THE DEVELOPMENT OF A REGIONAL ENERGY ASSESSMENT MODEL

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Summary

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Shropshire Energy Team initiated this study to examine energy consumption and associated emissions in the predominately rural county of Shropshire. Current use of energy is not sustainable in the long term and there are various approaches to dealing with the environmental problems it creates.

Energy planning by a local authority for a sustainable future requires detailed energy consumption and environmental information. This information would enable target setting and the implementation of policies designed to encourage energy efficiency improvements and exploitation of renewable energy resources. This could aid regeneration strategies by providing new employment opportunities. Associated reductions in carbon dioxide and other emissions would help to meet national and international environmental targets.

In the absence of this detailed information, the objective was to develop a methodology to assess energy consumption and emissions on a regional basis from 1990 onwards for all local planning authorities. This would enable a more accurate assessment of the relevant issues, such that plans are more appropriate and longer lasting. A first comprehensive set of data has been gathered from a wide range of sources and a strong correlation was found between population and energy consumption for a variety of regions across the UK.

In this case the methodology was applied to the county of Shropshire to give, for the first time, estimates of primary fuel consumption, electricity consumption and associated emissions in Shropshire for 1990 to 2025. The estimates provide a suitable baseline for assessing the potential contribution renewable energy could play in meeting electricity demand in the county and in reducing emissions.

The assessment indicated that in 1990 total primary fuel consumption was 63,518,018 GJ/y increasing to 119,956,465 GJ/y by 2025. This is associated with emissions of 1,129,626 t/y of carbon in 1990 rising to 1,303,282 t/y by 2025. In 1990, 22,565,713 GJ/y of the primary fuel consumption was used for generating electricity rising to 23,478,050 GJ/y in 2025. If targets to reduce primary fuel consumption are reached, then emissions of carbon would fall to 1,042,626 by 2025, if renewable energy targets were also reached then emissions of carbon would fall to 988,638 t/y by 2025.

Keywords Local Authority, energy planning, the potential for renewable energy in Shropshire, energy related emissions, regional electricity consumption.

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1. Introduction

The economic and social transformations that have taken place in the UK over the last two to three hundred years have been founded on the simultaneous development of energy systems and increasing consumption of finite material resources.

Growing populations induced revolutionary changes in agriculture and industrial techniques to cope with the escalating demand for commodities. Power driven machinery, urban growth, improved transportation; better communications and global commerce changed the culture of contemporary society. As the social system became more complex, needs increased and expectations grew, stimulating additional technical innovations, medical advances and better education. These have improved standards of living, further increasing the population and the demand for high quality energy sources.

The continued increases in energy consumption and economic growth have not been without impact. Combustion of fossil fuels and nuclear power has created environmental problems on regional, national and global scales and caused concern about sustainability for the future. International cooperation aimed at limiting these problems has resulted in many initiatives in the UK to encourage resource efficiency and diversify the energy mix to include renewable and sustainable energy supplies.

The distribution and availability of renewable energy resources varies widely with location in the UK. Local public opinion is likely to play a significant role in determining the nature and siting of any renewable energy schemes and the implementation of efficiency measures. Therefore, any assessment of which mix of renewable and sustainable energy measures are most appropriate and the contribution they can make to future energy requirements will need to be on a regional basis, taking into account local climate and topography and historical infrastructure, institutional, technical, economic, environmental, cultural and social factors.

Indeed, all these factors and population trends would be expected to influence both current and future energy consumption. To examine the importance of these factors a model has been produced that correlates with these trends. The intended use of the model is for local planning authorities to be able to predict the future outlook on energy consumption and emissions on a regional basis throughout the UK.

The information provided by the models gives a baseline for energy planning, target setting, progress monitoring and assessing the potential contribution that renewable and sustainable energy systems could play in meeting electricity demand and reducing associated emissions. A model such as the one proposed here may enable a more accurate assessment of the relevant aspects, such that plans for a better economic and environmental future are more appropriate and longer lasting.

The methodology has been applied to a particular county in the UK, that of Shropshire (including Telford and the Wrekin) and was initiated by the Shropshire Energy Team (SET), now called the Marches Energy Agency. The SET, based in Shire Hall at Shropshire County Council was set up with European funding as the first of its kind in the UK. Its role was to act as advisor to the Local Authority to improve understanding of the issues associated with energy planning, in a rural area, for sustainable development.

This work was set in the context of Shropshire's Environmental Charter, the County Council Structure Plan, the Renewable Energy Assessment and Shropshire's Regeneration Strategy. The preparation of energy policy, target setting and effective exploitation of indigenous renewable energy sources requires detailed information on energy consumption and the state of the environment.

In the absence of these statistics, the aim was to provide the fundamental theoretical foundations necessary to enable the county to meet its share of the UK's obligations in reducing greenhouse gas emissions.

UK statistics, a full set of data for the county of Shropshire, utility supply data and studies of other areas were used to develop spreadsheet models on a business as usual scenario, to give, for the first time:

- An estimate of total primary fuel consumption for Shropshire for the base year of 1990 through to 2025.
- An estimate of environmental emissions from all sources including stationary combustion, petroleum transport and electricity for 1990 to 1997.
- An estimate of primary fuel consumption for electricity generation and electricity consumed by final user 1990 to 2025.
- An estimate of environmental emissions for electricity distributed through the National Grid 1998 to 2025.
- An estimate of domestic electricity consumption by final user 1981 to 2025
- An estimate of the effect of house completions on district electricity consumption in the domestic sector.
- An estimate of the effect of industrial land development on district electricity consumption.
- An estimate of the effect of commercial land development on district electricity consumption.
- An estimate of electricity consumption by rural and urban populations.
- An estimate of primary fuel consumption per person for rural and urban populations.
- An estimate of the contribution by renewable energy sources to primary fuel consumption and consumption by final user.
- An estimate of primary fuel consumption and consumption by final user required on achieving set targets.
- An estimate of emission (all sources) before and after target setting 1990 to 2025.
- An estimate of emissions saved with full exploitation of accessible and practicable renewable energy resources.

The rest of this chapter gives an outline of the thesis.

Outline of Thesis

Chapter 2 gives an overview of Shropshire's role in the industrial revolution, the evolution of energy systems and changes in society.

Chapter 3 deals with the effects on the environment of increasing energy and resource consumption, the issues of sustainability and strategies to achieve it.

Chapter 4 looks at those technologies and policies that could contribute to a sustainable energy system.

Chapter 5 examines the factors that affect renewable energy assessment, the role of local authorities and the setting up of the Shropshire Energy Team.

Chapter 6 gives information on the county of Shropshire.

Chapter 7 deals with the issues of energy planning and estimates energy consumption and associated emissions in Shropshire.

Chapter 8 looks at the energy consumption for electricity generation and the associated emissions.

Chapter 9 looks at district and sector electricity consumption.

Chapter 10 covers the effect of target setting and renewable energy exploitation.

Chapter 11 gives conclusions

Chapter 12 gives recommendations for further work.

2. Energy Systems and Resource Use

Historical development of the infrastructure and culture of society has an impact on current and future energy consumption. The preservation of the past may eventually prove to be no longer economically or environmentally viable. There may come a point when there has to be a choice between the costs of upkeep and repair or replacement. This chapter outlines the developments, beginning in Shropshire, which have provided the means to exploit different sources of energy for heat, light, appliance and motive power. These developments have led to increases in population, standards of living, mobility and complexity of social systems.

Even before the industrial revolution, the increased use of resources and energy accompanied the demands of the continuously rising population. Forests were cleared to grow food. Animal, wind and waterpower were developed to replace manpower. The reduced supply of wood promoted the use of surface coal as a heating fuel, causing acute health and pollution problems in larger centres of population [1]. In 1700, it is estimated that there were about 5.5 million people living in England and Wales [2]. A sharp decline in the death rate among children, due to better medical care and improvements in living conditions meant that this figure rose to over 9 million by 1801.

2.1 The Revolution of Coal and Iron

England, with its temperate climate, ample rainfall, fast flowing streams, navigable rivers and abundant mineral resources, was well equipped for power-driven growth. The first Industrial Revolution began in Shropshire [3] in the mid 18th century and dramatically changed the structure of the economy and society in less than a century. The predominantly agrarian economy, dependent on the availability of renewable resources was transformed into a predominantly industrial, market driven economy with an increasing dependency on finite mineral resources.

Two innovations set the stage for the industrial revolution: the smelting of iron ore with coal (in the form of coke) in blast furnaces and the steam engine.

2.1.1 The Driving Forces

Increasing demand, and the abundance of wood, meant that from the sixteenth century the iron industry flourished. To make pig iron, a blast furnace was charged with iron ore in intimate contact with the fuel. Early attempts to use coal as the fuel failed because the impurities that it contained (such as sulphur) were absorbed by the iron making it brittle, so charcoal derived from wood was used.

By the 17th century the iron industry was rapidly consuming timber. This, together with the demands of shipbuilding, where several thousand trees were used in the construction of a large ship, was rapidly deforesting Europe. The combination of scarce and expensive timber with water shortages at ironworks through the summer months meant the iron trade gradually declined. A method of ensuring a constant supply of water was required and endeavours to use coal as the fuel in iron smelting were revived.

Mines had been sunk to ever-greater depths in search of minerals (coal, tin etc.). The shafts, which filled with groundwater, were in constant need of pumping. These pumps were powered by hand or by draft animals at the pithead, but by the end of the 17th century a more powerful and cheaper solution was necessary. There was a practical need for some kind of engine to overcome this constraint on development.

2.1.2 Principal Innovations

In 1708, a Cornish blacksmith, Thomas Newcomen invented an atmospheric steam engine to drive mine pumps. The first full size engine was installed at a colliery near Dudley in 1712; the first in Shropshire was at the Madeley Glebe coal works in 1719. Although costly and cumbersome, these engines were soon serving most of the larger collieries in Great Britain. This made possible the opening of new, deeper, mines that would otherwise have been unworkable. There were over 100 at work before 1770.

Britain's richest veins of iron ore and coal were at Ironbridge Gorge. This enabled east Shropshire to develop the largest iron industry in England in the 18th century.

The quiet and seclusion, which attracted Monks to Shropshire thus removing them from temptation and sin, also attracted one of the principle innovators of the time. Abraham Darby I chose Shropshire so as to be 'away from prying eyes'.

In 1709 he re-built a blast furnace at Coalbrookdale, which was later to use Newcomen's engine to provide blast power. Here he successfully substituted coke, made from local low sulphur pit coal (clod coal), for charcoal in the iron-smelting process. Small quantities of pig iron suitable for casting were produced. His son, Abraham Darby II, improved the process and effectively established coke smelting as the preferred technique for making iron. He produced small quantities of bar-iron from coke-smelted pig, which could be used in forges. The Coalbrookdale Company developed the production of wrought iron in a reverberatory furnace in 1766, and made the first iron locomotive rails for Shropshire in 1767. Abraham Darby III built the world's first large cast iron arch bridge across the river Severn 1779-1781.

2.1.3 Economic Development

The limited availability of timber and the problem of flooded mines no longer constrained economic progress and a complex interlocking pattern of industrial development proceeded.

The steam engine encouraged coal production by clearing flooded mines and ensuring ventilation. Coke increased blast power. Steam engines ensured a constant water supply to wheels driving furnace bellows, rejuvenating the iron industry. Iron was in turn used to make more steam engines, which necessitated the improvement of metalworking techniques. To transport these heavy engines, canals, iron bridges & aqueducts, docks, harbours and better roads were built, supervised by growing numbers of skilled engineers such as William Jessop, John Metcalfe and Thomas Telford. Canals required steam engines to wind inclined planes and fill reservoirs. Professional Engineering Institutions were established, the first being the Institution of Civil Engineers in 1818 [4], with Telford as their first President. Technical progress in all sectors of commerce became inevitable.

2.1.4 Further Progress

Frequent overseas wars and the demand for munitions led to the opening of new iron works in Shropshire. A partnership between James Watt and Matthew Boulton succeeded in modifying Newcomen's engine to improve efficiency by using steam pressure to drive the piston, rather than atmospheric pressure. This was possible because John Wilkinson accurately bored the cast iron cylinder at his Broseley works using the cannon lathe he devised in 1774. Wilkinson was the first ironmaster to use Boulton & Watts rotative steam engine at the Willey iron works. His Snedshill works was the first blast furnace independent of waterpower. Wilkinson launched the first iron ships on the Severn in 1787.

Steam power provided a source of power superior to anything which man had previously been able to control. Industry no longer needed to be near rural waterpower sites. The application of steam stimulated the concentration of industry in mills and factories where it replaced waterpower. Industrial growth created towns and cities to which the rural population, affected as it was by agricultural changes and low wages, migrated. Enclosed fields permitted continuous growing of a wider variety of crops; more animals could be kept alive in winter. Roads and canals were used to transport foodstuffs and people had a more varied diet. Many locally made agricultural implements were replaced with mass produced factory made tools. Steam powered machines were introduced for reaping, threshing and ploughing and replaced manual labour.

Steam power improved spinning and weaving machinery in the textile industries bringing cheaper and more plentiful clothing. Soap could be manufactured in greater quantities improving hygiene. Coal was used to heat clay furnaces supplying the pottery market with sound but inexpensive goods. Steam power for grinding materials enabled the manufacture of earthenware pipes for drains and water supplies. Labour was divided so that workers became specialists in one particular operation or series of operations, increasing output. Structural wrought iron replaced stone in the construction industry and more bricks were made leading to better housing conditions. Steam locomotive power, developed to carry coal, was introduced to passenger traffic, in both railways (1830), and transatlantic shipping (1833). The development of railways increased the demand for iron and coal. New towns grew, businesses expanded, new technology was developed. Travel was possible on an unprecedented scale increasing foreign trade.

2.1.5 Society

The total population of England and Wales almost doubled from 9 million to 17.9 million [5] between 1801 and 1851. Large towns grew at the expense of the countryside, concentrating around coalfield areas in the North and the Midlands. Bad conditions in these towns such as overcrowding, poor housing, air pollution from coal burning, inadequate water supplies and lack of sufficient drains gave rise to health problems. Tuberculosis, smallpox, typhus, typhoid and cholera epidemics caused the death rate to rise again in the 1820's. Issues such as poverty, crime, education, town planning, transport and local government also created problems.

School reforms, such as those introduced by Samuel Butler (Headmaster of Shrewsbury Public School 1798-1836) improved education by widening the curriculum to include the studies: history, modern languages, science and organised games. Health reforms and medical advances in anaesthetics and antiseptics effectively tackled epidemic diseases by the 1870's and even though there was a fall in the birth-rate, the population continued to increase, more than doubling itself between 1851 and 1911 to around 36 million [6].

The growth in population provided the labour force for industry and stimulated the extension of the British Empire with the migration of people overseas. The productive capacity of the nation increased, with more industrial goods manufactured than ever before. A wider variety of goods were produced for home and overseas, the variety meant an increase in the standard of living for most people.

2.1.6 Increasing Demands

The rapid rise in both industrial output and population had dramatically increased demands for both materials and energy. Coal was considered the crucial resource fuelling economic growth and called 'the black diamond' (E. A. Martin 1896).

"The nuisance which coal has proved itself in the pollution of the atmosphere and in the denuding of wide tracts of country of all vegetation is recognised.............. at the same time, we must bear in mind that it is universally acknowledged that England owes her prosperity, and her pre-eminence in commerce, in great part, to her happy possession of wide and valuable coal-fields, and the length of time during which England will continue to hold her prominent position as an industrial nation is limited by the time during which her coal will last." [7]

Coal had many uses: to boil saltpans in the purification of salt, in fractional distillation to produce gas, tar and ammoniacal liquor and to make sulphuric acid. Coal gas was used throughout the country in inefficient gaslights. Coal tar in its primitive condition was used as a coating to prevent metal corrosion. Heating of coal tar yielded light oils and crude coal-naphtha and led to the discovery of paraffin oil. Increased heating yielded heavy oils (creosotes oils) and green grease (anthracene oils). The final product of distillation was pitch, which was used in the preparation of artificial asphalt and a fuel known as briquettes. Further distillation of the separate fractions yielded additional products which were used in grease removers, perfumes, solvents, dyes, lubricants, candle making, antiseptics and ointments. Ammoniacal liquor was used in the making of smelling salts and Plaster of Paris. Sulphuric acid was the key to the growth of the chemical industry, used in the manufacture of alkalis and soaps, which were necessary in the textile industry.

2.2 Steel and Electricity

Increased competition, concerns about the length of time coal would last with the continued increases in consumption and air pollution encouraged the pursuit of cheaper materials, improved communications and more efficient engines, ships and locomotives.

Henry Bessemer (1856) recognized the superiority of steel over iron whilst making canons for the Crimean war. Steel, a blend of iron and carbon, was tougher and more serviceable than iron. He developed the converter in which coke smelted pig was made into mild steel. Charles William Siemens (1866) used gas as the source of heat in steel making, making possible the use of any type of coal and simple control of temperature. Mild steel could now be produced cheaply and in bulk, this stimulated the output of steel and its use. Steel superseded iron in construction, shipping and allowed heavier railroad equipment to be designed. The development of a technique (Gilchrist-Thomas 1878) that allowed the use of phosphoric iron ores led to the rapid exploitation of such reserves in Germany and the United States. These countries soon surpassed Britain in the production of steel, which became the world's most important commodity, used in all heavy machinery, engineering and armaments.

The discovery of electromagnetic induction and the subsequent development of the electrical generator (Faraday 1831) made electric power possible, providing a new source of energy to supplement steam power. Work by Faraday and Wheatstone (1837) led to the earliest practical applications of electricity in Britain, the telegraph and the submarine cable, followed later by the telephone. Coal-fired steam turbines were applied to marine engines (1894) and also generated the electricity used in light railway, trams and electric furnaces.

Unlike steam-powered machines, electric motors needed no mechanical connection with their source of power and were quieter and cleaner. Electric motors replaced steam engines in factories to drive machinery, underground railways were electrified leading to higher speeds, and electric lighting replaced gas lamps. The introduction of electric lighting forced the invention and introduction of effective and cheaper gas-lamps. Waterpower also found a new use in hydroelectric power stations in areas with little coal. Large amounts of cheap electricity allowed the smelting of aluminium. Aluminium and its alloys were lighter than steel and more resistant to corrosion, permitting their use in kitchen equipment and aircraft.

2.3 *Oil, Nuclear Power and Natural Gas*

Except when used as a simple radiant heat source, coal began to be seen as having many disadvantages. It was heavy, it required large storage areas, its use was dirty and labour intensive, its industrial and commercial power applications were relatively inefficient. The demand for cheaper, faster travel and the subsequent production of the internal combustion engine, diesel engine and pneumatic tyre saw the growth of another new source of energy, crude oil.

Britain had abundant coal resources but no known oil. However, oil saved space and labour, was easier to transport between countries, was cleaner and produced more steam in proportion to weight. Oil provided the raw material to replace coal in fractional distillation to make derivatives with an enormous range of uses: making plastics, artificial rubber, detergents, anaesthetics, insecticides, explosives, chewing gum, wax polishes, dyes, cosmetics, food preservatives, artificial silk, adhesives, medicines, paints and chemicals. Lighter fractions of oil replaced coal as a fuel in transportation and farm machinery, heavier fractions replaced coal in electricity generation and the domestic heating market.

Buses replaced rail travel for short-distance passengers and some long distance ones. Lorries replaced rail travel in the goods market. Mass production by a moving assembly line created a huge demand for reasonably priced automobiles, stimulating extensive highway construction and worldwide exploration for oil.

The demand for electricity increased with the development of communications based industries. Military work on the atom bomb during the Second World War led to the development of civil nuclear power. The aim was to produce cheap electricity, but fear of possible hazards retarded its progress. Provision for storing long lived radioactive wastes and decommissioning costs resulted in high costs and political sensitivity.

The West obtained the majority of its crude oil from the vast Middle Eastern reserves. This oil was relatively cheap until the oil embargoes in 1973 and 1979. The sudden large price increases led to high inflation and interest rates, soaring international debt and caused a worldwide economic recession. For the first time since the industrial revolution there was a slowing down of energy consumption. These political and economic shocks caused the developed non-oil producing countries to take a serious look at their use of energy and the depletion of natural resources.

Oil was prospected for in less politically unstable areas. Energy efficiency, reclamation, recycling and cost-effectiveness were emphasised. Research efforts concentrated on the development of new materials not derived from oil and alternative energy sources. The demand for oil decreased and oil producing countries not belonging to the Organisation of Petroleum Exporting Countries (OPEC) increased their oil production. Supply began to exceed demand and the surfeit of oil caused prices to drop. The invasion of Kuwait by Iraq in the summer of 1990 caused prices to rise again for a short time, but on the whole oil remains relatively inexpensive and demand from the transport sector means that consumption continues to be fairly steady.

Natural gas is found in many parts of the world, either in association with oil or on its own. This gas was originally considered a nuisance when discovered whilst drilling for oil and was disposed of by burning at the oil fields. However, gas could be transported easily over land by pipeline, it had a higher temperature of combustion and produced less emissions than coal or oil. It became logical to use the gas and it began to replace coal and oil in heating, drying and industrial processes. Recent uses for natural gas have included fuelling transport and generating electricity. Combined cycle gas turbines have further increased the generation efficiency of electricity and compared to coal or oil plant, are cheaper and operational earlier.

As population has increased so have demands for high quality energy sources and finite mineral resources. This increased consumption is associated with innovative technical and industrial developments and economic growth alongside improvements in transport systems, agriculture, healthcare and education that in turn have further increased population. History has provided us with the present infrastructure of society, which greatly determines energy consumption, without any great consideration of the detrimental impacts that development has on the environment.

3. Energy Systems and the Environment

As shown in chapter 2, the quantity of energy and resources demanded by society, and the quality of energy systems serving those demands has been continually evolving, with one energy source being gradually supplemented by, and/or substituted for, another.

Wood fires and manual labour replaced solar energy. Coal and coal products replaced wood. Oil and oil products replaced coal and coal products. Animal, wind, waterpower and hydraulics replaced manual labour. Coal fired steam engines and turbines replaced manual labour, animal, wind and waterpower. Electricity, oil and natural gas replaced steam power, with electricity generated by coal, hydropower, oil, civil nuclear power and natural gas.

3.1 Resource Consumption and Environmental Degradation

The development of energy systems, along with the increasing resource consumption associated with economic growth, has not been without problems. This chapter focuses on the environmental consequences of current consumption patterns.

3.1.1 Poverty and Economic Development

The World's population is estimated to increase from just fewer than 6 billion in 1998 to 10 billion by 2040. Currently, over one-third of these people, mainly in south Asia and sub-Saharan Africa [8], are without access to basic sanitation or safe drinking water, they suffer fuel poverty, lacking access to electricity [9] and modernised processing power [10]. It is estimated by the UN that 1.3 billion are living in absolute poverty. Over 5.2 million, including 4 million children under five, die yearly from waste-related diseases [11]. 800 million are chronically malnourished and a further 2 billion suffer from micronutrient deficiency [12].

It is this poverty that drives human exploitation of the environment for food and shelter. Increased consumption of material resources leads to the wealth necessary for poverty relief and social progress through economic development.

"In our modern economy the central purpose of life is shopping; the purpose of the family is to raise future workers and consumers; the purpose of schools is to teach marketable job skills; the purpose of Government is to boost business; the purpose of Third World nations is to provide cheap labour, raw materials and new markets." [13].

Gross Domestic Product (GDP) is the value of all goods and services produced domestically. The net money flow from exports and imports is added to GDP to give Gross National Product (GNP). Economic growth is conventionally defined as a real increase in GNP per capita [14], but this measure does not include environmental and social concerns. Economic growth is founded on increased consumption of energy. For developing countries every 1% growth in GDP requires a 1.5% growth in primary energy demand (PED) [15], compared to between 0.5-1% in developed countries (global average- a 1% growth in GDP supported by a 0.67% growth in PED [16]). The World Energy Council (WEC) estimates that US$20-30 trillion will be required for global energy investment for the period 1990-2020 [17].

The gap between rich and poor is widening with the world's 358 billionaires combined wealth now exceeding that of the world's poorest 2.5 billion people. The Worldwatch institute state that the typical Westerner consumes three times as much fresh water, ten times as much wood, fourteen times as much paper, ten times as much energy and nineteen times as much aluminium as someone living in a developing country. More than three quarters of the world's consumption of coal, oil, gas and uranium is used by one quarter of the world's population [18]. Even so, over 7 million people in the UK live in fuel poverty [19], with 30,000 to 40,000 [20] extra deaths during winter because of the cold.

3.1.2 Human Environmental Pressures

Real concern about the effect of human activities on the environment began in the late 1950's early 1960's when some commonly used organochlorine insecticides (*pp*-dichlorodiphenyltrichloroethane -DDT, aldrin, dieldrin and heptachlor) were unexpectedly found to affect wildlife, particularly birds [21]. Field observations and laboratory experiments were begun to determine the cause of toxicity. DDT and its metabolite DDE were shown to affect hormonal levels, breeding behaviour and egg physiology, resulting in the widespread decline of breeding success in several bird species [22]. This stimulated the study of the distribution and sub-lethal effects of many other substances released into the environment by human activities. The unforeseen persistence and ability of these substances, or their conversion products, to disturb the homeostatic mechanisms of many other organisms caused anxiety about the possible contamination of food species and the effects of pollutants on humans. Actions to limit these effects were directed mainly at local and occasionally regional pollution problems.

The environmental and social pressures related to existing patterns of development, the increased use of resources and conventional energy systems began to be taken seriously on an international level in the early 1970's. The impacts that the energy sector (exploration, mining, production, processing, transportation, storage, conversion, distribution, final use of energy, and disposal of wastes) put on the environment were a particular cause of concern (see Table 1). These impacts, which depend on the type of fuel and conversion technology used, were originally localized. They have become regional, national and global, depleting non-renewable minerals and causing damage to the atmosphere, landscape, rivers, seas and complex ecosystems.

This damage may be transient as with the visual intrusion caused by buildings and equipment at a power plant whilst on site, but more often the damage is medium to long term as with air, water and soil pollution, greenhouse gases and radioactive wastes. Large-scale energy projects such as hydroelectric dams can also cause irreversible loss of natural habitats.

Fuel	Coal	Oil	Large-Scale HEP	Nuclear	Natural Gas	All
Impacts on:-						
Natural Living	**Biotic Environment**					
Wildlife	• acid emissions damage flora and fauna • emissions can lead to declining populations, extinction's and substitution of species • thermal pollution alters ecosystems	• accidental releases of hydrocarbons and smothering damage or kill flora and fauna • declining populations • reduced reproductive success • shock-waves from seismic prospecting can kill marine life • clean-up techniques for spills often cause damage	• destruction of natural self-regulating ecosystems • produces ecosystem that needs managing to prevent sedimentation and soil erosion • levels of sediment, transport rate and light penetration altered • solubility of oxygen, nitrogen, carbon dioxide, ammonia and other chemical altered • flow, temperature, turbidity and nutrient levels altered • reduction of species diversity • substitution of species • downstream rivers have no flow during non-generation reducing food and oxygen levels • organic decay of covered vegetation • barrier to fish migration • loss of terrestrial habitats • long time-scale for many impacts on ecology to appear	• accidental releases of radiation • genetic damage		• transport of materials • disturbance of natural habitats • presence of plant and buildings
Natural Inanimate	• **Abiotic Environment**					
Land	• emissions damage natural habitats • subsidence • waste disposal • accidental releases of wastes • severe land disturbance and soil erosion • possible subsidence due to fuel extraction	• acid emissions • waste disposal • accidental releases during drilling, transportation etc. • coastal damage • prospecting now in rain-forests and arctic tundra • road building opening up previously inaccessible areas, resulting in settlement, logging and mining • possible subsidence during fuel extraction	• although there are numerous sites for small scale applications, large-scale opportunities are restricted by topography • reduced quality of downstream land • reduced natural fertilisation downstream • subsidence or seismic activity during filling and settling • increased soil erosion due to sudden water level changes • extensive civil engineering required • trapping of silt can prevent beach replenishment in river deltas allowing accelerated coastal erosion • flooding of land	• waste disposal • accidental releases of radiation • fire and explosion risk • possible subsidence during fuel extraction		• conflicting land use • land sterilisation • non-fuel material requirements • transport of materials • transport land use impacts • construction and maintenance of plant and buildings
Air	• material and toxic emissions, smog, NOx, SOx, acid, particulates • steam plumes • thermal discharges	• material and toxic emissions • oil refining associated with sodium dioxide and NO_x • gas flaring • NO_x, SO_x, smog, CO particulates, VOC's, • trace elements released when fuel is burned e.g. heavy metals, mercury, cadmium and lead	• avoided emissions when used to replace fossil fuel	• toxic emissions • accidental releases of radiation	• accidental releases • VOC's, CO, NO_x, CH_4, CO_2	
Water	• toxic and acid emissions • thermal pollution / discharges • large water consumption in cooling towers	• oil spills • accidental releases and leakage from pipelines • acid and toxic emissions • pollution from drilling mud's - barite, arsenic, cadmium, mercury • production waters often radioactive • brine injected into oil wells can contaminate groundwater	• can be used to suppress natural extremes of flow rate • can aid in trash removal and oxygenation of water • interference with water quality (flow rate, depth, residence time, salinity, and thermal behaviour) • increased sediment in lake water lowers light levels • possible eutrophication if reservoir acts as nutrient trap (rare because of large outflows and short retention times) • reduced river flow decreases dilution of pollution • possible drainage problems	• toxic emissions		
Climate	• global warming, rise in sea levels, thermal expansion of water, melting polar ice, changes in reflectivity, changes in wind and wave regimes, tidal surges, coastal erosion, saline intrusion into groundwater, loss of habitats, die-back of tropical forests, desertification of tropical forests and grasslands, shifts in climatic zones, increasing weather extremes	• CO_2 global warming, SO_x, NO_x		• nuclear winter	• CO_2 • CH_4 more potent a greenhouse gas than CO_2	

Table 1: Some Impacts of the Energy Sector

Fuel	Coal	Oil	Large-Scale HEP	Nuclear	Natural Gas	All
Impacts on:-						
	Human Environment					
Human Issues	• global warming, famine in tropical countries , poor harvest, crop damage, pollution, flooding, water stress, drought, increased risk of malaria • cost of clean technologies • cost of transport • odour • archaeological damage • wastes • sustainability	• found in politically unstable areas (1970's oil crises) • stability and security of supply • price controls • danger of single fuel dominating the energy mix • odour • transport of materials • archaeological damage • wastes • cost of clean technologies • sustainability	• avoided emissions when used to replace fossil fuel generation • high capital investment (construction costs) required therefore long payback periods • low running costs, low cost electricity from established plants • mature technology • capable of rapid response for power generation • may be used for base load and peak demand on a grid connected supply • suppression of flow rate extremes can aid river navigation and flood control • creation of productive fisheries in large lakes • recreational opportunities • opportunities restricted by environmental issues and finance • indigenous population displacement/ relocation and social problems • extensive civil engineering required • reduced fish harvests downstream • power/area ratio 5 kW/ha. To 21.7 kW/ha.	• high costs of building and operation • high decommissioning costs • lengthy decommissioning process takes over a century • long lead times • unpopular because of safety concerns • wastes • sustainability	• odour • transporting LNG by tanker expensive • fuel costs will rise as resources become scarce • low maintenance costs • sustainability	• external costs • visual intrusion, aesthetics • employment • unemployment • market competition • public opinion • planning issues • noise • transport of materials • environmental problems • line losses
Health and Safety	• risk of disease • effect on public health of routine emissions of particulates, sulphur dioxide and oxides of nitrogen • mining accidents and fatalities • subsidence • fatalities during mining and transportation 0.15-0.36 deaths / TWh [23] • navigational hazards during import	• contamination of tourist beaches • difficult salvage conditions at sea • decommissioning costly • risk of disease • effect on public health of heavy metals and other routine emissions • opening up previously inaccessible areas has introduced new diseases from colonists • oil spills, routine discharges • shipping regulations different in each country • risk of explosion at refineries • navigational hazards during import	• threat of catastrophic dam failures • at least 3,000 deaths in the 20th century • formation of downstream stagnant pools form mosquito breeding grounds in tropical locations • sudden water level changes can cause river bank collapses	• risk of major accidents, uncontrolled nuclear reaction and explosions • fire risk • technical problems • accidental releases of radiation • waste disposal and storage • military applications • risk of disease • effect on public health of routine emissions • sabotage • genetic damage • leukaemia clusters • plutonium found in children's teeth near power stations • seafood found to contain radioactive material near power stations • radioactive iodine half life 16 million years	• effect on public health of routine emissions • risk of fire and explosion	• public and occupational risk from accidents • failure of equipment • electric shock
Sustainable Development	• finite resource • conversion efficiency of electricity only power plants around 35%	• security of supply • finite resource	• potential sites limited by topography and environment • long term resource availability • short term resource shortage at times of low rainfall • power generation efficiencies may be as high as 90% • turbine generators can be reversed to pump water to high levels for energy storage at efficiencies of around 80% • schemes do not require imports of primary fuel • no emission problems • removal of downstream water resource	• finite resource	• finite resource • conversion efficiency around 50% for combined cycle gas fired turbines, 80% for CHP	• conversion efficiencies • diversity of supply • life cycle analysis • end of pipe technologies may replace one environmental problem with another

Table 1 (continued): Some Impacts of the Energy Sector

3.1.3 Sustainability

Current methods of energy production and use are mainly dependent on fossil fuels and uranium. These non-renewable mineral resources are formed over geological time scales and exist in finite amounts within the Earth's crust. The known and expected global reserves of these fuels show that there are unlikely to be supply problems in the very near future [24]. However, in the longer term (post 2050) the oil and gas supply will eventually become less reliable and more expensive as reserves are economically depleted. UN estimates of the length of time that total global proven resources are expected to last (business as usual) are: coal 670 years, oil 45 years, gas 63 years and uranium 51 years [25].

Possible maximum remaining UK reserves are estimated at: coal 300 years; gas 10-27 years (1,985 billion cubic metres), with oil peaking at 2010 (2,015 million tonnes) [26]. Therefore the UK will become increasingly dependent on gas from countries such as Russia after around 2010 [27] and demand for cheap oil is expected to exceed supply in about 2050 [28]. The possibility of future resource scarcity provides a powerful impetus towards a more diverse and sustainable energy mix.

Friends of the Earth have estimated the cuts in resource consumption and emissions needed in the UK for sustainable use of resources (see Table 2).

Cuts required in the UK to achieve sustainability:	By 2010	By 2050	To per person per year
Energy related CO_2 emissions	-30%	-88%	1.13 tonnes
Land	-7%	-27%	
Wood	-65%	-75%	0.24m^3 raw material equivalent
Water	-15%	-15%	144,000 litres
Cement	-18%	-72%	58 kg
Steel	-21%	-83%	27.4 kg
Aluminium	-22%	-88%	1 kg
Chlorine	-25%	-100%	
Construction aggregates	-12.5%	-50%	

Table 2: Reductions on 1990 Levels in Resource Consumption and Emissions, Required to Achieve Sustainable Use in the UK. [29].

Friends of the Earth also state that in 2050, for all countries to consume as the UK does now, would require the equivalent of 8.25 planet earth's worth of energy supplies, 1.25 planets for land, 3.5 planets for wood, 3.25 planets for cement, 5.75 planets for steel, 8.25 planets for aluminium and 2 planets for construction aggregates.

Thus to achieve a sustainable society will involve reducing total energy and resource flows and pollution from around 4 to 20 times [30]. This will require long-term strategic approaches on Government, national and international levels.

3.1.4 Biological Diversity

Although the precise number of species of flora and fauna is unknown, the United Nations assessment [31] is between 13 to 14 million, with only around 1.75 million species named. The total number of species becoming extinct each year in all habitats is roughly 20,000 [32] to 36,500 [33]. The annual rate of species reduction in tropical rain forests alone is 17,500 [34], primarily because of anthropogenic environmental degradation.

Global population increases, and growing numbers of buildings and roads have been accompanied by the loss of habitats such as forests, grasslands, wetlands and coral reefs. Overgrazing and poor soil management has led to soil erosion, depletion of plant nutrients, and increases in the area of desert and has clogged waterways with sediment. Excessive irrigation has caused water logging and salinization. Water has been removed from aquifers faster than natural replenishment rates. The unknown consequences of the loss of biological diversity encouraged international co-operation in environmental planning and management. More than 150 nations signed the global Biodiversity Convention [35] and in the UK the EU Habitats and Birds Directives also apply.

3.1.5 Pollution

The conversion of fossil fuels into useful energy results in the formation of a number of waste products. These pollutants have steadily accumulated in the environment reducing air quality and compromising human health. Groundwater supplies have been polluted; lakes and soils have been acidified. The scale of economic activities has disrupted natural cycles, threatening the global climate [36].

3.1.5.1 Air Quality and Acid Deposition

The combustion of fossil fuels in power plants, industry and transport is the source of many primary pollutants. These can remain in the atmosphere for anything from days to years, travelling for hundreds or thousands of miles, according to the size of particle and the amount of precipitation [37]. Secondary pollutants are formed when these pollutants react with other chemicals in the atmosphere or sunlight and can lead to local air quality problems.

Carbon monoxide, produced by partial combustion, reacts photochemically producing ground level ozone and also replaces oxygen in blood, inhibiting respiration in mammals by binding with haemoglobin. Volatile organic compounds, from leaks, spills and unburned hydrocarbons in liquid and gaseous fuels, are carcinogenic and contribute to the formation of photochemical smog's, which may be related to the increase in asthma and breathing related illnesses. Suspended particulate matter from fuel and inefficient combustion processes, can contain toxic trace contaminants such as mercury, cadmium and lead, reduce visibility and leave dirty deposits. Particles less than 2.5 micrometers can also enter the lungs.

The combustion of coal and oil, metal smelting and refining petroleum releases substantial amounts of sulphur into the atmosphere, approximately doubling the rate at which sulphur enters the environment from natural cycles [38]. Emissions to the atmosphere are predominantly sulphur dioxide (SO_2), a toxic, corrosive gas that damages plants and animals and oxidises to sulphuric acid when exposed to air and water. Nitrogen oxides form during any combustion process because of the presence of both nitrogen and oxygen in combustion air. Nitrogen dioxide contributes to the formation of smog, and all the nitrogen oxides can form with water to produce acid, lowering the pH of any precipitation.

Taller chimneys introduced following the Clean Air Act (1954, 1968,1993) meant that pollution travelled further away from the point of origin and took longer to become evident. Acid deposition is commonly called acid rain and causes damage to soils, plant and aquatic life, forests, lakes, rivers, groundwater, buildings, and can also aggravate respiratory disease. International agreements now exist in respect to SO_2, NOx, VOC's and CO_2.

3.1.5.2 Oil Spills

Considerable quantities of oil are shipped around the world. Accidental oil spills and tanker routine discharges and accidents release large amounts (estimated to be around 2.5 million tonnes/year) [39] of oil in the sea. A further 55,000 tonnes of oil are released annually in drill cuttings and mud's. Toxins in oil can reduce the reproductive success of plants and animals, or they can be killed if physically smothered. Spray dispersants used to remove surface oil spread the oil more widely in water column and cause even more damage. It took between 10 to 20 years for the ecological balance to be regained after the Torrey Canyon oil spill in Cornwall in 1967 [38]. Decommissioning the 155 North Sea oilrigs is expected to cost between £4.4 - 5.5 billion.

3.1.5.3 Radioactive Substances

Nuclear power creates hazardous radioactive wastes requiring high cost long-term management. Radioactive isotopes are chemically identical to non-radioactive isotopes and become incorporated into bones and other body tissues with accidental exposure. They pass into food chains, becoming more concentrated in successive members of the food chain. The incidents at Three Mile Island (1979) and Chernobyl (1986) served to highlight the serious environmental impact of radioactive contamination [40].

3.1.5.4 Climate Change

The chemical composition of Earth's atmosphere partly determines the mean surface temperature (about 15°C) and therefore climate. Heat (long wave infra-red radiation from earth's surface) is trapped in the lower atmosphere (troposphere) in a natural process called the greenhouse effect principally by water vapour, carbon dioxide, ozone, nitrous oxide and methane. Without the greenhouse effect the mean temperature would be around -18°C. Natural concentrations of greenhouse gases are controlled by the major gaseous, sedimentary and hydrologic biogeochemical cycles.

Natural pre-industrial concentrations of carbon dioxide in the atmosphere were around 280 ppm [41]. Measurements started in 1957 and have shown that the combustion of fossil fuels and wood, industry, agriculture and deforestation are increasing the concentrations of these gases and also adding others to the troposphere altering its chemical content [42]. By 1997, carbon dioxide concentration was over 360 ppm. CFC's and N_2O also continue to deplete the ozone in the stratosphere, which filters harmful UV radiation. Increased exposure to UV radiation is expected to increase the occurrence of skin cancer and eye cataracts, interfere with the immune system and cause damage to terrestrial and marine ecosystems.

As the concentrations of these gases increase so does the mean land and sea based temperature. 1998 was the warmest in terms of surface global average temperature [43], around 0.58°C above the 1961-1990 average [44]. The IPCC reports that there will be a steady rise in average global temperature of 0.2°C each decade through the 21st century. The Meteorological Office, Hadley Centre, estimates a 3°C rise in average global temperature by 2080, with rises as high as 8 degrees over some land masses.

This could possibly lead to climate change. The impacts of which are unpredictable and subject to much contrary scientific speculation [45, 46, 47, 48]. Some suggest there will be global cooling and that the albedo effect of stratospheric cloud cover is the dominant factor in determining the short-range climate [49, 50], others suggest that global warming will actually improve environmental conditions [51, 52].

But, if worst case predictions prove to be correct, global warming could potentially lead to: melting polar ice fields, sea level rises of 5 cm/decade, flooding, changes in wave patterns and tidal surges, increased coastal erosion, saline intrusion into groundwater supplies, changes in wind and rainfall patterns, increases in weather extremes, decreased microbe activity in soil and die back for tropical rain forests in northern South America and central Southern Africa [53], increased water stress, increased risk of malaria, shifting climatic zones and therefore disruption of agricultural practises leading to reduced yields and increased risk of hunger.

With mounting evidence and increasing concerns, the prospect of global warming has meant that environmental issues have reached the top of the political agenda on an international scale. A precautionary approach has been adopted to reduce the risk of climate change [54, 55], with the need to limit average global temperature rises below 0.1°C per decade [56] to a maximum of 1°C [57]. For its' share in achieving this, Friends of the Earth estimate that UK energy related carbon dioxide emissions would need to be cut to 30% of 1990 levels by 2010 and 88% by 2050 [29].

Carbon dioxide is the biggest contributor to climate change. 90% of CO_2 is from respiration balanced with photosynthesis, 10% from anthropogenic sources. 30% of these emissions coming from fossil fuel power generation (see Table 3). Methane emissions also need to be controlled as it has 62 times the global warming potential of carbon dioxide. Methane concentrations have risen from the pre-industrial level of 0.8ppm to 1.7 ppm in 1995 [58]. In the European Union the biggest contributor to methane emissions is the agricultural sector, which is responsible for 45% of such emissions, with manure handling accounting for 15% of the total.

Greenhouse Gas	Contribution	Fossil Fuels	Deforestation
Carbon Dioxide	63.5%	6 GtC/y	2 GtC/y
CFC's	11.5%		
Methane	20.5%		
Nitrous Oxide N_2O	4.5%		

Table 3: Contributions to Climate Change from Anthropogenic Sources [59]

3.2 Sustainable Development

"Society's greatest challenge in the 21st century will be how to eliminate poverty without eliminating the planet." [60].

Acidification of Scandinavian aquatic systems was the major factor, which led to the UN Conference on the Human Environment at Stockholm in 1972 [61]. It brought together representatives of 113 countries and established the importance of environmental concerns as an international political issue. Several initiatives on international environment and development issues followed, yet concern continued to raise as environmental problems linked to social and economic development persisted.

The World Commission on Environment and Development, under the Norwegian Prime Minister Gro Harlem Brundtland, was established as an independent body, to analyse the socio-economic and environmental situations of the world and the interaction between them. The commission's report concluded that economic growth and rises in standards of living were not sustainable and would eventually cause irreversible environmental disturbances and exhaustion of natural resources.

> *"Many forms of development erode the natural resources upon which they must be based, and environmental degradation can undermine economic development...... Poverty is a major cause and effect of global environmental problems."* [62]

The overall recommendation was that human activities could and should be redirected towards a path of "sustainable development" with environmental protection integrated into social and economic development policies. Since 1987 there have been at least 80 definitions of sustainable development [63], stressing the need to leave the Earth in as good as, or better, condition than we found it, but for the report, sustainable development was defined as:

> *"Development which meets the needs of the present generation without compromising the ability of future generations to meet their own needs."* [62]

The report also proposed that a universal Declaration on environmental protection and sustainable development should be prepared and that an international conference be convened to review progress.

In December 1989, the UN General Assembly resolved to convene the United Nations Conference on Environment and Development (UNCED). The Brazilian government offered to host the conference at Rio de Janeiro. The date of June 1992 was chosen to coincide with the 20th anniversary of the Stockholm Conference, and UNCED became known as the "Earth Summit". Two documents were central to negotiations; a short statement of overall aims and principles known as the *Rio Declaration*, and an 'Action Plan' of specific measures designed to achieve sustainable development in the 21st Century known as Agenda 21 [64, 42].

3.2.1 Agenda 21

Agenda 21 recommends the development of environmentally sound, sustainable energy systems to reduce pollution and greenhouse gas emissions This involves reducing the use of fossil fuels, the promotion of energy efficient technologies, the use of new and renewable energy sources, and appropriate energy planning and policies.

Through Agenda 21, Government's pledge to introduce policies for sustainable development. Around two-thirds of Agenda 21 requires action by Local Authorities. Local Authorities determine social and economic infrastructures, oversee the planning process, establish local environmental policies and regulations, and assist in implementing national, and regional environmental policies. Local authorities as the level of government closest to the public and can play a vital role in providing information, raising awareness and promotion of sustainable development issues.

Although the contribution by individual areas is small, each area has a role in contributing to regional, national and international objectives. Global sustainability will only be achieved by a large number of local initiatives.

3.3 The UK Strategy

Long-term ecological sustainability is seen as becoming the primary economic driver.

> *" We are about the go through a sustainability revolution that will rival the agricultural and industrial revolutions in the way it will transform society - that will mean new thinking. "* [65]

The development of a sustainable society will require increases in the efficiency with which resources and materials are consumed. This will involve the use of innovative and appropriate technologies, which avoid or minimise environmental impacts, and energy prices that reflect their external environmental costs. Institutional, political and economic frameworks need to be in place to facilitate the transition to a more sustainable pattern of energy production and use. Such a radical change will require the setting of specific environmental targets to be delivered by a long-term energy policy.

3.3.1 Government Targets

The first comprehensive White Paper on the Environment [66] included a discussion of the greenhouse effect, town and country pollution control, energy efficiency, building regulations and the possibility of future taxes on energy. The threat of climate change was recognised by the 1994 Government, whose aim was to reduce emissions of carbon dioxide and other major greenhouse gases to 1990 levels by the year 2000. The ultimate objective was to:

> *"Stabilise greenhouse gas concentrations in the atmosphere at a level that will prevent dangerous anthropogenic interference with the climate system." [67]*

The environmental target set in 1999 was to reduce greenhouse gas emissions, again on 1990 levels, by 12.5% by 2008-2012, with emissions of CO_2 reduced by 20% by 2020.

New and renewable energy sources are seen as a vital step towards sustainable development [68]. The aim of Government policy is:

> *"To ensure secure, diverse and sustainable supplies of energy in the forms that people and business want and at competitive prices."* [69]

> *" This means creating an innovative and efficient economy, with a highly skilled and well-rewarded workforce, and firms that can compete against the best in the World."* [70]

A target of 5,000 MW of installed Combined Heat and Power (CHP) by 2000, 10 GW by 2010 was set as part of the Climate Change Programme. A target was set in 1994 of 1500 MW Declared Net Capacity (DNC) of new electricity generating capacity from renewable energy sources by 2000 [71], as part of Government energy policy. Achieving this target for renewable energy would have resulted in annual savings amounting to 2 million tonnes of CO_2, together with 100,000 tonnes of SO_2, and around 30,000 tonnes of NO_x [72]. The 1999 Government's target of 10% of electricity from renewables by 2010 will result in annual savings of 5 million tonnes CO_2 [73].

It would need a forested area three times larger than the UK to absorb the 160 Million tonnes of carbon produced in 1990 [74]. Even so, an increase in CO_2 absorption by large-scale planting of trees, especially broad leafed woodland, could minimise the effect of increases in emissions. The UK Sustainable Forestry Management Strategy [75] includes promoting the restoration of derelict land to woodland with the planting of native species. It also encourages the development of woodland industries including energy production and eco-tourism. Energy paper No. 62 [76] estimates that energy crops could contribute 100 MWe and agricultural and forestry wastes a further 100 MWe towards the renewable energy target. The National Biomass Energy Strategy [77] is intended to help achieve that aim, in order to contribute to sustainable development.

4. Sustainable Energy Systems

Concern for the environment and a serious commitment to sustainable development determines that the energy sector (particularly in electricity production) must alter the primary orientation of its strategy. To reduce dependence on fossil fuels, the move from cheapest possible supplies, regardless of environmental damage, to a cleaner and more environmentally friendly supply is necessary. This chapter describes those energy technologies which could contribute most to a more sustainable energy system in the UK and what kinds of changes will be needed at the institutional and policy level if they are to be implemented.

4.1 Criteria for Sustainability

There is a wide range of different technological options for dealing with producing electricity, specific environmental problems, or reducing demand. Some of these may be beneficial only in the short term and deal with immediate effects not the root cause of the problem (end of pipe approaches). Others offer preventative approaches.

The criteria for successful measures that could contribute most in the long term to a more sustainable energy system and combat climate change are:

1. They should entail only acceptable economic and environmental life cycle costs.
2. They should be cost effective.
3. They should improve resource use efficiency.
4. They should be able to be implemented relatively quickly.

4.2 Nuclear Power

There are around 430 nuclear power reactors providing 6% of the world's energy, 17% of the world's electricity. Fast breeder reactors use uranium around 60 times more efficiently than current thermal reactors and could be used to provide enough electricity globally to last for 5 centuries.

4.2.1 Financial Support

In the UK, nuclear power has benefited both from Government R&D funding and the Non-Fossil Fuel Obligation price support. Since 1979 over £2,000 million has been spent on R&D [78]. It is estimated that further £50,000-£100,000 million will be required for R&D to get nuclear fusion to the commercial stage [79]. From 1990 to 1998 nuclear power also received nearly £8,000 million from the fossil fuel levy. This was meant to pay for decommissioning, but was also used for running costs. Nuclear power no longer gets this direct subsidy.

4.2.2 Capital Costs

A rough estimate of installed capital costs for the UK nuclear capacity is £1,364,000/MW with the cost of reprocessing plants, fuel fabrication, waste facilities etc. being a further £455,000/MW [80].

The estimated costs for Sizewell B PWR were £1,896 million in 1982 and £2,648 million in 1991 [40]. For nuclear to meet majority of the 20% carbon dioxide saving target would require twelve Sizewell B sized reactors [81] (16 GW) these would be impossible to build by 2010.

4.2.3 Decommissioning

No commercial scale nuclear power plant has yet been fully decommissioned. The Superphenix fast-breeder reactor in France was to start this lengthy process (taking around 130 years) in 1999 at an estimated cost of £1.65 billion [82]. Over £600m of European Commission money allotted to making safe the reactor technology in the old Soviet bloc has been lost, wasted, embezzled or not spent [83].

A decommissioning programme is underway in the UK. This includes the Magnox at Calder Hall, Sellafield, which was set up in 1956 to provide weapons grade plutonium and the civil facility, Berkeley on the Severn Estuary, built in 1962. The decommissioning liabilities of BNFL were £4,608 million in 1989 and £438 million 1998 [40]. SPRU estimate the total cost of decommissioning the UK's nuclear plants could be around £70 billion, with £23.4 billion for decommissioning the Magnox reactors.

The PWR at Sizewell 'B' will be the only UK nuclear power station when other 1960's Magnox reactors and AGR's reach the end of their operational life around 2010-20.

4.2.4 Safety

Dounreay in Scotland is the site of the experimental Fast Breeder Reactor. Now closed, Greenpeace describe it one of the worst nuclear contaminated sites in Western Europe. In the 1960's around 170 kg [84] of weapons grade uranium, enough to make 12 atomic bombs went missing. A waste shaft was used as a nuclear waste disposal facility from 1959 till the 1970's. The DTI says the shaft does not provide standards of waste disposal acceptable today and that retrieval prior to treatment and final disposal is the best practicable environmental option. To extract the wastes from the shaft and wet silo is estimated to cost £215 - £355 million [85] and the clean-up programme to take up to 25 years.

MAFF have found high levels of caesium-137 and caesium-134 in feral pigeons within a 10-mile radius around Sellafield. The garden topsoil from a house used as a bird sanctuary in the village of Seascale is being removed as it is contaminated with radiation from pigeon droppings. A cull plans to kill hundreds of these pigeons and also mice, crows, starlings, sparrows, mosquitoes and possibly lobsters [86].

Other areas of concern are the health risks associated with radiation and potential catastrophe.

> *"One more Chernobyl anywhere in the world and the nuclear industry will be dead in the water in the UK. A smaller incident in the UK and the same will happen. ....But, the UK will not meet its environmental and resources responsibilities unless we have 30% of our electricity, generated from carbon free nuclear power in 2030, using a single mainstream route that has passed the safety regulations of at least 6 countries."* [74]

4.2.5 Emissions

Nuclear generated electricity has no direct CO_2 emissions. However, the nuclear fuel cycle is associated with emissions during mining, fuel enrichment and plant construction. These indirect emissions have been estimated as being in the region of 34 -60 grams CO_2/ kWh [87, 88].

4.2.6 Electricity Costs

Rader and Bossong estimated the comparative electricity costs from various sources (see Table 4) and stated that the costs of replacing all US fossil fuelled electricity capacity with nuclear power would be around £1.5 billion.

Technology	Cost
Opportunity costs of new nuclear plant	£0.075/kWh to £0.11/kWh
Nuclear costs with all decommissioning costs taken into account	£ 0.113/kWh to £0.15/kWh
Energy efficiency investment cost	£0.0075 /kWh to £0.03/kWh
Biomass electricity	£ 0.037 /kWh
Geothermal	£0.045/kWh
Large hydropower	£0.033/kWh
Small hydro	£0.09/kWh
Wind energy	£0.045/kWh
PV	£0.157/kWh
Solar thermal electricity	£0.037/kWh
Passive solar design	£0.019 / kWh energy saved
Active hot water and space heating	£0.034/kWh energy saved
Natural gas combined cycle gas fired turbines	£0.041/kWh

Table 4: Comparative Electricity Costs in the US [89] (on a 1999 basis).

Long lead times, high R&D, capital, operating & repair, decommissioning and financing costs, environmental and safety concerns, health hazards, and failure to find an economically, publicly and politically acceptable solution for storing long lived wastes has led many countries (e.g. France, Germany, Spain, Belgium, Sweden, Canada) to curtail their plans to transport waste, reprocess fuel or build new nuclear power plants.

Non- nuclear options are available that would meet more of the criteria necessary to contribute towards a sustainable energy system.

4.3 Natural Gas Technologies

Natural gas is seen as a key technology in the transition to a more sustainable future [90]. While natural gas is available, combined cycle gas fired turbine systems offer the most efficient, lowest cost and cleanest new build fossil fuel technology [91]. Combined cycle gas fired turbine technology in the UK is able to achieve power generation efficiencies of around 50-55% on natural gas, with scope for the use of the low grade waste heat in industry, commerce or district heating, further improving thermal efficiency. Emissions from currently available gas turbines are virtually sulphur and particulate free with very low NOx.

Around 12 GW of combined cycle gas turbine capacity was in place at the end of 1997, which was 18% of the total UK declared net capacity (DNC) of major power producers. The UK Government deferred giving licences to any new oil or non-combined heat and power (CHP) gas fired power stations [93] between 10 and 50 MW during the 1998 review of energy sources for power generation as it is assumed that North Sea supplies will be depleted within around 15 years [92].

4.4 Combined Heat and Power

CHP has been promoted since the late 1970's [94, 95]. CHP is an efficient, cost effective way to produce both heat and electrical power. Gas-fired CHP was exempt from the moratorium as using gas -fired CHP increases the conversion efficiency to 80% or more cutting emissions per kWh.

The UK's CHP capacity is around 4,000 MW and is reducing energy costs by over £2 billion and carbon emissions by around 5 million tonnes a year [96]. Increased use of CHP could account for saving at least half of the 7 million tonnes of carbon emissions achievable in the industrial sector [97].

4.5 Clean Coal Technologies

In the 1930's more than a million people were employed in the deep mines. Even after the development of nuclear power, coal still provided around 80% of the UK's electricity up to the 1970's. In 1979 the Conservatives were elected and Mrs. Thatcher's attack on the coal industry began. Massive job losses followed both the miner's strike (1984-1985) and electricity privatisation in 1990 when coal was replaced by cheap North Sea gas.

Coal provides about 40% of power generation worldwide, this is expected to double by 2020 [98]. It is predicted that the market for clean coal technology will be £300 billion by 2010 [99]. If sufficient R&D to develop clean coal technologies is undertaken this export opportunity could contribute significantly to the UK economy. The DTI programme for clean coal is to provide £12 million over 3 years from 1999 for this R&D.

Clean coal technologies are relatively unproven at full scale. Capital costs of IGCC are three to seven times the specific cost of a typical combined cycle gas fired turbine and twice the per kW cost of a traditional coal-fired power station. The estimated capital costs of pressurised fluidised bed are around $1,000 - $1,300/kW [100]. Clean coal technologies will take several years to develop, with plant taking around 3 years to build.

Clean coal technologies including pulverised fuel technology with de-SOx / de-NOx, circulating fluidised bed, pressurised fluidised bed, integrated gasification combined cycle, hybrid or topping cycles, are expected to achieve conversion efficiencies of between 42% to 47% [101]. In principle coal fired CHP could operate at efficiencies of 80% or more.

Even the best clean coal technology produces more carbon dioxide than a gas fired combined cycle gas fired turbine of similar efficiency, but, as coal is the UK's largest fossil fuel reserve, it contributes to long term strategic diversity [102].

4.6 Hydrogen Fuel Cells

Fuel cells are seen as the energy conversion technology of the future [103]. They convert the energy of a chemical reaction directly into low voltage direct current electricity and heat. The fuel cell in its simplest form is an electrolytic process in reverse with the fuel being hydrogen and the oxidant being oxygen. Fuel cells are expected to achieve efficiencies as high as 73% in CHP.

Hydrogen can be derived from fossil fuels or by renewably powered electrolysis. Electrolytic hydrogen would have no carbon dioxide production and sequestration costs associated with it but will be more costly than fossil fuel derived hydrogen until fossil fuel prices are much higher. Hydrogen from coal feedstocks will be more expensive than hydrogen from natural gas because of the extra costs of sequestration of carbon dioxide. This carbon dioxide can be stored in depleted natural gas fields or pumped back down boreholes into oil reservoirs to drive oil up the production wells.

Applications for fuel cells (see Table 5) will be where conventional technologies are too expensive on a specific power basis, such as domestic co-generation, secondary batteries and remote power sources. They could also replace small, low efficiency engines in garden machinery and hand-held power tools. Fuel cells used to replace the reciprocating engine would reduce inner city traffic pollution problems. Operation at temperatures lower than normal combustion also means that NOx levels are negligible.

	Type of fuel cell	Oxidant	Fuel	Operating temperature °C	Application	Notes
PAFC	phosphoric acid	clean air (without CO_2)	pure H_2 (hydrocarbons)	200	CHP max. power efficiency 40%	closest to commercialisation, 200 kWe CHP, Woking Park, Surrey
AFC	alkaline	pure O_2+H_2O (without CO_2)	pure H_2	60-120	astronautics	
SPFC	solid polymer	pure O_2	pure H_2	60-100	transport astronautics	
MCFC	molten carbonate	air + CO_2	hydrocarbons	650		developmental / demonstration
SOFC	solid oxide	air	any fuel	900-1000		developmental demonstration
DMFC	direct methanol		methanol liquid or vapour		transport	developmental
PEM	polymer electrolyte membrane				efficiency around 30%	demonstration

Table 5: Fuel Cells and Their Applications [104].

Cost is the biggest problem for increased uptake of fuel cells. Fuel cells are expensive because platinum is used as catalyst for the oxidation of hydrogen into water. Traditional technologies, which fuel cells could replace, are less bulky and mass produced, with automotive engines being as low as £30/kW. Other problems include: reduced performance because of the presence of nitrogen in air and ensuring the lifetime is longer than 40,000 hours which will be expected for commercial customers.

A large scale hydrogen industry will become important if a high proportion of electric power demand is met from intermittent sources such as wind and solar.

Guaranteed supply will rely on large storage facilities. This will become necessary when renewable energy accounts for 20%-25% of the electricity mix [105]. A 35 km by 35 km PV array electrolysis unit producing hydrogen for fuel cells, sited in one of the world's deserts could produce enough hydrogen to supply all the electricity needs of the UK [106].

4.7 Carbon Dioxide Capture and Storage

Fossil-fuelled power generation accounted for emissions of around 1.8 GtC/y worldwide in 1990. Continued use of fossil fuels without continuing to increase levels of carbon dioxide in the atmosphere can be achieved by removing it from the flue gases then long term storage, or by increasing its uptake in natural sinks.

4.7.1 Capture

Pressure swing adsorption (solvent absorption or adsorption onto a solid surface) is already used to supply carbon dioxide to the food industry. Carbon dioxide capture systems at power stations could use selexol or monoethanolamine (MEA) solvent absorption with a scrubber in the flue gas stream (see Table 6). A shift reaction converting CO to CO_2 and hydrogen optimises conditions for CO_2 removal. Captured CO_2 would need to be stored separate from the atmosphere.

500 MWe plant	Efficiency %	Emissions g CO_2/kWh	Power Cost US cents/kWh	Cost of Avoided Emissions $/tC
Natural Gas Combined Cycle CO_2 concentration in flue gas 3.4%		406	3.5	
NGCC with solvent absorption MEA capture	42.0	76	5.3	198
Coal Pulverised Fuel		800	5	
Coal PF with MEA capture	28.8	116	7.4	126
Coal Integrated Gasification CC		800	5	
Coal IGCC with MEA capture	28.2	114	11.2	313
Coal IGCC with shift reaction (CO to CO_2) and Selexol capture	35.5	170	6.3	58
Air-blown GCC MEA capture	25.3	402	9.3	403

Table 6: Power Generation With and Without Carbon Dioxide Capture [107].

4.7.2 Storage

Although not feasible yet, captured carbon dioxide would need to be dried, pressurised and transported to very large storage sites (see Table 7). This would increase the costs of electricity dramatically.

Storage Site	Global Capacity Gt. C
Disused oil fields	40 - 100
Disused gas fields	140 - 400
Deep saline-water reservoirs	50 - 100
Deep ocean	>1,000

Table 7: Carbon Dioxide Storage Sites [107, 108].

4.7.3 Sequestration

According to a UN estimate the global deforestation rate was 13.7 million ha/y from 1990 to 1995. It is hard to measure absorption rates of trees as this varies with species and climate, but in optimum conditions trees could sequester around 3.81 tonnes Carbon/y per hectare (0.23 ha./tonnes Carbon per year).

> *"if action is not taken soon to reforest large parts of the earth global warming could get out of control and further discussions about reducing carbon emissions will be irrelevant."* [109]

Maximum carbon dioxide absorption occurs in young rapidly growing trees, slowing as trees mature. Carbon dioxide is re-emitted when trees die and decay, or are burnt, but can be stored in long-lived timber products. 1998 costs for small sequestration schemes are put in the order of US$3-14/tC in developing and tropical countries, US$25/tC for large schemes and over US$70/tC in mid-latitude developed countries.

4.8 Energy Efficiency

Long-term reductions in carbon emissions need to be based on a reduction in the use of all carbon fuels. Economic recession and fuel switching has resulted in reductions in carbon dioxide and other environmental emissions in the UK. No further significant emission reductions are expected through electricity generation till after 2010 [110]. Until then continued reductions in emissions will require changes in the use of energy by final users.

Conservation and improvements in energy efficiency are the most economic and cost effective way to reduce electricity demand [111]. The physical laws of nature limit technical improvements. However, there are extensive opportunities for improved energy efficiency in supply and demand as many technologies are far from the theoretical limits. The obstacles to implementation and the gap between actual and potential uptake of energy efficiency are issues that need to be addressed by policy and regulatory reform, without which it is doubtful that the possible environmental benefits will be realised.

4.8.1 Uptake

Increased energy efficiency is expected to result in reduced fuel consumption, economic savings, increased profits, and create extra jobs. Despite these benefits the uptake of energy efficiency in the UK has remained relatively low.

According to a DETR survey only 2% of industrial, 25% of commercial and 22% of public sector organisations have an individual with full time responsibility for energy management. Reluctance to increase energy efficiency may be because of a lack of cheap capital to invest and a need for shorter payback times where expenditure on energy is a relatively small part of total expenditure.

There are some potential environmental impacts of energy efficiency measures that need to be continually reviewed, or there is a chance that one kind of environmental problem may be replaced with another. Some insulation materials can create a health hazard with sick building syndrome. There is a trade-off between the use of CFC's and efficiency in refrigerators. Compact fluorescent lamps require the use of mercury.

There is also some debate over whether energy efficiency actually does reduce energy consumption [112]. A small part of energy efficiency gains may be lost by changes in behaviour, with increases in consumption of energy enabled both by higher incomes and cheaper bills. The DTI energy model suggests that a 10% fall in electricity and gas prices may increase demand by 2 to 3%, equivalent to a 1 to 2% increase in total gas and electricity demand. Fashion may also contribute to increased energy consumption; for example, in the domestic sector the trend for lighting using multiple freestanding lamps and spotlights may consume more power than the traditional single central light.

Shopping mileage and fuel use is increasing for shop suppliers and consumers with the spread of out of town retail developments. Transport efficiency (MJ/kg of groceries) is now worse by a factor of 2.7% than in 1960. Transport fuel prices are elastic with people paying continually higher prices for fuel. Fuel efficiency improvements are being wiped out by a shift to larger people movers and higher-powered cars with more features.

4.8.2 Benefits

There is the potential in every sector to reduce emissions of SO_2, NOx, nuclear wastes, heavy metals and CO_2 (See Table 8). The environmental benefits of reducing electricity consumption are greater than other for other fuels as the conversion from primary fuels to delivered energy is an inefficient process. One estimate by John Curren of Eastern Electricity of the costs of energy efficiency options is £4 to £8 per tonne of carbon avoided.

Sector	Million tonnes of Carbon Saved
Industry and Services	
Energy efficiency	5.3
CHP	4.4
Savings in CO_2 emissions	9.6
Transport	
Vehicle efficiency	8.4
Vehicle use for given demand	1.7
Travel demand reduction	4.8
Savings in CO_2 emissions	14.9
Domestic	
Space heating efficiency	5.7
CHP	0.5
Efficiency for lights and appliances	1.4
Savings in CO_2 emissions	7.6
Renewable Energy	
Electricity from renewables	2.5
Heat from renewables	0.2
Savings in CO_2 emissions	2.7
Total savings in CO_2 emissions	34.8

Table 8: ETSU Estimate of Potential Reductions in Carbon Emissions for the UK

Full-scale implementation of energy efficiency has the potential to cut users bills by 16 to 40% [113]. Improved appliance efficiency alone, encouraged through eco and energy-labelling schemes [114, 115] could save between 10% and 30% of primary energy consumption in Europe [116], 21,000 GWh of electricity in the UK [117].

The UK Government have estimated that about 20% of all the energy used could be saved using proven technology having a payback period of less than five years (see Table 9). This could save energy costing £10 billion a year [118], with energy cost savings in industry and commerce around £4.5 billion a year.

Emission	Reduction
CO2	110 million tonnes
SO2	740,000 million tonnes
NOx	440,000 tonnes
Radioactive waste	6,500 cubic metres
Mercury	10 tonnes

Table 9: Environmental Benefits of a 20% Reduction in Energy Consumption

The average UK household wastes over £278 per annum [119], £6 billion nationally, through inefficient energy use. The domestic sector is responsible for over one-quarter of CO_2 emissions. Inadequately heated homes exacerbate chronic bronchial problems [120]. Part L of the Building Regulations [121], imposing a minimum thermal insulation requirement for all new buildings, was first introduced in 1974 (revised 1990, 1995). The capital investment needed to overcome fuel poverty through better insulation and improved appliances is put at around £2,500 per household [122]. Table 10 shows various measures for reducing emissions of carbon dioxide in the domestic sector.

In an effort to increase uptake of energy efficiency various schemes and information campaigns have been supported such as: The Home Energy Efficiency Scheme (to combat fuel poverty), Standards of Performance, the Energy Saving Trust and the Energy Efficiency Best Practice Programme. Greenpeace [123] report that a cost effective energy efficiency programme would create 20,000 new jobs and produce new industry worth around £1 billion.

Energy Efficiency Measure	CO_2 Emissions Reduction (kg/y)	Payback Period (y)
Insulation		
Loft 150 mm	750 - 880	2
Internal wall	590 - 720	3 - 4
Cavity wall	750 - 880	4 - 8
Timber floor	60 - 190	>8
External wall	720 - 1,120	>20
Double glazing	190 - 320	8 - 15
Double low E glazing	250 - 450	20
Draught proofing		
Fill gap between skirting and floor boards with mastic	125 - 250	<1
Windows and doors	125 - 250	2 - 6
Heating System		
Gas fired condensing boiler	1,250 - 1,700	3 - 6
Heating programmer	250 - 320	1 - 2
Room thermostat	125 - 250	3 - 8
Thermostatic radiator valves	125 - 250	2 - 7
Hot water system		
80 mm insulation on cylinder	125 - 190	<1
Hot water pipe insulation	60 - 125	2 - 10
Hot water timer	60 - 100	2 - 5
Water heater thermostat	125 - 250	4 - 10
Solar water heating	350 - 1,300	10 - 50
Appliances		
Low energy light bulb	125 - 175	1 - 2
Best available electric cooker	355	
Freezer/ Fridge freezer	360	
Fridge	160	
Dishwasher	55	
Television	75	
Washing machine	50	
Only using heat, lighting and appliances when needed	190 - 500	0

Table 10: Carbon Dioxide Emission Reductions from Measures in the Domestic Sector [124]

4.8.3 Energy Services

Market liberalisation and competition gives cheaper fossil fuels an advantage over environmentally benign but more expensive options. Energy utilities are concerned with economic efficiency, driving down the unit costs of energy and encouraging increased consumption to achieve greater profits.

A sustainable energy system will require a change in the way energy is marketed. The provision of energy services is concerned with resource efficiency, reducing the consumption of energy whilst maintaining the same levels of service. Marketing energy services may delay the need to expand existing supply infrastructures to satisfy increasing demands.

A strategy of integrated least use resource planning, based on carbon minimisation would favour end use efficiency, natural gas and renewable sources of energy.

4.9 Renewable Energy

Renewable energy sources of energy are defined as being continuously and sustainably available in our environment. The ranges of energy flows in the environment are diffuse and there are many different technologies available to concentrate and convert them into useful forms of energy (see Table11).

Environmental Energy	Source	Technologies	Usable Energy
Potential and Kinetic	Wind, hydro, ocean wave and tidal	Wind, hydro, ocean wave and tidal	Electricity
Heat and Radiation	Solar radiation, geothermal, environmental heat	PV, solar thermal, absorption, passive design, photochemical cells, ocean thermal, heat pumps	Eelectricity Heat Fuel
Chemical	Biomass, refuse	Combustion, gasification, fermentation, digestion, pyrolysis	Electricity Heat Fuel

Table 11: Renewable Sources of Energy

Although renewable sources of energy are not without environment impact, they produce significantly lower levels of environmental pollutants than fossil or nuclear fuels. They generally emit no greenhouse gases, or are neutral over their life cycle in greenhouse gas terms.

Accounting for the indirect environmental costs (externalities) of conventional power generation, through higher unit prices, is seen as an important part of a sustainable energy strategy [125]. If this were the case the environmental advantages of renewable energy would quicken commercial viability, although this will depend on institutional support. Large profit seeking fossil fuel corporations were alleged to have thought that "the prospect of cheap locally controlled power was too frightening" and believed to have deliberately restricted widespread development of alternative technologies in the 1970's [126].

4.10 Sustainable Energy Policy

In 1982 Nigel Lawson, Secretary of State for Energy, explained that the UK energy policy was to have no policy [127]. The free market, Thatcherite Government did not support a national energy policy just policy on the supply-side economics.

The wider issues associated with energy consumption:

- Exhaustion of reserves of fossil fuel and the geo-political security of energy supply;
- The long technical and institutional lifetime of the physical infrastructure built for energy production ranges from decades to generations. Major changes are often costly and difficult to implement unless at the end of its economic lifetime;
- The social structure, where attitudes, habits and traditions determine energy use, is hard to change by policies, changes that do occur can take generations;
- Climate change, where the time lag between reduction in emissions and a visible effect on climate is will be several generations or more, and other global and local environmental considerations;
- National industrial economic competitiveness;

Mean that, for any country, no responsible energy policy resulting in sustainability (see Table 12) can be formulated on a shorter time scale than between fifty to one hundred years [128].

The problems of implementing such a policy will require strong leadership, accurate, accessible information, and involvement and co-operation at all levels in society.

Objective	Elements of that objective
To reduce energy-related emissions	Establish appropriate global, regional, national and local environmental targets and social objectives for the future of the energy market involving government, public and private sectors.
	Develop appropriate indicators through which to measure and publish progress towards and achievement of the environmental and social objectives.
	Regularly monitor and review implementation strategies.
	Increase global co-operation and exchange of technology, expertise, education, training programs, information, statistics and data on the best available environmentally sound energy technologies.
	Legislate for standards of performance, safety controls and waste management in the conversion, storage, transportation and use of all types of energy, relative to international best practice.
	Legislate for higher efficiency standards for buildings, lighting, electrical appliances and road vehicles.
	Provide energy efficiency information and the Standard Assessment Procedure for existing buildings.
	Establish appropriate economic, institutional and regulatory conditions to increase commercial innovation in the area of demand side management and encourage the uptake of energy efficiency through improvement programs, product energy labelling and the provision of sustainable energy services.
	Establish guidelines and internationally standardised methods of evaluating external environmental effects and total lifetime social costs and risks for all energy systems.
	Set strong economic goals. Provide a system of full-cost pricing (carbon tax), compensating for external damages resulting from energy related activities including energy production and use, waste disposal and decommissioning.
	Guarantee long term funding for the Energy Savings Trust. Use funds arising from external cost levies to finance energy efficiency improvements, best available energy technologies and offset labour taxes.
	Develop financial incentives to increase uptake of energy services and reduce tax on energy efficiency materials and appliances. Allow tariffs to reflect real costs of producing electricity.
	Provide training and employment strategies in energy efficiency to suppliers and installers of energy consuming equipment.
To encourage sustainable energy technologies	Establish programs for the substitution of non-renewable energy sources. Increase the % obligations for renewable electricity generation rather than emphasising price convergence. Allow tariffs to vary between schemes.
	Introduce intelligent load management to cope with fluctuating demand better and to enable a higher renewable energy contribution in the future.
	Provide financial incentives to allow renewable energy entry into heat markets.
	Develop appropriate financial instruments, which require energy distributors to invest a percentage of turn over in sustainable energy projects. Concentrate on energy efficiency and conservation rather than increasing supply.
	Discourage the building of new power plants, which do not use waste heat.
	Establish a national policy on the siting of renewable energy developments to reduce the time taken for planning applications.

Table 12: Policies Required for a Sustainable Energy System [129, 130, 131, 132, 133, 134]

To encourage sustainable energy technologies	Increase Government R&D support for developing energy efficiency technologies and renewables, concentrating on areas still un-proven, with the primary aim being to make small-scale technologies more cost effective.
	Removal of tax on transport bio-fuels.
	Require local authorities to carry out assessments of renewable energy in their area.
	Require local authorities to set local and regional targets for renewable energy generation, subject to an environment impact assessment, within local and structure plans (strategic land use planning).
	Allow local authorities to implement renewable energy with partnerships and act as guarantor for supplies of wood crops and wood wastes to reduce risks.
To increase public support	Prevent the building of renewable energy schemes that would be within boundaries or areas which may affect Special Areas of Conservation, Special Protection Areas, Ramsar Sites, SSSIs, or National Nature Reserves, unless it can be demonstrated that there will be no significant detrimental impact on the ecological interests for which the designation was made.
	Prevent development in National Scenic Areas, Natural Heritage Areas and any locally designated areas, unless it can be demonstrated that the development will not adversely affect the landscape qualities for which the area has been designated.
	Projects should only be given planning permission if the developer agrees to monitor actual environmental impact arising from the development and carry out all mitigation measures considered justifiable by interested parties.
	Projects should only be given planning permission if the developer agrees to limit environmental impact on decommissioning by restoration of site.
	Increase financial support to information centres for businesses and the general public to raise awareness of energy efficiency design, CHP, small-scale renewable energy developments and environmental issues.
	Encourage local management and ownership of electricity generating schemes, isolated and grid connected. Allow greater choice of energy resource options.
	Require consultation with local people early in the planning stage to ensure that renewable resources are used in a responsible way.
	Increase provision of grants, subsidies and independent expert advice to low income households for energy efficiency measures.

Table 12(continued): Policies Required for a Sustainable Energy System [129, 130, 131, 132, 133, 134]

4.11 Barriers to the Development of a Sustainable Energy System

The environmental and social objectives of sustainability are obstructed by competition in energy markets and the lack of a definitive Government energy policy. Without improvements in end use efficiencies and reductions in per capita consumption of energy, the 21st century energy system, in which renewable energy will play a vital part, may be less sustainable than at present.

The development of a sustainable energy system will rely on stimulating technological innovation, but is frustrated by insufficient industrial support, the lack of R&D commitment and a bias towards conventional power technologies.

The majority of Government renewables R&D finance is aimed at medium to large-scale developments even though most renewable energy sources are diffuse and more suited to small-scale projects.

Conventional fuels provide a concentrated form of energy capable of being stored. This storage capability provides flexibility, allowing distributors to match fluctuations in demand, delivering energy when and where it is demanded. Because of diffuse nature of most renewable energy sources (except biomass), they lack this versatility. The small-scale integration of intermittent sources of energy in the total supply is not a problem. A high proportion of intermittent power from renewables would create technical problems in matching supply and demand, requiring intelligent load management and new methods of energy storage.

5. Regional Renewable Energy Assessment

5.1 Energy Distribution

The total technical energy resources in the environment that have the potential to be converted into useful energy are in excess of current demand. However, they are not evenly spread throughout the UK. Each renewable energy technology has particular technological characteristics with increasing efficiencies and reduced costs extending their geographical scope. These factors directly affect any assessment of which mix of renewable energy systems are best and appropriate for any given region.

5.2 Economics

Energy Paper 55 [135] recommended the full economic exploitation of alternative energy resources in the UK to improve or develop new domestic and export markets. This is expected to benefit both rural and urban economies as heavy and light engineering skills turn to the production of renewable energy equipment [130].

The economic feasibility of similar renewable energy projects varies with existing infrastructure and geographical location. Each site will have different levels of insolation, wind speeds and civil engineering costs etc. They will therefore convert different amounts of energy at different costs.

5.3 Targets

The uneven geographical distribution of resources has to be considered when setting emissions and renewable energy targets. The availability of resources and therefore cost of conversion technologies will vary between regions. This will affect the costs of meeting these targets, which can only be set if information is available on the local environment and energy consumption.

Emissions are often concentrated in a few small areas; any cost-benefit analysis of measures to meet air quality standards is strongest when addressed at the plant level, weaker at a regional level, and weakest when applied at a macro level [136].

Spending priorities also vary between regions (whether to spend to get the most employment, or the biggest reductions in emissions, or the cheapest electricity etc.). With limited availability of financial resources and differing problems to solve it is important that targets are set locally.

5.4 Public Acceptance

Exploitation of dispersed renewable energy resources will lead to a large number of smaller generating plants and greater local control. Increasing the numbers of off-grid, DIY renewable energy schemes could be encouraged as part of the Local Agenda 21 process, the publicly acceptable number of these plants will vary from region to region. Even though the sum total of such schemes may be a small proportion of supply, their contribution to local demand can ease pressure on the grid and boost rural economies.

5.5 Resource use

The material requirements of renewable energy systems will be affected by local geo-physical, technical, environmental and economic constraints. The use of toxic materials can be required in the manufacturing of Photovoltaics (PV). Conversion of diffuse resources requires more plant than conventional conversion technologies, so renewable energy technologies are more capital and construction material intensive per unit of energy output. A study by the International Institute for Applied Systems Analysis in Austria estimates that a 20 TW supply from renewable energy technologies would treble the demand for construction materials such as steel, concrete and glass with associated environmental impacts.

Once constructed, renewable energy technologies have minimal consumption of resources during their lifetime. Short energy payback times mean the total material consumption can be lower than the total material consumption of resources by conventional fuel-based technologies, reducing total lifetime environmental burdens.

The objectives of increased resource use efficiency and provision of energy services will require comparative impact analysis of new technologies with respect to the local environment and management of local resources.

5.6 Administrative Areas

Policies encouraging sustainable development will need to support small-scale rural renewable energy schemes [137]. It is appropriate to incorporate administrative boundaries when defining an area to set targets for the utilisation of local renewable energy resources. Data required for resource assessment is usually collected on the basis of administrative areas. They also provide the local decision-making framework which influences development.

Although many similar issues affect the development of renewable energy projects in the UK, there are distinct regional variations [138]. Therefore any assessment of the potential for renewable energy should be done on a regional basis. Countywide assessments of renewable energy potential would be of enormous value to a County Council in developing its Structure Plan and assessing proposed renewable energy developments within its boundaries. Each county should know how much energy it could generate, as well as how much energy it uses, and hence its possible energy balance.

5.7 Local Authorities

Local Authorities are in a position to be innovative and take a lead towards sustainability, or learn from the experience of other authorities.

> *"Local authorities remain the best placed of any organisation to provide the legal and administrative assistance and political impetus which are vital prerequisites of any renewable energy development. But, it is important to stress the variation in local authorities in terms of their physical, economic and social conditions, also in the drive, enthusiasm and interest of their officers and elected members."* [139]

Local authorities can:

- Provide political commitment to sustainability founded on European and UK Government frameworks;

- Provide a strategic approach to sustainable energy through economically and environmentally efficient policy initiatives;
- Provide long term overviews of housing requirements, population growth, industrial development, transport etc.;
- Provide technical expertise;
- Increase energy efficiency of buildings through planning and building control by improving on statutory minimum standards;
- Provide opportunities to exploit new technologies e.g. passive solar design, district heating schemes etc.;
- Provide the resources necessary to obtain local energy audits and renewable energy assessments;
- Provide information on sites where renewable energy developments would or would not be considered;
- Provide information and help with putting together a bid for financial assistance from the European Union;
- Set environmental and renewable energy targets;
- Create partnerships with relevant utilities and other organisations to facilitate the development of demonstration schemes.

Finance is unavailable for local authorities to finance major power generation projects, but they can play a major role in their successful development.

In 1992 Planning and Policy Guidance Note 12 (PPG12) [140] incorporated guidance on development plans and regional planning including renewable energy as a topic which should be included in structure plans. In 1993, PPG22 [141] was issued, which offered further guidance on the importance of including appropriate renewable energy policies into Unitary Development Plans, Structure and Local plans.

5.8 Shropshire County Councils Role in Setting up Rural Regions Energy Teams

Shropshire County Council (SCC) adopted an Environmental Charter in 1991 [142]. The Charter stated SCC's commitment to sustainable development and set out policy aims with regard to improving the environment, covering: energy, transport, pollution, resources, wastes, the natural and built environment, information, education and green economics. As a consequence of the Charter, the post of Environmental Co-ordinator was established to guide subsequent actions.

The Environmental Co-ordinator acting for SCC, in association with Energy Technology Promotion (ETP) Ltd., initiated the submission of a successful proposal [143] in September 1994 to the European Commission Directorate-General for Energy (DG-XVII) Regional and Urban Energy Planning Programme (PERU). The aim was to set up regional energy teams in three rural regions of the European Union (EU), these regions being characterised by the important role agriculture plays in the local economy.

At the time of the submission for European funding, none of the regions had a specialist energy department or agency. With support from an established energy team (Zweckverband Regionale Entwicklung und Energie -ZRE), from the region of Oberpfalz-Nord in Germany the three teams were created in Shropshire in the United Kingdom, Limousin in France and County Donegal in Ireland. Although closely linked with their respective local/regional authority, each team was autonomous, with its own management structure, procedures and qualified staff.

5.8.1 Function of the Energy Team's

Funding was sought for a three-year period. The teams were to act as advisors, leading to improved understanding and awareness of the principles and mechanisms of energy planning at all levels within their regional authorities. The teams were to undertake specific actions, including the preparation of measures and policies [144, 145]. The strategy was to enable sustainable development by providing appropriate legal, planning, administrative and financial frameworks for the cost effective development of renewable energy sources and implementation of energy efficiency measures.

The teams were to support small-scale renewable energy schemes and investment in energy efficiency, especially in the small and medium sized enterprises (SME's) based in these regions. They were to do this by providing private investors with information, expertise and identifying potential sources of funding.

5.8.2 Anticipated Results

It was expected that the investment in energy efficiency in SME's, brought about by the energy teams would enhance competitiveness and lead to greater opportunities for growth, employment creation and improved standards of living. Investment in renewable energy technologies was seen as an aid in the diversification of agricultural land use, leading to the creation of both part-time and full-time employment opportunities during the construction and operation of new plant.

It was expected that the reduced dependence of the regions on imported energy supplies due to the use of renewable and indigenous energy sources and improved energy efficiency would lead to an improvement in the environment due to a reduction in the emissions associated with fossil fuels. It would also improve the local balance of payments in the energy sector, stimulating local economies.

5.8.3 European Co-operation

The international nature of the project brought together rural regions from four member states which had similar characteristics and which faced common problems. A co-ordination secretariat was established in Brussels managed by ETP Ltd., a Shropshire registered company based in Oswestry. The co-ordination secretariat was to encourage close communication between each of the project partners: SCC (UK), ETP Ltd (UK), Conseil Regional Du Limousin (CRL) (F), Donegal County Council (DCC) (Ir.), Inishowen Energy Co-operative (Ir.), Forbairt (Ir.) and ZRE (D).

Workshops run by ZRE and exchange visits were arranged to enhance the opportunities of bringing together staff and personnel to explore common needs, find optimum solutions and to exchange information and experience. In this way, the social and economic cohesion between the regions was to be strengthened.

5.8.4 Dissemination of Information

The partners involved in the project were members of a variety of European-wide networks (see Table 13). Some of the networks were established with support from various EU programmes such as FEDARENE, Energie Cities, OPET, Relay Centres and the EnR. These networks were to be used to disseminate the experience of setting up energy teams in rural regions, together with the results and conclusions arising from the specific actions undertaken, to other similar, or interested regions of the EU and from central and eastern Europe.

Partner	Network Membership
Shropshire County Council	Council of European Municipalities (through the Association of County Councils)
Limousin and Shropshire	Assembly of European Regions, together they held the joint chair of sub-commission 5.1 - Strategic Planning
ZRE	OPET established under the THERMIE programme, and an associated member of the FEDARENE
ETP Ltd	The ETM Consortium, the OPET based in Brussels, Belgium
Inishowen Energy Co-op	Co-operated with the Holywell Trust, based in Derry, Northern Ireland, on an infrastructure project through the Interreg programme
Forbairt	OPET and has links with the FEDARENE. Contacts with organisations from other Atlantic areas, notably Bretagne and Galicia

Table 13: Network Membership of Rural Energy Team Partners

Close links were forged by the teams with major European organisations in the energy sector - the Commissions and other international institutions, national and regional associations, professional and trade associations, the financial institutions, and major equipment suppliers. These links were used to further disseminate the results.

5.8.5 Rural Regions Network

In addition to the existing networks, the energy teams were to establish a Rural Regions Network (RURENET) to enhance dissemination of information. The aim of this network would be to provide a permanent forum where the problems facing rural regions, such as, heavy reliance on agriculture, slow or declining population growth, strong tourist sector and the fact that most industrial companies are SME's etc., could be discussed from an energy and environmental viewpoint. Such a network was to complement work of the FEDARENE, Energie Cities and the ISLENET.

5.9 Shropshire Energy Team

The Shropshire Energy Team (SET) was launched in February 1995, as the first of it's kind in the UK. In addition to support through the PERU programme and Shropshire County Council, the SET secured pledges of support both financial and in-kind from Midlands Electricity plc the Department of Trade and Industry (DTI) through the Energy Technology Support Unit (ETSU), the Combined Heat and Power Association (CHPA) and the regional Energy Efficiency Office.

5.9.1 Shropshire Energy Team Programme of Work

Following the adoption of the Environmental Charter some limited polices were developed to encourage energy efficiency and the use of renewable energy sources in the County, but no formal energy plan was prepared.

The main aim of the SET was to advise the Local Authority on appropriate frameworks to help the County to fulfil its' Environmental Charter objectives. The target was set of more than meet the County's share of the nations obligations in reducing greenhouse gas emissions. The work undertaken by the SET [146, 147, 148, 149] was broadly classified as: Energy Planning, Renewable Energy and Energy Efficiency.

6. The County of Shropshire

Shropshire - a contraction of Shrewsburyshire. Shrewsbury is from the Anglo-Saxon scrobb, a shrub, and burh, a town, i.e. the town amongst shrubs [5].

6.1 Location and Landscape

Shropshire is a predominantly rural county, with the most varied landscape in the West Midlands, having 11 of the 13 periods of geological time represented in its geology. Located in the west of the region, it is part of the area along the Welsh border known as the Marches. Powys and Clwyd are to the west; Cheshire is to the north, Staffordshire to the east and Hereford and Worcester to the south. The border struggles between Anglo-Saxons, Welsh and Normans in medieval times resulted in many earthworks and castles.

Shropshire is divided by the Severn River, which wanders through the county for seventy miles, flowing from Wales to the Bristol Channel. It is Britain's longest river, with the second highest tides in the world and bores of up to five feet.

Designation	Area
Uplands	104,600 ha.
Sites of Special Scientific Interest and National Nature Reserves	6,600 ha.
Environmentally Sensitive Areas, in the south west	20,000 ha.
Prime Sites for Nature Conservation	10,700 ha.
Area of Outstanding Natural Beauty, South Shropshire	78,000 ha.
Shropshire Wildlife Trust Nature Reserves	834 ha.
Areas of Special Landscape Character	10 areas
World Heritage Site	Ironbridge

Table 14: Shropshire Landscape [150]

Shropshire covers an area of approximately 348,700 hectares. The quality of the natural and built environment gives Shropshire a unique character (see Table 14). Northern Shropshire is a glacial landscape, part of the Cheshire Plain. To the north and north-east of the river land is generally level or gently undulating, with good quality agricultural land, small woods, red sandstone ridges, historic park-lands, mosses and heaths. The northwest uplands around the Oswestry borderland are hill-farming areas. The range of small hills running across the northern plain contains most of the County's small lakes (meres), pools and other wetlands. The Severn Plateau runs through the centre of the county with settlements and industry in towns e.g. Shrewsbury and Bridgnorth.

Nearly one third of the County is uplands, mostly to the south and southwest. South Shropshire is one of the least populated areas in England. Around 78,000 hectares of the South Shropshire hills are designated as an Area of Outstanding Natural Beauty with a variety of landscapes varying from moorland and woodlands to arable farming.

Shropshire is ecologically important [151] with 95 Sites of Special Scientific Interest (SSSI's), two National Nature Reserves and 670 recognised Wildlife Sites.

6.2 Administrative Structure

Pre-1998 the administrative structure of the County of Shropshire was sub-divided into the 6 administrative areas:

- Bridgnorth
- North Shropshire
- Oswestry
- Shrewsbury & Atcham
- South Shropshire
- Wrekin

On April 1st 1998 the administration of the County of Shropshire was split between the new Shropshire County Council and Wrekin Unitary Authority.

6.3 Land Use

Around 81% of the total land area in Shropshire is used for agricultural purposes (see Table 15.). Dairy holdings are concentrated in the north and northwest, with the south and southwest noted for its livestock raising. Pigs and poultry farms are spread throughout the County.

Land Use	Shropshire	Hectares	UK Average
Grassland	46%	160,433	
Rough Grazing	3%	10,463	
Grassland & Rough Grazing			54%
Crops and Fallow	32%	111,605	22%
Total Agricultural Land	81%		76%
Woodland	8%	27,901	11%
Urban and Other	11%	38,364	13%

Table 15: Land Use in Shropshire and UK [152, 153, 154]

6.4 Population

In the period 1891 - 1931 Shropshire's population rose from 236,800 to 244,200. By 1961 the population of the County had grown to almost 300,000 (see Table 16). Between 1951 and 1991 population growth was dominated by growth in Wrekin District due to the establishment of Telford New Town.

Year	Shropshire Population	Shropshire Population Density (persons/hectare)	UK Population Density (persons/hectare)
1700	Under 136,000	Under 0.39	
1891	236,800	0.68	1.13
1931	244,200	0.70	
1951	290,000	0.83	
1961	297,800	0.85	
1971	337,100	0.97	1.80
1981	378,300	1.08	1.81
1991	406,387	1.16	1.86

Table 16. Population Densities of Shropshire and the UK [2, 5, 155]

At the time of the 1991 census the population of Shropshire was 406,387 making the county the third smallest in England in population terms. Shropshire was the 13th largest county, but, with an average density of 1.2 persons per hectare, was one of the least densely populated.

6.4.1 Population Growth

However, Shropshire was one of the fastest growing counties in the country. Between 1981 and 1991 its population grew by over 28,000 (7.4%). Shropshire was the 7th fastest growing county in England and Wales during the 1980's, and had the highest growth in population of any county in the north of England (north of a line between the Bristol Channel and the Wash) [155].

Urban areas accounted for some 92% of Shropshire's population growth between 1981 and 1991, with population growth in the Wrekin District accounting for over half of the County's population growth during the decade.

Rural areas saw an increase in population of less than 2%, although the south and west tended to see greater population rises than those in the north and east, which overall saw a small decline in population during the decade. The Wrekin and Bridgnorth experienced declines in their rural populations, with both South Shropshire and Oswestry districts having increases in their rural populations.

Overall the Shropshire population is expected to expand (see Table 17), with the age structure of all groups over the age of 45 predicted to increase by over 30% by 2008. National Road Transport Forecasts predict an increase in road traffic of between 27 to 43% between 1996 and 2011. Traffic in Shropshire is forecast to increase by 83 to 142% by 2025 [153]. A contributing factor to the outward migration of young people was thought to be the lack of investment in IT infrastructure and insufficient affordable public transport.

	Population	Per cent change				
District	1996 Base Year	1996-2001	1996-2006	1996-2011	1996-2016	1996-2021
Bridgnorth	50,800	-1.0%	-1.6%	-2.2%	-2.4%	-2.7%
North Shropshire	54,100	2.6%	4.5%	6.0%	7.4%	8.7%
Oswestry	34,600	3.8%	6.8%	9.3%	11.4%	13.2%
Shrewsbury & Atcham	97,100	-0.5%	-1.0%	-1.7%	-2.0%	-2.1%
South Shropshire	40,500	4.1%	7.0%	9.5%	11.9%	14.1%
Total new Shropshire	277,100	1.2%	2.1%	2.7%	3.5%	4.2%
Telford & Wrekin UA	144,200	6.4%	11.4%	15.6%	19.2%	22.2%
England	49,089,100	1.6%	2.9%	4.2%	5.6%	6.9%

	Total Population					
Year	1996	2001	2006	2011	2016	2021
Shropshire County	421,300	433,800	443,600	451,400	458,600	464,800

Table 17. Population Projections for England and Shropshire [156]

However, a report [157] published in 1998 showed that even though traffic congestion has added an average 2.5 hours per week to work related journeys since 1990 only 7% of commuters would switch to public transport even if their journey time doubled. The number of cars on the road in the UK is expected to increase to 36 million early in the 21st century.

6.4.2 Population Distribution

More than half the County's residents live in the four main towns of Telford, Shrewsbury, Oswestry and Bridgnorth, with the remainder of the population living in settlements of less than 10,000 persons.

The average population density of wards in Shropshire varies from 59.33 persons per hectare in Woodside ward in Telford, to 0.07 persons per hectare in Newcastle ward in South Shropshire [155].

When the Wrekin became a new unitary authority, new Shropshire County Council became the smallest county in population terms in England, with only 280,000 people, but the 14th largest in geographical terms at 320,000 hectares [158]. In new Shropshire, 44% of people live outside the towns, whilst Wrekin's population is largely urban.

6.5 Economic Development

Although the county is primarily agricultural, it has industries that include manufacturers of a variety of metal products & machinery and mineral workings (aggregates, coal, and clays).

The Wrekin district is the driving force behind the economic growth of the county, partly because of the growing success of Telford and infrastructure improvements. There is still a need to diversify and strengthen the vulnerable rural economy. The call for economic and infrastructure development needs to be balanced with SCC policy of protecting and enhancing the diversity and quality of Shropshire's natural and built environment. Government policy for regeneration also emphasises the need for involving local communities.

6.5.1 Regional Economic Development

Examination of economic development and employment growth [159] has shown that the top performing places are characterised by having a highly qualified workforce, a high rate of land change from rural to urban use, low density of population, good roads and other transport links and a rapidly growing hinterland. The poorest performing places being characterised by having a poorly skilled workforce, low rural to urban land changes, high population densities, traffic congestion and a stagnating hinterland.

Proposals [160] were set out in December 1997 to create nine Regional Development Agencies (RDA's) as statutory organisations with devolved budgetary powers. Created in 1998, their strategic remit was to promote regional economic and social regeneration within the ethos of sustainable development [161]. RDA's were to be business led and based on partnerships with all key stakeholders. Actions were to take into account both rural and urban needs and national priorities. Key functions being to:

1. Improve support for SME's;
2. Create employment;
3. Upgrade skills to make regions more internationally competitive;
4. Help and attract new inward investment;
5. Assist brown-field site regeneration.

Remediation techniques for brown-field sites are not cheap, prices of land for international business vary from around £100,000 to £1.25 million per hectare, reflecting the amount of infrastructure already in place.

Much of the west and south of Shropshire is classified as Objective 5(b); the areas around and including Telford are classified as Objective 2. New investment is required to further develop the social and economic infrastructure in Shropshire to ensure the future of market towns. As the industrial structure changes from traditional industries to the service sector, skills of the labour force will need to change to meet needs of new employers.

It is the aim of SCC to work with the Regional Development Agency for the West Midlands, along with the Government Office for the West Midlands and other relevant government departments and the European Commission to ensure the availability of resources for the benefit of Shropshire [162].

6.6 Employment

In 1984 unemployment in the county was 16% with nearly 23,000 people unemployed especially in Oswestry, Ludlow and North Shrewsbury. In 1989 unemployment was 4.7%, continuing to fall to 9% in December 1992 and 3% in December 1997 with 3,647 people claiming benefit.

Year	Indicator	Shropshire	West Midlands	UK
1993	GDP £ per head index	92.4	93.1 98.2	100
1995	GDP £ per head		£9,649	£10,134
1994	Average income per household index	96.9	92.9	100
1996	Av. weekly hours worked	M 43.5 F 38.1	M 42.3 F 37.7	
1996	Av. Weekly earnings	£302.4 M £327.7 F £227.9	£324.3	£351.7
April 1996	Av. Weekly earnings in the Wrekin	M £369.2 F £248.0		
1997	Av. Weekly earnings		M £360.10 F £256.00	M£391.60 F £283.00
1995	Persons in employment	155,400	2,018,400	26,265,000
Dec. 1997	Unemployment rate	3.0%	4.9% 6.2%	4.9%
Oct. 1997	% Claimants unemployed > 1 year	20.1%	31.4%	30.3%
1991	Av. Distance to work	8.7 km	7.4 km	8.0 km
1995	Proportion Achieving 5 GCSE's or equivalent by 19	73%	63.58%	70%
1996	Proportion of working age population in employment with NVQ level 3 or above	39.4%	37.0%	42.3%
1997	Proportion of companies > 50 employees recognised as investors in people	10.4% (54 workplaces)	12.9%	10.2%
1995 / 96	Total recorded crime per 1000 of population	Shrewsbury 32.34 Telford 64.36	West Mercia 70	96

Table 18: Economic and Social Indicators [162, 163]

The 1995 Census of Employment reported that 87,500 people were employed in Shropshire. Much of this employment is low skilled and relatively low paid, with an above average dependence on part time, seasonal employment and a high level of self employment.

Compared to the average in 1996 wages for males were the 14th lowest nationally and wages for females the 5th lowest nationally (see Table 18).

In 1991, 20,700 Shropshire residents worked outside the County and 13,200 people from outside worked in the County. Employment in the manufacturing and service sectors was predominately town based. 13% of the South Shropshire workforce and 4% of all workers in Shropshire were employed in agriculture (see Table 19). Over one-third of the full-time farms were involved in some form of farm diversification.

Year	1981		1989		1991		Change
Job	Number Employed						1981-1991
Agriculture, forestry, fishing	8,000	6.6%	6,600	4.4%	6,500	4.3%	-1,500
Energy & Water	2,800	2.3%	2,400	1.6%	2,400	1.6%	- 400
Mineral Processing	3,500	2.9%	4,200	2.8%	3,700	2.5%	200
Engineering	19,800	16.3%	23,100	15.5%	21,800	14.4%	2,000
Other Manufacturing	8,700	7.1%	14,700	9.9%	16,500	10.9%	7,800
Construction	7,100	5.8%	7,100	4.8%	6,600	4.4%	-500
Distribution	23,900	19.6%	33,100	22.2%	33,000	21.9%	9,100
Transport	6,300	5.2%	7,200	4.8%	6,500	4.3%	200
Finance	6,300	5.2%	9,300	6.2%	10,000	6.6%	3,700
Other Services	35,300	29.0%	41,500	27.8%	44,000	29.1%	8,700
Total Employed	121,700	100%	149,200	100%	151,000	100%	29,300
Total Number of Jobs			168,000				
Resident Labour Force			185,000				28,100
1996	208,700						
2011	233,900						

Table 19. Employment Structure [152, 153]

The total number of VAT registered companies and organisations in Shropshire totalled 14,386 in 1991. Excluding the self-employed, the number of registered workplaces amounted to 9,508. At most of these (88%), fewer than 25 employees worked; a further 6% of workplaces had less than 50 employees.

6.7 Tourism and Recreation

Shropshire's environment is one of its key assets and also a major attraction for investors. Shropshire's unspoilt rural character, the quality of its landscape, border castles, historic market towns and attractive villages all contribute to Shropshire's attraction for tourists.

Tourism and recreation are growing in importance. Rising demand requires new facilities. As well as benefiting the users, tourism and recreation provide jobs and make a valuable contribution to boosting and diversifying the rural economy.

6.8 The Planning Framework

An energy policy that encourages widespread uptake of small-scale schemes integrates closely with rural economic development and welfare policies. It has been shown that focusing on village level energy schemes [137] has important implications for economic and social change. They can offer a least cost alternative to grid extension and extend technical knowledge, skills and jobs.

The framework for controlling land use and development is mainly provided for by the town and country planning system [164]. Local authorities make decisions on proposals to build on land, or change its use [165]. These development control decisions must conform to development plans prepared by local planning authorities unless government guidance [166, 167, 168, 169, 170, 171, 172, 173] indicates otherwise.

Structure Plans are prepared by county councils and contain strategic policies as a framework for district councils. Local Plans are prepared by district councils and contain development control policies and proposals. Development Plans comprise these local plans and structure plans, except in London and metropolitan districts, where a Unitary Plan combines the function of structure and local plans.

6.8.1 Environmental Considerations

The Council for the Protection of Rural England (CPRE) state that planning should become supply limited rather than demand driven, with job creation concentrated in sectors that are relatively environmentally benign. They recommend [174] that the primary objective in planning policy must be protection of the environment as it provides the source and context for sustainable economic and social development.

An awareness of the state of the local environment is an essential basis of any long-term attempt to plan for sustainability [175]. The first step in policy making is to identify the un-sustainable demands on non-renewable resources. This, followed by survey of environmental resources allows the setting of realistic goals and objectives and the establishment of environmental indicators and monitoring programmes.

6.8.2 Town and Country Planning

The Town and Country Planning Act 1990 requires planning authorities to have regard to the environmental effects of implementing the policies during plan preparation. Local Agenda 21 also requires that local authorities consider the environment, working in partnership with the community to "think globally, act locally" and secure a more sustainable way of life.

Government advice [173], states that the planning system should contribute to the objectives of sustainable growth and development. These objectives mean that Development Plans should include policies to encourage:

1. The conservation of local environmental quality and biodiversity;
2. The appropriate use and protection of natural resources;
3. Integrated land use and infrastructure planning (particularly transport) to reduce energy consumption and pollution.

6.9 Shropshire Structure Plan

Shropshire County Council's Structure Plan is the countywide development strategy to take Shropshire into the 21st Century. It provides a co-ordinated basis for new infrastructure, economic development and environmental protection for each part of the County. It also establishes the broad strategy for integrating the County's role into policy planning for the nation and the West Midlands Region [172].

The County Council's Structure Plan strategy has the following aims:

1. To promote a high quality, attractive, safe environment by preserving and maintaining the setting of historic towns and rural character of the County;
2. To improve the quality of life and develop communities by providing appropriate infrastructure, homes, services and amenities for local people;
3. To support job creation and broaden the employment base by encouraging diverse, innovative and profitable business, welcoming appropriate small scale industrial and commercial developments in or adjacent to rural areas adversely affected by changes in the agricultural industry;
4. To raise educational achievement and provide higher quality employment skill training;
5. To alleviate traffic problems in both urban and rural areas, locating development so as to minimise travel, especially be private car, encouraging non-motorised travel and greater use of public transport.
6. To set up an environmental audit to examine energy and land use issues including the energy implications of planning and transportation policies

Energy policies are seen as a key factor in the evolution of a sustainable society in Shropshire [177]. The structure (location, orientation, size, population density etc.) of a sustainable society will depend on the type of energy resources available and their methods of distribution. The present structure of society determines the extent to which any of these resources may be practically implemented. Although the length of time it takes to change infrastructure constrains what can be done, energy conscious land use planning and positive actions to promote conservation, better building design and use of renewable resources in new developments will reduce future demand for energy, improving the quality of life for people and maintaining the environment [178, 162].

7. Energy in Shropshire

To be able to develop a practical, long term energy strategy in Shropshire requires an understanding of how the energy sector operates, with answers to questions such as:

1. What fuel sources are used?
2. How is energy generated, transmitted and distributed?
3. Where are the positions of primary energy import and export in the distribution infrastructure?
4. What is the general pattern of energy consumption and where are the areas of high, medium and low energy use?
5. What exactly are the environmental implications of this energy consumption?
6. What changes in the existing methods of power generation, transmission and distribution could lead to a decrease in environmental impact?
7. What is the potential for indigenous and renewable energy sources?
8. How can the nature of consumption be altered to reduce environmental impact?
9. How can energy efficiency and the development of renewable energy be encouraged?
10. What obstacles may be encountered in implementing a sustainable energy system?

7.1 Energy Planning

The knowledge provided by such an analysis would form the basis of an energy plan for the administrative districts and Shropshire as a whole, to build on Environmental Charter objectives and contribute to the UK's obligation in attaining international emission reduction targets.

A coherent energy plan should:

1. Decrease the dependence on using coal and nuclear power, which produce electricity at large, centralised power plants.
2. Act as a local focus and create a framework for action to improve energy use.

3. Identify those sectors where the greatest social, economic and environmental opportunities occur when reducing fossil fuel dependency;
4. Set realistic and achievable targets and time-scales for reduction of energy consumption, energy efficiency and economically feasible and environmentally appropriate renewable energy.
5. Measure progress towards achieving sustainability objectives on a yearly basis to validate any energy strategy.
6. Encourage a less wasteful use of energy to reduce energy costs.
7. Lead to the creation of new business and employment opportunities in building and servicing new technologies.
8. Provide manufacturers of renewable energy technologies with acceptable performance guidelines, covering: quality assurance, conversion efficiencies and noise levels.
9. Provide planners with sufficient information to enable comparative project evaluation and clear guidelines on locating renewable energy technologies and proximity to housing.
10. Ensure strict control over construction and plant operation, with financial liability for environmental protection falling on operators.
11. Encourage individuals and communities to have more control over the energy they use by getting more of their heat and electricity from locally available renewable energy resources.

7.1.1 Data Required

The initial step in preparing a strategic energy plan is to establish, as far as is practicable, the position with regard to energy consumption in the County. Ideally, annual accurate electricity, gas, oil and coal consumption data for the domestic, industrial, commercial, agricultural and road transport sectors within Shropshire is the minimum data required to allow environmental targets to be set.

The base year for this consumption data should be 1990 because this is the base date for most international, European and national energy and pollution targets. However, it is not possible to gain all this data for 1990 and even with the best data collection it will be impossible to establish exactly how much energy is used in the County in each successive year.

7.1.2 Difficulties in Obtaining Data

Although figures are available on national energy consumption, with the accuracy of government statistical agencies being ranked as equal sixth out of the 13 largest industrialised countries, alongside Germany and the USA [179]. It is very difficult to get accurate data for energy supply and demand on a regional basis in the UK. The reasons for this are as follows:

1. The exact source of electricity through the National Grid is not traceable and various assumptions have to be made.
2. Although the national gas and electricity supply network can be readily mapped, other fuels' such as oil, road fuel and coal have a fragmented supply system and are too complex to map.
3. Records of distribution for these many small to large companies cannot be easily accessed and do not necessarily correspond with the area information is required for.
4. Companies may be unable to provide detailed figures for energy use due to a lack of time and resources.
5. Public and commercial energy records of energy use are mostly based on costs.
6. There is a general lack of detailed energy use monitoring made on a regular basis.
7. Where fuel consumption records are kept, they may be only the total annual use and it is difficult to estimate the percentage of each fuel source used for each application.
8. The large number of private dwellings.
9. Data of equal quality and accuracy to the original data set will be required each year for any meaningful comparisons.
10. Since the privatisation of the electricity and gas industries, much of the existing data is considered to be commercially sensitive. Public bodies are therefore denied access to it, even though individual customer data is not necessary for energy planning.

11. The data that can be supplied by Public Electricity Suppliers is constrained by the Data Protection Act 1984 and Section 57 of the Electricity Act 1989.
12. The completeness and accuracy of available information is not guaranteed accurate or complete.
13. Where figures can be obtained from different suppliers of the same region it may be on varying basis e.g. postcode and ward, requiring data interpretation and manipulation.
14. Suppliers of information may not allow themselves to be recognised as the source of the data, or allow the existence of it to be publicised.

Because of these difficulties it is necessary to supplement what data is available for Shropshire by indirect determination of energy consumption figures based on information supplied by the public energy utilities in pre-privatisation days, UK national energy statistics and studies of other areas.

7.2 Estimation of Regional Energy Consumption and Associated Emissions

It is acknowledged that estimating energy consumption and associated emissions solely on pro rata national statistics will be very approximate, since national statistics will not reflect the local pattern of industrial, commercial, agricultural and transport activity, nor the particular fuel mix within the county. However, even a very preliminary estimate provides a useful basis for more detailed and more meaningful evaluation.

7.2.1 Aims and Objectives

There are no nationally published statistics currently available or data or easily obtainable on Shropshire primary fuel demand for energy use, electricity consumption or related emissions. The purpose of this work was to develop a methodology to answer these questions from 1990 onwards up to 2025, under a business as usual scenario, to provide baseline data for target setting, progress monitoring and determine the potential contribution that renewable energy resources could make to emission reductions.

Most importantly the methodology is intended to be applicable for use in other local authorities in the UK needing to carry out local energy accounting where data on both the state of the environment and on energy use is also scarce.

The method is intended to be straightforward and simple for a local authority to apply using commonly available data such as:

1. National population statistics from the Office of National Statistics.
2. Other statistics such as population figures, population density and number of households, gathered by local authority planning and information groups.

7.2.2 Scope

The area under consideration is the County of Shropshire including the administrative districts:

Bridgnorth

North Shropshire

Oswestry

Shrewsbury and Atcham

South Shropshire

The Wrekin Unitary Authority

7.2.3 UK Energy Supply

The final energy demand in the UK is met by a combination of primary and secondary fuels. Primary fuels are those that occur naturally, such as the fossil fuels coal, oil and natural gas, or are derived by directly harnessing naturally occurring energy, as in nuclear power and hydro-electricity. Secondary fuels, such as petroleum products, coke and secondary electricity are obtained from the conversion of primary fuels or other secondary fuels. All energy conversion processes are inefficient, limited by the laws of thermodynamics. This means that a large proportion of the heat value of primary fuels is lost as waste heat during conversion and subsequent transmission and distribution to final consumers.

7.2.3.1 Primary Fuel Input

For comparison and aggregation purposes energy consumption can be expressed in terms of the energy content of the primary and secondary fuels. For statistical purposes the tonne of oil equivalent is used [180] which is defined as 41.868 GJ or 11,630 kWh. The following figure shows UK inland consumption of primary fuels and equivalents for energy use from 1960 to 1997, with an average yearly rate of increase in demand of 0.87%.

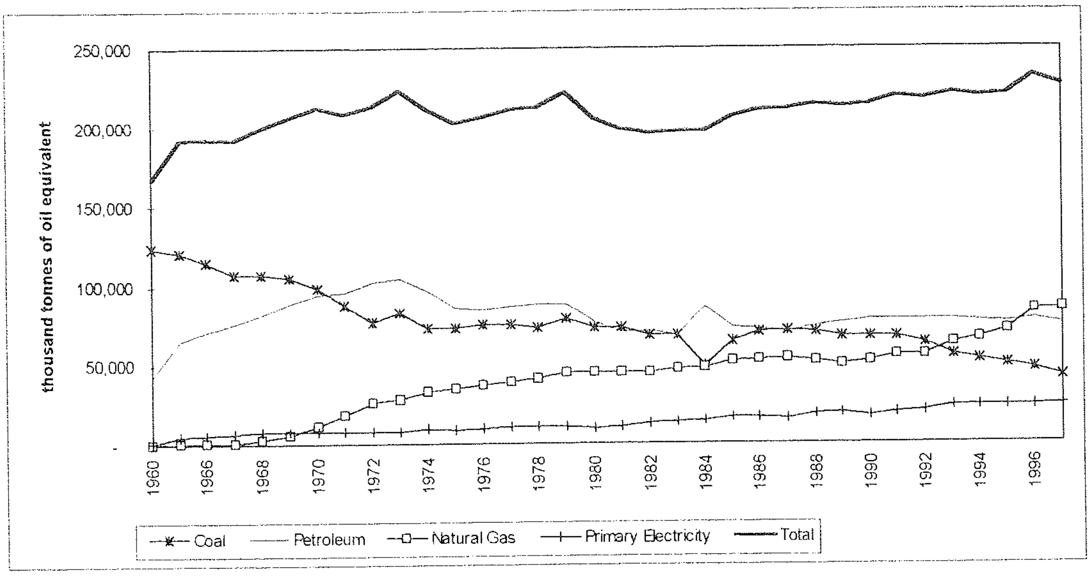

Figure 1: UK Inland Consumption of Primary Fuels and Equivalents for Energy Use, 1960 to 1997 [180 Tables 1.1 and 1.13].

1. The primary fuel input basis figures includes energy used or lost in the conversion of primary fuels to secondary fuels, energy lost in the distribution of fuels and energy conversion losses by final users.
2. Coal includes manufactured and other solid fuels, from 1988 includes wood, waste etc.
3. Petroleum includes crude oil, process oils, petroleum products plus natural gas liquids.
4. Natural gas includes colliery methane up to 1988, and from 1988 landfill gas and sewage gas.
5. Primary electricity includes nuclear, hydro and net electricity imports. Natural flow hydro-electricity includes onshore wind from 1988 but excludes pumped storage.

Total consumption rose at an average rate of 2% in the years 1960 to 1973 to over 223 million tonnes of oil equivalent (mtoe), dropping by 5% in 1974 and a further 4% in 1975 after the first oil embargo. Consumption increased to almost 1973 levels by 1979 but dropped by 8% in 1980, falling to under 200 mtoe till 1985 following the second oil embargo. Since 1985 consumption has increased with 1996 and 1997 demand exceeding the peaks of 1973 and 1979.

Figure 1 illustrates the move away from coal, which provided 74% of the primary fuel requirement in 1960, 36% in 1972 and only 19% in 1997. As oil replaced coal the demand increased from 26% of primary fuel requirement in 1960 to 48% in

1972. As natural gas replaced oil the demand increased from only 12% of the primary fuel requirement in 1972 to 37% in 1997, whilst the demand for oil decreased to 33%.

7.2.3.2 Conversion Losses

The magnitude of energy losses occurring during the conversion of primary and secondary fuels to electricity and other secondary fuels for 1997 is shown in Figure 2. 97% of the total conversion losses, just over 46 mtoe of the energy input, were lost during the production of electricity. This was equivalent to more than the total inland consumption of coal. Another 16 mtoe of the fuel input was consumed by the energy industries themselves, with 5 mtoe lost in distribution.

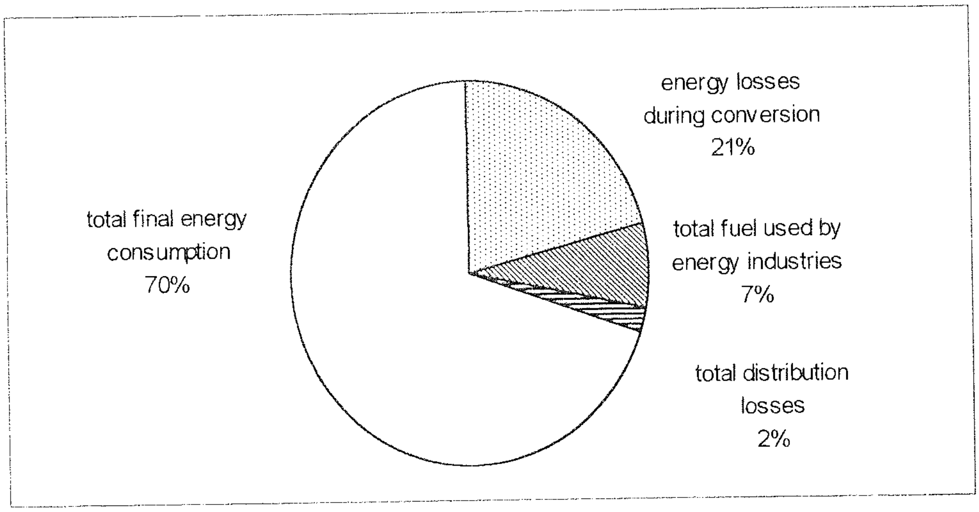

Figure 2: UK Consumption of Primary Fuels and Equivalents for Energy Use by Final User, 1997 [180 Tables 1.1, 1.2, 1.3].

1. Fuel input expressed in terms of the energy content of fuels from primary and secondary fuel supply, through conversion into secondary fuels (such as petroleum products, coke and breeze, coke oven gas and secondary electricity), to final users.
2. Total inland energy consumption of primary fuels and equivalents in 1997 was 226,904 thousand tonnes of oil equivalent with final users consuming nearly 158 mtoe. Transport 53 mtoe, domestic 45 mtoe, industry 38 mtoe and other final users 22 mtoe.

7.2.3.3 Energy Supplied to Final Users

The total final energy consumption is based on categories found in Standard Industrial Classifications (SIC) 1992 [181] and includes industry, transport, domestic and other final users (see Figure 3).

From 1960 to 1984 the industrial sector had the largest demand for energy, its share of the total final consumption being 42% and 30% respectively. Consumption gradually declined, as the number of energy intensive manufacturing industries also declined, from 1974 and by 1997 the industry share was only 24% of the total final consumption. Energy consumption in the transport sector has grown rapidly since 1960, remaining the largest consumer since 1988. Demand from the domestic sector continues to grow steadily with the increasing population but its share remains fairly constant at around 25 to 30% of the total final consumption. Agriculture, commerce, public administration and other services are included in the category other final users. Demand for energy in this sector had risen 48% over 1960 levels by 1997, although its share only went from 12 to 14% of the total final consumption.

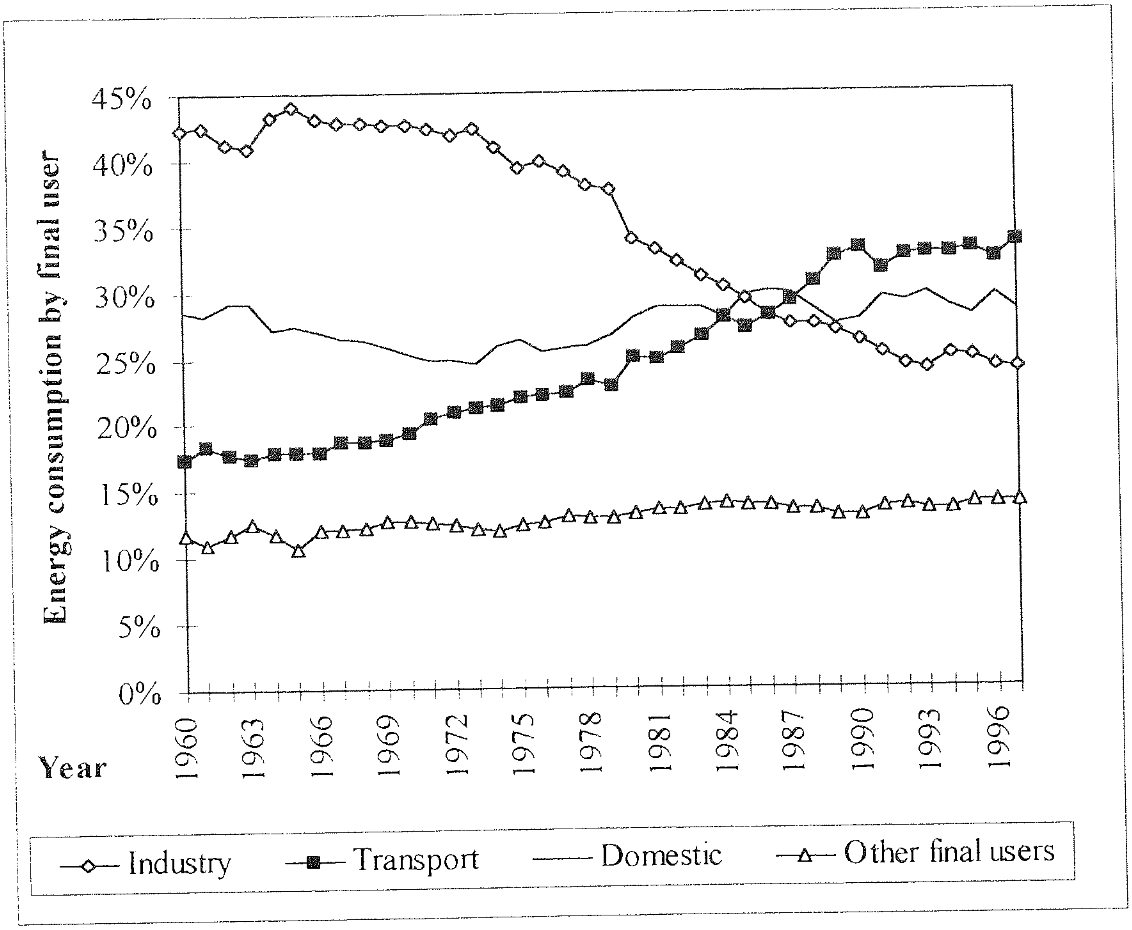

Figure 3: UK Final Energy Consumption by Sector 1960 to 1997 [180 Tables [180 Tables 1.6,1.17].

1. Includes conversion losses by final users.
2. Total final energy consumption by final user was 127 mtoe in 1960. Transport 22 mtoe, domestic 36 mtoe, industry 54 mtoe and other final users 15 mtoe.

The trend in final consumption of individual fuels by these sectors is shown in figure 4. The main fuels were coal, petroleum, and coke & breeze in 1960; petroleum, coal and electricity in 1970; and petroleum, natural gas and electricity since 1980.

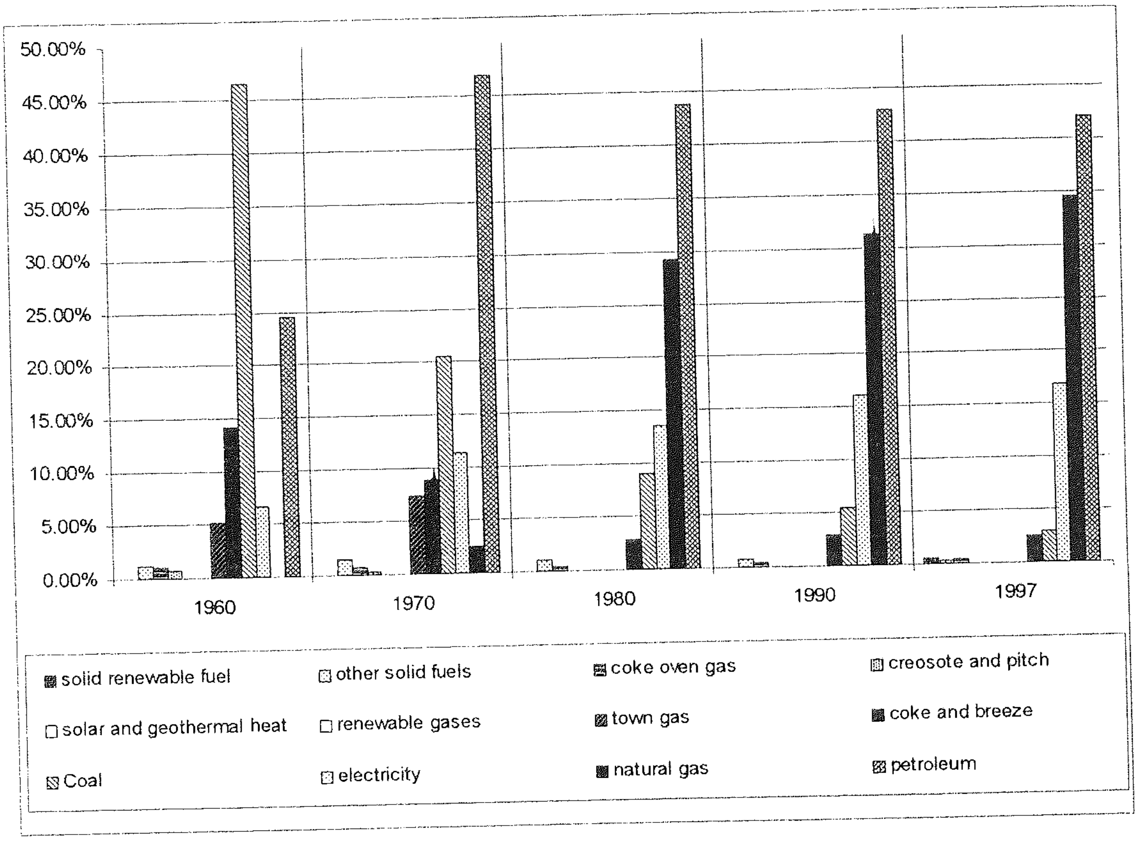

Figure 4: UK Final Energy Consumption by Type of Fuel 1960 to 1997 [180 Tables 1.6,1.17].

1. Includes conversion losses by final users.

Figure 5 shows the fuel consumption of each sector for 1997. The final user with the largest consumption of coal, coke & breeze and coke oven gas was the industry sector; the domestic sector was the largest consumer of natural gas and other solid fuels; road transport was the largest consumer of petroleum; with almost equal consumption of electricity by the sectors industry, domestic and other final users.

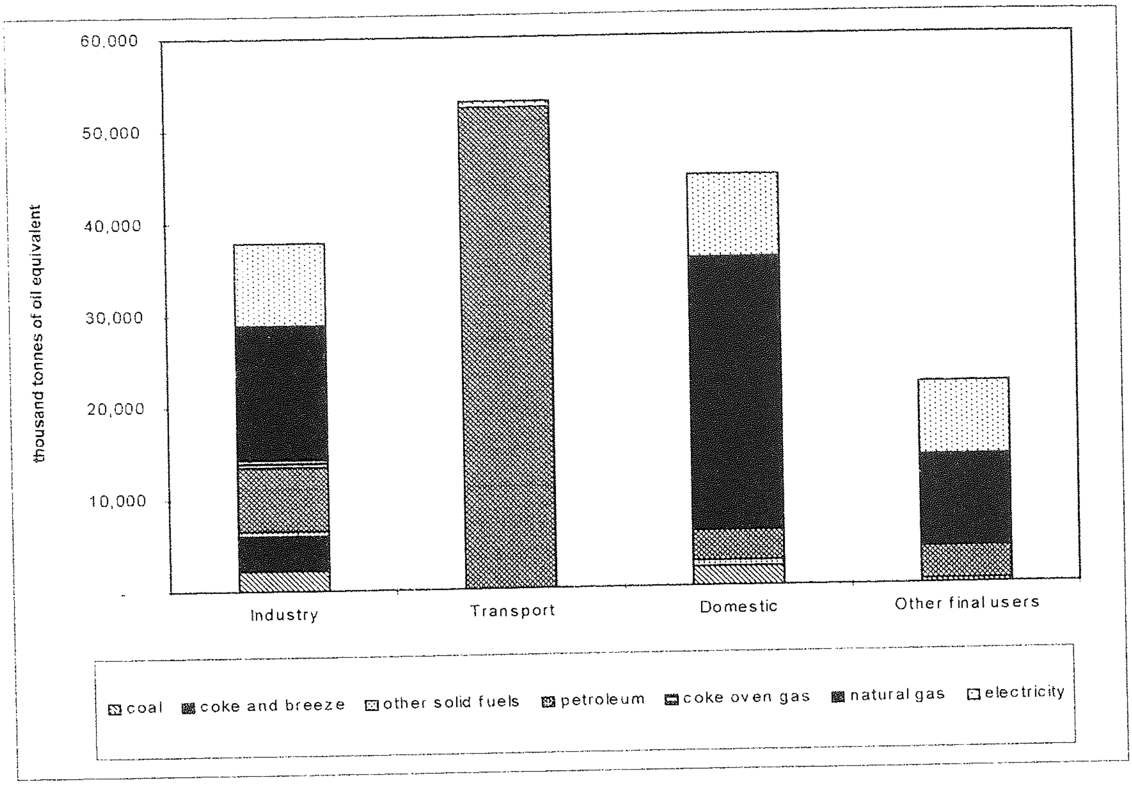

Figure 5: Final Energy Consumption by Type of Fuel for Each Sector 1997 [180 Tables 1.17].

1. Includes conversion losses by final users.

7.2.3.4 Useful Energy

Useful energy is the energy needed to provide the services - heating, cooling, lighting, motive and appliance power which are required by the final user. The amount of useful energy is not the same as the amount of supplied energy because losses occur when the supplied energy is converted into these useful services.

The significance of the conversion losses depends on the characteristics of the fuel and equipment used, and the purpose, conditions and method of operation. Much of the supplied energy is wasted in inefficient industrial processes and motorised vehicles; draughty, poorly insulated buildings and old appliances.

There is generally a lack of data on the purposes for which final users consume different fuels and on end-use efficiencies. Although some specific studies have been done [e.g. 182], no reliable statistics on all useful energy consumption are available. It has been estimated that there are further losses of between 25-30% during service provision [183] (see Figure 6).

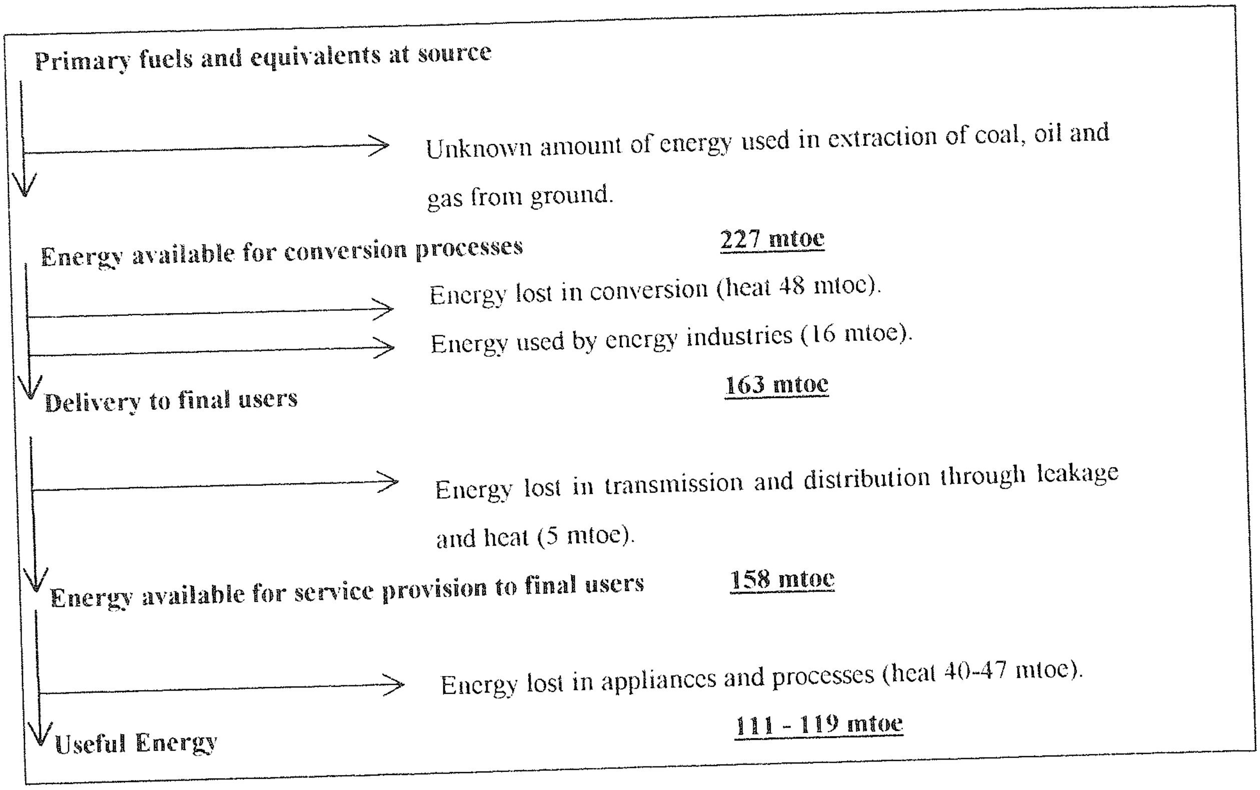

Figure 6: Useful Energy 1997.

7.2.3.5 Future Energy Consumption

Coal, natural gas, electricity and petroleum constitute the major part of consumption. Comprising 81% of total consumption by final user from all sources in 1970, steadily increasing to 96% in 1997. The long-term trends have shown continuing increases in demand for natural gas, petroleum and electricity with decreases in the demand for coal (see Table 20).

Year	Coal	Natural gas	Electricity	Petroleum	Total C, N. gas, E and P consumption by final user	as a % of total consumption by final user
1970	29,822	3,662	16,542	68,511	118,537	81.2%
1971	24,855	9,431	17,021	69,568	120,875	84.2%
1972	20,366	15,063	17,643	72,129	125,201	85.6%
1973	20,313	20,584	18,898	74,620	134,415	87.4%
1974	19,003	25,736	18,356	68,072	131,167	89.3%
1975	16,172	29,212	18,293	64,776	128,453	91.3%
1976	15,162	33,204	18,537	65,981	132,884	92.0%
1977	15,502	35,393	18,948	67,361	137,204	93.1%
1978	14,454	37,766	19,336	68,208	139,764	93.7%
1979	15,124	41,262	20,233	68,937	145,556	93.6%
1980	12,854	41,647	19,252	62,408	136,161	95.6%
1981	11,960	41,828	18,945	58,420	131,153	94.8%
1982	12,169	41,990	18,567	57,360	130,086	95.1%
1983	11,688	42,242	18,856	56,453	129,239	95.0%
1984	9,673	43,251	19,280	57,158	129,362	95.3%
1985	12,124	45,940	20,118	56,416	134,598	94.9%
1986	12,348	46,622	20,763	59,245	138,978	95.4%
1987	10,174	48,096	22,252	58,325	138,847	95.0%
1988	9,738	46,350	22,811	61,952	140,851	94.8%
1989	8,909	44,920	23,254	62,685	139,768	95.6%
1990	8,122	46,118	23,601	63,302	141,143	95.8%
1991	8,605	49,846	24,170	63,525	146,146	96.2%
1992	8,101	48,656	24,206	64,632	145,595	96.3%
1993	7,617	49,502	24,607	65,437	147,163	96.2%
1994	6,855	50,068	24,447	65,884	147,254	96.1%
1995	5,520	51,077	25,279	64,547	146,423	96.2%
1996	4,998	57,659	26,286	66,909	155,852	96.2%
1997	4,613	54,401	26,596	66,285	151,895	96.2%

Table 20: Main Consumption by Final User 1970 to 1997 (thousand tonnes of oil equivalent) [180 Tables 1.06, 1.17]

If these trends could continue without constraints, the dependence on fossil fuels would remain, with the total consumption by final user increasing exponentially. Consumption of gas would level off and be exceeded by consumption of electricity by the middle of the 21st century (see Figure 7 and Table 21).

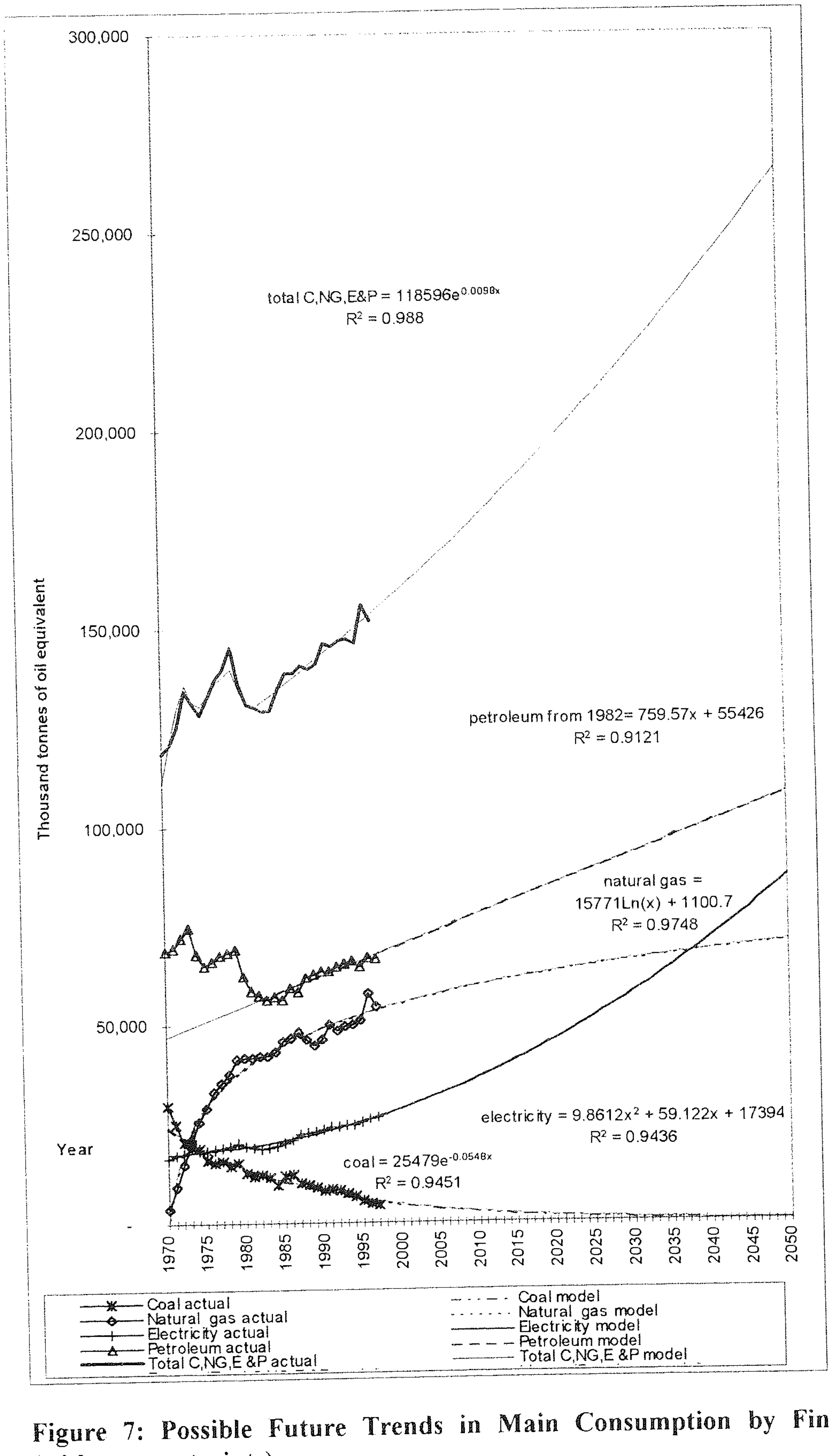

Figure 7: Possible Future Trends in Main Consumption by Final Users (without constraints)

Year	Coal Model	Natural gas Model	Electricity Model	Petroleum Model	Sum of C, NG, E & P Models	Total C, NG, E &P Model	Increase on 1990 level times by
1998	5,200	54,206	27,402	68,339	155,147	157,578	1.11
1999	4,923	54,741	28,043	69,098	156,805	159,130	1.12
2000	4,660	55,258	28,703	69,858	158,480	160,697	1.13
2001	4,412	55,759	29,384	70,617	160,172	162,280	1.14
2002	4,176	56,244	30,084	71,377	161,881	163,878	1.15
2003	3,954	56,715	30,804	72,137	163,609	165,492	1.17
2004	3,743	57,172	31,543	72,896	165,354	167,122	1.18
2005	3,543	57,616	32,303	73,656	167,118	168,768	1.19
2006	3,354	58,048	33,081	74,415	168,900	170,430	1.20
2007	3,175	58,469	33,880	75,175	170,700	172,108	1.21
2008	3,006	58,879	34,699	75,934	172,518	173,803	1.23
2009	2,846	59,278	35,537	76,694	174,355	175,515	1.24
2010	2,694	59,667	36,395	77,454	176,210	177,243	1.25
2011	2,550	60,047	37,272	78,213	178,083	178,989	1.26
2012	2,414	60,419	38,170	78,973	179,975	180,751	1.28
2013	2,286	60,781	39,087	79,732	181,886	182,531	1.29
2014	2,164	61,136	40,023	80,492	183,815	184,329	1.30
2015	2,048	61,482	40,980	81,251	185,762	186,144	1.32
2016	1,939	61,821	41,956	82,011	187,728	187,978	1.33
2017	1,836	62,153	42,952	82,771	189,712	189,829	1.34
2018	1,738	62,479	43,968	83,530	191,714	191,698	1.36
2019	1,645	62,797	45,003	84,290	193,735	193,586	1.37
2020	1,557	63,110	46,058	85,049	195,774	195,493	1.39
2021	1,474	63,416	47,133	85,809	197,832	197,418	1.40
2022	1,396	63,716	48,228	86,568	199,908	199,362	1.41
2023	1,321	64,011	49,342	87,328	202,002	201,325	1.43
2024	1,251	64,300	50,476	88,088	204,115	203,308	1.44
2025	1,184	64,585	51,630	88,847	206,245	205,310	1.46
2026	1,121	64,864	52,803	89,607	208,394	207,332	1.47
2027	1,061	65,138	53,996	90,366	210,562	209,374	1.49
2028	1,005	65,408	55,209	91,126	212,747	211,436	1.50
2029	951	65,673	56,442	91,885	214,951	213,518	1.52
2030	900	65,933	57,694	92,645	217,173	215,621	1.53
2031	852	66,190	58,966	93,405	219,413	217,745	1.55
2032	807	66,442	60,258	94,164	221,671	219,889	1.56
2033	764	66,690	61,569	94,924	223,947	222,054	1.58
2034	723	66,935	62,901	95,683	226,242	224,241	1.60
2035	685	67,176	64,251	96,443	228,555	226,450	1.61
2036	648	67,413	65,622	97,202	230,885	228,680	1.63
2037	614	67,647	67,012	97,962	233,234	230,932	1.64
2038	581	67,877	68,423	98,721	235,602	233,206	1.66
2039	550	68,104	69,852	99,481	237,987	235,503	1.68
2040	521	68,327	71,302	100,241	240,391	237,822	1.69
2041	493	68,548	72,771	101,000	242,812	240,164	1.71

Table 21: Possible Trends in Main Consumption by Final User (thousand tonnes of oil equivalent) (without constraints)

Year	Coal Model	Natural gas Model	Electricity Model	Petroleum Model	Sum of C, NG, E & P Models	Total C, NG, E &P Model	Increase on 1990 level times by
2042	466	68,766	74,260	101,760	245,252	242,529	1.73
2043	442	68,980	75,769	102,519	247,710	244,918	1.75
2044	418	69,192	77,297	103,279	250,186	247,330	1.76
2045	396	69,401	78,846	104,038	252,680	249,766	1.78
2046	375	69,607	80,413	104,798	255,193	252,225	1.80
2047	355	69,810	82,001	105,558	257,724	254,709	1.82
2048	336	70,011	83,608	106,317	260,273	257,218	1.83
2049	318	70,210	85,235	107,077	262,840	259,751	1.85
2050	301	70,406	86,882	107,836	265,425	262,309	1.87

Models - consumption by final user
Coal =25,479*EXP(-0.0548*(year-1969))
Natural gas =15,771*LN(year-1969)+1100.7
Electricity =9.8612*((year-1969)^2)+59.122*(year-1969)+17,394
Petroleum =759.57*(year-1981)+55,426
Sum of models =SUM of models (C,NG,E,P)
Total model =118,596*EXP(0.0098*(year-1969))

Table 21 continued: Possible Trends in Main Consumption by Final User (thousand tonnes of oil equivalent) (without constraints)

Table 21 shows that if trends since 1970 were maintained the main UK consumption could almost double from 1990 levels by 2050. The number of motorcars in the world is expected to increase to around 3 billion by 2020. The global number of aircraft is expected to double between 1999 and 2015 and total global energy demand is thought to triple by 2050 [184].

> *"It is virtually impossible to project what the energy situation could be in years ahead, there have been dramatic market changes in the past 50 years".* [185]

However, the future of the energy supply mix is extremely difficult to predict. Scientific and technological development sustains changes in society and behaviour and these trends are unlikely to continue. Section 1.2 detailed the environmental reasons why new patterns of consumption are welcome.

7.2.4 Preliminary Estimation of Total Primary Fuel Consumption for Energy Demand in Shropshire 1990 to 1997

As a start for estimating energy demand in Shropshire to 2025, national statistics for the total UK inland primary fuel consumption (PFC) were examined in detail (see Table 22). Annual figures given in tonnes of oil equivalent (toe) were converted to the equivalent Giga Joules per year (GJ/y) as most emission figures are quoted in grammes per GJ.

Total UK PFC (GJ/y) = toe/y * 41.868 GJ/toe

Year	1990		1991		1992		1993	
	%	GJ/y	%	GJ/y	%	GJ/y	%	GJ/y
Coal	31.38%	2,823,577,920	30.68%	2,828,602,080	29.20%	2,663,935,236	25.21%	2,334,392,208
Petroleum	36.44%	3,278,306,268	35.32%	3,257,079,192	35.93%	3,277,385,172	35.49%	3,286,679,868
Natural Gas	23.92%	2,152,015,200	25.26%	2,329,200,576	25.52%	2,328,237,612	28.71%	2,658,618,000
Nuclear Electricity	7.57%	680,648,076	7.91%	729,801,108	8.47%	772,632,072	9.76%	903,511,440
Natural Flow Hydro Electricity	0.21%	18,798,732	0.18%	16,663,464	0.22%	19,636,092	0.18%	16,286,652
Solar and Geothermal Heat	0.00%	334,944	0.00%	376,812	0.00%	376,812	0.00%	334,944
Net Imports of Electricity	0.48%	42,998,436	0.64%	59,075,748	0.66%	60,080,580	0.65%	60,164,316
Total	100%	8,996,679,576	100%	9,220,798,980	100%	9,122,283,576	100%	9,259,987,428
Year	**1994**		**1995**		**1996**		**1997**	
	%	GJ/y	%	GJ/y	%	GJ/y	%	GJ/y
Coal	23.94%	2,198,739,888	22.73%	2,101,773,600	20.15%	1,965,032,712	18.52%	1,759,167,756
Petroleum	35.37%	3,248,789,328	34.30%	3,171,417,264	33.56%	3,272,863,428	33.30%	3,163,964,760
Natural Gas	30.15%	2,768,772,708	32.46%	3,001,181,976	36.01%	3,512,557,728	37.23%	3,536,883,036
Nuclear Electricity	9.66%	887,685,336	9.62%	889,611,264	9.52%	928,590,372	10.13%	962,670,924
Natural Flow Hydro Electricity	0.21%	19,594,224	0.22%	20,431,584	0.14%	13,858,308	0.18%	17,249,616
Solar and Geothermal Heat	0.00%	376,812	0.02%	1,800,324	0.00%	376,812	0.00%	418,680
Net Imports of Electricity	0.66%	60,792,336	0.64%	58,740,804	0.62%	60,122,448	0.63%	59,661,900
Total	100%	9,184,750,632	100%	9,244,956,816	100%	9,753,401,808	100%	9,500,016,672

Table 22: UK Inland Consumption of Primary Fuels and Equivalents for Energy Use by Fuel Type 1990-1997 [180, 186]

1970's statistics were not used as oil supply was politically unstable and affected the usual pattern of energy consumption. Total UK PFC to 2025 was estimated by regression analysis using data from 1985 onwards. From 1985 to 1997 total UK PFC has grown exponentially (see Figure 8 and Tables 23 and 24).

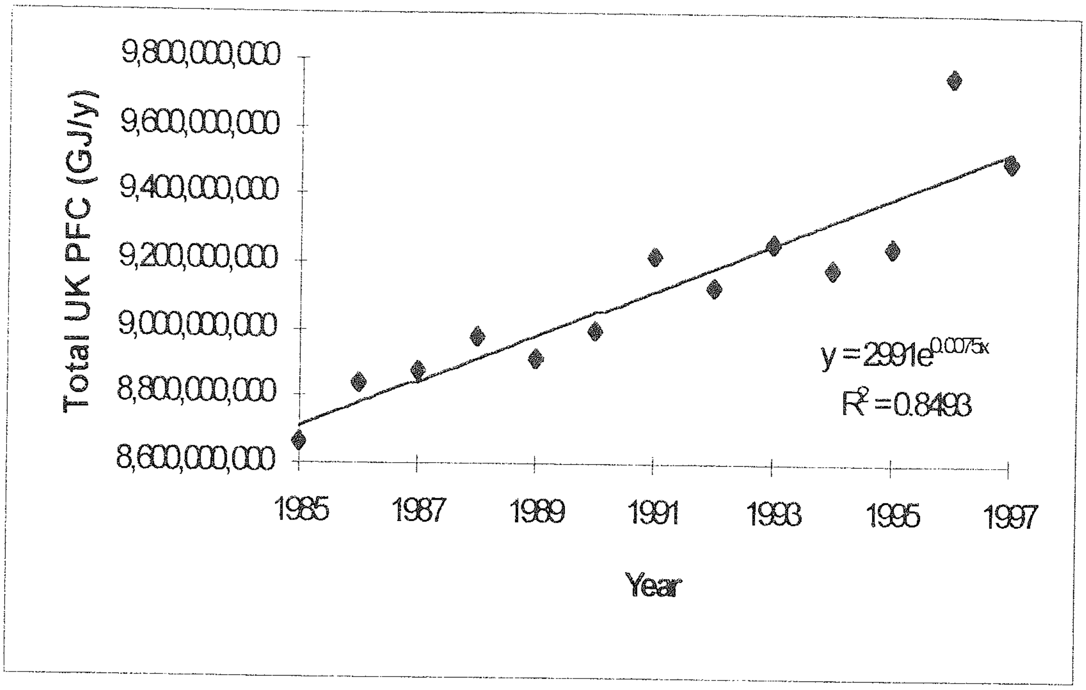

Figure 8: Total UK Primary Fuel Consumption for Energy Use 1985 – 1997 [180, 186]

Year	Total UK PFC GJ/y	Model total GJ/y	% Difference
1985	8,664,791,940	8,737,265,088	0.8%
1986	8,841,893,580	8,803,040,927	-0.4%
1987	8,876,895,228	8,869,311,940	-0.1%
1988	8,977,378,428	8,936,081,853	-0.5%
1989	8,909,552,268	9,003,354,424	1.1%
1990	8,996,679,576	9,071,133,436	0.8%
1991	9,220,798,980	9,139,422,701	-0.9%
1992	9,122,283,576	9,208,226,062	0.9%
1993	9,259,987,428	9,277,547,387	0.2%
1994	9,184,750,632	9,347,390,577	1.8%
1995	9,244,956,816	9,417,759,560	1.9%
1996	9,753,401,808	9,488,658,295	-2.7%
1997	9,500,016,672	9,560,090,769	0.6%
Total difference			3.5%
Average difference			0.3%

Model
Total UK PFC = 2,991 * EXP. (0.0075 * year)

Table 23: Model of Total UK Primary Fuel Consumption for Energy Use 1985 - 1997

Year	Total UK PFC GJ/y (model)	Year	Total UK PFC GJ/y (model)
1998	9,632,061,001	2012	10,698,432,353
1999	9,704,573,039	2013	10,778,972,243
2000	9,777,630,961	2014	10,860,118,453
2001	9,851,238,878	2015	10,941,875,547
2002	9,925,400,930	2016	11,024,248,125
2003	10,000,121,288	2017	11,107,240,819
2004	10,075,404,155	2018	11,190,858,299
2005	10,151,253,767	2019	11,275,105,267
2006	10,227,674,389	2020	11,359,986,463
2007	10,304,670,321	2021	11,445,506,662
2008	10,382,245,893	2022	11,531,670,673
2009	10,460,405,469	2023	11,618,483,343
2010	10,539,153,446	2024	11,705,949,557
2011	10,618,494,253	2025	11,794,074,233

Table 24: Model Estimate of Total UK Primary Fuel Consumption for Energy Use 1998 - 2025

The model shows that total UK PFC could be 1.31 times the 1990 level by 2025 and 1.58 times the 1990 level by 2050.

7.2.4.1 Average Annual PFC per person.

For 1985 to 1997 total UK population statistics were obtained from Census and other Office of National Statistics (ONS) data. These figures were used with total UK PFC figures given above to obtain the total average annual PFC per person (GJpp/y) (see Figure 9 and Tables 25 and 26).

Total average annual PFC per person (GJpp/y) = Total annual PFC (GJ/y) / Total population (pp)

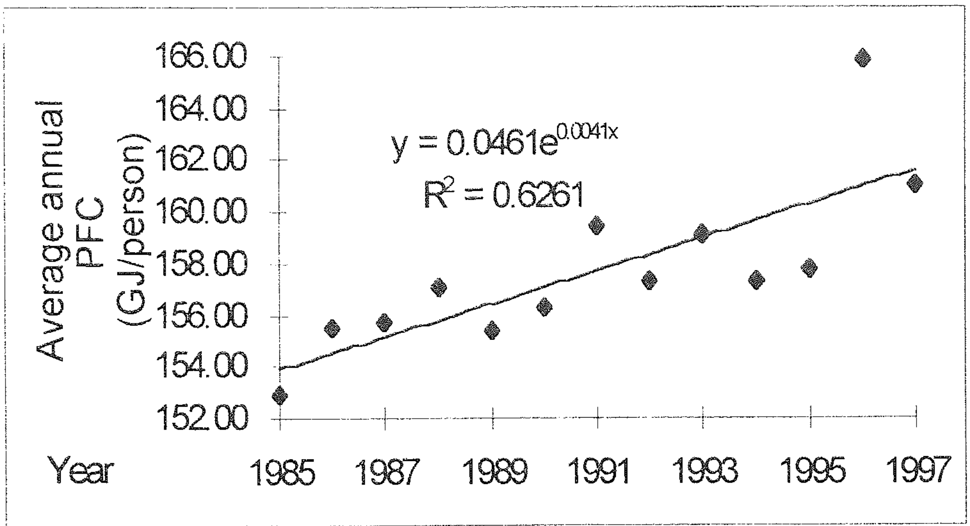

Figure 9: Total Average Annual PFC Per Person 1985-1997 [180, 186, 187]

Year	Total average annual PFC per person (GJpp/y)	Model total GJpp/y	% Difference
1985	152.86	153.89	0.7%
1986	155.53	154.52	-0.6%
1987	155.71	155.15	-0.4%
1988	157.06	155.79	-0.8%
1989	155.33	156.42	0.7%
1990	156.30	157.06	0.5%
1991	159.51	157.71	-1.1%
1992	157.26	158.35	0.7%
1993	159.13	159.00	-0.1%
1994	157.29	159.65	1.5%
1995	157.75	160.31	1.6%
1996	165.87	160.96	-3.0%
1997	160.99	161.62	0.4%
Total difference			0.1%
Average difference			0.0%

Model
Total average annual UK PFC per person = 0.0461 * EXP(0.004087 * year)

Table 25: Model of Total Average Annual PFC Per Person 1985-1997

Year	Total average annual PFC per person GJpp/y (model)	Year	Total average annual PFC per person GJpp/y (model)
1998	162.28	2012	171.84
1999	162.95	2013	172.55
2000	163.62	2014	173.25
2001	164.29	2015	173.96
2002	164.96	2016	174.67
2003	165.63	2017	175.39
2004	166.31	2018	176.11
2005	166.99	2019	176.83
2006	167.68	2020	177.55
2007	168.37	2021	178.28
2008	169.05	2022	179.01
2009	169.75	2023	179.74
2010	170.44	2024	180.48
2011	171.14	2025	181.22

Table 26: Model Estimate of Total Average Annual PFC Per Person 1998-2025

The model shows that total average annual PFC per person could be 1.16 times the 1990 level by 2025 and 1.28 times the 1990 level by 2050.

To ensure these figures for PFC per person were in the right order, the above model estimates of total average annual PFC per person 1998-2025 were compared to estimates from using models of population and total PFC (see Figure 11 and Tables 29 and 30). For UK population figures 1998 to 2010, the 1996 based principle projections of the Government Actuary Department (ONS) were used (see Figure 10 and Tables 27 and 28).

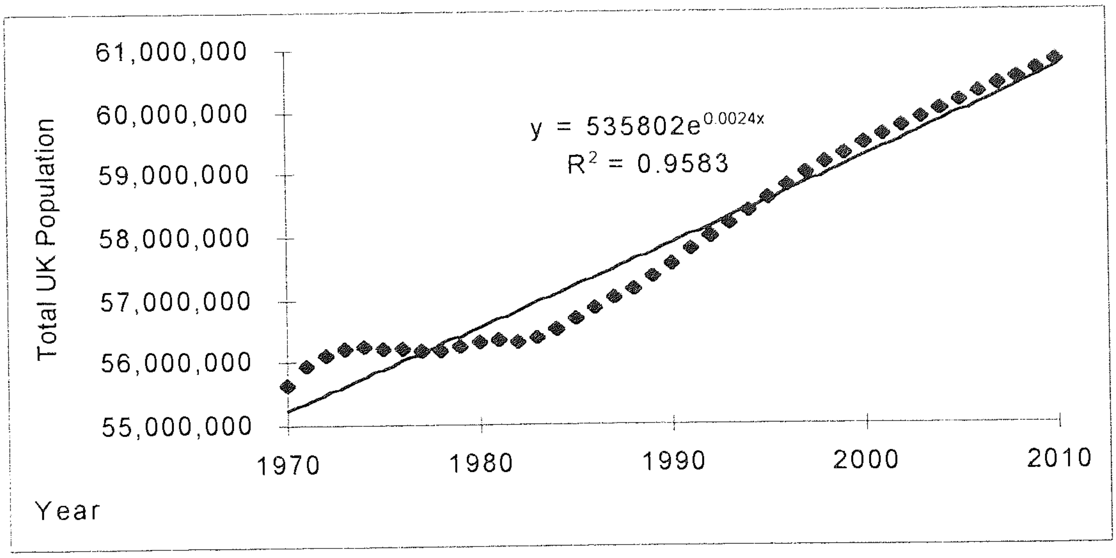

Figure 10: Total UK Population 1970 – 2010 [188, 189]

Year	UK Population	Model total UK population	% Difference
1970	55,632,200	55,236,083	-0.7%
1971	55,928,000	55,366,212	-1.0%
1972	56,096,700	55,496,647	-1.1%
1973	56,222,900	55,627,390	-1.1%
1974	56,235,600	55,758,441	-0.8%
1975	56,225,000	55,889,801	-0.6%
1976	56,216,100	56,021,470	-0.3%
1977	56,189,900	56,153,449	-0.1%
1978	56,178,000	56,285,740	0.2%
1979	56,246,100	56,418,342	0.3%
1980	56,329,700	56,551,256	0.4%
1981	56,352,200	56,684,483	0.6%
1982	56,318,300	56,818,025	0.9%
1983	56,376,900	56,951,881	1.0%
1984	56,505,900	57,086,052	1.0%
1985	56,685,300	57,220,539	0.9%
1986	56,851,900	57,355,343	0.9%
1987	57,008,600	57,490,465	0.8%
1988	57,158,400	57,625,905	0.8%
1989	57,357,500	57,761,664	0.7%
1990	57,561,000	57,897,743	0.6%
1991	57,807,900	58,034,143	0.4%
1992	58,006,500	58,170,864	0.3%
1993	58,191,200	58,307,907	0.2%
1994	58,394,600	58,445,273	0.1%
1995	58,605,800	58,582,962	0.0%
1996	58,801,500	58,720,976	-0.1%
1997	59,008,600	58,859,315	-0.3%
1998	59,171,000	58,997,980	-0.3%
1999	59,323,000	59,136,972	-0.3%
2000	59,473,000	59,276,291	-0.3%
2001	59,618,000	59,415,938	-0.3%
2002	59,759,000	59,555,915	-0.3%
2003	59,896,000	59,696,221	-0.3%
2004	60,029,000	59,836,857	-0.3%
2005	60,159,000	59,977,825	-0.3%
2006	60,287,000	60,119,125	-0.3%
2007	60,414,000	60,260,758	-0.3%
2008	60,541,000	60,402,724	-0.2%
2009	60,669,000	60,545,025	-0.2%
2010	60,798,000	60,687,662	-0.2%
Total difference			0.3%
Average difference			0.0%

Model
Total UK Population = 535,802 * EXP(0.0023531 * year)

Table 27: Model of Total UK Population 1970 - 2010

Year	UK Population (model)	Year	UK Population (model)
2011	60,830,634	2019	61,986,605
2012	60,973,943	2020	62,132,637
2013	61,117,590	2021	62,279,014
2014	61,261,575	2022	62,425,735
2015	61,405,899	2023	62,572,802
2016	61,550,564	2024	62,720,215
2017	61,695,569	2025	62,867,976
2018	61,840,916	2050	66,677,290

Table 28: Model Estimate of Total UK Population 2011 - 2025

The model shows that total UK population could be 1.09 times the 1990 level by 2025 and 1.16 times the 1990 level by 2050.

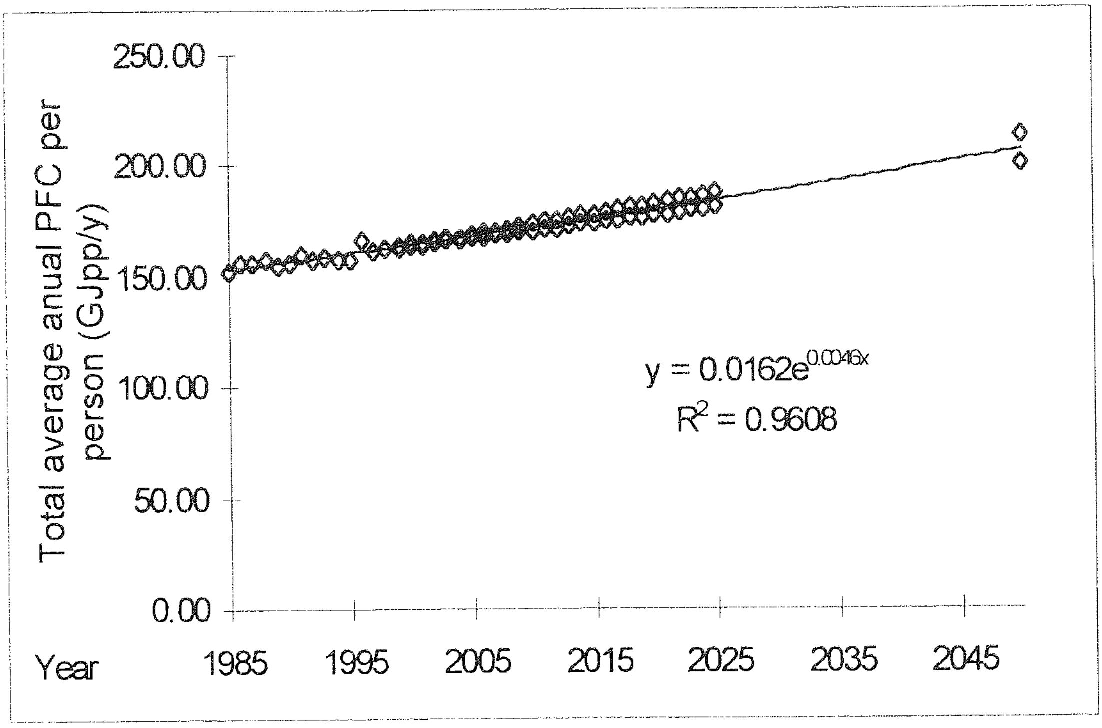

Figure 11: Estimate of Total Average Annual PFC Per Person using Models of Population and Total UK PFC 1985 - 2050.

Year	GJpp/y	Model	% Difference
1985	152.86	153.25	0.3%
1986	155.53	153.96	-1.0%
1987	155.71	154.67	-0.7%
1988	157.06	155.38	-1.1%
1989	155.33	156.10	0.5%
1990	156.30	156.82	0.3%
1991	159.51	157.55	-1.2%
1992	157.26	158.28	0.6%
1993	159.13	159.01	-0.1%
1994	157.29	159.74	1.6%
1995	157.75	160.48	1.7%
1996	165.87	161.22	-2.8%
1997	160.99	161.97	0.6%
Total difference			-1.2%
Average difference			-0.1%

Model
Total average annual UK PFC per person (2nd model) (GJ) = 0.0162 * EXP(0.0046 * year)

Table 29: Second Model of Total Average Annual PFC Per Person using Models of Population and Total UK PFC 1985 - 1997

Year	[1]Total UK Population	[2]Total average UK annual PFC GJ/y	[3]Total average PFC per person (GJpp/y)	[4]Total average PFC per person (GJpp/y) (model) = 0.0461 * EXP (0.0041 * year)	[5]Total average PFC per person (GJpp/y) (new model) = 0.0162 * EXP (0.0046 * year)
1985	56,685,300	8,664,791,940	152.86	153.89	153.25
1986	56,851,900	8,841,893,580	155.53	154.52	153.96
1987	57,008,600	8,876,895,228	155.71	155.15	154.67
1988	57,158,400	8,977,378,428	157.06	155.79	155.38
1989	57,357,500	8,909,552,268	155.33	156.42	156.10
1990	57,561,000	8,996,679,576	156.30	157.06	156.82
1991	57,807,900	9,220,798,980	159.51	157.71	157.55
1992	58,006,500	9,122,283,576	157.26	158.35	158.28
1993	58,191,200	9,259,987,428	159.13	159.00	159.01
1994	58,394,600	9,184,750,632	157.29	159.65	159.74
1995	58,605,800	9,244,956,816	157.75	160.31	160.48
1996	58,801,500	9,753,401,808	165.87	160.96	161.22
1997	59,008,600	9,500,016,672	160.99	161.62	161.97
		Total UK PFC GJ/y (model) = 2,991 * EXP (0.0075 * year)			
1998	59,171,000	9,632,061,001	162.78	162.28	162.72
1999	59,323,000	9,704,573,039	163.59	162.95	163.47
2000	59,473,000	9,777,630,961	164.40	163.62	164.23
2001	59,618,000	9,851,238,878	165.24	164.29	164.98
2002	59,759,000	9,925,400,930	166.09	164.96	165.75
2003	59,896,000	10,000,121,288	166.96	165.63	166.51
2004	60,029,000	10,075,404,155	167.84	166.31	167.28
2005	60,159,000	10,151,253,767	168.74	166.99	168.06
2006	60,287,000	10,227,674,389	169.65	167.68	168.83
2007	60,414,000	10,304,670,321	170.57	168.37	169.61

Table 30: Estimate of Total Average Annual PFC Per Person using Models of Population and Total UK PFC 1985 - 2050.

Year	[1]Total UK Population	[2]Total average UK annual PFC GJ/y	[3]Total average PFC per person (GJpp/y)	[4]Total average PFC per person (GJpp/y) (model) = 0.0461 * EXP (0.0041 * year)	[5]Total average PFC per person (GJpp/y) (new model) = 0.0162 * EXP (0.0046 * year)
2008	60,541,000	10,382,245,893	171.49	169.05	170.40
2009	60,669,000	10,460,405,469	172.42	169.75	171.18
2010	60,798,000	10,539,153,446	173.35	170.44	171.98
	UK Population (model) = 535,802 * EXP (0.0023531 * year)				
2011	60,830,634	10,618,494,253	174.56	171.14	172.77
2012	60,973,943	10,698,432,353	175.46	171.84	173.57
2013	61,117,590	10,778,972,243	176.36	172.55	174.37
2014	61,261,575	10,860,118,453	177.27	173.25	175.18
2015	61,405,899	10,941,875,547	178.19	173.96	175.99
2016	61,550,564	11,024,248,125	179.11	174.67	176.80
2017	61,695,569	11,107,240,819	180.03	175.39	177.62
2018	61,840,916	11,190,858,299	180.96	176.11	178.44
2019	61,986,605	11,275,105,267	181.90	176.83	179.26
2020	62,132,637	11,359,986,463	182.83	177.55	180.09
2021	62,279,014	11,445,506,662	183.78	178.28	180.93
2022	62,425,735	11,531,670,673	184.73	179.01	181.76
2023	62,572,802	11,618,483,343	185.68	179.74	182.60
2024	62,720,215	11,705,949,557	186.64	180.48	183.45
2025	62,867,976	11,794,074,233	187.60	181.22	184.29
2050	66,677,290	14,226,369,104	213.36	200.72	206.82
	L	M	N =M/L		

Model
Total average annual UK PFC per person (using Population and UK PFC models) = 0.01621 * EXP(0.004612 * year)

Table 30 (continued): Estimate of Total Average Annual PFC Per Person using Models of Population and Total UK PFC 1985 - 2050.

1. Figure 10, Tables 27 and 28.
2. Tables 23 and 24.
3. Table 25 to 1997.
4. Figure 9 and Tables 25 and 26.
5. Figure 11 and Table 29.

The estimates based on the two models show that the total average annual PFC per person could be 1.20 times the 1990 level by 2025 and 1.37 times the 1990 level by 2050.

7.2.4.2 Using These Models to Estimate PFC for Shropshire

As the figures from the first model of total average annual UK PFC per person (Table 25 and 26) were closer to statistical data than the second estimate it was used to estimate PFC in Shropshire (see Table 33). Population data was obtained from the Census, ONS and Shropshire County Council (see Figure 12 and Tables 31 and 32).

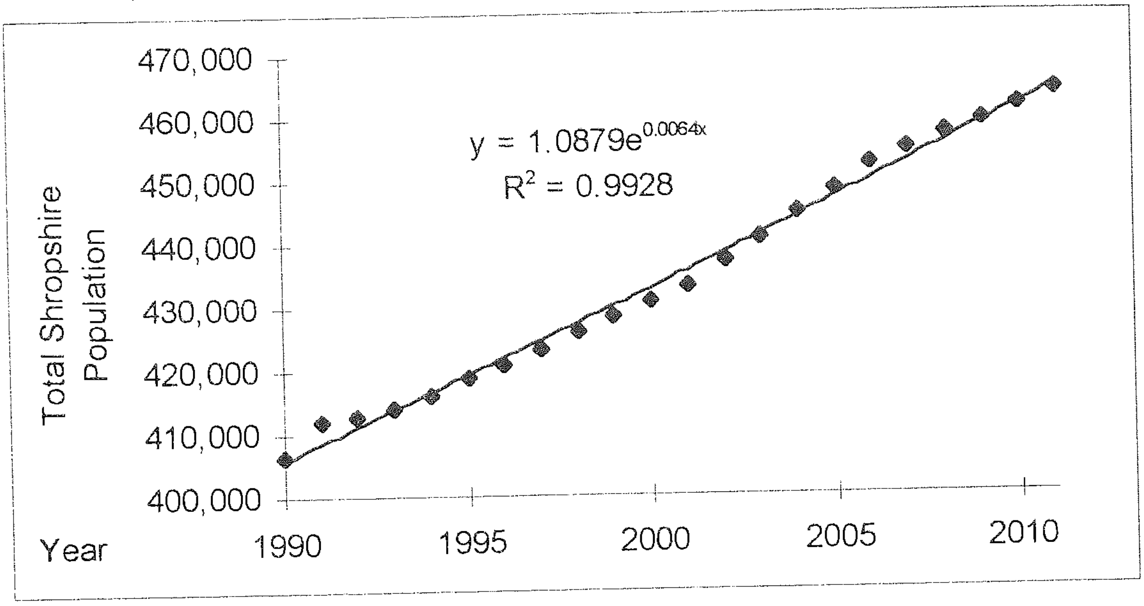

Figure 12: Total Shropshire Population 1990 – 2011 [188, 190, 191, 192, 193]

Year	Total Shropshire population	Model total Shropshire population	% Difference
1990	406,390	405,927	-0.1%
1991	412,000	408,552	-0.8%
1992	413,000	411,195	-0.4%
1993	414,000	413,854	0.0%
1994	416,000	416,531	0.1%
1995	419,000	419,225	0.1%
1996	420,700	421,937	0.3%
1997	423,300	424,666	0.3%
1998	425,900	427,413	0.4%
1999	428,400	430,177	0.4%
2000	430,900	432,959	0.5%
2001	433,300	435,760	0.6%
2002	437,200	438,578	0.3%
2003	441,000	441,415	0.1%
2004	444,800	444,270	-0.1%
2005	448,500	447,143	-0.3%
2006	452,300	450,035	-0.5%
2007	454,700	452,946	-0.4%
2008	457,100	455,876	-0.3%
2009	459,400	458,824	-0.1%
2010	461,800	461,792	0.0%
2011	464,200	464,779	0.1%
Total difference			0.0%
Average difference			0.0%

Model
Total Shropshire Population = 1.0879 * EXP(0.006447075 * year)

Table 31: Model of Total Shropshire Population 1990 - 2011

Year	Total Shropshire population (model)	Year	Total Shropshire population (model)
2012	467,785	2019	489,380
2013	470,811	2020	492,545
2014	473,856	2021	495,731
2015	476,921	2022	498,937
2016	480,005	2023	502,164
2017	483,110	2024	505,412
2018	486,235	2025	508,681

Table 32: Model Estimate of Total Shropshire Population 2012 - 2025

The model shows that total Shropshire Population could rise faster than for the UK as a whole and be 1.25 times the 1990 level by 2025 and 1.47 times the 1990 level by 2050.

Year	Total Shropshire Population	Total average annual PFC (GJ per person)	Estimated Total Shropshire PFC (GJ/y)	Estimated Total Shropshire PFC (Equivalent GWh/y)	Change %
1990	406,390	156.30	63,518,018	17,644	
1991	412,000	159.51	65,717,119	18,255	3.35%
1992	413,000	157.26	64,949,679	18,042	-1.18%
1993	414,000	159.13	65,879,941	18,300	1.41%
1994	416,000	157.29	65,431,653	18,175	-0.69%
1995	419,000	157.75	66,096,497	18,360	1.01%
1996	420,700	165.87	69,781,488	19,384	5.28%
1997	423,300	160.99	68,148,661	18,930	-2.40%
		= 0.046098446 * EXP (0.00408725*		year)	
1998	425,900	162.28	69,116,864	19,199	1.40%
1999	428,400	162.95	69,807,313	19,391	0.99%
2000	430,900	163.62	70,502,257	19,584	0.99%
2001	433,300	164.29	71,185,295	19,774	0.96%
2002	437,200	164.96	72,120,183	20,033	1.30%
2003	441,000	165.63	73,044,972	20,290	1.27%
2004	444,800	166.31	73,976,126	20,549	1.26%
2005	448,500	166.99	74,896,983	20,805	1.23%
2006	452,300	167.68	75,840,910	21,067	1.24%
2007	454,700	168.37	76,555,601	21,265	0.93%
2008	457,100	169.05	77,274,875	21,465	0.93%
2009	459,400	169.75	77,981,781	21,662	0.91%
2010	461,800	170.44	78,710,226	21,864	0.93%
2011	464,200	171.14	79,443,329	22,068	0.92%
	=1.0879 * EXP (0.006447075		* year)		
2012	467,785	171.84	80,384,754	22,329	1.17%
2013	470,811	172.55	81,236,029	22,566	1.05%
2014	473,856	173.25	82,096,319	22,805	1.05%
2015	476,921	173.96	82,965,720	23,046	1.05%
2016	480,005	174.67	83,844,328	23,290	1.05%
2017	483,110	175.39	84,732,239	23,537	1.05%
2018	486,235	176.11	85,629,554	23,786	1.05%
2019	489,380	176.83	86,536,372	24,038	1.05%
2020	492,545	177.55	87,452,793	24,292	1.05%
2021	495,731	178.28	88,378,918	24,550	1.05%
2022	498,937	179.01	89,314,852	24,810	1.05%
2023	502,164	179.74	90,260,696	25,072	1.05%
2024	505,412	180.48	91,216,558	25,338	1.05%
2025	508,681	181.22	92,182,542	25,606	1.05%
2050	597,645	200.72	119,956,465	33,321	
	M	N	O =M*N	P=O/3600	

Table 33: Estimated Total Shropshire PFC (GJ/y) and (Equivalent GWh/y) 1990 - 2050

The model shows that Estimated Total Shropshire PFC (GJ/y) could be 1.45 times the 1990 level by 2025 and 1.89 times the 1990 level by 2050.

7.3 *Environmental Implications of Energy Use in Shropshire*

As shown in Chapter 3 (Energy Systems and the Environment) the consequences of continued increases in consumption of fossil fuel for energy use could cause dramatic disturbances to the earth's environmental systems. These environmental costs need to be set in a Shropshire context [194], local actions being essential to reduce the potential global impacts.

7.3.1 Emissions to Air Associated with PFC

The largest single waste product from the combustion of fossil fuels is carbon dioxide; other emissions include methane, sulphur and nitrogen oxides, particulates (black smoke) and volatile organic compounds (VOC's) from unburned fuel (hydrocarbons).

National statistics on consumption of different fuel types and statistics for both combustion related emissions and emissions from other sources such as mining, leakage, landfill, sewage disposal, industrial processes and solvent use were examined. These were used with the total Shropshire PFC given in Table 33, to give, for the first time, an estimate of fossil fuel consumption and total annual emissions associated with energy use in the County. This estimate shows what order of emissions can be expected and forms a baseline for more detailed monitoring in the future.

7.3.1.1 Preliminary Estimation of Shropshire Emissions 1990 to 1997

The preliminary estimation of emissions assumes the same fuel mix as for the UK [180, 186]. Table 34 gives an estimate of the amount of fossil fuels consumed in Shropshire for energy use. This estimate along with the emission factors in Table 35 were used to show what emissions would be if they also followed the emissions trends for the UK (see Table 36 and Figure 13).

Approximate Energy Use	1990	Fuel type as a % of total	1991	Fuel type as a % of total	1992	Fuel type as a % of total
Total GJ/y	63,518,018		65,717,119		64,949,679	
Fuel	GJ/y	%	GJ/y	%	GJ/y	%
Coal	19,934,918	31%	20,159,596	31%	18,837,935	29%
Other Petroleum /Oil	8,053,493	13%	7,598,987	12%	7,848,840	12%
Petroleum for transport	15,091,881	24%	15,614,388	24%	15,327,088	24%
Total Petroleum	23,145,374	36%	23,213,375	35%	23,175,928	36%
Natural Gas	15,193,577	24%	16,600,335	25%	16,464,060	25%
Total	58,273,869	92%	59,973,305	91%	58,477,923	90%

Approximate Energy Use	1993	Fuel type as a % of total	1994	Fuel type as a % of total	1995	Fuel type as a % of total
Total GJ/y	65,879,941		65,431,653		66,096,497	
Fuel	GJ/y	%	GJ/y	%	GJ/y	%
Coal	16,607,973	25%	15,663,701	24%	15,026,557	23%
Other Petroleum /Oil	7,077,713	11%	6,949,861	11%	5,660,699	9%
Petroleum for transport	16,305,285	25%	16,194,334	25%	17,013,238	26%
Total Petroleum	23,382,999	35%	23,144,195	35%	22,673,937	34%
Natural Gas	18,914,669	29%	19,724,583	30%	21,456,846	32%
Total	58,905,641	89%	58,532,478	89%	59,157,341	90%

Approximate Energy Use	1996	Fuel type as a % of total	1997	Fuel type as a % of total
Total GJ/y	69,781,488		68,148,661	
Fuel	GJ/y	%	GJ/y	%
Coal	14,058,983	20%	12,619,444	19%
Other Petroleum /Oil	5,454,206	8%	5,509,706	8%
Petroleum for transport	17,961,755	26%	17,187,092	25%
Total Petroleum	23,415,961	34%	22,696,798	33%
Natural Gas	25,130,873	36%	25,371,939	37%
Total	62,605,817	90%	60,688,181	89%

Table 34: Estimated Annual Consumption of the Fossil Fuels, Coal, Petroleum and Natural Gas (GJ/y) for Energy Use in Shropshire 1990 - 1997.

Emissions from Fuels	Carbon	Methane	SO2	Smoke	NOx	VOC's	CO
1990	g/GJ	g/GJ	g/GJ	g/GJ	g/GJ	g/GJ	g/GJ
Coal	25,000	21	1,000	61	270	17	140
Other Petroleum/Oil	20,000	3	650	18	140	3	13
Petroleum for transport	15,438	5	61	98	748	468	2,807
Natural Gas	14,000	4	0	0	56	5	5
1991	g/GJ	g/GJ	g/GJ	g/GJ	g/GJ	g/GJ	g/GJ
Coal	25,000	21	971	61	270	17	140
Other Petroleum/Oil	20,000	3	650	18	140	3	13
Petroleum for transport	15,063	5	51	100	685	447	2,647
Natural Gas	14,000	4	0	0	56	5	5
1992	g/GJ	g/GJ	g/GJ	g/GJ	g/GJ	g/GJ	g/GJ
Coal	25,000	21	997	61	270	17	140
Other Petroleum/Oil	20,000	3	650	18	140	3	13
Petroleum for transport	15,225	5	55	104	646	443	2,538
Natural Gas	14,000	4	0	0	56	5	5
1993	g/GJ	g/GJ	g/GJ	g/GJ	g/GJ	g/GJ	g/GJ
Coal	24,000	21	1,000	61	270	17	140
Other Petroleum/Oil	20,000	3	650	18	140	3	13
Petroleum for transport	14,399	5	48	100	524	410	2,269
Natural Gas	14,000	4	0	0	56	5	5
1994	g/GJ	g/GJ	g/GJ	g/GJ	g/GJ	g/GJ	g/GJ
Coal	24,000	21	1,000	61	270	17	140
Other Petroleum/Oil	20,000	3	650	18	140	3	13
Petroleum for transport	14,957	11	53	110	528	286	1,936
Natural Gas	14,000	4	0	0	56	5	5
1995	g/GJ	g/GJ	g/GJ	g/GJ	g/GJ	g/GJ	g/GJ
Coal	25,000	17	940	51	270	14	220
Other Petroleum/Oil	19,000	3	590	17	140	2	15
Petroleum for transport	14,708	11	50	88	561	341	2,057
Natural Gas	14,000	4	0	0	61	5	8
1996	g/GJ	g/GJ	g/GJ	g/GJ	g/GJ	g/GJ	g/GJ
Coal	25,000	18	850	54	270	15	200
Other Petroleum/Oil	19,000	3	520	16	120	2	15
Petroleum for transport	14,340	11	33	92	481	300	1,632
Natural Gas	14,000	4	0	0	61	5	8
1997	g/GJ	g/GJ	g/GJ	g/GJ	g/GJ	g/GJ	g/GJ
Coal	24,000	18	850	51	270	14	200
Other Petroleum/Oil	19,000	3	520	16	120	2	15
Petroleum for transport	15,026	11	35	96	504	315	1,710
Natural Gas	14,000	4	0	0	61	5	8

Table 35: UK Annual Emission Factors for Coal, Petroleum and Natural Gas (g/GJ PFC) 1990 – 1997 [180, 186, 195]

Emissions from imported and other nuclear electricity, natural flow hydro-electricity, solar and geothermal heat, were assumed to be negligible. Emissions resulting from only the consumption of coal, petroleum and natural gas were considered.

Emission (t) = GJ of fuel * emission factor for that fuel (g/GJ) / $1 * 10^6$ g/t

Emissions from fuels	Carbon	Methane	SO2	Smoke	NOx	VOC's	CO
1990	t/y	t/y	t/y	t/y	t/y	t/y	t/y
Coal	498,373	419	19,935	1,216	5,382	339	2,791
Other Petroleum/Oil	161,070	24	5,235	145	1,127	24	105
Petroleum / transport	232,985	71	918	1,483	11,296	7,060	42,361
Natural Gas	212,710	61	0	0	851	76	76
Total from fossil fuels	1,105,138	574	26,088	2,844	18,657	7,499	45,333
1991	t/y	t/y	t/y	t/y	t/y	t/y	t/y
Coal	503,990	423	19,575	1,230	5,443	343	2,822
Other Petroleum/Oil	151,980	23	4,939	137	1,064	23	99
Petroleum / transport	235,193	78	798	1,568	10,691	6,985	41,337
Natural Gas	232,405	66	0	0	930	83	83
Total from fossil fuels	1,123,567	591	25,313	2,934	18,127	7,433	44,341
1992	t/y	t/y	t/y	t/y	t/y	t/y	t/y
Coal	470,948	396	18,781	1,149	5,086	320	2,637
Other Petroleum/Oil	156,977	24	5,102	141	1,099	24	102
Petroleum / transport	233,358	78	849	1,591	9,900	6,789	38,893
Natural Gas	230,497	66	0	0	922	82	82
Total from fossil fuels	1,091,780	563	24,732	2,881	17,007	7,215	41,715
1993	t/y	t/y	t/y	t/y	t/y	t/y	t/y
Coal	398,591	349	16,608	1,013	4,484	282	2,325
Other Petroleum/Oil	141,554	21	4,601	127	991	21	92
Petroleum / transport	234,778	78	783	1,636	8,537	6,688	36,995
Natural Gas	264,805	76	0	0	1,059	95	95
Total from fossil fuels	1,039,729	524	21,991	2,777	15,072	7,086	39,507
1994	t/y	t/y	t/y	t/y	t/y	t/y	t/y
Coal	375,929	329	15,664	955	4,229	266	2,193
Other Petroleum/Oil	138,997	21	4,517	125	973	21	90
Petroleum / transport	242,214	171	855	1,781	8,549	4,631	31,345
Natural Gas	276,144	79	0	0	1,105	99	99
Total from fossil fuels	1,033,284	600	21,036	2,862	14,855	5,016	33,727
1995	t/y	t/y	t/y	t/y	t/y	t/y	t/y
Coal	375,664	255	14,125	766	4,057	210	3,306
Other Petroleum/Oil	107,553	17	3,340	96	792	11	85
Petroleum / transport	250,231	193	851	1,501	9,545	5,798	34,997
Natural Gas	300,396	86	0	0	1,309	107	172
Total from fossil fuels	1,033,844	551	18,316	2,364	15,703	6,127	38,559
1996	t/y	t/y	t/y	t/y	t/y	t/y	t/y
Coal	351,475	253	11,950	759	3,796	211	2,812
Other Petroleum/Oil	103,630	16	2,836	87	655	11	82
Petroleum / transport	257,565	193	594	1,646	8,643	5,395	29,312
Natural Gas	351,832	101	0	0	1,533	126	201
Total from fossil fuels	1,064,502	563	15,380	2,492	14,626	5,742	32,407
1997	t/y	t/y	t/y	t/y	t/y	t/y	t/y
Coal	302,867	227	10,727	644	3,407	177	2,524
Other Petroleum/Oil	104,684	17	2,865	88	661	11	83
Petroleum / transport	258,247	194	595	1,650	8,666	5,409	29,390
Natural Gas	355,207	101	0	0	1,548	127	203
Total from fossil fuels	1,021,005	539	14,187	2,382	14,282	5,723	32,199

Table 36: Estimation of Emissions (t/y) from Coal, Petroleum and Natural Gas Consumption for Energy Use in Shropshire 1990 - 1997.

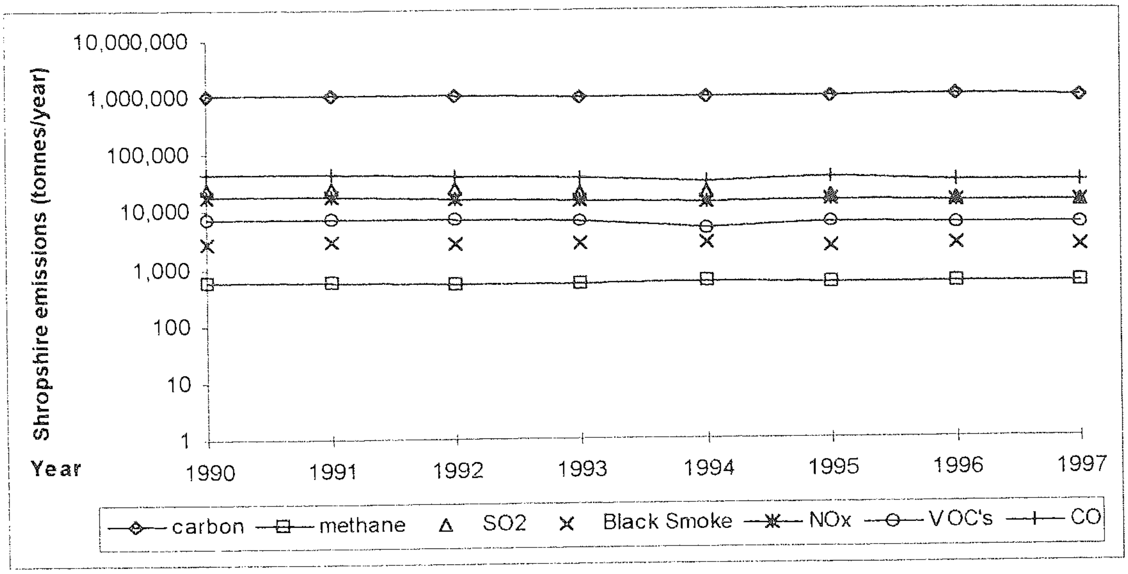

Figure 13: Estimation of Emissions (t/y) from Coal, Petroleum and Natural Gas Consumption for Energy Use in Shropshire 1990 - 1997

Emission factors were calculated for the UK based on total emissions from all sources, total fuel consumption and population (average annual total emissions all sources per GJ PFC (g/GJ) (see Table 37) and average annual emissions all sources per person (g/person) (see Table 38). These factors were used to give a second estimate of emissions for Shropshire (see Table 39). These second figures were then compared to the estimate of emissions for Shropshire in Table 36 that were based on emission factors for individual fuels.

UK Average Annual Total Emissions (all sources) per GJ PFC (g/GJ) = Total Emissions from all sources (g) / Total GJ PFC

Year	Carbon	Methane	SO2	Black Smoke	NOx	VOC's	CO
	g/GJ	g/GJ	g/GJ	g/GJ	g/GJ	g/GJ	g/GJ
1990	17,784	486	419	50	303	266	740
1991	17,197	449	385	50	302	263	712
1992	17,297	471	381	51	280	266	682
1993	16,415	451	345	50	254	265	628
1994	16,223	422	296	47	241	230	526
1995	16,009	413	256	39	248	253	593
1996	15,789	381	208	35	211	216	476
1997	15,474	374	181	36	215	218	478

Table 37: UK Average Annual Emission Factors (All Sources) (g / GJ PFC) 1990 - 1997.

UK Average Annual Total Emissions (all sources) per Person (g/person) = Total Emissions from all sources (g) / Total Population

Year	Carbon	Methane	SO2	Black Smoke	NOx	VOC's	CO
	g/person	g/person	g/person	g/person	g/person	g/person	g/person
1990	2,779,660	75,937	65,565	7,870	47,411	41,608	115,686
1991	2,743,050	71,616	61,479	7,975	48,177	41,984	113,600
1992	2,738,831	74,526	60,338	8,016	44,323	42,185	108,057
1993	2,612,077	71,712	54,888	7,957	40,470	42,154	99,895
1994	2,551,605	66,376	46,545	7,329	37,949	36,253	82,764
1995	2,525,348	65,130	40,354	6,074	39,160	39,877	93,472
1996	2,618,981	63,128	34,489	5,782	35,033	35,900	78,995
1997	2,491,162	60,195	29,104	5,785	34,552	35,113	76,910

Table 38: UK Average Annual Emission Factors (All Sources) (g / Person) 1990 - 1997.

Average Annual Total Emissions (all sources) for Shropshire (t) = (Average Annual Total Emission Factor (g/person) * Total Shropshire Population (from Table 31)) / 1 * 10^6 g/t

Year	Carbon	Methane	SO2	Black Smoke	NOx	VOC's	CO
	t/y	t/y	t/y	t/y	t/y	t/y	t/y
1990	1,129,626	30,860	26,645	3,198	19,267	16,909	47,014
1991	1,130,137	29,506	25,330	3,286	19,849	17,297	46,803
1992	1,123,444	30,570	24,750	3,288	18,181	17,304	44,324
1993	1,081,400	29,689	22,724	3,294	16,755	17,452	41,356
1994	1,061,468	27,612	19,363	3,049	15,787	15,081	34,430
1995	1,058,121	27,290	16,908	2,545	16,408	16,708	39,165
1996	1,101,805	26,558	14,509	2,433	14,738	15,103	33,233
1997	1,054,509	25,480	12,320	2,449	14,626	14,863	32,556

Table 39: Second Estimation of Emissions (All Sources) (t/y) in Shropshire 1990 - 1997.

It was assumed that the difference between the first estimation of emissions (from combustion of fossil fuels) and the second estimation (from all sources) for Shropshire (see Table 40) could be classed as emissions from other sources (i.e. not combustion processes involving fossil fuels). Negative numbers also give an indication of any over-estimation

Year	Carbon	Methane	SO2	Black Smoke	NOx	VOC's	CO
	t/y	t/y	t/y	t/y	t/y	t/y	t/y
1990	24,488	30,286	558	355	610	9,410	1,681
1991	6,570	28,915	17	351	1,722	9,864	2,462
1992	31,664	30,007	18	407	1,174	10,089	2,609
1993	41,671	29,165	733	517	1,683	10,366	1,849
1994	28,183	27,013	**-1,673**	187	931	10,065	703
1995	24,277	26,738	**-1,407**	181	705	10,581	606
1996	37,304	25,995	**-871**	**- 59**	112	9,361	826
1997	33,504	24,942	**-1,867**	67	344	9,140	356

Table 40: Difference Between First (Coal, Petroleum and Natural Gas Only) and Second Estimations of Emissions (All Sources) (t/y) in Shropshire 1990 – 1997 (possible emissions from other sources).

These emissions from other sources were examined in greater detail. This was to see where they could come from, if they are relevant to Shropshire and where any over-estimation is likely to occur.

7.3.1.2 Emissions from Sources Other than Stationary Combustion of Fossil Fuels

Emissions from sources other than combustion of fossil fuels include emissions from combustion of fuels other than fossil fuels and non-combustion processes. Emissions of carbon can originate from non-petroleum based transport, waste and fugitive emissions from other fuels. Emissions of methane can originate from deep coalmines, open cast coal mines, off shore oil and gas rigs, gas leaks, landfill and other waste disposal sites, human sewage disposal and livestock. SO_2 emissions can originate from fossil fuel extraction and distribution. Black Smoke emissions can originate from construction, mining and quarrying, industrial processes and waste. NOx and CO emissions can originate from fossil fuel extraction and distribution, and waste. VOC's can originate from fossil fuel extraction and distribution, industrial processes, solvent use, waste and forestry (see Table 41).

	Carbon	Methane	SO_2	Black Smoke	NO_x	VOC's	CO
Total UK Emissions (000 tonnes)	160,000	4,371	3,774	453	2,729	2,395	6,659
Contribution from Fossil Fuels as a Percentage of Total UK Emissions							
Solid Fuels	41%	19% (deep & open cast mining	76%	40%	29%	2%	6%
Oil Products	35%	29% (offshore oil & gas and leakage)	23%	51%	64%	36%	91%
Gas	19%		0%	0%	6%	0.2%	0.2%
Total (000 tonnes)	96% 153,000	48% 2,101	99% 3,755	91% 411	99% 2,707	38% 910	97% 6,439
Contribution from Different Sectors to Total UK Emissions							
Domestic	14%	0.02%	3%	33%	3%	1.7%	4%
Commercial	5%		2%	1%	2%	0.04%	0.1%
Power Stations	34%	0%	72%	6%	24%	0.5%	1%
Refineries	3%	0%	3%	0.4%	2%	0%	0.02%
Other Industry	23%	0.02%	16%	13%	9%	1.7%	4%
Transport	21%	0.2%	3%	47%	56%	41.6%	90%
Agriculture	0.6%	27% (Livestock)	0.2%	0.2%	0.1%	3.3% (Forestry)	0.02%
Total (000 tonnes)	100% 159,000	27% 1,185	99% 3,774	100% 453	96% 2,730	49% 1,171	99% 6,640
Extraction and Distribution of Fossil Fuels					4%	13%	

Sources of Emissions of Methane			Sources of Emissions of VOC's	
Deep Mined Coal	19%		Solvent Use	26%
Open Cast Coal	0.2%		Industrial Processes	12%
Offshore Oil/gas	21%			
Gas Leakage	8%			
Landfill/Waste Disposal	23%			

Table 41: UK Sources of Emissions 1990 (from IPCC and UNECE definitions) [180, 186, 195]

7.3.1.3 Final Estimation of Emissions (All Sources) in Shropshire 1990 - 1997

The estimate of emissions for Shropshire was re-assessed based on UK statistics for each year and assuming the following:

1. There are no emissions of methane associated with offshore oil and gas, or deep and open cast mining.
2. Emissions of VOC's are included from industrial processes and solvent use, allowing for industries in Telford and the Wrekin [196].
3. Initial figures for emissions of SO2 1994 - 1997 for stationary combustion are over-estimated (negative figures in Table 40 used for corrections).
4. Initial figures for emissions of Black Smoke 1996 from transport are over-estimated (negative figure in Table 40 used for correction).

5. Stationary combustion processes from all fossil fuel sources include electricity generation, heating, cooking, cooling, etc.

This gave the final estimation of total emissions as given in Table 42. Emission factors are given for carbon content of emissions. In terms of weight of CO_2 emitted the carbon figure is multiplied by the molecular weight of CO_2 and divided by the atomic weight of carbon.

Relative atomic mass of oxygen = 16.0

Relative atomic mass of carbon = 12.0

Molecular weight of CO_2 = (12 + (2*16) = 44, therefore

Weight of CO_2 emitted = Carbon Content * (44/12)

Year	tonnes/ year	Carbon	%	CO_2	Methane	%	SO_2	%	Black smoke	%	NO_x	%	VOC's	%	CO	%
1990	Stationary combustion	872,153	77%	3,197,894	504	3%	25,170	94%	1,361	43%	7,361	38%	439	3%	2,972	6%
	Petroleum transport	232,985	21%	854,280	71	0%	918	3%	1,483	46%	11,296	59%	7,060	42%	42,361	90%
	Other	24,488	2%	89,788	18,140	97%	558	2%	355	11%	610	3%	9,410	56%	1,681	4%
Total		1,129,626	100%	4,141,962	18,714	100%	26,645	100%	3,198	100%	19,267	100%	16,909	100%	47,014	100%
1991	Stationary combustion	888,374	79%	3,257,373	513	2%	24,514	97%	1,367	42%	7,437	37%	449	3%	3,004	6%
	Petroleum transport	235,193	21%	862,373	78	0%	798	3%	1,568	48%	10,691	54%	6,985	40%	41,337	88%
	Other	6,570	1%	24,089	24,328	98%	17	0%	351	11%	1,722	9%	9,864	57%	2,462	5%
Total		1,130,137	100%	4,143,835	24,919	100%	25,330	100%	3,286	100%	19,849	100%	17,297	100%	46,803	100%
1992	Stationary combustion	858,422	76%	3,147,547	485	2%	23,883	96%	1,290	39%	7,107	39%	426	2%	2,822	6%
	Petroleum transport	233,358	21%	855,648	78	0%	849	3%	1,591	48%	9,900	54%	6,789	39%	38,893	88%
	Other	31,664	3%	116,101	25,420	98%	18	0%	407	12%	1,174	6%	10,089	58%	2,609	6%
Total		1,123,444	100%	4,119,296	25,983	100%	24,750	100%	3,288	100%	18,181	100%	17,304	100%	44,324	100%
1993	Stationary combustion	804,951	74%	2,951,487	446	2%	21,208	93%	1,140	35%	6,534	39%	398	2%	2,512	6%
	Petroleum transport	234,778	22%	860,851	78	0%	783	3%	1,636	50%	8,537	51%	6,688	38%	36,995	89%
	Other	41,671	4%	152,795	24,578	98%	733	3%	517	16%	1,683	10%	10,366	59%	1,849	4%
Total		1,081,400	100%	3,965,134	25,102	100%	22,724	100%	3,294	100%	16,755	100%	17,452	100%	41,356	100%
1994	Stationary combustion	791,070	75%	2,900,591	429	2%	18,508	96%	1,081	35%	6,307	40%	386	3%	2,382	7%
	Petroleum transport	242,214	23%	888,118	171	1%	855	4%	1,781	58%	8,549	54%	4,631	31%	31,345	91%
	Other	28,183	3%	103,339	23,543	98%	-	0%	187	6%	931	6%	10,065	67%	703	2%
Total		1,061,468	100%	3,892,048	24,143	100%	19,363	100%	3,049	100%	15,787	100%	15,081	100%	34,430	100%
1995	Stationary combustion	783,613	74%	2,873,248	358	2%	16,058	95%	863	34%	6,159	38%	329	2%	3,562	9%
	Petroleum transport	250,231	24%	917,515	193	1%	851	5%	1,501	59%	9,545	58%	5,798	35%	34,997	89%
	Other	24,277	2%	89,014	23,269	98%	-	0%	181	7%	705	4%	10,581	63%	606	2%
Total		1,058,121	100%	3,879,776	23,820	100%	16,908	100%	2,545	100%	16,408	100%	16,708	100%	39,165	100%
1996	Stationary combustion	806,937	73%	2,958,768	370	2%	13,916	96%	846	35%	5,983	41%	347	2%	3,095	9%
	Petroleum transport	257,565	23%	944,404	193	1%	594	4%	1,586	65%	8,643	59%	5,395	36%	29,312	88%
	Other	37,304	3%	136,780	22,601	98%	-	0%	-	0%	112	1%	9,361	62%	826	2%
Total		1,101,805	100%	4,039,952	23,164	100%	14,509	100%	2,433	100%	14,738	100%	15,103	100%	33,233	100%
1997	Stationary combustion	762,758	72%	2,796,780	345	2%	11,724	95%	732	30%	5,616	38%	315	2%	2,810	9%
	Petroleum transport	258,247	24%	946,906	194	1%	595	5%	1,650	67%	8,666	59%	5,409	36%	29,390	90%
	Other	33,504	3%	122,847	21,412	98%	-	0%	67	3%	344	2%	9,140	61%	356	1%
Total		1,054,509	100%	3,866,533	21,950	100%	12,320	100%	2,449	100%	14,626	100%	14,863	100%	32,556	100%

Table 42: Final Estimation of Emissions (All Sources) in Shropshire 1990 - 1997, Corrected for Methane, Black Smoke and SO_2)

8. Electricity Generation in Shropshire

The electricity supply network in Shropshire has been examined in detail [197] to determine the capacity to absorb electricity generated from small-scale renewable energy schemes (typically under 500 kWe) without major reinforcement. The analysis suggested that the network has the available capacity to absorb between 400 GWhe/y to 500 GWhe/y from embedded generation.

In the UK, electricity generated by power stations is transmitted via the national transmission system owned by the National Grid Company plc, to the Public Electricity Suppliers (PES's) distribution system. In 1997 [180] this distribution system covered an area of 242,011 sq. km. The fifteen PES's distributed 294,911 GWh of electricity to 26,611,000 customers (average electricity distributed 0.0111 GWhe/customer; average customer density 313 customers/sq. km, average 2.22 people/electricity customer).

In Shropshire electricity is distributed by two PES's: Midlands Electricity (MEB) and MANWEB. The total area covered by MANWEB is 12,000 sq. km. MANWEB distributed 18,353 GWh of electricity to 1,357,000 customers in 1997, an average of 0.01352 GWhe/customer, with an average customer density of 113-customers/sq. km. The total area covered by MEB is 13,300 sq. km. MEB distributed 25,555 GWh of electricity to 2,220,000 customers in 1997, an average of 0.01115 GWhe/customer, with an average customer density of 167-customers/sq. km.

This suggests that in Shropshire 400 GWhe/y from embedded generation could supply between 29,576 - 34,749 customers (65,066 - 76,447 people). 500 GWhe/y could supply between 36,969 - 43,436 customers (81,333 - 95,559 people).

8.1 Ironbridge Power Station

The only power station within the Shropshire area is the one in Ironbridge. The station's fuel is 98-99% coal, with only 0.8% - 2% oil consumed during start-up. The power station has a declared net capacity (DNC) of 950 MW, with an average conversion efficiency of approximately 35%-36%. The higher the load, the higher the efficiency, but the station is no longer used for base load. Intermittent use has seen generation drop from 723 MW in 1992 to 308 MW in 1996. This means that the emissions of carbon dioxide, and oxides of nitrogen and sulphur discharged per unit of electricity generated have slightly increased again due to the reductions in efficiency (see Table 43).

		Tonnes of waste produced					Tonnes of gaseous emissions				
Year	GWh	Ferrous metals	Non-ferrous metals	Chemicals and oils	Special waste	General waste	Dust	CO2	SO2	NOx	HCl
1992	6,342							6,043,926	72,933	22,831	8,245
1993	5,599							4,999,907	62,149	20,156	6,159
1994	4,357	65	0	38	4	767	610	3,838,517	48,798	15,685	4,792
1995	3,624	376	1	94	32	3,127	1,000	3,218,112	38,414	13,409	3,624
1996	2,697							2,446,179	33,982	10,249	2,997
		Tonnes of waste produced/GWh					Tonnes of gaseous emissions produced/GWh				
1992	6,342							953	11.5	3.6	1.3
1993	5,599							893	11.1	3.6	1.1
1994	4,357	0.0149		0.0087	0.0009	0.176	0.14	881	11.2	3.6	1.1
1995	3,624	0.1038	0.0003	0.0259	0.0088	0.8629	0.2759	888	10.6	3.7	1.0
1996	2.697							907	12.6	3.8	1.1

Table 43: Waste and Emissions from Ironbridge Power Station 1992 – 1996 [198, 199, 200]

Before privatisation of the electricity industry, Ironbridge belonged to the Central Electricity Generating Board (CEGB) and directly employed 0.43 people/MW DNC (including canteen workers). Since privatisation direct employment has fallen to 0.19 people/MW DNC (0.03 - 0.07 people/GWh generated).

Electricity at Ironbridge is generated at 22,000 volts and then stepped up to 400,000 volts by transformers before transmission. The station does not supply Shropshire directly as the electricity it produces is fed into the National Grid System.

8.2 Estimation of Shropshire PFC for Electricity Generation and Electricity Consumed by Final User

To estimate the amount of the PFC in Shropshire used for electricity generation and electricity consumed by final user, UK statistics on electricity generation from primary fuels, nuclear, natural flow hydro, renewables and other fuels (ignoring imports) were examined.

From 1990 the amount of PFC used for electricity generation has fallen exponentially as the use of higher efficiency conversion technologies for fossil fuels (especially natural gas) and renewable energy exploitation has increased (see Figure 14 and Tables 44 and 45).

% Primary Fuel Used for Electricity Generation = (Primary Fuel used for Electricity Generation / Total Consumption of Primary Fuels) * 100%

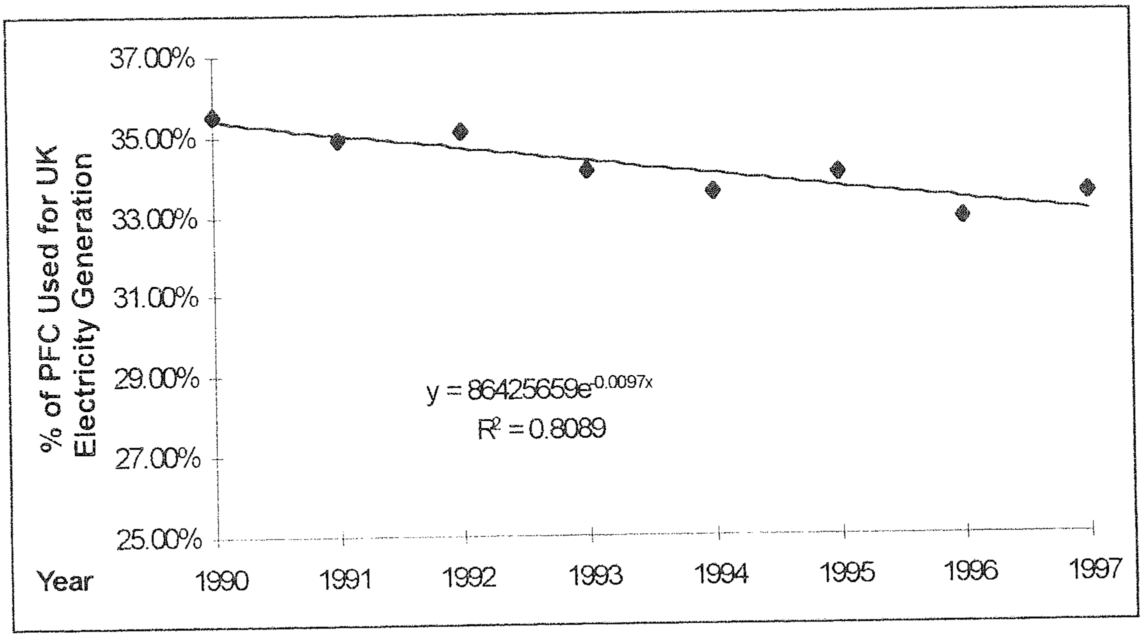

Figure 14: UK Percentage of PFC Used in Generating Electricity 1990 – 1997 [180, 186]

Year	Total PFC Used for Electricity Generation (%)	Model (%)	% Difference
1990	35.53%	35.76%	0.7%
1991	34.90%	35.42%	1.5%
1992	35.14%	35.08%	-0.2%
1993	34.09%	34.74%	1.9%
1994	33.60%	34.40%	2.4%
1995	34.02%	34.07%	0.2%
1996	32.88%	33.74%	2.6%
1997	33.53%	33.42%	-0.3%
Total difference			8.7%
Average difference			1.1%

Model
Total PFC Used for Electricity Generation (%) = (86,425,659 * EXP (-0.0097 * year)) * 100%

Table 44: Model of UK Percentage of PFC Used in Generating Electricity 1990 - 1997

Year	Total PFC Used for Electricity Generation (%)	Year	Total PFC Used for Electricity Generation (%)
1998	33.09%	2012	28.89%
1999	32.77%	2013	28.61%
2000	32.46%	2014	28.34%
2001	32.15%	2015	28.06%
2002	31.83%	2016	27.79%
2003	31.53%	2017	27.52%
2004	31.22%	2018	27.26%
2005	30.92%	2019	27.00%
2006	30.62%	2020	26.73%
2007	30.33%	2021	26.48%
2008	30.04%	2022	26.22%
2009	29.75%	2023	25.97%
2010	29.46%	2024	25.72%
2011	29.17%	2025	25.47%

Table 45: Model Estimate of UK Percentage of PFC Used in Generating Electricity 1998 - 2025

The model shows that the UK percentage of PFC used in generating electricity could be 0.72 times the 1990 level by 2025 and 0.56 times the 1990 level by 2050.

The percentage of PFC for electricity generation consumed by final user as electricity has also increased since 1990 as net electricity supplied (taking into account fuel industry consumption, transmission losses etc.) has increased (see Figure 15 and Tables 46 and 47).

% Primary Fuel Used for Electricity Generation Consumed as Electricity by Final User = (Electricity Consumed by Final User / PFC for Electricity Generation) * 100%

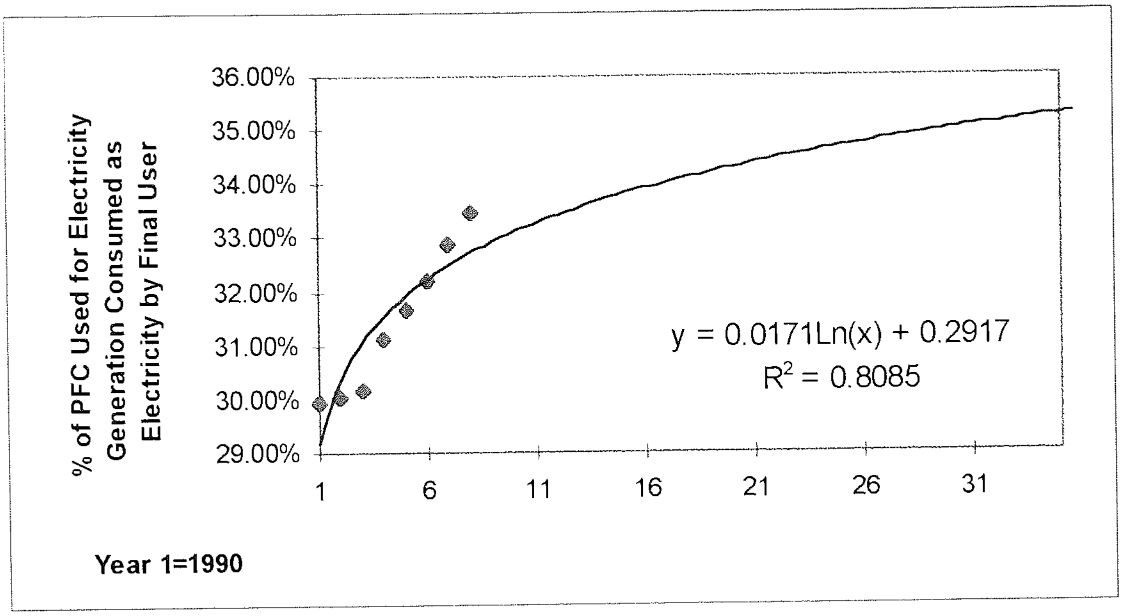

Figure 15: UK Percentage of PFC Used for Electricity Generation Consumed as Electricity by Final User 1990 - 1997.

1. Years 1 =1990, 6=1995, 11=2000, 16=2005, 21=2010, 26=2015, 31=2020.

Year	[1] Conversion Efficiency (%)	Model %	% Difference
1990	29.96%	29.17%	-3%
1991	30.05%	30.36%	1%
1992	30.16%	31.05%	3%
1993	31.14%	31.54%	1%
1994	31.66%	31.92%	1%
1995	32.21%	32.23%	0%
1996	32.87%	32.50%	-1%
1997	33.45%	32.73%	-2%
Total difference			0.2%
Average difference			0.0%

Model
% PFC Used for Electricity Generation Consumed as Electricity by Final User = 0.0171*LN(year - 1989) + 0.2917

Table 46: Model of UK Percentage of Primary Fuel Used for Electricity Generation Consumed as Electricity by Final User 1990 - 1997.

1. % PFC used for electricity generation consumed as electricity by final user.

Year	[1] Conversion Efficiency (%)	Year	[1] Conversion Efficiency (%)
1998	32.91%	2012	34.50%
1999	33.08%	2013	34.57%
2000	33.25%	2014	34.64%
2001	33.39%	2015	34.71%
2002	33.53%	2016	34.77%
2003	33.66%	2017	34.83%
2004	33.77%	2018	34.89%
2005	33.88%	2019	34.95%
2006	33.99%	2020	35.01%
2007	34.08%	2021	35.06%
2008	34.18%	2022	35.11%
2009	34.26%	2023	35.16%
2010	34.35%	2024	35.25%
2011	34.42%	2025	35.30%

Table 47: Model Estimate of UK Percentage of Primary Fuel Used for Electricity Generation Consumed as Electricity by Final User 1998 - 2025.

1. % PFC used for electricity generation consumed as electricity by final user.

The model shows that the UK percentage of PFC used for electricity generation consumed as electricity by final user could be 1.18 times the 1990 level by 2025 and 1.21 times the 1990 level by 2050.

The following were used to give an estimate of the consumption of PFC used in Shropshire for electricity generation (GJ/y) and total consumption of electricity by final user (GWh/y) for 1990 - 2025 (see Tables 48 and 49):

1. The estimate of total Shropshire PFC consumption (GJ/y) in Table 33;
2. The model of total PFC used for electricity generation (%) (Tables 44 and 45);
3. The model of % PFC used for electricity generation consumed as electricity by final user (Tables 46 and 47).

PFC Used for Electricity Generation (GJ/y) = Total PFC (GJ/y) * % PFC Used for Electricity Generation

Consumption of Electricity by Final User (GWh/y) = PFC Used for Electricity Generation (GWh/y) * % PFC used for electricity generation consumed as electricity by final user (Conversion Efficiency)

The estimate of total electricity consumption by final user was compared to supply data provided by the SET/MEA [201].

Year	Total PFC	PFC Used for Electricity Generation			[1]Conversion Efficiency	Consumption of Electricity by Final User	[2]Supply Data	Difference between supply data and estimate
	GJ/y	%	GJ/y	GWh/y	%	GWh/y	GWh/y	%
1990	63,518,018	35.53%	22,565,713	6,268	30.0%	1,878	1,807	3.95%
1991	65,717,119	34.90%	22,937,657	6,372	30.1%	1,915	1,850	3.49%
1992	64,949,679	35.14%	22,825,185	6,340	30.2%	1,912	1,893	1.00%
1993	65,879,941	34.09%	22,459,308	6,239	31.1%	1,943	1,937	0.29%
1994	65,431,653	33.60%	21,985,136	6,107	31.7%	1,934	1,980	-2.35%
1995	66,096,497	34.02%	22,485,956	6,246	32.2%	2,012	2,024	-0.58%
1996	69,781,488	32.88%	22,945,371	6,374	32.9%	2,095	2,067	1.37%
1997	68,148,661	33.53%	22,849,972	6,347	33.5%	2,123	2,110	0.62%
Total difference								7.80%
Average difference								0.97%

Table 48: Estimate of Shropshire PFC Used for Electricity Generation and Consumption of Electricity by Final User (ignoring imports) 1990 - 1997.

1. % PFC used for electricity generation consumed as electricity by final user.
2. Assuming annual increase in consumption by final users of around 43 GWh/y between 1990 and 1996.

Year	Total PFC	PFC Used for Electricity Generation			[1]Conversion Efficiency	Consumption of Electricity by Final User
	GJ/y	%	GJ/y	GWh/y	%	GWh/y
1998	69,116,864	33.09%	22,873,841	6,354	32.91%	2,091
1999	69,807,313	32.77%	22,879,331	6,355	33.08%	2,103
2000	70,502,257	32.46%	22,884,044	6,357	33.25%	2,113
2001	71,185,295	32.15%	22,882,706	6,356	33.39%	2,123
2002	72,120,183	31.83%	22,959,438	6,378	33.53%	2,138
2003	73,044,972	31.53%	23,029,373	6,397	33.66%	2,153
2004	73,976,126	31.22%	23,097,805	6,416	33.77%	2,167
2005	74,896,983	30.92%	23,159,586	6,433	33.88%	2,180
2006	75,840,910	30.62%	23,225,087	6,451	33.99%	2,193
2007	76,555,601	30.33%	23,217,643	6,449	34.08%	2,198
2008	77,274,875	30.04%	23,209,555	6,447	34.18%	2,203
2009	77,981,781	29.75%	23,195,781	6,443	34.26%	2,208
2010	78,710,226	29.46%	23,186,454	6,441	34.35%	2,212
2011	79,443,329	29.17%	23,176,506	6,438	34.42%	2,216
2012	80,384,754	28.89%	23,224,777	6,451	34.50%	2,226
2013	81,236,029	28.61%	23,244,163	6,457	34.57%	2,232
2014	82,096,319	28.34%	23,263,564	6,462	34.64%	2,239
2015	82,965,720	28.06%	23,282,981	6,467	34.71%	2,245
2016	83,844,328	27.79%	23,302,415	6,473	34.77%	2,251
2017	84,732,239	27.52%	23,321,865	6,478	34.83%	2,257
2018	85,629,554	27.26%	23,341,331	6,484	34.89%	2,262
2019	86,536,372	27.00%	23,360,813	6,489	34.95%	2,268
2020	87,452,793	26.73%	23,380,312	6,495	35.01%	2,274
2021	88,378,918	26.48%	23,399,827	6,500	35.06%	2,279
2022	89,314,852	26.22%	23,419,358	6,505	35.11%	2,284
2023	90,260,696	25.97%	23,438,906	6,511	35.16%	2,290
2024	91,216,558	25.72%	23,458,470	6,516	35.25%	2,297
2025	92,182,542	25.47%	23,478,050	6,522	35.30%	2,302

Table 49: Estimate of Shropshire PFC Used for Electricity Generation and Consumption of Electricity by Final User (ignoring imports) 1998 - 2025.

1. % PFC used for electricity generation consumed as electricity by final user.

The estimates show that the total PFC used for electricity generation in Shropshire could be 1.04 times the 1990 level by 2025 and 1.06 times the 1990 level by 2050. The total consumption of electricity by final user (GWh/y) could be 1.27 times the 1990 supply data level by 2025 and 1.33 times the 1990 supply data level by 2050 (ignoring imports).

8.2.1 Emissions Associated with Generation of Electricity

To estimate the emissions associated with electricity in Shropshire, UK statistics on emissions from power stations were examined (UNECE definitions, all fuels, all electricity except imports) [180, 186] to determine average emission factors for electricity generated from PFC and distributed through the National Grid (see

Table 50) and average emission factors for electricity consumed by final user (see Table 52).

Year	Carbon	CO2	SO2	Black Smoke	NOx	VOC's	CO
	g/GJ	g/GJ	g/GJ	g/GJ	g/GJ	g/GJ	g/GJ
1990	16,879	61,891	845	8	244	4	16
1991	16,561	60,724	786	8	213	4	14
1992	15,753	57,759	766	7	206	3	13
1993	14,572	53,429	665	7	181	3	12
1994	14,258	52,278	583	6	172	2	7
1995	13,898	50,958	509	6	154	2	6
1996	13,408	49,162	405	6	140	2	5
1997	12,652	46,390	342	6	126	2	4

Table 50: UK Average Annual Emission Factors (g/GJ) for Generation of Electricity from PFC, which is Distributed Through the National Grid 1990 – 1997

These emission factors were used with estimates of PFC used for electricity generation to give emissions for Shropshire (see Table 51).

Annual Total Emissions Associated with Electricity Generation in Shropshire (tonnes) = (Average Annual Emission Factor for Electricity Generation (g/GJ) * Annual PFC Used for Electricity Generation in Shropshire (GJ/y)) / 1 $*10^6$ (g/t).

Year	PFC Used for Electricity Generation	Carbon	CO2	SO_2	Black Smoke	NOx	VOC's	CO
	GJ/y	tonnes	tonnes	tonnes	tonnes	tonnes	tonnes	tonnes
1990	22,565,713	380,896	1,396,618	19,062	191	5,507	92	353
1991	22,937,657	379,872	1,392,864	18,031	178	4,889	86	328
1992	22,825,185	359,555	1,318,367	17,479	164	4,699	78	299
1993	22,459,308	327,266	1,199,975	14,940	149	4,055	71	270
1994	21,985,136	313,454	1,149,330	12,823	135	3,776	43	150
1995	22,485,956	312,503	1,145,845	11,439	139	3,460	39	132
1996	22,945,371	307,647	1,128,039	9,301	143	3,212	36	114
1997	22,849,972	289,093	1,060,009	7,819	142	2,869	36	86

Table 51: Estimate of Emissions (tonnes) from Generation of Electricity (transmitted through the National Grid) in Shropshire 1990 - 1997.

Year	Carbon	CO2	SO2	Black Smoke	NOx	VOC's	CO
	g/GJ	g/GJ	g/GJ	g/GJ	g/GJ	g/GJ	g/GJ
1990	56,332	206,549	2,819	28	814	14	52
1991	55,110	202,071	2,616	26	709	12	48
1992	52,226	191,494	2,539	24	683	11	43
1993	46,799	171,595	2,136	21	580	10	39
1994	45,029	165,105	1,842	19	542	6	21
1995	43,147	158,205	1,579	19	478	5	18
1996	40,786	149,550	1,233	19	426	5	15
1997	37,821	138,677	1,023	19	375	5	11

Table 52: UK Average Annual Emission Factors (g/GJ) for Electricity Consumed by Final User 1990 - 1997.

The emission factors for electricity consumed by final user were used with supply data to give a second estimate of emissions for Shropshire (see Table 53). These compare well with the first estimate (-2.3% to +4% difference between emissions based on estimated PFC and emissions based on supply data).

Equivalent GJ/y Consumed by Final User = Supply Data (GWh/y) * 3600 (GJ/GWh)

Annual Total Emissions Associated with Electricity Consumption by Final User in Shropshire (tonnes) = (Average Annual Emission Factor for Electricity Consumed by Final User (g/GJ) * Annual Equivalent GJ/y Electricity Consumed by Final User) / 1 *10^6 (g/t).

Year	Consumption of Electricity by Final User		Carbon	CO_2	SO_2	Black Smoke	NOx	VOC's	CO
	Supply Data GWh/y	GJ/y	tonnes	tonnes	tonnes	tonnes	tonnes	tonnes	tonnes
1990	1,807	6,504,484	366,408	1,343,495	18,337	183	5,297	88	340
1991	1,850	6,660,534	367,063	1,345,899	17,423	172	4,724	83	317
1992	1,893	6,816,584	356,001	1,305,336	17,307	162	4,653	78	296
1993	1,937	6,972,635	326,309	1,196,466	14,897	149	4,043	71	270
1994	1,980	7,128,685	320,995	1,176,980	13,132	139	3,867	44	153
1995	2,024	7,284,736	314,313	1,152,482	11,505	140	3,480	40	133
1996	2,067	7,440,786	303,483	1,112,773	9,175	141	3,169	35	113
1997	2,110	7,596,836	287,319	1,053,503	7,771	141	2,852	36	86

Table 53: Estimate of Emissions (tonnes) from Electricity Consumption by Final User in Shropshire 1990 - 1997

8.2.1.1 Emissions Associated with Generation of Electricity up to 2025

The accessible and practicable renewable energy resources that could contribute to electricity supply in Shropshire have been examined thoroughly by the SET/MEA [202, 203, 204] and estimated for the years 2005 and 2025. To determine the potential these resources could have in emission reduction, (if fully exploited), it is necessary to estimate what the emissions associated with electricity generation would have been for a business as usual scenario.

An examination of emission factors for 1993 - 1997 showed that the effect of a 1% increase in amount of PFC used for generating electricity being consumed by final user (conversion efficiency), due to better efficiency of use, reduced transmission and distribution losses etc. gave the following average reductions in emissions:

Emission	Reduction in emission (g/GJ)
Carbon	1,449
CO_2	5,313
SO_2	150
Black Smoke	1
NO_x	41
VOC's	1
CO	4

Table 54: Reduction in Emissions Due to a 1% Increase in the Amount of PFC Used for Generating Electricity Being Consumed by Final User.

Using the model of UK percentage of PFC used for electricity generation consumed as electricity by final user in Table 47, the emission reduction figures in Table 54 and assuming that further reductions in black smoke, VOC's and CO are negligible beyond the year 2000 gives the emission factors in Table 55.

Year	[1] Conversion Efficiency	Carbon	CO2	SO2	Black Smoke	NOx	VOC's	CO
	g/GJ	g/GJ	g/GJ	g/GJ	g/GJ	g/GJ	g/GJ	g/GJ
1998	32.91%	12,618	46,265	403	5	123	1	4
1999	33.08%	12,358	45,314	376	5	115	1	3
2000	33.25%	12,124	44,453	351	5	108	1	3
2001	33.39%	11,909	43,667	329	5	102	1	3
2002	33.53%	11,712	42,944	309	5	97	1	3
2003	33.66%	11,529	42,275	290	5	91	1	3
2004	33.77%	11,359	41,651	272	5	87	1	3
2005	33.88%	11,200	41,068	256	5	82	1	3
2006	33.99%	11,051	40,521	240	5	78	1	3
2007	34.08%	10,910	40,005	226	5	74	1	3
2008	34.18%	10,777	39,516	212	5	70	1	3
2009	34.26%	10,651	39,053	199	5	66	1	3
2010	34.35%	10,531	38,612	186	5	63	1	3
2011	34.42%	10,416	38,192	174	5	60	1	3
2012	34.50%	10,306	37,790	163	5	57	1	3
2013	34.57%	10,202	37,406	152	5	54	1	3
2014	34.64%	10,101	37,037	142	5	51	1	3
2015	34.71%	10,004	36,683	132	5	48	1	3
2016	34.77%	9,912	36,342	122	5	45	1	3
2017	34.83%	9,822	36,014	113	5	43	1	3
2018	34.89%	9,735	35,697	104	5	40	1	3
2019	34.95%	9,652	35,391	95	5	38	1	3
2020	35.01%	9,571	35,094	87	5	36	1	3
2021	35.06%	9,493	34,808	79	5	33	1	3
2022	35.11%	9,417	34,530	71	5	31	1	3
2023	35.16%	9,344	34,260	63	5	29	1	3
2024	35.25%	9,221	33,809	50	5	26	1	3
2025	35.30%	9,151	33,553	43	5	24	1	3

Table 55: Estimated Average Annual UK Emission Factors for Generation of Electricity from PFC, which is Distributed Through the National Grid 1998 - 2025, (current technology trends, all fuels, all electricity except imports).

1. % PFC used for electricity generation consumed as electricity by final user.

These emission factors were used with the estimate of PFC used for electricity generation in Table 49, to give the following emissions associated with electricity generation for Shropshire to 2025.

Year	PFC used for electricity generation	Carbon	CO2	SO_2	Black Smoke	NOx	VOC's	CO
	GJ/y	tonnes	tonnes	tonnes	tonnes	tonnes	tonnes	tonnes
1998	22,873,841	288,618	1,058,268	9,211	122	2,803	31	93
1999	22,879,331	282,749	1,036,748	8,597	118	2,634	27	77
2000	22,884,044	277,435	1,017,261	8,041	114	2,481	24	62
2001	22,882,706	272,514	999,217	7,532	114	2,341	24	62
2002	22,959,438	268,901	985,969	7,088	114	2,220	24	62
2003	23,029,373	265,515	973,557	6,673	115	2,107	24	63
2004	23,097,805	262,379	962,055	6,286	115	2,001	24	63
2005	23,159,586	259,399	951,128	5,921	115	1,902	24	63
2006	23,225,087	256,664	941,100	5,577	116	1,808	24	63
2007	23,217,643	253,312	928,812	5,237	116	1,715	24	63
2008	23,209,555	250,133	917,153	4,914	116	1,626	24	63
2009	23,195,781	247,053	905,862	4,607	115	1,541	24	63
2010	23,186,454	244,167	895,280	4,316	115	1,461	24	63
2011	23,176,506	241,407	885,157	4,039	115	1,385	24	63
2012	23,224,777	239,366	877,676	3,783	116	1,315	24	63
2013	23,244,163	237,129	869,473	3,534	116	1,247	24	63
2014	23,263,564	234,987	861,621	3,294	116	1,181	24	63
2015	23,282,981	232,934	854,092	3,063	116	1,118	24	63
2016	23,302,415	230,962	846,861	2,841	116	1,057	24	63
2017	23,321,865	229,066	839,907	2,627	116	998	24	63
2018	23,341,331	227,239	833,210	2,420	116	942	24	63
2019	23,360,813	225,478	826,752	2,219	116	887	24	63
2020	23,380,312	223,777	820,517	2,025	116	834	24	64
2021	23,399,827	222,134	814,492	1,837	116	782	24	64
2022	23,419,358	220,544	808,662	1,654	117	732	24	64
2023	23,438,906	219,005	803,017	1,477	117	684	24	64
2024	23,458,470	216,304	793,114	1,179	117	602	24	64
2025	23,478,050	214,845	787,766	1,010	117	556	24	64

Table 56: Estimate of Emission (tonnes) for Generation of Electricity from PFC, which is distributed through the National Grid in Shropshire 1998 - 2025 (current technology trends, all fuels, all electricity except imports).

Taking the emissions for electricity consumption 1990 - 1998 from those for stationary combustion in Table 42 gives a more detailed summary of estimated total emissions for Shropshire as given in Table 57. Carbon emissions for stationary combustion (heating, cooking, cooling etc.), generation of electricity and petroleum transport are illustrated in Figure 16.

Year	Tonnes/ year	Carbon	%	CO2	Methane	%	SO2	%	Black Smoke	%	NOx	%	VOC's	%	CO	%
1990	Stationary combustion	491,257	43%	1,801,276	504	3%	6,107	23%	1,170	37%	1,854	10%	347	2%	2,619	6%
	Electricity	380,896	34%	1,396,618	0	0%	19,062	72%	191	6%	5,507	29%	92	1%	353	1%
	Petroleum transport	232,985	21%	854,280	71	0%	918	3%	1,483	46%	11,296	59%	7,060	42%	42,361	90%
	Other	24,488	2%	89,788	18,140	97%	558	2%	355	11%	610	3%	9,410	56%	1,681	4%
Total		1,129,626	100%	4,141,962	18,714	100%	26,645	100%	3,198	100%	19,267	100%	16,909	100%	47,014	100%
1991	Stationary combustion	508,502	45%	1,864,509	513	2%	6,483	26%	1,188	36%	2,547	13%	363	2%	2,676	6%
	Electricity	379,872	34%	1,392,864	0	0%	18,031	71%	178	5%	4,889	25%	86	0%	328	1%
	Petroleum transport	235,193	21%	862,373	78	0%	798	3%	1,568	48%	10,691	54%	6,985	40%	41,337	88%
	Other	6,570	1%	24,089	24,328	98%	17	0%	351	11%	1,722	9%	9,864	57%	2,462	5%
Total		1,130,137	100%	4,143,835	24,919	100%	25,330	100%	3,286	100%	19,849	100%	17,297	100%	46,803	100%
1992	Stationary combustion	498,867	44%	1,829,181	485	2%	6,404	26%	1,127	34%	2,408	13%	348	2%	2,523	6%
	Electricity	359,555	32%	1,318,367	0	0%	17,479	71%	164	5%	4,699	26%	78	0%	299	1%
	Petroleum transport	233,358	21%	855,648	78	0%	849	3%	1,591	48%	9,900	54%	6,789	39%	38,893	88%
	Other	31,664	3%	116,101	25,420	98%	18	0%	407	12%	1,174	6%	10,089	58%	2,609	6%
Total		1,123,444	100%	4,119,296	25,983	100%	24,750	100%	3,288	100%	18,181	100%	17,304	100%	44,324	100%
1993	Stationary combustion	477,685	44%	1,751,512	446	2%	6,268	28%	991	30%	2,479	15%	327	2%	2,241	5%
	Electricity	327,266	30%	1,199,975	0	0%	14,940	66%	149	5%	4,055	24%	71	0%	270	1%
	Petroleum transport	234,778	22%	860,851	78	0%	783	3%	1,636	50%	8,537	51%	6,688	38%	36,995	89%
	Other	41,671	4%	152,795	24,578	98%	733	3%	517	16%	1,683	10%	10,366	59%	1,849	4%
Total		1,081,400	100%	3,965,134	25,102	100%	22,724	100%	3,294	100%	16,755	100%	17,452	100%	41,356	100%
1994	Stationary combustion	477,617	45%	1,751,261	429	2%	5,685	29%	945	31%	2,531	16%	343	2%	2,232	6%
	Electricity	313,454	30%	1,149,330	0	0%	12,823	66%	135	4%	3,776	24%	43	0%	150	0%
	Petroleum transport	242,214	23%	888,118	171	1%	855	4%	1,781	58%	8,549	54%	4,631	31%	31,345	91%
	Other	28,183	3%	103,339	23,543	98%	-	0%	187	6%	931	6%	10,065	67%	703	2%
Total		1,061,468	100%	3,892,048	24,143	100%	19,363	100%	3,049	100%	15,787	100%	15,081	100%	34,430	100%
1995	Stationary combustion	471,110	45%	1,727,403	358	2%	4,619	27%	723	28%	2,698	16%	290	2%	3,430	9%
	Electricity	312,503	30%	1,145,845	0	0%	11,439	68%	139	5%	3,460	21%	39	0%	132	0%
	Petroleum transport	250,231	24%	917,515	193	1%	851	5%	1,501	59%	9,545	58%	5,798	35%	34,997	89%
	Other	24,277	2%	89,014	23,269	98%	-	0%	181	7%	705	4%	10,581	63%	608	2%
Total		1,058,121	100%	3,879,776	23,820	100%	16,908	100%	2,545	100%	16,408	100%	16,708	100%	39,165	100%
1996	Stationary combustion	499,290	45%	1,830,729	370	2%	4,615	32%	703	29%	2,771	19%	312	2%	2,980	9%
	Electricity	307,647	28%	1,128,039	0	0%	9,301	64%	143	6%	3,212	22%	38	0%	114	0%
	Petroleum transport	257,565	23%	944,404	193	1%	594	4%	1,586	65%	8,643	59%	5,395	36%	29,312	88%
	Other	37,304	3%	136,780	22,601	98%	-	0%	-	0%	112	1%	9,361	62%	826	2%
Total		1,101,805	100%	4,039,952	23,164	100%	14,509	100%	2,433	100%	14,738	100%	15,103	100%	33,233	100%
1997	Stationary combustion	473,665	45%	1,736,771	345	2%	3,905	32%	590	24%	2,747	19%	279	2%	2,723	8%
	Electricity	289,093	27%	1,060,009	0	0%	7,819	63%	142	6%	2,869	20%	36	0%	86	0%
	Petroleum transport	258,247	24%	946,906	194	1%	595	5%	1,650	67%	8,666	59%	5,409	36%	29,390	90%
	Other	33,504	3%	122,847	21,412	98%	-	0%	67	3%	344	2%	9,140	61%	356	1%
Total		1,054,509	100%	3,866,533	21,950	100%	12,320	100%	2,449	100%	14,626	100%	14,863	100%	32,558	100%

Table 57: Final Estimation of Emissions (all sources) in Shropshire 1990 - 1997 Showing Emissions for Generation of Electricity from PFC.

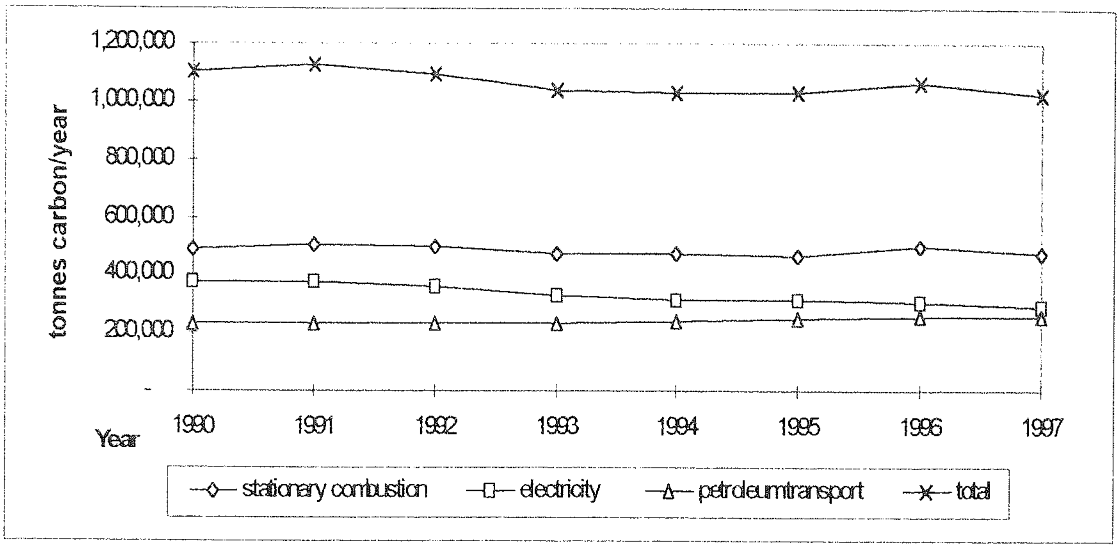

Figure 16: Estimate of Carbon Emissions from Stationary Combustion, Generation of Electricity and Petroleum Transport in Shropshire 1990 to 1997.

If these trends continue in Shropshire, carbon emissions from petroleum-based transport will exceed both carbon emissions from generation of electricity (by around 2002) and from stationary combustion (by around 2025).

9. District Energy Consumption Estimation

All potential renewable energy schemes are based on local resources. To gain the necessary public support for successful implementation it would be of benefit to be able to determine the contribution such schemes could make to local demand and reductions in emissions. To this end, local, rather than regional energy consumption must be estimated.

National statistics have been examined to determine energy consumption for Shropshire as a whole in chapters 7 and 8. To validate the methodology for estimating regional energy consumption and develop models to estimate local energy consumption, the data available on Shropshire districts and studies of other areas were examined.

9.1 Shropshire District Electricity Data

Electricity supply data [201] for Shropshire districts for 1990 and 1996 is given in the following tables:

District 1990	Domestic		Agriculture		Commercial		Industrial		Total	
Bridgnorth	85.74	5%	12.99	1%	42.87	2%	152.99	8%	294.59	16%
North Shropshire	75.73	4%	22.41	1%	58.63	3%	49.28	3%	206.05	11%
Oswestry	41.07	2%	7.81	0.4%	46.26	3%	18.91	1%	114.03	6%
Shrewsbury & Atcham	134.89	7%	13.02	1%	111.31	6%	67.86	4%	327.08	18%
South Shropshire	69.10	4%	16.49	1%	31.04	2%	29.10	2%	145.74	8%
Wrekin	156.90	9%	5.86	0.3%	152.04	8%	404.52	22%	719.31	40%
Shropshire	563.42	31%	78.57	4%	442.14	24%	722.66	40%	1806.80	100%

District 1996	Domestic		Agriculture		Commercial		Industrial		Total	
Bridgnorth	113.69	6%	13.89	1%	44.25	2%	166.35	8%	338.188	16%
North Shropshire	99.47	5%	27.32	1%	66.69	3%	54.12	3%	247.592	12%
Oswestry	44.99	2%	8.33	0.4%	49.97	2%	20.42	1%	123.708	6%
Shrewsbury & Atcham	154.70	7%	13.67	1%	118.03	6%	74.17	4%	360.558	17%
South Shropshire	94.64	5%	19.39	1%	34.43	2%	32.17	2%	180.625	9%
Wrekin	195.99	9%	7.80	0.4%	169.81	8%	442.62	21%	816.214	39%
Shropshire	703.467	34%	90.398	4%	483.177	23%	789.843	38%	2066.89	100%

Table 58: Shropshire Electricity Consumption (GWh) for 1990 and 1996

1. The largest consumer of electricity was the industrial sector, especially in the Wrekin.
2. The smallest consumer of electricity was the agricultural sector.

District 1990	Domestic	Agriculture	Commercial	Industrial	Total
Bridgnorth	29%	4%	15%	52%	100%
North Shropshire	37%	11%	28%	24%	100%
Oswestry	36%	7%	41%	17%	100%
Shrewsbury & Atcham	41%	4%	34%	21%	100%
South Shropshire	47%	11%	21%	20%	100%
Wrekin	22%	1%	21%	56%	100%

District 1996	Domestic	Agriculture	Commercial	Industrial	Total
Bridgnorth	34%	4%	13%	49%	100%
North Shropshire	40%	11%	27%	22%	100%
Oswestry	36%	7%	40%	17%	100%
Shrewsbury & Atcham	43%	4%	33%	21%	100%
South Shropshire	52%	11%	19%	18%	100%
Wrekin	24%	1%	21%	54%	100%

Table 59: Shropshire District Electricity Consumption (%) for 1990 and 1996

1. In Bridgnorth and the Wrekin the industrial sector was the largest consumer of electricity.
2. In North and South Shropshire and Shrewsbury & Atcham the domestic sector was the largest consumer of electricity.
3. In Oswestry the commercial sector was the largest consumer of electricity.

District 1990	Domestic	Agriculture	Commercial	Industrial
Bridgnorth	15%	17%	10%	21%
North Shropshire	13%	29%	13%	7%
Oswestry	7%	10%	10%	3%
Shrewsbury & Atcham	24%	17%	25%	9%
South Shropshire	12%	21%	7%	4%
Wrekin	28%	7%	34%	56%
Shropshire	100%	100%	100%	100%

District 1996	Domestic	Agriculture	Commercial	Industrial
Bridgnorth	16%	15%	9%	21%
North Shropshire	14%	30%	14%	7%
Oswestry	6%	9%	10%	3%
Shrewsbury & Atcham	22%	15%	24%	9%
South Shropshire	13%	21%	7%	4%
Wrekin	28%	9%	35%	56%
Shropshire	100%	100%	100%	100%

Table 60: Shropshire Sector Electricity Consumption (%) for 1990 and 1996

1. In the domestic and commercial and industrial sectors the Wrekin was the largest consumer of electricity.
2. In the agricultural sector North Shropshire was the largest consumer of electricity.

District	Domestic	Agriculture	Commercial	Industrial	Total
Bridgnorth	27.95	0.90	1.39	13.36	43.60
North Shropshire	23.74	4.91	8.06	4.83	41.54
Oswestry	3.92	0.52	3.71	1.52	9.67
Shrewsbury & Atcham	19.81	0.65	6.72	6.31	33.48
South Shropshire	25.54	2.90	3.39	3.07	34.89
Wrekin	39.09	1.94	17.78	38.09	96.90
Shropshire	140.05	11.83	41.03	67.18	260.08

Table 61: Increase in Shropshire Sector Electricity Consumption (GWh) Between 1990 and 1996.

1. The largest increase in consumption was in the domestic sector.
2. The smallest increase in consumption was in the agricultural sector.
3. The largest overall increase in consumption was in the Wrekin.
4. The smallest overall increase in consumption was in Oswestry.

District	Domestic	Agriculture	Commercial	Industrial	Total
Bridgnorth	33%	7%	3%	9%	15%
North Shropshire	31%	22%	14%	10%	20%
Oswestry	10%	7%	8%	8%	8%
Shrewsbury & Atcham	15%	5%	6%	9%	10%
South Shropshire	37%	18%	11%	11%	24%
Wrekin	25%	33%	12%	9%	13%
Total	24.9%	15.0%	9.3%	9.3%	14.4%

Table 62: Percentage Change (Increases) in Shropshire Sector Electricity Consumption Between 1990 and 1996.

1. The largest percentage change was in the domestic sector.
2. The smallest percentage change was in the commercial and industrial sectors.
3. The largest overall percentage change in consumption was in South Shropshire.
4. The largest percentage change in the domestic and industrial sectors was in South Shropshire.
5. The largest percentage change in the agricultural sector was in the Wrekin.

Year	District	% of Total Population	% of Total Electricity Consumed
1990	Bridgnorth	12%	16.3%
1990	North Shropshire	13%	11.4%
1990	Oswestry	8%	6.3%
1990	Shrewsbury & Atcham	23%	18.1%
1990	South Shropshire	9%	8.1%
1990	Wrekin	34%	39.8%
1996	Bridgnorth	12%	16.4%
1996	North Shropshire	13%	12.0%
1996	Oswestry	8%	6.0%
1996	Shrewsbury & Atcham	23%	17.4%
1996	South Shropshire	10%	8.7%
1996	Wrekin	34%	39.5%

Table 63: Percentage Population Compared to Percentage of Total Electricity Consumed by Final User in Shropshire 1990 and 1996.

1. Oswestry has 8% the total population in Shropshire but only consumed 6% of the total electricity.
2. Bridgnorth has 12% of the total population in Shropshire but consumed over 16% of the total electricity.

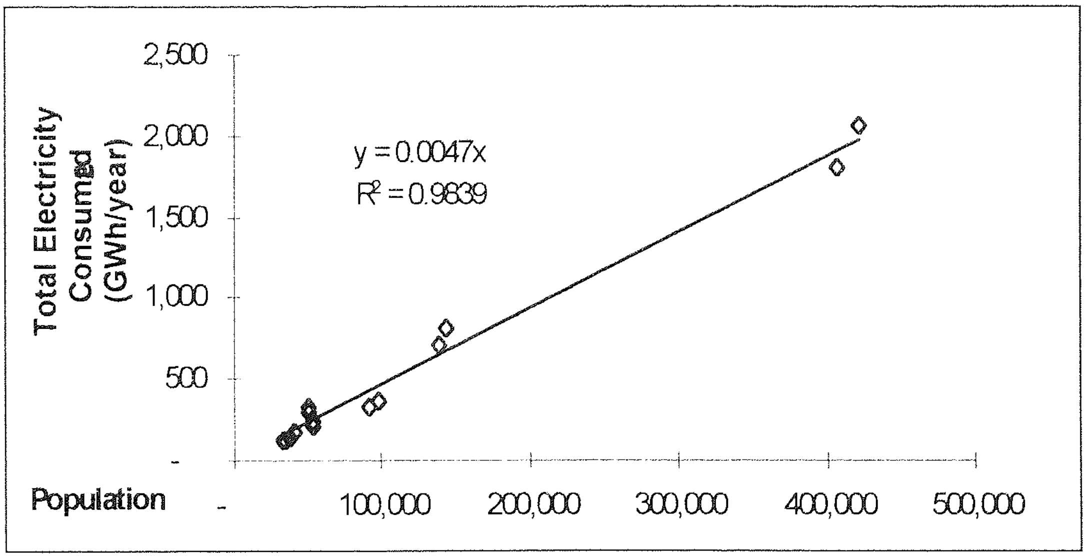

Figure 17: Relationship Between Population and Electricity Consumption in Shropshire Districts 1990 - 1996.

Figure 17 and Table 64 give a model for total annual consumption of electricity by final user in Shropshire based on population levels. The model shows that on average, each person in Shropshire consumed 0.0047 GWh of electricity per year for 1990 and 1996.

Year	District	Population	Supply Data (GWhe/y)	Model	% Difference
1990	Shropshire	406,390	1,807	1,910	6%
1990	Bridgnorth	50,511	295	237	-19%
1990	North Shropshire	52,873	206	249	21%
1990	Oswestry	33,508	114	157	38%
1990	Shrewsbury & Atcham	91,749	327	431	32%
1990	South Shropshire	38,230	146	180	23%
1990	Wrekin	139,515	719	656	-9%
1996	Shropshire	420,700	2,067	1,977	-4%
1996	Bridgnorth	50,800	338	239	-29%
1996	North Shropshire	54,100	248	254	3%
1996	Oswestry	34,600	124	163	31%
1996	Shrewsbury & Atcham	97,100	361	456	27%
1996	South Shropshire	40,500	181	190	5%
1996	Wrekin	144,200	816	678	-17%
Total difference					107%
Average difference					8%

Model
Total Electricity Consumed by Final User (GWhe/y) in Shropshire Districts = 0.0047 * Population of District

Table 64: Model of Total Electricity Consumed by Final User in Shropshire Districts.

This simple model provides a reasonable estimate for electricity consumption for Shropshire as a whole. Consumption in Oswestry and Shrewsbury & Atcham is over-estimated by around 30 - 40%. Consumption in Bridgnorth is under-estimated by around 20 - 30%.

9.2 Estimation of Domestic Electricity Consumption in Shropshire

Domestic electricity use was examined to see what was the relationship between consumption and the number of households (family units) with residents. Only houses with residents were considered as it is assumed that only these households consume electricity.

To estimate the total number of households with residents in Shropshire in 1996, data from Shropshire County Council and the ONS was examined (see Figure 18 and Table 65).

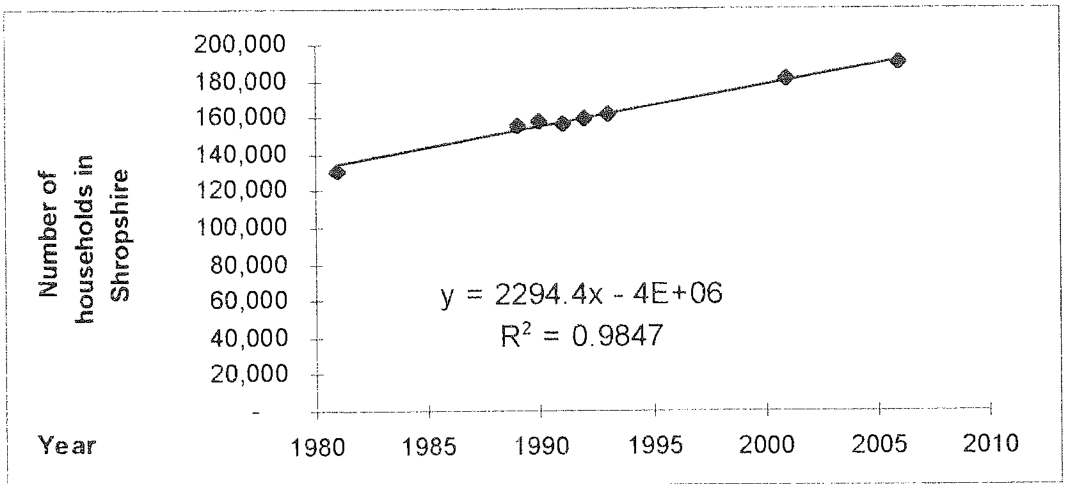

Figure 18: Number of Households with Residents in Shropshire 1981 – 2006 [152, 205, 206, 207, 208]

Year	Number of Households	Model	% Difference
1981	130,782	134,220	2.6%
1989	155,370	152,576	-1.8%
1990	157,726	154,870	-1.8%
1991	156,883	157,164	0.2%
1992	159,476	159,459	0.0%
1993	161,713	161,753	0.0%
2001	180,920	180,108	-0.4%
2006	189,380	191,580	1.2%
Total difference			-0.1%
Average difference			0%

Model
Number of Households with Residents in Shropshire = (2,294.4 * year) - 4,410,986

Table 65: Model of Number of Households with Residents in Shropshire 1981 - 2006

The model gives the total number of households with residents in Shropshire in 1996 as 168,636. Assuming these households were distributed between districts as in the 1991 Census (see Table 66), the domestic electricity consumption (GWh/y) was plotted against the number of households to determine the relationship (see Figure 19).

District	Number of households	%
Bridgnorth	19,148	12%
North Shropshire	20,292	13%
Oswestry	13,337	9%
Shrewsbury & Atcham	36,410	23%
South Shropshire	15,281	10%
Wrekin	52,415	33%
Shropshire	156,883	100%

Table 66: Number of Households with Residents in Shropshire Districts 1991 [206]

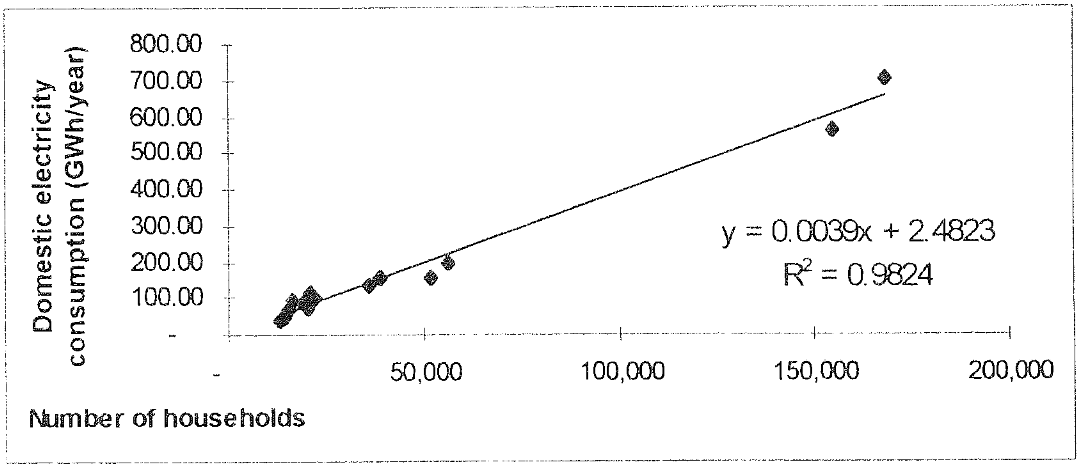

Figure 19: Relationship Between Domestic Electricity Consumption and Number of Households with Residents in Shropshire 1990 - 1996.

Domestic electricity consumption depends on the total number of households with residents. Figures were estimated for Shropshire up to the year 2025 (see Tables 67 and 68) using the above model for number of households. The average consumption per household (GWhe/household) was also estimated.

Average Annual Domestic Electricity Consumption per Household (GWhe/hh) in Shropshire = Annual Domestic Electricity Consumption (GWhe) / Number of Households (hh)

District	Domestic Electricity Consumption by Final User			
	Number of Households	GWhe/year	Model	% Difference
Bridgnorth 1990	18,902	85.74	76	-11.1%
North Shropshire	20,032	75.73	81	6.4%
Oswestry	13,166	41.07	54	31.1%
Shrewsbury & Atcham	35,943	134.89	143	5.8%
South Shropshire	15,085	69.10	61	-11.3%
Wrekin	51,742	156.90	204	30.2%
Shropshire	154,870	563.42	606	7.6%
Bridgnorth 1996	20,583	113.69	83	-27.2%
North Shropshire	21,812	99.47	88	-12.0%
Oswestry	14,336	44.99	58	29.8%
Shrewsbury & Atcham	39,138	154.70	155	0.3%
South Shropshire	16,426	94.64	67	-29.7%
Wrekin	56,342	195.99	222	13.4%
Shropshire	168,636	703.47	660	-6.2%
Total difference				27.1%
Average difference				1.9%

Model
Annual Domestic Electricity Consumption by Final User in Shropshire (GWhe/y) = (0.0039 * Number of households) + 2.4823

Table 67: Model of Domestic Electricity Consumption by Final User in Shropshire 1990 and 1996.

Year	Number of Households	Domestic Electricity Consumption (GWhe)	Average Annual GWhe/household		
			Shropshire	Great Britain	Difference between Shropshire and GB
1981	130,782	513	0.003919	0.004101	-4.4%
1982	136,515	535	0.003918	0.003989	-1.8%
1983	138,809	544	0.003918	0.003950	-0.8%
1984	141,104	553	0.003918	0.003944	-0.7%
1985	143,398	562	0.003917	0.004096	-4.4%
1986	145,692	571	0.003917	0.004224	-7.3%
1987	147,987	580	0.003917	0.004239	-7.6%
1988	150,281	589	0.003917	0.004157	-5.8%
1989	155,370	608	0.003916	0.004106	-4.6%
1990	157,726	563.42	0.003572	0.004116	-13.2%
1991	156,883	614	0.003916	0.004273	-8.4%
1992	159,476	624	0.003916	0.004286	-8.7%
1993	161,713	633	0.003915	0.004396	-8.9%
1994	164,048	642	0.003915	0.004282	-8.6%
1995	166,342	651	0.003915	0.004269	-8.3%
1996	168,636	703.47	0.004172	0.004460	-6.5%
1997	170,931	669	0.003915		
1998	173,225	678	0.003914		
1999	175,520	687	0.003914		
2000	177,814	696	0.003914		
2001	180,920	708	0.003914		
2002	182,403	714	0.003914		
2003	184,697	723	0.003913		
2004	186,992	732	0.003913		
2005	189,286	741	0.003913		
2006	189,380	741	0.003913		
2007	193,875	759	0.003913		
2008	196,169	768	0.003913		
2009	198,464	776	0.003913		
2010	200,758	785	0.003912		
2011	203,052	794	0.003912		
2012	205,347	803	0.003912		
2013	207,641	812	0.003912		
2014	209,936	821	0.003912		
2015	212,230	830	0.003912		
2016	214,524	839	0.003912		
2017	216,819	848	0.003911		
2018	219,113	857	0.003911		
2019	221,408	866	0.003911		
2020	223,702	875	0.003911		
2021	225,996	884	0.003911		
2022	228,291	893	0.003911		
2023	230,585	902	0.003911		
2024	232,880	911	0.003911		
2025	235,174	920	0.003911		

Table 68: Model Estimate of Domestic Electricity Consumption by Final User in Shropshire 1981 -2025

1. Where cell is shaded the following models are used: (1) Number of Households with Residents in Shropshire = (2,294.4 * year) - 4,410,986. (2) Domestic Electricity Consumption by Final User = (0.0039 * Number of households) + 2.4823.

The model shows that total annual domestic electricity consumption (GWh/y) could be 1.31 times the 1990 level by 2005 rising to 1.63 times the 1990 level by 2025 as the number of households increase. However, the average domestic electricity consumption per household could be 1.10 times the 1990 level by 2005 falling to 1.09 times the 1990 level by 2025 as the proportion of houses built to stricter building regulations with more thermal insulation increases.

In 1990 the average domestic electricity consumption per household was 13.2% lower in Shropshire than the figure for Great Britain, which is published by the Building Research Establishment [209, 210, 211] (see Table 68). In 1996 consumption in Shropshire had increased, but was still 6.5% lower than the figure for Great Britain.

9.3 Effect of Land Development on Electricity Consumption by Final User in Shropshire

Shropshire County Council data on changes in the number of house completion's and land area taken up by development [152] for April 1983 to March 1993 (see Table 69) were compared to changes in sector electricity consumption (see Table 70).

District	Residential	Industrial	Commercial (Retail and Office)	Total ha/y
Bridgnorth	13.6	1.4	1.0	16.0
North Shropshire	24.9	2.7	1.5	29.1
Oswestry	17.6	2.3	1.7	21.6
Shrewsbury & Atcham	41.8	2.3	3.6	47.7
South Shropshire	15.1	1.8	1.1	18.0
Wrekin	113.0	48.3	8.6	169.9
Shropshire	226.0	58.8	17.5	302.3

Table 69: Average Annual Increases in Land Taken up by Development (Hectares per Year) From 1983 - 1993 in Shropshire.

District	Domestic	Industrial	Commercial	Total
Bridgnorth	4.66	2.23	0.23	7.12
North Shropshire	3.96	0.81	1.34	6.11
Oswestry	0.65	0.25	0.62	1.52
Shrewsbury & Atcham	3.30	1.05	1.12	5.47
South Shropshire	4.26	0.51	0.56	5.33
Wrekin	6.52	6.35	2.96	15.83
Shropshire	23.34	11.20	6.84	41.38

Table 70: Average Annual Increases in Sector Electricity Consumption (GWhe per Year) 1990 - 1996 in Shropshire.

9.3.1 Residential Land Development

The effect of residential land development on domestic electricity consumption can be seen in Table 71.

1. Residential land development in Oswestry caused the smallest increase in domestic electricity consumption, with around 13-house completions per hectare.
2. Residential land development in Bridgnorth caused the largest increase in domestic electricity consumption, with around 15-house completions per hectare.

District	House Completion's (hh)	ha/hh	hh/ha	GWhe/ha	ha/GWhe
Bridgnorth	207	0.07	15.25	0.34	2.92
North Shropshire	345	0.07	13.84	0.16	6.29
Oswestry	223	0.08	12.64	0.04	26.93
Shrewsbury & Atcham	468	0.09	11.19	0.08	12.66
South Shropshire	266	0.06	17.64	0.28	3.55
Wrekin	945	0.12	8.36	0.06	17.34
Shropshire	2,454	0.09	10.86	0.10	9.68

Table 71: Effect of House Completion's on Electricity Consumption in the Domestic Sector in Shropshire.

Figure 20 and Table 72 give a model for additional annual domestic electricity consumption in Shropshire due to residential land development. This only gives a rough estimate for Shropshire as a whole and is not reliable for estimating consumption by district. The average GWhe/ha found in Table 71 may give a better estimation.

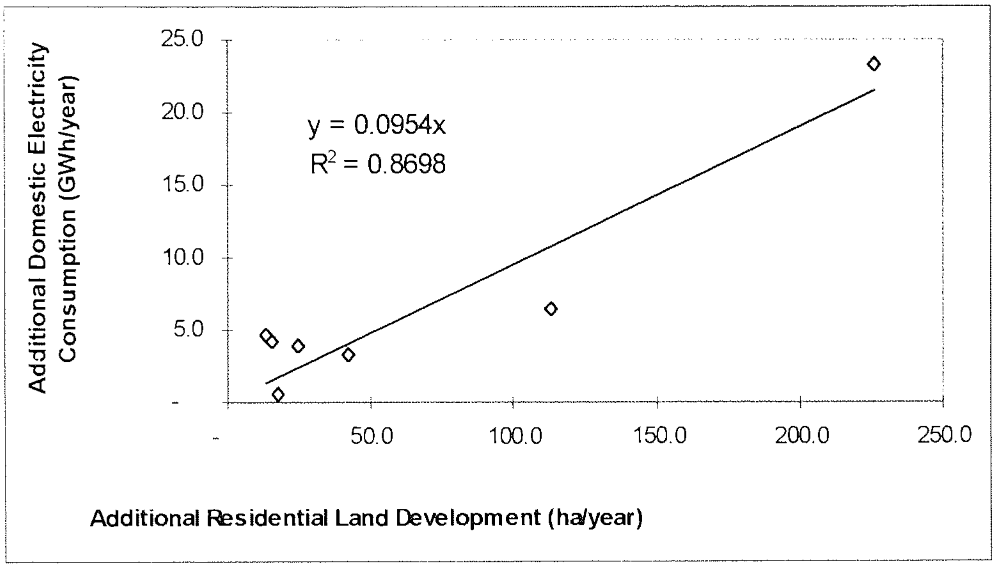

Figure 20: Relationship Between Additional Domestic Electricity Consumption and Area of Residential Land Development in Shropshire

District	GWhe/y	Model GWhe/y	% Difference
Bridgnorth	4.7	1.30	-72%
North Shropshire	4.0	2.38	-40%
Oswestry	0.7	1.68	157%
Shrewsbury & Atcham	3.3	3.99	21%
South Shropshire	4.3	1.44	-66%
Wrekin	6.5	10.78	65%
Shropshire	23.3	21.56	-8%
Total difference			57%
Average difference			8%

Model
Additional Annual Domestic Electricity Consumption Due to Residential Land Development (GWh/y) in Shropshire = 0.0954 * Area of Residential Land Development (ha/y)

Table 72: Model of Additional Annual Domestic Electricity Consumption (GWhe/y) Due to Residential Land Development in Shropshire

9.3.2 Industrial Land Development

Figure 21 and Table 73 give a model for additional annual industrial electricity consumption in Shropshire due to industrial land development. This only gives a rough estimate for Shropshire as a whole and is not reliable for estimating consumption by district, for which the average GWhe/ha may give a better estimation.

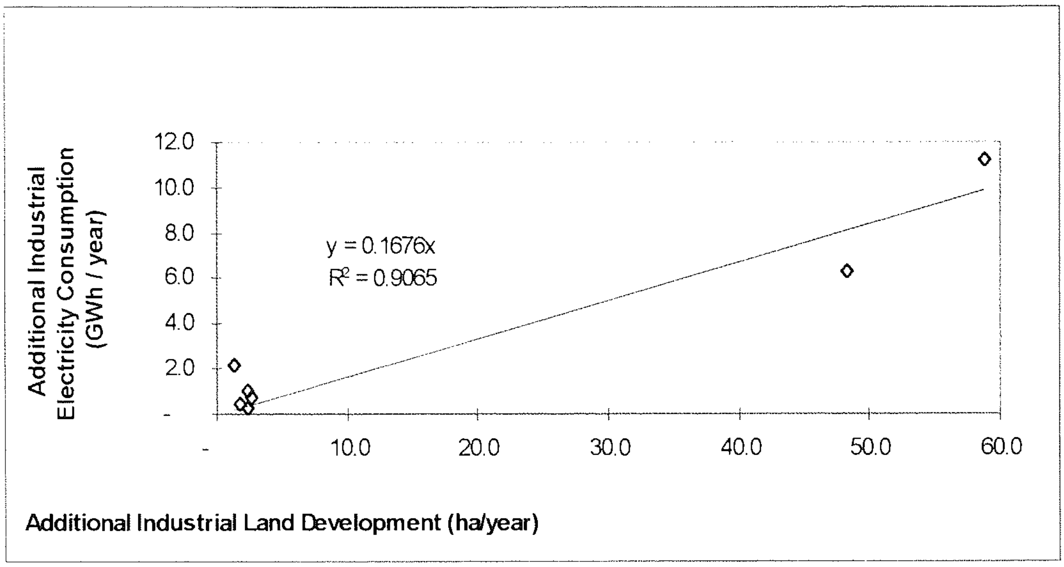

Figure 21: Relationship Between Additional Industrial Electricity Consumption and Area of Industrial Land Development in Shropshire.

District	GWhe/ha	ha/GWhe	GWhe/y	Model GWhe/y	% Difference
Bridgnorth	1.6	0.88	2.2	0.23	-89%
North Shropshire	0.3	9.05	0.8	0.45	-44%
Oswestry	0.1	20.91	0.3	0.39	52%
Shrewsbury & Atcham	0.5	5.03	1.1	0.39	-63%
South Shropshire	0.3	6.34	0.5	0.30	-41%
Wrekin	0.1	367.44	6.3	8.10	28%
Shropshire	0.2	308.80	11.2	9.85	-12%
Total difference					-170%
Average difference					-24%

Model
Additional Annual Industrial Electricity Consumption Due to Land Development (GWh/y) in Shropshire = 0.1676 * Area of Industrial Land Developed (ha/y)

Table 73: Model of Additional Annual Industrial Electricity Consumption (GWhe/y) Due to Industrial Land Development in Shropshire.

9.3.3 Commercial Land Development

Figure 22 and Table 74 give a model for additional annual commercial electricity consumption in Shropshire due to commercial land development. This provides a reasonable estimate for Shropshire as a whole, Oswestry, Shrewsbury & Atcham, South Shropshire and the Wrekin. The typical range for study estimates is +/- 30% [212], so the model is not reliable for Bridgnorth and North Shropshire, for which the average GWhe/ha may give a better estimation.

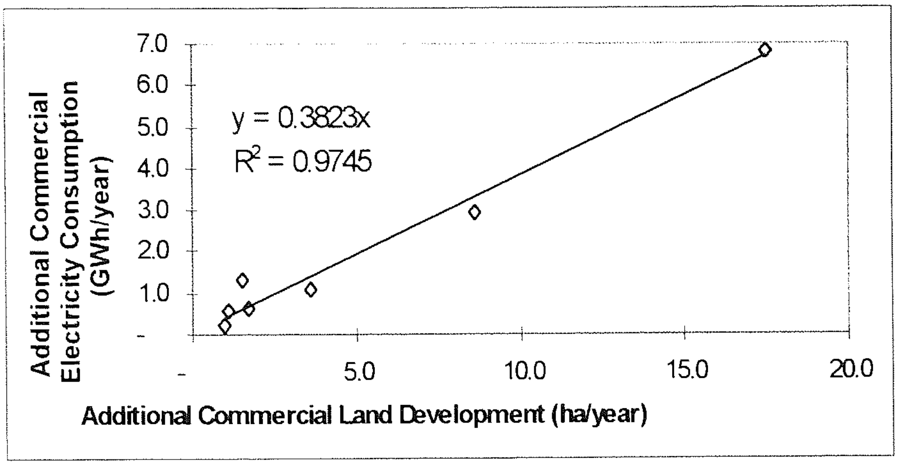

Figure 22: Relationship Between Additional Commercial Electricity Consumption and Area of Commercial Land Development in Shropshire.

District	GWhe/ha	ha/GWhe	GWhe/y	Model GWhe/y	% Difference
Bridgnorth	0.23	4.33	0.23	0.38	65%
North Shropshire	0.90	1.12	1.34	0.57	-57%
Oswestry	0.36	2.75	0.62	0.65	5%
Shrewsbury & Atcham	0.31	3.22	1.12	1.38	23%
South Shropshire	0.51	1.95	0.56	0.42	-25%
Wrekin	0.34	2.90	2.96	3.29	11%
Shropshire	0.39	2.56	6.84	6.69	-2%
Total difference					20%
Average difference					3%

Model
Additional Annual Commercial Electricity Consumption Due to Commercial Land Development (GWh/y) in Shropshire = 0.3823 * Area of Commercial Land Development (ha/y)

Table 74: Model of Additional Annual Commercial Electricity Consumption (GWhe/y) Due to Industrial Land Development in Shropshire.

9.3.4 Development Land Allocations

The additional electricity consumption from projected changes in land development for Shropshire [153, 178] can be seen in Table 75.

	Residential					Industrial			Commercial		
District	House building	ha/ hh	ha	GWhe/ ha	GWhe	ha	GWhe/ ha	GWhe	ha	GWhe/ ha	GWhe
Bridgnorth	140	0.0656	9.18	0.343	3.14	22	1.59	34.99	22	0.23	5.08
North Shropshire	370	0.0722	26.73	0.159	4.25	54	0.30	16.11	54	0.90	48.37
Oswestry	190	0.0791	15.03	0.037	0.56	50	0.11	5.50	50	0.36	18.18
Shrewsbury & Atcham	450	0.0894	40.21	0.079	3.18	93	0.46	42.50	93	0.31	28.92
South Shropshire	250	0.0567	14.18	0.282	4.00	38	0.28	10.78	38	0.51	19.50
Wrekin	1,000	0.1196	119.58	0.058	6.89	335	0.13	44.04	335	0.34	115.40
Shropshire	2,400	0.0921	221.05	0.103	22.83	592	0.19	112.73	592	0.39	231.35
Total Districts	2,400		224.90		22.02			153.93			235.45
			Model =0.0954*ha=		21.46	Model =0.1676*ha=		99.22	Model =0.3823*ha=		226.32

Table 75: Projected Increases in Electricity Consumption Resulting From Land Development for Shropshire 1996 - 2011

1. House completions of 2,400 per year could result in additional consumption of electricity of around 22 GWhe/y.
2. If, by 2011, all the indicative Structure Plan allocation of development land was used for industrial purposes the additional consumption of electricity could be between 100 - 154 GWhe.
3. If, by 2011, all the indicative Structure Plan allocation of development land was used for commercial purposes the additional consumption of electricity could be between 226- 236 GWhe.

9.4 District Electricity Consumption Estimation

Using the average PFC (GJ/person), % PFC for electricity generation and % conversion efficiency in chapters 7 and 8 (Tables 25 & 26, 44 & 45 and 46 & 47 respectively) gave estimates of electricity consumption that compared well with supply data for the County of Shropshire (as shown in Table 48).

Data on electricity consumption, population figures from national statistics and studies of other areas covering the years 1990 to 1997 were gathered to determine whether this approach could be employed to estimate electricity consumption elsewhere. The methodology was applied to a total of 59 data sets (including Shropshire Districts and the UK).

The data sets also gave the model in Figure 23. Both the estimates of electricity consumption from this model and those obtained from the above mentioned methodology are given in Table 76 and compared to supply data.

Published figures for Coventry [213] had no definition of whether it applied just to the City or the City and surrounding area [214]. With no corresponding population figure the data was not used for the model. Using just the City population even with a high 0.01269 GWhe/person resulted in a figure over 60% less than the published figure.

Electricity consumption and population data was available for County Donegal [215], but even with a low 0.00323 GWhe/person the resulting figure was over 40% higher than the published figure. Electricity consumption in County Donegal, with its high reliance on turf and oil, is uncharacteristic of typical UK consumption. It is also in the Republic of Ireland so the data was not used for the model.

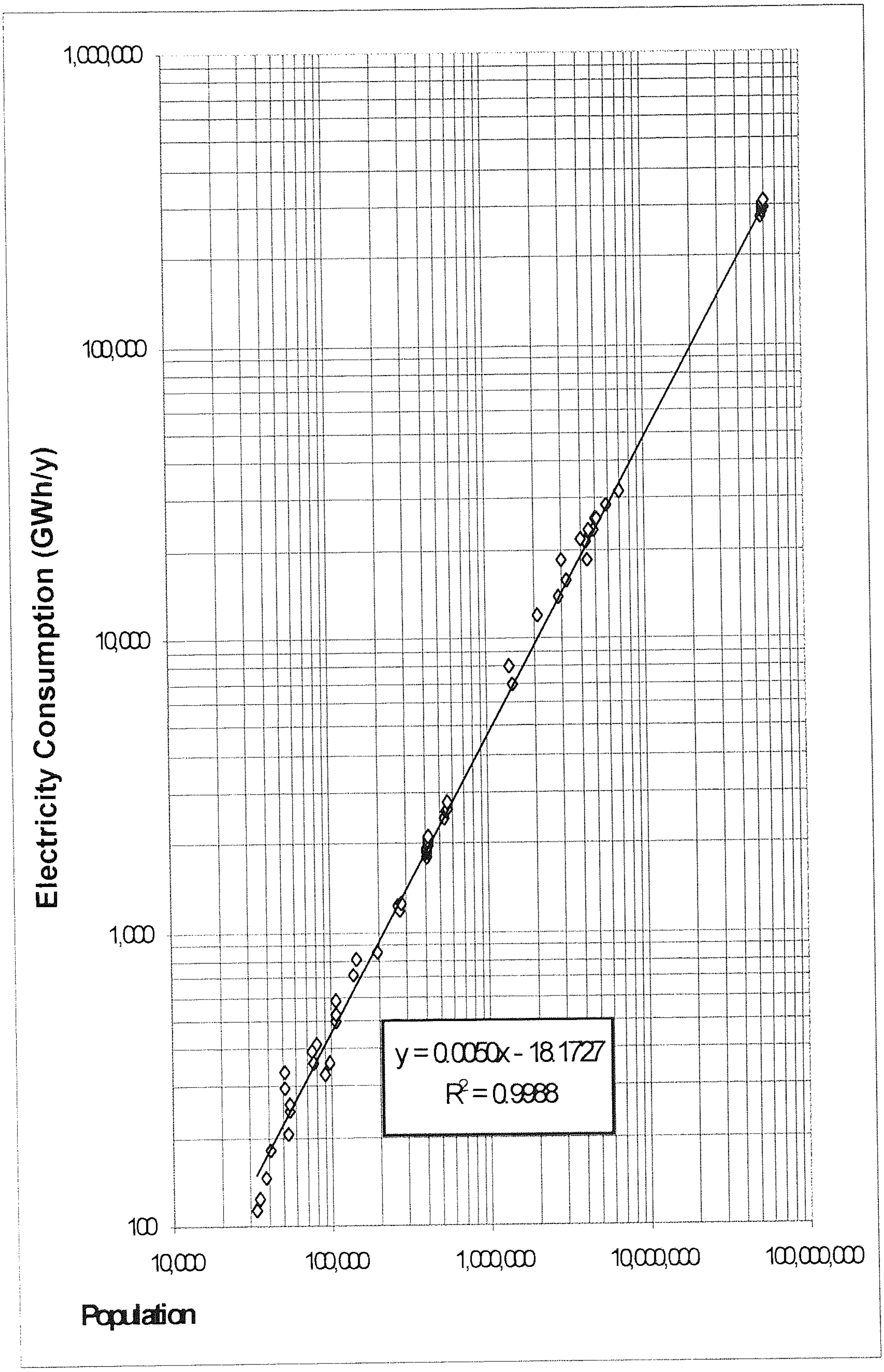

Figure 23: Relationship Between Population and Electricity Consumption in the UK.

Year	Area	Population	Supply Data GWhe/y *	Model	% Difference	Estimated GWhe/y	% Difference
1990	Shropshire	406,390	1,807	2,014	11.5%	1,878	4.0%
1990	Bridgnorth	50,511	295	234	-20.4%	233	-20.8%
1990	North Shropshire	52,873	206	246	19.5%	244	18.6%
1990	Oswestry	33,508	114	149	31.0%	155	35.8%
1990	Shrewsbury & Atcham	91,749	327	441	34.7%	424	29.6%
1990	South Shropshire	38,230	146	173	18.7%	177	21.2%
1990	Wrekin	139,515	719	679	-5.5%	645	-10.4%
1996	Shropshire	420,700	2,067	2,085	0.9%	2,095	1.4%
1996	Bridgnorth	50,800	338	236	-30.3%	253	-25.2%
1996	North Shropshire	54,100	248	252	1.9%	269	8.8%
1996	Oswestry	34,600	124	155	25.2%	172	39.3%
1996	Shrewsbury & Atcham	97,100	361	467	29.6%	484	34.1%
1996	South Shropshire	40,500	181	184	2.0%	202	11.7%
1996	Wrekin	144,200	816	703	-13.9%	718	-12.0%
1991	Shropshire	412,000	1,850	2,042	10.4%	1,915	3.5%
1992	Shropshire	413,000	1,893	2,047	8.1%	1,912	1.0%
1993	Shropshire	414,000	1,937	2,052	5.9%	1,943	0.3%
1994	Shropshire	416,000	1,980	2,062	4.1%	1,934	-2.3%
1995	Shropshire	419,000	2,024	2,077	2.6%	2,012	-0.6%
1997	Shropshire	423,300	2,110	2,098	-0.6%	2,123	0.6%
1997	MANWEB	3,009,082	18,353	15,027	-18.1%	15,093	-17.8%
1997	Midlands	4,922,742	25,555	24,596	-3.8%	24,692	-3.4%
1997	Eastern	7,022,669	31,916	35,095	10.0%	35,226	10.4%
1997	East Midlands	5,100,138	25,553	25,483	-0.3%	25,582	0.1%
1997	London	4,332,900	21,444	21,646	0.9%	21,734	1.4%
1997	Northern	3,226,392	15,739	16,114	2.4%	16,184	2.8%
1997	Northern Ireland	1,470,170	6,930	7,333	5.8%	7,374	6.4%
1997	Norweb	4,825,174	23,254	24,108	3.7%	24,203	4.1%
1997	Hydro-Electric	1,396,994	8,004	6,967	-13.0%	7,007	-12.5%
1997	Scottish Power	3,991,413	21,688	19,939	-8.1%	20,021	-7.7%
1997	Seeboard	4,401,641	18,582	21,990	18.3%	22,079	18.8%
1997	Southern	5,763,156	28,663	28,798	0.5%	28,908	0.9%
1997	Swalec	2,128,753	11,872	10,626	-10.5%	10,678	-10.1%
1997	South Western	2,876,035	13,778	14,362	4.2%	14,426	4.7%
1997	Yorkshire	4,541,341	23,580	22,689	-3.8%	22,779	-3.4%
1997	UK PES Distribution	59,008,600	294,911	295,025	0.0%	295,986	0.4%
1990	Gloucestershire	528,362	2,438	2,624	7.6%	2,442	0.2%
1993	Gloucestershire	543,931	2,562	2,701	5.4%	2,552	-0.4%
1994	Gloucestershire	549,600	2,618	2,730	4.3%	2,555	-2.4%
1996	Gloucestershire	556,300	2,795	2,763	-1.1%	2,771	-0.9%
1996	Gloucester	106,800	503	516	2.6%	532	5.7%
1996	Cheltenham	106,700	587	515	-12.2%	531	-9.5%
1996	Cotswold	81,500	419	389	-7.1%	406	-3.1%
1996	Forest of Dean	76,000	391	362	-7.5%	379	-3.2%
1996	Stroud	108,000	531	522	-1.7%	538	1.3%
1996	Tewkesbury	77,300	363	368	1.5%	385	6.1%
1996	Leicester UA Area	270,493	1,236	1,334	8.0%	1,347	9.0%
1990	Milton Keynes	199,000	864	977	13.1%	920	6.5%
1990	Newcastle upon Tyne	277,600	1,189	1,370	15.2%	1,283	7.9%
1995	Newcastle upon Tyne	282,300	1,250	1,393	11.5%	1,356	8.4%
1993	County Fermanagh	54,033	259	252	-2.6%	254	-2.0%
1990	UK	57,561,000	274,430	287,787	4.9%	266,034	-3.1%
1991	UK	57,807,908	281,050	289,021	2.8%	268,654	-4.4%
1992	UK	58,006,493	281,470	290,014	3.0%	268,599	-4.6%
1993	UK	58,191,230	286,131	290,938	1.7%	273,038	-4.6%
1994	UK	58,394,616	284,264	291,955	2.7%	271,433	-4.5%
1995	UK	58,605,782	293,942	293,011	-0.3%	281,404	-4.3%
1996	UK	58,801,500	305,656	293,989	-3.8%	292,853	-4.2%
1997	UK	59,008,600	309,251	295,025	-4.6%	295,986	-4.3%
Total difference					167.0%		123.6%
Average difference					2.8%		2.1%

Model

Total Electricity Consumption (GWhe/y) = (0.005 * Area Population) - 18.1727

Table 76: Comparison of Estimated, Model and Supplier Electricity Consumption Figures

1. Assuming 2.22 people per electricity customer for the PES distribution grid.
2. PES data. Average PFC per person (GJ/y), PFC used for electricity generation (%) and conversion efficiency (%) from DUKES and Energy Report-Blue Books or the following models:
   Average PFC for Energy Use per Person = 0.046098446 * EXP (0.00408725 * year)
   % PFC for Electricity Generation = 86425659 * EXP (-0.0097 * year)
   Conversion Efficiency = 0.017 * LN (year-1989) + 0.2917
3. * References [201, 213, 216, 217, 218, 219, 220, 221, 222, 223, 224, 225, 226, 227, 228, 229]

Table 76 shows that district electricity consumption can be reasonably estimated by either method using population figures. The model and estimate only giving a result that is over 30 % higher than supply data for Oswestry and Shrewsbury & Atcham. The model only giving a result which is over 30 % lower than supply data for Bridgnorth.

Year	Area	GWhe/ person	Year	Area	GWhe/ person
1992	County Donegal	0.00323	1992	UK	0.00485
1990	Oswestry	0.00340	1991	UK	0.00486
1990	Shrewsbury & Atcham	0.00356	1994	UK	0.00487
1996	Oswestry	0.00358	1997	Northern	0.00488
1996	Shrewsbury & Atcham	0.00371	1996	Shropshire	0.00491
1990	S. Shropshire	0.00381	1996	Stroud	0.00492
1990	N. Shropshire	0.00390	1993	UK	0.00492
1997	Seeboard	0.00422	1997	London	0.00495
1990	Newcastle upon Tyne	0.00428	1997	Southern	0.00497
1990	Milton Keynes	0.00434	1997	Total UK PES distribution	0.00498
1995	Newcastle upon Tyne	0.00443	1997	Shropshire	0.00498
1990	Shropshire	0.00445	1997	E.Midlands	0.00501
1996	S. Shropshire	0.00446	1995	UK	0.00502
1991	Shropshire	0.00449	1996	Gloucestershire	0.00502
1997	Eastern	0.00454	1996	Cotswold	0.00514
1996	Leicester UA Area	0.00457	1996	Forest of Dean	0.00514
1996	N. Shropshire	0.00458	1990	Wrekin	0.00516
1992	Shropshire	0.00458	1997	Midlands	0.00519
1990	Gloucestershire	0.00461	1997	Yorkshire	0.00519
1993	Shropshire	0.00468	1996	UK	0.00520
1996	Tewkesbury	0.00470	1997	UK	0.00524
1996	Gloucester	0.00471	1997	Scottish Power	0.00543
1993	Gloucestershire	0.00471	1996	Cheltenham	0.00550
1997	N.Ireland	0.00471	1997	Swalec	0.00558
1994	Shropshire	0.00476	1996	Wrekin	0.00566
1994	Gloucestershire	0.00476	1997	Hydro-Electric	0.00573
1990	UK	0.00477	1990	Bridgnorth	0.00583
1993	County Fermanagh	0.00479	1997	MANWEB	0.00610
1997	South Western	0.00479	1996	Bridgnorth	0.00666
1997	Norweb	0.00482	1994	Coventry	0.01269
1995	Shropshire	0.00483			

Table 77: Average Consumption of Electricity (GWhe per Person)

Not including Coventry or County Donegal, consumption in these areas varied from 0.00340 GWhe/person in 1990 in Oswestry to 0.00666 GWhe/person in 1996 in Bridgnorth, with the average being 0.005 GWhe per person (see Table77).

9.5 District PFC per Person

As electricity consumption can be estimated using PFC etc., it was assumed that a better estimate of district average PFC (GJ/person) could be obtained from supplier electricity consumption data (see Figure 24 and Table 78).

Annual PFC Used for Electricity Generation (GWh/y) = Annual Consumption of Electricity by Final User GWh/y (Supplier Data) / % PFC Used for Electricity Generation Consumed as Electricity by Final User (Conversion Efficiency)

Total Annual Consumption of Primary Fuels (GWh/y) = Annual PFC Used for Electricity Generation (GWh/y) / % of Total PFC Used for Electricity Generation

Total Annual Consumption of Primary Fuels (equivalent GJ/y) = Total Annual Consumption of Primary Fuels (GWh/y) * 3600 (seconds/hour)

Total Average Annual PFC per Person (GJpp/y) = Total Annual Consumption of Primary Fuels (GJ/y) / Population

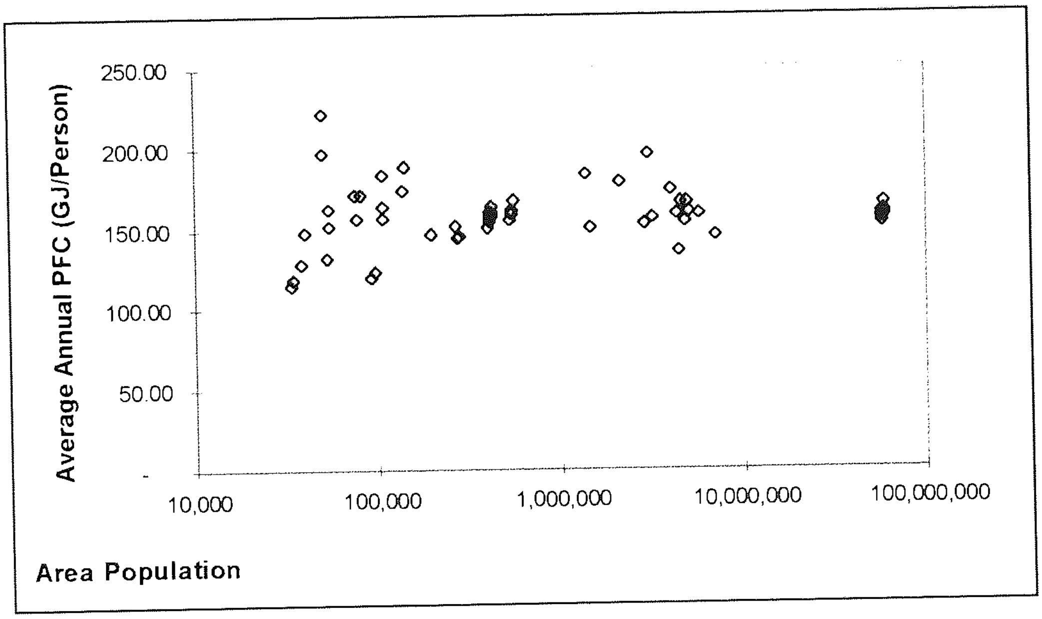

Figure 24: District Average Annual PFC (GJ/Person) Estimated from Supplier Electricity Consumption Data.

Figure 24 shows that there is no direct relationship between the average annual PFC per person estimated from supplier electricity consumption data and area population.

Year	Area	Population	Total PFC Equivalent	Average PFC per Person
1990	Shropshire	406,390	61,102,019	150.35
1990	Bridgnorth	50,511	9,962,349	197.23
1990	N. Shropshire	52,873	6,968,088	131.79
1990	Oswestry	33,508	3,856,378	115.09
1990	Shrewsbury & Atcham	91,749	11,061,191	120.56
1990	S. Shropshire	38,230	4,928,470	128.92
1990	Wrekin	139,515	24,325,543	174.36
1996	Shropshire	420,700	68,837,121	163.63
1996	Bridgnorth	50,800	11,263,272	221.72
1996	N. Shropshire	54,100	8,245,994	152.42
1996	Oswestry	34,600	4,120,066	119.08
1996	Shrewsbury & Atcham	97,100	12,008,300	123.67
1996	S. Shropshire	40,500	6,015,673	148.54
1996	Wrekin	144,200	27,183,816	188.51
1991	Shropshire	412,000	63,496,185	154.12
1992	Shropshire	413,000	64,290,897	155.67
1993	Shropshire	414,000	65,692,659	158.68
1994	Shropshire	416,000	66,999,362	161.06
1995	Shropshire	419,000	66,494,527	158.70
1997	Shropshire	423,300	67,722,964	159.99
1997	Manweb	3,009,082	589,061,406	195.76
1997	Midlands	4,922,742	820,218,178	166.62
1997	Eastern	7,022,669	1,024,382,053	145.87
1997	E.Midlands	5,100,138	820,153,986	160.81
1997	London	4,332,900	688,270,734	158.85
1997	Northern	3,226,392	505,161,961	156.57
1997	N.Ireland	1,470,170	222,426,608	151.29
1997	Norweb	4,825,174	746,364,841	154.68
1997	Hydro-Electric	1,396,994	256,897,918	183.89
1997	Scottish Power	3,991,413	696,102,205	174.40
1997	Seeboard	4,401,641	596,411,433	135.50
1997	Southern	5,763,156	919,973,142	159.63
1997	Swalec	2,128,753	381,045,987	179.00
1997	South Western	2,876,035	442,221,329	153.76
1997	Yorkshire	4,541,341	756,828,199	166.65
1997	Total UK PES distribution	59,008,600	9,465,519,979	160.41
1990	Gloucestershire	528,362	82,447,775	156.04
1993	Gloucestershire	543,931	86,889,310	159.74
1994	Gloucestershire	549,600	88,588,045	161.19
1996	Gloucestershire	556,300	93,086,820	167.33
1996	Gloucester	106,800	16,752,297	156.86
1996	Cheltenham	106,700	19,549,897	183.22
1996	Cotswold	81,500	13,954,697	171.22
1996	Forest of Dean	76,000	13,022,163	171.34
1996	Stroud	108,000	17,684,831	163.75
1996	Tewkesbury	77,300	12,089,630	156.40
1996	Leicester UA Area	270,493	41,164,690	152.18
1990	Milton Keynes	199,000	29,218,572	146.83
1990	Newcastle upon Tyne	277,600	40,209,354	144.85
1995	Newcastle upon Tyne	282,300	41,066,284	145.47
1993	County Fermanagh	54,033	8,775,413	162.41

Table 78: District Average Annual PFC (GJ/Person) Estimated from Supplier Electricity Consumption Data

Figure 25 shows that there is also no direct relationship between average annual PFC per person and population density (see also Table 79) [230].

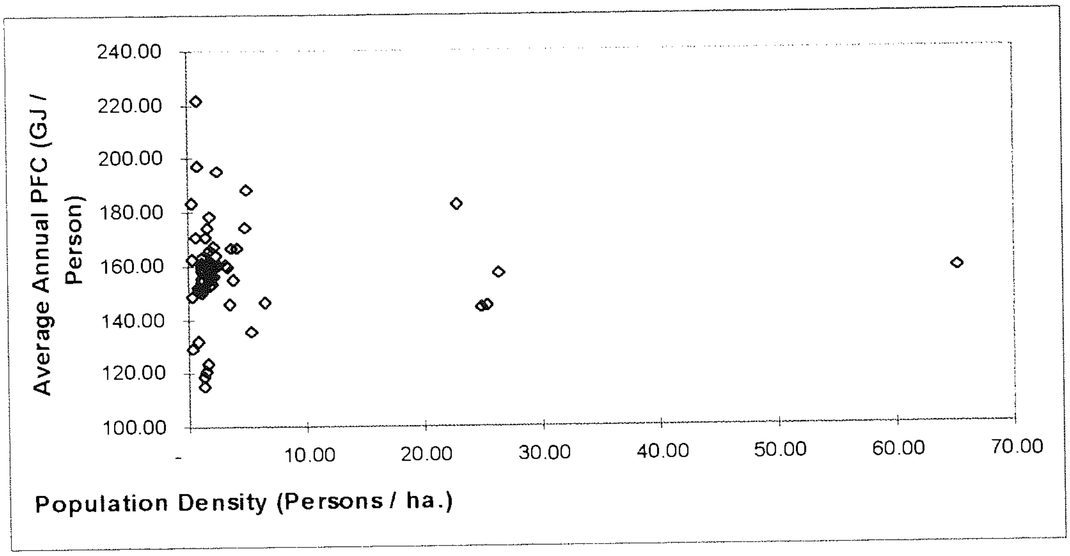

Figure 25: Relationship Between Average Annual PFC (GJ/Person) and Population Density (Persons/ hectare (ha.)).

However, Figures 26 and 27 show that there is a linear relationship between energy density and population density.

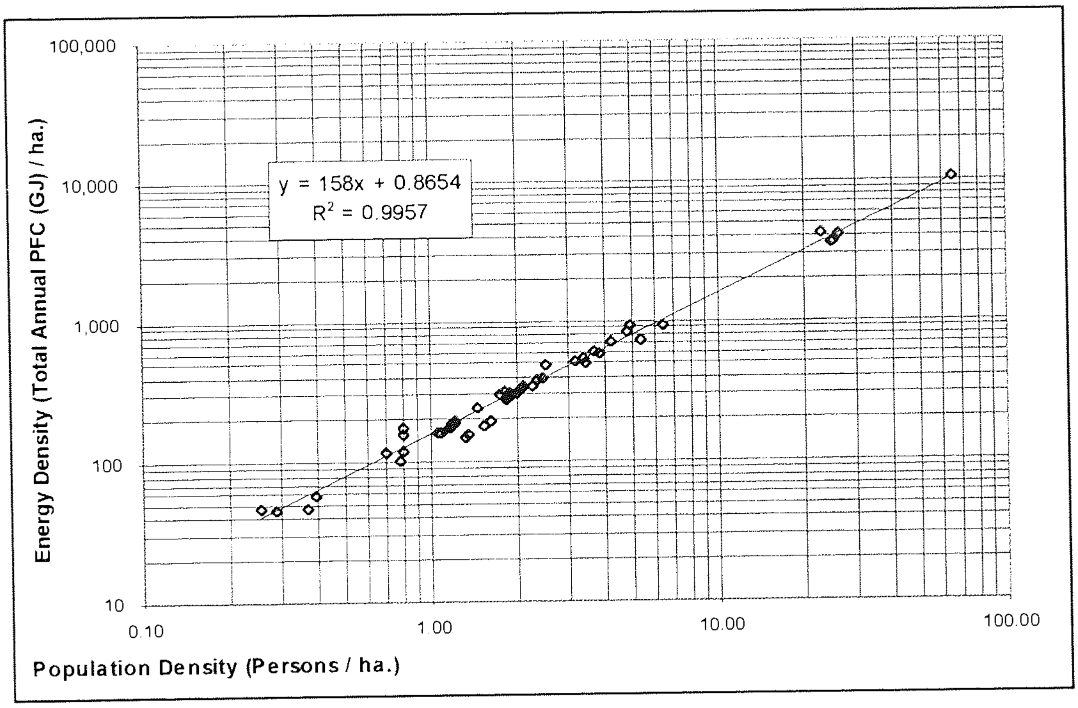

Figure 26: Relationship Between Energy Density (Total Annual PFC (GJ) / ha.) and Population Density (Persons/ ha.).

Year	Area	Area	Pop Density	Energy Density
		ha.	Persons/ha.	GJ/ha.
1990	Shropshire	348,700	1.17	175.23
1990	Bridgnorth	63,300	0.80	157.38
1990	N. Shropshire	67,900	0.78	102.62
1990	Oswestry	25,600	1.31	150.64
1990	Shrewsbury & Atcham	60,200	1.52	183.74
1990	S. Shropshire	102,700	0.37	47.99
1990	Wrekin	29,000	4.81	838.81
1996	Shropshire	348,700	1.21	197.41
1996	Bridgnorth	63,300	0.80	177.93
1996	N. Shropshire	67,900	0.80	121.44
1996	Oswestry	25,600	1.35	160.94
1996	Shrewsbury & Atcham	60,200	1.61	199.47
1996	S. Shropshire	102,700	0.39	58.58
1996	Wrekin	29,000	4.97	937.37
1991	Shropshire	348,700	1.18	182.09
1992	Shropshire	348,700	1.18	184.37
1993	Shropshire	348,700	1.19	188.39
1994	Shropshire	348,700	1.19	192.14
1995	Shropshire	348,700	1.20	190.69
1997	Shropshire	348,700	1.21	194.22
1997	MANWEB	1,200,000	2.51	490.88
1997	Midlands	1,330,000	3.70	616.71
1997	Eastern	2,030,000	3.46	504.62
1997	E.Midlands	1,600,000	3.19	512.60
1997	London	66,500	65.16	10,349.94
1997	Northern	1,440,000	2.24	350.81
1997	N.Ireland	1,350,600	1.09	164.69
1997	Norweb	1,250,000	3.86	597.09
1997	Hydro-Electric	5,439,000	0.26	47.23
1997	Scottish Power	2,295,000	1.74	303.31
1997	Seeboard	820,000	5.37	727.33
1997	Southern	1,690,000	3.41	544.36
1997	Swalec	1,180,000	1.80	322.92
1997	South Western	1,440,000	2.00	307.10
1997	Yorkshire	1,070,000	4.24	707.32
1997	Total UK PES distribution	24,201,100	2.44	391.12
1990	Gloucestershire	265,327	1.99	310.74
1993	Gloucestershire	265,327	2.05	327.48
1994	Gloucestershire	265,327	2.07	333.88
1996	Gloucestershire	265,327	2.10	350.84
1996	Gloucester	4,053	26.35	4,133.31
1996	Cheltenham	4,663	22.88	4,192.56
1996	Cotswold	116,452	0.70	119.83
1996	Forest of Dean	52,634	1.44	247.41
1996	Stroud	46,076	2.34	383.82
1996	Tewkesbury	41,440	1.87	291.74
1996	Leicester UA Area	255,087	1.06	161.38
1990	Milton Keynes	30,851	6.45	947.09
1990	Newcastle upon Tyne	11,179	24.83	3,596.86
1995	Newcastle upon Tyne	11,179	25.25	3,673.52
1993	County Fermanagh	187,700	0.29	46.75

Table 79: District, Area, Population Density and Energy Density.

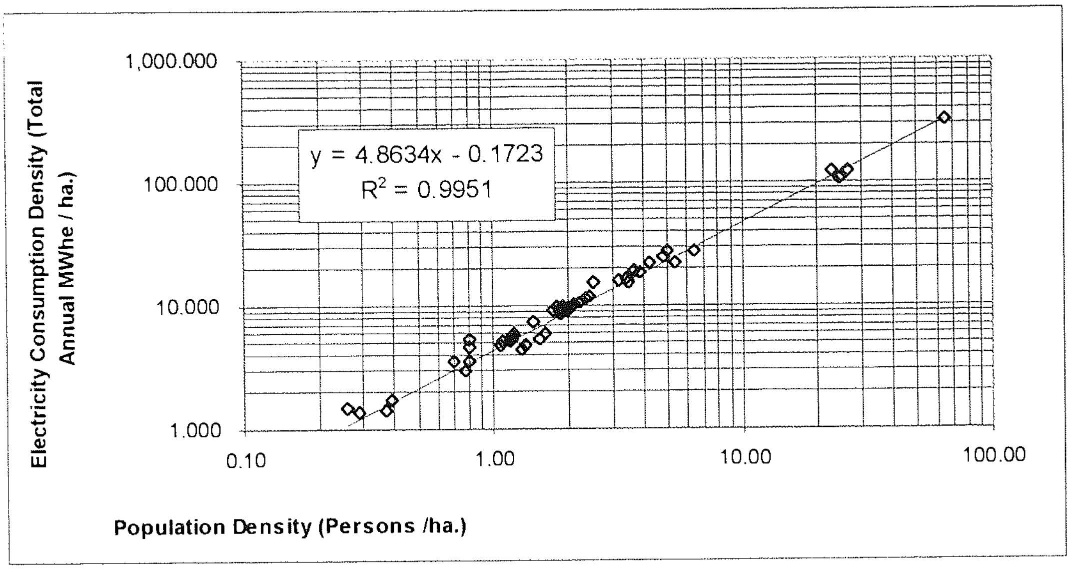

Figure 27: Relationship Between Energy Density (Electricity Consumption Density (Annual MWhe / ha.) and Population Density (Persons/ ha.).

The relationship between energy density and population density allows the estimation of both PFC and electricity consumption in the rural and urban areas of each district. If data on the corresponding total land area and population is available, the model can be applied to population densities in the range 0.26 persons/hectare to 65 persons/hectare. Table 80 gives these figures for the districts of Shropshire for 1990.

Energy Density (Total Annual PFC per Hectare) (GJ / ha.) = (158 (GJ / Person) * Population Density (Persons / ha.)) + 0.08654 (GJ / ha.)

Electricity Consumption Density (Annual MWhe per Hectare) (MWhe / ha.) = 4.8634 (MWhe / Person) * Population Density (Persons / ha.)) - 0.1723 (MWhe / ha.)

Annual Electricity Consumption (GWhe/y) = Electricity Consumption Density (Annual MWhe per Hectare) (MWhe / ha.) * (1 GWhe/y / 1,000 MWhe/y) * Area (ha.)

1990	Urban	[1] Area	Population Density	Energy Density	Total PFC	[2,3] Estimated Electricity Consumption	[4] Electricity Consumption from Model
District	Population	ha.	Persons /ha.	GJ/ha.	GJ	GWh/y	GWh/y
Bridgnorth	20,597	2,031	10.14	1,603	3,255,997	96	100
North Shropshire	25,199	3,693	6.82	1,079	3,984,532	118	122
Oswestry	14,219	2,741	5.19	820	2,248,914	66	69
Shrewsbury & Atcham	64,219	6,054	10.61	1,677	10,151,571	300	311
South Shropshire	16,633	2,284	7.28	1,151	2,629,921	78	80
Wrekin	128,886	21,562	5.98	945	20,382,106	603	623
Shropshire County	269,753	38,365	7.03	1,112	42,653,042	1,261	1,305
1990	Rural						
Bridgnorth	29,914	61,269	0.49	78	4,779,308	141	135
North Shropshire	27,674	64,207	0.43	69	4,427,940	131	124
Oswestry	19,289	22,859	0.84	134	3,067,363	91	90
Shrewsbury & Atcham	27,528	54,146	0.51	81	4,396,166	130	125
South Shropshire	21,597	100,416	0.22	35	3,499,134	103	88
Wrekin	10,629	7,438	1.43	227	1,685,774	50	50
Shropshire County	136,631	310,335	0.44	70	21,855,685	646	611

Table 80: Estimated Electricity Consumption by Final Users in Urban and Rural Populations for Shropshire Districts 1990

1. No urban, rural land use data in existence [231] yet [233]. Crude estimation of rural and urban areas only, based on land use change figures, assuming total land change follows pattern of what existed in the first place [232].
2. Estimate assumes 35.53% of total PFC used for electricity generation in 1990.
3. 29.96% of PFC used for electricity generation consumed as electricity by final user in 1990.
4. Estimated from Annual GWhe = (MWhe/ha) * 1GWh/1000MWh * Area (ha.). (MWhe/ha. Estimated from model in Figure 27).

1990	Urban	Total Annual PFC	Annual PFC GJ/Person
District	Population	GJ	
Bridgnorth	20,597	3,255,997	158.08
North Shropshire	25,199	3,984,532	158.12
Oswestry	14,219	2,248,914	158.16
Shrewsbury & Atcham	64,219	10,151,571	158.08
South Shropshire	16,633	2,629,921	158.11
Wrekin	128,886	20,382,106	158.14
Shropshire County	269,753	42,653,042	158.12
1990	Rural		
Bridgnorth	29,914	4,779,308	159.77
North Shropshire	27,674	4,427,940	160
Oswestry	19,289	3,067,363	159.02
Shrewsbury & Atcham	27,528	4,396,166	159.7
South Shropshire	21,597	3,499,134	162.02
Wrekin	10,629	1,685,774	158.6
Shropshire County	136,631	21,855,685	159.96

Table 81: Estimated Annual PFC Per Person (GJ/y) in Urban and Rural Populations for Shropshire Districts 1990

Annual PFC per person is similar in the urban areas of Shropshire and lower than in the rural areas (see Table 81).

The results have shown the following:

For Shropshire 1990 to 1996

1. The industrial sector was the largest consumer of electricity.
2. Wrekin District was the largest consumer of electricity.
3. The agricultural sector was the smallest consumer of electricity.
4. Oswestry District was the smallest consumer of electricity.
5. In Bridgnorth and Wrekin Districts, the industrial sector was the largest consumer of electricity.
6. In North and South Shropshire and Shrewsbury & Atcham Districts, the domestic sector was the largest consumer of electricity.
7. In Oswestry District, the commercial sector was the largest consumer of electricity.
8. In the domestic, commercial and industrial sectors, Wrekin District was the largest consumer of electricity.
9. In the agricultural sector, North Shropshire was the largest consumer of electricity.
10. The domestic sector had the largest increase in electricity consumption.
11. The agricultural sector had the smallest increase in electricity consumption.
12. Wrekin District had the largest increase in electricity consumption.
13. Oswestry had the smallest increase in electricity consumption.
14. The domestic sector had the largest percentage increase in electricity consumption.
15. The commercial and industrial sectors had the smallest percentage increases in electricity consumption.
16. South Shropshire District had the largest percentage increase in electricity consumption.
17. The largest percentage increase in electricity consumption in the domestic and industrial sectors was in South Shropshire.
18. The largest percentage increase in electricity consumption in the agricultural sector was in Wrekin District.
19. Population is a significant factor for predicting electricity consumption.

20. The rural populations in each district require more primary fuel per person (annual PFC GJ/Person) than urban populations.

The industrial sector and Wrekin District are the main consumers of electricity and therefore biggest producers of associated emissions in Shropshire. Therefore these are the areas that energy efficiency measures and alternative energy supply options would have the greatest impact in improving the Shropshire environment for the present time. The domestic sector and South Shropshire District had the largest percentage increases in electricity consumption implying that energy efficiency measures and alternative energy supply options in these areas will become more important as time goes by. Although Oswestry was the smallest consumer of electricity, the commercial sector was the dominant factor; this suggests that energy efficiency in the tourism industry should be investigated.

Data sets may be presently available for other areas of the UK although the 59 data sets used for the model were sufficient for the purposes of this project. The evidence shows that population data can be used to predict electricity consumption for a variety of regions across the UK between 1990 and 1997 for sizes of population ranging from around 30,00 (for a district) to 59 million (the whole of the UK).

It has to be noted that whilst the model was successful over most of the areas investigated the two main exceptions were at the extremes of low electricity consumption per person (Oswestry and Shrewsbury & Atcham) and high electricity consumption per person (Bridgnorth and The City of Coventry). While the model may not work in the case of County Donegal, (not in the UK and with atypical energy resources), the wider application of the methodology may be appropriate to investigate possible relationships between population and energy consumption in regions of other countries.

10. The Potential for Renewable Energy to Contribute to a Higher Quality Environment in Shropshire

Shropshire Regeneration partnership published a regeneration strategy in March 1998 [162], with the goal of raising the quality of life for Shropshire people. The primary aim was to encourage a higher quality environment, with the promotion of environmental sustainable development in town and country as Strategic Objective 1b. Two of the specific objectives being to reduce primary energy consumption by 20% by 2010 and to provide 8% of primary energy from renewable energy sources by 2005.

10.1 Required Decrease in PFC and Increase in Contribution by Renewables

With a current development scenario (no new renewable energy schemes or energy efficiency drives in Shropshire) it is assumed that the estimated contribution to PFC from all renewable energy sources (including biofuels (heat and electricity), hydro and other renewable generated grid supplied electricity) will be 1.58% in 2005 and 1.91% in 2010. This equates to 328 GWh/y and 417 GWh/y respectively (see Table 82).

Assuming that the target to reduce PFC by 20% is a reduction on what PFC would otherwise have been for the year 2010, rather than the PFC in the base year of 1990. Total consumption by final user (CFU) will need to be cut from 14,686 GWh/y to 12,483 GWh/y by 2005, and from 15,555 GWh/y to 12,444 GWh/y by 2010 (see Table 83).

Assuming that the target to increase renewable energy to 8% of PFC is an increase based on the target PFC. Then a 1,415 GWh/y contribution to PFC will be required from renewable energy in 2005 (around 1,000 GWh/y as CFU). To keep this 8% share constant, a total contribution of 1,639 GWh/y to PFC will be required from renewable energy in 2025 (around 1,200 GWh/y as CFU).

Year	Estimated Total PFC	Conversion Efficiency	Consumption by Final User (CFU)	Estimated Contribution to PFC from Renewables	Estimated Contribution to PFC from Renewables	Estimated Contribution to CFU from Renewables
	GWh/y	%	GWh/y	%	GWh	GWh/y
1990	17,644	69%	12,158	0.61%	107	74
1991	18,255	69%	12,600	0.65%	118	81
1992	18,042	69%	12,473	0.75%	135	93
1993	18,300	69%	12,672	0.70%	129	89
1994	18,175	69%	12,606	0.95%	172	119
1995	18,360	69%	12,755	0.97%	179	124
1996	19,384	70%	13,488	0.90%	175	122
1997	18,930	70%	13,193	1.02%	193	134
1998	19,199	70%	13,402	1.11%	214	149
1999	19,391	70%	13,558	1.18%	229	160
2000	19,584	70%	13,715	1.25%	244	171
2001	19,774	70%	13,870	1.31%	260	182
2002	20,033	70%	14,074	1.38%	276	194
2003	20,290	70%	14,277	1.45%	293	206
2004	20,549	70%	14,482	1.51%	311	219
2005	20,805	71%	14,686	1.58%	328	232
2006	21,067	71%	14,894	1.64%	346	245
2007	21,265	71%	15,058	1.71%	364	258
2008	21,465	71%	15,224	1.78%	381	271
2009	21,662	71%	15,387	1.84%	399	284
2010	21,864	71%	15,555	1.91%	417	297
2011	22,068	71%	15,725	1.98%	436	311
2012	22,329	71%	15,936	2.04%	456	325
2013	22,566	71%	16,130	2.11%	476	340
2014	22,805	72%	16,326	2.17%	496	355
2015	23,046	72%	16,524	2.24%	516	370
2016	23,290	72%	16,725	2.31%	537	386
2017	23,537	72%	16,929	2.37%	559	402
2018	23,786	72%	17,134	2.44%	580	418
2019	24,038	72%	17,342	2.51%	602	435
2020	24,292	72%	17,553	2.57%	625	452
2021	24,550	72%	17,766	2.64%	648	469
2022	24,810	72%	17,982	2.70%	671	486
2023	25,072	73%	18,200	2.77%	695	504
2024	25,338	73%	18,421	2.84%	719	523
2025	25,606	73%	18,644	2.90%	744	541

Table 82: Contribution by all Renewable Energy Sources to Primary Fuel Consumption and Consumption by Final User Under a Current Development Scenario.

Year	Target PFC	Target PFC	Target CFU	Renewables Target	Renewables Target PFC	Renewables Target CFU
	%	GWh/y	GWh/y	%	GWh/y	GWh/y
1990	0%	17,644	12,158	0.2%	34	23
1991	1%	18,072	12,474	0.7%	128	88
1992	2%	17,681	12,224	1.3%	222	153
1993	3%	17,751	12,292	1.8%	315	218
1994	4%	17,448	12,102	2.3%	409	284
1995	5%	17,442	12,117	2.9%	503	349
1996	6%	18,221	12,678	3.3%	597	415
1997	7%	17,605	12,270	3.9%	690	481
1998	8%	17,663	12,330	4.4%	770	537
1999	9%	17,646	12,338	4.9%	862	603
2000	10%	17,626	12,343	5.4%	954	668
2001	11%	17,599	12,344	5.9%	1,046	734
2002	12%	17,629	12,385	6.5%	1,138	800
2003	13%	17,653	12,421	7.0%	1,230	866
2004	14%	17,672	12,455	7.5%	1,323	932
2005	15%	17,684	12,483	8.0%	1,415	999
2006	16%	17,696	12,511	8.0%	1,416	1,001
2007	17%	17,650	12,499	8.0%	1,412	1,000
2008	18%	17,601	12,484	8.0%	1,408	999
2009	19%	17,546	12,464	8.0%	1,404	997
2010	20%	17,491	12,444	8.0%	1,399	996
2011	20%	17,654	12,580	8.0%	1,412	1,006
2012	20%	17,863	12,749	8.0%	1,429	1,020
2013	20%	18,052	12,904	8.0%	1,444	1,032
2014	20%	18,244	13,061	8.0%	1,459	1,045
2015	20%	18,437	13,220	8.0%	1,475	1,058
2016	20%	18,632	13,380	8.0%	1,491	1,070
2017	20%	18,829	13,543	8.0%	1,506	1,083
2018	20%	19,029	13,707	8.0%	1,522	1,097
2019	20%	19,230	13,874	8.0%	1,538	1,110
2020	20%	19,434	14,042	8.0%	1,555	1,123
2021	20%	19,640	14,213	8.0%	1,571	1,137
2022	20%	19,848	14,385	8.0%	1,588	1,151
2023	20%	20,058	14,560	8.0%	1,605	1,165
2024	20%	20,270	14,736	8.0%	1,622	1,179
2025	20%	20,485	14,915	8.0%	1,639	1,193

Table 83: Targets for Reduction in PFC and Increase in Renewables.

10.2 Renewable Energy Resources in Shropshire

Assessments of the potential for electricity generation from renewable energy resources in Shropshire in terms of installed capacity (MWe) and annual production (GWhe/y) for the years 2005 and 2025 have been made. The Energy Technology Support Unit (ETSU) have assessed the accessible resources [234], whilst the Shropshire Energy Team have assessed the practicable resources, based on data supplied by ETSU [202, 203, 204].

10.2.1 Theoretical Biomass Resources

Possible wood fuel resources in Shropshire comprise forestry residues, wood wastes and short rotation coppice. Forestry residues result from the management of both coniferous and deciduous woodland. Wood wastes are produced by domestic, commercial and industrial activities. Short rotation coppice using Willow and Poplar could be grown and harvested specifically for use as a fuel. The potential for electricity generation would depend on the type and size of conversion technology used because both affect conversion efficiency (see Tables 84, 85 and 86) [210].

	Year	2005	2025	
	Unit	Fluid Bed Combustion	Fluid Bed Combustion	Model [210]
Forestry Residues	odt/y	10,122	10,122	
Waste Wood	odt/y	10,449	10,449	
Short Rotation Coppice	odt/y	0	33,482	
Total Resource	odt/y	20,571	54,053	
Calorific Value	GJ/odt	19	19	
Total Calorific Value	GJ/y	390,849	1,027,007	
Generation Efficiency	%	23.7%	26.2%	(0.0039* MWe) + 0.2247
Gross GWhe/y	GWhe/y	25.8	74.6	
Availability	%	90%	90%	
MWe		3.270	9.467	
% Labour used in Pretreatment	%	58%	50%	0.0717*LN(MWe) + 0.66
Total Labour per MWe		1.90	2.12	0.2079*LN(MWe) + 1.6495
Total Labour per MWe		1.89	2.12	1.6649*(MWe^ 0.1065)
Total Labour		6.2	20.04	
100th Plant Costs per MWe	£	£2,579,943	£2,196,129	(-61938*MWe)+2782476

Table 84: Theoretical Resource from Combustion for 2005 and 2025

	Year	2005	2025	
	Unit	Pyr-Eng	Pyr-Eng	Model [210]
Forestry Residues	odt/y	10,122	10,122	
Waste Wood	odt/y	10,449	10,449	
Short Rotation Coppice	odt/y	0	33,482	
Total Resource	odt/y	20,571	54,053	
Calorific Value	GJ/odt	19	19	
Total Calorific Value	GJ/y	390,849	1,027,007	
Generation Efficiency	%	37.8%	40.7%	(0.0028* MWe) + 0.3629
Gross GWhe/y	GWhe/y	41.1	116.0	
Availability	%	85%	85%	
MWe		5.517	15.575	
Total Labour per MWe		2.1	3.32	0.994*(MWe^ 0.4387)
Total Labour		11.6	51.63	
1st Plant Costs (close coupled) per MWe	£	£2,693,235	£2,198,681	(-49170*MWe)+2964488
Learning Factor for 10th Conversion Plant	%	47.65%	47.65%	100 * (No. of plant built^-0.3219)
Pretreatment Total Plant Costs (TPC)	£	2,869,950	7,442,104	454577*MWe+362213
Conversion TPC	£	3,165,078	5,588,040	(505514*MWe+3853042) * learning factor
Generation TPC	£	4,977,932	12,774,282	775136*MWe+701788
TPC 10th Plant	£	11,012,960	25,804,427	
TPC per MWe 10th Plant	£	1,996,318	1,656,819	

Table 85: Theoretical Resource from Pyrolysis for 2005 and 2025

	Year	2005	2025	
	Unit	Gas-Eng	Gas-Eng	Model [210]
Forestry Residues	odt/y	10,122	10,122	
Waste Wood	odt/y	10,449	10,449	
Short Rotation Coppice	odt/y	0	33,482	
Total Resource	odt/y	20,571	54,053	
Calorific Value	GJ/odt	19	19	
Total Calorific Value	GJ/y	390,849	1,027,007	
Generation Efficiency	%	33.9%	36.1%	(0.0025* MWe) + 0.3265
Gross GWhe/y	GWhe/y	36.8	103.0	
Availability	%	85%	85%	
MWe	3.270	4.941	13.834	
Total Labour per MWe		1.98	3.09	0.9945*(MWe^ 0.431)
Total Labour		9.78	42.69	
1st Plant Costs per MWe	£	£3,505,537	£2,928,915	(-64836*MWe)+3825876
Learning Factor for 10th Conversion Plant	%	47.65%	47.65%	100 * (No. of plant built^-0.3219)
Pretreatment Total Plant Costs (TPC)	£	1,372,814	4,292,171	328256*MWe-249022
Conversion TPC with tar cracker	£	5,431,092	9,991,319	(1075999*MWe+6080653) * learning factor
Generation TPC	£	4,608,138	11,729,346	800717*MWe+651984
TPC 10th Plant	£	11,412,044	26,012,837	
TPC per MWe 10th Plant	£	£2,309,773	1,880,314	

Table 86: Theoretical Resource from Atmospheric Gasification for 2005 and 2025

From the same biomass resources, the above Tables show:

Fluid bed combustion:

1. Would initially have the lowest total plant costs.
2. Would have the lowest efficiency.
3. Would have the lowest labour requirements because of the low need for pre-treatment of feedstock.

Pyrolysis:

4. Would have the lowest total plant costs by the 10^{th} plant.
5. Would have the highest efficiency.
6. Would have the greatest labour requirements because of the need to pre-treat feedstock.

Atmospheric Gasification:

7. Would initially have the highest total plant cost because of the need for a tar cracker in gas clean up.
8. Would have lower total plant costs than combustion by the 10^{th} plant.
9. Would have higher conversion efficiency than combustion.
10. Would have higher labour requirements than combustion because of the need to pre-treat feedstock.

Where feedstock and electricity requirements are separated a de-coupled system is required. Toft [210] found that de-coupled pyrolysis systems are less economic than close-coupled pyrolysis systems because of scale economies in the conversion plant. It is cheaper to transport oil than wood feedstock and it is more economical to site a single large conversion plant near to the feedstock source then transport the pyrolysis liquid to generators, than to have multiple small close-coupled systems.

10.2.2 Accessible and Practicable Resources

The accessible resources were defined as being both free from major institutional, planning and environmental constraints on development and able to be exploited at less than 10p/kWhe (8% discount rate). The practicable resources were defined as being both free from developmental constraints, able to be exploited at less than

10p/kWhe (15% discount rate) and whose development is likely to be publicly acceptable.

It is assumed that any electricity generated from Shropshire's renewable energy resources will be used within the region to contribute directly to local CFU.

Year	2005	2010	2025	Unit
Forestry Residues	7	7	7	GWh/y
Wood Wastes	8	8	8	GWh/y
Short Rotation Coppice	-	6	24	GWh/y
Landfill Gas	49	49	49	GWh/y
Agricultural Wastes	221	249	330	GWh/y
Municipal Solid and General Industrial Waste	205	205	205	GWh/y
Wind Power	102	102	102	GWh/y
Small-Scale Hydro	10	10	10	GWh/y
Photovoltaics	245	256	290	GWh/y
Total Accessible Resources	847	892	1,025	GWh/y
Total Accessible and Other Renewables	1,079	1,189	1,566	GWh/y
Estimated Contribution to Target CFU	8.6%	9.6%	10.5%	%

Table 87: Full Exploitation of Shropshire's Accessible Resources (assuming linear increases in output).

If this was the case, then full exploitation of the accessible resources would mean that the extra renewable energy development would help to achieve the target 8% of target CFU from renewables by 2005 and exceed the target at just over 10% by 2025 (see Table 87).

Year	2005	2010	2025	Unit
Forestry Residues	7	7	7	GWh/y
Wood Wastes	8	8	8	GWh/y
Short Rotation Coppice	-	6	24	GWh/y
Landfill Gas	49	49	49	GWh/y
Agricultural Wastes	20	22	29	GWh/y
Municipal Solid and General Industrial Waste	-	-	-	GWh/y
Wind Power	-	-	-	GWh/y
Small-Scale Hydro	8	8	8	GWh/y
Photovoltaics	-	-	-	GWh/y
Total Practicable Resources	92	100	125	GWh/y
Total Practicable and Other Renewables	324	397	667	GWh/y
Estimated Contribution to Target CFU	2.6%	3.2%	4.5%	%

Table 88: Full Exploitation of Shropshire's Practicable Resources.

Full exploitation of the practicable resources would mean that even with the extra renewable energy development only 2.6% of target CFU would be provided from renewables by 2005 and 4.5% by 2025 (see Table 88 and Figure 28). Most of this contribution would be from larger-scale renewable energy developments outside the county feeding into the national grid as the practicable resources would only contribute 0.74% of target CFU in 2005 and 0.84% in 2025 (9.2% and 10.5% of renewables CFU target).

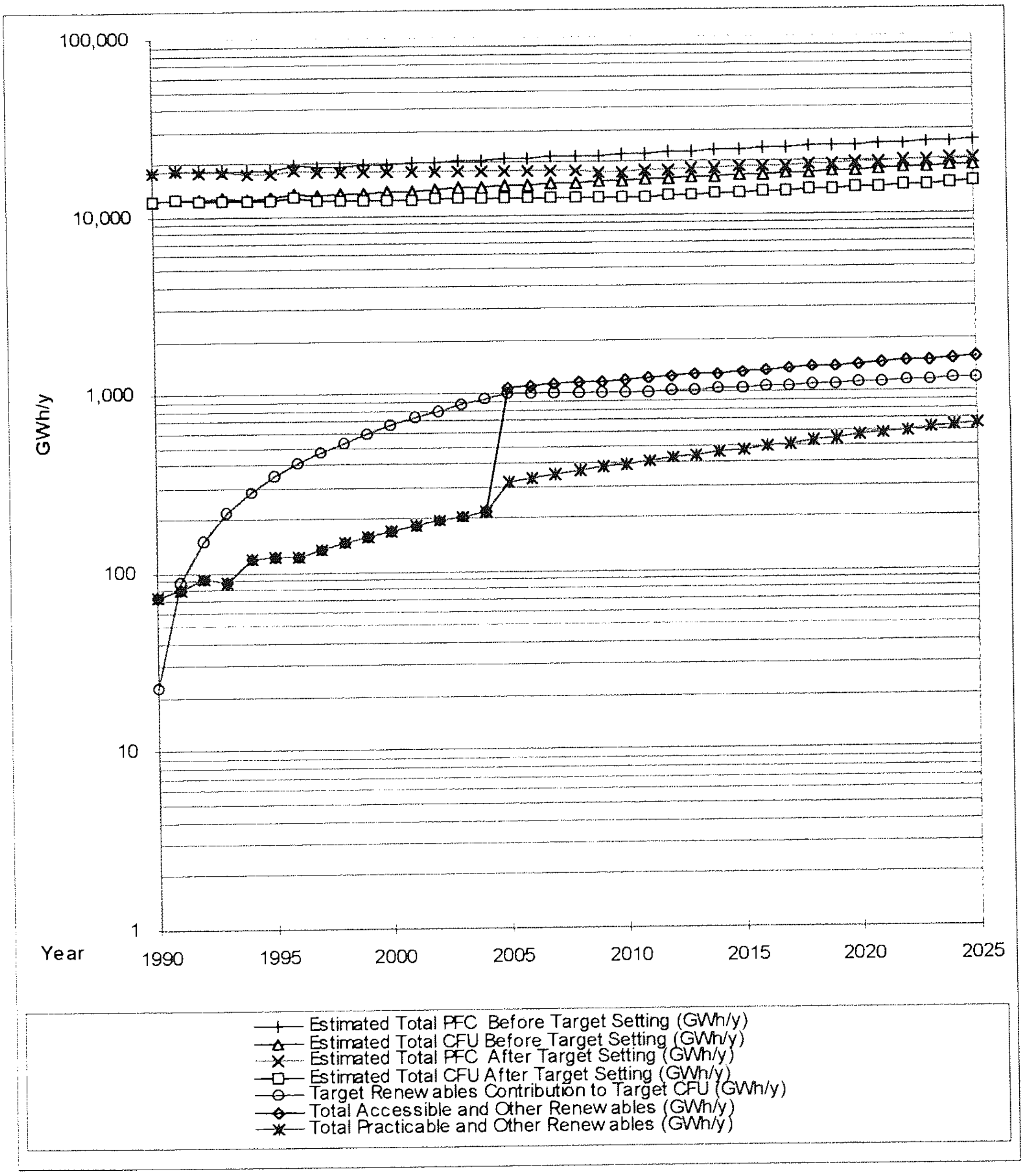

Figure 28: PFC and CFU Before and After Target Setting and Accessible and Practicable Renewable Energy Resources

10.3 The Potential to Reduce Emissions in Shropshire if Target Reduction in PFC is Achieved

Emission factors for Shropshire, based on total emissions (tonnes/year) as estimated in Table 57 and total primary fuel consumption (GJ PFC/ year) as estimated in Table 33 are shown in Table 89.

Year	Carbon	CO2	Methane	SO2	Black Smoke	NOx	VOC's	CO
	g/GJ	g/GJ	g/GJ	g/GJ	g/GJ	g/GJ	g/GJ	g/GJ
1990	17,784	65,209	295	419	50	303	266	740
1991	17,197	63,056	379	385	50	302	263	712
1992	17,297	63,423	400	381	51	280	266	682
1993	16,415	60,187	381	345	50	254	265	628
1994	16,223	59,483	369	296	47	241	230	526
1995	16,009	58,699	360	256	39	248	253	593
1996	15,789	57,894	332	208	35	211	216	476
1997	15,474	56,737	322	181	36	215	218	478
1998	14,703	53,912	293	185	33	215	208	428
1999	14,418	52,866	283	164	31	203	202	400
2000	14,138	51,840	274	145	29	193	196	374

Table 89: Average Annual Emission Factors (All Sources) (g/GJ PFC) for Shropshire 1990 - 2000.

Assuming there are no further significant improvements in emission factors with current technology and fuel mix after the year 2000, the estimated total emissions are shown in Table 90.

Emissions of SO_2 and black smoke are unlikely to reach 1990 levels before 2025 with continuing decreases in consumption of solid fuels. NOx, and CO emissions are also unlikely to reach 1990 levels before 2025, depending on increases in petroleum-based transport. Emissions of methane are likely to continue to increase on 1990 levels with the expected growth in population and therefore rubbish and sewage (if there is no expansion in Landfill gas collection). With continued growth in industrial activity in Telford and the Wrekin, emissions of VOC's are likely to reach 1990 levels by around 2019. Although changes in the fuel mix since 1990 have led to decreased carbon emissions, without a significant contribution from a more sustainable energy system, these emissions will exceed 1990 levels by around 2012.

Year	Carbon	CO2	Methane	SO2	Black Smoke	NOx	VOC's	CO
	tonnes/y	tonnes/y	tonnes/y	tonnes/y	tonnes/y	tonnes/y	tonnes/y	tonnes/y
1990	1,129,626	4,141,962	18,714	26,645	3,198	19,267	16,909	47,014
1998	1,016,244	3,726,229	20,225	12,784	2,269	14,854	14,402	29,603
1999	1,006,475	3,690,407	19,753	11,419	2,158	14,200	14,090	27,944
2000	996,765	3,654,805	19,293	10,199	2,052	13,574	13,785	26,378
2001	1,006,422	3,690,214	19,479	10,298	2,072	13,705	13,919	26,633
2002	1,019,639	3,738,678	19,735	10,433	2,099	13,885	14,101	26,983
2003	1,032,714	3,786,618	19,988	10,567	2,126	14,063	14,282	27,329
2004	1,045,879	3,834,889	20,243	10,701	2,153	14,242	14,464	27,677
2005	1,058,898	3,882,626	20,495	10,835	2,180	14,420	14,644	28,022
2006	1,072,243	3,931,559	20,753	10,971	2,207	14,601	14,829	28,375
2007	1,082,348	3,968,608	20,949	11,075	2,228	14,739	14,969	28,642
2008	1,092,517	4,005,895	21,146	11,179	2,249	14,878	15,109	28,912
2009	1,102,511	4,042,540	21,339	11,281	2,269	15,014	15,248	29,176
2010	1,112,810	4,080,303	21,539	11,386	2,291	15,154	15,390	29,449
2011	1,123,174	4,118,306	21,739	11,492	2,312	15,295	15,533	29,723
2012	1,136,484	4,167,109	21,997	11,628	2,339	15,476	15,717	30,075
2013	1,148,520	4,211,239	22,230	11,752	2,364	15,640	15,884	30,394
2014	1,160,683	4,255,836	22,465	11,876	2,389	15,806	16,052	30,715
2015	1,172,974	4,300,905	22,703	12,002	2,414	15,973	16,222	31,041
2016	1,185,396	4,346,452	22,944	12,129	2,440	16,142	16,394	31,369
2017	1,197,949	4,392,481	23,187	12,257	2,466	16,313	16,567	31,702
2018	1,210,636	4,438,997	23,432	12,387	2,492	16,486	16,743	32,037
2019	1,223,456	4,486,006	23,680	12,518	2,518	16,661	16,920	32,377
2020	1,236,413	4,533,513	23,931	12,651	2,545	16,837	17,099	32,719
2021	1,249,506	4,581,523	24,184	12,785	2,572	17,015	17,280	33,066
2022	1,262,739	4,630,042	24,441	12,920	2,599	17,196	17,463	33,416
2023	1,276,111	4,679,074	24,699	13,057	2,627	17,378	17,648	33,770
2024	1,289,625	4,728,625	24,961	13,195	2,655	17,562	17,835	34,128
2025	1,303,282	4,778,701	25,225	13,335	2,683	17,748	18,024	34,489

Table 90: Estimation of Emissions (All Sources) in Shropshire 1998 - 2025, Before Target Setting

Year	Target PFC (20% reduction in PFC by 2010)	Carbon	CO2	Methane	SO2	Black Smoke	NOx	VOC's	CO
	GJ/y	tonnes/y	tonnes/y	tonnes/y	tonnes/y	tonnes/y	tonnes/y	tonnes/y	tonnes/y
1990	63,518,018	1,129,626	4,141,962	18,714	26,645	3,198	19,267	16,909	47,014
1991	65,059,948	1,118,835	4,102,396	24,670	25,076	3,253	19,650	17,124	46,335
1992	63,650,686	1,100,975	4,036,910	25,463	24,255	3,222	17,817	16,958	43,437
1993	63,903,543	1,048,958	3,846,180	24,349	22,042	3,195	16,252	16,928	40,116
1994	62,814,387	1,019,009	3,736,366	23,177	18,588	2,927	15,155	14,478	33,053
1995	62,791,672	1,005,215	3,685,788	22,629	16,063	2,418	15,588	15,873	37,207
1996	65,594,598	1,035,697	3,797,555	21,774	13,639	2,287	13,854	14,197	31,239
1997	63,378,254	980,693	3,595,876	20,414	11,458	2,277	13,602	13,823	30,277
1998	63,587,515	934,945	3,428,131	18,607	11,762	2,087	13,666	13,250	27,235
1999	63,524,655	915,892	3,358,271	17,975	10,391	1,963	12,922	12,822	25,429
2000	63,452,032	897,089	3,289,325	17,363	9,179	1,847	12,216	12,407	23,740
2001	63,354,912	895,715	3,284,290	17,337	9,165	1,844	12,198	12,388	23,704
2002	63,465,761	897,283	3,290,036	17,367	9,181	1,847	12,219	12,409	23,745
2003	63,549,126	898,461	3,294,358	17,390	9,193	1,849	12,235	12,426	23,776
2004	63,619,469	899,456	3,298,005	17,409	9,203	1,851	12,248	12,439	23,803
2005	63,662,436	900,063	3,300,232	17,421	9,209	1,853	12,257	12,448	23,819
2006	63,706,365	900,684	3,302,509	17,433	9,216	1,854	12,265	12,456	23,835
2007	63,541,149	898,348	3,293,944	17,388	9,192	1,849	12,233	12,424	23,773
2008	63,365,397	895,864	3,284,834	17,340	9,166	1,844	12,200	12,390	23,707
2009	63,165,243	893,034	3,274,458	17,285	9,138	1,838	12,161	12,351	23,633
2010	62,968,181	890,248	3,264,242	17,231	9,109	1,832	12,123	12,312	23,559
2011	63,554,663	898,540	3,294,645	17,391	9,194	1,850	12,236	12,427	23,778
2012	64,307,803	909,187	3,333,687	17,597	9,303	1,871	12,381	12,574	24,060
2013	64,988,824	918,816	3,368,991	17,784	9,401	1,891	12,512	12,707	24,315
2014	65,677,056	928,546	3,404,669	17,972	9,501	1,911	12,645	12,842	24,572
2015	66,372,576	938,379	3,440,724	18,162	9,601	1,932	12,779	12,978	24,833
2016	67,075,462	948,317	3,477,162	18,355	9,703	1,952	12,914	13,115	25,096
2017	67,785,792	958,359	3,513,985	18,549	9,806	1,973	13,051	13,254	25,361
2018	68,503,644	968,509	3,551,198	18,746	9,910	1,994	13,189	13,394	25,630
2019	69,229,098	978,765	3,588,805	18,944	10,015	2,015	13,329	13,536	25,901
2020	69,962,234	989,130	3,626,811	19,145	10,121	2,036	13,470	13,680	26,176
2021	70,703,135	999,605	3,665,219	19,348	10,228	2,058	13,612	13,824	26,453
2022	71,451,881	1,010,191	3,704,033	19,552	10,336	2,079	13,756	13,971	26,733
2023	72,208,557	1,020,889	3,743,259	19,759	10,446	2,101	13,902	14,119	27,016
2024	72,973,246	1,031,700	3,782,900	19,969	10,556	2,124	14,049	14,268	27,302
2025	73,746,033	1,042,626	3,822,961	20,180	10,668	2,146	14,198	14,419	27,591

Table 91: Estimation of Emissions (All Sources) in Shropshire 1990 - 2025, if the 20% Reduction in PFC Target is Achieved by 2010.

Achieving the 20% reduction in PFC in 2010 will result in drops in emissions from 1990 levels of 21% for carbon, 8% for methane, 66% for SO_2, 43% for black smoke, 37% for NOx, 27% for VOC's and 50% for CO (see Table 91). Keeping the reduction in PFC at a steady 20% of what would otherwise be expected for the years following 2010 will mean a return to increases in emissions.

10.4 The Potential for Renewable Energy Development in Shropshire to Further Reduce Emissions

Emission factors for electricity from the national grid are shown in Tables 50 and 55 (g/GJ PFC used for electricity generation). The equivalent emission factors per GWh electricity consumed by final user in Shropshire (t/GWhe CFU), based on total emissions associated with electricity (Tables 51 and 56) and total electricity CFU (Tables 48 and 49), are shown in Table 92.

Year	Carbon	CO2	SO2	Black Smoke	NOx	VOC's	CO
	t/GWh	t/GWh	t/GWh	t/GWh	t/GWh	t/GWh	t/GWh
1990	210.8	773.0	10.6	0.1	3.0	0.1	0.2
1991	205.3	752.8	9.7	0.1	2.6	0.05	0.2
1992	189.9	696.3	9.2	0.1	2.5	0.04	0.2
1993	169.0	619.6	7.7	0.1	2.1	0.04	0.1
1994	158.3	580.4	6.5	0.1	1.9	0.02	0.1
1995	154.4	566.3	5.7	0.1	1.7	0.02	0.1
1996	148.8	545.8	4.5	0.1	1.6	0.02	0.1
1997	137.0	502.3	3.7	0.1	1.4	0.02	0.04
1998	138.0	506.2	4.4	0.1	1.3	0.01	0.04
1999	134.5	493.1	4.1	0.1	1.3	0.01	0.04
2000	131.3	481.3	3.8	0.1	1.2	0.01	0.03
2001	128.4	470.7	3.5	0.1	1.1	0.01	0.03
2002	125.7	461.1	3.3	0.1	1.0	0.01	0.03
2003	123.3	452.2	3.1	0.1	1.0	0.01	0.03
2004	121.1	444.0	2.9	0.1	0.9	0.01	0.03
2005	119.0	436.3	2.7	0.1	0.9	0.01	0.03
2006	117.1	429.2	2.5	0.1	0.8	0.01	0.03
2007	115.2	422.5	2.4	0.1	0.8	0.01	0.03
2008	113.5	416.3	2.2	0.1	0.7	0.01	0.03
2009	111.9	410.3	2.1	0.1	0.7	0.01	0.03
2010	110.4	404.7	2.0	0.1	0.7	0.01	0.03
2011	108.9	399.4	1.8	0.1	0.6	0.01	0.03
2012	107.5	394.3	1.7	0.1	0.6	0.01	0.03
2013	106.2	389.5	1.6	0.1	0.6	0.01	0.03
2014	105.0	384.9	1.5	0.1	0.5	0.01	0.03
2015	103.8	380.5	1.4	0.1	0.5	0.01	0.03
2016	102.6	376.2	1.3	0.1	0.5	0.01	0.03
2017	101.5	372.2	1.2	0.1	0.4	0.01	0.03
2018	100.4	368.3	1.1	0.1	0.4	0.01	0.03
2019	99.4	364.5	1.0	0.1	0.4	0.01	0.03
2020	98.4	360.9	0.9	0.1	0.4	0.01	0.03
2021	97.5	357.4	0.8	0.1	0.3	0.01	0.03
2022	96.5	354.0	0.7	0.1	0.3	0.01	0.03
2023	95.7	350.7	0.6	0.1	0.3	0.01	0.03
2024	94.2	345.3	0.5	0.1	0.3	0.01	0.03
2025	93.3	342.2	0.4	0.1	0.2	0.01	0.03

Table 92: Estimated Average Annual Emission Factors (t/GWh) for Electricity Consumed by Final User in Shropshire 1990 - 2025.

It is assumed the target output from renewable energy in Shropshire is electricity, and that this electricity replaces electricity from the national grid. Emissions saved by developing such schemes are shown in Table 93, with total emissions if both targets for PFC reduction and increased renewables are achieved, shown in Table 94.

Year	Target Contribution from Renewables to PFC	PFC/ GWhe from grid CFU	Could replace electricity from grid	Carbon	CO2	SO2	Black Smoke	NOx	VOC's	CO
	GJ/y	GJ/GWhe	GWhe/y	t/y	t/y	t/y	t/y	t/y	t/y	t/y
1990	120,602	12,489	10	2,036	7,464	102	1	29	0	2
1991	460,194	12,398	37	7,621	27,945	362	4	98	2	7
1992	797,647	12,055	66	12,565	46,072	611	6	164	3	10
1993	1,135,130	11,596	98	16,541	60,649	755	8	205	4	14
1994	1,472,634	11,103	133	20,996	76,986	859	9	253	3	10
1995	1,810,076	11,112	163	25,156	92,238	921	11	279	3	11
1996	2,147,499	11,101	193	28,793	105,575	870	13	301	3	11
1997	2,485,017	10,828	229	31,440	115,280	850	15	312	4	9
1998	2,770,834	10,940	253	34,962	128,194	1,116	15	340	4	11
1999	3,102,398	10,881	285	38,340	140,581	1,166	16	357	4	10
2000	3,434,019	10,828	317	41,632	152,652	1,207	17	372	4	9
2001	3,765,699	10,780	349	44,846	164,436	1,239	19	385	4	10
2002	4,097,436	10,737	382	47,989	175,960	1,265	20	396	4	11
2003	4,429,231	10,696	414	51,066	187,244	1,283	22	405	5	12
2004	4,761,084	10,659	447	54,083	198,306	1,296	24	413	5	13
2005	5,092,995	10,625	479	57,044	209,161	1,302	25	418	5	14
2006	5,096,509	10,592	481	56,322	206,515	1,224	25	397	5	14
2007	5,083,292	10,562	481	55,460	203,355	1,146	25	375	5	14
2008	5,069,232	10,534	481	54,632	200,317	1,073	25	355	5	14
2009	5,053,219	10,507	481	53,821	197,343	1,004	25	336	5	14
2010	5,037,454	10,482	481	53,047	194,507	938	25	317	5	14
2011	5,084,373	10,458	486	52,959	194,182	886	25	304	5	14
2012	5,144,624	10,435	493	53,023	194,418	838	26	291	5	14
2013	5,199,106	10,413	499	53,039	194,478	790	26	279	5	14
2014	5,254,164	10,392	506	53,073	194,600	744	26	267	5	14
2015	5,309,806	10,372	512	53,122	194,780	699	26	255	5	14
2016	5,366,037	10,353	518	53,186	195,014	654	27	243	6	15
2017	5,422,863	10,335	525	53,263	195,297	611	27	232	6	15
2018	5,480,291	10,317	531	53,353	195,629	568	27	221	6	15
2019	5,538,328	10,300	538	53,456	196,004	526	28	210	6	15
2020	5,596,979	10,283	544	53,570	196,422	485	28	200	6	15
2021	5,656,251	10,268	551	53,695	196,880	444	28	189	6	15
2022	5,716,151	10,252	558	53,830	197,377	404	28	179	6	16
2023	5,776,685	10,238	564	53,975	197,909	364	29	169	6	16
2024	5,837,860	10,213	572	53,829	197,374	293	29	150	6	16
2025	5,899,683	10,199	578	53,987	197,954	254	29	140	6	16

Table 93: Estimation of Gross Emissions Saved (t/y) in Shropshire 1990 - 2025, if Electricity from the Grid was Replaced by Target Electricity from Renewable Energy Schemes.

Achieving both targets will result in decreases in emissions from 1990 levels of 26% for carbon, 69% for SO_2, 43% for black smoke, 39% for NOx, 27% for VOC's and 50% for CO by 2010 (see Table 94).

Year	Carbon	CO2	Methane	SO2	Black Smoke	NOx	VOC's	CO
	tonnes/y	tonnes/y	tonnes/y	tonnes/y	tonnes/y	tonnes/y	tonnes/y	tonnes/y
1990	1,127,590	4,134,498	18,714	26,534	3,197	19,238	16,909	47,012
1991	1,111,214	4,074,452	24,670	24,714	3,249	19,552	17,123	46,329
1992	1,088,410	3,990,838	25,463	23,644	3,217	17,653	16,955	43,427
1993	1,032,418	3,785,531	24,349	21,287	3,188	16,047	16,925	40,102
1994	998,013	3,659,381	23,177	17,729	2,918	14,902	14,475	33,043
1995	980,059	3,593,549	22,629	15,142	2,407	15,309	15,870	37,196
1996	1,006,904	3,691,980	21,774	12,768	2,273	13,553	14,194	31,228
1997	949,253	3,480,596	20,414	10,607	2,262	13,290	13,819	30,268
1998	899,983	3,299,937	18,607	10,646	2,072	13,326	13,246	27,223
1999	877,552	3,217,689	17,975	9,226	1,947	12,565	12,818	25,419
2000	855,456	3,136,673	17,363	7,972	1,829	11,844	12,403	23,731
2001	850,869	3,119,854	17,337	7,925	1,825	11,812	12,384	23,693
2002	849,294	3,114,076	17,367	7,916	1,827	11,823	12,405	23,734
2003	847,395	3,107,114	17,390	7,910	1,827	11,830	12,421	23,764
2004	845,372	3,099,699	17,409	7,908	1,828	11,836	12,434	23,790
2005	843,019	3,091,071	17,421	7,907	1,827	11,839	12,442	23,805
2006	844,362	3,095,994	17,433	7,992	1,829	11,868	12,451	23,821
2007	842,888	3,090,590	17,388	8,045	1,824	11,858	12,419	23,759
2008	841,232	3,084,517	17,340	8,093	1,819	11,844	12,384	23,694
2009	839,213	3,077,115	17,285	8,134	1,813	11,825	12,345	23,619
2010	837,200	3,069,735	17,231	8,171	1,807	11,806	12,307	23,545
2011	845,581	3,100,463	17,391	8,308	1,824	11,932	12,421	23,764
2012	856,164	3,139,270	17,597	8,465	1,846	12,090	12,569	24,046
2013	865,776	3,174,513	17,784	8,611	1,865	12,233	12,702	24,301
2014	875,473	3,210,069	17,972	8,757	1,885	12,378	12,836	24,558
2015	885,258	3,245,944	18,162	8,903	1,905	12,524	12,972	24,818
2016	895,131	3,282,148	18,355	9,049	1,925	12,670	13,110	25,081
2017	905,097	3,318,687	18,549	9,195	1,946	12,818	13,248	25,347
2018	915,155	3,355,569	18,746	9,342	1,966	12,968	13,389	25,615
2019	925,309	3,392,801	18,944	9,489	1,987	13,118	13,530	25,886
2020	935,560	3,430,388	19,145	9,636	2,008	13,270	13,674	26,160
2021	945,910	3,468,338	19,348	9,784	2,029	13,423	13,819	26,437
2022	956,361	3,506,657	19,552	9,932	2,051	13,578	13,965	26,717
2023	966,914	3,545,350	19,759	10,082	2,073	13,734	14,113	27,000
2024	977,871	3,585,526	19,969	10,263	2,095	13,899	14,262	27,286
2025	988,638	3,625,007	20,180	10,414	2,117	14,058	14,413	27,575

Table 94: Estimation of Emissions (All Sources) in Shropshire 1990 - 2025, if Both Targets are Achieved and Renewable Energy Contributes Zero Emissions.

Although these emissions will be saved, others will be added, depending on which type of renewable energy is used to replace electricity from the grid.

10.4.1 Accessible Resources

If the total annual electricity output from the accessible resources was used to directly replace electricity from the grid, at point of use, as electricity consumed by final user, then in 2005 each GWhe of renewable electricity would replace the equivalent of 10,625 GJ PFC of the fuel mix used for electricity generation. Thus the 847.16 GWhe/y would replace 9,000,797 GJ of primary fuel and save carbon emissions of 100,813 tonnes (see Table 95).

Year	Contribution by Accessible Resources	Replaces PFC Used for Electricity Generation	Carbon	CO2	SO2	Black Smoke	NOx	VOC's	CO
	GWhe/y	GJ/y	tonnes/y	tonnes/y	tonnes/y	tonnes/y	tonnes/y	tonnes/y	tonnes/y
2005	847.16	9,000,797	100,813	369,649	2,301	45	739	9	24
2006	856.03	9,067,452	100,206	367,421	2,178	45	706	9	25
2007	864.90	9,135,283	99,669	365,453	2,060	45	675	9	25
2008	873.77	9,204,144	99,194	363,713	1,949	46	645	9	25
2009	882.64	9,273,912	98,774	362,173	1,842	46	616	10	25
2010	891.51	9,344,483	98,403	360,811	1,739	47	589	10	25
2011	900.38	9,415,770	98,075	359,607	1,641	47	563	10	26
2012	909.25	9,487,696	97,785	358,545	1,546	47	537	10	26
2013	918.12	9,560,198	97,530	357,609	1,453	48	513	10	26
2014	926.99	9,633,218	97,306	356,789	1,364	48	489	10	26
2015	935.86	9,706,707	97,111	356,072	1,277	48	466	10	26
2016	944.72	9,780,622	96,941	355,449	1,193	49	444	10	27
2017	953.59	9,854,925	96,794	354,912	1,110	49	422	10	27
2018	962.46	9,929,583	96,669	354,454	1,029	49	401	10	27
2019	971.33	10,004,564	96,564	354,067	950	50	380	10	27
2020	980.20	10,079,843	96,476	353,746	873	50	359	10	27
2021	989.07	10,155,395	96,405	353,485	797	51	340	10	28
2022	997.94	10,231,198	96,349	353,280	723	51	320	11	28
2023	1,006.81	10,307,234	96,307	353,126	650	51	301	11	28
2024	1,015.68	10,373,012	95,647	350,704	521	52	266	11	28
2025	1,024.55	10,449,315	95,621	350,609	450	52	247	11	28

Table 95: Estimation of Gross Emissions Saved (t/y) in Shropshire 2005 - 2025, if Electricity from the Accessible Resources was Used to Replace Electricity from the Grid.

By 2025 each GWhe of renewable electricity would replace the equivalent of 10,199 GJ PFC of the fuel mix used for electricity generation. Thus the 1,024.55 GWhe/y would replace 10,449,315 GJ of primary fuel and save carbon emissions of 95,621 tonnes.

Emission factors [235] prepared by the US Council for Renewable Energy Education (t/GWh) for the total fuel cycle for electricity generation from various renewable energy technologies were used to estimate the added emissions from the mix of accessible resources (see Table 96). These were published in 1988 / 1989 and advances in technology since will probably have improved upon them.

Year	Carbon	CO2	SO2	Black Smoke	NOx	VOC's	CO
	t/y	t/y	t/y	t/y	t/y	t/y	t/y
2005	618	2,267	81	255	303	377	5,568
2006	622	2,280	82	258	307	382	5,643
2007	626	2,294	83	262	311	387	5,718
2008	629	2,307	84	265	315	392	5,793
2009	633	2,320	85	269	319	397	5,869
2010	636	2,334	86	272	323	402	5,944
2011	640	2,347	88	276	327	407	6,019
2012	644	2,360	89	279	331	412	6,094
2013	647	2,374	90	282	335	417	6,169
2014	651	2,387	91	286	340	423	6,244
2015	655	2,400	92	289	344	428	6,319
2016	658	2,414	93	293	348	433	6,394
2017	662	2,427	94	296	352	438	6,469
2018	666	2,440	95	300	356	443	6,544
2019	669	2,454	96	303	360	448	6,620
2020	673	2,467	97	306	364	453	6,695
2021	676	2,480	98	310	368	458	6,770
2022	680	2,494	99	313	372	463	6,845
2023	684	2,507	100	317	376	468	6,920
2024	687	2,520	101	320	380	473	6,995
2025	691	2,534	103	324	384	478	7,070

Table 96: Added Emissions from Electricity Produced by the Accessible Resources in Shropshire 2005 - 2025.

Although the added emissions of carbon are insignificant compared to the emissions avoided, full exploitation of the accessible resources would increase emissions of black smoke, VOC's and CO from 2005, with emissions of NOx increasing after 2020 (See Tables 97 and 98). This is because of the expected reduced use of coal in the conventional fuel mix and the increase in the use of biomass (58% of total accessible resources in 2005, rising to 61% in 2025).

Year	Carbon	CO2	SO2	Black Smoke	NOx	VOC's	CO
	t/y	t/y	t/y	t/y	t/y	t/y	t/y
2005	159,204	583,746	3,701	326	1,466	391	5,607
2006	157,080	575,960	3,482	329	1,409	397	5,682
2007	154,269	565,652	3,259	332	1,351	402	5,757
2008	151,568	555,748	3,050	335	1,296	407	5,832
2009	148,912	546,010	2,850	338	1,244	412	5,906
2010	146,401	536,803	2,663	341	1,196	417	5,981
2011	143,972	527,897	2,485	344	1,150	421	6,056
2012	142,225	521,491	2,326	347	1,109	427	6,131
2013	140,246	514,237	2,170	351	1,069	432	6,206
2014	138,332	507,219	2,021	354	1,032	437	6,281
2015	136,478	500,420	1,878	357	996	442	6,356
2016	134,680	493,825	1,742	360	961	447	6,431
2017	132,933	487,421	1,611	363	928	452	6,506
2018	131,235	481,196	1,485	366	897	457	6,581
2019	129,583	475,138	1,365	369	867	462	6,656
2020	127,974	469,238	1,249	373	838	467	6,731
2021	126,406	463,487	1,138	376	811	472	6,806
2022	124,875	457,876	1,031	379	785	477	6,881
2023	123,381	452,398	928	382	759	482	6,956
2024	121,345	444,930	759	385	716	487	7,031
2025	119,916	439,691	663	388	693	492	7,106

Table 97: Estimation of Net Total Emissions from Generation of Electricity in Shropshire 2005 - 2025, with Full Exploitation of the Accessible Resources.

Year	Carbon	CO2	SO2	Black Smoke	NOx	VOC's	CO
	t/y	t/y	t/y	t/y	t/y	t/y	t/y
2005	100,195	367,382	2,220	- 210	436	-368	-5,544
2006	99,584	365,141	2,095	-213	399	-373	-5,619
2007	99,043	363,159	1,977	-216	364	-378	-5,694
2008	98,565	361,406	1,864	-220	330	-383	-5,768
2009	98,142	359,853	1,757	- 223	297	-388	-5,843
2010	97,767	358,477	1,653	-226	266	-393	-5,918
2011	97,435	357,260	1,553	-229	235	-398	-5,993
2012	97,141	356,184	1,457	-232	206	-403	-6,068
2013	96,883	355,236	1,364	-235	177	-408	-6,143
2014	96,655	354,402	1,273	- 238	150	-413	-6,218
2015	96,456	353,672	1,185	- 241	122	-418	-6,293
2016	96,282	353,036	1,100	-244	96	-423	-6,368
2017	96,132	352,485	1,016	-247	70	-428	-6,443
2018	96,004	352,014	934	-250	45	-433	-6,517
2019	95,895	351,613	854	-253	20	-438	-6,592
2020	95,803	351,279	776	-256	- 5	-443	-6,667
2021	95,729	351,005	699	-259	-29	-448	-6,742
2022	95,669	350,786	623	-262	- 52	-453	-6,817
2023	95,623	350,619	549	-265	- 76	-458	-6,892
2024	94,959	348,184	420	-268	-114	-463	-6,967
2025	94,930	348,076	347	-272	-137	-468	-7,042

Table 98: Total Emissions Saved (+) or Extra Emissions (-) with Full Exploitation of the Accessible Resources.

10.4.2 Practicable Resources

If the total annual electricity output from the practicable resources was used to directly replace electricity from the grid, at point of use, as electricity consumed by final user, then in 2005 each GWhe of renewable electricity would replace the equivalent of 10,625 GJ PFC of the fuel mix used for electricity generation. Thus the 91.91 GWhe/y would replace 976,514 GJ of primary fuel and save carbon emissions of 10,937 tonnes (see Table 99).

Year	Contribution by Practicable Resources	Replaces PFC Used for Electricity Generation	Carbon	CO2	SO2	Black Smoke	NOx	VOC's	CO
	GWhe/y	GJ/y	tonnes/y	tonnes/y	tonnes/y	tonnes/y	tonnes/y	tonnes/y	tonnes/y
2005	91.91	976,514	10,937	40,104	250	5	80	1	3
2006	93.58	991,274	10,955	40,167	238	5	77	1	3
2007	95.26	1,006,118	10,977	40,249	227	5	74	1	3
2008	96.93	1,021,035	11,004	40,347	216	5	72	1	3
2009	98.60	1,036,015	11,034	40,459	206	5	69	1	3
2010	100.28	1,051,049	11,068	40,583	196	5	66	1	3
2011	101.95	1,066,130	11,105	40,718	186	5	64	1	3
2012	103.62	1,081,252	11,144	40,861	176	5	61	1	3
2013	105.29	1,096,410	11,185	41,012	167	5	59	1	3
2014	106.97	1,111,599	11,228	41,171	157	6	56	1	3
2015	108.64	1,126,816	11,273	41,335	148	6	54	1	3
2016	110.31	1,142,058	11,320	41,505	139	6	52	1	3
2017	111.99	1,157,320	11,367	41,679	130	6	50	1	3
2018	113.66	1,172,602	11,416	41,858	122	6	47	1	3
2019	115.33	1,187,900	11,466	42,040	113	6	45	1	3
2020	117.01	1,203,213	11,516	42,226	104	6	43	1	3
2021	118.68	1,218,538	11,568	42,414	96	6	41	1	3
2022	120.35	1,233,875	11,620	42,605	87	6	39	1	3
2023	122.02	1,249,221	11,672	42,798	79	6	36	1	3
2024	123.70	1,263,301	11,649	42,711	63	6	32	1	3
2025	125.37	1,278,640	11,701	42,903	55	6	30	1	3

Table 99: Estimation of Gross Emissions Saved (t/y) in Shropshire 2005 - 2025, if Electricity from the Practicable Resources was Used to Replace Electricity from the Grid.

By 2025 each GWhe of renewable electricity would replace the equivalent of 10,199 GJ PFC of the fuel mix used for electricity generation. Thus the 125.37 GWhe/y would replace 1,278,640 GJ of primary fuel and save carbon emissions of 11,701 tonnes.

Emission factors prepared by the US Council for Renewable Energy Education (t/GWh) were used to estimate the added emissions from the mix of practicable resources (see Table 100).

Year	Carbon	CO2	SO2	Black Smoke	NOx	VOC's	CO
	t/y	t/y	t/y	t/y	t/y	t/y	t/y
2005	15	55	13	43	51	64	949
2006	15	55	13	44	52	65	968
2007	15	55	13	44	53	67	987
2008	15	55	14	45	54	68	1,006
2009	15	55	14	46	55	69	1,025
2010	15	55	14	47	56	71	1,044
2011	15	55	14	48	57	72	1,063
2012	15	55	15	49	58	73	1,082
2013	15	55	15	50	60	74	1,101
2014	15	55	15	50	61	76	1,120
2015	15	55	15	51	62	77	1,139
2016	15	55	16	52	63	78	1,158
2017	15	55	16	53	64	80	1,177
2018	15	55	16	54	65	81	1,196
2019	15	55	16	55	66	82	1,215
2020	15	55	17	56	67	83	1,234
2021	15	55	17	56	68	85	1,253
2022	15	55	17	57	69	86	1,272
2023	15	55	18	58	70	87	1,291
2024	15	55	18	59	71	89	1,310
2025	15	55	18	60	72	90	1,329

Table 100: Added Emissions from Electricity Produced by the Practicable Resources in Shropshire 2005 - 2025.

Although the added emissions of carbon are insignificant compared to the emissions avoided, full exploitation of the accessible resources would increase emissions of black smoke, VOC's and CO from 2005, with emissions of NOx increasing after 2013 (See Tables 101 and 102). This is also because of the expected reduced use of coal in the conventional fuel mix and the increase in the use of biomass (91% of total practicable resources in 2005, rising to 93% in 2025).

Year	Carbon	CO2	SO2	Black Smoke	NOx	VOC's	CO
	t/y	t/y	t/y	t/y	t/y	t/y	t/y
2005	248,476	911,079	5,684	153	1,873	87	1,009
2006	245,724	900,988	5,353	154	1,783	88	1,029
2007	242,350	888,618	5,023	155	1,694	90	1,047
2008	239,144	876,861	4,711	156	1,609	91	1,066
2009	236,034	865,458	4,415	157	1,528	92	1,085
2010	233,114	854,752	4,135	157	1,451	93	1,104
2011	230,317	844,495	3,867	158	1,379	95	1,123
2012	228,237	836,870	3,622	159	1,312	96	1,142
2013	225,959	828,516	3,382	160	1,248	97	1,161
2014	223,774	820,505	3,152	161	1,185	99	1,180
2015	221,676	812,812	2,931	162	1,125	100	1,199
2016	219,658	805,411	2,718	163	1,068	101	1,218
2017	217,713	798,283	2,512	163	1,013	102	1,237
2018	215,838	791,407	2,314	164	959	104	1,256
2019	214,027	784,767	2,123	165	908	105	1,275
2020	212,276	778,346	1,938	166	858	106	1,294
2021	210,582	772,132	1,758	167	809	108	1,313
2022	208,940	766,112	1,585	168	763	109	1,332
2023	207,347	760,274	1,416	169	717	110	1,352
2024	204,670	750,458	1,133	170	641	111	1,371
2025	203,160	744,919	973	170	598	113	1,390

Table 101: Estimation of Net Total Emissions from Generation of Electricity in Shropshire 2005 - 2025, with Full Exploitation of the Practicable Resources.

Year	Carbon	CO2	SO2	Black Smoke	NOx	VOC's	CO
	t/y	t/y	t/y	t/y	t/y	t/y	t/y
2005	10,922	40,049	237	-38	29	-63	-946
2006	10,940	40,112	225	-39	25	-64	-965
2007	10,962	40,194	214	-39	21	-66	-984
2008	10,989	40,292	203	-40	17	-67	-1,003
2009	11,019	40,404	192	-41	13	-68	-1,022
2010	11,053	40,528	181	-42	10	-70	-1,041
2011	11,090	40,662	171	-43	6	-71	-1,060
2012	11,129	40,806	161	-43	3	-72	-1,079
2013	11,170	40,957	152	-44	-1	-73	-1,098
2014	11,213	41,115	142	-45	-4	-75	-1,117
2015	11,258	41,280	133	-46	-7	-76	-1,136
2016	11,304	41,450	124	-47	-11	-77	-1,155
2017	11,352	41,624	114	-47	-14	-78	-1,174
2018	11,401	41,803	105	-48	-17	-80	-1,193
2019	11,451	41,985	96	-49	-21	-81	-1,212
2020	11,501	42,171	87	-50	-24	-82	-1,231
2021	11,552	42,359	79	-50	-27	-83	-1,250
2022	11,605	42,550	70	-51	-30	-85	-1,269
2023	11,657	42,743	61	-52	-33	-86	-1,288
2024	11,633	42,656	46	-53	-38	-87	-1,307
2025	11,686	42,847	37	-54	-42	-89	-1,326

Table 102: Total Emissions Saved (+) or Extra Emissions (-) with Full Exploitation of the Practicable Resources.

11. Conclusions

This work was initiated by Shropshire Energy Team to examine the implications of energy consumption in the county of Shropshire. The aim was to develop a methodology to assess energy and electricity consumption and associated emissions on a regional basis from 1990 onwards. This data is not readily available to local authorities but is essential for energy planning, setting targets and monitoring progress towards a more sustainable future.

A first comprehensive set of data was gathered from a wide range of sources, together with a full set of data for Shropshire, to produce a new parametric model. Climate, topography, available resources, history, infrastructure, land development, institutional, technical, economic, environmental, cultural, and social factors affect the characteristics and properties of a region which determine present and future energy use. The model demonstrates that there is a strong correlation between energy consumption and population for regions with populations from around 30,000 to 59 million (the whole of the UK). The model was successful in predicting electricity consumption for a variety of regions across the UK between 1990 and 1997. The two main exceptions were at the extremes of low electricity consumption per person (0.003 GWh/person) and high electricity consumption per person (0.007-0.127 GWh/person). The relationship between population density and energy density allows the estimation of energy consumption in rural and urban areas for population densities in the range 0.26 persons/hectare to 65 persons/hectare.

The methodology has been applied to the county of Shropshire to provide the theoretical foundations necessary to enable strategic planning for the county to meet its share of the UK's obligations in reducing greenhouse gas emissions.

The specific intentions of the work were as listed below:

- To estimate primary fuel consumption and environmental emissions in Shropshire for 1990, the baseline year for target setting.
- To estimate primary fuel consumption and environmental emissions in Shropshire up to 2025.

- To estimate the primary fuel consumed during the generation of electricity consumed in the county, to determine the potential contribution that energy efficiency schemes and renewable energy projects could make in reducing emissions.

For Shropshire the results indicate that:

1. Total primary fuel consumption in 1990 (population 406,390) was 63,518,018 GJ/y and can be expected to increase to 92,182,542 GJ/y in 2025 (population 508,681) with a business as usual scenario.
2. Average annual primary fuel consumption per person in urban areas is 158 GJ/person, which is lower than the 160 GJ/person for rural populations.
3. Total annual emissions of carbon in 1990 were 1,129,626 t/y falling to 1,054,509 t/y in 1997. Emissions can be expected to rise again, exceeding 1990 levels by 2020, reaching 1,303,282 t/y in 2025 with a business as usual scenario.
4. 22,565,713 GJ/y of primary fuel was used to generate the electricity consumed in 1990 and can be expected to rise to 23,478,050 GJ/y in 2025.
5. The total consumption of electricity by final user in 1990 was 1,878 GWh/y rising to 2,123 GWh/y by 1997 and can be expected to rise to 2,302 GWh/y in 2025. The methodology was validated by comparisons with supply data (1990 –1996) as differences were between -2.35% and + 3.95%.
6. Total annual emissions of carbon associated with electricity were 380,896 t/y in 1990 falling to 289,093 t/y in 1997.
7. If current trends in the fuel mix used for generating electricity and energy efficiency continue then total annual emissions of carbon associated with electricity could continue to fall to 214,845 t/y by 2025.
8. If current trends continue carbon emissions from petroleum-based transport will be dominant by 2025, exceeding carbon emissions from generation of electricity and stationary combustion.
9. The average consumption of electricity per year for each person was 0.0047 GWh for 1990 and 1996.

10. Electricity consumption in the domestic sector was 563.42 GWh in 1990 (households with residents 157,726) and can be expected to increase to 920 GWh by 2025 (households with residents 235,174).
11. Residential land development in Oswestry (13 house completions per hectare) caused the smallest increase in domestic sector electricity consumption. Residential land development in Bridgnorth (15 house completions per hectare) and South Shropshire (18 house completions per hectare) caused the largest increase in domestic sector electricity consumption.
12. The average additional annual domestic sector electricity consumption per hectare of residential land developed was 0.0954 GWh/y between 1990 and 1996.
13. House completions of 2,400 per year will require around 225 hectares and result in an additional consumption of electricity in the domestic sector of around 22 GWh/y
14. The average additional annual industrial sector electricity consumption per hectare of land developed was 0.1676 GWh/y between 1990 and 1996.
15. 592 hectares of development land used for industrial purposes will result in an additional consumption of electricity in the industrial sector of between 100 to 154 GWh/y.
16. The average additional annual commercial sector electricity consumption per hectare of land developed was 0.3823 GWh/y between 1990 and 1996.
17. 592 hectares of development land used for commercial purposes will result in an additional consumption of electricity in the commercial sector of between 226 to 236 GWh/y.
18. With current development trends 20,805 GWh/y of primary fuel will be required in 2005 for the consumption by final user of 14,686 GWh/y (71% conversion efficiency). Renewable energy sources will contribute 1.58% to primary fuel consumption in 2005. This equates to a 328 GWh/y contribution to primary fuel consumption (PFC) or 232 GWh/y to consumption by final user (CFU).
19. Total consumption (CFU) will need to be reduced to 12,444 GWh/y by 2010 to achieve a 20% target reduction by 2010.

20. To provide 8% of primary energy from renewable energy sources by 2005 will require 1,415 GWh/y (1,000 GWh/y as CFU). To keep this 8% share constant 1,639 GWh/y will be required in 2025 (1,200 GWh/y as CFU).

21. The theoretical biomass resource of 20,571 odt/y in 2005 would be sufficient for: a 3.27 MWe fluid bed combustion conversion plant employing 6 people at a cost of £2.6 million/MWe; a 5.52 MWe pyrolysis conversion plant employing 11 people at a cost of £2.7 million/MWe (£2 million/MWe at 10th plant built); or a 4.94 MWe atmospheric gasification conversion plant employing 9 people at a cost of £3.5 million/MWe (£2.3 million/MWe at 10th plant built)

22. The theoretical biomass resource of 54,053 odt/y in 2025 would be sufficient for: a 9.47 MWe fluid bed combustion conversion plant employing 20 people at a cost of £2.2 million/MWe; a 15.58 MWe pyrolysis conversion plant employing 51 people at a cost of £2.2 million/MWe (£1.7 million/MWe at 10th plant built); or a 13.83 MWe atmospheric gasification conversion plant employing 42 people at a cost of £2.9 million/MWe (£1,8 million/MWe at 10th plant built).

23. Full exploitation of accessible resources would help achieve the target 8% (to CFU) by 2005 and help contribute just over 10% by 2025.

24. Full exploitation of practicable resources would only help to contribute 2.6% to target CFU by 2005 and 4.5% by 2025.

25. A 20% target to reduce primary fuel consumption, from what it would be without the target by 2010, would see total carbon emissions continuing to fall until 2001, when they would start to rise again. The 1990 level would not be exceeded in 2025 when 1,042,626 t/y can be expected.

26. Keeping the reduction in PFC at a steady 20% of what would otherwise be expected for the years following 2010 will mean a return to increases in emissions.

27. An 8% target to increase the contribution from renewable energy to primary fuel consumption by 2005 would require 1,000 GWh/y as energy consumed by final user (or replacing 479 GWh of grid electricity). To keep this 8% share constant in 2025, will require 1,200 GWh/y as energy consumed by final user (or replacing 578 GWh of grid electricity). The 8%

target by 2005 could be met by exploitation of Shropshire's accessible resources, but not only the practicable resources.

28. Assuming that the renewable energy would contribute no carbon, then if both targets were reached, emissions would continue to fall until 2010, when they would start to rise again. The 1990 level would not be exceeded in 2025 when 988,638 t/y can be expected.

29. New support systems will be required to promote investment in small-scale renewable energy projects and energy efficiency schemes to realise the environmental benefits. This support and a change in public opinion will be required to develop more than the practicable resources in order to guarantee that targets are reached on time. Even so, increases in petroleum-based transport emissions may negate any efforts in further reducing emissions associated with electricity.

12. Further Work

The models would be more accurate if supply companies had to make data more easily available to local authorities, or the DTI published these statistics on a regional basis.

The following are suggestions for refining the existing models to improve confidence in the results:

- Update the models yearly with the publication of UK statistics and as data on energy consumption in other areas become available.
- Ideally, gather supply data for Shropshire on an annual basis.
- Obtain accurate statistics on urban and rural land use when the DTI database becomes available. This will give a better estimate of primary fuel consumption per person and electricity consumption for rural and urban populations.
- Estimate gross and net emissions saved in Shropshire if electricity from the accessible and practicable resources was used to replace fossil fuel generated electricity only.
- Obtain more up to date emission factors for the total fuel cycle in electricity generation for all the renewable energy technologies relevant to Shropshire.

The following are suggestions for additional areas of work:

- Obtain gas data for Shropshire and other areas to determine whether there are any relationships between consumption and population or population density.
- Include economic models to determine the direct and indirect expenditure during the construction, operation and maintenance of renewable energy technologies using input - output analysis. This would identify those technologies that would benefit local industry the most.
- Take into account any waste heat from renewable energy schemes in assessing the contribution to total primary fuel consumption. Combined heat and power may be only rational use of biomass in power production. Heat could be used for drying feedstocks or exported to increase revenue and improve viability.
- Include models to determine end use of energy in the domestic sector.

- Compare the specific costs of renewable energy technologies per tonne of carbon saved, with the specific costs of various energy efficiency measures to determine best use of capital.
- Investigate whether methodology could be applied to areas outside stated range and if these relationships exist in other countries needing to do energy planning.

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