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# COMBINED HEAT AND POWER GENERATION SCHEMES: A FEASIBILITY STUDY.

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## 1. INTRODUCTION.

The immediate and wide-ranging impact of the 1973-74 energy crisis demonstrated the vulnerability of the British economy to changes in the supply of energy resources. In particular, it prompted an assessment of the present situation as regards energy use and the association of energy policies with broader social and economic policies. An outcome of this evaluation and policy making exercise is that it revealed that an almost total lack of detailed knowledge exists about this subject. It can be suggested that, in general, insufficient time has been given to a discussion of the resource limitations of the social and economic system. In this paper, there is an analysis of one potential energy conservation scheme, the provision of combined heat and electrical power generation (C.H.P.) plants in urban areas. Throughout the analysis, illustrated by a case study in Leeds, concern with the possible social and economic impact of such a scheme is emphasised. It is hoped that in doing so, not only are relevant questions raised, but the need for an analysis beyond a conventional financial accounting approach is highlighted.

The context of C.H.P. schemes is provided by the obvious need to reduce the amounts of energy used in Britain and to improve the efficiency with which such energy is consumed. The complementary nature of such desires is succinctly expressed in recent Government statements on the matter:

> "The more efficiently energy is used, the less are the resources that need to be put into producing it. The objective must therefore be to create a situation which minimises the resources required for energy use and for energy production taken together" (Department of Energy, 1978, p.4).

A major use of energy in the United Kingdom is the provision of space and water heating in domestic, commercial and public service buildings. Approximately one third of all energy consumed in the country is taken for this purpose. It follows that an increase in the efficiency of the production of space and water heating for such buildings would lead to a significant reduction in overall energy consumption. Evidence, from Europe in particular, demonstrates that the implementation of C.H.P. schemes, and associated district heating schemes, can provide a more efficient means of space and water heating than the current methods used in Britain. In 1974 a Combined Heat and Power Group was established, under the auspices of the Department of Energy,

> "... to consider the economic role of combined heat and power in the United Kingdom and to identify technological, institutional, planning, legal and other obstacles to the fulfillment of that role and to make recomendation" (Department of Energy, 1977, p.3).

The published work of the Group has concentrated, to a great extent, upon technological and economic analyses of C.H.P. schemes. In this paper the examination is extended to discuss some areas with which the Group did not concern themselves at length; for instance, an assessment of the feasibility of establishing C.H.P. schemes in particular cities. Before proceeding to describe the methods and results of the case study in Leeds (presented in Sections 3 and 4), a general discussion of these and other factors in the following section offers a suitable background.

## 2. SOME ISSUES RELATED TO THE PROVISION OF C.H.P. SCHEMES.

At the outset, it is necessary to describe, in non-technical language, the basic rationale behind C.H.P. schemes. This serves to provide a knowledge of the scale at which such schemes may work and also of the amount of savings which they may lead to as a result of increased efficiency. District heating schemes provide heat alone for a collection of buildings, or possibly one large building, from a central boiler. This boiler is fired by a primary energy source, coal, gas or oil for example, removing the need for a separate boiler for hot water and separate heating units in each building. However, any power utiliised, such as for electrical appliances, must be provided wholly from the National Grid. In C.H.P. schemes, as the name implies, the common source provides both electrical power and heat for space and water heating, and, therefore, would complement the National Grid. Rather than use a common boiler, as in a district heating scheme, C.H.P. schemes consist of a unit which produces electrical power and which is designed to provide hot water at a temperature suitable for heating purposes. Such units are in existence in industry for powering and heating factory units.

It is possible, but not common practice, to introduce similar units in areas where sufficient joint demand for heat and power exists. C.H.P. schemes involve a more complicated and hence more expensive mechanical unit than district heating schemes and they are more sensitive to the demand mix for heat and power. Hence their location and efficient use is of greater import than that for district heating schemes where only the scale of heat demand is an important factor in their spatial location. The problems associated with the location of C.H.P. schemes may therefore be said to be greater although this is not to undermine the importance of correct location of district heating schemes.

Given the technical complexity of C.H.P. schemes, although all the technological problems associated with their use seem to have been solved, why should they be introduced? The basic argument supporting C.H.P. schemes is the efficiency with which they use the primary energy used to fire them. About a third of the primary energy used in Britain is attributable to the power stations supplying the National Grid with electricity. Only 31% of this energy is distributed through the Grid to consumers, the remaining 69% being written off as waste. Whilst no process can be acheived with no loss due to friction, inefficiency or natural waste, the level of efficiency in this industry gives concern as,

> "... the structure of the (electricity supply) industry ... may now be conditioned to accept a wastage rate of close on 70% of irreplaceable energy resources as an immutable fact of life" (Goldsmith, 1978, p.155).

The majority of the wasted energy is lost not for technological reasons but because no need exists for it in the form it takes, lukewarm water at about 30°C. This is discharged into rivers, sea, and by cooling towers into the atmosphere. By modifying the electricity production unit it is possible to produce the waste energy in the form of hot water at about 85°C - 100°C which is suitable for space and water heating. The efficiency of the unit to produce electricity is reduced to just below 30% but the overall thermal efficiency increases to 75% when the total amount of useable energy is calculated. On purely energy efficiency grounds, therefore, a cogent argument can be made for the introduction of C.H.P. schemes. It should be noted that the above efficiency figures are not relevant to nuclear power stations, but it should be remembered that the overall energy efficiency of such units could also be improved if the local communities used the heat dissipated by them.

An additional advantage offered by C.H.P. schemes is that they can be fuelled by various fuels, such as coal, and hence remove some of the present dependence upon oil. As today's anxiety over future energy supplies is centred on oil, ways of overcoming the present dependency are especially attractive. Coal, on the other hand, is relatively plentiful and its supply is not subject to the vagaries of international politics and finance. By using coal for heating purposes, oil would be used only where substitutes cannot be found in the short-term, notably the internal combustion engine. One argument against coal and one which contributed partly to its demise for domestic heating is the environmental and health effects it has. By removing the maintenance and operating responsibility from the individual household the risk to individuals of contracting health problems due to coal will be incomparable with the situation when each house had its own fireplaces and also the general environmental effects will be reduced.

The level of thermal comfort provided with C.H.P. schemes, and district heating schemes, is comparable with that provided by central heating schemes currently in use in both domestic and office accomodation. The only difference being that the boiler providing the water for the radiators is located away from the building which is being heated. It is therefore relatively straightforward to connect buildings with central heating to a C.H.P. scheme and the costs of adapting other buildings to C.H.P. is likely to be, at most, no more expensive than having their own central heating installed. Related to this is the technical problem of laying and routing of the insulated pipes which will carry the water from the production point to the demand point. This is characteristic, although not the most important, of the problems faced in introducing a C.H.P. scheme. The problems are not technological in nature but are caused by organisational and legal difficulties. No single problem is a particular obstacle and, in isolation, it could be circumvented, but when taken as a group the overall problem is of significant size and it is this rather than any technological problem which faces any potential C.H.P. scheme.

Bearing in mind that the E.E.C. has strongly recommended its member countries to consider the setting up of C.H.P. schemes, it is interesting to note the experience of other countries before examining the British context further. It is the abundance of successfully implemented schemes which lead the C.H.P. Group to believe that no technological difficulties remained (Energy Paper 20, 1977), and it is the social, legal, political and organisational problems peculiar to this country which remain to be addressed.

An often-cited example of a C.H.P. scheme in Europe is the large, local authority-owned scheme in Vasteras, Sweden. This supplies the heat and electricity for 95% of the town's 100,000 population. The simple description of this scheme, "large, local authority-owned", immediately highlights two of the problems faced in Britain: ownership and scale of generation. The fact that no monopoly exists in the Swedish electricity supply industry allows each local area to implement the scheme most suited to its particular needs. In contrast, in Britain, since the late 1940s monopolistic, nationalised industries have been responsible for the production and supply of all energy types (with the exception of petroleum), each pursuing autonomous development policies. This alone has greatly undermined the possibility and feasibility of a national integrated energy policy. However, given this general backcloth, legislation regarding heat and electricity supply does assist in the establishment of these energy efficient schemes. For instance, the original 1947 Electricity Act presented no real legislative barrier to the joint production of heat and electricity, although the major responsibility of the Electricity Boards was the production of electricity per se.

> "The C.E.G.B.'s principal duty is to develop and maintain an efficient, co-ordinated and economical supply of electricity" (Department of Energy, 1976, p.6).

Whilst other potential suppliers, such as local authorities, are permitted to produce heat and electrical power, and may sell the heat to the general public they must offer the electricity to the Central Electricity Generating Board (C.E.G.B.) at the Board's marginal cost of production. As the C.E.G.B. operate on a much larger scale than any local authority could, this requirement means that it would be uneconomic for an authority to produce electricity. Finally, whilst a number of private firms operate their own C.H.P. schemes, private entrepreneurs cannot sell either heat or electricity to people away from their own land. This legislation makes it likely that only the C.E.G.B. at the present time, could consider implementing various C.H.P. schemes, although it is possible for local authorities to introduce district heating schemes.

Recently, however, a number of reports such as the Plowden Report (Department of Energy, 1976) on the organisation of the electricity supply industry and the later Department of Energy (1978a) publication have proposed the abolishment of the legislative obstacles to the development of C.H.P. schemes. Similarly, the passing of the 1976 Local Authority Act should enable the local authorities to play a significant role. For instance, the Plowden Report gave,

"... special consideration to the implications of the industry's functions and structure for its participation in combined heat and power schemes ... There are signs that private industry is taking more interest in such schemes but great expansion would be impossible without the active collaboration of the electricity supply industry. Industry's structure must not impede the economic use of resources".

Specifically,

"... schemes must be tailored around a known demand for heat (and power). This will arise in a small area and is unlikely to call for more than a small generating plant. In such cases, knowledge of local conditions and a... response to local requirements are as important as technical sophistication. Local knowledge is the strength of the distribution side of the industry and the responsibility for identifying opportunities for such schemes and for initiating them must rest with the distribution side. It would also be sensible for the distribution side to take the responsibility for running them, although such schemes would need to be coordinated with the rest of the generating system" (Department of Energy, 1976, p.21).

The overall framework for a feasibility study offered in this paper is consistent with these sound suggestions.

The legislative obstacles are not seen as the only reasons why C.H.P. schemes have not been developed as much as they may have. In particular, the concern with consumers freedom of choice has been apparent particularly in the Government's Green Paper on Energy Policy wherein it states that

"... freedom of the consumer to choose between fuels which reflect economic cost should, where possible, be maintained and increased" (Department of Energy, 1978, p.3).

Unfortunately this objective, which is also emphasised by the C.H.P. Group, undermines the very advantage of establishing C.H.P. schemes. The issue of individual freedom of choice and the withdrawal of this for the general good and the trade-off between these is an issue which merits and requires detailed consideration before any scheme is introduced. It must be considered before any scheme which requires the adaptation to C.H.P. from other heating schemes is introduced. When C.H.P. is built into a new development the issue of freedom of choice is muted as an individual not wishing to have C.H.P. can always buy or rent alternative accomodation. Whilst freedom of choice and individual rights must be seen as of fundamental importance, the contemporary supply system does, in fact, result in a large number of households being captive to one form of energy. For example, tenants of local authority housing, which form 30% of the housing sector, are in the position of not being able to choose the form of heating they would like.

The second problem raised was the question of the scale of development, specifically, the scale of the initial establishments. The path taken in other countries, such as Denmark and Sweden, is to locate small C.H.P. units in the vicinity of high heat and power demand areas. It is this path which, it is argued, the British authorities should take (especially in times of economic recession). In the early 1970s, for example, the London Electricity Board considered the introduction of a C.H.P. scheme in a large-scale redevelopment of the South Bank. As time progressed from initial planning stages the development was reduced drastically as a result of political and economic change and the forecast demand levels for heat and power were not forthcoming. Had a C.H.P. plant been built it would have functioned at too low a level of efficiency to be economically viable. It is therefore sound practice to develop firstly small-scale local C.H.P. plants and to extend when and where it is practical to do so.

It is ironic, in the light of the above argument, that there has been a recent trend in Great Britain to build large power stations away from urban areas. This is facilitated by the National Grid and it allows the costs of transporting the raw materials to be reduced and the benefits of scale economies to be received. Some smaller, older power stations still exist in and around urban areas, and, although they are low down on the National Grid's "merit table", it is proposed that they may play an important role in the initial development of C.H.P. schemes. Whilst these sites are not the only feasible areas, they do appear to be one natural place to commence, and their conversion to permit the joint production of heat and electricity could greatly increase their thermal efficiency. A detailed analysis will be required to ascertain whether the local heat and power demand is sufficient to warrant their conversion and it may be that other sites, near hospitals or schools, are more attractive. One immediate advantage of the old power stations is that there will be little difficulty of land availability for such developments.

The basic requirement for an efficient C.H.P. scheme is that the correct mix of heat and power demand must be present in the area that the scheme will serve. As such the location of C.H.P. schemes in an urban area is dependent upon the spatial configuration of the land-use in that area. Thus an essential prerequisite to the investigation of the feasibility of C.H.P. schemes is a detailed investigation of specific urban areas. In fact, the C.H.P. Group stress the practical importance of pilot "lead city" demonstration schemes, although they recognise that,

> "... they have not examined the relationship between the present location of power stations areas of high heat-load densities in any detail" (Department of Energy, 1978b, p.10).

Towards this end the Department of Energy's commisioning of case studies of five urban areas - London, Glasgow, Leeds, Bradford and Merseyside - has provided a useful data base from which to undertake a detailed analysis (Department of Energy, 1978c).

It is the data base for Leeds which is used in the case study detailed below. This study shall examine the feasible locations for a variety of C.H.P. schemes fuelled by different types of primary energy. A central concern is with the sensitivity of these feasible locations to the type of C.H.P. plant and fuel used.

## 3. COMBINED HEAT AND POWER GENERATION SCHEMES: FEASIBILITY CRITERIA.

This section will outline and exemplify an analytical approach to examine the feasibility of C.H.P. schemes in urban areas. The data base for Leeds, which was collected for the Department of Energy, is utilitsed, and it is demonstrated that local knowledge of a city is extremely useful in such an assessment. The heat load density studies of the various cities are based on a sample of the land-use activities from a large number of zones. Whilst in district heating the focus is wholly on domestic heat load, the inherent complementary nature of domestic, commercial and institutional activities in C.H.P. schemes requires more detailed information. (The maps of heat loads for British cities (see Department of Energy, 1978c) only examine the feasibility of district heating schemes, and it is interesting to note that the spatial patterns are different from those for C.H.P. schemes (see below)).

A half-kilometre grid, following the Ordnance Survey grid, was the basis of the sample survey. One zone in six was selected for detailed fieldwork, and data for each zone was collected on the total number of dwellings, the total floor area of all commercial and institutional buildings, and the total floor of all industrial buildings. This provides necessary information for the following analysis.

Given this data base, it is possible, using a system of multipliers, to identify the amounts of heat and power which are demanded by each of the three activities in a zone. The multipliers required are obviously average figures for, say, the amount of energy used by a dwelling. If a suitable data base were available it would be advantageous to disaggregate by types of dwelling, size and also be the ability of the occupants to pay the rate for the kind of heating to be introduced. If the provision of a heating scheme which costs the user more may lead to an increased pressure on the household budget then it will not be of overall social benefit. The use of disaggregate data is of benefit but bearing in mind the nature of the current work an aggregate data base will suffice.

The multipliers employed in this application are the amount of electricity (mega-watts (MW)) required for heating the average dwelling, the amount of electricity for heating commercial and institutional buildings, and the amount of electricity used for power in industry. The first two loads were obtained from the Department of Energy figures (Department of Energy, 1977) and the third needed to be calculated specifically. The Central Statistical Office publishes the amount of floorspace contained in industrial establishments in Great Britain and the Department of Energy give details of the amount of electricity used in such establishments (C.S.O., 1979; Department of Energy, 1979). These figures exclude iron and steel works which use a much greater amount of electricity for their floor-space than other industries and if included would considerably bias the results. Furthermore, there is little of this type of industry in the Leeds area. Data published in Leach et.al. (1979) indicates that 64% of all electricity is used to drive stationary machinery; this can be used to give the fraction of the total industrial load associated with power and, subsequently, the industrial load per unit of floorspace can be derived.

The Kennedy and Donkin survey (Department of Energy, 1978d) gives the aggregate stock of the three types of building in each zone of Leeds. Simple arithmetic gives the total power load, $W_i$, and the total heat load, $Q_i$, in zone i. The overall philosophy of C.H.P. schemes is to meet the demand for power and, simultaneously, make use of the associated hot water for heating purposes. By introducing such a scheme in any zone savings may be made but the mix of demands for heat and power will make some zones more suitable than others. It is therefore necessary to define some criteria by which the amount of savings can be compared.

Perry et.al. (1978) have formulated two such measures, one based on energy savings and one based on cost savings. In the following example both will be used but, firsly, it is necessary to examine how they were derived. Their derivation requires a knowledge of the efficiency of the boilers used to provide the heating water at present, $\eta_B$, and of the generators used to provide the electricity for power at the moment, $\eta_G$. The efficiency is defined to be the amount of useful energy derived from a unit of primary energy input (for example, fuel oil, coal, gas) to the boiler of generator. The efficiency depends upon the specific type of boiler or generator but again average figures, taken from Perry et.al., will be used here. Knowledge of the amount of heat and power demanded by the consumer, $Q_i$ and $W_i$, respectively, and of the efficiency of the producing equipment, $\eta_B$ or $\eta_G$, allows the total amount of primary energy required $(E_c)$ to be calculated, where

$$E_c = \frac{W_i}{\eta_G} + \frac{Q_i}{\eta_B}. \qquad (3.1)$$

This value, $E_c$, is the total amount of primary energy used to provide $Q_i$ units of heat and $W_i$ units of power from the current type of generators and boilers.

In order to examine the level of energy saved by introducing a C.H.P. scheme, it is necessary to derive the total amount of primary energy needed to provide the same level of demands. The strategy followed in deriving this measure is to firstly calculate the amount of primary energy required to generate the desired amount of power in each zone, $W_i$; the efficiency of the C.H.P. plant's power production sector, $\eta_W$, allows this amount to be calculated. Consequently, the associated amount of heat produced from this quantity of primary energy can be calculated by multiplying it by the heat production efficiency of the C.H.P. plant, $\eta_H$. Two cases need examination: if there is sufficient heat produced to meet demand the primary energy supplied is sufficient to meet all demand, and if there is not sufficient then the surplus needs to be provided from the conventional system already in use and the amount of primary energy used is increased.

The total amount of primary energy used in the C.H.P. system provide $W_i$ units of power is $W_i/\eta_W$. The amount of heat thus produced is $(W_i/\eta_W).\eta_H$.

<u>Case (i)</u> : $Q_i \leqslant (W_i/\eta_W).\eta_H$.

There is sufficient heat produced to meet demand. Thus the total primary energy requirement for the C.H.P. plant is,

$$E_{CHP} = \frac{W_i}{\eta_W}. \tag{3.2}$$

<u>Case (ii)</u> : $Q_i > (W_i/\eta_W).\eta_H$.

There is not sufficient and an amount $(Q_i - \frac{W_i}{\eta_W}.\eta_H)$ must be provided by the current system.

This requires $(Q_i - \frac{W_i}{\eta_W}.\eta_H).\ \frac{1}{\eta_B}$ units of primary energy,

and,

$$E_{CHP} = \frac{W_i}{\eta_W} + (Q_i - \frac{W_i}{\eta_W}.\eta_H).\ \frac{1}{\eta_B}. \tag{3.3}$$

Whilst the potential energy savings accruing from the establishment of such schemes is obviously an important criterion determining their feasibility, financial aspects are also of significance. When making a decision based upon financial grounds the price of energy is of fundamental importance, particularly the price differentials between various fuels. Both these criteria will be applied to examine the feasibility of C.H.P. schemes in Leeds.

## 4. COMBINED HEAT AND POWER GENERATION SCHEMES: A FEASIBILITY STUDY OF LEEDS.

Local knowledge and the availability of the Department of Energy's (1978d) data base were the major reasons for selecting Leeds as the case study. The feasibility criteria can be readily applied to the other cities examined by the Department of Energy (1978c), and, in fact, it is suggested that comparative analyses will provide additional insight into the overall feasibility of C.H.P. schemes.

As to be expected in an industrial, Metropolitan District of approximately three-quarters of a million people, a variety of activities (industrial, service, residential) are found in Leeds, each with its particular demand for heat and electrical power. The fundamental feature in an assessment of the feasibility of C.H.P. schemes is the spatial patterns of these activities, specifically their locational association. In order to attain the technologically-possible high thermal efficiency of a C.H.P. scheme, it is essential that the separate local demands for heat and electricity are correlated. (The heat-power ratio is very significant).

Bearing this in mind, special attention was given to the potential location of C.H.P. plants in relation to relatively small, power stations in the city, hospitals and industrial estates (see Figure 1). In addition, there was the opportunity to comment on two proposed schemes which were abandoned and the desirability of changing an established district heating project into a C.H.P. scheme. Both criteria, energetic and economic, which were outlined in the previous section, were employed. In the analysis of energy savings, three types of plant were considered: diesel, gas turbine, and steam turbine; percentage energy savings for each zone were calculated, and, in the assessment of specific zones, absolute energy savings and the level of demand for heat and power were studies. In the analysis of operating cost savings, attention focuses on the gas turbine and the use of different primary energy supplies: natural gas, gas oil and fuel oil.

Figure 2 represents the relationship between percentage energy savings and the heat/power ratio for different types of plants; the positions of particular zones on the individual curves are indicated. Whilst raising important locational questions, obviously, the selection of the type of plant is of paramount importance. Figures 3,4, and 5 portray the spatial pattern of energy savings (and dis-savings), and they clearly demonstrate the sensitivity of plant types to the land-use pattern.

Similar spatial heterogeneity was found in relation to operating costs, although particular differences are especially important in determining the feasibility of specific schemes. This suggests the need to carefully consider both aspects in any assessment. Figure 6 describes the relationship between percentage cost savings for a gas turbine plant and the heat/power ratio. As in Figure 2, the zonal variety of the results is depicted. Figures 7 and 8 present the variation of possible cost savings over space, and they should be compared with Figure 4 in particular. As no cost savings were accruing at current for gas oil, no map is included, although, obviously, with differential price changes, the situation may alter.

In general, these preliminary results are in accordance with the decision to abandon the two proposed schemes indicated in Figure 1. However, as there are long lead-times involved in the establishment of

C.H.P. schemes, there is nothing to suggest that, at some future date (when the real price of energy has increased), such developments will not be feasible. A fundamental planning corollary, therefore, is the need for continuous monitoring and analysis. The feasible sites, as to be expected, are, in general, in areas where there is a combination of heavy industry and residences. (Note the opportunities in association with Kirkstall power station). Interestingly, the demand for power in light industrial estates, such as Seacroft, appeared insufficient for development at present. It was also reassuring that the successfully established C.H.P. plant at the infirmary was demonstrated by the analysis; the continual and uniform demand from hospitals is important, and the present examination suggests that a detailed investigation of the opportunities for implementing a similar project at Cookridge hospital would be worthwhile. Finally, whilst the Holt Park district heating scheme is successful, at present, a change-over to a C.H.P. scheme is unwarranted.

This section has, therefore, exemplified an approach to comme ce an assessment of the feasibility of C.H.P. schemes in cities. Although it is primarily introductory, sufficient details have been given to demonstrate the practical benefits of its adoption.

## 5. CONCLUSION.

The undoubted viability of C.H.P. schemes assisting in the direction of energy conservation in particular situations is a topic which is likely to become of increasing importance in the future, and, obviously, it deserves and requires further research - a cogent argument can be made for utilising energy more efficiently. Whilst a variety of significant legislative and organisational issues remain to be solved, this analytical framework, which can be easily applied, presents a sound foundation to examine the feasibility of specific C.H.P. schemes. Suggested extensions include the incorporation of establishment costs to complement the operating costs, and the relative cost savings of plants other than the gas turbine should be calculated.

Finally, although these schemes are not short-term projects, it would be unwise to be complacent today. Although partiuclar details of the future are, of course, highly uncertain, there seems no doubt that increases in the real prices of energy and physical shortages of different energy sources will occur, and, therefore, it is advisable to undertake a more detailed examination of these issues to enable enhanced preparedness. Given the long time-lags, purposeful action must commence now. If the necessary planning is not forthcoming, existing choices may gradually disappear.

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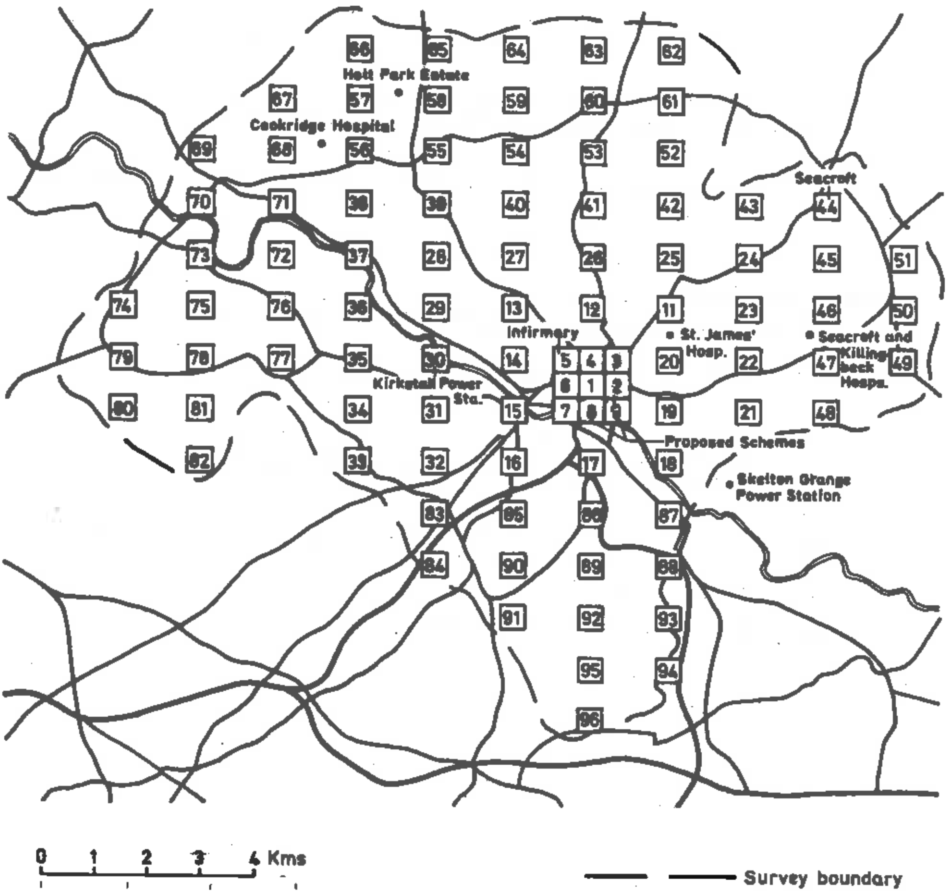


Fig.1 - The study area - Leeds

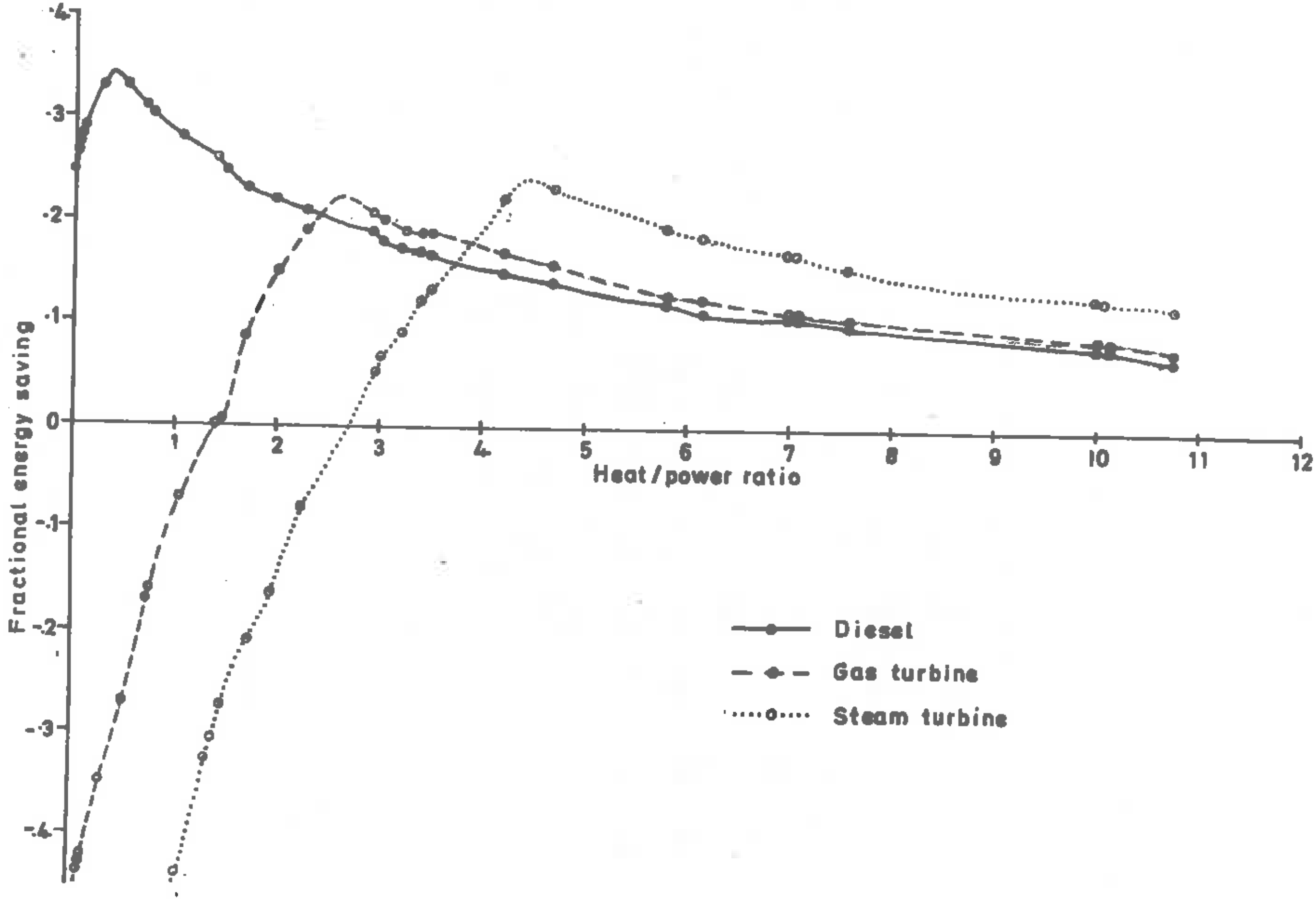


Fig.2 Energy saving for different heat/power ratios

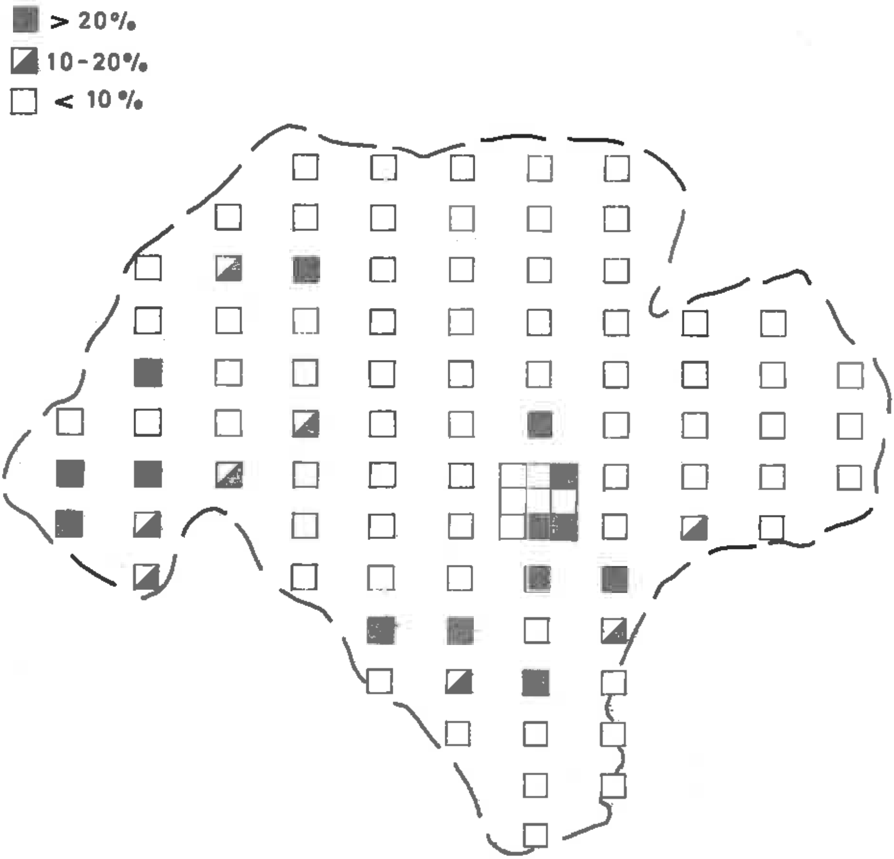


Fig.3 - Diesel - energy saving

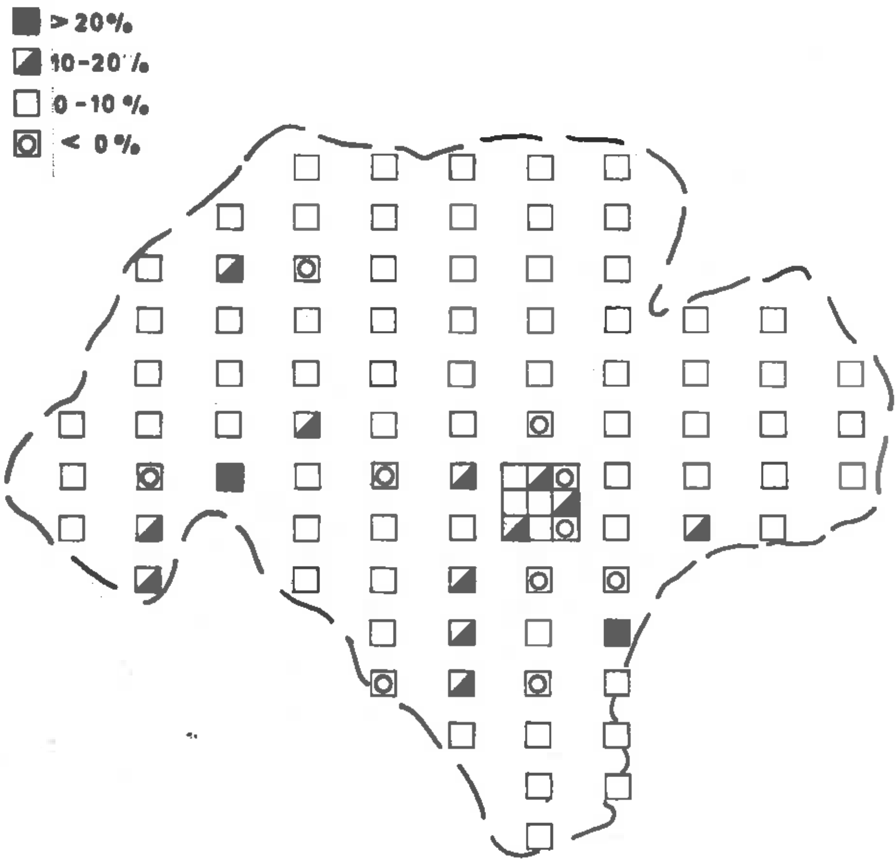


Fig.4- Gas- energy saving

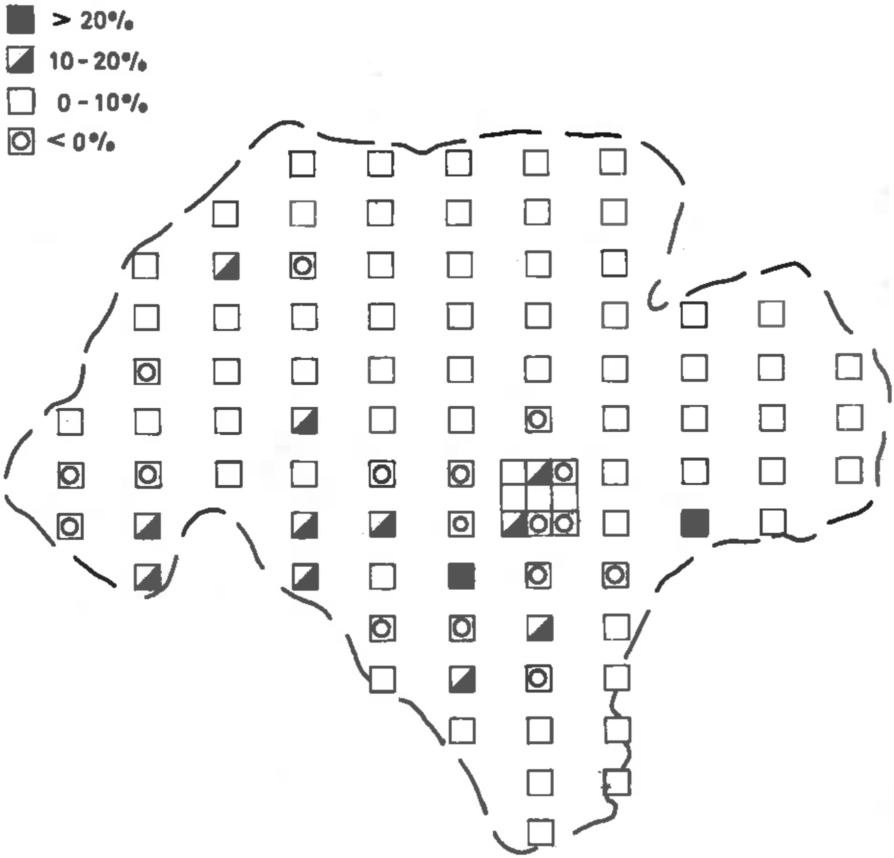


Fig. 5 - Steam - energy saving

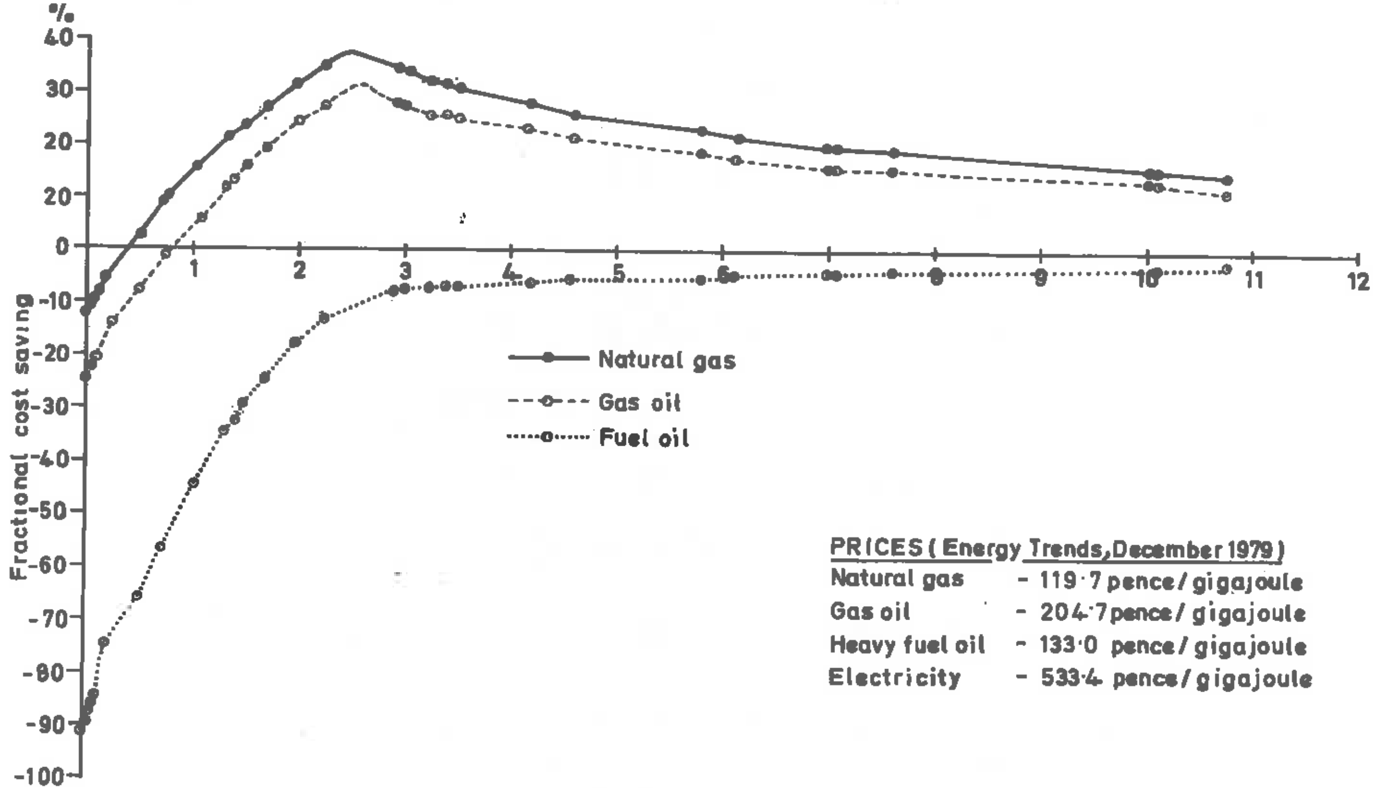


Fig.6. Cost savings for gas turbines at different heat/power ratio

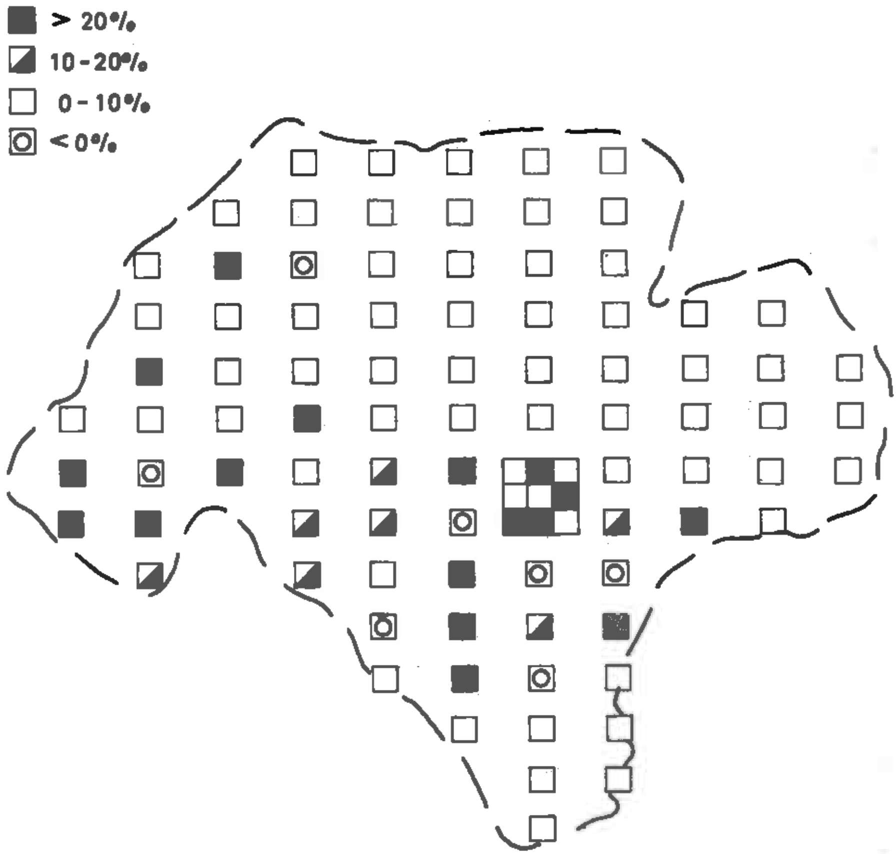


Fig. 7 - Natural gas-cost saving

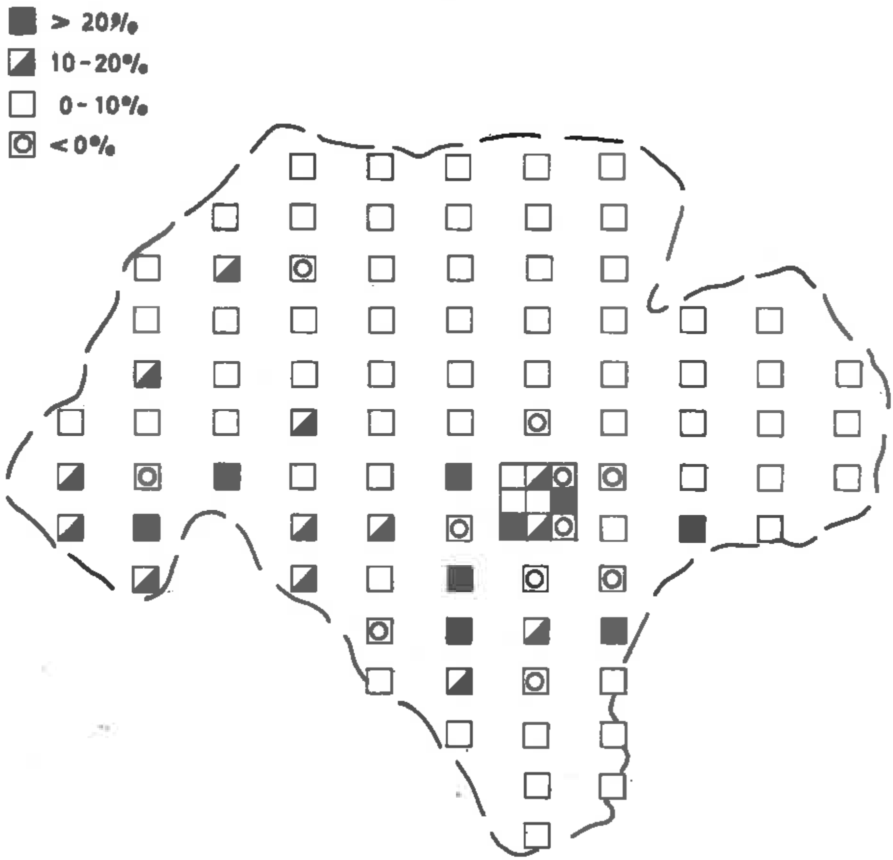


Fig 8 - Fuel oil - cost saving