree that the schemes have had an effect. On East Coast Parkway in Singapore, traffic volume fell 15% in the first year of electronic road tolls. Average traffic speed went from 30km/h to 60km/h and the number of single-occupant cars declined.

In Trondheim, traffic also went down. The greatest impact was on the distribution of vehicle flow during the day. Norwegians now pay attention to tolls, and come and go at less concentrated times than before.

Certainly, things were not plain sailing. Before the introduction of the Trondheim toll ring, most citizens were opposed. In the early 1990s, 72% of those questioned in a random sample survey were dissatisfied with the idea of a scheme. Two months after its start, only 48% were opposed. Today, 36% of citizens of Trondheim disapprove of tolls. The numbers of dissenters will keep falling. Publicity campaigns have helped explain the logic of road pricing to Trondheim's citizens.

Road pricing exists elsewhere. The San Diego Interstate 15 plan was started four years ago. Solo drivers could purchase monthly permits for 70 dollars. A fully automated system then began in 1998: it deducts a fee for every trip. Tolls vary between 50 cents and 4 dollars, and can change every few minutes. In surveys, most users have so far been pleased about the reduction in journey times.

There continues in public debate to be a set of misleading objections to the principle of road tolls.

First, some believe that building roads is better. Yet experience shows that they quickly clog. Second, some say that road tolls would raise British firms' costs. But road pricing would actually make life cheaper for companies. Having your chief executive or lorry-load stuck in traffic is what is really bad for profits. Third, some say that road tolls would hurt the poor. In fact most people in the lowest fifth of the income distribution in Britain do not own a car; road tolls are going to have little effect on them. Moreover, toll revenue can be converted into cash for better public transport and into tax reductions. Both can be designed to help the less well-off. Fourth, by introducing road pricing throughout Britain, we could even begin, if we wished, to lower the tax on petrol. That tax is a blunt weapon; it strikes as much on pretty country lanes as crowded city streets. Tolls are a sharp one. Fifth, there is no alternative to road tolls. The demand for travel will

continue to grow. Doing nothing will leave our grandchildren stuck fast in carbon dioxide and concrete.

Prices work – and would on roads too.

Idea 4: Something Dramatic Will Soon Have to be Done about Air Transport Emissions

Although it is perhaps not widely realized, there are signs that airplanes are going to be one of our biggest problems in the long term.

Greenhouse gas emissions in the UK air transport industry show an extraordinary rise since the early 1990s. Between 1990 and 2002, emissions from the air industry went from approximately 20 million tonnes to nearly 40 million tonnes. Indeed they peaked above 40 million around the turn of the millennium, but were knocked down by the world-wide drop in passengers after the September 11 terrorist attacks on the Twin Towers.

In terms of the sheer levels of emissions, air is still a noticeably smaller source than road transport (the latter is approximately 1.7 times the former). But the rate of growth of emissions from air transport has recently been exceptionally fast. On current rates of growth -- a mechanical criterion that may not be an exact guide to the future -- UK air emissions will exceed UK road emissions by around the end of the decade after this one.

It is therefore almost certain that punitive tax levels will soon be needed – either on flights themselves or on airplane fuel.

Conclusions

The scientific evidence suggests that we should be deeply concerned about global warming. It is necessary for our country, and the planet, to move away from the use of fossil fuels. The core of our problem is increasingly around travel. Over the last third of a century, Industry has halved its final energy use, whereas the figure for Transport has doubled.

Energy and travel are profoundly interwoven. In thinking about the future, this lecture has argued four things.

1. We need to invent a new kind of financial incentive -- a form of long-dated bond -- to solve global warming. These 2045 Global Warming Bonds would be financed by the taxpayers of the future. This boils down to the idea that unborn babies should pay. Although that sounds harsh, it is efficient and fair for the rich generations of the future to compensate us for a change in our behaviour. Moreover, this kind of scheme has a better chance of success than a policy that

relies alone on negotiated international agreements without immediate incentives.

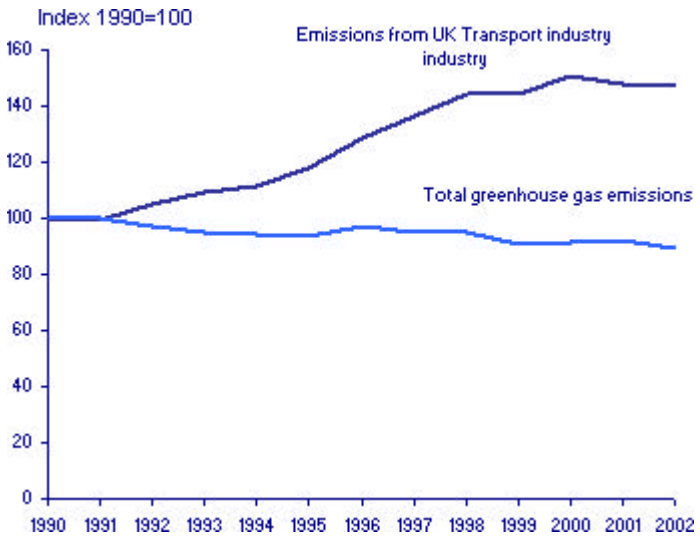
2. Huge land areas are going to have to be given over to the production of green energy. This has to be explained to, and accepted by, our citizens.

3. We ought to have road pricing throughout the UK.

4. Something dramatic -- probably in the form of much higher taxes on fuel or flights -- will soon have to be done about air transport emissions.

Figure 1

Transport is the Growing Problem

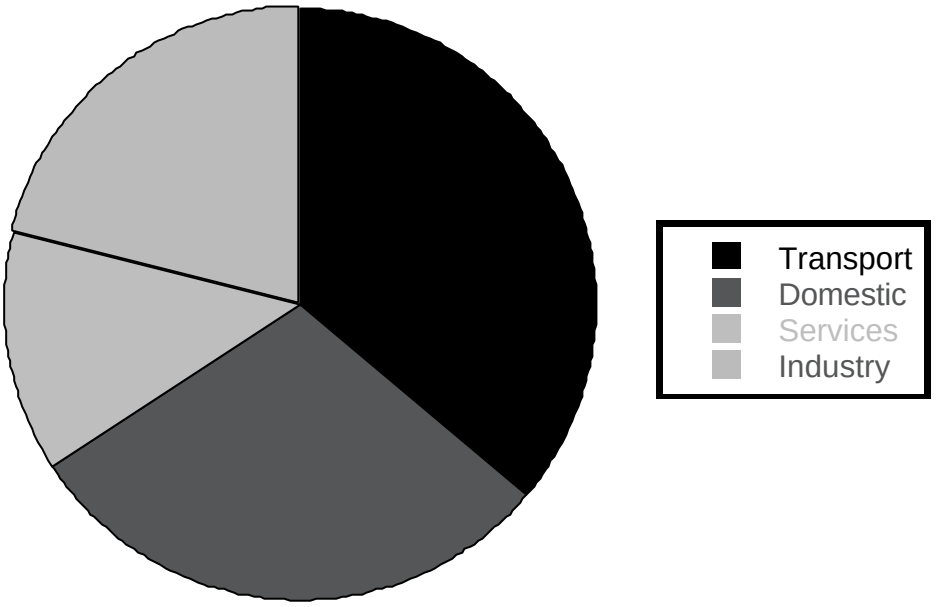


Greenhouse gas emissions, UK, 1990 - 2002

Figure 2

The Pattern of UK Energy Consumption Today

Final energy consumption by sector



2004

Figure 3

The Pattern of UK Energy Consumption in the 1970s

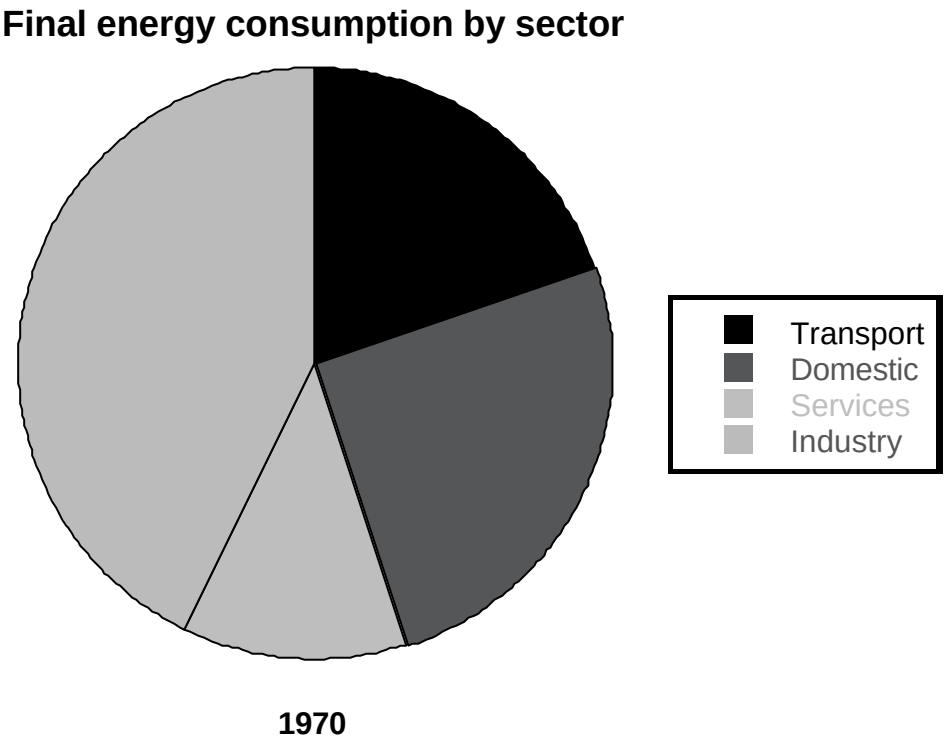
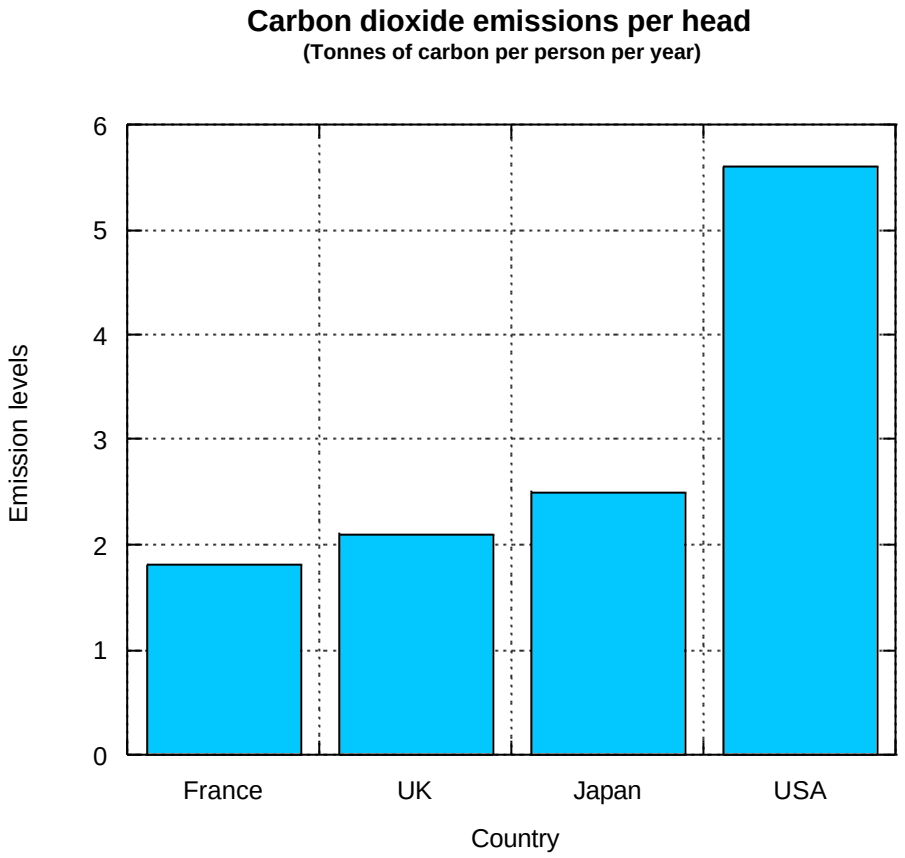


Figure 4

International Comparisons of CO2 Emissions



*** Appendix on the Number of Wind Turbines Needed to Power Hydrogen Cars in Britain**

How many wind turbines are needed to supply all the energy for today's UK transport needs?

The following is a calculation of the number of wind turbines required to provide enough energy to fuel the UK's transport today. This calculation is based on the premise that we use wind turbines to generate that energy which in turn is used to generate hydrogen and then the hydrogen is used to power vehicles. The wind turbines are likely to be offshore and the most efficient way to transport the energy inland is as electric power. Once inland, the electricity can be used to electrolyse water into hydrogen at locations across the country. New vehicles would be required that were capable of storing and burning the hydrogen.

The energy chain would look like this

<u>Calculation</u>
(This draws on work with J. Oswald, Chartered Engineer)

From DTI 'UK Energy Sector Indicators 2003' DTI publication 6339/6.0k/02/03/NP, chart 11.8.
The UK annual consumption of transport energy:
= 54 (MTOE) Million Tons Oil Equivalent.
Note: this has been steadily increasing.

The conversion of electric power into stored pressurized hydrogen (an energy store) is approximately 50% efficient, ref. Ulf Bossel 'The

Hydrogen Illusion'. Ulf Bossel is founder and organiser of the European Fuel Cell Forum, based in Switzerland.

So renewable energy required = 54 / 0.5 = 108 MTOE.

*Converting units to average daily MW = 108*1000*11.63*1000/(365*24) = 143,000 MW*
Conversion factor of 11.63 taken from ref DTI 'UK Energy in Brief, November 2000'

Today typical wind turbines are 2MW power. Let us assume larger, 3MW, units are developed and installed for this application.

Number units required = 143,000/3 = 47,794 units.

The wind only blows part of the time. Using an average capacity factor of 50% gives the approximate number of wind turbines required 47,794/0.5 = 96,000 units of 3MW size. Call it 100,000 units as an approximation. [It might even be argued that this is an under-estimate, if wind capacity below 50% is assumed.]

Where would the UK put them?

To keep the wind turbines out of sight and in a reasonable windy area, let us assume they are placed offshore and strung around the periphery of the entire country. What approximate density, given a rectangular band of turbines, is then required?

The straight line distance north to south = 680 miles (ref road map)
Straight line distance east to west = 200 miles
Periphery = 2(680+200) = 1760 miles = 2800 km*

Number per km = 100,000/2800 = 36 units / km

Wind turbines create blockage to the wind and have to be spaced apart to ensure the wind is undisturbed for neighbouring wind turbines. AEA report for Greenpeace 'Sea Wind East' argues that a spacing of 0.5km is required. In other words, there are two per linear km. Therefore a band of wind turbines 18 deep would give the required 36 wind turbines per km. This represents slightly less than

an approximately 10 km deep strip of wind turbines around the periphery of the UK.

If on shore, how much land is required ?
100,000 units at 4 units per square km means 25,000 square km required. Total UK land area = 244,000 square km. For example, the area of Wales = 20,000 square km.

In conclusion

- *Approximately 100,000 wind turbines (each 3MW) would generate enough electricity to manufacture sufficient hydrogen to provide the power for today's UK transport needs.*
- *A reasonable spacing of these around the coastline of the UK (2,800km long) would require a band of wind turbines approximately 10 km deep.*

Alternatives

This calculation shows how dispersed renewable energy is: you need a lot of equipment over a large area to collect the energy for today's needs. Wind turbines are the most effective renewable technology available and are being installed widely. Other renewable energy forms such as bio-fuels, wave power, solar are also dispersed forms of power and require big installations to get the large quantities of power for today's needs. Fundamentally, their power per unit size is much worse than equivalent fossil fuel powered machines. Nuclear power is another alternative which is free from CO2 production.

110,000 MW of power could be generated within 100 nuclear power stations each of 1,100MW generating capacity. Ref Sizewell B (the UK's most recent nuclear station), for example, has a generating output of 1,200MW.