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ENERGY CONSERVATION IN INDUSTRY

DP/EGY/83/001

EGYPT

Technical report: Plant surveys on energy conservation techniques (Textile Industry) *

Prepared for the Government of Egypt
by the United Nations Industrial Development Organization,
acting as executing agency for the United Nations Development Programme

Based on the work of J.G. Roberts
Expert in Energy Conservation Techniques

United Nations Industrial Development Organization
Vienna

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—> Pembleton

TABLE OF CONTENTS

1. Purpose of Mission

The mission was undertaken at the request of the Government of the Arab Republic of Egypt to assist in carrying out plant energy surveys in Textile industries forming part of the Energy Consevation in Industry project ECIP activities.

1.1 Duty Station

Cairo El Tabbin Institute with travel to selected textile mills.

1.2 Background Information

Research and development undertaken within the past decade in various countries has generated many technological and non-technological means, not only for conservation and more efficient use of energy but also to derive substitutions for oil through other renewable sources of energy, useful in particular to industry.

This point is of great importance to the country, where domestic consumption of oil-based energy amounts to some 75% of all the energy obtained from local oil production, thus depriving the country's economy of valuable foreign exchange earnings. To counteract this situation, the government, in conjunction with the management of industrial enterprises and supported business leaders, decided upon taking action to bring about a reduction in domestic oil consumption without affecting the total energy demand and end use.

The objectives of the country's Development Plan up to and including the year 2000, are to accelerate industrial development so that national income is increased and employment opportunities for a steadily growing population are constantly created. The present structure of the industrial sector in the country includes 117 public and about 70 private sector companies varying in size from medium to large.

The government's development plan for the six-year period 1982-87, has placed priority on development of heavy mechanical industries as well as on electrical, electronic, petro-chemical, textile, mining, chemical and food industries, all of which are energy-intensive undertakings.

At present, studies and collected data indicate that in all these industries a considerable amount of the supplied energy is not utilised and thus is lost and therefore wasted, in some cases reaching up to 40% of the energy input. One of I.E.C.C's top priorities is therefore to combat this situation without effecting production outputs and living standards and without incurring capital and labour costs in excess of that of the value of the energy saved.

In particular, sectors such as the iron and steel industry require considerable attention on account of the fact that these industries alone consume up to 12% of the energy consumed by the country as a whole. The I.E.C.C. can most certainly play an important roll in streamlining this operation and thus achieving energy saving of considerable magnitude.

In the same way, chemical and metallurgical undertakings, as well as refractories and the cement industry in the country are also energy users of considerable magnitude and are therefore also considered priority areas for action by I.E.C.C.

As such, I.E.C.C. will be involved in investigating the merits of alternate sources of energy (i.e. nuclear energy) and those of renewable sources of energy (solar, wind, tide) for application in specialised areas. In addition, hydro-electrical power generation will also be considered for utilisation in small to medium scale applications.

The objectives to be achieved through implementation of this project, can be summarised as follows;

(a) establishing I.E.C.C. as a permanent and independent institution in the country;

(b) creating a core of trained specialists at I.E.C.C. to carry out on-going activities in energy conservation in the country;

(c) creating a number of trained specialists to act as advisors on energy conservation in all industrial and commercial sectors in the country;

(d) programmes and methodologies of training (including diagnostic and remedial aspects) concerning identification of energy saving measures;

(e) establishing a research and testing facility for the purpose of assessment and evaluation of energy saving and their applications.

These objectives will not only be instrumental in demonstrating to authorities in industrial and commercial organisations the opportunities and desirability of energy conservation but will also provide the means of putting these conservation ideas into practice

1.3 Duties of Consultant

The consultant will be attached to the ECIP and will specially be required to;

1. Assist ECIP staff in setting out the procedure for carrying out plant energy surveys using mobile diagnostic energy vehicle MDEV.

2. Supply the ECIP with the average energy consumption norms in international textile industries.

3. Assist a group of ECIP in carrying out plant energy surveys in one of the national textile factories.

4. Conduct seminars and training workshops in the above field.

The consultant will also be expected to prepare a final report, setting out the findings of the mission and recommendations to the Government on further action which might be taken.

2. Activities

The work programme undertaken is shown in Annex 1.

2.1 Survey of Textile Mills for Suitability for Initial visits by ECIP Energy Bus

Following a series of energy workshops conducted at ECIP El Tabbin Institute earlier in 1985 engineers from some twenty-five textile factories submitted reports on the energy use and opportunities for energy conservation at their factory sites.

A survey of these reports was made to select sites suitable for follow-up visits. Two were chosen El Nasr Spinning and Weaving Co Ltd (CHOURBAGI) and Cairo Silk Textiles Ltd both situated in Cairo. Visit reports are appended in Annex 2.

2.2 Energy Bus Visit

After preliminary familiarisation with the energy bus and the instrumentation it contained there was time for only one visit to a textile site. This was made to El Nasr Spinning and Weaving Co (CHOURBAGI). Successful measurements were made of boiler efficiency at this site and a start was made in auditing the distribution of use of electrical power. The methods required for completing an audit on this site were discussed with ECIP staff and it was agreed that work with the energy bus would continue at this site to establish a detailed audit

2.3 Discussion of Energy Auditing Techniques with ECIP Staff

The operations required for energy audit of textile sites was discussed with Dr Ahmed Amin and his colleagues. The importance of first determining the major energy using items of machinery was stressed rather than making a detailed analysis which is very time-consuming. This is then followed by increasing detail analysis only where it is considered essential. Detailed examples and published reports were discussed and copies left for the ECIP library

The importance of establishing regular monitoring of energy as a management tool in mills was stressed. The methods of doing this on a weekly or monthly basis for each major production centre in the factory were explained. Analysis of monthly data for energy requirment per unit in relation to production levels time worked and other factors was shown to be relevant in assessing energy efficiency.

2.4 Collaboration Between ECIP and TDC Alexandria

The opportunity was taken to meet Mr Magdi El Aref, Technical Director, Textile Consolidated Fund and head of Textile Development Centre Alexandria to discuss the progress of the energy activities initiated in the earlier consultancy visit made in January/February 1983 (Post 11-aa/H/31.9.B Textile Development Centre Phase II DP/GG7/77/008).

Further energy surveys had been made with extensive coverage of the textile industry.

Dr Ahmed Amin of ECIP was present at the meeting and was introduced to Mr Magdi El Aref. The suggestion was made that there should be collaboration in the Textile Industry to enable maximum benefit to be made of the use of the instrumentation available in the Energy Bus to improve energy efficiency.

2.5 Seminar

A one-day seminar was conducted at the El Tabbin Institute on 25th September 1985 to an invited audiance from the Egyptian Textile Industry in ECIP staff. Twenty-five people attended. The seminar was based on the papers appended as Annex 3.

3. Findings

1. The Energy Conservation Industry Project (ECIP) is well equipped for energy auditing in the textile and other industries

2. ECIP staff have only a slight knowledge of textile processing most of which was aquired during the visits undertaken to textile mills

   A further source of textile processing knowledge is required if maximum improvements in energy efficiency are to be identified in this industry. This would be aquired by extensive collaboration with TDC Alexandria and by further visits by UNIDO experts.

3. An initial programme undertaken with engineers from textile mills is a successful first step and should be extended and buil upon.

4. The two industry sites visited showed major opportunities for improvements in energy efficiency. Managements were keen to be involved they needed outside support to expand their site auditing. This could be filled by ECIP staff with the energy bus. In addition support would be required to establish projects for improved energy efficiency identified at each site.

5. The low cost of fuel oil and electricity is still a major problem and could be inhibiting to capital expenditure for improved energy efficency.

4. Recommendations

1. The ECIP Energy Bus should be used for short factory visits to examine boiler combustion and to tune boilers to achieve consistently higher levels of energy efficiency. This would make an immediate and beneficial impact on energy conservation and should be followed up by further site audits.

   At the same time as the initial visit energy and production data should be collected and factory managements encouraged to use this data to relate energy use and production by calculating total energy use per unit of production. This should then be monitored and used as a management tool to ensure maximum efficiency of energy use.

2. For maximum advantage in the Textile Industry there should be collaboration between El Tabbin Institute ECIP staff and TDC Alexandria. This would provide a combined expertise on Energy Efficiency for ECIP staff and Textile Processing expertise for TDC.

   The first steps in this have been taken in the meeting arranged between Dr Ahmed Amin (ECIP) and Mr. Magdi El Aref (TDC).

3. A demonstration project should be set up at Cairo Silk Co. to demonstrate two major points to the Textile Industry:

(a) The improved energy efficiency achievable by boiler replacement.

and (b) The importance of the use of heat exchangers on continuous washing ranges. The need to install three units has been identified (See Report Annex 2) and the potential saving is 280 tonnes of oil per year.

4. Further training is recommended for both ECIP staff and selected Industrial Energy Managers in energy management for improved efficiency.

5. An incentive from Government is recommended to encourage Industry to make the necessary capital expenditures which are in many cases necessary to achieve increased efficiency of energy use. The current low cost of oil (mazoot) at 7.5 £ Egyptian makes projects which could save 20% of oil used unattractive whereas at International Oil Prices the pay back would be between 1 and 2 years.

ANNEX 1

Work Programme

September, 1985

9	Travel to Cairo.
10	Briefing UNDP Cairo.
11	El Tabbin Institute. Introduction to ECIP staff and preliminary discussions and factory selection.
12	Meeting Mr. Sabry UNDP Cairo. Visit to El Nasr Spinning and Weaving Co. (CHOURBAGI).
15	Visit to Cairo Silk Textiles Co. (Arrival of Energy Bus at El Tabbin Institute).
16/17	Discussions staff ECIP El Tabbin Institute. Energy Auditing procedures. Preparation for seminar. Examination of instrumentation and Energy Bus.
18	Visit to Cairo Silk Textiles Co.
19	Visit to El Nasr.
21	Visit to Cairo Silk Textiles Co.
22	Discussion ECIP staff Energy Auditing procedures
23	Discussion with Mr. Magdi El Aref TDC Alexandria. Energy Audit commenced at CHOURBAGI using Energy Bus.
24	El Tabbin Institute. Discussion workshop Energy Audit. Preparation for Seminar.
25	Seminar and Report Preparation.
26	Final report preparation.
28	De-briefing UNDP Cairo (Brought forward to 26).
29	Travel to Manchester.

ANNEX 2

VISIT TO CAIRO SILK TEXTILES CO. CHOJBRA ELKIMA

KALYOBIE CAIRO ON SUNDAY 15TH SEPTEMBER, 1985

JOHN G. ROBERTS

UNIDO ADVISOR ON ENERGY CONSERVATION

Summary

Basic data collected at this factory has been further analysed. Its continuing collection is recommended for monitoring on a monthly basis. Energy saving potential of about 280 tonnes of oil per year have been identified but would require fitting three heat exchangers.

Areas for measurement and investigation using the "Energy Bus" have been identified.

PERSONNEL

In the company of Dr Ahmed Amin ECIP we met Eng. Mahmoud El Kholy, general manager, Chemical Affairs and eng. Sami Farg Wanis, Planning Department and thank them for their assistance.

DISCUSSION

Eng. Samir had attended the workshop for Energy Managers organized by ECIP at the Tabbin Institute and had written a report on his company providing basic information related to energy conservation.

The company's activities are mainly weaving of fabrics and their dyeing, printing and finishing. At present the output of weaving, 2400 tonnes planned per year cannot all be processed in the dyeing and finishing department.

The results in grey fabrics being passed to other factories for preparation processing.

Capacity of dyeing, finishing and printing is currently being expanded. A complete preparation range (Kleineweffers) is installed and will be commissioned into operation as soon as new boilers are (early 1986). Associated with this equipment is a new STORK rotary screen printing unit (12 colour).

This new equipment will enable CAIRO SILK to process all its grey cloth output.

Examination of the data provided in eg. Samir's report gives the following derived information.

WEAVING SECTION

Annual Energy Input

		G.J.	Cost L.E.	Toe*	% of Total as GJ	as lost	as Toe
Electricity	5,100,000KWh	18,360	83,130	431	34.7	93.2	34.7
Heavy Oil+	8100 Tonnes	34,506	6,075	810	65.3	6.8	65.3
Grease	18t for lubrication						
Total		52,866	89,205	1,241			

* Based on delivered energy. Generation losses would raise electricity to 1006 toe.

\+ Note that this value is estimated and is consumed as Steam in the sizing department. This gives a value of 34.5GJ/t of yarn sized just for drying. This value must be checked as it is extremely high.

Relating energy use to production input

Annual production output for weaving is quoted as 2000 t

Overall specific energy consumption 52886 GJ/2000 t

= 28.4 GJ/t

This value is in line with interational value eg. UK average 29.3 GJ/t. It should be noted that the UK value includes space heating not required in Egypt.

In the sizing department assumming half yarn is sized for warp, then energy consumption is 34506 GJ/1000

= 34.5 GJ/t

As this energy is consumed in a drying operation for which the norm is not more than 5 GJ/tonne.

This is based on an estimated oil consumption which must be revised.

DYEING SECTION

Annual Energy Inputs

		GJ	Cost L.E.	Toe*	% of Total as GJ	as Cost	as Toe
Electricity	210,000KWh	756	34,230	17.7	0.8	58.6	0.8
Heavy Oil	1,800 t	76,680	13,500	1800.0	86.0	23.1	86.0
Light Oil	270 t	11,745	10,665	275.7	13.2	18.3	13.2
Oil and Grease	6 t (lubrication)						
TOTALS		89,181	58,395	2093.4			

Relating Energy Use to Production Output

Annual production in dyeing 1300 t

Specific Energy Consumption 89181 GJ/1300 t

= 68.6 GJ/t

Tour of Factory

Boiler House

Two oil-fired boilers each having 6 t/hr output were clearly not operating efficiently. Fans delivered air at a fixed rate irrespective of fuel delivered to the burners. An open port at the back of the boiler was discharging carbonaceous dust. These boilers will shortly be replaced by two new units each with 22 t/hr output.

It is recommended that engineers from Tabbin Institute measure efficiencies of the old boilers immediately and compare with the new boilers when they are operational.

New Preparation Section

A new preparation range (Kleineweffers) has been installed but will not be commissioned until there is sufficient steam available from the new boilers. This is excellent equipment and will have a potential output of 1800m/8hr shift. As the average weight of fabric is 250g/linear meter this is a production rate of 4.5t/8hr shift or approximately 0.5t/hr.

In the unit are two washing sections which operate in counter flow reaching 95°C. Effluent is discharged to waste at this temperature. A major part of this energy can be recycled by using a heat exchanger [Pozzi heat exchangers can recover 75% of available heat in this situation].

How much heat can be recovered depends on the rate of use of washing water - 5 to 10 Kg water per Kg of fabric is usual.

At the lowest value of 5Kg the saving can be calculated per hour - 0.5t fabric = 2.5t of water.

Water temperature 95°C at discharge - 25°C incoming.

Heat effluent $2.5 \times 10^6 \times (95-25) \times 4.2$ J = 735 MJ.

If operation is for 20 hours/day and 300 amp/year the total energy in the effluent is 4410 GJ.

Using a heat exchanger 75% can be recovered. This is 3307 GJ or 77.6 tonnes of oil measured at the machine. This becomes 93 tonnes in boiler fuel.

There are two washing sections operating in the same way so that the potential for saving is 2 x 93 tonnes or 186 tonnes on this are one piece of equipment.

In the next stage of processing a similar situation applies on the mercerizing range. A further potential saving of 93 tonnes exists assumming all fabric is mercerized.

It is recommended that Pozzi heat exchangers are fitted.

Dyeing Section

Yarn is dyed in a single Theis package dyeing machine and is dried in a hot air recirculating unit. This unit should be checked by instrumentation on the "Energy Bus" to ensure optimum operation with hot air discharge of not less that 0.2Kg water/Kg air. Measurements should also be made to check the value of fitting a heat exchanger on this air discharger to pre-heat water for dyeing.

Fabric is dyed on jigs and winches. Major heat losses were occuring as many of these machines were fitted with lids which were left open. Steam use with lids closed is halved.

Fabric finishing is carried out on stenters, control of exhaust flows would be examined as for the yarn dyeing driers.

Recommendations

1. The energy analysis commenced by Eng. Samir should be continued and extended to measure Total Energy per Unit Production in the way shown in this report. It should be continued on a monthly basis and progress plotted.

   In this way the changes as the new boilers and new equipment are brought into operation will be monitored.

2. Serious consideration should be given to fitting heat exchangers to each washing section of the Kleineweffers range and the mercerizer.

3. The Tabbin Institute through the ECIP "Energy Bus" should make measurements of efficiency of the old boilers, and then when commissioned, the new units.

   In addition they should also measure the efficiency of driers and similar equipment.

CAIRO SILK

Supplementary Reports of Visits made on

Wednesday, 18th September, 1985, and

Saturday, 21st September, 1985

18th September

This visit was made to establish with Dr Ahmed Amin the suitability of this factory for a visit by the ECIP audit team and the 'Energy bus' Eng. Hassan Aly accompanied us around the site.

It was decided that the operation of the boilers would make a suitable target for the operation of the instrumentation on the Energy bus and would form the basis of a practical workshop. It was seen to be particularly suitable in that it would enable comparisons to be made between the old boilers shortly to be removed and the new installation now nearing completion.

Subsidiary targets were also identified. These were:

1. Examination of distribution of energy by departments for electricity this could be done in two ways:

    a) By estimating total installed load for each department and applying an average use factor and then opportioning total electricity use to each department.

    This could be done on an annual, monthly or daily basis.

and b) By measurement of daily total load and the loads to each section at the transformer stations using the instrumentation available to ECIP.

For steam there are only two departments involved; weaving, and dyeing and finishing.

In the weaving department steam use should be estimated at the sizing machines which are the only major steam load. This can be done by estimating the quantity of water removed in drying and measuring losses from the machine by convection radiation and in the exhaust and flows.

In dyeing and finishing measurements should be made of air flow temperatures humidities, and flow rates at all drying units, bakers and stenters and estimates also made of machine losses.

For water using machines steam use can be measured from total water use per day together with temperature cycle data. Again machine losses should be estimated and included.

Opportunities for heat recovery and possible modifications in mode of use of machine should be identified. For example there are possibilities for heat recovery on the Kleinewefers range, the mercerizer and the yarn dyeing machine.

Modification could possibly be made on the dampers of driers and stenters to obtain maximum efficiency without loss of process speed.

This plant would be ideal for a demonstration project on heat exchange based on the preparation range (Kleinewefers) and the mercerizer.

<u>21st September</u>

This visit was made with Dr Hasham to meet Engineer Samir Farah Wanis to discuss the establishment of energy monitoring.

The methods to be used to make further calculations based on the data collection already in progress were outlined and discussed in detail. Engineer Samir was encouraged to make these calculations on a monthly basis for use as a management tool to control energy efficiency. It was also requested that monthly information be passed to Dr Ahmed Amin ECIP at El Tabbin Institute. This was agreed by Eng. Samir.

VISIT TO EL NASR SPINNING AND WEAVING CO. (CHOURBAGI)

CAIRO 12th, 19th and 23rd September, 1985

by JOHN G. ROBERTS

UNIDO Advisor on Energy Conservation

Summary

This factory has been identified as eminently suitable for a full energy audit to be made by ECIP. In preliminary visits the basis for energy monitoring was established and major opportunities for energy conservation were identified. A reduction in energy use of 30 to 40% is achievable.

Personnel

12th September. In the company of Dr Nashat of ECIP we met Eng. Mahmoud Amin, General Director and the Chief Engineer.

19th September. In the company of Dr Said Abd-El Wahal we met Chairman Salah El-Attair, Eng. Samin Planning Manager and the Chief Engineer.

23rd September. The Energy Bus was manned by a group of ECIP engineers under the Project Leader Dr Ahmed Amin. The consultants reponsible for the supply of the energy bus Mr. Paul Thorne and Mr. Bah Achley were also present, the Chief Engineer of Chourbagi also played an active role.

The Chourbagi personnel are thanked for their help and interest.

Discussion

Eng. Nagura from Chourbagi had attended the ECIP workshop at the El Tabbin Institute and had prepared a basic data report. From this report the following preliminuary information was derived.

Basic processes carried out at this mill are spinning, weaving, dyeing printing and finishing.

Production in weaving is 772t/yr based on the yarn input. However, it became clear during the visits that the annual material flows through departments of the factory were complicated but could be summarized as follows:-

Spinning	2400t
Weaving	703t
Weaving at other factories	1600t
Socks knitted	60,000 doz. (approx. 60t)
Knitting	60t polyamide
	250t cotton
Dyeing and Finishing	11.5 million meters
	2185t

There is movement of yarn and fabric in and out of this factory at intermediate stages which makes it impossible to arrive at any value for overall production. Hence production must be considered by departments.

Energy Inputs

The annual energy input during 1984.

		GJ	Cost L.E.	% of Total Energy	T oil Equivalent
Electricity	19008264 kWh	68430	184380	85.5	1606*
Heavy oil (Mazoot)	3781 t	161070	28375	13.2	3781
Light oil (Solar)	96620 1	2923	2899	1.3	90
Kerosine	127580 1	4465	Printing Thickener		
Benzine	180213 1	6307	Transport Fuel		
Oil	44070		for Lubrication		
TOTAL		233423	215654		

* Not including energy required to produce

Of these fuels, electricity is mainly used in spinning and weaving but on the basis of present information its use cannot be split by departments. The best estimate should be obtained by opportioning total electricity between spinning, weaving and dyeing and finishing on the basis of total installed motor capacity and electrical heating capacities in each department modified by the approximate running hours.

A simple estimate based upon a norm of 10GJ/t electricity use for spinning and for weaving and 3GJ/t for dyeing and finishing.

	Electricity GJ	Heavy Oil GJ	Light Oil GJ	Total GJ	Production t	Specific Energy Requirement GJ/t
Spinning	43795	-	-	43795	2400	17.8
Weaving	13002	7030	-	20032	703	28.5
Dyeing & Finishing	11633	154040	3923	169596	2185	77.6

These values lie near the norms for Western European practice.

Spinning		but this value includes a major element for space heating.
Weaving		this value also includes a major element for space heating.
Dyeing and Finishing	53GJ/t	

Visit to Site

The site visit clearly indicated that this is a suitable factory to be the subject of an audit to be carried out by EPIC. The following observations are relevant.

Boiler House

Two fire tube boilers of about 12t/hr capacity produce steam at 5 bar. There is also an older boiler kept as spare. These boilers need careful measurement of their efficiencies and should be adjusted to give maximum performance. These boilers appear to be producing large amounts of carbonaceous ash which is blown out of an open port at the boiler back end which suggests that efficiencies should be capable of more improvement.

Condensate

No condensate is returned to the boilers. This situation is wasteful. All traps on steam lines should be checked to ensure that they are working efficiently. Consideration should then be given to installing a proper condensate recovery system. It is estimated that 10-15% of total oil consumption can be saved by such an installation and it would also substantially reduce water treatment costs.

Pipe work

Pipe work is poorly insulated and losses in the distribution system are likely to be high. In the course of the plant audit planned to be carried out using the ECIP 'Energy bus', an estimate of the total length and size of the poorly insulated system pipes should be determined, and the losses assessed. These are likely to be of the order of 20% of the total steam roused.

Jet dyeing

No recovery of heat is made on these machines. Re-use of banked cooling water for machine make-up and recovery of water heat from hot effluent could recover the equivalent of 130 tonnes of oil each year.

This is estimated as follows. There are 12 dye tubes of Platt Langclose manufacture. These operate with 100 Kg load and a liquor to goods ratio of 10:1. One cycle is completed per shift. Thus the total water usage in the dyeing process each day is 12 x 100 x 10 x 3 Kg or 36t/day. This water is heated to 140°C in dyeing then cooled to about 90°C before discharge. Thus the daily energy used in dyeing is:

$$36 \times 10^6 \times (140-25) \times 4.2/10^9 \text{ GJ or } 17.4 \text{ GJ}$$

of this 7.6 GJ appears in the cooling water which is steam and could be reused directly and 9.8 GJ is discharged to drain. Of the latter 75% could be recovered by heat exchange.

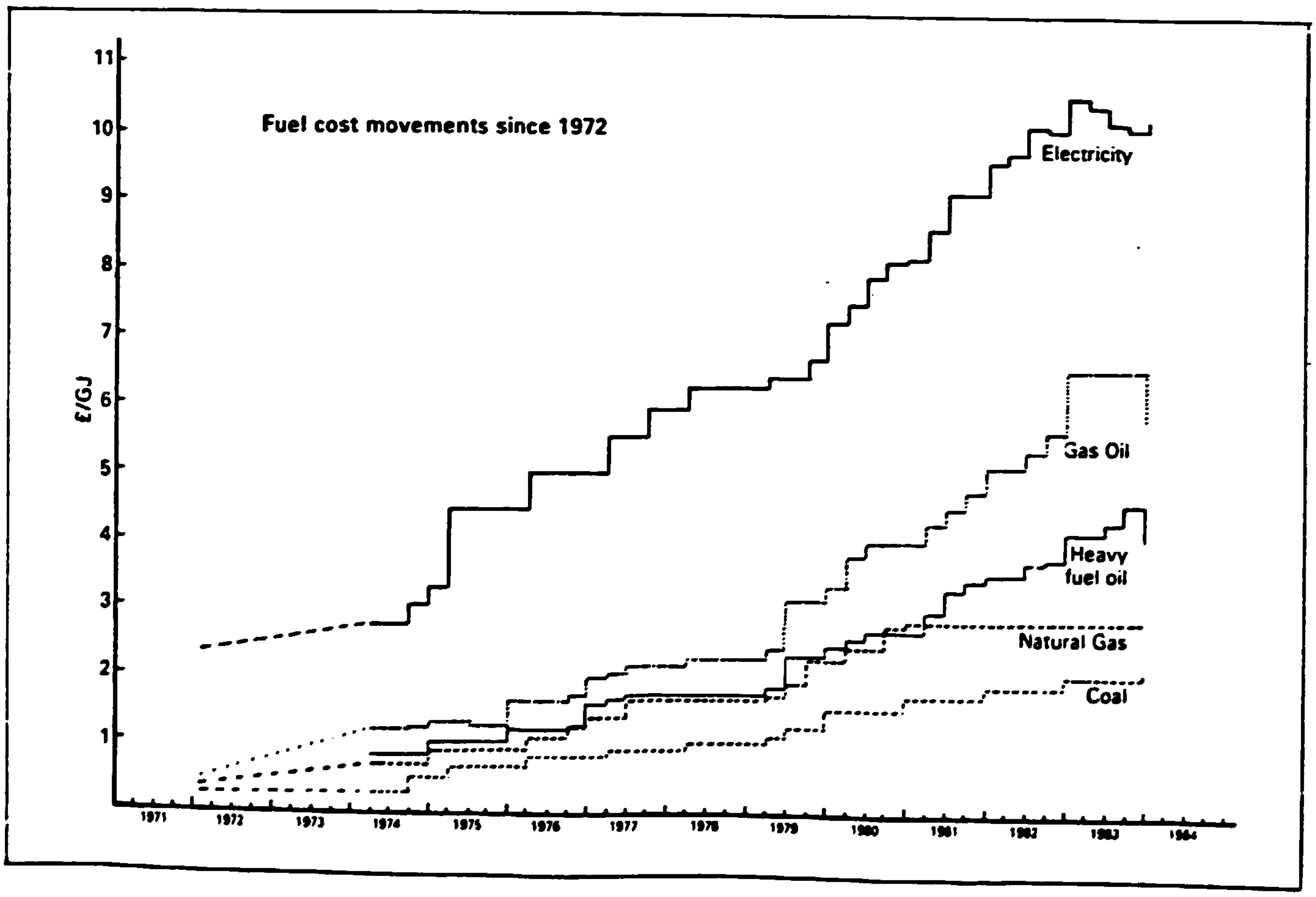
Thus a total of 15GJ/day could be saved which is about 130 tonnes of oil per year. This does not take into account any hot pre-washing or hot rinsing carried out on these machines.

<u>Energy monitoring</u>

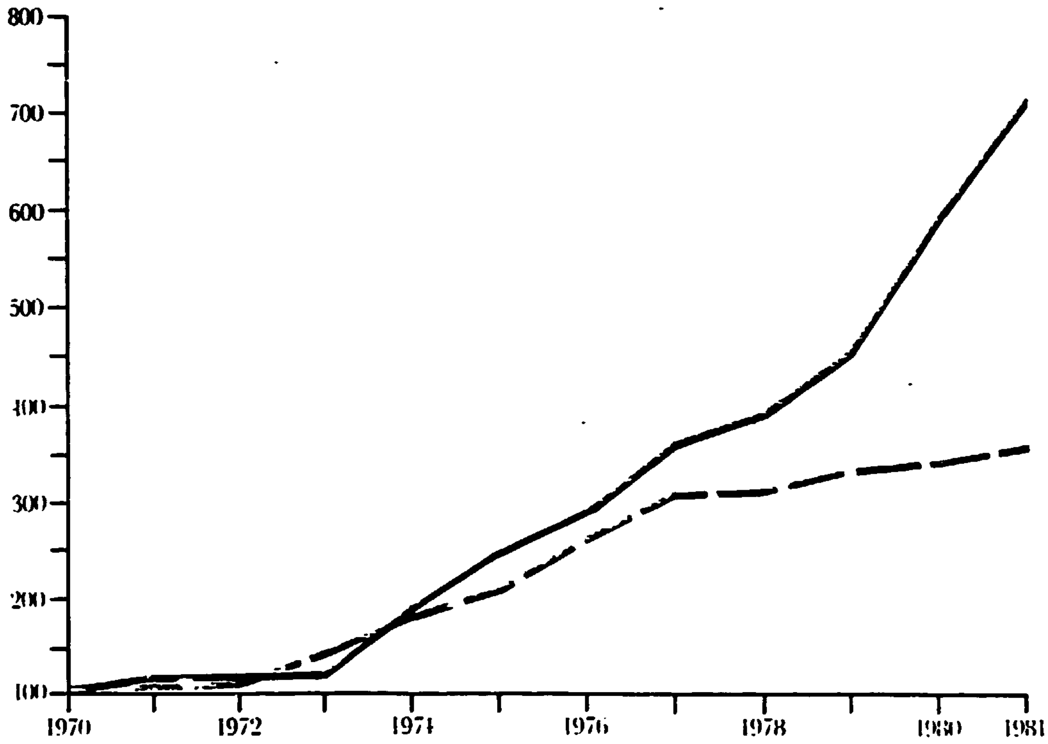
Values for monthly data to enable monitoring of energy use are available at this factory. The collection of this data is a suitable way for calculating energy per unit of production by department was discussed. Detailed analysis is to be made on data from July, 1984 to date. This will be available for the ECIP audit and will form the basis of a continuing analysis which will form an essential management tool for monitoring energy efficiency.

THE FUTURE AVAILABILITY OF ENERGY

The cost of energy is increasing rapidly in the UK. Oil prices have risen by 2x since January 1979. The days of cheap energy are over.



Energy costs have risen more rapidly than other wholesale costs so that energy increasingly forms a more important element of total production costs.

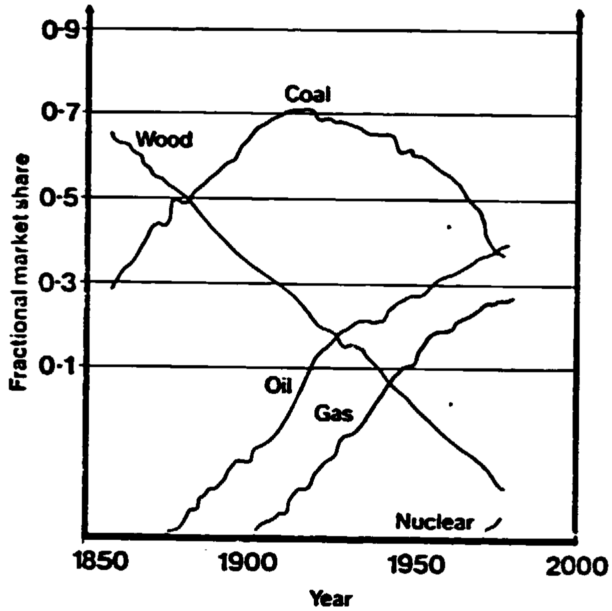


Current Prices Index 1970-1981.

Industrial Fuel Prices

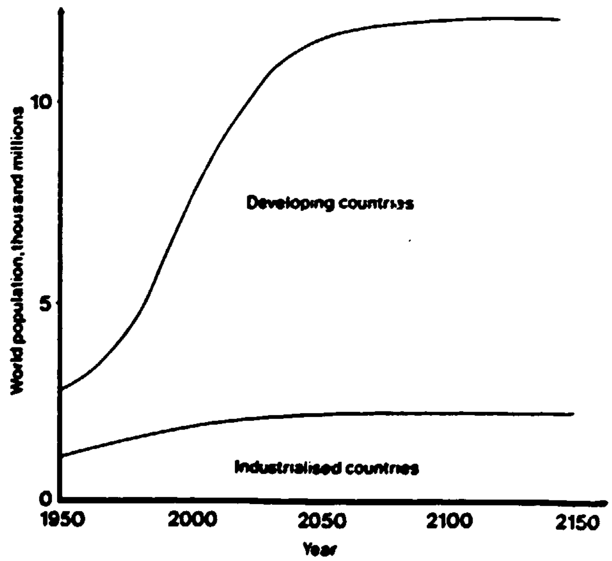
Wholesale Prices, excluding crude oil and carbonised coal.

The balance of source of fuel used has changed and is still changing.



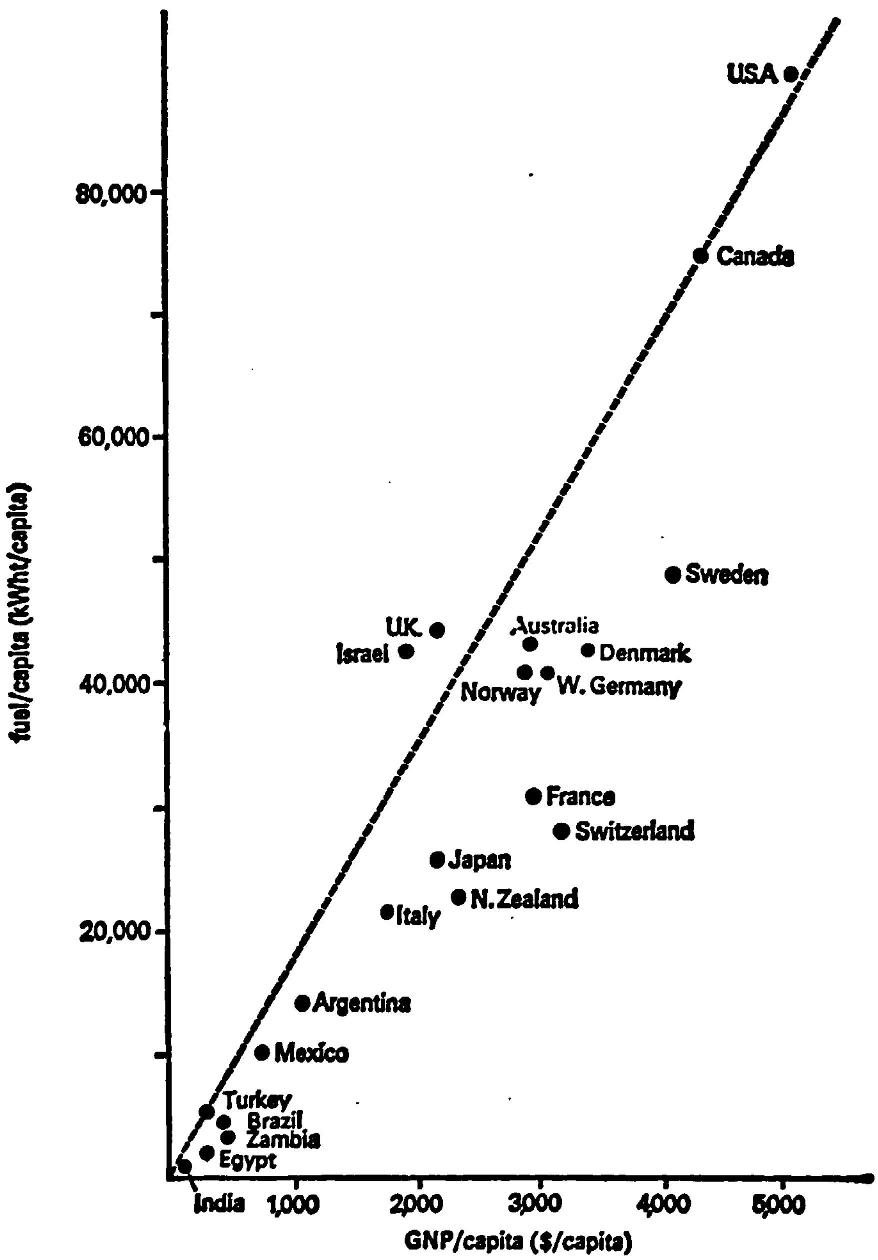
History of global primary energy substitution.

The total amount used is increasing and the increasing world population is a contributing factor.



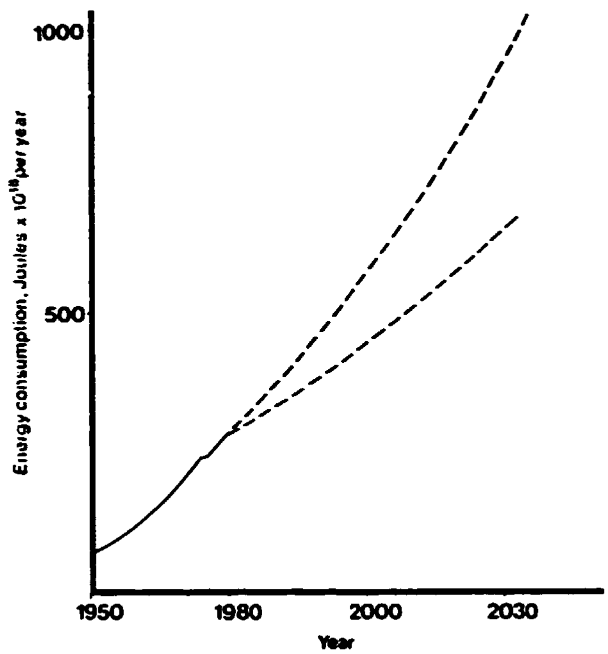
World population projections showing proportions in developing and industrialised countries.

Energy use can be relateu to production and with developing countries seeking to expand their production there will be increasing demands on energy resources.



Per capita fuel use and gross national product for selected countries, 1970. (Source: U.N. *Statistical Yearbook*).

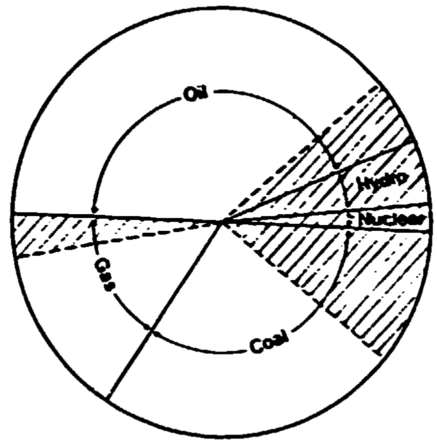
World demand for energy is increasing



Global primary energy consumption in high and low IIASA projections.

World Energy Demand 1928-1978

	Million tonnes oil equivalent	Coal	Oil	Natural Gas %	Others	Total
1928	1160	74	16	3	7	100
1938	1275	68	21	6	6	100
1948	1730	57	27	8	8	100
1958	2800	47	33	11	9	100
1968	4590	34	42	18	6	100
1978	6685	27	46	19	6	100



World primary energy sources in 1978; the proportions used to generate electricity shaded.

This increase is largely in oil and nuclear energy. Coal, because of difficulties in mining has shown only a small increase and in some areas a decrease.

Increases in Energy Demand 1973-1978

Million tonnes oil equivalent

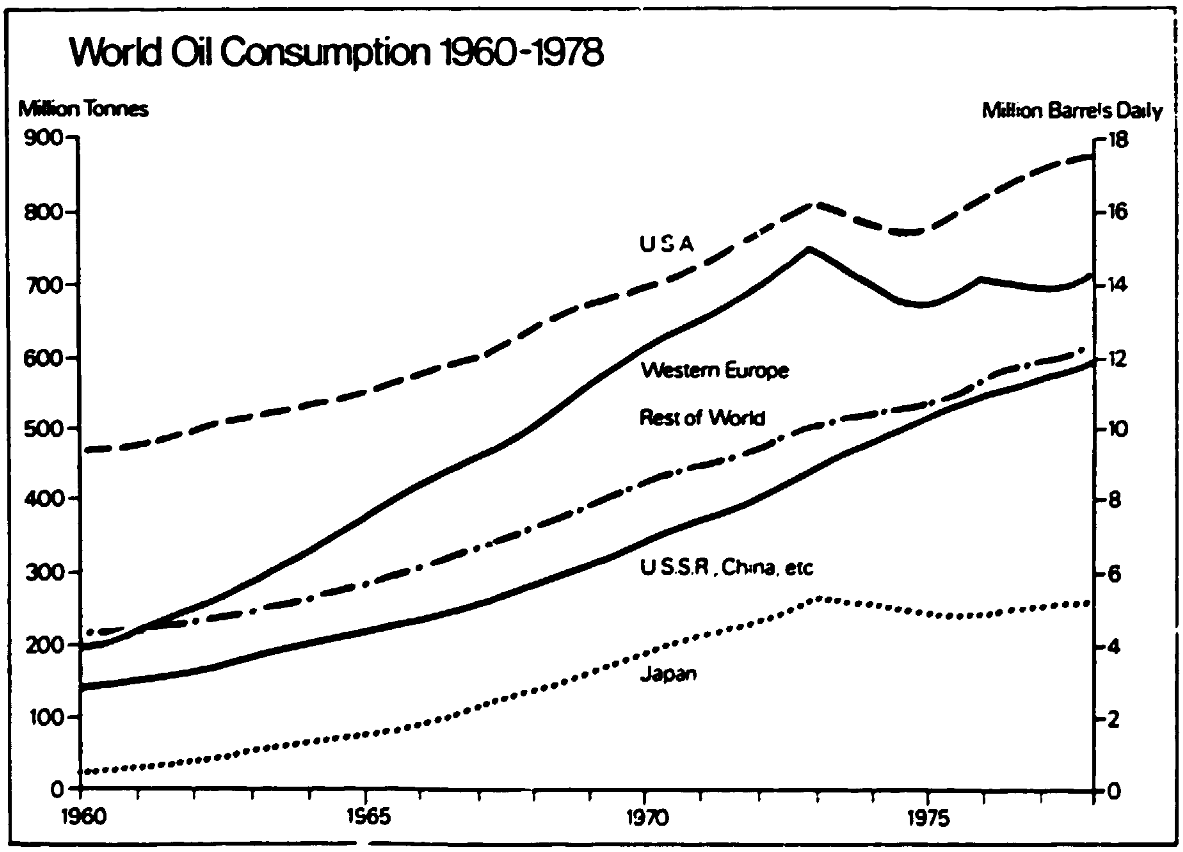
	Coal	Oil	Natural Gas	Hydro	Nuclear	Total
World*	39	140	25	59	92	355
West. Europe	–18	–34	49	17	22	36
Japan	–7	–6	12	–	10	9
N. America	24	73	63	14	59	107
Rest of World	40	107	27	28	1	203

**(excluding USSR, China etc)*

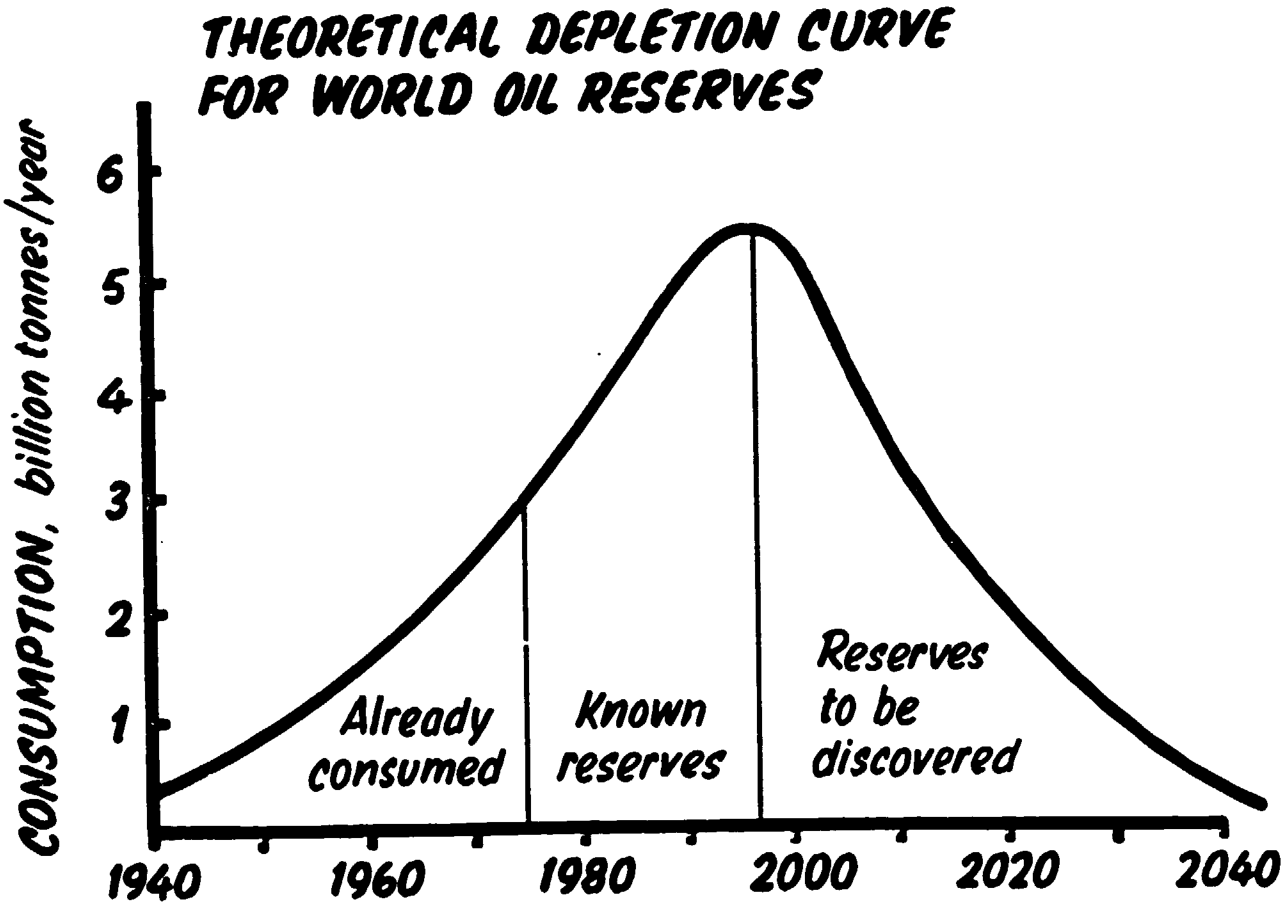
Many countries rely heavily on imported oil for a large part of their energy requirement.

1977 Country	Mtoe Energy Demand	Net oil imports	Country	Energy Demand	Net oil imports
AUSTRALIA	67.8	13.7	LUXEMBOURG	3.7	1.4
AUSTRIA	23.3	9.0	NETHERLANDS	63.3	23.9
BELGIUM	45.2	24.3	NEW ZEALAND	11.1	3.8
CANADA	201.8	12.9	NORWAY	20.6	4.6
DENMARK	20.4	16.7	SPAIN	69.4	44.1
GERMANY	260.7	133.5	SWEDEN	48.7	27.5
GREECE	13.8	9.4	SWITZERLAND	23.4	12.6
ITALY	134.9	90.2	TURKEY	n.a.	n.a.
IRELAND	7.4	5.5	UNITED KINGDOM	211.4	51.3
JAPAN	348.1	260.4	UNITED STATES	1,795.7	414.0

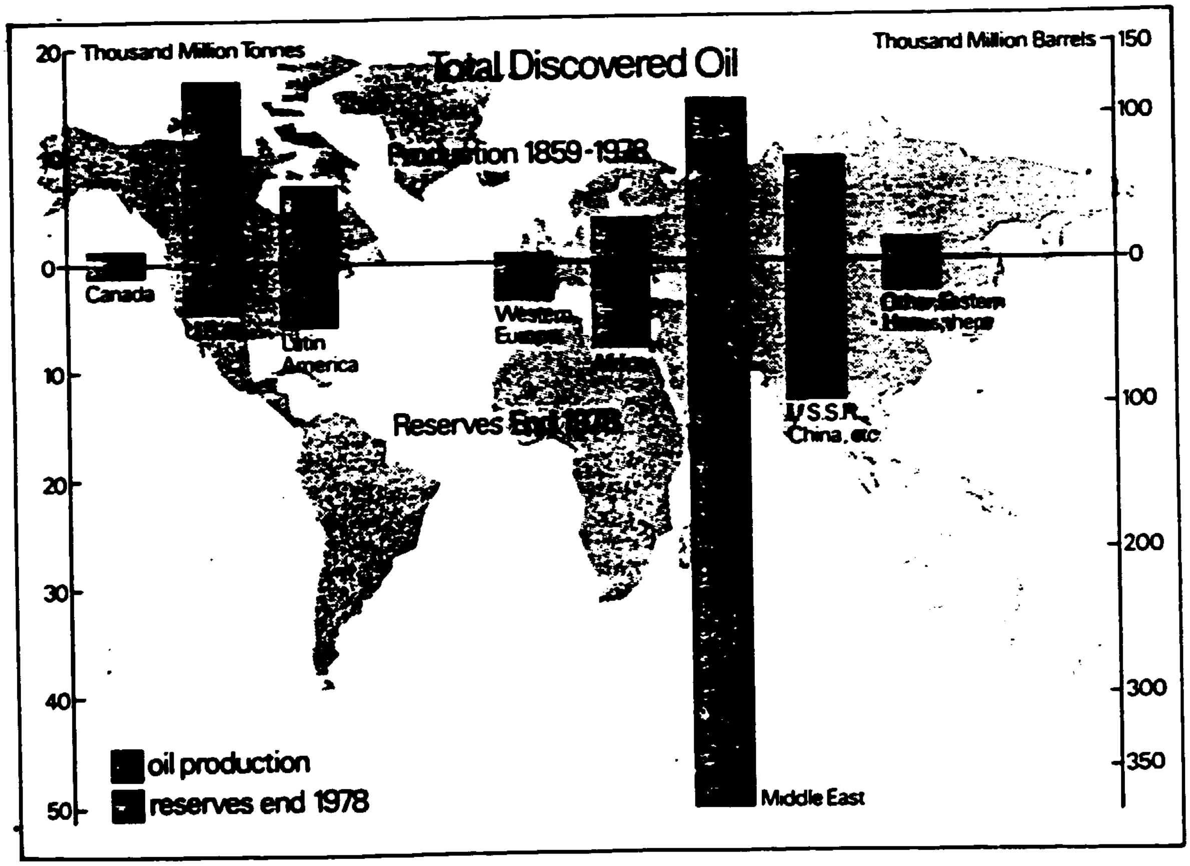
The overall increase in oil consumption is huge and only in Western Europe does this show signs of levelling off and this is in part due to the economic recession.



World-wide depletion of known reserves shows the seriousness of the oil situation.



Oil is located in relatively few areas.

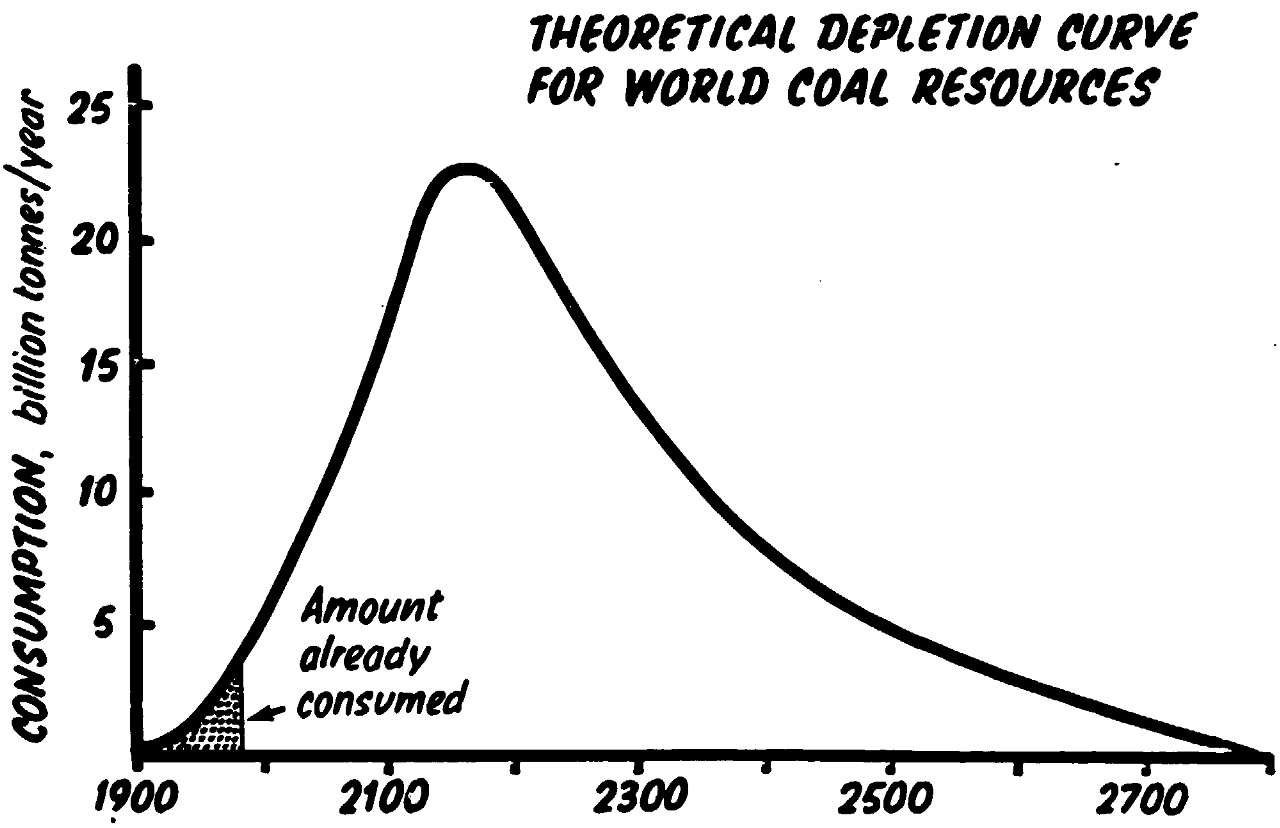


Natural gas occurs in association with oil fields and reserves are of limited lifetime.

NATURAL GAS

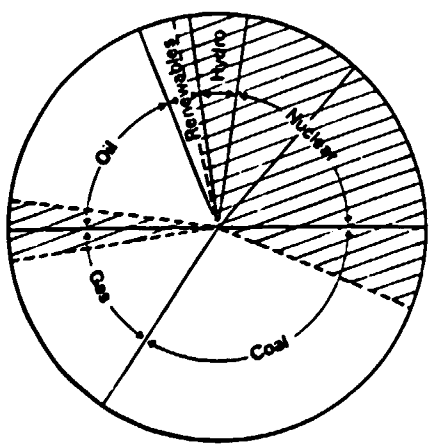
RESERVES	10^{12} M^3
ASIA PACIFIC	3
EUROPE	6
(UK)	(1.5)
MIDDLE EAST	19
AFRICA	9
AMERICAS	11
COMMUNIST COUNTRIES	24
TOTAL	72
CONSUMPTION IN 1972	1.1
UK	0.25

Of fossile fuels only coal shows a long term possibility of supplying needs but much of the known reserves are going to be very difficult to mine.



In the UK a forward projection of energy sources shows increases in the need for nuclear power.

MTCE					
	67	73	76	77	2000
COAL	165.8	133.0	122.0	122.7	170
NUCLEAR AND HYDRO	11.7	12.1	14.8	16.3	95
NATURAL GAS	2.1	44.2	58.8	62.8	50 - 90
OIL	122.6	164.2	134.2	136.6	150
RENEWABLE SOURCES					10
TOTALS	302.2	353.5	329.8	338.4	475 - 515

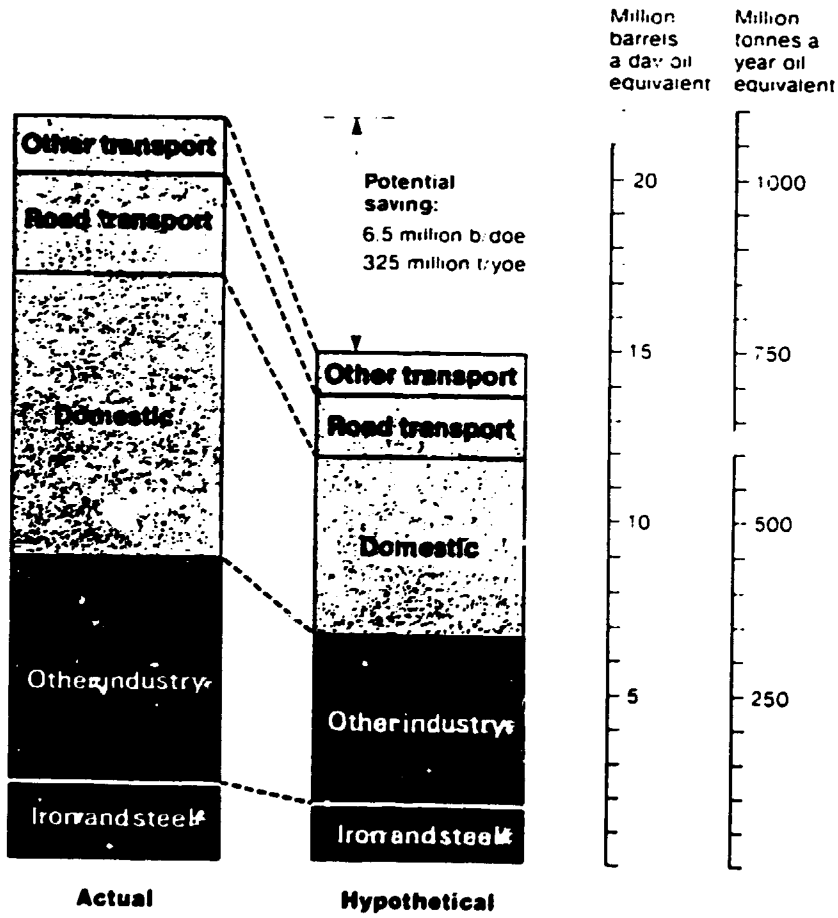


World primary energy sources in 2030 as projected in IIASA high scenario showing (shaded) proportions allocated to electricity generation.

There is one energy resource that can play an important part in extending supplies of all fuel that is ENERGY CONSERVATION.

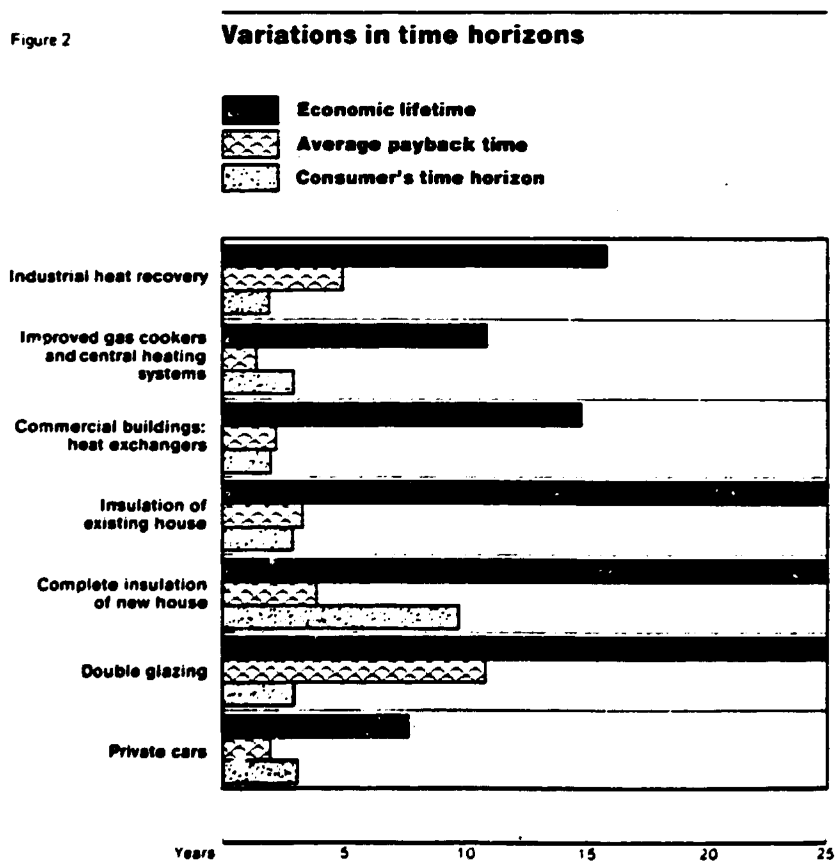
In Western Europe it is believed 30% of energy can be saved.

The potential for improved energy efficiency



Primary energy consumption (excluding non-energy uses) in Western Europe in 1975.

Figure 2


Variations in time horizons
Economic lifetime
Average payback time
Consumer's time horizon
Industrial heat recovery
Improved gas cookers and central heating systems
Commercial buildings: heat exchangers
Insulation of existing house
Complete insulation of new house
Double glazing
Private cars
Years
5
10
15
20
25

INEXPENSIVE ENERGY METERING TECHNIQUES

Instruments for measuring the consumption of energy, for instance flowmeters for fuels, steam or air, can be expensive to buy and install, and to maintain in reliable order. Disinclination to incur such costs may sometimes stand in the way of adequate energy monitoring. There are, however, a number of inexpensive techniques for measuring energy consumption without sophisticated instrumentation which lend themselves either to short term tests or to continuing energy monitoring. Such methods are often quite accurate enough to serve as adequate alternatives to more conventional metering for at least some of the energy measurements of a factory. They also sometimes make it possible to get quick answers to energy questions without the delay of waiting for instrument delivery.

Steam Measurement via Condensate

In giving up its heat on condensing, one pound of steam turns into one pound of water. With certain provisos, therefore, steam consumption can be determined by collecting and measuring the condensate from a machine, department etc. This is strictly true only for a dry saturated steam supply, and if there is no escape of flash steam on collection. Normal steps should therefore be taken to remove water from the supply main by suitable trapping.

Depending on the rate of flow, duration of test etc., the collection vessel may be anything from a bucket to a large drum. The collected condensate can be weighed or its volume measured, and the time also recorded to calculate the hourly rate of flow. If the steam trap(s) discharge to atmospheric pressure above the level of water in the container some of the condensate will "flash off" into steam and be lost. So will any steam passing due to faulty operation of a trap.

If the condensate is released as it is formed, rather than being retained in the plant and being cooled below steam temperature, correction for this loss by flash steam may be made, adding the following percentage weights to the collected condensate.

steam pressure, p.s.i.g.	10	25	60	100	150
% correction for flash	3	6	11	15	19

If, instead of discharging to atmosphere above the water in the container, the trap discharge pipe dips below the surface of cold water, the condensate plus all the steam, whether true flash or from faulty traps, is collected and measured.

Unless the steam supply is effectively superheated, even good trapping will not ensure steam free from entrained water droplets, and a deduction may be made from the weight of collected condensate. 5% would be a typical figure for this correction with a well drained supply.

A modification of this method may be employed for the continuous monitoring of major steam users or whole departments where a pumping trap or float-switched electric pump are used for returning condensate to the boilers. The volume of condensate delivered per operation of the pump will usually be fairly constant. A mechanical or electromechanical counter fitted to such a pump will give convenient weekly or daily steam consumption figures.

Alternatively, and perhaps better if a pump runs for a high proportion of the time, the total running time of an electric pump may be recorded by a cheap elapsed time meter (cost less than £10). The necessary gallons/hour factor is determined by test on the particular installation.

Steam Production from Feed Water Meter

The steam output of a boiler, per week, day or hour, must often be known in order to check either the efficiency of steam raising or of steam utilisation in a factory. Steam flow meters are appropriate for large and medium sized boilers, but are not always practical on smaller plant or where the necessary skilled attention may be lacking.

For about 10% of the cost of a steam meter, a feed water meter may be provided, from which a useful alternative measure of output can be calculated. Such meters are generally more robust and less temperamental than steam flow meters.

Steam generation will be less than the metered input (combined returned condensate and make up water) by the amount of blowdown and the water carried over by steam as entrained droplets or, if it should happen, by priming.

Priming should be avoided for other, more important reasons, and in any case there is no way of correcting for this in calculations. Unless the steam is superheated on leaving the boiler, there will be some entrained water. Unless the extent of this has been established by testing, the wetness can be assumed at say 5%. The quantity of blowdown should, in the interests of efficiency and water treatment costs, be known and carefully controlled - specified for the boiler operator in terms of inches of water in the gauge glass per shift, or other convenient way.

On the above basis, the steam production over a given period would be calculated as :-

$$\text{steam production, lb} = (\text{feedwater, gal} - \text{blowdown, gal}) \times \frac{100 - 5}{10}$$

Such steam production figures may usefully be compared, say weekly, with boiler fuel consumption to indicate boiler efficiency, and with units of works production to indicate efficiency of utilisation. The latter ratio may be used for the information of production staff as an index of energy cost control.

Elapsed Time Meters

Where energy consumption is at a predetermined rate, the consumption of an appliance may be recorded by an elapsed time meter which adds up the total time of intermittent operation. Examples include on/off (rather than modulating) gas or oil burners for boilers or warm air space heating units and the on load and off load running time of air compressors.

Electrically operated elapsed time meters cost under £10, and can be applied to any operation which depends on, or can result in, the application of mains voltage. A simple conversion factor, for calculating energy consumption from hours run, must be established by suitable test or by reference to manufacturers' specification.

The application to air compressors is particularly helpful in continuously monitoring trends in the use and wastage (due to leaks) of compressed air.

Electricity Monitoring

Information taken from monthly electricity bills is not very suitable for monitoring because the intervals are too long, and the "months" between meter readings often vary considerably in length.

Weekly readings of consumption from the factory main kWh meter are a better basis for monitoring, and can be related to output, working hours, last year's corresponding figure or a predetermined target. A weekly note of the level of maximum demand since the last resetting of the kVA meter often gives a rough idea of what combination of circumstances have caused a new peak of electrical demand.

In trying to control either total consumption (kWh) or maximum demand (kVA) it is helpful to know the actual levels of demand at various times of day, night, week ends etc. Quite a lot of light can be shed on this by short periods of frequent reading of the kWh meter. For instance, readings morning and evening for a week show up the pattern of days within a week. Readings every three hours for one day would possibly identify a period calling for more detailed investigation, and this would then be checked every half hour for the three hour period in question.

There is obviously a limit to the useful information which this meter reading will yield. A fully detailed continuous picture may be obtained by hiring a load recorder from the electricity supply Board for a few weeks. It is unusual for this not to show up some unexpected features and associated opportunities for saving.

Analysis of Fuel Delivery Records

Sometimes it is useful to know how the weekly fuel consumption of a factory has varied with seasons and with varying levels of activity, for instance over the past year. One reason for wanting to know this is to estimate the share of the fuel consumption which is attributable to space heating when space and process heating are from the same boilers.

In the case of oil, and sometimes coal, the record of invoiced deliveries (which is almost always available) will often be a good second best in the absence of actual metered weekly consumptions.

If the cumulative deliveries over the year are plotted on a graph with a calendar base a reasonably smooth curve can then be drawn through the points. Stock variations at delivery dates will cause most points to lie to either side of the curve. The slope of the curve at any date represents the rate of fuel consumption in gal/day or gal/week, and will normally be less in the summer when space heating requirements are nil. Such a curve may also indicate the occurrence and extent of variations in fuel consumption due to such causes as increased production or improvement in boiler efficiency after servicing.

Data Comparisons

The logging of fuels, electricity, water on a weekly basis is quite widely practised, less frequently steam and boiler-supply water are regularly recorded. However it is only infrequently found that production date can be provided on the same basis. The records exist in different books and are rarely compared. The full value of such collected data is only realized when comparisons are made. A combined log should show Fuel, Electricity, Water, Steam-Production and computed from these should be Boiler Efficiency, Fuel/water usage ratio Fuel/Production ratio.

ENERGY MANAGEMENT

Background

Energy is of vital concern to all, and at little or no extra cost or danger to quality or safety, it is often possible to achieve appreciable savings merely by eliminating fairly obvious waste. However, sustained success in saving energy depends to a great extent on attitudes to cost and waste held by personnel at all levels.

Energy Audit

The achievement of any big improvement usually requires careful and thorough planning, and should start with an Energy Audit in which all usage of energy is compared with values which are known from experience to be reasonable. Any important differences are then investigated more closely and at least sufficiently to quantify the savings possible and indicate any measures - and their cost - which may be advisable.

Such a procedure allows priorities to be decided between the various possibilities, and allows the manager responsible to prepare a case for the allocation of an appropriate share of strictly limited resources in cash and management time.

Technology

An analysis showing just how energy is presently being used is invaluable in any consideration of technical or procedural changes. Thus, in a specific case, measuring the amount of steam used by different dyeing machines at different stages in the dyeing process pointed quite clearly to wastage resulting from using open vats relying on boiling for the necessary liquor circulation. Also, a detailed examination of the usage of electricity in factories throughout the day, at night, and at weekends will often pinpoint possibilities of avoiding waste and of reducing costs.

The measures necessary to achieve worthwhile savings will vary greatly, and while it may be possible to introduce some almost immediately at little or no cost, others, particularly where they required significant changes, may have to wait for a major reorganization or even machinery replacement.

Energy management covers a wide range of activities and usually requires close cooperation between different branches of management.

Routine monitoring

The work necessary to ensure compliance with standards can form part of a specific investigation or Energy Audit or of routine monitoring, but preferably all three. However, whereas a full investigation may be quite detailed, with attention focussed on small elements and short time intervals, routine monitoring must be periodic and should be arranged to take up as little time as possible.

Its main fuction is to draw attention to anything abnormal, and usually some grouping is essential. And as well as a way of maintaining standards, routine monitoring should be seen as a means of improving performance. It should be pointed out that by itself the recording of meter readings achieves nothing, and that it is the actions taken which are important. Thus, it is usually preferable for managers to do their own meter reading since they are likely to be more inquisitive and quicker to react to anything off-standard.

A useful by-product of monitoring can be appropriate publicity within the firm to make all personnel aware of the need for savings and how they can be obtained, as well as drawing attention to past achievements with some indication of just how they have been achieved.

Metering

Most managers have to make do with less metering than they would like, and there is scope for much ingenuity in obtaining adequate control information. Thus, while it is important to have a minimum of basic instrumentation, some instruments are very expensive both to buy and to maintain. Steam flow meters are a case in point, and while, for example, the efficient operation of boilers of any size requires output and fuel input data, adequate data of output can often be obtained by using comparatively inexpensive feed water metering (after making appropriate allowances). Elapsed time meters are also very useful, particularly where energy usage is at a constant rate.

Distribution and control

Big savings can often be achieved by doing no more than shutting off sources of energy when they are not required, but the distribution mains must have appropriate valves, switches, or taps.

Space heating

Heat is lost from buildings mainly through the structure - that is by conduction through walls, windows, the roof, etc., and through ventilation, representing the heat content of all air leaving the building.

These losses depend primarily on the U (or conductivity) values of the structure, the number of air changes per hour, and the difference in temperature between the inside and the outside. Most of these losses are, however, readily calculated. It is estimated for the total UK Industry that there is a possible saving of between £50m and £100m per year.

<u>What should be done</u>

* Create an appropriate climate within the firm. Saving energy depends to a great extent on the attitude of mind of personnel at all levels.

* Eliminate all obvious waste. This often equires no more than the application of common sense, and can cost little or nothing.

* Organize an Energy Audit to find out just what savings are possible.

* Organize an appropriate system of routine monitoring which will show up any abnormal conditions - and ensure that the system is used correctly and intelligently at all times.

* Make full use of any information relevant to performance.

* Always adopt appropriate forms of heating. The use of radiant heat, for example, is often advantageous in high buildings with poor U values and high rates of ventilation.

* Ensure that ventilation is no greater than is really necessary.

<u>Further information</u>

Further information and advice about saving energy can be obtained from your Research Association.

ENERGY AUDITS

Dr J.G.Roberts (Shirley Institute)

At this stage in the Seminar there can be no doubt that there is complete agreement that energy conservation is an important requirement in all future industrial processing. Our known energy resources are of limited quantity or are difficult of access or are difficult to harness. It is only necessary to look at the distribution of known oil reserves to realize how uncertain the future for oil could be (Figure 1.). Reserves are predicted to last into the next century at our present and predicted levels of usage but with the political uncertainties of the Middle East where the major known reserves of oil lie one cannot be sure of their continuing availability at present levels.

The current world situation, with the major difficulties brought about by inflation and trade recession, is in no small way associated with the uncertainties surrounding availability of energy and its increasing cost. So it is not surprising that energy conservation is seen as being so important - it is without doubt the cheapest alternative energy source.

In the short term there are many actions which have already been advocated and discussed. Longer term planning will require a more detailed knowledge of the make-up of energy content of materials which are in every-day use. This information can only be obtained by detailed audits of the manufacturing processes involved making due allowance for the energy content of the basic materials used. The analysis and control of energy use has not generally been developed to the same extent as for control of man-power and materials or for machine utilization. Basic energy auditing even at a relatively simple level can result in the identification of surprisingly large opportunities for the saving of energy and hence reducing costs.

Further aspects of planning in the longer term include the choice of processing routes and the choice of materials in particular where equivalent products can be made. The classic example of this latter type is in the choice of containers for food products. The choice might lie between a glass bottle, a tin plate can, an aluminium can or a waxed paper carton. The main basis for choice is probably price but is also subject to factors such as suitability of the container material in relation to its contents or its durability in handling, distribution or storage. However, in long-term planning, it could well be that the factor of increasing energy costs over several years could have a major influence on the overall economics of the choice. The use of energy auditing will provide the necessary background information to enable strategies to be planned.

The Departments of Energy and Industry saw early the importance of energy auditing and have in the past four or five years been involved in a wide range of audit studies in industry. These studies are now being published and are available in the Energy Audit Series Reports for such industries as Iron Casting, Brick Making, Dairying, Brewing and many others.

A study has also been made in the Textile Industry but here the situation is much more complicated by reason of the multiplicity of processing steps which lie between the initial fibre production and the dyed and finished fabric. As a result of the many stages of processing it is not surprising to find that the production of textile materials requires large amounts of energy. In the full audit analyses carried out by Shirley Institute for the Department of Industry it has been found that the gross energy requirement for a white polyester/cotton workwear fabric is about 270 GJ/tonne and for a 100% nylon knitted shirting fabric it is about 470 GJ/tonne.

At this stage some explanation of the units for energy may be necessary. The studies under the Energy Audit and Thrift Schemes of the Departments of Industry and Energy have generally been standardized as far as possible using S I units. This has meant that energy is measured in multiples of joules (J)

$$k = 10^3, \text{ Mega} = 10^6, \text{ Giga} = 10^9 \text{ and Tera} = 10^{12}$$

These units may not be readily relatable to the more familiar units used and the following approximate conversion factors might be helpful:

1 GJ		10 therms
	or	1 million B.t.u
	or	300 kWh
	or	240.000 thermies

In terms of net oil or coal equivalent

1 GJ		24 kg oil
	or	34 kg coal

So, reconsidering the gross energy requirement for the two textiles, it could be considered that the polyester/cotton workwear fabric required the equivalent of 9 tonnes of oil per tonne of its production and the 100% polyester knitted shirting fabric 16 tonnes/tonne.

If this is brought down to the level of an individual garment making due allowance for the quantity of fabric we get for a warehouseman's coat or a laboratory coat in white polyester/cotton, 272 MJ or 9 kg of coal or 6.5 kg of oil as the energy content.

Similarly for a dyed polyester/cotton shirt the values are

88 MJ or 3 kg of coal or 2 kg of oil

TABLE 1 ENERGY CONTENT (GER) FOR GARMENTS

Garment	Energy (GER) MJ
Boiler suit dyed PES/CO	567
Warehouseman's coat white PES/CO	272
Shirt white PES/CO	73
Shirt dyed PES/CO	88
Shirt dyed knitted nylon	95
Dress printed textured PES	314
Worsted suit polyester/wool	492

The amount of energy tied up in textiles is high compared with other items of production.

	GJ/tonne
Textiles	200 - 500
Bricks	2.6
Glass bottles	23
Cast iron	44
Diesel engine	86

These high total energy contens result from the large number of processing steps that textile materials pass through and, in the case of man-made fibres, the relatively high energy contents of the raw materials. In the case of a polyester/cotton shirting fabric which is dyed and finished the gross energy requirement over-all is about 445 GJ/tonne and this can be broken down to the following stages:

	GER (GJ/tonne)
Fibre production	100
Spinning	90
Weaving	80
Dyeing	75
Finishing	100

How are the values arriv

In our auditing work the first objective was to determine the Gross Energy Requirement (GER) for selected products within the textile industry and then to break down these GER values to identify the energy contributions of all raw materials, production processes, factory services and any other factors. The GER is defined as the total amount of fuel energy, consumed or rejected as waste, needed to provide a tonne of product. As such, it must also include any primary fuel (coal, oil, gas etc) wasted during conversion to a form of secondary energy (e.g. electricity), as well as the gross heat of combustion of any process materials that have alternative uses as fuels.

Also used in auditing work is Process Energy Requirement (PER) which is the amount of energy both direct and indirect in the fuel inputs to an individual process to make a tonne of products.

Four regression levels of inputs for inclusion in the calculation of GER can be defined. These are summarized in Figure 2.

Level 1 includes all direct inputs of energy to the process and its associated services, including transport, within the specified audit boundary. As such it corresponds with the conventional fuel audit carried out by individual firms for costing purposes. Even in the most energy intensive industries, level 1 may contribute less than 50% of the total energy requirement of the product, and further regression is necessary in the analysis.

Level 2 includes all direct energy inputs to the manufacture of materials used in the process and will largely be accounted for by the direct energy requirements of previous processes in the textile chain. For material inputs from outside the textile industry GER estimates or values are usually available from other sources. Energy overheads are included at this level. In this study only the generation overhead for electricity has been used. This assumes a 30% efficiency for generation and transmission by the central grid. Studies up to level 2 are generally found to include some 90% of total energy requirements from natural sources.

For the purpose of this talk I am going to illustrate the findings in textile energy audits for a 50/50 polyester/cotton dyed shirting fabric of about 100 g/m^2.

Total Energy Content

Cotton - although this fibre is grown and hence harnesses energy from solar radiation there is an energy requirement in the growth and harvesting processes. As cotton is imported the energy required for fertilizers, pesticides and farming and for the harvesting and ginning do not directly affect U.K. energy use. Nevertheless, it is of interest to see the values estimated.

Polymer growing fertilizers pesticides etc.	1.7 GJ/tonne
Fibre production harvesting and ginning	31.4 GJ/tonne

Source A.H.Woodhead 9th International TNO Conference 1976

Polyester - the most commonly used preparative route for the production of polyester in the U.K. involves the polymerization of terphthalic acid (TA) and ethylene glycol (EG) which are obtained from the crude oil products para-xylene and ethylene, respectively. Comparatively recent technology has improved both the energy and overall economics of preparation of these intermediates. Some continuous air oxidation of p-xylene, followed by high pressure recrystallisation of TA from water has now replaced the less direct route of producing dimethylterephthalate (DMT) and the catalysed air-oxidation of ethylene to ethylene oxide, followed by reaction with water to form EG has also replaced the earlier circuitous route.

Polymerisation is still frequently a batch process from which molten polymer is cast into a ribbon and diced into chip form, ready for re-melting and a subsequent extrusion stage. The use of continuous polymerisation techniques and their integration with the spinning of polyester staple have been introduced recently, but are dependent upon product ranges and market conditions which will allow long production runs. Under ideal conditions, appreciable energy savings should be possible from such process integration, following the elimination of the casting, dicing, drying and re-melting stages of batch production. Spinning and subsequent processing obviously differ considerably for staple continuous filament products. For the purposes of this audit the polymer was taken as the starting material. In the case of staple, the polymer (after careful drying and re-melting in the batch method), is extruded through spinnerets with up to several thousand holes each; the fibres are subsequently drawn to improve their strength and orientation in tows of up to several million filaments and treated with an appropriate finish before cutting and baling.

In the case of continuous yarns, only a small number of filaments (5-50) are extruded from each spinneret, and each yarn must be drawn, processed, and wound individually; this greatly increases the machinery and energy requirements compared with staple yarns, as well as those of space, air conditioning and other services.

Examination of the batch methods for polymer production and subsequent staple fibre production shows that the GER to the second level is 174.3 GJ/tonne (Figure 3). Corresponding estimates for continuous filament production of mean decitex of 115 give 221.4 GJ/tonne.

Development of continuous methods for polymer production enable energy savings to be made by elimination of the polymer handling and chip cutting and drying. Savings of some 15% can be made. However, the continuous processing line has very high fixed energy overheads (85-90%) and this makes the production route extremely vulnerable to under-utilization of capacity. At the same time the full potential of this development has yet to be realized.

Another potential use for energy saving is the utilization of waste from which polymer is regenerated. Fibre can be produced from waste for an energy use of 46 GJ/tonne. In-plnt waste is normally utilized but so far the possibility of exploiting more general sources of waste, such as polyester-containing fabrics has not been fully explored.

Spinning, cotton system - A number of stages of fibre preparation are required for the spinning process.

Firstly, the compressed bales must be opened up to a soft fleece, with as few remaining tufts of fibre as possible; in addition raw cotton requires cleaning of dust and seed particles, and this is usually achieved by a system of pneumatic transport through a number of beating and cleaning points. Material loss at this stage may be 5% or more, compared with only some 2% for 'clean' man-made fibres.

The next step, carding, continues this process, but also serves to parallelise the fibres to a considerable degree; material losses here may by of the order of 4% for cotton and 2% for man-mades.

The rope-like sliver produced by this process still contains a proportion of short fibres, and in the production of higher quality fine yarns, these are often removed by a combing process. Losses here, and in the necessary preparative stages may be 15% or higher, again depending on the grade of the cotton and the desired yarn quality.

The orientation of fibres and evenness of the sliver is improved by a number of passages through drawframes, and blending of cotton and man-made fibres is also commonly done at this point. From here, the final stage before spinning is a preliminary spinning operation carried out on speed frames in which the thick sliver is narrowed to a lightly twisted roving.

Ring spinning is still the most widely used method of yarn production, although other methods, principally open-end spinning, are making progress, at least for coarser yarns. (This latter method also removes the necessity for a roving production stage).

The spun yarn must be rewound from small tubes onto larger packages, usually cones, and at the same time cleared of faults; cones are suitable for many textile uses, but further operations such as assembly of weavers' beams, or doubling may be necessary.

Despite every attempt to clean the fibres at earlier stages, there can be appreciable amounts of dust and fly generated at all these stages, especially carding, spinning and winding, and appropriate suction and air cleaning devices, are required. Temperature and humidity control are also important to a trouble free spinning process.

Total material losses, both intentional and otherwise, can be appreciable; for example 100 kg of 50/50 polyester/cotton yarn may typically require 56 kg of polyester and 70 kg of cotton; some of this waste may however be reusable for lower quality applications.

The gross energy requirement for spinning a polyester/cotton yarn of 24's count is 63.0 GJ/tonne (Figure 4). The energy requirement is related to the yarn count (Figure 5) as can be seen from the gross energy requirement for the production of a finer cotton yarn which was obtained by audit at a second mill. In this case the production of a 47's count cotton yarn required 87.6 GJ/tonne.

It is interesting to compare a break-down of the energy requirements for the two mills.

Process	Mill A	Mill B
	GJ/tonne yarn	
Opening (cotton)	0.42	0.80
(=per tonne raw cotton)	0.60	0.58
Carding, combing drawing, roving	2.08	1.91
Spinning	5.35	8.17
Winding	1.65	3.42
Air conditioning	1.32	5.11
Fuel oil	17.12	11.87
Lighting	2.30	2.35
Miscellaneous	0.44	0.97

As might be expected the energy requirements of opening (expressed in terms of raw cotton input) are similar in the two mills, as are those of the carding, combing, drawing and raising processes. The lighting requirements are also very similar.

Power requirements of spinning depend amongst other things on yarn count, package dimensions and spinning speed, and it can be seen from above that a doubling in count in Mill B compared with Mill A has produced a 53% increase in energy use. Likewise, the power requirement for winding the finer yarn is approximately double that for the 24's count yarn.

Air conditioning in Mill B is approximately four times that in Mill A; this is partly because of a higher airflow (500,000 cfm in B as opposed to 250,000 cfm in A) but also because Mill B was equipped with air re-circulation and filtration equipment. Since the surveym Mill B has reduced its air change rate some 20-30% from a perhaps unnecessarily high level, but is still paying the higher energy costs of a better environmental control system. Dust control legislation is likely to affect energy use in this area in future.

Comparison of the fuel oil usage for steam generation (and this largely for heating purposes) is difficult to make because of the difference in mill layouts etc., but would appear in both cases to be unduly large. Traditional mill design is wasteful of space (indeed there are often many completely unused rooms) and window areas are large. A few areas such as the ring spinning rooms do produce a heat surplus from the machinery, and the lower heating equipment for Mill B is perhaps one of the benefits of its recirculating air system; to an extent this would seem to justify the extra air conditioning costs discussed above. In both cases, relatively large heating requirements still follow the normal weekend stoppages in winter.

It should be noted the heating requirement can be completely eliminated by use of the heat generated by the spinning machinery. This is sufficient to maintain the correct levels of temperature provided the mill operates continuously.

In the case of one spinning mill (Mill B) a detailed estimate of the movement of energy within the site was made (Figure 6). From this estimate of the ultimate disposition of the energy could be made. Of the total energy input of 3971 GJ for an early winter month (36% was fuel oil and 64% electricity) the greater part left the site via the air conditioning exhaust 2715 GJ (68%) with 725 GJ (18%) lost through roofs and walls of the building and 534 GJ (14%) passing through the boiler house chimney.

Weaving - necessary preliminaries for the weaving process include assembly of the warp yarns onto beams, and in the case of cotton and man-made fibres, a sizing operation to improve the strength and abrasion resistance of the warp; a common size mixture for polyester/cotton yarns is a starch-polyvinyl alcohol mix (although a variety of other substances can be used) applied from aqueous solution, and dried over steam heater rollers.

A separate rewinding stage onto smaller shuttle packages (for the weft yarn) has now been largely dispensed with on modern looms, or incorporated into an automatic attachment such as the Unifil on each loom; weft supply is therefore usually from cones.

Weaving energy is related to the yarn count as a greater number of weft threads are generally inserted when finer yarns are used which require a correspondingly greater number of loom moverments.

For the weaving of 40's polyester/cotton yarn to produce a shirting fabric of about 100 g/m^2 the gross energy requirement is 78.2 GJ/tonne (Figure 7).

Dyeing and finishing - processes vary considerably depending on the type of fabric involved and its end use. There are three disctinct phases in the sequence of operations.

The first stage is preparation and it is in this stage of processing that the fabric is cleaned. Sizing materials, lubricating oils, spin finishes, natural fats and waxes and other impurities are removed by scouring, usually in hot alkaline liquors containing detergents. The fabric may then be brushed, cropped and/or singed to remove loose, and surface, fibres. The fabric may also be bleached at this stage to improve its base colour, this is particularly important when natural fibres are present in the fabric.

The second stage is to add colour or patterning to the fabric by dyeing or printing processes. These are to some extent complicated by the presence of two fibres in the same fabric which necessitates the use of two dye systems. Recent developments enable some pairs of fibres to be dyed simultaneously.

The third and final stage is to apply, as required, a finish which can include; resins for minimum-care or shrink proofing, softeners, soil release agents, flame retardants or water proofing finishes. At this stage the fabric is stabilized at its final width and weight by mechanical means.

Clearly there is a wide variety of processing steps which may be applied in the dyeing and finishing stages of manufacture. Further complicating factors from the point of view of auditing this section of the textile industry lie in the variety of types of machinery on which the processes can be carried out. Choice of machines is, to a large extent dependent on the size of the batch of material to be processed but can also be influenced by the final fabric requirements.

In this study two works were the subject of audit. There were considerable variations in the types of processing and of the types of fabric processed. However, it has been possible to separate out the processing steps and the energy requirements for a number of fabrics including shirtings and workwear. This present study is concerned with a dyed shirting fabric of polyester/cotton blend (100 g/m^2). Both shirting and workwear fabrics were processed by similar routes.

In preparation for dyeing the fabric was singed, desized, scoured and bleached. The fabric was singed by passage through a gas flame to remove surface fibres. Size applied to facilitate weaving was next removed in a pad-steam operation on a continuous range. For this the fabric was impregnated with a solution containing a starch degrading enzyme and then steamed to activate the enzyme and thus partially degrade the starch component of the size. The degraded material thus rendered soluble was removed by washing in a series of wash tanks in which the fabric was agitated in an alkaline detergent bath and then rinsed in a series of wash tanks containing hot water flowing counter-current to the fabric. Bleaching followed next in which the fabric was impregnated with an alkaline solution of hydrogen peroxide, steamed and rewashed. The fabric was then dried by passage over steam-heated cylinders.

Fabrics which are to be dyed are next heat-set at about 210°C on a stenter, this process stabilizes the structure of the fabric. The dye solutions used to impregnate the fabric are a mixture comprising a Disperse dye for the polyester component and a Vat dye for the cotton component. The fabric is pre-dried and then the Disperse dye fixed on the polyester fibres by the Thermosol process (i.e. by heating to about 190°C on a stenter). It is then treated further by padding with chemical developing solutions for the Vat component of the dye mixture, it is steamed to promote the reaction, washed, oxidized to complete dye fixation and washed to remove residual traces of unfixed dye and chemicals and is then dried on steam-heated cylinders.

A finishing treatment is applied to stabilize the fabrics and to give properties of crease resistance. This consists of an impregnation with a solution of the crosslinking agent and its catalyst together with a softener. The fabric is dried over heated cylinders and then heated to about 160°C on a stenter. In the case of work-wear fabric it is then passed through a compressive shrinkage unit to further stabilize the fabric against shrinkage. This consists of moistening with steam and then passing over a steam-heated cylinder at about 120°C under a rubber blanket.

These processes are mainly steam consumers and thus indirectly require an input of fuel oil. Approximately 80% of the total process energy requirements is in heating water or drying fabric.

Chemical inputs are difficult to estimate but consist mainly of alkalis, detergents and dyestuffs. Total usage is of the order of 150 kg/tonne.

Analysis of all these processes (Figure 8) yields a process energy requirement for a dyed polyester/cotton shirting fabric of 128.7 GJ/tonne and with an estimated 50 GJ/tonne for chemicals a gross energy requirement of 178.7 GJ/tonne. A parallel audit for white fabric gives a PER of 78.4 GJ/tonne with 25 GJ/tonne for chemicals.

A major factor in the energy consumption in these finishing processes is the requirement for heating water and for drying fabrics. It should be noted that in the processing of both the shirting and workwear fabrics that the fabric was dried at three or four points in their processing cycle. From IETS data the average energy use can be related to water use and some 0.6 MJ are required for each litre of water used. Hence a major factor in energy conservation lies in the reduction of the overall quantities of water used. This is a factor which has not yet been fully appreciated. In the case of dyeing fabrics where two fibres are present, i.e. polyester/cotton blends, it is necessary to dye both component fibres. This frequently means two separate dyeing steps with a consequent higher energy requirement than is the case with fabrics containing a single fibre type.

The composition of the fabric is dictated by the required properties of the end product and this in turn determines the rpocessing required.

Thus the total requirement to produce the shirting fabric in dyed form is 442.1 GJ/tonne. This can be broken down as follows per tonne of final fabric:

Polyester staple production	97.6 GJ
Spinning 47's count	87.6 GJ
Weaving	78.2 GJ
Dyeing	75.3 GJ
Finishing	103.4 GJ
Total	442.1 GJ

These results show the levels of total energy in a chosen textile broken down into the various processing stages. In realaity they are just the first steps in the level of auditing which will be required to provide the most useful information. What will be increasingly required will be sufficient information to establish the energy requirements which represent the levels of best practice. This information can be arrived at in two ways. One would be by casting the net much more widely and carrying out audit in many more establishments so that results can be compared between a range of mills carrying out similar operations. The second method would be by detailed survey, machine by machine, with detailed monitoring and analysis to establish the level of best practice and tot establish the effects of changing styles and level of throughput on energy requirements. At the same time comparisons can be made with the theoretcial requirement and areas worthy of further R & D work can be identified.

In the first method information can already be placed together. In the Industrial Energy Thrift Scheme, surveys have been made in most sectors of industry and the range of levels of energy usage have been identified. For example in dyeing and finishing the range of energy requirement (at the first level of analysis) is quite broad (Figure 9) and is closely paralleled by similar figures found in France (Figure 10). The use of these values is important in targeting; that is in setting targets for reduction in the energy requirement per tonne of production. This has been successfully employed in the Dyeing and Finishing sector of the textile industry in France, where reductions amounting to about 20% over 1974 levels have been achieved. It is hoped that with the support of the Department of Energy that a pilot scheme will be established for the UK dyers and finishers.

The second approach is also being examined in the UK. My colleague Mr Geoff. Parish is working on a monitoring scheme with the collaboration of a finishing unit of Tootals. This project is sponsored by the EEC, the UK Government through the Department of Industry and a number of industrial companies. This work will take the form of establishing the patterns of energy usage at machine level throughout the works and will establish levels of energy usage corresponding to individual machines and their type of production.

The results of these studies will be of considerable interest but it would not be correct to sit back to await the production of reports. Simple auditing steps can be taken by everyone and the possibilities should be examined. Advice is available from many sources - the Energy Audit Booklets in the Department of Energy's Fuel Efficiency Booklets, a wide range of consultants and, of course, the Shirley Institute.

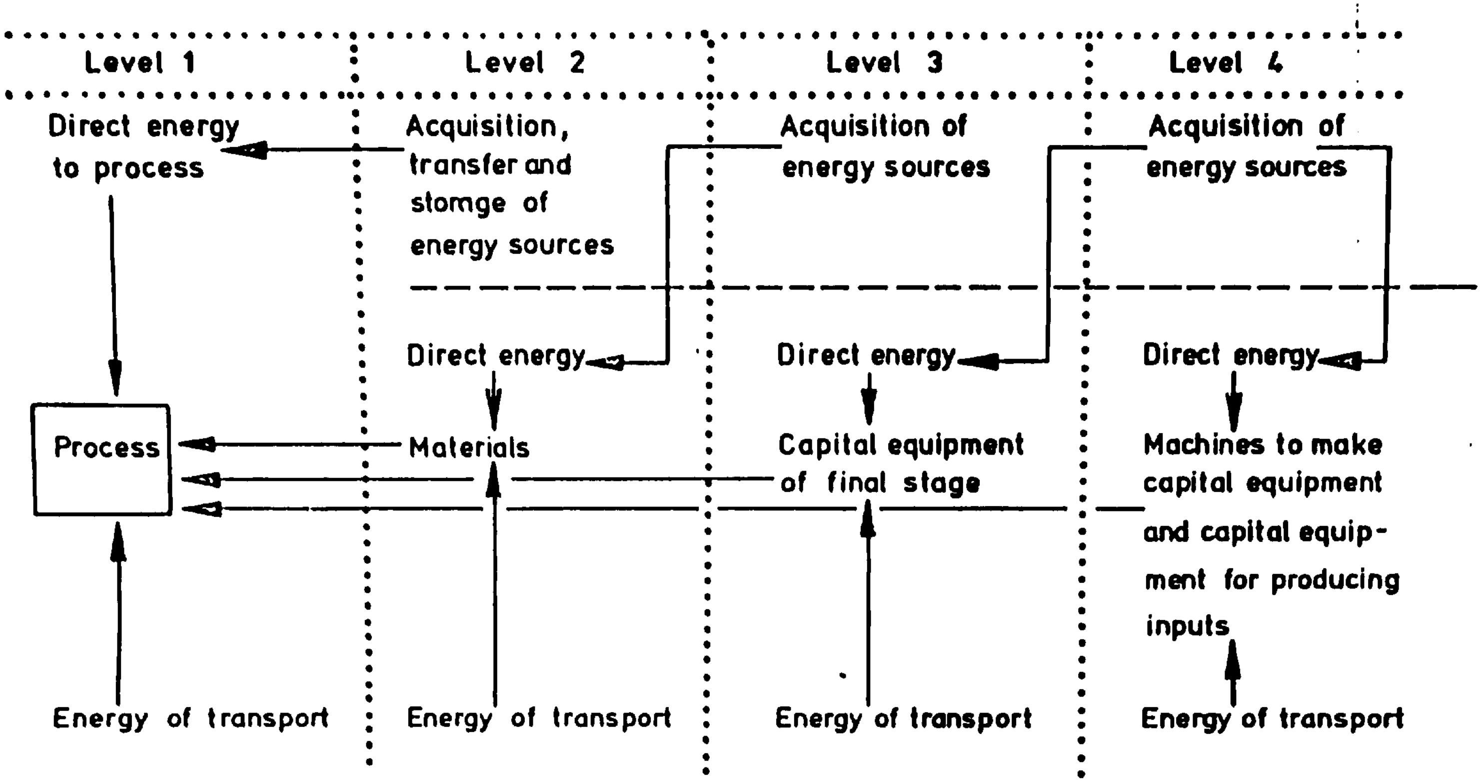
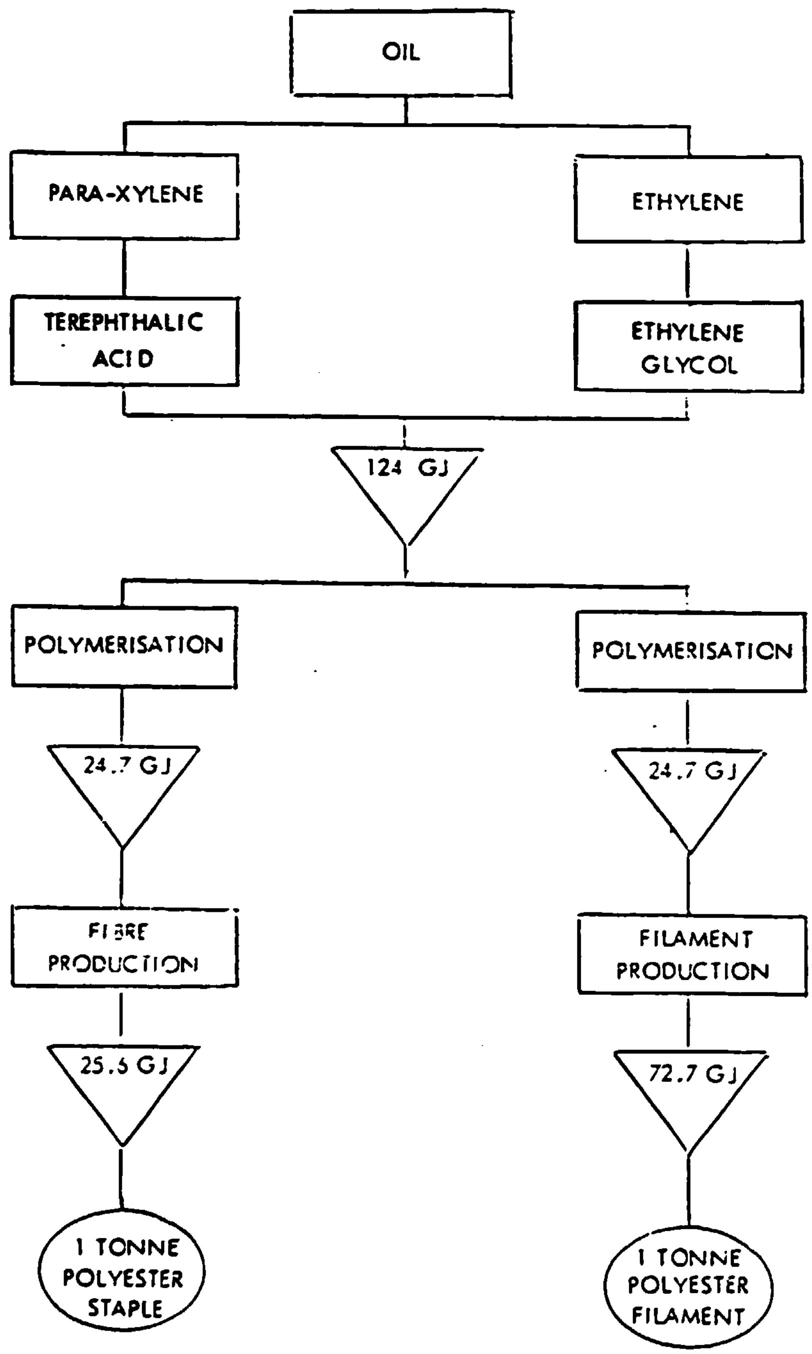


FIGURE 2 LEVELS OF ENERGY AUDITS (IFIAS)

PRODUCTION OF POLYESTER FIBRE FIGURE 3



POLYESTER STAPLE

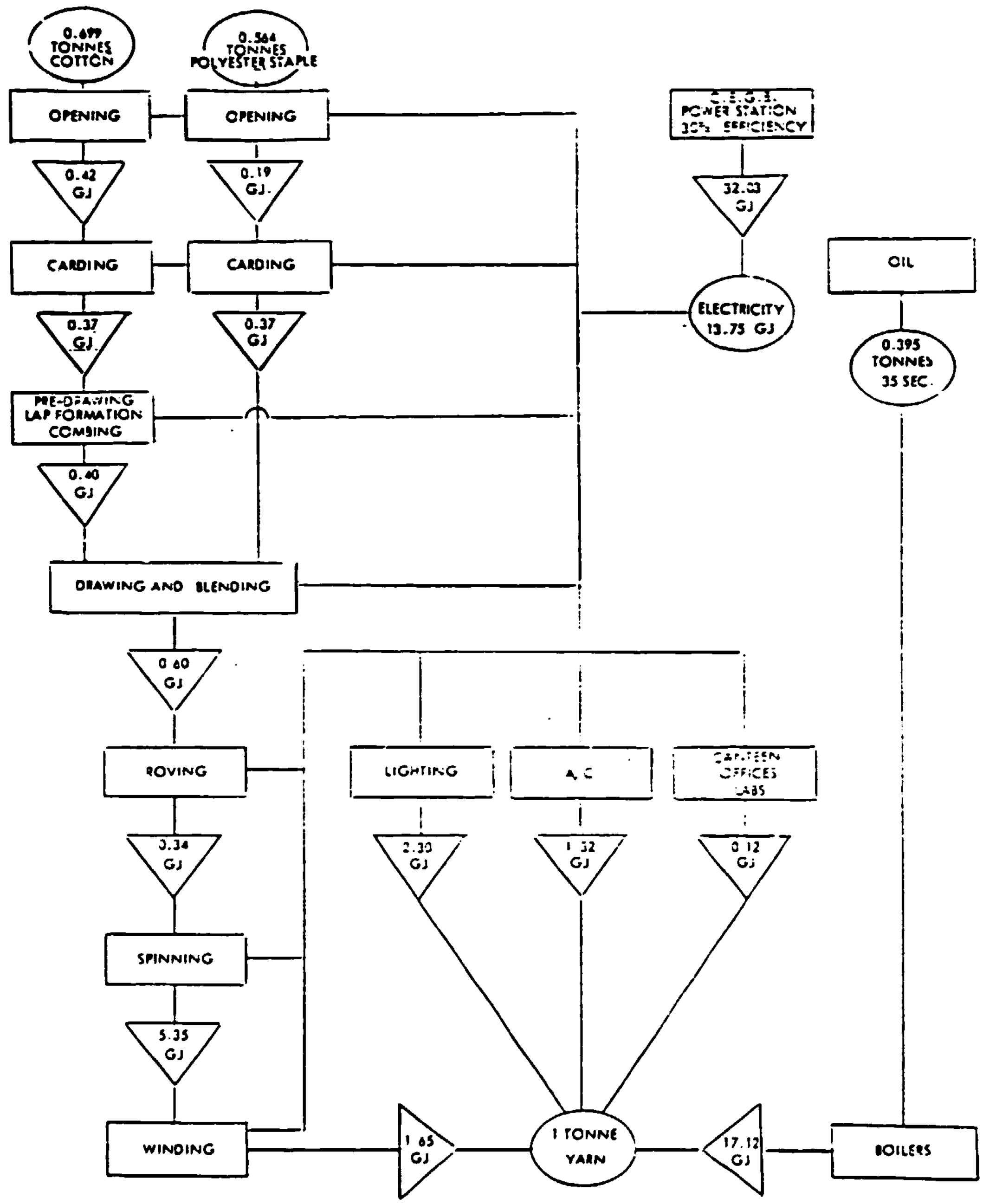
GER 174.3 GJ/TONNE

POLYESTER FILAMENT (115 DTEX)

GER 221.4 GJ/TONNE

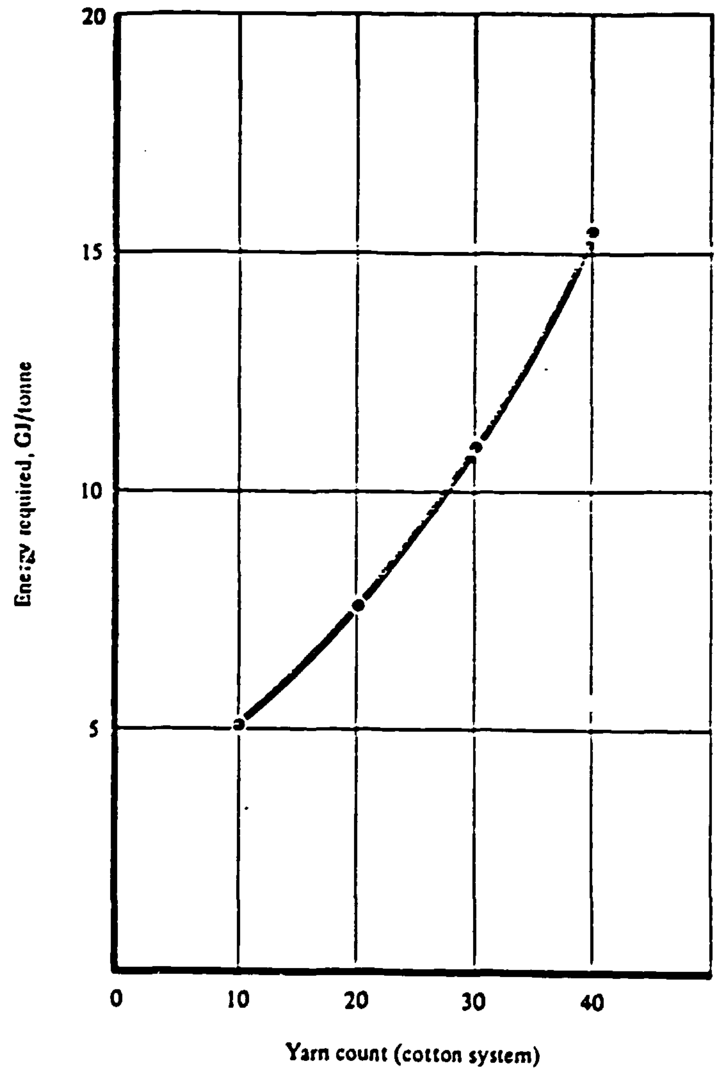
SPINNING OF POLYESTER-COTTON (50-50) 24's COUNT YARN FIGURE 4

MILL A.



PER 63.0 GJ/TONNE

FIGURE 5 **VARIATION IN ENERGY REQUIRED TO SPIN YARNS OF DIFFERENT COUNTS (ENERGY USED BY SPINNING MACHINE AND NOT TOTAL ENERGY AS DISCUSSED IN THE TEXT)**



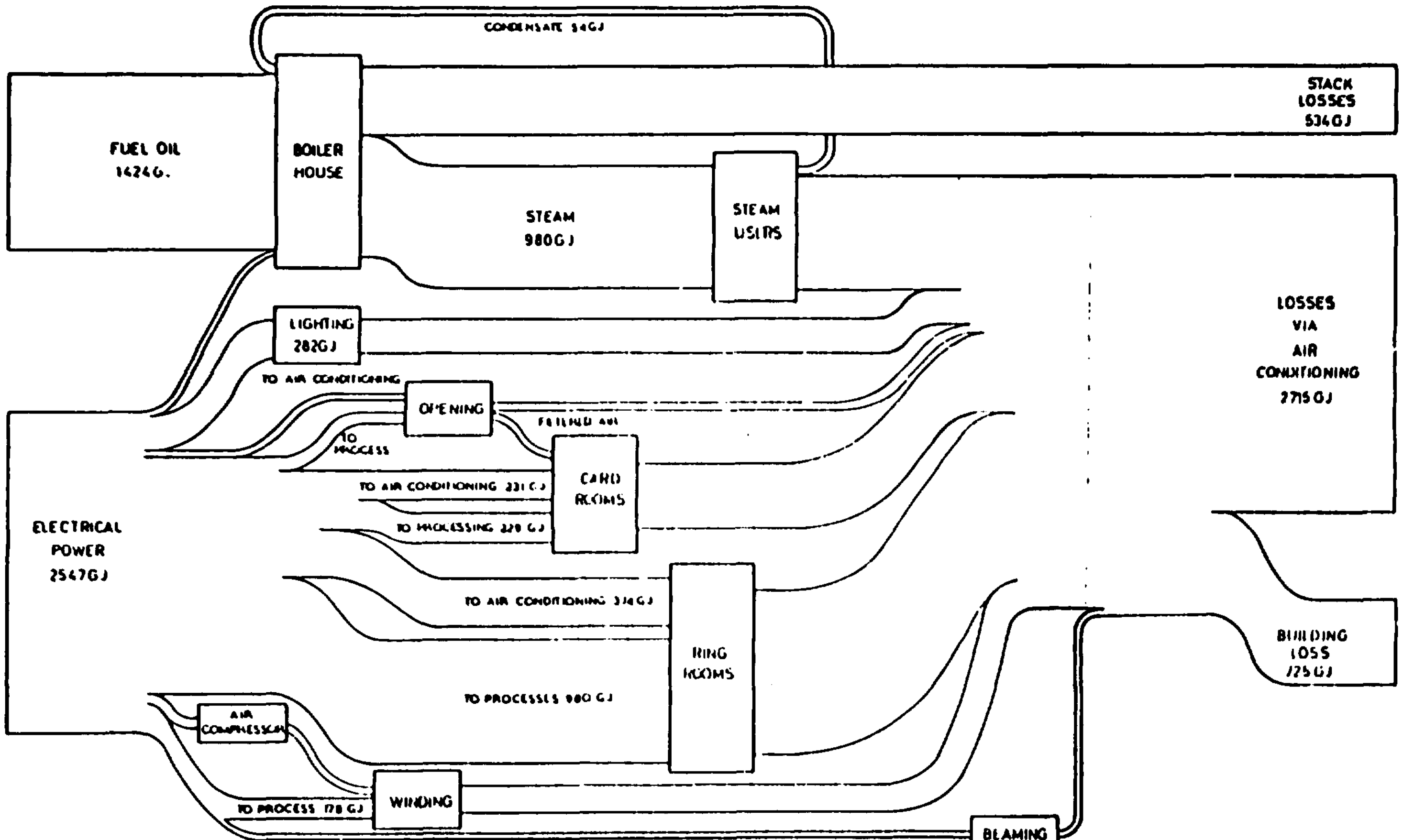
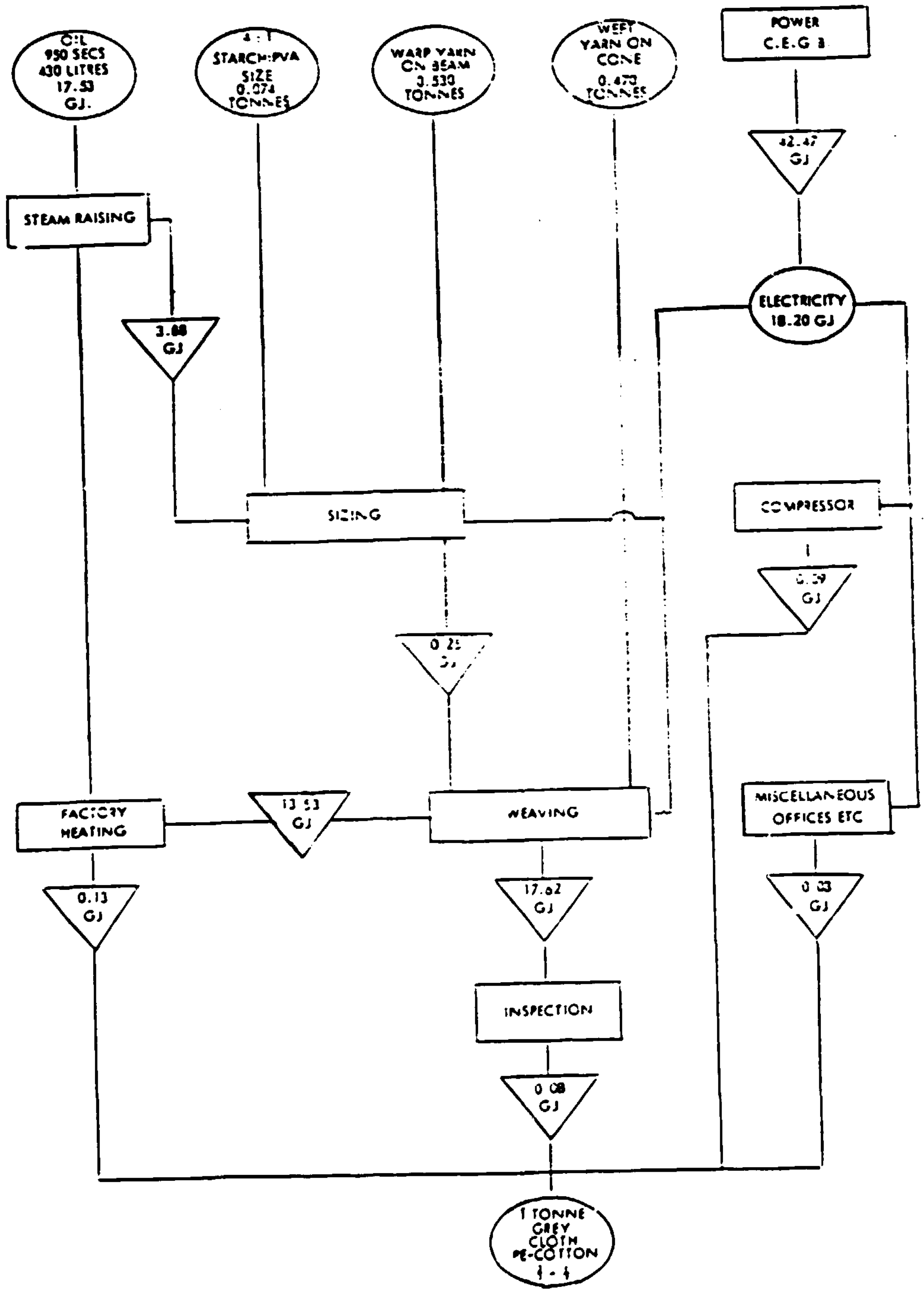


FIGURE 6 ENERGY FLOWS IN SPINNING MILL B

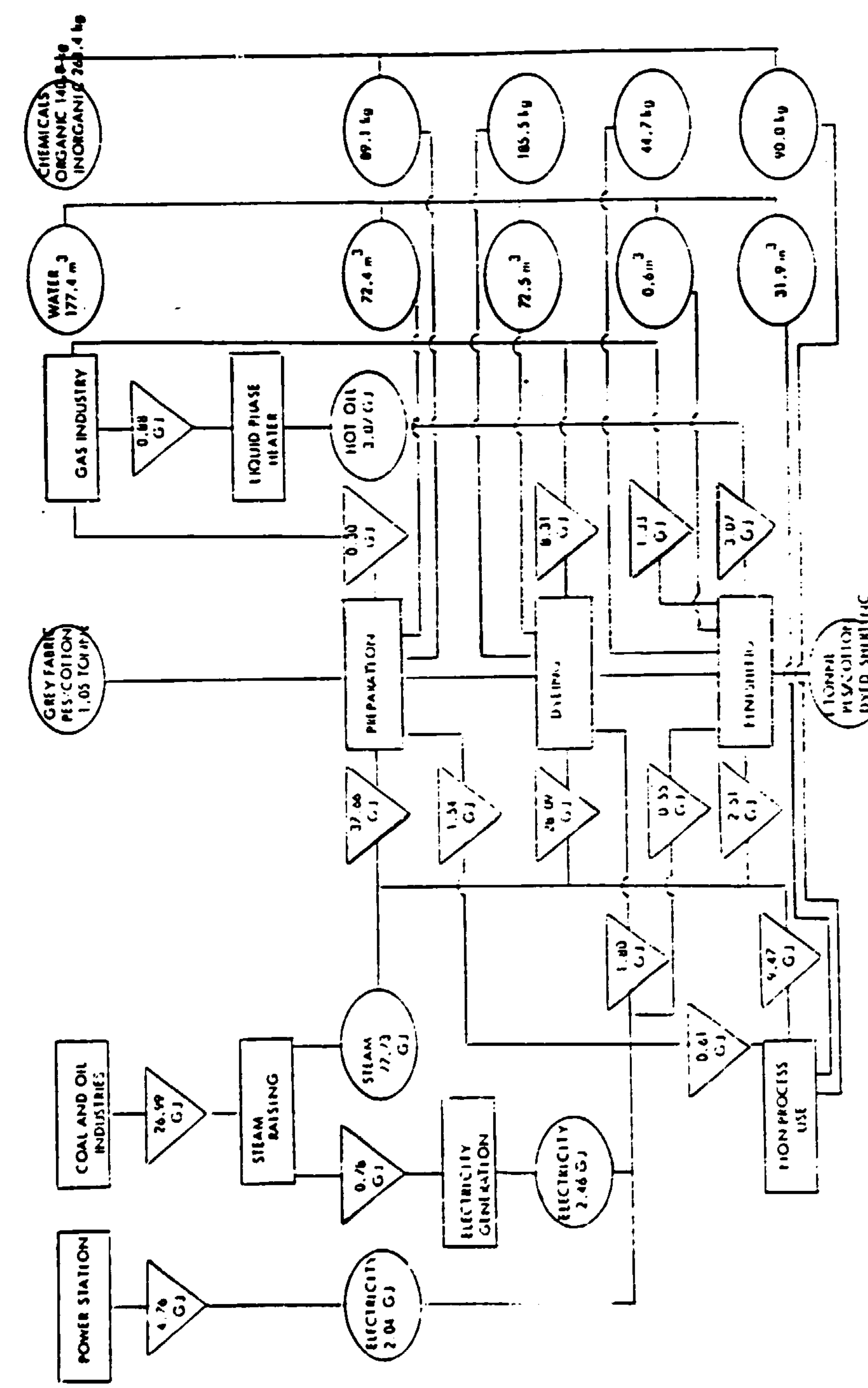
WEAVING OF POLYESTER-COTTON FABRIC

FIGURE 7



PER 78. /TONNE

DYEING AND FINISHING OF POLYESTER/COTTON SHIRTING **FIGURE 8**



PER 128.7 GJ/TONNE

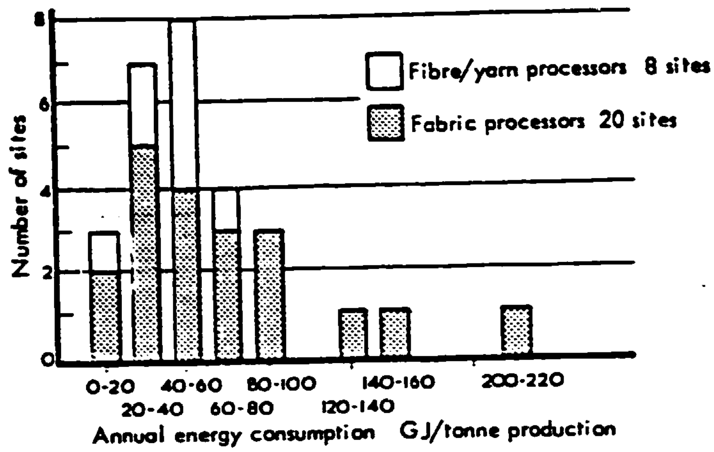


FIGURE 9 RANGE OF ENERGY CONSUMPTIONS IN UK DYEING AND FINISHING SECTOR (1976-77) AVERAGE 52.6 GJ/tonne

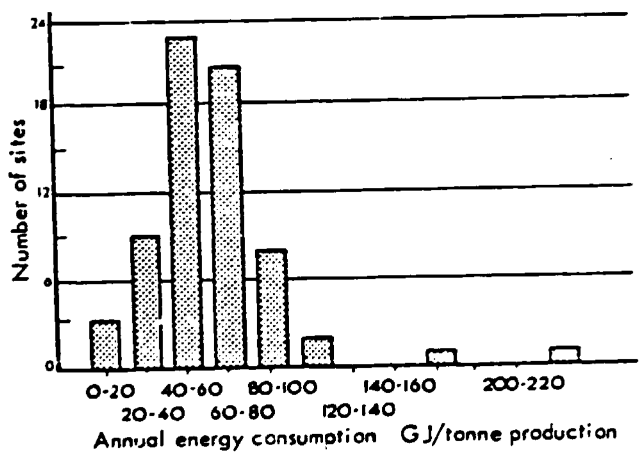


FIGURE 10 RANGE OF ENERGY CONSUMPTIONS IN FRENCH DYEING AND FINISHING SECTOR (1978) AVERAGE 57.4 GJ/tonne