ONLINE COMPANION
to ONE MILLION CLIMATE JOBS

Prepared by the
Campaign against Climate Change
Trade Union Group
in conjunction with
Bakers, Food and Allied Workers Union
Communication Workers Union
Fire Brigades Union
National Union of Students
Public and Commercial Services Union
Transport Salaried Staffs Association
Unite, the union
University and College Union

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This online technical companion is designed to do several things. First, we provide the footnotes and references for the printed version of the booklet. Second, we show how we calculated the estimates we use. Third, we provide various background papers that readers may find useful. And finally, we direct the reader towards further reading. This companion will be updated at intervals.

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This report was written by a group of trade unionists, environmental activists and experts working under the umbrella of the Campaign against Climate Change Trade Union Group. The trade union movement has many different emphases, priorities and policies. While all the unions involved support the general argument, not all of them agree with every demand. All of us, however, are united in the demand for one million climate jobs in the UK to save the planet.

GENERAL PRINCIPLES

Growth and Technological Progress

In this booklet, we show that it is possible for one million workers to cut CO_2 emissions in the UK by more than 80% in twenty years, using the technology we have now. So our calculations are also based on what is possible now, with current technology.

In practice, three important processes in the real world will influence the actual costs and labour needed for 80% cuts in CO_2.

One process is that as technologies mature, they become more efficient. This is particularly true once the stage of mass production is reached. So we can assume that the number of workers needed to manufacture and install 1 GW of wind or solar power will decline steadily over the 20 years of our project. The same is likely to be true of electric cars and buses, and we can expect considerable innovation in industrial processes. All this would suggest that by the end of the 20 years we will need fewer than the one million workers we will need with today's technology.

However, two countervailing processes push in the opposite direction. One is that our strategy for renewable energy relies heavily on offshore wind. At the moment both onshore and offshore wind farms are situated in the best available sites, where the least investment is needed. But we are planning to move further and further out into deeper water, and that will increase the labour needed for each turbine. This will to some extent balance increases in productivity.

The other countervailing process is economic growth. In this report we calculate the energy needed for the economy as if the economy does not grow. In fact it is very likely that there will be considerable economic growth over a twenty year period, which will translate into increased demand for energy.

So productivity will rise, but increased amounts of energy will also be needed.

The question is whether productivity in the key sectors of a low carbon economy will rise faster than economic growth. If productivity rises faster, we will need fewer than a million jobs. If economic growth is faster, we will need more than a million jobs.

One way to answer this question is to make assumptions about capital costs, interest rates, oil prices, productivity increases, and economic growth. Many reports do this. The difficulty is that the assumptions one makes can so easily produce the answer one wants. Supporters of oil can so easily stack the deck, and so can supporters of renewables. Moreover, it becomes very difficult for the reader to see and evaluate the effect of the assumptions – the stacking and biases – on the overall argument.

So what we have done here is assume that productivity increases and innovation will be balanced by deeper water and economic growth. In practice, it will not work out quite like that. But this assumption allows us to make a simple argument – given the technology we have now, a million workers could cut emissions by more than 80% in 20 years.

Round Numbers and Estimates

A word about our approach to statistics and estimates is also in order.

Writers on jobs, climate and renewable energy tend not to show their calculations. Their reports are often stocked with authoritative numbers, and sometimes there is a reference to a website from which these numbers have been derived. Sometimes these numbers have been produced on a computer, and sometimes on a calculator. In all cases, the author has made assumptions, on the basis of which they have added, subtracted, multiplied and divided the raw data. But it is usually not possible to see what those assumptions were. Without knowing these assumptions, it is difficult to know how far we can rely on the numbers the author produces.

This problem is particularly acute with reports produced on commission for corporations and not peer reviewed, but the problem is there in other reports and articles too.

For these reasons, we have tried to show our calculations, so that subsequent researchers can follow our logic.

The alert reader will also notice that we present most of our estimates as round numbers. One reason for this is that we are writing to be understood by ordinary people working in many industries.

They, and all the rest of us, find it easier to understand if you write: 'The government spends £66 billion pounds a year, but they get £37 billion of that money back.'

By contrast, they will find it harder to make sense of 'Expenditure will be £66.379 billion, but £36.812 billion of that will be reclaimed.'

The more important reason for using round numbers, however, is that in most of the cases we deal with here, both the numbers we are working with and the final estimates are at best approximate. Figures to three decimal places usually reflect fantasies about precision.

There are some reasonably accurate numbers. The measurements of levels of CO_2 in the air over Hawaii, for instance, are solid and reliable. Governments also have good reasons to keep track of the amount of coal, oil and gas sold within their borders. This means that they have reasonably accurate figures for carbon dioxide emissions.

We also have reasonable numbers for the amount of methane in the atmosphere each year. That is easy to count. You just analyse a sample of air. So we can also tell how much the methane levels go up and down each year.

But we do not know how much methane is emitted each year. How much comes from gas leaks? How much from the digestion of cattle, or from rice paddies, or from frozen methane? There is no accurate way of measuring. And once the methane is in the atmosphere, we do not know how much of disappears into sinks or breaks down.

So we know whether the amount in the atmosphere is going up or down each year, and by how much. But as for how much methane is emitted each year globally, estimates can vary by factors of two or three. Calculations of methane lost in gas leaks in England, or the amount of methane from the digestion of sheep, face similar problems.

As the reader will notice below, the calculation of job numbers is also not an easy matter. Many official employment statistics do not divide up the workforce in ways helpful to our purposes. Industry estimates of jobs tend to be exaggerated.

In many cases there is no obvious way of deciding what is a direct job and what is an indirect job. In theory a direct job is a worker in the industry, and an indirect job is a worker in the supply chain. But sometimes a worker making train carriages is counted as direct, and sometimes as indirect. Sometimes a worker making materials for building a wind turbine blade is classified as direct, and sometimes indirect. And so on.

In the literature, specialists also take quite different approaches to counting jobs. American sources tend to count 'job years'. So if an American source says there are 20,000 jobs, they usually mean 1,000 jobs a year for 20 years.

European sources tend to count permanent jobs. So in this report when we say 300,000 jobs, we mean an average of 300,000 jobs over a 20 year period. That would be counted as 6,000,000 'job years'.

Most sources only count jobs within the country – this can be very misleading when the wind turbine is manufactured in Denmark and assembled in Britain. Some American sources count only jobs within the particular American state, so that fracking jobs in Pennsylvania do not include the machinery made in Texas.

So we pay considerable attention below to the details of how jobs numbers are calculated. Our estimates of job numbers are as precise as we can make them. But they are estimates.

FREQUENTLY ASKED QUESTIONS

Jonathan Neale

What about health and safety?
What will happen to electricity bills?
What happens to the One Million Jobs after 20 years?
What role is there for cooperatives, small businesses and community groups?
Where would the jobs be located?
What about the 'Jevons Paradox' or 'Rebound Effect'?
What about embodied energy – the fossil fuels used to make the renewable energy?

What about health and safety?

Many trade unionists are concerned that the new climate jobs will be badly paid, casual, insecure and unsafe. These are reasonable worries, because many jobs in construction and renewable energy now have just these drawbacks. Moreover, jobs in manufacturing wind turbines and solar power often involve working with dangerous chemicals. And work at sea with wind power and marine power has always been unsafe, even without rogue employers.

But our climate jobs will not be like that. The first reason is that these will be government jobs. They will not be contracted out to cowboy firms. Employment will be on permanent contracts, on government wage scales.

But even that, as public sector trade unionists know all too well, does not protect health and safety on the job. No amount of regulation, or mission statements can change that. Regulations are important, and it is crucial that health and safety officers and union representatives have the right to call in independent inspectors. But none of this will work properly without strong trade union organisation on the job.

Unions will have to build that organisation. But they will start from a strong position. It will not be a simple process to win one million new public sector jobs. That will require massive campaigning by the unions, and in all probability extensive protests and industrial action as well. A movement that has won a million climate jobs will change much else in the process. It would be a sorry union that would not be able to build workplace organisation under such circumstances.

None of this means that jobs will be safe. They will only be safer. The dangers are real, so constant care and strong union organisation will be necessary.

What will happen to electricity bills?

Under our proposals, utility bills will not rise.

However, it is perfectly reasonable to fear that they might. Renewable energy like wind, solar, wave and tidal power currently costs more than coal and gas – often much more. That means any transition to renewable energy now costs more. Someone has to pay that cost – there has to be some kind of subsidy.

The subsidy for renewables now usually takes one of two forms. Both of them increase the cost of electricity bills for most households.

One form of subsidy is a requirement that the electricity company buy a certain percentage of their energy from renewable supplies. Because renewable energy is more expensive than coal and gas, the electricity company pays more. They then pass on this extra cost by increasing household electricity bills. This has been the usual form of subsidy in the UK.

The problem is that this is an unfair way of charging for electricity. In fair tax systems, the rich pay a larger percentage of their income, because they can afford to do so. But when the electricity company passes on the cost, everyone pays the same extra percentage of their bill.

But it's even more unfair than that. The poorer people are, the larger the percentage of their income they spend on electricity and heating. At one extreme, if you are a pensioner in a leaky house, you may have to choose between heating and eating. At the other extreme, if you make £200,000 a year, heating is a small part of your total expenses.

Moreover, electricity companies charge small users, like households, at a higher rate than they charge large users, like businesses and industry. So if you subsidise renewable energy by raising utility bills, the poor and middle income people, bear an even more unfair share of renewable energy subsidies.

There are other forms of energy subsidy that are unfair in similar ways. For instance, in some countries, the government or the electricity company gives richer consumers a grant or loan to install solar energy on the roof. Much of this solar energy will not be used in the home. So under a 'feed-in tariff' the consumer is guaranteed a high price for the solar energy they sell back into the national grid.

The electricity company then shares out the extra cost of the feed-in tariff between other consumers. This means that the grant or loan reduces the amount the affluent household with solar power on the roof pays in bills. But it increases the amount paid by poorer households who cannot match the grant or afford the loan.

Again, middle income people and the poor pay more.

Our proposals work quite differently. We recognise that renewable energy will cost more. If you look at the chapter on costs, you will see that we have suggested that the consumer should pay one half of the cost of renewable electricity, which is about the same amount they are paying now for electricity from coal or gas. We suggest the other half should be paid by a government subsidy. This government subsidy would come from some form of tax on the rich – we suggest many possible forms.

In technical language, most forms of subsidy for renewable energy today are 'regressive' – most people pay a larger percentage of their income, and the rich pay less. Our proposals are 'progressive' – the rich will pay more.

However, with our proposals most people will also switch their heating from gas to electricity. This means that your electricity bill will rise, but your gas bill will go down. Our aim is no rise in the combined cost of your electricity and gas bills.

There is also another way our proposals are fair. We suggest that the National Climate Service will insulate and renovate everyone's house for free – including private rented housing. That will reduce everyone's heating bills. But it will have a particularly important effect on the bills of people on low incomes with very draughty houses.

Again, this would have to be paid for with a subsidy. And again, we propose that this subsidy should come from general taxation on the income or wealth of the rich.

What happens to the one million jobs after twenty years?

This report outlines what a National Climate Service with a million new workers could do over twenty years. But what happens to those one million workers at the end of the 20 years?

The jobs continue. Here's why.

We have estimated that for the first 20 years we will need roughly 400,000 workers in renewable energy, 310,000 in transport, and 185,000 in insulating and converting buildings. We will continue to need most of these workers.

These numbers are averages. At the beginning of the twenty years, hardly any workers will be maintaining renewable energy. By the end of the 20 years, there will be roughly 240,000 workers in manufacturing and installing renewable energy, and another 240,000 in maintenance. Moreover, the working life of a wind turbine or a solar array is about 20 years.

Just as we come to the end of building the first generation of renewable energy, we will need to start recycling the parts and installing the second generation. By that point we are likely to need fewer workers, because technology will have improved, but we may still need 160,000, for a steady total of 400,000 workers in renewable energy.

So at the end of 20 years we will have 310,000 public transport workers in the National Climate Service, plus all the bus and train jobs we already have at the beginning of those 20 years. And all those workers will be needed for many more years to run the buses and trains.

However, the building workers will largely have done their job. All the houses, and many public and business buildings will have been converted. Some of these workers will find new work in building new low carbon housing in the public sector, or for councils. Some can retrain for new climate jobs. Indeed, we expect that over the second half of the first 20 years, many building workers will retrain to work in the maintenance of renewable energy, often using similar craft skills.

We will also need new jobs to reduce emissions further. These will be jobs in agriculture, in changing industrial processes, in building additional renewable energy for use in heating materials in industry, and in recycling. Taking all these things together, we will need a million jobs dedicated to lowering carbon emissions each year for the foreseeable future.

Finally, if we do get a million climate jobs in this country, it will not only happen here. We will inspire people and movements in other countries, some or all of whom will do likewise. In that case, there will be a lot of jobs training people who come here from other countries, or going overseas to help them, or building parts here for export.

What role is there for cooperatives, small businesses and community groups?

The main reason for having one million jobs in a government run National Climate Service is simple. We want to promise everyone who loses a high carbon job a new permanent job at the same wage. We want to do this because it is right, but also because if we do not make that promise we will split unions and communities. It will not be easy to win a million jobs, and we need all the support we can get.

If we promise people a job with a private company or a cooperative, everyone will know it's a lie. The only believable promise is a job in a government run climate service.

But many people want a space for cooperatives, community groups and small businesses within the climate jobs. This is reasonable. We can make spaces for that.

There will be half a million indirect jobs in the supply chain, and a great deal of room for small business there.

One obvious place for community and cooperative groups is in running and managing wind farms, wave power and tidal power. The climate service could manufacture the turbines and install them. This is mostly factory work, and centralised by its nature. But if community groups run the wind farms, look after them, and repair them, that will build local support for wind power, and give local people control over where they go and how they operate.

It may also make sense for local councils to employ community work forces in some form to renovate buildings. However, this work will wind down over time, and workers will need to be able to transfer to energy or transport jobs.

It is easy to think of other opportunities for cooperatives as well. If we get a million jobs, we can argue this out, and experiment. But we will still need the majority in public sector jobs, and iron clad promises that people will have security of employment.

Where would the jobs be located?

The National Climate Service will have to balance two considerations in deciding where jobs go. On the one hand, jobs need to be distributed around the country so that people in all regions feel included. On the other hand, it makes sense to have more jobs in areas of high unemployment.

There are also factors in the nature of the job to consider. About half of the jobs would be in public transport and the insulation and conversion of buildings. In the nature of things, these jobs would be local, and pretty evenly spread across the country.

Another 400,000 jobs would be in renewable energy. Some of these jobs would also be spread around the country, particularly jobs building and running the national grid, and jobs installing and maintaining solar power.

But some jobs would be concentrated in particular areas. Many of the jobs would be in the manufacture of wind, solar, wave and tidal power. These would in effect be factory jobs. Solar manufacturing could be done anywhere. But offshore wind, wave and tidal turbines would have to be built on or very near the coast, or with good connections by water. These are very large structures, and difficult to transport over land.

Maintaining offshore wind, wave and tidal power would also have to be done from bases on the shore. As it happens, many people in Britain live within an hour of the shore or a big river.

The National Climate Service will have to take all these factors into account. To see how this might work in practice, look at the case study in the main booklet of fracking and climate jobs in Salford and the Fylde.

What about the 'Jevons Paradox' or 'Rebound Effect'?

A common worry is that using renewable energy will not in fact cut emissions because of the 'Jevons Paradox'. This is an idea first developed in 1865 in a book on *The Coal Question* by the economist William Stanley Jevons. The paradox is also sometimes called the 'rebound effect'.

What Jevons said was this: As people used more and more coal, they learned to use it more and more efficiently. So the same weight of coal could provide more heat and power. You might think that would mean people would then use less coal. In fact, they used more coal. The more efficient coal was, the cheaper it was, and the more money people had left over to spend on other things. And those other things involved burning more coal in trains, factories and mills, and to heat larger houses.

1865 was a long time ago. Since that time economists have shown that the same thing happens with oil and natural gas. The better we get at using the fuel, the more we use. And the paradox also works with other natural resources, like water.

Many people therefore assume, quite reasonably, that the same thing will happen with renewable energy. We will build more and more renewable energy, but emissions will still increase at the same time. It is easy to see how this would work. We increase the amount of renewables so that they supply half of all energy. But the total amount of energy used is increasing too, so we are also using more and more fossil fuels too.

Moreover, we can save money on household bills by insulation and conversion to save energy. That gives people more money to spend. And public transport costs less than cars. That gives people more money to spend too. They go right out and spend more on things that take more energy to make and run.

That is likely to be the problem with most plans for renewable energy. But that won't happen with our plans for climate jobs. The reason is simple. Our plan gets close to 100% renewable energy. Within thirty years, we could be there for everything except air travel.

Once everything runs on renewable energy, we simply make selling coal, oil and gas illegal. People won't be able to do it. There may be more demand for energy. But that demand will have to be satisfied by renewables. And if it can't be satisfied by renewables, it won't happen. This will be a matter of agreed public policy, in much the same way that selling anthrax is illegal now.

There need to be some qualifications here. One problem is air travel. It is very difficult to think how to fly with renewable energy. The solution here will be fixed limits to the number of flights allowed.

Moreover, 100% renewables mean that planet warming emissions can be cut to almost nothing, but that does not solve the problem of other resources, like water. The Jevons Paradox need not be a problem for climate change, but will still be a problem.

What about embodied energy – the fossil fuels used to make the renewable energy?

The oil, coal and gas that are burned in making a wind turbine or an electric bus emit CO_2. This means that renewable energy is not simply emission free.

These fossil fuel emissions are called 'embodied energy'.

Likewise, buses and trains do not only use the electricity or oil it takes to run them. There is also the oil, gas and coal burned in getting the fuel from the ground to the tank. There is the fuel burned and emissions produced in making the buses and trains, and all the raw materials. And there is the fuel burned and emissions produced in making and maintaining the roads and rail lines.

How much difference do these embodied emissions make?

Some, but not all that much. One reason is that the amount of embodied energy is not large. The relevant literature has been summarised in L. D. Danny Harvey's magnificent two volumes on *Energy and the New Reality*, Earthscan, London, 2010.

Harvey uses the idea of 'payback time'. This is the length of time the wind farm takes to produce an amount of energy equal to all the energy used in making the turbines, transporting them, making and transporting the materials, building the factories, and so on.

For different studies of wind farms, the payback time varies from two to eight months (Harvey, 2:161-4). A wind turbine lasts 20 to 25 years. The amount of fossil fuel energy used in making a wind farm is tiny compared to the amount of energy produced.

For solar PV cells, the usual payback time is 2 to 4 years. Estimates for payback times for concentrated solar power vary from 6 months to 2.5 years. (Harvey, 2:38-40, using his table on p. 39 but allowing for the point he makes about the limits of process-based calculations on p. 40; and Harvey, 1:64-5.)

This means that the time needed to produce as much renewable energy as was used in making the solar power is about 10% to 20% of the total lifespan of the solar device. Energy is not the same as emissions. But these numbers would suggest that the emissions reductions from using solar power would be in the region of 80% to 90%, rather than 100%.

Fewer researchers have done the calculations for embodied energy in transport. But Harvey (1:251-4) has a detailed table based on the work on Lenzen in 1999 on energy use in mega-joules per passenger kilometre in Australia. These numbers show that the amount of embodied energy in transport is about a third to a half of the total energy used.

This is true for buses and trains, as well as for cars. Public transport uses less fuel and less embodied per passenger than cars do.

So embodied energy is not that large when the transition to a low carbon economy begins. As the transition gathers pace, there will be fewer and fewer embodied emissions.

At the start of the transition wind turbines are manufactured using electricity from coal. And they are transported using trucks powered by oil. But after 20 years all the electricity at the factory will come from renewable energy. Moreover, renewable electricity will provide most of the energy for the transport as well. Embodied emissions were low to begin with. After 20 years they will be tiny.

There are limits to this process. Ships for installing and maintaining offshore wind farms will still need to need use oil. And large wind turbines will probably still need large trucks powered by diesel to get them to the wind farms.

So after 20 years the effects of embodied energy will be real, but very small.

(Parts of this answer were adapted from Jonathan Neale, *Transport Workers and Climate Change: Our Jobs, Our Planet*, www.capitalandclass.org, 2012, Appendix 3.]

Notes on Chapter One
Unemployment and Costs

[1] Office for National Statistics (ONS), *Labour Market Statistics May 2013*.

[2] Rob Wilson, Rachel Beaven, Mike May-Gillings, Graham Hay and James Stephens, *Working Futures 2012-2022*, March 2014, p. 26.

[3] For different versions of the analysis that emphasise inequality, see Joseph Stiglitz, *The Price of Inequality*, Penguin, 2013; Paul Krugman, *End this Depression Now!*, Norton, 2012; and Thomas Piketty, *Capital in the Twenty-First Century*, Harvard, 2014. For different versions of the analysis that looks to problems with profits and investments, see Chris Harman, *Zombie Capitalism*, Haymarket, 2010; Andrew Kliman, *The Failure of Capitalist Production*, Pluto, 2011; and Jonathan Neale, *What's Wrong with America*, Vision, London, 2004.

[4] See the mainstream economist David Blanchflower, 'Wages fall as the mystery of the British and American job markets gets deeper still', *Independent*, 13 October 2014; the Marxist Michael Roberts, 'Where is the economic recovery?' www.thenextrecession.wordpress.com, 20 September 2014; and *World Economic Outlook: Legacies, Clouds, Uncertainties*, International Monetary Fund, October 2014.

Direct and indirect workers

[5] Here are the calculations for the section 'So we need to do something different'. We calculate the numbers of direct and indirect workers as follows.

Different writers and reports label jobs as direct and indirect in different ways. These are slippery concepts. But what we mean here is simple. Direct workers are people employed by the National Climate Service. Indirect workers are people employed by companies who are supplying the National Climate Service with all the things the NCS workers don't make – telephone lines, stationary, steel, glue, buses, and so on.

Based on the calculations in the notes to Chapters 5, 6 and 7 below, we use the following multiples for indirect jobs in the supply chain:

	Direct jobs	Multiple	Indirect Jobs
Energy workers	400,000	0.5	200,000
Railway workers	120,000	0.67	80,000
Bus workers	180,000	0.5	90,000
Building workers	185,000	0.5	92,500

That is a total of 462,500 indirect jobs.

The estimates for bus and railway workers may seem low to some readers, but we explain them in Chapter 7.

The remaining 115,000 direct jobs are almost all in training, research, teams offering advice in industry and agriculture, waste, and building cycle lanes. On average, these would have a multiple of less than 0.5. We estimate the average multiple might be 0.3, for a total of 34,350. That would mean a total of 496,850 indirect jobs. We round to 500,000 indirect jobs.

This gives us an estimate of 1,000,000 direct jobs and 500,000 indirect jobs. We add another 225,000 induced jobs. Induced jobs are the jobs created by the increased spending of direct and indirect workers, and 15% is a standard estimate for induced jobs. That gives a total of 1,725,000 direct, indirect and induced jobs.

Now assume the National Climate Service employs almost 1,000,000 new workers at the start of 20 years. But by the end of the 20 years, about 240,000 workers for the NCS are people displaced from high carbon jobs.

240,000 may seem a low estimate. But in aviation we plan for job losses of about a third, all of which should be covered by retirement over a 20 year period. We also plan for similar job losses over 20 years in road freight, which again should be covered by retirement. (For a detailed explanation of why, see notes 11 and 19 to Chapter 6 on Transport.)

There are sectors where most workers would lose their jobs over twenty years: oil, gas, and coal. But again, over 20 years half of these workers would retire in any case, and some of the rest will be part of natural turnover of employment. Workers in North Sea oil and gas will also have skills that will be very valuable in offshore wind.

We are assuming that all power station workers and workers on the national grid will keep their jobs working on a new grid, and we have not counted them as part of the one million new climate jobs. A large proportion of car industry jobs will become bus manufacturing jobs, and another proportion will manufacture electric cars.

So 240,000 seems a reasonable estimate for the number of displaced workers in the NCS at the end of 20 years. Therefore, we estimate that over the course of 20 years, there will be an average of 120,000 displaced workers in the NCS each year, and an average of 880,000 new workers.

However, where these direct jobs are transferred jobs, and not new jobs added to the total economy, they would have no extra stimulating effect on indirect and induced jobs. So from the total of 1,725,000 new jobs, we have to subtract 120,000 displaced jobs, 60,000 indirect jobs and 27,000 induced jobs. That leaves us a total of 1,518,000 new jobs, which we round to 1.5 million.

Costs of the one million jobs

We calculate the costs to the government of one million jobs in the following way:

According to ONS, *Annual Survey of Hours and Earnings, 2013 Provisional Results*, median annual earnings in 2013 were £29,000 for men, £24,000 for women, and £27,000 for everyone. Mean annual gross pay was £35,000 for men, £28,000 for women, and £32,000 for all. To give an idea of the range, the annual median income in pounds for different groups was:

Annual median income in £s

Professionals	37,000
Associate professionals and technical	30,000
Skilled trades	25,000
Process, plant and machine operator	23,000
Administrative and secretarial	21,000
Caring, leisure and service	18,000
Sales and customer service	17,000
Elementary	17,000

'Elementary' includes jobs like cleaning. The mean figures are inflated by some high salaries at the top. The median figures mean that half the people in this category are paid more, and half less. The figure for both men and women is depressed by discrimination against women. So we have elected to go with a mean income of £30,000 a year for climate jobs, or £30 billion for a million jobs.

Employers pension contributions are calculated at 16.5% of 30,000 = £4,950 times 1,000,000 = £4,950,000,000, rounded to £5 billion. We have made no allowance for employers' national insurance contributions, as this would be the government paying itself.

We estimated the cost of materials, fuel, supplies, rent and interest in the following way.

The total number of economically active people in the UK was 30.4 million in Feb 2014 (ONS, *Summary of Labour Market Statistics*, May 2014). They worked an average of 32 hours – including part-timers and people working a second job. That is equivalent to 26 million workers at 37.5 hours a week.

Assume that one million climate workers are supplied by half a million workers in the supply chain. Assume that the number of workers in the supply chain is proportional to the share of those workers in total employment, which is 1/52. Total UK GDP was £1.7 trillion in 2013. Multiply that by 1/52 and the result is £33 billion.

(In the published booklet, which went to press a month before this *Online Companion*, we used an older figure for GDP, and so estimated £31 billion. We have revised this estimate in what follows.)

This raises the question of why we do not calculate the total costs as a proportion of the total economy. Why do we not simply say 1.5 million workers are 1/18 of the total economy, or £94 billion? The answer is that in calculating the costs of the one million climate jobs, we are only calculating the cost of labour, and not adding on amounts for profit, rent, interest, etc.

Indeed, capital costs will in general be quite low. For renewable energy, the customary way to think of the capital costs is the cost of manufacturing and installing the turbine, the tower or the panels. In our calculation we have included these as part of our million jobs, and the capital costs of setting up a wind turbine plant, for instance, are not that large. Again, the capital costs are not large in setting up insulation and renovation teams, if one assumes that the tools and materials come from the supply chain. The capital costs of expanding the bus system, again, are not great – the main item is the cost of buses, which are counted as part of the supply chain.

The cost of setting up a new, second rail network, on the other hand, is quite large. But here we have allocated an average of 85,000 direct jobs over 20 years to do exactly that, which again means they are not counted as capital costs.

This gives us the following figures for costs for one year:

£30 billion in wages for one million jobs
£5 billion in employers' pension contributions
£33 billion in other costs

Total cost: £68 billion

How much money the government can recover

Now for the calculations on how much money the government will get back. There will be about 400,000 energy and electricity workers out of one million, so we assume that electricity will account for about 40% of total costs. We also assume that because of the high cost of renewable energy the government will subsidise one half of the cost of electricity bills. So the income from those bills will be 20% of the total expenditure of £68 billion.

The government gets back £13.6 billion a year from electricity bills. We round that to £14 billion.

For the bus system, we are planning for a doubling of the number of workers and a fivefold increase in the number of passengers (See notes to Chapter 6).

There are currently about 5 billion passenger journeys by local bus in the UK, and the combined government subsidies are about £0.50 per journey, so the total government subsidy is about £2.5 billion. Operating revenue is about £6.3 billion. So total revenue is about £8.8 billion.

(*Department for Transport Statistics, 2013, Table BUS0503b, Net government support for local bus travel, England*; *Table BUS0101, Passenger journeys on local bus services, Great Britain*; and *Table BUS0401b, Operating revenue on local bus services, Great Britain*.)

We can roughly estimate that after nationalisation of the bus services, costs would be about £7.5 billion without having to pay out profits.

Passenger kilometres on coaches are about a fifth of the pkms on local buses (Department for Transport Statistics, 2013, *Table NTS0305, Average Distance travelled by mode, Great Britain 1995/7 to 2012*). Of course operating and labour costs are lower for coaches, because they go faster on average. So will assume that costs for coaches are on the order of £1 billion. The cost of bus and coach services together is about £8.5 billion.

We are suggesting a doubling of the number of bus and coach passengers, with 2.5 times the seat occupancy. That is a five times the current number of passengers.

So the cost for the whole of the increased network would be twice £8.5 billion, which is £17 billion.

Without a change in prices, the ticket revenue for local buses would be £6.3 bn times 5 = £31.5 billion. The ticket revenue for coaches would be £2.5 billion. The total ticket revenue would be £34 billion. Less £17 billion costs, that is £17 billion a year net from ticket sales.

We assume that £5 billion of that would go towards reductions in the cost of tickets. That would leave £12 billion a year in net income from bus tickets.

Assuming that the government continued the current subsidy of £2.5 billion for bus travel, there would be a total of £7.5 billion available to reduce the cost of bus tickets by about a quarter.

On the railways the situation is a bit more complicated. (See notes to Chapter 6.) Here we assume that an average of 85,000 jobs over 20 years will go to extending the rail network, and 35,000 new jobs to running the new network.

Currently we have 120,000 jobs in rail, 15,000 of them notionally in freight. (Again, see notes to Chapter 6.)

Income for rail is as follows (see Note 11 to Chapter 6):

Ticket sales	£7.7 bn
Freight	£1.2 bn
Govt subsidy	£4.0 bn
TOTAL	£12.9 bn

After renationalisation, we can reduce the total cost to £11 billion at most, because we would not be subsiding profits.

We plan for a second rail network. We assume the following averages over a 20 year period (see Note 11 to Chapter 6):

Existing rail workers	120,000
New workers building new rail	80,000
New workers working in new rail	40,00

To make our calculations easier, we will assume that for the first 13 years there will be:

120,000 existing rail workers
120,000 workers building new rail

And that for the last seven years there will be:

120,000 existing rail workers
120,000 workers operating new rail.

In practice, the situation will be complicated, with some new rail lines coming into service in four years or less, and some only after 20 years. But we are making these assumptions for ease of calculating the possible return from tickets.

We also assume that government expenditure on subsidy will continue to be £4 billion, and that this will not be counted as part of the new National Climate Service budget.

Then the existing rail system will have a revenue of £9 billion, a subsidy of £4 billion, and costs of £11 billion. That will allow £2 billion to be put towards a fall in ticket prices.

We assume that after 13 years, a whole new network will have been built, employing an equal number of workers to the old one.

Then there will be 70,000 workers in rail freight working on the old network. They will bring in £1.2 bn times 70,000/15,000 = £5.6 bn a year. We round to £6 billion.

At the moment rail carries 70 billion passenger kms. After 14 years, the old and new networks combined will carry 160 bn pkms. (See Note 11 to Chapter 6.) That will bring in £7.7 bn times 160/70 = £17.6 bn a year. We round to £18 billion.

Then the total income over the last seven of the 20years will be:

rail freight	£6 bn
passengers	£18 bn
continuing subsidy	£4 bn
TOTAL INCOME	£28 billion a year

We assume the total cost of running both the old and the new network will be twice the cost of running the old network. Two times £11 billion is £22 billion. Subtract that from £28 billion income each year, and there is £6 billion clear each year. This still leaves the £4 bn a year subsidy available to reduce the cost of rail tickets.

£6 billion net for each of 7 years is an average of £2.1 billion over the full 20 years. We round that to £2 billion.

Estimated return to government

£14 bn from electricity bills
£12 bn from bus tickets
£2 bn from train tickets

For a total of £28 billion on tickets and electricity bills.

We assume that homes and buildings will be renovated for free. The work will be done without charging owners, occupiers or tenants. The savings on heating bills will go to whoever is paying the bills.

Taxes and Benefits

Now for the calculations of how much the government recovers in new taxes paid and benefits unpaid once an unemployed worker takes up a public sector job.

Mattias Dolls, Clement Fuest and Andreas Peichl, *Automatic Stabilizers and Economic Crisis: US vs. Europe*, Institute for the Study of Labor, July 2009, p. 14, estimate a return to the government of 44%.

However, the authors are using data from Euromod, which does not include spending on VAT and other indirect taxes. To allow for this, we have used the estimates for indirect taxes in Richard Murphy, 'Cut Government Debt by Increasing Spending', Compass, 2009 at www.compassonline.org.uk. For a person on £25,000 a year, Murphy estimates the effect of indirect taxes at 4%. This gives us a total rate of 48%, and 48% of £30 billion is £14.4 billion, which we have rounded to £14 billion.

Dolls et al are working from data from 2007, but on balance the UK tax and benefit system has not changed that much since.

Then we have to add in the money the government recovers in taxes and benefits from indirect and induced workers. We estimated above that there will be 725,000 indirect and induced workers. But some direct workers will be people displaced in the old high carbon economy being given new National Climate Service jobs. In those cases the workers, and the indirect and induced workers dependent on their jobs, do not represent new workers taken out of unemployment. So the government makes no net saving on taxes or benefits in these cases. We estimated that the net number of indirect and induced workers would be about 500,000, after allowing for these transfers from the old economy.

500,000 is one half of 1 million workers, and one half of the £14 billion recovered from a million workers is £7 billion, recovered from these new workers. This may be a bit high because the workers in these sectors might be paid less, but a lot of the supply chain will be manufacturing work, and the mean income will be inflated by very high salaries at the top.

This gives us a total of funds recovered by the government each year of:

£28 billion from electricity bills and bus and train tickets
£21 billion in taxes and benefits

For a total of £49 billion recovered each year.

So the government spends £68 billion. They recover £49 billion each year.

The net annual cost to the government is £19 billion a year.

How to pay for the £19 billion a year

[6] Now for the calculations for the section on 'How to Pay for It'. The cost per person per week works out as follows.

The total net cost is £19 billion a year. There are 63.4 million people in the UK, and 52 weeks a year, or almost 3.3 billion person weeks a year. That is £5.77 per person per week.

For taxes on the richest two thirds of one percent of taxpayers, we start with HMRC, *Income Tax Statistics and Distributions, Table 2.5 Income Tax Liabilities by Income Range 2011-12 to 2014-15*. According to the table for 2014-15, 222,000 out of a total of 29,900,000 taxpayers had a declared income of £107.4 billion, on which they paid £41.5 bn in taxes, a rate of about 37%. If this was raised to 50%, they would pay half of £107.4 bn, or £53.7 bn. Subtract the £41.5 bn paid, and that is another £12.2 bn. We round to £12 billion.

Note, however, that Mike Brewer, Luke Sibera, and Liam Wren-Lewis, in *Racing Away: Income Inequality and the Evolution of High Incomes*, Institute of Fiscal Studies Briefing Note 76, 2008, p. 9, using data from 2005-2006, estimated that the top one percent were paying an effective tax rate of 27%, taking into account tax breaks. Assuming the ratios have held steady over ten years, that suggests that for the top two thirds of one per cent, another 41.5 billion would bring their effective tax rate to just under 40%.

This all assumes that the richest two-thirds of one per cent are telling the truth to the taxman. If they are by any chance under reporting, their real rates of tax are lower.

For the Robin Hood Tax, also called the Tobin Tax, www.robinhoodtax.org.uk estimates that a tax of £1 for every £2000 in a transaction would raise £20 billion a year. However, this estimate may be high, because a transaction tax might reduce the number of transactions by making those based on extremely small margins uneconomic. So our estimate is that it will raise between £10 billion and £20 billion a year.

For information on tax loopholes and tax evasion, see Richard Murphy, *The Missing Billions – The UK Tax Gap*, TUC Touchstone Pamphlet 1, 2008; Richard Murphy, *Closing the European Tax Gap: A Report for Group of the Progressive Alliance of Socialists and Democrats in the European Parliament*, 2012; and his invaluable regular blogging at www.taxresearch.org.uk. Also useful is the more official House of Commons Committee of Public Accounts, *HMRC Tax Collection: Annual Report and Accounts 2012-13 (Thirty-fourth Report of Session 2013-14)*, for which bless Margaret Hodge.

Using Murphy’s estimates, we have a possible £25 billion from closing loopholes and £74 billion from illegal tax evasion. That is a total of £99 billion. £19 billion of that, less than a fifth, is all we would need to cover net spending for climate jobs.

However, a more recent report by Murphy, *The Tax Gap: Tax evasion in 2014 and what can be done about it*, PCS, 2014, has updated these estimates. See also http://www.taxresearch.org.uk/Blog/2014/09/22/new-report-the-tax-gap-is-119-4-billion-and-rising/. The updates suggest that tax avoidance is down to £19 billion, largely because tax rates have fallen, but that tax evasion has risen to £82 billion. The total of both is £101 billion, instead of £99 billion.

For the idea of a tax on wealth, we follow the delightful suggestions of Thomas Piketty in *Capital in the Twenty-First Century* (Harvard University Press, Cambridge, 2014). His figures are approximate, but they assume that total UK wealth is now at least 6 times the national income, and that in a 'medium-high inequality' example in Europe in 2010, the top 1% of adults own about 25% of the wealth (p. 248). 6 times £1.7 trillion national income times 25% is £2.55 trillion in wealth for the top 1%. Piketty's figures are a bit higher than some other researchers use, because he does not simply rely on the income and wealth declared to Her Majesty's Revenue and the Survey of Personal Incomes, but relies on other sources as well.

A tax of one half of one percent on the wealth of the top 1% would raise 1/200 times £2.55 trillion = £12.75 billion a year.

For the possibility of a form of quantitative easing, we draw on Josh Ryan-Collins, Tony Greenham, Giovanni Bernardo, and Richard Werer, *Strategic Quantitative Easing: Stimulating investment to rebalance the economy*, New Economics Foundation, 2013.

[7] For subsidies, see the essay by Barbara Harriss-White's on *Subsidies to Fossil Fuel Based Energy Worldwide* which will be published in the next edition of this Companion.

[8] For World War Two, see Jonathan Neale, *Stop Global Warming*, Bookmarks, pp. 50-55; and Paul Koistinen, *Arsenal of World War II*, University Press of Kansas.

Notes on Chapter Two
The Dangers of Climate Change

[1] For the general reader, the best up-to-date introduction to climate change is Mike Berners-Lee and Duncan Clark, *The Burning Question*, Profile, London, 2013. James Hansen, *Storms of My Grandchildren*, Bloomsbury, London, 2009, is also useful and readable. The International Transport Workers Federation has useful *Climate Justice Factsheets* by Jonathan Neale on many aspects of climate change, at www.itfglobal.org. Tyler Volk, *CO_2 Rising*, MIT Press, Cambridge, 2008, provides a good clear explanation of the carbon cycle and the chemistry of climate change.

The current state of the detailed science is in Intergovernmental Panel on Climate Change, *Climate Change 2013: The Physical Science Basis* (www.ipcc.ch). For a detailed guide to recent worrying studies, see Dahr Jamail, 'As Casualties Mount, Scientists Say Global Warming Has Been "Hugely Underestimated"', *Truth-Out*, 20 October 2014. See also Herring, S. C., M. P. Hoerling, T. C. Peterson, and P. A. Stott, Eds., Explaining Extreme Events of 2013 from a Climate Perspective', Bull. Amer. Meteor. Soc., (2014) 95 (9), S1–S96; and Paul J. Durack, Peter J. Gleckler, Felix W. Landerer, and Karl E. Taylor, 'Quantifying Underestimates of Long-Term Upper-Ocean Warming', *Nature Climate Change*, October 2014, draft available at http://www-pcmdi.llnl.gov/about/staff/Durack/dump/oceanwarming/140926a_Duracketal_UpperOceanWarming.pdf.

Bill McKibben, *Eaarth: Making a Living on a Tough New Planet* (St Martins, New York, 2011) is a good introduction to the effects of climate change now. Christian Parenti, *Tropic of Chaos: Climate Change and the New Geography of Violence* (Nation Books, New York, 2011) is a detailed survey of the links between war and climate change now.

Jonathan Neale, *Stop Global Warming: Change the World* (Bookmarks, London, 2008) has a chapter on how climate disasters turned into social catastrophes in New Orleans and Darfur. Eric Klinenberg, *Heat Wave* (University of Chicago Press, Chicago, 2003) is a study of one heat wave in Chicago that says a lot about the general relationship between neoliberalism and climate disasters. Naomi Klein, *The Shock Doctrine: The Rise of Disaster Capitalism* (Penguin, London, 2008) explains how neoliberal elites use disasters to restructure society.

For rises in surface temperature, see World Bank, *Turn Down the Heat: Climate Extremes, Regional Impacts and the Case for Resilience* (Washington, 2013, www.worldbank.org), and the videos of Kevin Anderson's lucid and useful presentation to a Campaign against Climate Change conference in 2013 at https://www.youtube.com/watch?v=-bS27d-ATYs and https://www.youtube.com/watch?v=7S1QNYfAg1o.

Notes on Chapter Three
Overview of Climate Jobs

We have arrived at our estimates for emissions in the following way.

The UK government's provisional estimates for 2013 are:

CO_2 emissions in megatonnes (Mt)

Power stations	145
Other energy supply	33
Business	75
Transport	117
Public	10
Residential	77
Agriculture	4
Industrial Processes	10
Land use and forestry	-8

For our purposes, we are restating these statistics somewhat differently:

Revised CO_2 emissions in megatonnes (Mt)

Transport	178
Electricity production	145
Heating residential buildings	77
Business combustion	65
Producing oil, coal and gas	33
Heating public and business buildings	20
Industrial processes	10
TOTAL	528

Here are the reasons for our revisions:

'Other energy supply' consists of emissions from oil and gas extraction and refineries. This category also includes emissions from coal mining, but these are not high because there is little mining in the UK.

Electricity use in businesses, homes, public buildings, and transport is counted as emissions under power stations.

Business includes both industrial combustion for heating materials and combustion for heating business premises. We have estimated the heating of premises at 10 Mt, and the heating of materials at 65 Mt. Public (10 Mt) is the heating of public buildings by combustion – burning oil, coal, gas or wood. We have added business and public building heating together to get a figure of 20 Mt for 'Heating public and business buildings'.

Industrial processes are CO_2 emissions released from the process itself, not from fossil fuels burned for heating materials. The most important process here is cement production, where carbon is extracted from limestone and sent into the air as CO_2.

We have added the 65 Mt of business combustion, the 33 Mt of oil, gas and coal production, and the 10 Mt of industrial processes together for a total of 108 Mt from industry.

The reasons for our estimate of 178 Mt for transport emissions are explained in detail in Note 1 to Chapter 6. To simplify, we have included international aviation and shipping emissions, and made an allowance for the increased effect of aviation emissions in the upper atmosphere.

Emissions from agriculture are 4 Mt. These are just CO_2 emissions. Agricultural emissions of methane and nitrous oxide are much higher. Land use, forestry and land change emissions are -8 Mt, which means that land use and planting trees created a net drop in emissions of 8 Mt.

For our purposes in the main report we have left out the emissions from agriculture and land use at this point, to make the table easier to follow.

So our totals are now:

CO_2 emissions in megatonnes (Mt)

Transport	178
Electricity production	145
Heating residential buildings	77
Business combustion	65
Producing oil, coal and gas	33
Heating public and business buildings	20
Industrial processes	10
TOTAL	528

Further Reading:

The best place to go for careful and informed discussion of the numbers on emissions and emission reductions is the magisterial two volumes of LD Danny Harvey, *Energy and the New Reality*, Earthscan, London, 2010.

There are now quite a few general studies of the possibility of drastic reductions in emissions. Particularly useful for Britain are Paul Allen, Laura Blake, Peter Harper, Alice Hooker-Stroud, Philip James and Tobi Kellner, *Zero Carbon Britain: Rethinking the Future*, Centre for Alternative Technology, 2013; and Christine Brown, David Elliott, David Finney, Ian Crossland, and Christopher Watson, *Pathways to 2050: Three Possible UK Energy Strategies*, Report of a British Pugwash Working Group, 2013. For other countries, see Jonathan Neale, *Our Jobs, Our Planet: Transport Workers and Climate Change*, a report for the European Transport Workers Federation, 2011, republished with technical appendices at www.climateandcapitalism.com); Mark Z Jacobson and Mark A. Delucchi, 'Providing all global energy with wind, water, and solar power' Parts 1 and 2, *Energy Policy*, 39 (2011) 1154-1190; Michael Renner, Sean Sweeney, and Jill Kubit, *Green Jobs: towards decent work in a sustainable, low-carbon world*, United Nations Environmental Programme, Nairobi, 2008; ITF Climate Change Working Group and Global Labor Institute, *Transport Workers and Climate Change*, International Transport Workers Federation, 2010; Sven Taske, *Energy [r]evolution: a sustainable world energy outlook*, Greenpeace International, Amsterdam, 2012; and WWF and Ecosys, *The Energy Report: 100% Renewable Energy by 2050*.

Different radical approaches to the politics of climate change can be found in Naomi Klein, *This Changes Everything: Capitalism vs. The Climate* (Allen Lane, London, 2014) and in three books by contributors to this report: John Cowsill, *Safe Planet: Renewable Energy + Workers Power*, Earth Books, London, 2014; Martin Empson, *Land and Labour: Marxism, Ecology and Human History*, Bookmarks, London, 2013; and Jonathan Neale, *Stop Global Warming: Change the World,* Bookmarks, London, 2008.

Notes on Chapter Four
Renewable Energy Jobs

The notes for this chapter are provided as a running commentary, rather than individual footnotes.

Calculating the number of jobs needed in renewable energy is not an easy matter, and many figures in the literature are at best back of the envelope estimates.

Here are our final estimates:

	Terawatt hours	Jobs
Onshore wind	80	20,000
Offshore wind	480	216,000
Wave and tidal	80	54,000
Solar	80	54,000
Grid and storage	0	56,000
TOTAL	720 TWh	400,000 jobs

Here is how we arrive at these estimates:

Onshore wind jobs

For onshore wind, the traditional rule of thumb in the industry has been that there are 10 direct jobs in manufacture and installation for every GW of installed capacity and 0.33 jobs in maintenance each year. These figures have been questioned by Max Wei, Sanna Patadia and Dan Kammen, 'Putting renewables and energy efficiency to work: How many jobs can the clean energy industry generate in the U. S.?' *Energy Policy*, 2010, draft available at http://rael.berkeley.edu/node/585. Their estimates partly rely on reports for individual projects, but it would make sense that the number of jobs would be falling with increased productivity.

However, the most careful study of wind power jobs available is *Green Growth: the impact of wind energy on jobs* *and the economy*, European Wind Energy Association, 2012, www.ewea.com, based on data collected by Deloitte. The most recent data are for 2010, so it is a bit out of date. The figures are for the European Union. The great advantage to this report is that the data have been collected 'bottom up' – by examining the annual reports of all the wind sector companies and questionnaires to all the major companies.

Green Growth (pp. 13, 36 and 55) gives the following figures for the EU:

Wind power installed

9,332 MW in 2010
84,324 MW over the last 20 years

Direct jobs in wind in EU in 2010

Developers	14,519
Wind turbine manufacturers	45,449
Component manufacturers	32,115
Service providers	43,779
Total direct employment in wind	135,863
Total indirect employment in wind	102,292

The jobs with developers are wind farm jobs – mostly maintenance and installation. Wind turbine and components are factory jobs. Service providers include things like R&D, transport, financial workers, and services for wind farms.

The total income for the sector was €18.3 billion. However, a lot of turbines are exported from Europe – net exports in 2010 were €5.6 billion (that is exports minus imports). This suggests that about 70% of the jobs were for turbines in Europe and 30% were for exports.

That would suggest roughly 95,000 direct jobs for turbines for Europe and 72,000 indirect jobs.

It is reasonable to assume that the old formula of 0.33 maintenance still holds. With 84,000 MW of total installed capacity, and assuming one indirect job for every two direct jobs, that would give us an estimate of 28,000 direct jobs and 14,000 indirect jobs in maintenance.

That leaves 67,000 direct jobs for 9,332 MW installed in 2010. That works out at 7.2 direct workers per MW installed.

It also leaves 58,000 indirect jobs for 9,332 MW installed. That is 6.2 indirect workers per MW installed. That is 13.4 direct and indirect workers.

This is a smaller number of direct workers and a larger number of indirect workers than we might have expected. But the distinction between direct and indirect is to some extent in the eye of the statistician. An integrated National Climate Service would be likely to include some indirect functions.

So we will go with an estimate of 9 direct workers and 4.5 indirect workers per MW installed, for a total of 13.5 workers per MW. This is 10% less than the estimate we used in our report four years ago.

We plan for 80TWh from onshore wind after 20 years. That means installing enough capacity each year to provide 4 TWh. One GW producing at 100% of capacity provides 8.760 TWh a year (24 times 365 + 8,760).

Of course no wind farm supplies 100% of capacity. The load factor for onshore wind is now about 0.28 in the UK. That means the actual electricity supplied over a year is 28% of the maximum possible. There will be improvements in load factor as the technology develops. On the other hand, at present wind farms are built in the best possible sites, and we are assuming that we will build many more in less productive sites. Balancing improvements in technology with shortfalls in sites, we will assume a load factor of 0.28. This will give us 2.45 TWh for each GW installed. For 4 TWh installed a year, we need about 1.6 GW installed a year.

If we assume 9 direct workers per MW installed, that is 9,000 workers per GW, or 14,400 for 1.6 GW a year.

Then there are the jobs in maintenance. We assume 0.33 jobs per MW, or 333 jobs per GW in place. If 1.6 GW are installed each year for 20 years, the average total in place in each year will be 16 GW. That gives an estimate of 5,333 maintenance workers in an average year – none at the beginning of the first year and 10,666 at the end of the twentieth year.

So in an average year there will be 14,400 jobs in manufacture and installation, and 5,333 jobs in maintenance. We round the total to 20,000 direct workers in onshore wind.

Offshore wind jobs

Now we turn to estimating jobs in offshore wind. Onshore wind is a much more developed technology than offshore wind. This means we have no reliable job figures based on actual employment. So the best guide we have is to compare the costs of offshore and onshore wind.

We plan for 480 TWh of electricity after 20 years from offshore wind. We will assume a load factor of 0.34 for offshore wind. This is a better than onshore wind, because offshore wind blows much more steadily, although this is offset a bit by turbines breaking down more often. It is also very close to the actual load factor for UK offshore wind now. As with onshore wind, there will be a trade-off between improving technology and putting wind farms further out to sea, and we assume these factors will balance out.

A load factor of 0.34 means we need a total of 160 GW of offshore wind after 20 years to supply 480 TWh of electricity a year. (480 divided by 0.34 times 8.760 TWh = 480 divided by 3 = 160.)

That requires installing 8 GW of offshore wind in each of years.

How many jobs would be involved? There are no reliable estimates of jobs numbers in offshore wind, so we have to estimate by comparing costs with onshore wind.

Until recently, it was usually assumed that offshore wind would require about 50% more jobs than onshore wind. However, the UK has installed more offshore wind than any other country, and costs have been much higher than that.

A series of recent reports have documented the problems: *Offshore Wind Toward 2020: On the path to competitiveness*. Roland Berger Associates, 2013; Philip Greenacre, Robert Gross and Phil Heptonstall, *Great Expectations: The cost of offshore wind in UK waters – understanding the past and predicting the future*, UK Energy Research Centre, 2010; Clare NcNeil, Mark Rowney and Will Straw, *Pump Up the Volume: Bringing down costs and increasing jobs in the offshore wind sector*, Institute for Public Policy Research, 2013; *A Study into the Economics of Gas and Offshore Wind*, a report for Greenpeace and WWF-UK by Cambridge Economics, 2012; and *Offshore Wind Power: Summary Report*, Technology Needs Assessment from the Low Carbon Innovation Coordination Report, 2012.

These are useful and thoughtful reports, and they all address the same problems in different ways. The starting point for each of the reports is cost. In 2000 there was a generally accepted narrative in the industry, in government and among many investors. This narrative accepted that offshore wind would be expensive at first. In particular, it would be more expensive than onshore wind. The reasons are obvious. Offshore wind is out in the ocean, it's harder to build, it requires foundations and boats, and it is harder to maintain, because there's a lot of wind and waves out there.

However, the accepted narrative said that the cost of meeting these challenges would come down rapidly once economies of scale and mass production kicked in. This is a new industry, and the learning curve should be steep. Moreover, the higher output from stronger and steadier wind should balance the technical challenges offshore.

By 2010 people in the industry and government, though, were starting to worry because costs were higher than expected. In the UK electricity suppliers have to buy a certain proportion of renewable electricity. The government fixes the prices for different kinds of renewables. In effect, this is a subsidy for renewable energy from consumers' electricity bills. In 2009 the

Department of Energy felt compelled to raise the price for offshore wind electricity under this scheme by a third (Greenacre et al, p. 57; McNeil et al, p. 34).

What are the barriers to bringing down costs? Although the authors might not put it quite this way, they are describing an industry facing two sets of problems.

One set of problems is that the UK government has not organised, mentored and overseen the development of the industry. Instead, the government has relied on an imaginary 'market' to solve any problems. The other set of problems are technical engineering challenges. These require innovation, and they require large investments in research and development.

The two sets of problems are, of course, related. In the paragraphs that follow, we will suggest ways that coordination by a National Climate Service could overcome these market and engineering problems, and bring down costs substantially.

One problem is finance. Until 2008 there was enough finance for offshore wind. Since the crash that year, lenders and investors have been more careful. Much of the problem is that manufacturers and developers are unsure about what the medium term price regime will be. At the moment there is a guaranteed price regime for renewables. But this only covers wind farms that start producing electricity by 2017.

For wind farms that start producing in 2018, there will be another price regime. (It takes 8 or 9 years at the moment for the average wind farm to become operational.) The government has left unclear how the new price regime will work. And there is no guarantee that it will cover all wind farms.

Moreover, industry executives are not encouraged by the noises coming from the UK government. So they are speeding up projects that can come on stream by 2017, and holding back on investment and work for later projects.

A National Climate Service would solve all these problems with finance and investment.

Another problem is a shortage of turbine manufacturers. Siemens and Vestas have built almost 90% of the offshore wind turbines in the world. Siemens has built two thirds of all the offshore turbines installed off the coast of the UK. (McNeil, et al, p. 17; Roland Berger Associates, p. 6). So Siemens and Vestas dominate the industry, and turbines account for about half the cost of setting up an offshore wind farm.

One result is that prices for turbines stay high, because there is little competition and because of regulatory capture. Half of global offshore wind is being installed off the coast of the UK. The price of wind power is effectively set by a small number of people in the UK government who determine pricing regimes. They have given in to pressure from Siemens and Vestas to keep prices high. (This is to state starkly what is said rather more politely by Greenacre, et al, p. 57. See also McNeil et al, p. 34.)

Then there is marinisation of turbines, an engineering problem. Until now, wind turbine technology has basically taken an onshore wind turbine and put it in the ocean on top of a steel foundation. Everyone in the industry now knows that marinisation of turbines is needed – designing turbines with the ocean environment particularly in mind.

This is partly because taller turbines can be used at sea. But it is also because turbines designed for land have been breaking down rather more than expected at sea. This reduces the total amount of electricity produced from each turbine, and repairs can be difficult or delayed at sea.

Bottlenecks in the supply chain are also a considerable problem. They routinely lead to delays of two years or longer.

There are two underlying problems with the offshore wind supply chain. One is that because there is no UK manufacturer, there is no complex cluster of suppliers around that manufacturer.

The other has to do with scale. With onshore wind, there are now so many orders that manufacturers are able to produce one turbine a week. That allows industrial habits to develop, which makes solving engineering problems far easier. (The experience in many industries is that large scale production leads to far more engineering progress than research and development does.)

Steady production on a large scale in one place in the UK would also create steady work for a cluster of suppliers. But now many suppliers are understandably oriented on the onshore wind business, simply because there is much more of it. However, onshore wind investment fluctuates a great deal in response to changes in stimulus money and subsidies in key countries, particularly the US. So at times offshore wind goes to the back of the line, and there are long delays.

A National Climate Service with large and steady production of offshore wind could nurture a local supply chain.

The supply chain bottlenecks are most acute with vessels. Among the vessels needed are ornithological and mammal surveying craft (about 30mlong); geophysical survey vessels (50m long, very stable); geotechnical survey vessels (90m long); cable laying vessels (converted barges); vessels to dig trenches for cable (90m); trenching remotely operated undersea vessel; cable plough (lays and buries cable, cost £10 million each); work class undersea remotely operated vessel for various jobs; foundation installation vessels or floating cranes; array cable laying vessels; substation installation vessel (floating crane); sea based support vessels (including transporting crew, anchor handling, barges, dive support, ROV handling); turbine installation vessel; transfer vessels (about 7 per port, £1.5 million each new); and jack barges or floating cranes for large component replacement. (See BVG Associates, *A Guide to an Offshore Wind Farm*, the Crown Estate, 2010.)

The most important of these are the installation vessels for turbines, foundations and substations. Some of these are barges converted to 'jack up' vessels, and some are floating cranes. They are typically 140m long with a crew of about 100. They cost £150,000 to £270,000 a day to rent. New built, they cost about £150 million, but at the moment they are only built in East Asia.

The vessels currently in use, moreover, are not purpose built for offshore wind. Where possible, wind farm developers do use boats built for the offshore oil and gas industry. However, North Sea oil and gas fields are still operating, and they are the priority for the owners of these vessels. So there is often a delay of two years while everyone waits for an available vessel.

There are also delays in finding smaller vessels for routine repairs, and barges or floating cranes for large component replacements. Doing these jobs quickly matters. More things go wrong at sea than developers initially expected, because the turbines are not designed specifically for use at sea. But time spent out waiting for repairs is time when no electricity is being produced.

These problems would be solved by a National Climate Service that build its own ships.

There are also bottlenecks in project development – everything that has to be done for a wind farm before the manufacture and installation start.

Project development typically takes eight or nine years in the UK now. The many environmental surveys take time. Raising the finance can take two years or more, and so can getting planning permissions offshore and onshore. The various undersea and geological surveys take time to ensure that the chosen site will support the structures. The meteorological surveys take time to make sure the wind will be sufficient.

Wind farm developers could in theory run all these processes simultaneously. But it would be financially foolish, because if part of the process does not work, the rest will not.

These development costs are only about 4% of the total costs over the lifetime of the wind farm. But the delays in effect set back the development of offshore wind by half a generation. Moreover, investors are having to make long term decisions based on guesses about what the market will look like, and they are having to make guesses about what government support and the supply chain will look like ten years down the line. The whole industry becomes uncertain.

But a National Climate Service would centralise the development process, and do all the required surveys and planning applications. The NCS could steadily work through many sites, select those that would work best, and then allocate them to public or private developers.

This would save money, because teams would not have to be assembled over and over again. There would be no problem raising finance. It would also protect the environment better. When private companies employ scientists to do environmental impact studies for a project, the pressure of money is always on both company and scientists to approve the project.

Grid connections are another problem now. Each developer in the UK now has to ensure its own cabling back to shore, and its own connections to the national grid. This means that the first developer in any region offshore has to bear the full cost of connecting back to the grid. That raises costs and deters investors.

But a National Climate Service could avoid these problems by planning all the connections over a period of time.

In short, there is good reason to believe that the costs of offshore wind to a National Climate Service would be much less than the current costs.

However, one of our general principles is that we will be conservative in our estimates, and work from the actual costs now rather than anticipated costs in the future. Otherwise, it is all too easy for the wish to be the mother of the estimate.

So we will estimate the number of jobs needed in offshore wind by looking at the difference in costs now.

The Department for Business, Innovation and Skills has published a list of Renewables Obligation Certificate Levels per MWh. These give the level of relative cost the government expects from various technologies. They are:

<u>Confirmed ROC levels per MWh for 2014/15</u>

Onshore wind above 5 MW	0.9
Offshore wind	2.0

(Source: Northern Ireland Department of Enterprise, Trade and Investment, *Existing and confirmed ROC/MWh levels from 1 April 2013* at www.detini.org.)

The confirmed levels for offshore wind will fall, however, to 1.8 in 2016/17.

These ratios do not compare the cost of Megawatts installed. Instead, they compare the likely cost of Megawatt hours actually produced.

We estimated above that it would take 20,000 direct jobs a year to install and maintain enough capacity for 80 TWh of onshore wind.

Let us take the confirmed ratio for 2016/17 of 1.8 offshore wind to 0.9 onshore wind. Then offshore wind jobs would be 480/60 times 20,000 times 1.8/0.9 = 240,000 jobs.

However, we do have to bear in mind that the ROC figure for offshore wind is in part the result of regulatory capture, and that a centralised NCS would be able to install capacity more cheaply. So we will make a conservative estimate that the actual number of jobs required will be 90% of the confirmed ROC figure.

That gives an estimate of 216,000 jobs each year in offshore wind.

However, maintenance jobs are a larger proportion of the labour and costs for offshore wind. We estimate that compared to offshore wind, there are 3 times as many jobs per GW installed in maintaining offshore wind farms. Offshore turbines are more likely to break down. They are harder to fix, because they are at such a distance. Bad weather can often delay repair work because vessels cannot get to the turbines. And swift repair work is important in maintaining a good load factor.

That is 1,000 jobs maintaining each 1.0 GW of offshore wind installed. For 160 GW installed over 20 years, that means 0 maintenance workers at the beginning of the first year and 160,000 at the end of 20 years. That is an average of 80,000 workers a year in maintenance.

The remaining 136,000 jobs each year will be in installing

8 GW of offshore wind a year. That is 17,000 jobs per GW installed, compared to 9,000 per GW for onshore wind.

Jobs in Solar, Wave and Tidal Energy

Now we turn to jobs in other kinds of renewable energy. We have suggested that at the end of 20 years we should have:

80 TWh from solar energy
80 TWh from wave and tidal energy
Almost 80 TWh from solar energy imported, in exchange for 80 TWh of UK wind energy exported.

This would give us almost 240 TWh in all, one-third of the planned total electricity supply, for using to balance irregularities in the supply of UK wind.

Reliable estimates suggest that more than 80 TWh of wave and tidal power are available.

For good introductions to wave and tidal power in the UK, see the Carbon Trust, *Accelerating Marine Energy: The potential for cost reduction*, 2011; AMEC Environment and Infrastructure, *UK Wave Energy Resource*, Carbon Trust, 2012; Carbon Trust, *Marine Energy Briefing, 27 July 2012*; and BVG Associates, *Wave and Tidal Energy in the Pentland Firth and Orkney Waters: How the projects could be built*, The Crown Estate, 2011.

The most recent, and probably most reliable, estimate for wave resource is from AMEC's 2012 report to the Carbon Trust on *UK Wave Energy Resource.* That report says that at least 70 TWh/yr are practical. A covering note from the Carbon Trust at the beginning of that report says 32-42 TWh/yr. The Carbon Trust's *Marine Energy Briefing 27 July 2012* says 70TWh/yr.

Carbon Trust, Accelerating *Marine Energy: The potential for cost reduction,* 2011; and Carbon Trust, *UK Tidal Current Resource and Economics*, 2011, both estimate that 40 TWh of wave power are economically available.

But note that the British Pugwash report suggests much higher figures for tidal power, and lower ones for wave power.

So a reasonable estimate would be that 110 TWh of wave and tidal power could be economically available. For our purposes here, we have suggested building enough capacity to produce 80 TWh. This should certainly be possible. There is also no question that 80 TWh of solar PV (photovoltaic) energy is available.

How many jobs will be involved? In the booklet, for simplicity, we have suggested:

Solar	80 TWh	54,000 jobs
Wind and tidal	80 TWh	54,000 jobs

The actual situation will be a bit more complicated. There are two constraints. One is that solar energy is likely to cost much less than wind and tidal. The other is that we will need a mix of all three to balance output.

Below are the Department of Enterprise, Trade and Investment levels for Renewables Obligation Certificates for various forms of energy. These give us some ideas of their estimates of ratios of cost at the moment.

<u>Confirmed ROC levels per MWh for 2014/15</u>

Onshore wind above 5 MW	0.9
Offshore wind	2.0
Solar PV up to 50 KWh	4.0
Solar PV above 50 KWh	2.0
(for 2016/17	1.8)
Tidal barrage	2.0
Tidal stream	2.0
Tidal stream	5.0
Wave	5.0

(Source: Northern Ireland Department of Enterprise, Trade and Investment, *Existing and confirmed ROC/MWh levels from 1 April 2013*.)

However, there has been a dramatic fall over the last three years in the price of Solar PV. This is due to two factors. One is technological progress. The other is global manufacturing 'overcapacity', particularly in China.

(Jamil Anderlini, 2013, 'Chinese Industry: Ambition in Excess', *Financial Times*, 16 June 2013. For background see Krister Aanesen, Stefan Heck and Dickon Pinner, *Solar Power: Darkest before dawn*, McKinsey & Company, 2012.)

This 'overcapacity' is the result of manufacturers building more factories while governments are cutting back on subsidies. However, it is difficult to tell how much of the fall in prices is due to overcapacity and how much is due to technological progress.

There are many reports suggesting that prices for solar energy are about to fall to levels comparable with coal or gas, particularly in sunny places like California. However, prices have not actually fallen that far yet. No one is calling for the withdrawal of subsidies to solar energy yet. And the UK is less sunny than California, so solar energy will still be somewhat more expensive.

For all these reasons, a reasonable estimate for now is that the cost of solar electricity is now about double the cost of wind energy.

The cost of most wave and tidal energy will be much higher. The ROC levels rank tidal barrage and tidal lagoon energy at the same rate as solar energy. However, there are environmental and political problems with proposals like the Severn Barrage, and almost all the tidal and wave power under development in the UK is of the more expensive sort.

These are new technologies, and there is everything to learn. The designs for tidal turbines have begun to converge. But there are still many quite different designs of wave turbine, and we do not know yet which will work best. The technology for tidal power is more advanced than for wave, but they both have a long way to go.

The companies involved are trying to solve several basic kinds of engineering problems. They are trying to work out what sort of design and mechanisms would work best. They are trying to work out how to make their machines and components robust enough to survive in heavy seas and strong tides, but light enough to be affordable. (Light is relative – these are very large structures mostly made of steel.)

They are trying to learn how to arrange the devices in arrays so they are cheap to install, but without the turbines interfering with each other too much. They are building turbines in different ways to adjust to the very different waves, tides, depths and sea bottoms of different sites. They are experimenting with materials. And they are developing specialist vessels which can deal with installing very heavy devices in high seas and strong tides, and other vessels suited to speedy repair work in high seas.

In other words, this is a very young industry. A great deal of the work will be in research and development, and in evaluating and redesigning prototypes. There is still not a functioning commercial scale marine energy farm anywhere in the world. Devices are manufactured one by one, not by tens or hundreds. This means that costs are still high. On reasonable estimate by David Elliott is that current tidal energy projects will cost about three times as much as onshore wind for the same output of electricity, and wave energy will cost four times as much. (Christine Brown, David Elliott, David Finney, Ian Crossland and Christopher Watson, *Pathways to 2050: Three Possible UK Energy Strategies*, Report of a British Pugwash Working Group, 2013, p. 66.)

So the estimates we have are:

<u>Ratio of cost to onshore wind</u>

Solar PV in 2016/17 (ROC)	2.0
Tidal now (ROC)	5.0
Tidal in future (Elliott)	3.0
Wave now (ROC)	5.0
Wave in future (Elliott)	4.0

For the purposes of an estimate, let us assume 80 TWh of solar PV, 40 TWh of tidal, and 40 TWh of wave. We will also assume that solar PV is in fact 1.9 – falling prices would suggest it has gone down at least that far. Then the total cost of solar, tidal and wave energy would be 2.7 times the cost of 160 TWh of onshore wind.

Assuming that the number of jobs is roughly proportional, that means 160/80 times 2.7 times 20,000 = 108,000 jobs for 160 TWh of solar PV, wind and tidal.

In the booklet, we have allocated that in equal halves:

54,000 jobs in solar
54,000 jobs in wave and tidal

It is probably more accurate to split the jobs:

38,000 jobs in solar
70,000 jobs in wave and tidal

But in practice a climate service might produce slightly more solar power and slightly less wind and tidal if solar was that much cheaper.

Jobs in Grid and Storage

Our estimate for jobs in extending the grid and building electricity storage is 56,000 jobs a year for 20 years. This is on the assumption that the work of cabling electricity from offshore wind, wave and tidal power is already counted as part of the jobs and cost of these forms of energy.

However, this is a very approximate estimate. Building enough energy storage, in particular, may increase the number of jobs required. For more on storage, see John Cowsill, *Safe Planet*.

Other Technologies

For the problems with biofuels, Biofuel Watch (www.biofuelwatch.co.uk) is a consistently useful site. The next edition of this Companion will include on essay on biofuels by Almuth Ernsting.

For critical approaches to carbon capture and storage, see Robin Lovelace and Luke Temple, 'Carbon Capture and

Storage: bury the myth and focus on the alternatives', *Metis*, (2012) 3: 20-26, Institute for Public Policy Research; Christine Ehlig-Economides and Michael J. Economides, 'Sequestering carbon dioxide in a closed underground volume', *Journal of Petroleum Science and Engineering* (2010) 70:123-130; and Emily Rochon, *False Hope: why carbon capture and storage won't save the planet*, Greenpeace International, 2008. For more positive, but still careful, approaches see House of Commons, Energy and Climate Change Committee, *Carbon Capture and Storage*, Ninth Report of Session 2013-14, 2014; and Low Carbon Innovation Coordination Group, *Technology Needs Assessment, Carbon Capture and Storage in the Power Sector, Summary Report*, 2012.

It seems clear that the carbon capture part of clean coal is workable. The controversy is mainly about storage. Critics of CCS argue that it will be too expensive, in money and energy, to move large amounts of CO_2 through pipelines over the necessary distance to storage caverns. They also argue that the rate of leakage is likely to be unacceptably high, and that underground reservoirs will not be able to store much gas.

What is clear is that no full size power station has been built anywhere that captures all its CO_2 emissions and stores them. There have been small demonstration projects, and plants where part of the CO_2 has been captured. The date at which CCS engineers expect the technology to be workable at scale is sometime after 2020.

It is unclear why implementation has been so delayed. One possibility is that there are technical problems that the engineers have so far been unable to solve. Another possibility is that the energy industry has been unwilling to implement because adding fully working CCS technology could easily double the already very high costs of a new power station.

For some of the problems with nuclear energy, see David Elliott, ed., *Nuclear or Not?* Palgrave, London, 2007; David Elliott, *Fukushima, Impacts and Implications*, Palgrave Pivot, London, 2012; and Joseph Mangano, *Mad Science: The Nuclear Power Experiment*, OR Books, New York, 2012.

Notes to Chapter Five
Building Jobs

The notes for this chapter are still being prepared, and will be in the second edition of this *Companion*, which should go online in December 2014.

Notes to Chapter Six
Transport Jobs

[1] Here are the official statistics for CO_2 emissions by mode of transport:

<u>Emissions in Megatonnes of CO_2</u>

Cars and taxis	65
HGVs	23
Light vans	15
Buses and coaches	4
Rail	2
International aviation	33
Domestic aviation	2
Other non-road	3
Shipping	12
TOTAL	159

The figures are for 2011 from *Department for Transport statistics, 2013, ENV0201, Greenhouse Gas Emissions by Transport Mode*. This is the last year for which we have a detailed breakdown. But the total transport emissions are the same for 2013, so we can assume that the split remains roughly the same.

The figures for international emissions for aviation and shipping are from bunker sales. These are sales of aviation and shipping fuel in the UK.

We make some adjustments to these figures.

We have, rather arbitrarily, assigned a third of the figures for light vans to freight and two thirds to passengers in cars, vans and taxis. These figures slightly underestimate the impact of buses and trains, because if you include emissions from electricity used by trains the total is 8 Mt, not 6 Mt.

Most of Other non-road is military aviation. We will add that to international aviation and domestic aviation, to make a total of 38 Mt from aviation. However, emissions from aviation have a stronger warming effect than other emissions, because they are discharged high in the atmosphere. There is dispute about how much stronger they are. See Alice Bows with Kevin Anderson and Paul Upham, *Aviation and Climate Change: Lessons for European Policy*, Routledge, London, 2008; J Penner, D Lister, D Griggs, D Dokken and M McFarland, *Aviation and the Global Atmosphere*, Cambridge, Cambridge University Press, 1999; Christine Jardine, *Calculating the Environmental Impact of Aviation Emissions*, University of Oxford Environmental Change Institute, 2005; and LD Danney Harvey, *Energy and the New Reality, 1: Energy Efficiency and the Demand for Energy Services*, pp. 314-319.

We have decided to multiply the effect of aviation emissions by 1.5, so 38 Mt of aviation emissions have the impact of 57 Mt of emissions.

This gives us the following table:

<u>Emissions in Megatonnes of CO_2</u>

Cars and taxis	70
HGVs	23
Light vans	10
Buses and coaches	4
Rail	2
Aviation	57
Shipping	12
TOTAL	178

[2] Here is the modal split between different kinds of land passenger transport.

<u>Passenger kilometres per year, in billions</u>

643	cars, taxis and vans
70	trains
42	buses
15	walking
5	motorcycles
5	bicycles
780	TOTAL

(Source: Department for Transport, *Transport Statistics Great Britain, TSGB0101, Passenger transport by mode, annual from 1952.)*

Buses

[3] The CO_2 emissions for various forms of transport in the UK now are:

Grams per passenger kilometre

Domestic plane trip	293
International plane trip	154
Passengers in vans	157
Average car passenger	121
Motorbike	120
Black cab taxi	219
Regular taxi	176
Local bus (not London)	109
Average local bus	101
Local bus in London	81
Coach	29
London underground	63
Light rail	62
National rail	47
International rail	12
Car passenger on ferry	133
Foot passenger on ferry	19

These figures are from the tables in Defra, *Carbon Smart, Greenhouse Gas Conversion Factors Repository*, at www.ukconversionfactorscarbonsmart.co.uk. To be precise, these are numbers for CO_2 equivalent emissions, but CO_2 makes up the great majority of the total.

Carbon Smart gives figures for business travel by car, assuming one person in the car or van. We have adjusted these for an assumption of 1.6 people in the car, the average in a UK journey.

The figures for air travel given above have not been adjusted for the increased warming effect from emissions higher in the atmosphere.

The figures for coach travel, foot passengers on ferry, and international rail (Eurostar) give some idea of the cuts in emissions that are possible.

[4] The figures for buses in the table above are not that much better than for the average car passenger: The reason is that the UK is at the bottom of the table for average seat occupancy rates in Europe:

<u>Average number of seats filled on a bus</u>

United Kingdom	9
Sweden	9
Finland	13
Ireland	15
Portugal	16
Italy	17
France	18
Germany	18
Denmark	19
Austria	25
Netherlands	25
Spain	28
Belgium	32

(Source: European Environment Agency, *Indicator Fact Sheet: TERM 2002 29 EU – Occupancy Rates of Passenger Vehicles*, p. 4.)

These figures are the latest we could find, but they are 15 years out of date. And the UK figures are actually for 1998. Since that time the average number of trips on London buses has increased by 46%, but the average number of trips on buses outside of London has declined by 12%. The average distance travelled by bus within London has increased 62%, and the average distance travelled by bus outside of London has increased by 2%. So the figures for 2013 are not much different. We will assume 10 seats filled per bus as the current average in the UK.

(Department for Transport, *National Travel Survey 2013, Table NTS0104* and *Table NTS0106*.)

Our plan for buses assumes we can increase seat occupancy to 25. Austria, Netherlands, Belgium and Spain already do that well, or better, so we can do it to.

If we increase seat occupancy rates per bus from 10 to 25, we bring the average emissions per bus passenger down from 101 to 40 grams of CO_2 per kilometre. This is about a third of the 121 grams per kilometre for the average car passenger.

[5] Here is how our plan for bus workers would work.

In the calculations that follow for bus and train workers, we speak of both old and new workers. The old workers are those already employed. The new workers are those hired by the National Climate Service. They are part of the one million climate jobs. We also speak of total workers, which includes both old and new workers.

So we are planning for

300,000 existing bus and train workers
300,000 new bus and train workers
600,000 total bus and train workers

Speaking in this way allows for ease of calculation. However, operating separate old and new systems would be impossible. We would have to nationalise both the buses and the railways. New NCS employees would work alongside the existing employees, with the same wages and conditions.

We currently have 180,000 bus workers. We plan to double the number of bus workers, and increase passenger occupancy from 10 to 25. This will give us five times as many passenger kilometres on buses.

There are two sources for our estimate of numbers of bus workers. One is *Department for Transport statistics*, *bus0207 jobs in transport*, based on a count of employees of the major bus corporations. This estimates that there are 124,000 local bus workers, not including coach workers.

The other is Ekosgen, *Employment in Sustainable Transport*, a report by the Campaign for Better Transport and Sustrans, 2010, p. 4. This gives an estimate of 173,800 jobs, based on earlier statistics for both local bus and coach workers. They also estimate 82,587 indirect jobs in the supply chain for buses. The Ekosgen study seems more reliable.

So we would hire another 180,000 new bus workers in the National Climate Service. That would bring the total number of direct bus workers to 360,000 workers.

We assume that with increased occupancy rates the number of passenger kilometres per worker can increase by 2.5. This assumption relies upon encouraging users with frequent services, but also many reserved bus lanes and whole roads reserved for buses at certain times, as well as tickets at half or less than current prices.

So a bus network with 2 times the workers, and 2.5 times the occupancy per worker, would carry 5 times as many pkms. Buses carried 42 billion passenger kilometres in 2012. The expanded bus service would carry 210 billion pkms. (Department for Transport, *Transport Statistics Great Britain*, *Table TSGB0101*.)

Emissions per pkm on buses would go down in proportion to the increase in seat occupancy, from about 100 grams to about 40 grams.

This would be expensive, but much of the expense would be offset by the economic advantages arising from reduced congestion. The direct cost of congestion is often estimated at around 2% of the national GDP, but this figure can be much higher in heavily congested urban areas. This represents annual costs in the magnitude of hundreds of billions of euros (€200 billion alone in the European Union).

(Source: Alan Flausch, 'Embracing Public Transport', *Outreach on Climate Change and Sustainable Development*, www.stakeholderforum.org/sf/outreach)

Most of us would save on fares, petrol and the hidden costs of goods transportation. Above all, there would be huge advantages in terms of both cutting emissions and creating jobs.

(6) People prefer good public transport to cars: see Reid Ewing, Keith Bartholomew, Steve Winkelman, Jerry Walters, and Don Chen with Barbara McCann and David Goldberg, *Growing Cooler: Evidence on Urban Development and Climate Change*, 2009.

Trains and HGVs

[7] As with buses, railway emissions can be cut by increasing the number of seats occupied on each train. Britain does less well now than most other European countries.

<u>Seats occupied in an average train</u>

Austria	88
United Kingdom	95
Belgium	96
Germany	100
Greece	102
Denmark	103
Sweden	111
Finland	126
Ireland	131
Portugal	139
Spain	142
France	183

(Source: European Environment Agency, *Indicator Fact Sheet: TERM 2002 29 EU – Occupancy Rates of Passenger Vehicles*, p. 4.)

These figures from 1999 are the latest we could find. The UK stopped collecting such data in 1998, and most of the rest of Europe a few years later. We suspect the influence of privatisation here.

Since that time the average number of rail trips has increased by 49%, and the average distance travelled by rail has increased 38% (Department for Transport, *National Travel Survey 2013, Table NTS0104 and Table NTS0106*.) But much of these increases in rail journeys reflect increases in services, rather than changes in occupancy rates.

Another DfT source says that 'Changes in [passenger journeys] broadly reflect changes in supply, measured by [rail] vehicle mileage run, which has grown by over 50% in London, but 9% outside London since 2004/05.' (*Railway Technical Web Pages*, at www.railway-technical.com, 'Railway Statistics for Britain'.)

These statistics suggest that there has been an increase in seat occupancy rates, probably by about 20%. That would suggest that UK occupancy rates are now about 114 seats per train.

Our plan is to double this occupancy rate on the new parts of the train network to 228 seats per train. This is higher than the French rate of 183 seats in 1999, but not so high as to be impossible.

[8] Increasing numbers of transport experts recognise the environmental necessity of moving people out of their cars. As Peter Lawrence, chair of Railfuture has said, 'At a time of concerns on global warming, the requirement to reduce the use of fossil fuels and ever increasing road congestion, modal shift is becoming increasingly essential.' (Quoted in ‘Put Beeching in Reverse’, *Railwatch*, September 2001.)

[9] In some instances restoring the lines axed by Lord Beeching would be an expensive or impractical option. Many of the tracks were built-over immediately after they were closed, by a Conservative government determined to make roads the future. But there are still long stretches that remain viable. And sections of pre-Beeching track have already been restored by local authorities, British Rail, and railway enthusiasts, especially in scenic areas where they attract tourists.

The process slowed down after privatisation, but has recently picked up again. Examples are the opening of the lines from Edinburgh to the Scottish Borders and from Airdrie to Bathgate, a line closed to regular traffic since 1956.

Similarly, the opening of the line from Oxford to Milton

Keynes represents the first stage in the resurrection of the old 'Varsity Line' from Oxford to Cambridge closed by Beeching.

A report by the director of the Transport, Research and Information Network lists ten lines in the South East alone that are obvious contenders for re-opening. (Paul Salveson, *Beeching in Reverse – The Case for a Programme of Line and Station Reopening*, Transport Research and Information Network, 2001.)

The restoration of some of the pre-Beeching network is now supported by influential organisations like the Association of Train Operating Companies, Campaign for Better Transport, and the Rail Passengers Council. However, the lines restored so far represent only a small fraction of the pre-existing track, and we can do much better than that.

Restoring a significant proportion of the old network can be achieved if it isn't pursued simply as the ad hoc resurrection of discrete stretches of track, or through Government or EU funded add-ons to the existing "Heritage Lines". Instead it needs to be a fully integrated element of a new network that meets current and future public needs. Such a network would restore the inter-city links broken by the Beeching axe, connect at strategic points with existing main lines, and ensure that every town of over 20,000 people has a direct railway service.

This would enormously increase the scope and convenience of rail travel. But such a prospect is much more likely to be realised with the re-nationalisation of the rail industry as sought by the rail unions and groups like Action for Rail.

[10] For HGV emissions see Note 1 to this chapter.

[11] For a more detailed discussion of possible changes to HGV transport in Europe, with extensive notes, see Jonathan Neale, *Transport Workers and Climate Change: Our Jobs, Our Planet*, 2011, at www.climateandcapitalism.org, pp. 27-30.

On the face of it, switching half of road freight to rail would lead to the loss of half of driving jobs over twenty years. But over twenty years we would expect half of drivers to retire, and a smaller number to leave the industry. So a ban on hiring new drivers into the industry would mean no one had to lose their jobs.

In practice, the loss of jobs would be much smaller. A change in the speed limit to 50 mph would increase the number of driving jobs, for each trip would take longer, and seriously reduce emissions. We would also have considerably more use of smaller electric trucks and vans, which again would create more driving jobs.

Moreover, there would be a large number of new driving jobs on the buses and training new bus drivers.

In short, HGV drivers would not need to worry. But they would need a restriction on new recruitment to the industry, and the back up security of a climate job if needed.

Here are our calculations of how the jobs and emissions in rail would change:

Ekosgen, *Employment in Sustainable Transport*, Campaign for Better Transport and Sustrans, 2010, p.4, estimates that there are 83,700 direct workers in rail and 90,000 workers in the supply chain, for a total of 173,700 direct and indirect workers in rail.

This estimate shows more workers in the supply chain than direct workers. This is almost certainly because the construction of rolling stock and track has been classed as indirect work. By contrast, in a National Climate Service we would expect most of that work to be done in house. The figure of 173,000 may also have increased slightly since 2010. So we would estimate 120,000 direct rail workers now, and 60,000 indirect workers, for a total of 180,000.

Now we have to calculate the split between workers in rail freight and in passenger services. There are no direct counts, so we have to extrapolate from the cost of the freight service. In 2012-13 the funding of the railways was as follows:

Railway funding

Ticket sales	£7.683 billion
Other income	£1.227 billion
TOTAL SALES	£8.960 billion
Government subsidy	£4.016 billion
TOTAL income	£12.976 billion

(Source: Office of Rail Regulation, *GB rail industry financial information 2012-13*, April 2014, p. 7.)

We assume that almost all other income is from freight. On the above figures, rail freight is then 14% of total sales. Rail freight income is also about 10% of total income.

Presumably, the percentage of freight workers among all rail workers is somewhere between 14% and 10%. We will estimate that freight workers are 12.5% (one-eighth) of all rail workers.

We have estimates the current rail workforce at about 120,000. This would mean there are roughly 15,000 freight workers.

Domestic freight transport is:

Billion ton kilometres a year

Road	151
Water	43
Rail	21

(Source: *Department for Transport statistics 2013, Table TSGB 0403*. The figure for road is for 2010, and the figures for water and rail for 2011.)

We plan to move half of road freight onto rail. That means moving 75 bn tonne kms from road to rail. There would then be 96 bn tonne kms on rail in total.

There are now about 15,000 workers in rail freight. After the switch there would be about 70,000 freight workers in rail: 55,000 new workers and 15,000 existing workers.

At this point we need to repeat what we said at the beginning of Note 5: In the calculations that follow for bus and train workers, we speak of both old and new workers. The old workers are those already employed. The new workers are those hired by the National Climate Service as part of the one million climate jobs. We also speak of total workers, including both old and new workers. So we are planning for:

300,000 existing bus and train workers
300,000 new bus and train workers
600,000 total bus and train workers

Speaking in this way allows for ease of calculation. However, operating separate old and new systems would be impossible. We would have to nationalise both the buses and the railways. New NCS employees would work alongside the existing employees, with the same wages and conditions.

We plan to double the length of the rail network.

The current rail network is just under 16,000 track kilometres. Track kilometres are different from route kilometres. A route with tracks going in two ways may be 100 Km long, but it has 200 track kms.

We plan to build 16,000 new track kilometres - 8,000 in rail, and 8,000 in light rail.

8,000 track kms of rail is about 7 times the length of the planned HS2 high speed rail. (HS2 will be 351 miles long, or 1123 track kms, not including the spur to Heathrow.)

8,000 track kms of new rail is 2,500 miles of double track. For comparison, the motorway network now is just over 2,100 miles.

This new network would not be much cheaper to build than current plans for HS2 and underground extensions. It would also be built quite differently.

Plans for rail expansion now are limited by several constraints. First, the government and corporations do not plan serious reductions in car transport. That means that in urban areas they have to think in terms of underground construction and tunnels. But tunnels are enormously expensive to build.

Governments and corporations also think in terms of a private railway system that has to compete with air travel and car travel. This means they emphasize high speed rail because it will be more attractive. One suspects they also favour high speed rail because they are ashamed when they see the high speed systems in France, Spain, or Japan.

Governments also think of high speed rail in terms of new build. As with HS2, this arouses a lot of opposition from people who will lose their homes, or see their quality of life and property values fall.

High speed rail uses more energy per km, however. That means more emissions at the moment, or more electricity needed in a future low carbon economy. Moreover, the building constraints are tighter for high speed rail. The curves, in particular, have to be gentler, and the road bed more reliable. This means high speed rail beds are somewhat more expensive to build, though there is controversy about how much. But it also restricts the routes high speed rail can take.

There is also some question whether it makes sense to build a fully high speed rail network in the UK. A really high speed network could make commuting to work possible from quite distant cities, and this would increase energy use.

However, we can construct a new rail system in a new way, by building on road ways and rights of way that are already there.

For inter-city travel, this means we can use the road beds from old, discontinued lines. But it also means we can convert roads to rail lines. This would work particularly well with motorways. In places one side of the motorway could be converted to two train lines, and the other side reserved for trucks and buses. This would make construction far cheaper, and less disruptive.

In urban areas, we would not have to tunnel. Instead we could build light rail systems right on the existing roads and rights of way. 'Light rail' is mostly what used to called 'trams'. The cars run on rails built into the road. Electric lines run overhead. The advantage to this light rail is that the trains can be much longer than buses, and so use much less energy per passenger.

There are platforms at regular intervals, where people can wait for the train. This means they do not have to waste time paying for or punching a ticket, and can easily enter a long train from a long platform. It also means people feel safer, and can shelter from rain. The platforms are generally a more distant from each other than bus stops, but much closer than train stations.

Such a light rail system can run along a crowded street with much other traffic. Trams have long been used in this way, and it is common in Europe. But particular streets can also be reserved for light rail.

There is also an option, rather like light rail, called 'Bus Rapid Transit' (BRT). In BRT, there are platforms and lanes reserved for buses. The buses run in effect like trains. The advantage to BRT is that it can be built immediately, at very low cost. In the long term, though, light rail is cheaper because the trains can be longer. So it might make sense in some areas to build BRT first, and then convert the lines to light rail later.

All this means that in our new network we would have few tunnels, because we would be building urban transit above ground. And intercity rail would be much cheaper to build, because much of it would be on established road beds.

Without these changes, it would be prohibitively expensive to build a whole new rail system.

So we plan to build:

8,000 track kms (2,500 route miles) of new train lines
8,000 track kms (2,500 route miles) of new light rail

The old rail network of 16,000 track kms would continue to have 120,000 workers. But that network would be more than half freight. The split would about 70,000 freight workers and 50,000 passenger workers. (The split is notional, because of course many staff would be serving both services.)

Those freight workers would make it possible to move half of road freight to rail.

At the moment, on the present network, 105,000 workers produce 70 billion passenger kilometres (*Department for Transport statistics, TSGB0101, Passenger transport by mode*).

If this number was reduced to 50,000 passenger workers, and the proportions remain the same, they would produce 50/105 times 70 = 33 bn pkms. However, we will assume a 20% increase in pkms from increased seat occupancy, a more integrated transport system, lower fares, and the abolition of first class. This would bring the traffic on the old network to 40 bn pkms.

For the new inter-city and high speed rail, we calculate as follows. There are 8,000 new track kilometres. On the old network of 16,000 kms, about an eighth of the traffic was freight, and the total passenger kms were 70 billion. On the new network we assume that longer and higher trains, an integrated transport network, and cheaper fares will produce doubled seat occupancy. So the number of pkms would be 8,000/14,000 times 2 times 70 bn = 80 bn pkms.

We also plan another 8,000 km of light rail. Here we assume that light rail trains of several cars will manage the same occupancy rate as ordinary trains now. So the passenger kms would be 8,000/14.000 times 70 bn = 80 bn. That gives us:

<u>Passenger kilometres per year</u>

40 bn	old network
80 bn	new intercity and high speed
40 bn	new light rail
160	TOTAL

We assume that 120,000 new jobs will be required each year to run the new system, on top of the 120,000 for the current system. But how many jobs will be required to build the new system?

We do have one reasonable estimate for the number of jobs needed to build HS2:

Jobs Needed for HS2, Phases 1 and 2

Planning and design	72,000
Construction	204,000
TOTAL	276,000

(Source: Leo Eyles, *HS2 – Job Analysis*, Albion Economics, June 2013, pp. 4-5 and 11-12.)

Phases 1 and 2, including a 30 mile spur to Heathrow, will be 381 route miles long, or 1,219 track kilometres. That is 226 workers per track km. This number includes the workers building electric lines and stations.

It does not include the workers who will maintain and operate the line, and it does not include the workers making rolling stock. We have included them in the figures for day to day operation of the railway, and this is one of the reasons we have increased our estimate of the number of current direct railway workers from 90,000 to 120,000.

HS2, however, is likely to be a much more difficult job than the lines we are proposing, which will often be based on existing road beds. There will also be economies of scale and experience in building such a large system. So we estimate 150 workers per track kilometre. For 8,000 track kilometres, that is 1.2 million job years over 20 years. That is also 60,000 workers in an average year.

If you look at the very large costs of rail construction in the UK and the US, this seems like a very small number of jobs. Remember, however, that those figures are inflated by inefficiency, corruption, privatisation, profit taking, and cumulative interest on very long term loans. They also include the cost of rolling stock, and a great deal of tunnelling and new cutting.

Estimates for France, Spain and China are much lower, sometimes 80 or 90% lower. (Gerald Olivier, Jitendra Sondhi and Nanyan Zhou, *High-Speed Railways in China: A Look at Construction Costs*, China Transport Topics No. 9, World Bank, July 2014, p. 7.)

Light rail will require many fewer workers. We have found no estimates for the number, but there are cost estimates for light rail. Estimates for Europe and the UK suggest a cost of about £12 million per route km, or £6 million per track km. It is possible to build light rail for much less, as has been done in Portland in the US and Besancon in France. But in both cases the savings require much shorter trains, which defeats the purpose. (Paul Griffiths, *Briefing Paper: Costs of Light Rail Schemes*, UK Tram, 2012, pp. 23-25.)

UK GDP is about £1.7 trillion, and the workforce is about 26 million full time equivalents. We will assume that the total costs are proportional to the number of workers. This is a rough approximation, but the best we have for our purposes here. Then one worker would be equal to £65,000 of cost. We will also assume 5 indirect workers for every 10 direct workers.

A cost of £12 billion per track km would then mean roughly 90 workers, 60 direct and 30 indirect. However, with a very large programme of building light rail, there are likely to be economies of scale. And these estimates of cost probably include rolling stock. So we will assume 50 direct workers per track km.

For 8,000 track kms of light rail, that would be 3200,000 job years over 20 years. That is an average of 16,000 jobs a year. There will also be jobs building new depots and facilities for rail freight. We assume these will require 4,000 jobs in an average year.

Total number of jobs each year building new rail network

60,000	inter-urban
16,000	light rail
4,000	new freight facilities
80,000	TOTAL

That is 1.6 million jobs years over 20 years. We have planned for 2.4 million job years for railway workers over 20 years. That suggests that about two thirds of the work would be done in building railways, and a third in running them. But at the start almost all the work would be in building new railways, and in the end almost all of it would be in running the new railways.

Of course, at the moment it is widely repeated that it takes a very long time to build a new railway system. And indeed it does, when governments are limiting expenditure and construction companies are powerful enough to demand a long run of work. But China has just built 10,000 route kilometres, or 20,000 track kilometres, of high speed rail in seven years from start to finish. That is2.5 times the amount of inter-urban rail we want to build (Livier, Sondhi and Zhou, 2014, p. 8).

These calculations give us:

Billion passenger kilometres in public transport

160	trains and light rail
210	buses (Note 5)
370	TOTAL

This would give us, from Note 2:

Billion passenger kilometres each year

385	cars, taxis and vans
210	buses
160	trains
15	walking
5	motorcycles
5	bicycles

Shared Taxis

[12] ONS, *All in Employment by Status, Occupation and Sex”, Quarter 2: April-June 2012.*

[13] To calculate the pkms for shared taxis, people carriers and minibuses, we assume an average of 4 passengers, 25 hours driving a week, 50 km an hour, and 44 weeks a year for 214,000 drivers. That is a total of 47.08 bn pkms.

We assume that this is roughly three times the current pkms for taxis – separate statistics for taxis are unavailable. So historic taxi pkms were 16 bn, and future will be 47 bn. This changes the split in Note 11 to:

<u>Billion passenger kilometres per year</u>

338	cars and vans
210	buses
160	trains
47	shared taxis
15	walking
5	motorcycles
5	bicycles

How much will the emissions be for shared taxis? A black cab has emissions of 219 grams per km (see Note 3 above). We will assume 300 grams, to make allowances for some shared cab drivers upgrading to minivans or people carriers. Then emissions will be 75 grams per passenger. For 47 bn pkms, that is 0.075 times 47 bn = roughly 3 Mt of CO_2 a year.

[14] <u>Billion vehicle miles</u>

Rural roads	129	43%
Rural roads	112	36%
Motorways	64	21%
TOTAL	305	100%

(Source: Department for Transport, *Annual Road Traffic Estimates: Great Britain 2013*, 5 June 2014, p. 2.)

Cycling and Walking

[15] For much more detail on cycling, see David Moxon's essay *The Case for Cycling* , which will be included in the next edition of this Online Companion.

[16] Cycling and walking now account for 20 bn passenger kms. With encouragement for cycling, more public transport, and more cycling lanes, we assume a tripling to 60 bn passenger kilometres.

That will change our table from Note 13 above to:

<u>Billion passenger kilometres a year</u>

298	cars and vans
210	buses
160	trains
47	shared taxis
60	walking and cycling
5	motorcycles

This will create a considerable number of jobs outside the National Climate Service. For example, Oxford has a population of about 150,000 with students. It has seven bike shops, three online retailers, four mobile repairers, bicycle hire, and a manufacturer and distributor of accessories. We would estimate that the total employment would be over 50 but under 100. If every 150,000 people can keep 50 people in work then a population of 60 million would need 20,000 workers.

Comparable figures are provided by the city of Copenhagen. This has a population close to two million and estimates that the number of jobs associated with cycling in the city is 650. According to Vivavelo, the congress of the German cycling industry, there are 278,000 full-time jobs in related industries in Germany, including retail, tourism and infrastructure. Bike sharing schemes have also become a source of employment in many countries, with typically 200 jobs being created in large cities. (World Health Organization Regional Office for Europe, *Unlocking New Opportunities: Jobs in Green and Healthy Transport*, Copenhagen 2014, pp. 7, 11 and 20.)

[17] Over 100 million electric bikes were sold in China in the ten years before 2002, and emissions were about a tenth of those for electric cars. (See Daniel Cusick and Climate Wire, 'Can E-Bikes Displace Cars?' www.scientificamerican.com, Feb. 22, 2012.)

Electrification

[18] For detailed work on using vehicle batteries to store electricity, see John Cowsill, *In What Ways Can Electric Vehicles Assist the UK Renewable Energy Strategy*, Masters thesis, University of London, 2009, download at http://roar.uel.ac.uk/600/; and John Cowsill, *Safe Planet*, Earth Books, London, 2014, pp. 45-52.

If we electrify all cars, trains, buses and shared taxis we can cut transport emissions dramatically. This is how it would work:

We will start with electric cars. We know from Note 16 above, that we will still have 246 bn passenger kilometres for cars and passenger vans. How much electricity will we need to replace all of that?

The official UK government figures for companies to use in calculating their emissions from cars can be found at the Defra, *Carbon Smart*, *Greenhouse Gas Conversion Factors Repository*, at www.ukconversionfactorscarbonsmart.co.uk, table for *Passenger Vehicles*.

This table gives 193 grams of CO_2 as the average emissions per kilometre from a car, with a low of 159 grams from an average small car and 289 from an average large car.

The US Department of Energy, at www.fueleconomy.gov, has figures for the electricity consumption of many makes of electric car. They list 21 makes of electric cars that have emissions of 27 to 32 KWh per 100 miles, which is 17 to 20 KWh per 100 kilometres.

Carbon Smart gives a figure of 494 grams per KWh for the CO_2 equivalent emissions in the UK in 2014. We will round to 500 grams per Kwh. So an electric car that uses 20 KWh per 100 km is creating emissions of 100 grams of C02 per kilometre.

This is a figure per car. But there are 1.6 passengers per car on average in the UK. So the emissions per passenger kilometre are 62.5 grams. And the amount of electricity used per passenger is 12 KWh per 100 km, or 0.12 KWh per km.

The total emissions for cars will be 298 bn passenger kms. At 12 Kwh per 100 pkms, that is 36 Terawatt hours.

We assume from Note 13 above that passengers in shared taxis create about 75 grams in emissions per km, which is 20% more than the 62.5 grams for car passengers. That would equate to 15 TWh per 100 pkms.

For 47 bn passenger kilometres in shared taxis, that would be 7 Terawatt hours.

The current rail system is 30% electric and 70% diesel. The diesel trains have emissions of 2.1 Mt a year (*Department for Transport statistics: Energy and Environment, Tables TSGB0302* and *TSGB0306*). The rail system uses just over 4TWh of electricity a year. (*Digest of United Kingdom Energy Statistics 2012*, p. 132.)

We assume that a network that is double the size will use twice as much energy. If the system was all electric, that would be 200/30 times 4 TWh = 27 TWh.

Buses and coaches currently have emissions of 4.3 Mt a year (*Department for Transport statistics: Energy and Environment, Table TSGB0306*).

We assume that doubling the size of the bus and coach system will double the emissions. That would give us 8.6 Mt a year. At 0.5 kilos of CO_2 per KWh, that is the equivalent of 17 Terawatt hours. However, we assume that as with cars, electric buses will require at least a third less energy. That gives us a total of 12 TWh a year for electric buses.

Current emissions from delivery vans are 10 Mt of CO_2 (see Note 1 above). Our plans would involve a considerable increase in vans, with extensive use of vans as final delivery vehicles for rail freight, and some replacement of HGVs with vans. Let's assume a tripling of van use, which would be 30 Mt if run on diesel. At 0.5 kilos of CO_2 per KWh, would be the equivalent of 60 Terawatt hours.

However, we assume that as with cars, electric buses will require at least a third less energy. That gives us a total of 40 TWh.

If we add these figures together, we get:

<u>Annual electricity use in Terawatt hours</u>

Car, vans and motorcycles	72
Delivery vans	40
Shared taxis	14
Buses	12
Trains	27
TOTAL	165

For comparison, current electricity production is 360 TWh, and we are proposing a total production of 720 TWh after 20 years.

So we can eliminate all emissions from cars, taxis, vans, buses and trains.

All of these calculations assume, of course, that there will be no increase in demand for transport over 20 years. This is a ludicrous assumption. But let us return to the general principle we stated at the beginning of this *Online Companion*. In all our calculations, we assume that technological advance will balance economic growth.

Of course, such a perfect balance will not happen in practice. In this case, most of the transport we have been talking about is passenger transport. We can expect considerable progress in electric vehicles. On the other hand, if transport is cheaper and quicker, people will be tempted to use more of it.

There are limits to this temptation – about half of journey miles carry people to work and school. But a particular problem might be that with better transport people would choose to live further out from city centres. The long term solution to this would be planning and building controls that encourage people to live densely in cities, something that we will need anyway.

Aviation

[19] We calculated in Note 2 that total aviation emissions are 38 Mt of CO_2 a year, and that they have roughly the same impact as 57 Mt of emissions at ground level.

In the text of our booklet we suggest that the number of flights be cut so as to reduce emissions by about a third. How would this affect job security?

Short haul flights use less fuel than long haul flights. But they use more fuel per kilometre, because so much of fuel use is in take-off and landing. So this would require a cut of a bit less than half in the total number of flights. That would lead to a cut of a bit less than half of ground staff, and a bit less than a third of airborne staff.

A reduction in air speeds would also reduce emissions and increase the number of air borne staff needed. So cuts in airborne staff would be about 20% over 20 years. Cuts in ground staff would be closer to 40%.

In the text of our booklet we have written that the overall reduction in workers in aviation would be 25,000 jobs out of 100,000 over 20 years. After checking our calculations, we think the figure would be closer to 32,000 jobs over 20 years.

This could still allow jobs security for everyone working in the industry. 1,600 jobs would be lost each year. But 2,500 workers would retire each year. And additional workers leave the industry for other reasons.

However, we need to repeat what we say in the booklet. The process of job losses will not be smooth. Aviation workers will need limits set to new hiring, and a government run register that requires employers to hire people with experience in the industry first. And they will need the background security of a promised job in the National Climate Service if they need one.

We plan for cuts in emissions of one third by reducing short haul flights. We estimate we can cut the remaining emissions by half again through design changes, changes in flight paths, and slower speeds.

That is a total cut of two-thirds in emissions, from 57 Mt of CO_2 to 19 Mt.

However, there is currently a steady increase in plane journeys. It will be necessary to limit flights to a certain number. Luckily, the mechanism to do this is already in place. Airports have 'slots', and control what flights fly when. There would then also need to be some way to allocate flights fairly, or the price of flights would rise to a level where it was impossible for most people to fly.

Several things would help in limiting flights. An obvious one is teleconferencing. Slightly longer holidays would allow people to take the train. Clustered business trips could allow people to visit several people in one trip. The abolition of first class and business class would save space.

High speed trains are also an obvious way to persuade people away from planes. Long distance high speed trains, in particular, can develop a romance of their own. But the trains need not be very fast. Any increase in speed above 125 mph, or 2000 kph, requires increasing speed to move the air at the front of the train out of the way, and the resistance increases with the square of the speed. (See Note 21 on shipping as well.)

For further useful discussions of emissions in aviation, see the work of Alice Bows and colleagues in Alice Bows, Sarah Mander, Richard Starkey, Mercedes Bleda and Kevin Anderson, *Living within a Carbon Budget*, Tyndall Centre, Manchester, 2006; Alice Bows with Kevin Anderson and Paul Upham, *Aviation and Climate Change: Lessons for European Policy*, Routledge, London, 2008; Alice Bows and Paul Upham, 'Aviation in a Low Carbon EU', in G Stefan Gossling and Paul Upham, eds., *Climate Change and Aviation*, Earthscan, 2009.

J Penner, D Lister, D Griggs, D Dokken and M McFarland, *Aviation and the Global Atmosphere*, Cambridge, Cambridge University Press, 1999, is the now classic work for the IPCC on the environmental impact of aviation emissions. But see also Christine Jardine, *Calculating the Environmental Impact of Aviation Emissions*, University of Oxford Environmental Change Institute, 2005; and LD Danny Harvey, *Energy and the New Reality, 1: Energy Efficiency and the Demand for Energy Services*, pp. 314-319.

In Intergovernmental Panel on Climate Change, *Climate Change 2013, Mitigation of Climate Change*, Chapter 8 on Transport provides a survey of the current literature.

An interesting perspective from the trade union point of view is Caroline Molloy and Roger Sealey, *PCS Aviation Review: Protecting Jobs, Protecting the Planet*, Public and Commercial Services union, 2012.

[20] *Zero Carbon Britain 2030*, (2010 edition), p. 130.

Shipping

[21] For the importance of slow speeds, and for other ways to reduce fuel use, see Jonathan Neale, *Transport Workers and Climate Change: Our Jobs, Our Planet*, pp. 34-38; Phillipe Crist, *Greenhouse Gas Emissions Reduction Potential from International Shipping*, Joint Transport Research Centre, OECD and International Transport Forum, Discussion Paper No. 2009-11 2009; Øyvind Buhaug et al, *Prevention of Air Pollution from Ships: Second IMO GGH Study*, International Maritime Organisation, 2009; and Kevin Anderson and Alice Bows, 'Executing a Scharnow turn: reconciling shipping emissions with international commitments on climate change', *Carbon Management*, 2012 December; 615-628.

The basic point is that bulk carriers, like grain ships and oil tankers, move slowly and use little fuel. Container ships move far more quickly. The main job the fuel does is to create energy to part the water at the bow of the ship. The resistance increases with the square of the speed. This means that the amount of fuel uses increases very nearly with the square of the speed of the ship or boat.

Slower speeds, design changes, and changes in loading and running practices can in theory reduce emissions by much more than 50%. In the long run, it even looks like modified forms of sails will make a comeback.

However, shipping is a sector where we can see a strong argument for increased journeys. It is far and away the most efficient way to move freight. And there should be a future for romantic and exciting intercontinental travel. At the moment, shipping is limited to cruises and other forms of luxury travel, which are dependent because they depend on space and large numbers of service staff. Slow hips with bunks, where young people did their own cooking and cleaning, would allow people to cross oceans with minimal emissions, and would become legends.

Summary

[22] Our final calculations for transport jobs and emissions are as follows. From Note 16, we assume a modal split for land passenger transport as follows:

<u>Billion passenger kilometres a year</u>

298	cars and vans
210	buses
160	trains
47	shared taxis
60	walking and cycling
5	motorcycles

Emissions from cars, taxis, vans, buses, rail, and other are reduced by a shift to public transport, and then reduced to nothing by electrification (Note 18). Emissions from aviation are reduced by two thirds (Note 19). Emissions from HGVs are reduced by three quarters (Note 11). Emissions from shipping are cut by half (Note 21).

So the changes in annual emissions will be:

Annual emissions of CO_2 in Mt	Before	After
Car, taxi and van passengers	70	0
Aviation	57	19
HGVs	23	6
Shipping	12	6
Delivery vans	10	0
Buses and trains	6	0
Other	4	0
TOTAL	178	31

That is a cut in transport CO_2 emissions of 83%.

The new jobs in the National Climate Service will be:

180,000 new jobs on buses
120,000 new jobs on building and running railways
10,000 new jobs building cycle lanes

TOTAL: 310,000 new transport jobs

Increased electricity demand: 165 TWh (Note 18).

Chapter Seven
Jobs in Industry

The official data on UK greenhouse emissions give the following emissions from Industry:

Business Combustion	75 Mt CO_2
Industrial Processes	10 Mt CO_2

(The data for CO_2 emissions in industry in this chapter are from Department of Energy and Climate Change (DECC), *2012 UK Greenhouse Gas Emissions, Final Figures*, 2014; DECC, *2012 Final UK Figures: Data Tables*, 2014; and DECC, *2013 UK Greenhouse Gas Emissions, Provisional Figures and 2012 UK Greenhouse Gas Emissions, Final Figures by Fuel Type and End User*, 2014.)

The official data also give us:

Total emissions from Energy Production of 178 Mt, of which Electricity Production at power plants was 145 Mt. The remainder, 33 Mt, came from the extraction, mining and refining of coal, oil and gas.

We subtract 10 Mt of Business Combustion as the estimated proportion for heating in business premises, not for industrial combustion as such.

That leaves us with:

Megatonnes of CO_2 per year

Business	65
Industrial process	10
Producing fossil fuels	33
TOTAL	108 Mt

We assume that almost all of the emissions from producing coal, oil and gas can be eliminated by eliminating use of those fuels. But nothing is ever perfect so we estimate a reduction from 33 Mt to 1 Mt.

We assume that design changes and changes in materials can reduce, but not eliminate, emissions from industrial processes. The largest source of emissions here come from the manufacture of cement. In that process limestone is heated to very high temperatures and the limestone is broken down and emits CO_2. The major possible change here is to replace limestone with other materials, such as gypsum. This is much more expensive, but it works. It should also be possible to replace cement with other materials, such as wood and bricks, in some uses. So we estimate that we could reduce industrial process emissions from 9 to 6 Mt.

But then there are 65 Mt from burning oil, coal, gas and wood to heat materials in industry. The largest emitters here are Chemicals, Food and Beverages, and Mineral Products like cement, lime and asphalt. We will continue to need many of these products. We assume that design and process changes can reduce the emissions here to 55 Mt.

We assume that we can then replace 31 Mt of that 55 Mt with renewable electricity. But electricity is not an efficient way to heat. So we assume that, as with domestic heating, the renewable electricity involved will require a multiple of 2.5. As the carbon footprint of electricity is currently 0.5 kilos per KWh, 5 KWh will be equivalent to 1.0 kilo of emissions. So 155 TWh are required each year to replace 31 Mt of emissions with renewable energy.

All of this reduces our emissions of CO_2 from industry as follows:

<u>Megatonnes of CO_2</u>

	Before	After
Business	65	24
Process	9	6
Producing fossil fuels	34	1
TOTAL	108	31

That is a cut of 71% in industrial emissions of all kinds. It requires an extra 155 Mt of renewable electricity.

Notes to Chapter Nine
Agriculture and Waste

The issues raised in this chapter are treated at length in the essay by Suzanne Jefferey that follows.

These notes deal only with the calculations we have made on cuts in emissions. For ease of understanding, we give the notes as a continuous text, rather than a series of footnotes.

This chapter deals with emissions from other gases besides carbon dioxide. Here are the figures for 2012:

<u>UK Emissions in Mt of C02 equivalent (CO2e)</u>

	Methane	Nitrous oxide	F-gases
Energy Supply	7	2	0
Transport	0	1	0
Business	0	1	13
Residential	1	0	2
Agriculture	22	30	0
Waste	20	1	0
LULUCF	0	1	0
TOTAL	50	36	15

TOTAL OF ALL GASES: 101 Mt CO2e

(Source: Department of Energy and Climate Change, *2012 UK Greenhouse Gas Emissions, Final Figures*, 4 February 2014, p. 9.)

We have rounded these numbers to the nearest Mt. In the case of f-gases, we have added emissions from industrial process (0.3) to business emissions (12.4) and then rounded to 13.

LULUCF is Land Use, Land Use Change and Forests.

All of these numbers are at best approximations. Governments keep track of how much oil, coal and gas is burned, so figures for CO_2 emissions are reasonably accurate. There is no accurate way to keep track of methane leaks, leaks from f-gases, or nitrous oxide emissions from fields. So there is an element of guess work to these numbers.

These numbers are stated as tons of carbon dioxide equivalent. Methane, nitrous oxide and f-gases are all much more powerful than carbon dioxide – one molecule of methane creates much more warming than a molecule of CO_2. So a ton of carbon dioxide equivalent (CO2e) is the amount of methane or nitrous oxide that has the same warming effect as a ton of carbon dioxide.

The Importance of Methane

Methane is made of carbon and hydrogen (CH4). When the carbon in living things decays in the air, the carbon combines with oxygen to make carbon dioxide. When the carbon in living things decays without contact with air, the carbon combines with hydrogen to make methane.

So when carbon matter breaks down in the digestive systems of animals, or people, there is no air and methane is created. Burps and farts are mostly methane.

Natural gas is also almost all methane. This methane was originally created when animal matter decayed under water or in swamps hundreds of millions of years ago.

Half of other greenhouse gas emissions are methane, and methane emissions are very important in the short term. The reason is that methane emissions do not stay in the air for long – on average, about 12 years. Carbon dioxide emissions stay in the air for 100 years or more.

So we say that one ton of methane CO2e has the same warming effect as one ton of CO_2. But the ton equivalent of methane does the warming in an eighth of the time. Over 100 years, the methane and the carbon dioxide equivalents have the same effect. But over the first 12 years, the methane has eight times the warming effect.

So in the short term, if we can cut methane emissions of 50 Mt by two thirds (33 Mt), that has the same effect in the first twelve years as a cut of 264 Mt of carbon dioxide would in the same twelve years. Over the long haul of a century, carbon dioxide emissions are much more important, because human activity creates so much more carbon dioxide emissions.

But over the short haul, quick reductions in methane emissions will give us a chance to reduce total warming while we wait for the effect of carbon dioxide reductions to kick in.

Methane in Agriculture

Almost all agricultural methane in the UK comes from the digestive systems of cattle and sheep, because they take much longer than other animals to digest their food.

Other animals create much less methane. Chickens make very little. Pigs also make little methane in digestion. But when pigs are kept in dense concentrations, their waste forms pools that give off significant emissions. This can be dealt with by giving pigs more space, which would be more expensive and kinder.

Cattle produce much more methane in the UK than sheep and goats, because the total weight of all the cattle in the country is much more than the total weight of all the sheep and goats.

It is worth noting that cattle are a source of not only beef but also milk and cheese. They are thus a key part of many vegetarian diets.

We assume that methane emissions from cattle, sheep and goats can be cut from 22 Mt of CO2e to 12 Mt over 12 years. This can be done by:

Changes in the feed given to cattle
Changes in grazing practices
Eating more chicken and pork instead of beef and mutton

These changes will cut UK emissions by 10 Mt. But they will cut total global emissions by more than that. The reason is that about half our food is imported. So changes in UK diet reduce not just agricultural emissions here, but also agricultural emissions in other countries.

(Department for Environment, Food and Rural Affairs, *Food Statistics Pocketbook 2012 (in year update)*, p. 34, says that 48% of food is imported. This figure is based on farm gate value, that is to say prices. In poorer countries, measuring in prices will understate the proportion of nutrition in the food. However, the majority of imported UK food comes from other rich countries.)

Nitrous Oxide in Agriculture

Nitrous oxide emissions from agriculture are 30 Mt of CO_2 equivalent. Fertilisers contain a great deal of nitrogen. When this nitrogen is exposed to air, rather than turned into the soil, some of it combines with oxygen to make nitrous oxide.

These emissions can be reduced. One way is care in the application of fertiliser, making sure it is not exposed to air for long, and that excessive amounts of fertiliser are not used. Another way is planting large amounts of legumes that fix nitrogen in the soil. We estimate that with such measures, we could reduce nitrous oxide emissions from agriculture from 30 Mt to 20 Mt of CO_2 equivalent.

Climate Jobs in Agriculture

We have been talking about changes in animal feed, grazing practices, and the use of fertiliser. We suggest 25,000 climate jobs to help farmers make these changes. These would be jobs in research, and in teams that could advise and work alongside farmers.

This is an area where UK research teams could possibly have a large effect on global emissions. Even quite small technical innovations to reduce emissions from agriculture could have quite large effects if adopted across the globe.

Food Miles and the Food Industry

This chapter is about 'other greenhouse gases', so we have not considered food miles here. Shipping food over long distances does not increase the emissions of methane and nitrous oxide. Instead, food miles increase the emissions of carbon dioxide from burning oil for transport, mostly in trucks.

So food miles are important, but they are important to transport emissions of CO_2. Reductions in food miles will help to cut fuel use in transport.

Similarly, the notes to this chapter have not dealt with CO_2 emissions from the food industry. These come mainly from two sources. One is the use of electricity in the food business and supermarkets, for lighting, heating and refrigeration. The other is emissions from industrial processes in the food industry that burn fuel directly in the plant. The emissions in both cases are part of the larger industrial emissions covered by the notes in the chapters on energy and on industry.

George Monbiot, *Heat*, Penguin, London, 2006, has a wonderful chapter on how emissions from supermarkets can be cut by 90%.

Waste

The word waste has two meanings here. One refers to people wasting food and materials. The other refers to the waste people produce. This note refers to waste of the second kind. For reducing waste, see the essay by Suzanne Jefferey.

There are 20 Mt of methane emissions from waste management. The main problem is landfills. The organic material in landfills decays without contact with air, and the carbon combines with hydrogen to form methane. This methane then leaks up out of the landfill into the atmosphere.

The solution to this is well established, and has already reduced landfill emissions across the world. Pipes are built into a new landfill site. The pipes gather the methane and carry it to the surface. There the methane is burnt, and becomes carbon dioxide. That burning still gives off CO_2, but because the warming effect of a methane molecule is 25 times the effect of a molecule of CO_2, the warming effect of the CO_2 after burning is only 4% of the warming effect of the leaking methane.

Dealing with leaks from established landfills is more difficult, but at least some can be burned off.

In the long term, emissions can be reduced further by producing less waste in the first place and using other methods than landfill.

There are also some emissions from the processing of human waste in sewage, and various technical ways of reducing this.

We estimate that in 20 years we could reduce methane emissions from waste from 20 Mt of CO_2 equivalent to 5 Mt of CO_2 equivalent.

F-gases

F-gases are the various fluoridated gases used in refrigeration. They are very powerful greenhouse gases, and even small leaks can have significant effects. However, there are alternative technologies, and we can simply ban all f-gases and still have refrigeration that works. So we can reduce emissions from f-gases in businesses, homes and factories to nothing by regulation alone.

For more on this, see Paula Tejón Carbajal and David Kanter, *HFCs: A growing threat to the climate*, Greenpeace International, 2009; and James Mate, Claudette Papathanaspoulos, and Sultan Latif, *Cool Technologies: Working without HFCs*, Greenpeace, 2012.

Methane Leaks

There are 7 Mt CO_2e of methane emissions and 2 Mt CO_2e of nitrous oxide emissions from 'energy supply'. This means mining, drilling, extraction and refining of oil, gas, and coal. In the UK almost all of this now comes from extraction and refining of oil and gas. Most of these emissions are in fact methane leaks. Remember, natural gas is mostly composed of methane.

We plan to reduce the use of oil, gas and coal to almost nothing. That will reduce methane leaks and other emissions to almost nothing as well.

In addition, there are 2 Mt CO_2e of nitrous oxide emissions from transport and business. These will be mostly eliminated by a switch to electricity.

In all, we estimate that emissions from these sources can be reduced from 12 Mt CO_2e to 1 Mt CO_2e.

Land Use

Now we come to emissions from land use, mainly farming, grazing and forestry. To simplify a very complex situation, cutting down forests increases the amount of CO_2 that gets into the air from the soil. Planting trees increases the amount of carbon in the soil, and also takes carbon from the air to grow the trees. Other changes in farming and crops can also affect the amount of carbon sequestered.

The amount of carbon locked into forests is also affected by the mix of trees planted, and the amount of undergrowth. The crucial thing is to avoid planting trees which grow quickly and are harvested quickly, and to allow climax forests to remain in place.

Increased forestry, devoted more to storing carbon than to producing wood, is a way not just of reducing emissions, but of actually taking carbon out of the air. In effect, forestry provides negative emissions.

We estimate, conservatively, that new forestry projects could have the equivalent effect each year to a reduction in emissions of 6 Mt CO_2e. So instead of 1 Mt CO_2e of nitrous oxide emissions from land use, we would have -5 Mt CO_2e for land use emissions.

To make it easier for readers to understand, at the beginning of the booklet and these notes we ignored net emissions from changes in land use. See the notes to Chapter 3. In fact the net change in CO_2 emissions in 2012 was -7 Mt. What we are doing here is assuming that net can be changed to -12 Mt year after year.

Jobs in Waste and Forestry

We estimate that in the National Climate Service there will be room for 20,000 new jobs in waste management and forestry. However, more jobs could make a serious difference in these areas, and in recycling.

If our estimates of the number of jobs needed in other sectors prove high in practice, or if we can have more than a million jobs, these sectors could be allocated more jobs. They could also use more jobs after 20 years, when the renovation of homes and buildings would be finished.

Summary of Emissions Cuts

We can now summarise the possible cuts in emissions over 20 years:

Estimated cuts in other greenhouse gases in Mt of CO_2e

	Before	After
Methane in agriculture	22	12
Nitrous oxide in agriculture	30	20
Waste management	21	5
Energy supply and methane leaks	12	1
F-gases	15	0
Land Use Changes	1	-5
TOTAL	101	33

A word of caution is in order here. The figures for current emissions of other greenhouse gases are very rough estimates. This means that our figures for cuts in emissions must also be very rough estimates. What we are really saying is that, with a little help from forestry, cuts in the region of two thirds of other greenhouse gas emissions are possible.

Essay on
Waste and Agriculture
by Suzanne Jeffery

Waste

Although in the booklet we provide figures for potential jobs in waste management aggregated with those in forestry and agriculture, there is huge further potential for creating climate jobs in areas specific to waste. It is also important to discuss waste because of its contribution to greenhouse gas emissions.

This happens in two ways. Firstly, there are the direct emissions, primarily of methane, caused by dumping waste in landfill.

In 2006 waste treatment, largely from landfill, released nearly 22% of the UK's methane emissions, which is 2% of all greenhouse gases (J. Beasley et al, *Advancing Resource Efficiency in Europe*, European Environmental Bureau (EEB), 2014, introduction and p. 20).

This, however, underestimates the problem. More and more of our waste is being sent to other countries to landfill there, which means it doesn't appear in the UK emissions figures.

Then there is the significant contribution to CO_2 emissions due to the energy consumed in making new products to replace those thrown away.

Across the EU 10 million tonnes of furniture waste is generated annually and around 5.8 million tonnes of textiles become "waste" each year (Beasley, et al, introduction and p. 31.). It is suggested that 2.7 tonnes of CO_2 is saved per tonne of furniture reused simply by avoiding landfill (Beasley, et al, p. 31).

A serious strategy to tackle waste should aim to reduce waste overall in the first place. For the remaining waste, reuse and recycling should be the primary methods used. Landfill should be avoided. The vast majority of material can be reused or recycled, and landfill is not necessary except in the smallest number of cases for some material which can't be recycled.

Some proposals have examined the possibility of establishing accredited reuse and repair centres which could contribute to ensuring that "waste" stays out of landfill and is prepared instead for reuse.

Studies indicate that 10 times more jobs are created per tonne of material processed when recycled and reused, rather than sent to landfill or incineration (Anna MacGillivray, *More Jobs, Less Waste*, Friends of the Earth, 2010, p. 15). It is estimated that potentially 100,000 new climate jobs could be created, with around 70% of all material recycled or reused.

(This calculation is made by using the figures produced for the number of jobs that could be created across the EU from the *Advancing Resource and Efficiency* report, cited above, p. 36. The UK population is 12% of the EU population, hence it is suggested that the UK would benefit from 12% of the potential jobs suggested in this report. In addition to this the Friends of the Earth report, *More Jobs, Less Waste* suggested an additional 70,300 new jobs with 70% recycling across municipal and commercial waste. These figures are based on what is described as the New Austerity context which presumes a waste generation matching the activity of an economy in austerity. This may be an underestimation of the potential waste being generated.)

This would include waste across the different sectors, including household waste, commercial and industrial waste, and construction and demolition waste.

The main type of jobs created would be in collection and sorting. Much of the success of recycling depends on the ability to have material separated at an early stage. Mixed recycling means that material is rarely recycled as the original material. Researchers stress the need for "closed loop" recycling which allows material to be reused, thus avoiding generating additional waste in the process of recycling.

Jobs would also be created in processing recyclable material, bailing and crushing, for example, ready for use in other sectors.

Even greater potential exists for creating jobs in remanufacture, reuse and repair. This is because of the labour intensive and often skilled nature of the work. Many of these jobs would be created locally since waste is generated locally, which would have the additional benefit of reducing emissions from travel and transportation.

While excessive waste is generated in all areas of our society, food waste in particular has become endemic. It is estimated that one third of all current food production ends up as waste (WRAP, *Household Food and Drink Waste in the UK 2012*, 2012).

Bio waste which includes food waste makes up 30-40% of all municipal solid waste in Europe. In the UK research by WRAP (The Waste and Resources Action Programme) shows that 7 million tonnes of household food and drink "waste" was generated in 2012. Most of this ends up in landfill where it makes a significant contribution to methane emissions (WRAP, *Household Food and Drink Waste in the UK 2012*, 2012).

The shocking reports of individuals being prosecuted for "bin diving" and taking perfectly edible food put in the bin by supermarkets, highlights the problems with a system that wastes tonnes of good food at the same time as many people are going without.

As in other areas of waste the aim in the first instance should be to dramatically reduce the amount of food being wasted. WRAP suggest that 60% of all food waste is avoidable and a further 17% potentially avoidable. According to some research reducing food waste on the current average diet by 50% could reduce emissions by round 14% (L Blake et al, *People, Plate and Planet*, Centre for Alternative Technology, 2014, p. 30). This requires, among other things, a concerted effort at public education.

However, where waste is unavoidable, climate jobs could be created by increasing the extent to which we separate the collection and processing of bio waste. Some commentators suggest that food waste could be used again to feed animals such as pigs and chickens, rather than feeding these animals the crops that could go to human consumption. Food waste can also be used to produce organic fertiliser.

There is some cynicism about the importance of tackling waste and the need for recycling. To some extent this is understandable when governments respond to recycling targets by exporting waste to other countries. Some of it is deliberately generated by the media and vested interests whose profits depend on our generating waste to sustain consumption.

Because of this, public education about the need to reduce waste, and about the value of recycling and reuse, are vital. This means changing awareness about waste as part of campaigning for climate jobs. The number of jobs suggested here is based on 70% recycling and reuse across all waste streams. However this should not represent a ceiling and it should be possible to aim for zero waste in most areas.

Agriculture

Agriculture is not one of the industries from which we have calculated the precise number of climate jobs that could be created in the near future. This is because the data is not available from which we can generate precise and reliable figures.

It is important, nonetheless, that we outline the steps that need to be taken in the longer term to tackle the environmental damage caused by current agricultural methods and forms of food production and consumption. To do so, we need to adopt a global perspective rather than limit the discussion to Britain.

We also need to think of agriculture as providing a potential carbon sink as well as, at present, being a net producer of greenhouse gas emissions.

According to the IPCC, agriculture, forestry and other land use together produce 24% of global greenhouse gases (IPCC, 2014: Summary for Policymakers, in: *Climate Change 2014, Mitigation of Climate Change*, p.8). At least 17% comes from agriculture and ongoing changes to land use (Bellarby J, Foereid B, Hastings A, and Smith P, *Cool Farming: Climate impacts of agriculture and mitigation potential*, Greenpeace, 2008.)

The main greenhouse gases that they contribute are methane and nitrous oxide, although there is also a CO_2

contribution. These chiefly come from the use of fertilisers and the rearing of livestock.

37% of global anthropogenic methane comes from agriculture, largely due to livestock production (*What's feeding our food? The environmental and social impacts of the livestock sector*, Friends of the Earth, 2008). Livestock contributes very directly to greenhouse gases because ruminant animals, cows and sheep for current livestock production, produce methane gas as a result of their methods of digestion. There is also some methane produced from manure.

This has contributed to increased greenhouse gases because of the big increase in livestock production in the last 30 or so years, as the amount of meat and dairy produce has increased in the diet of most people in the developed world. Similar dietary changes are beginning to take place for some of the more affluent sections of the population in the developing world. A Friends of the Earth report comments that the 'UN's food organisation suggest that the "livestock sector" emerges as one of the top two or three most serious contributors to environmental problems both locally and nationally' (*What's feeding our food?* p. 4).

A further significant factor has been the shift away from mixed farming to intensive monoculture farming since the 1980's. As soil is a carbon sink, agriculture generally, and monoculture farming especially, erodes top soil, thus releasing carbon from the soil. Croplands have the lowest carbon stock concentration of all biomass except for deserts and semi-deserts (J. Bellarby, B. Foereid, A. Hastings, and P. Smith, *Cool Farming: Climate impacts of agriculture and mitigation potential*, Greenpeace, 2008, p. 20).

In addition, this type of intensive farming requires a much greater input of nitrogen fertiliser, pesticides and antibiotics to generate the yields necessary. These inputs, especially nitrogen fertiliser, are an important source of greenhouse gases. The use of fertilisers is said to have increased by over 800% in about 45 years (Bellarby et al, p. 17). Nitrogen fertiliser in particular is often overused, with an excess remaining on the soil. This produces nitrous oxide which is another powerful greenhouse gas.

Any serious strategy for the reduction of greenhouse gases needs to examine how we can improve the management of agricultural land. This has to ensure that fertiliser use is dramatically reduced and land is farmed in a way that minimises the erosion of the carbon content of the soil. Many people argue that there is a need to move to more sustainable forms of agriculture and that this does have the ability to meet current and future needs for food production.

Indeed some people would suggest that the current methods of farming were introduced to meet the needs of agri-business rather than providing affordable and healthy food for the population. The major supermarket chains, food manufacturing companies and fast food restaurants are key players in this area because of their huge market share, and they look to large economies of scale to maximise their profits.

Another factor today is the close connection between the hugely powerful petro-chemical industry and the manufacture of ammonia, the basic ingredient of nitrogen-based fertilisers. A side-effect of fracking in the US has been a reduction in the cost of gases used in ammonia production and therefore of the grain fed to cattle reared to produce dairy products and meat.

Meat production in particular is extremely inefficient in providing food for humans, compared with other sources. Livestock uses 70% of all agricultural land (*What's feeding our food?* p. 6). This is partly as a result of land for grazing but increasingly modern livestock production has turned to growing crops to feed animals.

The Greenpeace report into global farming notes that 'since 1945 more land was converted to cropland than in the previous two centuries combined' (Bellarby et al, p .23). Today, one third of the world’s cereal is fed to animals. These are crops which could be used to feed people. Grain feeding of animals produces much less food than it consumes. Six kilos of plant protein produces one kilo of meat protein (Philip Lymbery and Isobel Oakeshott, *Farmageddon: The true cost of cheap meat*, Bloomsbury, London, 2014, p. 336).

The argument to reduce meat consumption is no doubt contentious. Many people inside and outside the trade union movement associate increased meat consumption with an overall improvement in diet. Previous low meat diets were a result of low income and poverty and were nutritiously poor. The aim of ensuring all people have a standard of living which allows a good and healthy diet is still very much a priority for the trade union movement and is sadly a necessity for many people in austerity Britain.

Nonetheless, it seems clear that the ever-increasing volume of meat consumption is neither nutritionally necessary nor a requirement for a good and healthy diet. Overconsumption of meat is linked to many of the main causes of death in the developing world, including heart disease and cancer.

The priority should be to ensure the production of food which is sustainable, healthy and affordable for millions of ordinary people. It is invariably the poorest who suffer most from methods of farming and food processing which prioritise the maximisation of profit over other vital concerns.

It’s not easily possible to identify the number of jobs that could be created with a more sustainable approach to agriculture. It is possible to suggest though, that bringing about the necessary changes would generate jobs in research, education and public information, and more secure and varied jobs in farming.

The current type of single crop intensive farming is not labour intensive. After the Second World War the UK had around half a million farmers, by the 1980s this had fallen by two thirds (Lymbery and Oakeshott, p. 313). In Argentina, which has seen a huge growth in single crop mega-farms, the authorities suggest that it takes one person to work five hundred hectares of soya (Lymbery and Oakeshott, p. 205).

Overall, if we are to achieve a situation in which agriculture can move from being one of the largest contributors to greenhouse gas emissions to a sector that is a net carbon sink, absorbing rather than emitting carbon, it will require the kind of changes discussed above.

It will require changes to farming practices, so that fertiliser use is dramatically reduced, changes to cropland and grazing land management, so that less land is left bare and cultivated soils are restored to organic soil alongside the restoration of degraded land. And because livestock production is both inefficient and contributes significantly to ill-health and greenhouse gas emissions there should be a concerted effort to reduce meat consumption.

Notes to Chapter Ten
Total Jobs and Emissions Cuts

From our calculations in previous chapters, we estimate the following totals:

Average number of jobs each year

Renewable energy	400,000
Transport	310,000
Building conversions	185,000
Research and training	35,000
Industrial support and advice	25,000
Agricultural research and advice	25,000
Waste and forestry	20,000
TOTAL	1,000,000

Electricity Production in Terawatt Hours

Now	360
In 20 years	720

Of which
180 TWh will be for current uses
225 TWh will be for increased demand in heating buildings
165 TWh will be for increased demand in transport
155 TWh will be for increased demand in industry

For a total of 725 Terawatt hours, which is close enough.

Reductions in MTs of CO_2 emissions in 20 years

	Before	After
Renewable energy	145	7
Transport	178	31
Buildings	97	5
Industry	108	31
TOTAL	528	74

This is a cut in CO_2 emissions of 86% in 20 years.

Total greenhouse gas reductions, in Mt of CO2e

	Before	After	Cut
Carbon dioxide	528	74	86%
Other greenhouse gases	101	33	67%
TOTAL	629	107	

This is a total cut of 83%.

The figure for transport emissions after 20 years, of 31 Mt, is 1 Mt more than the figure given in the published booklet. This is because at the time of going to press we had not fully allowed for the extra effect of military aviation. However, the difference is small and does not affect the final percentages.

Of course, if we achieve a million new climate jobs, the actual shape of jobs and emission cuts will look somewhat different. These are estimates given current technology.

Our calculations here are not intended to be an exact map. For an actual project, there would be an army of people making the sorts of calculations we make here. And experience will alter those plans. Some things will prove easier. Some projects will turn out to be more difficult than expected. And many people will have entirely new ideas.

Our intention here has been to demonstrate that a million new climate workers, backed by regulations and collective enthusiasm, would be able to cut greenhouse gas emissions from the UK by more than 80%.

This does not mean that a million workers or 20 years need to be the limits in practice. With another 100,000 workers, we could produce enough electricity to power all combustion in industry. Two million workers could achieve cuts of 80% in no more than 11 or 12 years, allowing an extra year or two for chaos.

Notes to Chapter Eleven
What You Can Do

Useful websites

Campaign against Climate Change, www.campaigncc.org

Campaign against Climate Change trade union group, www.climate_change_jobs.org

The South African campaign for One Million Climate Jobs is at www.climatejobs.org.za

The Green Economy Network of unions and environmentalists in Canada is at www.greeneconomynet.ca

For updates on issues and studies, Climate Progress at www.thinkprogress.org/climate/issue/

Climate and Capitalism is good for left political discussion at www.climateandcapitalism.com

Philip Pearson of the TUC blogs about environment at www.touchstoneblog.org.uk

Trade Unions for Energy Democracy is an international network of unions at www.unionsforenergydemocracy.org

To find a union to join, use the TUC's online union finder at http://www.tuc.org.uk/about-tuc/union-finder

Or if none of those unions are right for your situation, you can join a Unite Community branch at http://www.unitetheunion.org/growing-our-union/communitymembership/

Real Climate is a group of climate scientists who explain the issues clearly for the non-scientist at www.realclimate.org

Kevin Anderson, a scientist at the University of Manchester, blogs regularly at kevinadnerson.info

David Elliot, an energy specialist at the Open University, blogs regularly at http://delliott6.blogspot.co.uk/

DESMOG UK covers climate deniers at www.desmog.uk

Notes to Case Study One
Floods – the sharp end of climate change

[1] Committee on Climate Change, *Managing climate risks to well-being and the economy,* ASC Progress report, 2014.

[2] Department of Communities and Local Government, *Operational Statistics Bulletin, 25 November 2013*, Appendix 19; Chartered Institute of Public Finance and Accountancy, *Fire and Rescue Service Statistics 2008*, 2013, at www.cipfastats.net.

[3] Defra, *UK Climate Change Risk Assessment* (CCRA), 25 January 2012.

[4] Department of Communities and Local Government, *UK floods 2014: government response and recovery*, 11 April 2014.

[5] Dan Stephens, 'Fire and Rescue Service response the widespread winter flooding', *Fire*, March 2014.

[6] Fire Brigades Union, Freedom of Information requests to individual fire and rescue services, January-March 2014.

[7] Defra, *The National Flood Emergency Framework for England*, 2013.

[8] The data was obtained through Freedom of Information requests to individual fire and rescue services by the Labour Research Department, January-February 2013.

[9] P. Pall et al, 'Anthropogenic greenhouse gas contribution to flood risk in England and Wales in autumn 2000', *Nature*, (2011) 470: 382-385.

[10] Cabinet Office, *Independent Government Review of summer 2007 floods*, June 2008 (the Pitt Review).

Notes to Case Study Two
Fracking and Jobs in Salford and the Fylde

[1] For the dangers of fracking, start with Elizabeth Ridlington and John Rumpler, *Fracking by the Numbers: Key Impacts of Dirty Drilling at the State and National Level*, Environment America, October 2013; J. Broderick et al, *Shale Gas: an updated assessment of environmental and climate change impacts*, a report commissioned by The Co-operative and undertaken by researchers at the Tyndall Center, University of Manchester; and the 'Reports and Evidence' section at www.frack-off.org.uk.

Naomi Klein, *This Changes Everything: Capitalism vs. the Climate*, Allen Lane, London, 2014, has good discussions of both the dangers of fracking and the political importance of the anti-fracking movement in Canada and the United States.

There is also the question of methane leaks from fracking. Fracking appears to be quite leaky – see Robert W. Howarth, Renee Santoro, and Anthony Ingraffea, 'Methane and the Greenhouse Gas Footprint of Natural Gas from Shale Formations', *Climatic Change*, 106 (2011): 679-90. This is important because methane has a much stronger warming effect than carbon dioxide, and almost all the warming effect from methane takes place in the 20 years after the methane enters the atmosphere.

[2] See Note 2 to chapter 2 for the importance of leaving most of the already discovered reserves of conventional fossil fuels in the ground.

[3] Estimates of the number of jobs in fracking is a fraught subject. Most estimates come from studies in the US, because the fracking boom is so advanced there. Studies friendly to the industry quote high numbers of jobs, and environmentalists quote low numbers. Here we also use American data, of two kinds. One set of data come from a regional study, and the other from national statistics on employment.

The most useful local study is Frank Mauro, Michael Wood, Michele Mattingly, Mark Price, Stephen Herezenberg, and Sharon Ward, *Exaggerating the Employment Effects of Shale Drilling: How and Why*, Multi-State Research Collaborative, November 2013. This is thoughtful, detailed and full of useful data and important qualifications.

The study covers the states of Maryland, New York, Ohio, Pennsylvania, Virginia and West Virginia. Geologically, these are the Marcellus and Utica gas fields. The authors add up the employment and drilling statistics for each state to reach regional totals. The key numbers are:

	Shale wells drilled	Employment
2002	1	23,353
2003	5	24,830
2004	14	25,714
2005	98	26,985
2006	370	29,419
2007	515	32,115
2008	852	37,074
2009	1,017	36,322
2010	1,864	39,545
2011	2,296	51,326
2012	1,737	59,774
TOTAL	8,749	

There are several things to say about this table:

First, only 20 wells were drilled in the years 2002 to 2004.

Second, the number of jobs really takes off in 2011 and 2012. This may reflect increasingly expensive wells. But it also reflects an accumulation of jobs extracting and transporting the gas where wells have already been drilled.

Third, at the start of this period there were already 23,000 jobs in conventional drilling and extraction. At the end of 2003, just before fracking took off, there were still only 25,000 jobs. So some of the 59,774 jobs in 2012 were still jobs in conventional extraction, because working wells last a long time.

Let us now arrange these statistics to show the number of jobs above 25,000 in each year, the number of shale wells drilled each year, and the cumulative number of shale wells.

	Wells drilled	Total wells	Jobs over 25,000
2004	14	20	714
2005	98	118	1,985
2006	370	488	4,419
2007	515	1,003	7,115
2008	852	1,855	12,074
2009	1,017	2,872	11,322
2010	1,864	4,736	14,545
2011	2,296	7,032	26,326
2012	1,737	8,769	34,774

The figures above fit roughly with 10 jobs per well drilled in the year of drilling, and one job in extraction each year for each established well.

For the period 2010-2012, there were:

5,897 wells drilled
20,537 well years of maintenance
75,645 job years

These figures also fit the pattern of ten jobs in drilling each well. They also show a maturing field, with a ratio between drilling and maintenance jobs of about three to one. As more wells are drilled, the ratio will decline.

However, these figures may underestimate the total fracking jobs in two ways. First, these are only figures for jobs in the six states. Many jobs in the supply and distribution chain will come from beyond these states.

Secondly, we have been calculating as if from 2004 onwards there continued to be 25,000 jobs each year in conventional drilling and extraction from conventional wells. In fact conventional drilling was largely replaced by fracking, and some of the older wells will have closed down.

If we assume that conventional jobs declined by one third, or 8,000 jobs, over the eight years between 2005 and

2012, then we have another 32,000 fracking job years.

That would give us the following totals for 2005-2012:

Wells drilled	8,769
Average wells drilled each year	1,100
Average wells maintained	3,400
Job years	144,568
Average jobs each year	18,000

And for the height of the boom in 2010-2012:

Wells drilled	5,897
Average wells drilled each year	1,600
Average wells maintained	6,800
Total job years	97,645
Average jobs each year	32,500

At the height of the boom that is 1,600 wells drilled in an average year and 32,500 jobs in an average year.

That suggests that at the height of a fracking boom the number of jobs would be about 20 times the number of wells drilled that year.

Mauro et al, however, calculate the number of jobs per well rather differently. They write (p. 15):

'In the region as a whole, shale-related employment grew by almost 33,000 jobs as 8,750 wells were drilled. An estimated 3.7 jobs were created for every well drilled in the region.'

This figure of 3.7 jobs per well drilled is widely quoted. However, it is quite an unusual way of calculating jobs per well. What they have done is to divide the jobs in one year by the total number of wells drilled over many years. Everyone else does the calculation we have done above – divide the total number of job years by the total number of wells drilled. This is an unfortunate mistake in what is otherwise a very important and useful study.

We can also check our estimates for jobs by looking at a different set of data – the national statistics for gas and oil drilling in the US:

<u>Number of employees by sector in June 2012, USA</u>

189,582	Oil and gas extraction
93,703	Drilling oil and gas wells
284,331	Support activities for oil and gas operations
124,807	Oil and gas pipeline construction
78,850	Oil and gas field machinery and equipment
771,273	TOTAL JOBS

(Bureau of Labor Statistics, Quarterly Census of Employment and Wages: *QCEW Data Viewer: County, MSA, State and National Data by Industry*, at www.bls.gov/cew.)

However, these include jobs in conventional oil and gas drilling, as well as in shale gas and shale oil drilling. Shale oil drilling represented a bit over half of the work.

('API: US shale and well expenditures surges in 2011', *Oil and Gas Journal*, April 30, 2013, gives a figure of slightly over half, and the proportion may have risen in 2012. This source is summarising statistics from the American Petroleum Institute.)

That suggests a figure of about 450,000 jobs in drilling shale gas wells in 2012. There were about 22,000 shale wells drilled that year. (Ridlington and Rumpler, p. 20.) That is an average of 20.5 workers per shale gas well drilled per year.

So both the regional study and the national statistics suggest about 20 workers per will drilled at the height of the boom.

Let us assume, just for a moment, that there is one well drilled each year for ten years, that drilling then falls to nil, and that a well keeps producing for 10 years.

We are also assuming that there are 10 jobs drilling each well, and one job for each well in operation. Then there are:

110 jobs the first year, growing to
20 jobs in the tenth year, but
9 jobs in the eleventh year, falling to
1 job in the nineteenth year.

In that case, over 20 years there are 200 job years, or an average of 10 jobs a year.

Of course, in practice the boom in fracking may last for fewer years, and the life of a well may be shorter or longer.

But we will take an estimate of 20 jobs a year per well for drilling and production at the height of the drilling boom, and 10 jobs in an average year over a period of 20 years. Given the uncertainties, this is only an estimate, but perhaps not too far out.

This is about three-quarters of the estimate in the published text of the booklet.

[4] Now, we estimate that the UK industry will grow to be 5% of the size of the US industry in 2012. That would be:

1,000 wells drilled a year nationally
20,000 fracking workers at the height of the boom
10,000 fracking workers a year over 20 years

By contrast, we are campaigning for a million climate jobs nationally.

Assume that Salford and the Fylde are blessed with gas, and so between them they have five times as many wells as the natural average. But also assume that Fylde will have twice as many wells as Salford, because it covers more territory.

The population in the Fylde is 325,000, and in Salford 240.000. That is a total of 565,000, about 0.9% of the UK total. If these two areas had a proportional share of 1,000 wells drilled a year, it would be 9 wells. If they have five times their share, that would be 45 wells.

If the Fylde has twice as many wells as Salford, of those 45 wells drilled each year, 30 would be drilled in the Fylde and 15 in Salford. That would be 600 jobs a year for the Fylde at the height of the boom, and 300 jobs for Salford.

However, these jobs would be for Salford, not in Salford. Most of the jobs in the American statistics are in support, machinery and pipelines, not in the actual drilling. So the number of jobs for people in Salford or the Fylde would be much lower.

These calculations give us the following tables:

Jobs at height of fracking boom

	Fracking	Climate
National	20,000	1,000,000
Fylde	600	4,500
Salford	300	4,500

Average jobs over 20 years

	Fracking	Climate
National	10,000	1,000,000
Fylde	300	4,500
Salford	150	4,500

That is 50 times as many climate jobs nationally at the height of the boom, and 100 times as many climate jobs in an average year.

These are approximate estimates. Circumstances could change in various ways. It has been suggested that there may be as many as 2,000 wells a year at the height of a UK boom. We think this is unlikely. It may well be the case that the height of the fracking boom lasts less long than we have estimated. The US totals include some jobs in manufacture of equipment and support that might be better classified as indirect jobs. It is possible that the number of wells in the Fylde would be even higher.

All of these factors could change the number of fracking jobs in our two case studies. But in every case, the number of climate jobs would be much higher, as we show in the next note.

[5] This note gives the background to our calculations of the number of climate jobs on the Fylde.

We assume that there will be 4,500 new climate jobs in an average year on the Fylde, for the reasons given in the previous note.

Renewable UK says 4,200 GW of wind are expected from the Celtic Array – http://www.renewableuk.com/en/renewable-energy/wind-energy/offshore-wind/development-rounds.cfm.

Since the booklet went to press, Centrica and Dong have scrapped their first planned group of windfarms in the Celtic Array. They said that 'challenging conditions' on the seabed made 'the project unviable with current technology' (Press release, 31 July 2014).

The *Financial Times* report on the matter said that anxiety about future levels of government support also played a part in the decision (John Murray Brown, 'Blow to UK renewables as Celtic Array is scrapped', *Financial Times*, 31 July 2014).

Darius Snieckus, writing in *RECHARGE*, reinforced this point:

'[Regional developer] Regen, based in southwest England, says the reason given by developers Centrica and Dong for their decision - "technical challenges" presented by the seabed geology - is secondary to the government's backsliding ambitions in offshore wind. "While the technical challenges of ground conditions have been cited as the reason for the demise... the root cause is arguably political," says programme manager Ian Godfrey. “There is a big mismatch between the potential UK offshore wind pipeline of 37GW and the government’s target for 10-12GW by 2020. The recently announced *Contract for Difference* budget for offshore wind appears to reduce this ambition further. These disparities do not create the stable and appetising investment climate required by the industry.”'

(Darius Snieckus, 'Politicians Blamed for Celtic Disarray', RECHARGE 1 August 2014, www.rechargenews.com.)

This suggests, though we cannot be sure, that extensive development in the Celtic Array would still make sense for a National Climate Service.

The reader is also referred to our long discussion in the notes to Chapter 4 about the ways that offshore wind would work far more economically with consistent government support.

We will assume here that 4.2 GW of capacity would be possible in the Celtic Array. In our discussion of offshore win in the notes to Chapter 4, we estimated that there would be 17,000 jobs per GW of offshore wind installed, and 1,000 jobs per GW each year in maintenance.

That would be 71,400 job years over 7 years, or an average of 7,200 jobs each year in manufacture and installation of the Celtic Array.

There would also be jobs in maintenance, rising from 600 jobs by the end of the first year to 4,200 jobs by the end of the seventh year.

We suggest that the port of Fleetwood on the Fylde would get very little of the work in manufacture, but some of the work in installation and about two-thirds of the work in maintenance once the wind farms were completed. This would be about 2,800 jobs a year.

[6 and 7] Now we will calculate the other jobs in Salford and the Fylde. If you add the population of the Fylde and Salford together, they have 0.9% of the UK population. We suggest that each place would have the same number of climate jobs, because the Fylde has about a third more people, but Salford has about a third more unemployed.

0.9% of 1,000,000 climate jobs is 9,000 jobs. Let us first look at how the jobs would be divided between different sectors if they were in the same proportion as nationally:

Jobs in average year	Fylde	Salford	Nationally
Renewable energy	1,800	1,800	40%
Transport	1,350	1,350	30%
Buildings	800	800	18%
Other	550	550	12%
TOTAL	4,500	4,500	100%

But we suggest that the actual jobs could be most sensibly allocated a bit differently, for several reasons:

Even though the Fylde has a third more people, and a much larger area, there is less scope for public transport because it is a mainly rural area. So we have suggested slightly fewer than average number of jobs in public transport jobs in the Fylde.

We have suggested that Salford would have almost the average number of jobs in public transport, because there is scope for rail freight depots, but Salford has a third fewer people needing transportation.

We have suggested a third more jobs in converting buildings in the Fylde than in Salford, because the population is bigger.

We have also suggested that the Fylde would have more than its share of renewable energy jobs, because it is so well placed as a base and depot for offshore wind. To balance, there would be fewer jobs in advising industry, training or research.

Salford, with a long industrial history and a university strong in architecture and engineering, would have just over the expected numbers of workers in renewable energy, almost all of them in manufacturing, and just under the expected numbers in advising industry, training and research.

That would give us the following numbers:

	Fylde	Salford
Renewable energy	2,400	2,000
Transport	1,000	1,250
Buildings	1,000	750
Other	100	500
TOTAL	4,500	4,500
Fracking jobs		
- at height of boom	600	300
- in average year	300	150