# INTRODUCTION TO SOME ASPECTS OF ENERGY CONSERVATION AND ENERGY DEMAND

R.J. Eden

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Summary

This introductory discussion indicates types of information about energy demand that may be useful for a better understanding of a national energy system. Some methods for obtaining this information are listed and are illustrated by case studies relating to the use of energy in the UK.

## 1. Background to the problems to be examined

Models for forecasting energy demand tend to be based primarily on past trends with various levels of sophistication for handling subsectors of an economy. However, there has in the past been relatively little input to these models concerning the influence of technological change on past energy consumption and the effects of possible but uncertain future technological changes. Discussions of the potential for energy conservation have tended to concentrate either on dirigiste technological solutions, or on economic models that take account of market forces through elasticities based on past data but do not specify the technological adaptation that could achieve the indicated results. In the case of technological solutions with greater efficiency of energy use, the estimates for energy savings compared with trend curves take relatively little account of the substantial improvements in efficiency that have occurred in the past and which are already implicit in the trend curves.

Technological change is stimulated by the need for energy conservation only in special circumstances such as in the generation of electrical power. In many situations there are other primary causes for technological change involving economy in resources other than energy, and these may lead to an increase or to a decrease in the use of energy for a given product and output. An analysis of these changes and their effect on energy demand is essential for a better understanding of the future demand for energy.

Energy conservation involves at least three interrelated sets of problems:

1) The optimal choice of primary energy sources and rates of depletion to conserve those resources whose early depletion or scarcity would have adverse social or economic effects.
2) Improvements in the efficiencies with which energy is used, by means of technological change and the avoidance of waste.
3) Changes towards alternative products or alternative patterns of demand that reduce the growth in energy demand.

This report is concerned mainly with the second of these aspects of energy conservation, as well as with problems relating to the analysis of energy demand and technological change. However, a discussion of improved efficiencies in the use of energy can rarely be considered in isolation from problems of energy supply or demand for products. In many circumstances energy conservation can be achieved only by capital investment and the resulting benefit has to be considered in relation to alternative uses for the capital, which, for example, might be used to increase energy supply or to increase the output of industrial products.

Although the problems of economic optimization in relation to energy demand are an essential feature in the formulation of energy policies, there are also a range of technical problems concerning the use of energy that require solution before economic optimization can be realistically examined. This report is concerned with topics involving this range of technical problems with particular emphasis on the use of energy by the industrial sector. They include the following topics:

1) An assessment of objectives concerning information about the use of energy, that play a key role in the changing pattern of industrial energy demand.
2) Methods by which these objectives can be attained including both economic and technological studies.
3) Case studies in which the methods are applied to obtain information about important aspects of the use of energy.
4) Methods for studying the rate of change of energy demand following the introduction of new technologies.

These four topics will be discussed in the next **four** sections of this report.

## 2. Objectives concerning information on the use of energy

This section is concerned with describing the types of information on energy demand which are available and other types which would be relevant to a more detailed understanding of the use of energy but which are not yet available in a suitable form.

### 2.1 Energy demand by major sectors and energy overheads

National energy statistics give data on energy used by major sectors of the economy. In the UK this is presented on a heat supplied basis rather than a primary fuel basis, thus it does not represent the full impact of each sector on energy demand in terms of primary fuels. In order to obtain the latter, it is necessary to consider the "overheads" or conversion losses that are incurred by the energy industries and distribute these overheads pro rata amongst the major sectors. This analysis will be outlined here but it should be noted that it does not include other indirect costs of energy such as the energy required to manufacture or construct a power station or a refinery. The latter type of indirect energy costs will be considered later.

The energy supplied and the overheads of the UK energy industries in 1972 are shown in Table 1. The overheads for petroleum arise primarily in the refineries but allowance is made also for energy conversion losses for purchased electricity that is used in the refineries. The major part of the energy overheads for coal comes indirectly from the losses associated with electricity used in the collieries. The natural gas overheads are estimated since they are not shown in the published statistics. Manufactured fuels include town gas, coke and breeze and coal briquettes, but for simplicity their energy overheads have been averaged.

The electricity supply figures in Table 1 include overheads incurred by the primary fuels supplied, but the largest item comes from conversion losses in electricity generation, which had an average efficiency of 29.1 per cent for fossil fuel stations and 25.7 per cent for nuclear powered stations.

The net and gross energy demand for major sectors of the economy can be obtained from the statistics showing net energy supplied from different fuels or energy sources and by the use of Table 1. The energy supplied to industry is shown in detail in Table 2 for illustration of the method, and the results for all sectors are shown in Table 3. The energy overheads associated with the household sector are high because of the relatively large proportion of energy that is supplied in the form of electricity.

## 2.2 Useful energy

We have seen that fuel substitution from coal to petroleum or from petroleum to electricity leads to an increase in the energy overheads associated with a given net energy supplied. There is, however, a compensating effect that helps to reduce the resulting gross energy demand. In many situations equipment using electricity operates at a higher efficiency in terms of net energy used than equipment based on petroleum, for example an electric motor may operate at 90 per cent efficiency whereas a diesel might attain 35 per cent. Similarly an oil fueled engine may be more efficient than a coal fueled engine.

Thus, by analyzing the types of equipment run on various fuels and measuring their efficiency of energy conversion, one may be able to reach an "effective efficiency" for the use of a given fuel in a factory, or more approximately in an industry or in a major sector of the economy. When the effective efficiency is multiplied by the thermal energy input one obtains the "useful energy" that is available. The effective efficiencies will, of course, change with time as technological improvements are introduced. Typical values for effective efficiencies at the present time are indicated in Table 4, but it should be emphasized that they will vary both within industries or other sectors, and between countries and will change with time. It would however be valuable to have a more detailed study of these efficiencies. It would be useful also to have detailed studies of system efficiencies where the different flexibilities are taken into account as well as the conversion efficiencies of equipment, it is often claimed that this would give a higher figure for electricity than is indicated in Table 4 (b) and it would be useful to have an analysis of circumstances in which this claim is valid.

## 2.3 Energy use by industrial groups

The energy used by industrial groups in the UK is shown in Table 5. The energy overheads for the primary fuel industries have been neglected but electricity overheads are calculated on the basis of 28 per cent efficiency. The reduction in the energy used for iron and steel between 1960 and 1972 is due to improved efficiency in the use of energy by the industry. The marked rise in the use of energy by the chemicals industry is due mainly to the rapid growth of the petrochemicals industry, though the captive energy associated with the energy content of petrochemical feedstock is not included in the figures in Table 5.

## 2.4 Energy required for certain industrial products

Efficiency in the use of energy is a difficult concept to define in relation to manufacturing industry. In general, a reduction in the amount of energy used for a given product can be achieved only at the cost of capital investment or changes in the labor required. Improvements in the sense of less energy for a given product are usually associated with re-equipment of a production unit. In order to help understand these changes it is useful to analyze the energy required in different industrial processes and hence to obtain the energy required for some of the main products. Methods for this analysis will be outlined in the next section, some results of such studies are given in Table 6.

Having obtained the energy content (or energy cost) of the appropriate materials used in a product one can then proceed to analyze the energy required to produce complex products. For example the energy required for the production of an automobile in the USA has been analyzed by Berry. His result is that approximately 3 tons of oil equivalent are required for a 2 ton vehicle.

## 2.5 Summary of objectives in energy analysis

It is evident from the foregoing discussion that multiple objectives are involved in energy analysis. These arise essentially because any energy-using system is not isolated or self-contained and because the energy used is not the only parameter describing the system, neither is it the most significant part of financial costs in most situations. Thus any list of objectives must also emphasize that the energy analysis may be (and often will be) only a contributing element towards a larger analysis of economic or social benefits. Having noted these qualifications the following four types of objective indicate the general direction in which a study of energy demand could proceed:

(1) The analysis of particular production processes in detail so as to deduce an energy efficiency, from

which a better understanding can be obtained of the effects on energy consumption of technological change. Such an analysis can also provide an input to a wider technico-economic study to assess the potential for energy conservation, taking account of other costs besides those for energy.

(2) The analysis of energy consumption in an aggregated form either to forecast energy demand or to indicate policies for reducing future demand. It is important in this context to note the difficulty of introducing technological change and social adaptation into trends shown by aggregated data, unless more detailed process analysis has also been carried out in some of the main energy-using sectors.

(3) Alternative forms of aggregated data that are of value include energy consumption associated with particular technologies or with particular types of demand. The former can provide a useful input to the assessment of policies on research and development towards the more efficient use of energy, and for indicating the effects of technological change on future energy demand. The latter, for example the energy associated with the production of food, could indicate the potential consequences of a future shortage of energy.

(4) The assessment of energy costs and energy flows is

required as part of the input to a national economic model, or an industrial system model in which energy forms one of the key variables, or a world model in which a long-term picture might be considered in terms of physical variables such as energy and materials.

## 3. Methods for analyzing the use of energy in manufacturing industry

### 3.1 Statistical analysis

Energy statistics are available for most industrial nations giving the supply of energy to various sectors of the economy. Some aspects of this type of data have been discussed and illustrated in section 2. It was noted there that neither net energy supplied, nor gross energy including energy overheads, is entirely satisfactory as a measure for the use of energy. For example, the former does not make allowance for the flexibility or efficiency with which different forms of energy may be used. The latter does not give the full impact of energy demand on resources since it does not include indirect energy costs such as those for supplying materials or constructing power stations, refineries or factories. In order to assess efficiencies of different energy-forms, or to obtain indirect energy costs another form of analysis is required.

Under certain conditions, such as the homogeneity of a product and the dominant energy costs being internal to an industry, a first approximation can be made from statistical data for the energy requirements to make the product. An example is given by the cement industry in the UK which used on average 7.4 GJ/tonne of cement in 1972.

### 3.2 Input-output analysis

The use of input-output tables is a standard technique in economics. These tables describe in financial terms the goods and services that individual industries buy from and sell to each other. They may be expressed in terms of input-output coefficients $a_{ij}$ which form a square matrix A, the input-output matrix. These coefficients may be used to form a system of linear equations in which the output $X_i$ of a given sector i is expressed as the sum of the sector's sales to all other sectors (including itself) and its sales to final demand $Y_i$,

$$X_i - \sum_j a_{ij}X_j = Y_i \tag{3.2.1}$$

Thus $a_{ij}$ is the input coefficient that gives the requirements of the product of sector i per unit of the output of sector j. The system has as many equations as there are industries.

Input-output tables and coefficients are constructed from national census data. The coefficients therefore relate to the last census, which was in 1968 for both the UK and the USA. One of the key problems is to find a way for updating these coefficients without taking a full census, and amongst the methods that should be considered are detailed studies of technological change and its effect on physical input and output variables. Detailed energy studies could make a contribution in this area if only as a prototype for wider studies.

Input-output analysis can be used in a variety of ways for energy studies including, for example, the estimation of energy intensiveness in a given industry. This is the fraction of the costs of the industry that are spent on energy, or (more precisely) the amount spent on energy per 1000 financial units of output. These energy costs may be calculated either on a direct basis from purchases from the energy industries or they can be calculated so as to include also the indirect energy costs due to the energy costs of other industries whose products are purchased by the given industry that is being analyzed.

The disadvantages of the use of input-output analysis for estimating the energies required to make given products are:

(a) The tables are obtained for groups of industries in a given country, typically 90 in number. The resulting level of aggregation makes it difficult to estimate the energy costs for particular industrial products except where the output of an industry is unusually homogeneous.

(b) The tables provide financial costs of the energy required and these cannot readily be converted into the physical amounts of energy used, partly because of energy price fluctuations and partly because some industries obtain energy at special prices that are highly confidential.

(c) Input-output tables can be supplemented by an analysis in greater detail of the census information. This has the disadvantage that it is not very recent and may not be closely related to future energy requirements. It also involves a considerable amount of detailed work but this is certainly worthwhile for a range of the more significant products in relation to energy consumption.

### 3.3 Process analysis

Process analysis of energy costs for a given product involves a series of approximations which successively enlarge the system that is associated with the manufacture of the product. The general guidelines for this procedure are based on the idea of a separable energy cost, namely, the extra energy which is required for manufacturing the particular product compared with a world in which it was not manufactured. Thus, having chosen a product for study, such as steel plate in factory A in country X, one has to identify the network of production processes that are involved directly, and then indirectly, in its manufacture. The direct chain includes the mining of iron ore and its preparation, processing through a steel mill and rolling to give steel plate. The average direct energy used at each stage to give a tonne of finished product can then be estimated from the fuel used with due allowance of credits where the resulting energy from the fuel is used also for other purposes. The indirect chains include the energy overheads discussed in section 2, but they include also the energy required for providing other materials used in steelmaking, such as oxygen or limestone, and the energy required for making the factory machinery and other equipment. Where equipment is used only partially for a given product the energy required is allocated pro rata, and of course the energy for the equipment is divided by the total quantity of material that it handles before replacement. Further indirect costs may be included until the procedure converges. Clearly the method involves initial estimates of indirect energy costs, for example, of the steel for machines. These may be obtained from the direct energy costs of steel obtained either by process analysis or from input-output analysis.

Process analysis is not free from ambiguities, thus it is essential at each stage and in each case study to note special assumptions or conventions that are adopted. For example, where there is more than one product from a given raw material input like petrochemical feedstock, there are a variety of ways to allocate the energy content of the feedstock amongst the final products. These problems are a feature of econometric process analysis and their resolution may depend on the use that is to be made of the analysis.

### 3.4 Energy models and economic models

This topic is included for completeness but it will be discussed only briefly. Energy demand can be estimated from models based on statistical trends using data of the type indicated in section 2 and in subsection 3.1. It can also be estimated from economic models since energy demand is usually contained in these as one or more parameters. However, it should be noted that economic models are not usually designed with energy forecasting in mind, and, for example, it is unlikely that the coefficients for price elasticity are sufficiently well-known to give a realistic estimate of the response to sudden large changes in the price of energy. On the other hand they may give a better indication of the response to market forces than idealized scenarios based on what may be technologically feasible.

## 4. Case studies

In this section case studies of energy required in the production of iron and steel and for aluminium are outlined and some of the difficulties encountered in assessing the specific energy used are noted.

### 4.1 Iron and steel

Statistical data on the energy used for steel production in the UK show that there has been a significant reduction in the specific energy per tonne of crude steel output. Some illustrative figures are shown in Table 7, where it is seen that the specific energy calculated on a net energy supplied basis has fallen from 31.1 GJ/tonne of crude steel in 1960 to 24.6 GJ/tonne in 1972.

In order to establish the reasons for this substantial improvement in the use of energy for steelmaking it is necessary to analyze the steelmaking process to identify the main stages at which energy is consumed and to consider the developments that took place between 1960 and 1972. One can then begin to consider which of these changes are now completed and which are still under way, so that further improvements in energy use may be expected from them. For the longer term future it is also necessary to consider further changes in technology for steelmaking that may, for example, be caused by a change in the availability of different primary fuels.

Approximate average percentages for the energy used in the main stages of steelmaking are given in Table 8. The word average must be emphasized because, for example, the amount of energy used at each stage depends on the proportion of scrap iron to pig iron. For electric steelmaking there may be 100 per cent scrap iron and all the energy is used for steelmaking, rolling, finishing, and miscellaneous processes. For basic oxygen steelmaking there may be as much as 30 per cent scrap iron, but since the carbon in pig iron is essential to the process the percentage of pig iron cannot fall much below 70 per cent. In that case the production of 1 tonne of crude steel would require about 0.8 tonne of pig iron and 0.33 tonne of scrap iron.

Thus for a forecast of future energy requirements for iron and steelmaking it is necessary to estimate future demand and not only the proportions of different technologies in the industry but also the amount of scrap that may be available. The latter in turn depends on the nature of steel products and the rate of obsolescence as well as on the rate at which the world steel demand is going. The nature of the steel products is also of great importance since there are wide variations in the amount of energy required to make different types of steel and steel product, ranging from just over 20 GJ/tonne for bulk steel to over 40 GJ/tonne for stainless steel. In addition the amount of steel scrap produced by the industry, which averages 0.36 tonne for each tonne of finished product, can be as high as 1 tonne/tonne for steel castings.

In conclusion we note the main changes that contributed to the reduction in specific net energy noted in Table 7. These are:

(1) The use of a higher proportion of imported ore which has about twice the iron content of home produced iron ore.

(2) Improvements in blast-furnace operation.

(3) Introduction of the basic oxygen process for steelmaking whose only use of energy is for making the oxygen that is required.

(4) Further development of integrated steelworks and heat recovery systems.

## 4.2 Aluminium

Aluminium is obtained primarily from bauxite ore although it can also be obtained from clay. The production process involves the reduction of bauxite to alumina (aluminium oxide) in a Bayer plant in which 2 tonnes of ore yields about 1 tonne of alumina.

In the next stage the alumina is dissolved in a bath of molten cryolite which is carbon lined and into which a carbon anode projects. Molten aluminium is heavier than the cryolite solution and forms a cathode at the bottom of the bath. Under electrolysis aluminium is deposited on the cathode and oxygen on the anode. The process uses about 2 tonnes of alumina and net electrical energy within the range 48 GJ to 65 GJ per tonne of aluminium produced. The reduction process also uses 500 kg of carbon in the anode for each tonne of aluminium. In addition 10 to 15 GJ of thermal energy is used at this stage.

One of the difficulties in converting the above figures to an average value for specific energy required to produce a tonne of aluminium is caused by the wide variation in estimates of electricity overheads. A significant amount of electricity for aluminium production is obtained from hydroelectric power, and where this is not integrated into a national or regional electric grid but is used mainly for the aluminium plant it would seem reasonable to use a conversion efficiency of (say) 90 per cent. Other aluminium plants may produce their own electric power at (say) 35 per cent efficiency, but others may take power from a national grid which has an average conversion efficiency of 29 per cent. Alternatively including indirect energy costs for energy production the national grid efficiency might be as low as 25 per cent.

The figures for energy costs in aluminium production given in Table 9 are based on 28 per cent conversion efficiency for electricity, and lead to a specific energy of 306 GJ per tonne of aluminium.

This result is not a final figure in relation to aluminium products since (1) the shaping and extrusion plants use extra energy ranging from 35 GJ to 60 GJ per tonne of product, and (2) a proportion of scrap is produced in the shaping process which has then to be recycled.

Recycled aluminium requires only about 5 per cent of the energy for producing aluminium from bauxite ore. Thus the forecasting problem concerning energy for aluminium requires an estimate of the likely proportion of recycled aluminium in relation to total production.

Figures for specific energy in aluminium production have also been obtained by statistical analysis and by the use of input-output tables. Provided due allowance is made for different assumptions about the conversion efficiency for electricity generation, and for imports or exports of aluminium, and for the nature of the finished product (aluminium ingots, rolled aluminium, tube, etc.) the figures are in reasonable agreement with each other and with the figure of 306 quoted in Table 9.

# 5. A method for studying the rate of change of energy demand as a new technology is introduced

## 5.1 The model of Lees and Lo

This model can be illustrated by taking the simplest case for an automobile population in which it is assumed that there are only two types of vehicle. The standard type 1 consumes $g_1(t)$ units of energy per kilometre, and a new efficient type consumes $g_2(t) < g_1$ units.

It is assumed that in year 0 all vehicles are of type 1. Then type 2 is introduced at a proportional rate that increases linearly in successive years until year j. After year j it is assumed that the proportion of cars of type 2 produced each year remains constant. It is further assumed that no cars of type 2 are scrapped before year j, but then they are scrapped at the same rate as for type 1 cars.

The following equations result:

Phase (i), $0 \leq t \leq j$ , $n = n_1 + n_2$ ,

$$\frac{dn}{dt} = (b - d)n \quad ,$$

$$\frac{dn_2}{dt} = (bqt)n - 0$$

Phase (ii), $j \leq t$ ,

$$\frac{dn_2}{dt} = (bqj)n - dn_2 \quad ,$$

$$\frac{dn}{dt} = (b - d)n \quad .$$

These equations can readily be integrated and explicit assumptions made about the values of the constants so as to obtain the energy saved by the introduction of type 2 vehicles. Additional information has to be inserted about the average annual distance driven per vehicle. More complicated types of population mix can readily be included, and the model can be extended to other types of energy consuming system.

## 5.2 Further References

The general problem of productive efficiency and related models has been discussed by T.C. Koopmans (1957) in his book "3 Essays on the State of Economic Science." More recent references on the problem of exhaustible resources are given by G. Heal (see list of references).

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Table 1. Energy supplied and overheads for UK energy industries (1972)

Source: UK energy statistics

Units: $10^9$ GJ

| Energy industry | Gross energy input | Net energy output | Energy Overheads | Ratio overheads to net energy |
|---|---|---|---|---|
| Petroleum | 4.27 | 3.91 | 0.36 | 0.092 |
| Coal | 3.27 | 3.20 | 0.07 | 0.022 |
| Natural gas | 1.07 | 1.01 | 0.06 | 0.059 |
| Manufactured fuels | 1.27 | 0.91 | 0.36 | 0.40 |
| Electricity | 2.87 | 0.77 | 2.10 | 2.73 |

Note: the gross energy input includes overheads associated with fuels or electricity used by each industry.

Table 2. Energy consumption and overheads for UK industry (1972)

Source: UK energy statistics and Table 1

Units: $10^9$ GJ

| Energy source | Net energy supplied | Overheads | Gross energy supplied |
|---|---|---|---|
| Petroleum | 1.20 | 0.11 | 1.31 |
| Coal | 0.32 | 0.01 | 0.33 |
| Natural gas | 0.34 | 0.02 | 0.36 |
| Manufactured fuels | 0.45 | 0.18 | 0.63 |
| Electricity | 0.26 | 0.72 | 0.98 |
| Totals | 2.57 | 1.03 | 3.61 |

Table 3. Net energy used and gross energy required for major sectors in the UK 1972

Source: UK energy statistics and Table 1

Units: $10^9$ GJ and percentages

| Sector | Net energy used | | Energy overheads | Gross energy required | |
|---|---|---|---|---|---|
| | $10^9$ GJ | Per cent of total primary energy | $10^9$ GJ | $10^9$ GJ | Percent of total |
| Industry | 2.57 | 29 | 1.03 | 3.60 | 41 |
| Household | 1.54 | 17 | 1.01 | 2.55 | 29 |
| Transport | 1.28 | 15 | 0.13 | 1.41 | 16 |
| Other users | 0.77 | 9 | 0.50 | 1.27 | 14 |
| Energy industries | 2.67 | 30 | (included under net energy used) | (included above) | (included above) |
| Total primary energy | 8.83 | 100 | | 8.83 | 100 |

Table 4. Typical values for average efficiencies of fuel and energy utilization

Units: Percentages (a) efficiencies of use of net energy
(b) efficiencies of use of gross energy (including overheads)

| | Household | Industry | Transport |
|---|---|---|---|
| (a) Coal | 30-45 | 55-85 | 10 |
| (a) Gas | 65-80 | 65-85 | - |
| (a) Petroleum | 65-80 | 65-85 | 20 |
| (a) Electricity | 90 | 90 | 90 |
| (b) Coal | 29-44 | 54-83 | 10 |
| (b) Gas | 61-75 | 61-80 | - |
| (b) Petroleum | 60-73 | 60-78 | 18 |
| (b) Electricity | 24 | 24 | 24 |

Note: The above estimated efficiencies refer to equipment efficiencies and may differ considerably from system efficiencies (if the latter can be defined.)

Table 5. Energy used by main industrial groups in the UK

Source: UK energy statistics

Units: $10^6$ GJ

| | 1960 | 1972 | average annual percentage growth |
|---|---|---|---|
| Iron and steel | 806 | 756 | -0.5 |
| Engineering and other metals | 437 | 584 | 2.4 |
| Food, drink and tobacco | 192 | 265 | 2.2 |
| Chemicals | 354 | 510 | 3.1 |
| Textiles etc. | 207 | 190 | -0.7 |
| Paper and printing | 144 | 181 | 1.0 |
| Bricks etc. | 111 | 84 | -2.3 |
| China, glass | 80 | 92 | 1.2 |
| Cement | 106 | 133 | 1.9 |
| Other trades | 225 | 444 | 5.8 |
| Total | 2662 | 3239 | 1.6 |

Note: Electricity overheads are included on the basis of 28 per cent efficiency of conversion.

Table 6. Energy requirements for the production of certain materials

Units: MJ/kg material and kg oil/kg material

| Material | MJ/kg | kg oil/kg |
|---|---|---|
| Magnesium (a) | 315 | 7 |
| Aluminium (a) | 220-320 | 5-7 |
| Steel (bulk) | 25-35 | 0.5-0.8 |
| Copper | 70 | 1.5 |
| Zinc | 40 | 1.0 |
| Glass | 22-45 | 0.5-1.0 |
| Paper | 9-18 | 0.2-0.4 |
| Plastics (b) | | |
| polythene | 90 | 2.0 |
| polyester fibre | 220 | 4.9 |

Note: (a) This depends strongly on the conversion efficiency for electricity generation

(b) This includes 45 MJ or 1 kg of oil equivalent for the energy in the petrochemical feedstock.

Table 7. Trends in energy for steelmaking in the UK

Source: Iron and Steel statistics for the UK

| | 1960 | 1972 |
|---|---|---|
| Net energy supplied (million GJ) | 768 | 623 |
| Crude steel production (million tonnes) | 24.7 | 25.3 |
| Specific net energy (GJ/tonne crude steel) | 31.1 | 24.6 |

Table 8. Approximate average percentages of the energy used in the main stages of steelmaking

Sources: See references on steelmaking

| Stage | Percentage |
|---|---|
| Coke oven plant | 10 |
| Ore and sinter preparation | 7 |
| Blast furnace plant | 40 |
| Steelmaking | 10 |
| Rolling and finishing | 20 |
| Miscellaneous | 13 |

Table 9. Energy used for producing aluminium

Source: Industrial enquiries

Units: GJ/tonne aluminium

| Process | Electricity | | Thermal energy | Total |
|---|---|---|---|---|
| | Input energy | Conversion overheads | | |
| Bayer plant | 2 | 5 | 36 | 43 |
| Anode preparation | - | - | 2 | 2 |
| Carbon anodes energy content | - | - | 18 | 18 |
| Reduction plant | 64 | 165 | 14 | 243 |
| Total | 66 | 170 | 70 | 306 |

Note: A conversion efficiency of 28 per cent has been assumed for calculating electricity overheads.