A framework for UK self sufficiency for food and energy from renewable resources

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Abstract

This paper examines the capability of the United Kingdom to provide for it's energy requirements. Current energy use by buildings, for transport and for human consumption is assessed and then an estimate of potential reduction is made. Along side this, the current land use in the UK is detailed and a new potential mix of uses proposed. The new proposed land use mix makes significant use of biofuels to provide energy for transport, a quantification of which is made. The country's heat and electrical load is quantified, and this is contrasted with a potential increase in renewable electricity generation from wind, wave and tide. All calculations are set within a realistic framework of social, political and economic boundaries.

Introduction

Over the last fifty years the developed world has become accustomed to a very high standard of living. We are generally warm, well fed, have a large disposable income. This has largely been driven by cheap fossil fuel, the continuous progression of technology and use of cheap labour to construct the products we buy.

However, we have it on reasonably good authority that the use of fossil fuels with the consequential release of CO_2 into the atmosphere is leading to global warming and some catastrophic climatic events that we would rather avoid (Smith, I., 1993). Secondly we are increasingly aware that we can't simply keep generating larger quantities of waste without considering what to do with it (Read, A., 2001).

There are additional areas of concern that may become more apparent in the near future. In the UK we have had the luxury of being generally self-sufficient in energy from our coalmines and north sea oil and gas. While we still have coal for a long time we are relying on cleaner gas to generate electricity and heat our buildings, and oil to fuel the transport. The oil and gas will run out in the North Sea in the next decade and forcing imports from alternative supplies in Russia and other overseas areas. The security and availability of these resources will no longer be under British control so given a problem in these places we could be cut off. Securing these resources has been a source of conflict in the past and one we could do without.

The UK could potentially be insulated against many of these issues if we achieved self-sufficiency for the fundamentals but still traded high value commodities. For fundamentals read fuel and food. These are two commodities that we need to maintain a reasonable standard of living that we take for granted and are part of our security that we also take for granted.

How easy would it be for the UK to be self-sufficient in food and fuel using renewable resources and without using coal, oil, or gas? Food has been included within the equation because its production uses energy, and the land used to grow food can be used to collect energy. Given that the amount of land is fixed, the amount and type of food we eat does effect how much energy we have to keep warm and drive and fly about. Food and petrol are both stored energy and we may be coming to make choices as to which one to feed the most.

Renewable energy defines any energy that comes from wind, waves, tides, the rain in hydro-power and the sun. The sun's energy is collected and stored in plants. The amount of energy arriving on the UK in this form is limited by the sun, wind and rain landing on the country and is fixed. The energy is also much more diffuse than a gas flame so it is more expensive to collect. There is a balance between reducing the energy consumption against the cost of collecting the energy from these renewables. I will explore how we could reduce the energy we use in the UK is and how it might affect our lifestyle, and how this consumption can be met.

For this exercise all the energy units are reduced into multiples of watt-hours, one watt for one hour. A thousand (kilo) watt hour (kWh) is the energy unit used in domestic electrical meters. A thousand billion watt hours (TWh) is a unit for consumption on a national scale. Land area is measured in hectares (ha) that is 10,000m^2. Most of the energy figures relate to the consumption over a year.

Transport, oil, land and food.

Demand for oil
Table 1 shows we are currently using about 640 TWh a year of energy from oil to make diesel and petrol for transport. This paper proposes a reduction to 35% of the current level of consumption. In crude terms this could be achieved by doubling the transport fuel efficiency and by reducing the number of journeys made. Increasing fuel efficiency is achieved mainly through technological improvement (hybrid vehicles, regenerative breaking, better combustion).

Table 1: Energy Use in the UK, 2003 (DTI 2004)

Energy Use	TWh Consumption	Current Source
Heating in buildings	772	Mostly Gas
Electrical power	337	Fossil + Nuclear
Industry	85	Oil
Transport	640	Oil

Reducing the number of journeys requires economic and social change that is more far reaching. Much of the travel undertaken today is not done so for pleasure but out of necessity, to get to work and school. This travel uses up our time as well as energy. It can be argued that this is not something that people want to do, and they would welcome another way of life that didn't involve so much travel. Technology is making this easier and some effort is being made to allow people to work at home more. However there is always a need for personal contact and this needs to be dovetailed with working arrangements. Making services local to individuals will reduce the need to use a car or other fossil fuel consuming transport to make use of them. Having a choice of services that one needs to travel a distance get to, is an energy and time wasting strategy. By creating good local schools by good governance rather than using market forces would help this.

There are other themes running through this paper that keep production local and reduce the amount goods have to travel and reduce the energy spent on it.

Industry uses an additional 85 TWh of oil which could similarly be reduced to 35%. Oil used for domestic heating and agricultural services will be replaced with electricity.

Table two shows this leaves 255 TWh of energy to meet the transport and industry needs for oil derivatives.

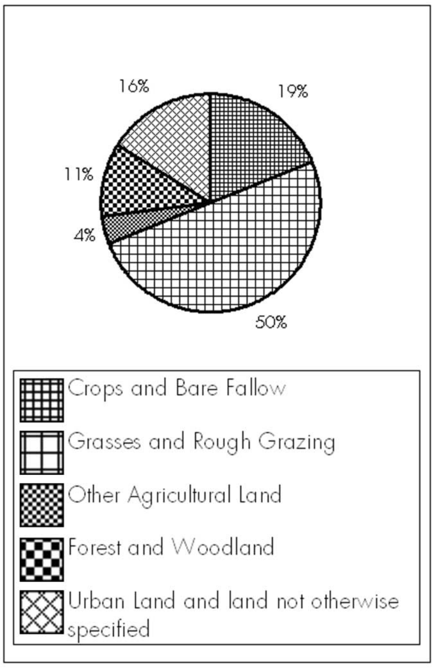
Table 2: Proposed Future Energy Consumption

	CURRENT (DTI figures)	reduction →	PROPOSED (Author's figures)
Heating in buildings	772 TWh *Gas*	50%	386 TWh *Heat Pump* ↓
Electrical power	337 TWh *Fossil; Nuclear*	85%	154 TWh 284 TWh 438 TWh Total *Renewables*
Transport +Industry	725 TWh *Oil*	35%	255 TWh *Biomass*

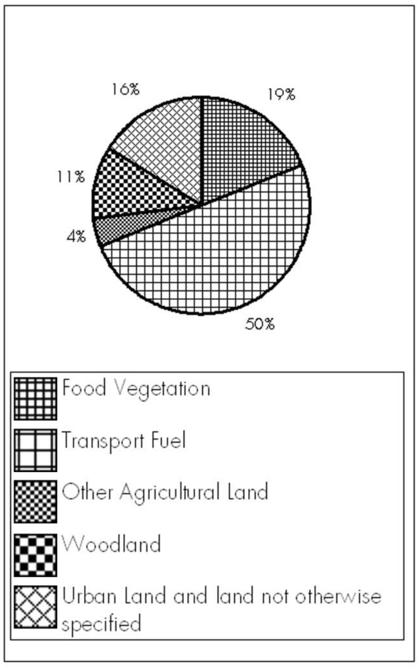
There is about 1000 kWh per m2 of sunlight energy falling on the ground in the UK in a year (Gillett 2006). You can make diesel from plants. The yield from biodiesel using rape seed oil is about 1.14 kWh/m2 (SAC, 2001; Turley *et al* 2003). Anaerobic Digestion (AD) can also be used to release the sun's energy from plants. Grass is an effective substrate for this process and grows well in Britain's temperate climate. Conventional silage production yields 20 to 40 tonnes/ha/yr (SAC, 2001). Anaerobic Digestion will yield 0.55 cubic meters of methane for every kilo of volatile organic solid (Steffen *et al* 1998). At 30 tonnes/ha/yr this can produce 3.1 KWh/m2 gross which will be reduced by 15 to 20% in parasitic production loads. AD allows the nitrates required for the high production to be recovered and returned to the ground.

Land, energy and food
The total land area of the UK is 24.5 million Ha. Currently there is about 18 million Ha of land that is used in some form of agriculture. roughly 12.7 million ha is down to grasses and rough grazing and the rest is arable. Of the remaining 7.5 million Ha, 1.2 million is urban and the rest used for recreation, forestry and natural habitats (DEFRA 2004).

Figure 1: Current land use in the UK



Proposed



With an energy yield of 2 KWh/m2 the existing grass area will meet the proposed transport demand for 253 TWh per year.
The remaining, most fertile, arable 5.3 million ha is available for food production This is just under 0.09 Ha per person. On average we each eat about 4 KWh's worth of food a day or 1500 kWh per year (Dorling and Kindersley, 2004). The total annual budget of 90 TWh for our population of 60 million. The yield of grain is 5 to 10 tonnes per ha. which is an energy content of 1.7 KWh to 3.4 KWh per m2. The energy from the straw can be used to meet the parasitic loads. A yield of 1.7KWh / m2 would provide the required food from the 5.3 million ha of arable land. The food would be largely vegetarian as growing meat takes more food and land area to produce.
The rest of the land in the UK devoted to "Countryside" could be used to feed animals for meat in a less intensive manner.

Figure 2: Proposed Land Use

Other energy demands:

Having dealt with food and transport we still need energy for heating and electricity for lighting, power etc.
Table 1 shows the current load for heating to be 772 TWh, this could be halved by bringing the building stock up to the proposed building regulations standards. The policy of raising the standards of building insulation and air tightness to reduce heating needs of buildings is being pursued currently (ODPM, 2006).
The remaining 386 TWh of heat would come from electricity used to drive heat recovery or heat pump systems that produce more heat energy for the electrical energy put in. With a ratio of 2.5 heat out to electricity in one will need 154 TWh of electrical energy.
We currently use about 337 TWh of electricity for power and lighting etc. We are suggesting that this is marginally reduced to 85% of the current usage by using more efficient appliances with better controls. The benefits of these savings will be taken up with more equipment needing power. On this basis we need 285 TWh of electricity and a further 154 TWh for the heating, making a total of 438 TWh.

Most of the renewable technologies that generate electricity rely on the sun, wind, tides and waves. These occur intermittently, and while having a range of sources available reduces the problem there is a need to store the energy when there is a surplus for when there is not. Say 40 % of the energy would need to be stored and not used directly. If half of the energy stored is lost we need to generate an additional 20%, therefore needing a total of 526 TWh.

We suggest that the electrical storage is distributed in the consumers' properties. Fridges and freezers that form a large part of the base electrical load of a household can store the coolth in freezer packs built in that allow the appliance to stay cool for a period of time. Indeed any form of heat can be stored in the building fabric. Appliances increasingly have battery storage in them for portability. In the future buildings can have there own hydrolyser/fuel cell arrangement to store electricity in hydrogen. The losses in these electrical storage systems generate heat that can then be used in the building for heating, hot water generation or cooling. This creates a distributed and robust energy network that is very resilient to failure due to any one large provider failing. The infrastructure for the electrical distribution is in currently in place. Some storage at the generator may also be needed especially in the case of wind which varies considerably.

The table below sets out what the DTI has suggested is possible from wind, tidal and hydro. A theoretical value for wave power has been added.

The DTI analysis was done in 1999 assuming 600 KW turbines for onshore and 1.5 MW ones for off shore. The sizes of commercial machines have more than doubled since then so that one would expect the potential yield to have gone up.

Table 3: Potential Sources of Renewable energy (DTI 1999)

Energy Source	TWh Value	Data Source
Wind	418	Maximum "Available " wind development in UK –(DTI 1999)
Tidal	50	Estimated tidal power available around UK – (DTI 1999)
Small scale hydro	10	Potential for small scale Hydro electricity: DTI
Large scale hydro	5	Current large scale hydro electricity: Inferred from DTI
Wave	10	Author's proposal from wave
Total non PV	493	

This leaves a shortfall of 33 TWh that can be met with photovoltaic (PV) panels. At a rate for generation of 100 kWh per m2 of panel we will need 330 million m2. This is 5.5 m2 of PV per person.

Further alternatives are available such as Anaerobic Digestion, a process by which volatile wet wastes of high degradability are broken down by bacteria in the absence of air creating methane and carbon dioxide. The methane is a clean fuel that can then be used in a variety of ways such as combined heat and power (CHP) or transport. The water, nutrients and fibre of the remaining digestate are separated allowing water to be discharged to a water course, nutrients to be sold to agriculture and fibre to be sold for soil conditioning.

The 10 million tonnes of kitchen waste every year (Milton Keynes Town Council, 2002) in the UK could produce 7 TWh, or 1% of the existing heating load. This could be supplemented by agricultural wastes.

Too try and put a scale on the economics behind the creation of infrastructure for renewable energy generation the following assumptions were made. As a rule of thumb turbines will generate the equivalent of the peak output for 30% of the time. Therefore a 1 KW machine should produce 2600 KWh in an 8760 hour year. The capital cost of onshore wind is £600 to $1000 /KW installed. (DTI 1999). The capital cost per KWh per year at this rate is £0.23 to £0.38. If one allows £0.50 per kWh to cover the cost of storage and additional network infrastructure the 500 TWh proposed in table 2 costs £250 Billion. Over 20 years this is £12.5 billion per year. Or £416 per adult per year (Dale *et al* 2003), which is comparable to current fuel bills. This also compares to the UK's current investment in energy of about £ 7.5 billion per year spend mostly in oil / gas and electricity industries (DTI 2004).

Discussion:

There are various ways of presenting the information and trying to balance the energy needs and supply. Here are some justifications for the choices made:

Transport needs high energy fuel and liquid or gas hydrocarbons from bio fuel are ideal. This is why I have split out the agriculture to service the transport sector rather than to

supply heating or electricity. I think this is an important decision as it will affect how we design buildings now. Wood can be used to heat buildings but it is bulky and requires a lot of material be handled and equipment to be maintained. This doesn't suit most buildings in urban sites. It would be better if the handling and processing was handled in local refineries in the country, and the refined fuel brought into the current petrol stations. In addition the storage required for the electrical energy be it in heat, batteries or fuel cells, is bulky and better done in a building than a car or aeroplane.
The UK was chosen as the unit for this exercise in self-sufficiency. A much smaller unit of a family or a town could work and would reduce the transport costs. However it would not be big enough to gain the benefits of an industrialised agricultural base or the range of renewables available in the UK at different times. Taking a global view would allow one a much greater diversity of energy sources and take full advantage of trade to get the cheapest source. The Little Britain argument for national security has been made above. However the other argument is more to do with the standard of governance and avoiding exporting ones problems. The weaning off fossil fuels will be an expensive process which will need a shared commitment to achieve. While fossil fuels are still available it is possible to say that one has moved to a renewable technology and sell that credit, while carrying on using black market coal. This is easier to achieve and police within our borders. Also there is a temptation to do nothing if it is believed that the problem is being dealt with elsewhere, and this is not the case.

Trade and application elsewhere:
However, trade will allow us enjoy a much higher standard of living as we can buy more food than we can grow here from countries that have more land per capita. The UK is well endowed with wind energy so it is more likely that we would want to import more produce than energy.
It is interesting to apply the self sufficiency logic to other countries. Clearly city states like Singapore and Hong Kong would not have enough land to feed itself and will rely on trade. Bangladesh has the highest population density for a country of any size (Dorling and Kindersley, 2004). The available land per person is about 0.1 Ha, which in the UK would provide enough food and little more. They don't have the luxury of surplus land for energy crops. The energy from the sun is greater so the output from PV solar cells would be greater.

Manufacturing:
We consume a great deal of Stuff like computers, cars, toys which are manufactured in economies that have cheaper labour, transported around the world, then sold, used and disposed of in landfill. The flux of this trade for new Stuff is good for economies but is not sustainable given the waste that is produced and the raw materials used. There is increasing pressure to not have any waste and all products should be capable of being reconstructed and reused in some form or another. The WEEE (Waste Electrical and Electronic Equipment) directive from the EU requires the suppliers of electrical goods to take back from a customer the products that they replace, be it a light bulb or computer, and recycle it. This is a challenge to the designers and manufacturers of products to allow this to happen, and will be another stimulus for the knowledge based economy. It will also mean that the local economies will not only be selling the Stuff (the retail trade is a major economic driver) but having to collect and potentially reprocess it. This keeps some of the value added in the local economy before the materials are shipped back to the manufacturing countries.

What would it feel like?
The aim of the new economy would be to live a more locally based life where one is much more aware of one's energy and food consumption. It should be no less comfortable. It would involve less commuting travel, and transport generally would be reduced as more commodities such as food and fuel are produced locally. Wealthier countries would continue to buy surplus energy for foreign travel and more exotic food, but they would pay the real renewable cost for this.

We would continue to buy things and indeed this would be good for the economy.

How would we get there?
Fossil fuels are like cigarettes were 50 years ago. They are widely used, are pleasurable and we are completely addicted to them. Banning smoking in public places 50 years ago would have been political suicide. However as the dangers became apparent, public opinion changed and now smokers are considered social lepers and have to huddle outside in the rain.
The same can happen with fossil fuels, but the public must be brought along with it to allow

the politicians to put the necessary controls in place. The leadership needs to be there to win the argument. It will require changes that will curb people's choices of lifestyle which won't be popular. However it will be easier make the changes while fossil fuels are cheap and available rather than being forced to make them later when they are less plentiful and expensive. In that case we would have the double whammy of the expensive development costs for renewables as well as expensive or unreliable sources of oil or gas.

There are various mechanism that can be put in place to reduce dependency on fossil fuels. One is the Domestic Carbon trading credits (Hillman and Fawcett 2004). In this system every adult gets an equal share of their carbon ration used in the UK. If they use more than the average individuals have to buy credits from others who use less. The intention is that the total amount of credits goes down per year. This stimulates the market to firstly reduce the energy we use and secondly produce renewable energy that falls outside the system.

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