INTERNATIONAL DISTRICT HEATING ASSOCIATION
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IN THE POLISH MANNER

WHY WASTE ALL THAT HEAT?

COMMITTEE ACTIVITIES

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Why Waste All That Heat?

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The combined production of heat and electricity is a long-established and successful technique for obtaining and putting to good use the maximum possible total of energy from fuels consumed in all types and sizes of electricity generating plants. Instead of the profligate waste of most of the fuel, inherent in thermodynamic generation of electricity alone, it ensures by utilizing the heat as well, that nearly all the energy produced in the boilers, gas turbines or engines is of real benefit. The common uses for this heat are for space, water and process heating and for air conditioning by means of absorption chillers. In many countries the heat is distributed in regions, towns, districts and villages for these purposes and for increased food production, road heating, swimming baths and, at very low cost, to keep sports grounds and stands frost-free. Insulated pipes transmit the heat as hot water to buildings and other loads. The cold water is returned to the power station unless, as in a few schemes, a once-through single pipe is used.

Each megawatt of electricity generated inevitably results in roughly two megawatts of heat, which if not used, has to be rejected into the atmosphere or waterways. The consequential heat pollution causes complaints.

It is apparently almost unknown outside engineering circles that the combined production of heat and electricity makes good use of nearly all (75 to 85%) of the energy in the fuel consumed instead of very little (20 to 40%) when electricity only is produced. Few realize that it also makes practicable further energy economies on an enormous scale. In district, town and regional heating schemes, power station reject heat is used instead of consuming primary fuels in the many thousands of boilers and heaters for domestic, commercial, industrial and public buildings. This technique saves also on building costs and space, roads, labour, materials and on the energy used by fuel vehicles.

Comparisons of Fuel Usage

The smaller boilers and heaters have maximum efficiencies of between 30 and 80% when new, clean and tested under ideal conditions on continuous load. Probably, they have annual utilization efficiencies (fuel into heat actually used) of between 15 and 55% under normal conditions and on intermittent load. The comparisons are shown graphically; performance data are from surveys in Germany, Scandinavia and USA. They are not unlike a comparison of the ratio of miles per gallon of a new perfectly adjusted car, driven at an optimum, constant speed under ideal conditions, with the annual miles per gallon of average use.

The largest boiler and total energy plants on continuous loads for extensive industrial and district heating schemes may have annual efficiencies of 75 to 85%, but the fuel they use could be saved if these loads could be supplied by power station reject heat, which would otherwise have to be dumped.

It needs a single responsible authority in each country to be able to see such opportunities for conservation and to take action.

Electric heating and transport. Electric heating may be 100% effective in its use of electricity, but the sad truth is that it dissipates 75 to 80% of all primary fuels used to create and distribute that electricity, unless the supply is from a combined energy station. Similarly, electric vehicles and trains, if supplied from power only stations, waste more primary fuel than if they were engine driven.

Heating—the largest energy demand. The latest statistics on energy consumption include the following figures:

	Per Cent of Total	
Sector	EEC	UK
Energy—including heating and cooling	8.3	8.5
Industry—including heating and cooling	38.5	37.4
Transport	14.9	14.4
Household	38.3	39.7
	100.0	100.0
Dependence on imported fuels	50.0	60.8

There is evidently a larger potential for economy in the use of fuel by using heat from power stations instead of from individual boilers and heaters, than by any other method of energy conservation. It therefore justifies a high priority in national and EEC campaigns. Again it calls for an organized authority having energy, heat and electricity, as a single responsibility.

Could all district heating be supplied from combined stations? Fortunately the answer is 'yes,' due to the fact that the heat/electricity ratio of production generally equates with that of the respective loads. During peak electricity loads there is a shortage of heat from the turbines. This is economical for design, because a town's heating mains and associated heat accumulators contain tens of thousands of tons of hot water which smooth out such interruptions. Small 'peaking' stations that are sometimes provided at economically strategic locations also help to balance the supplies of both forms of energy.

Electricity output is slightly reduced when heat also is used, but so are the electric heating and cooling loads. The sale of three times the amount of energy as before, for almost the same capital outlay and running costs, is generous compensation for the loss of say 10% of electricity.

A Policy of Combined Production

An announcement of policy and a programme for introducing combined heat and power stations, would undoubtedly give considerable impetus to the timely and rapid development of the district heating and other loads which are essential for the feasibility of the whole concept. The combined stations could be new ones, total energy sets, converted 'redundant' power stations, refuse incinerators or existing gas-turbine peaking stations modified to include waste heat boilers. National capital investment could be reduced by fewer power stations, fewer grid lines and cables, and by the saving on cooling towers costing up to £2M each, which sum would pay for heat mains to serve 20 000 domestic consumers.

Whether district heating schemes are to serve new or existing property, transportable boiler plants, as illustrated, are often used initially. In time these small schemes are interconnected and served from a district heating boiler house, which in turn is later replaced by a connection to the primary mains from a power station. In this way, no needless premature investments on heat mains and power station are made.

Refuse incinerators using non-recyclable waste as a fuel, provide energy for district heating, and in some cases, electricity too. This method of conservation solves refuse disposal and environmental problems and supplies about 10% of a town's heat load. It is useful at times when extra heat is needed, such as at peak electricity loads.

Sources of Energy

Will new sources of energy be a certain solution to the problem of balancing supply and demand? Engineers can look hopefully at ideas such as energy from nuclear fusion, uranium from the sea and energy from waves and tides, but they have to discriminate between possibilities and certainties. Engineers have the responsibility of making present decisions and plans for the future, on a certain foundation of facts and proven techniques.

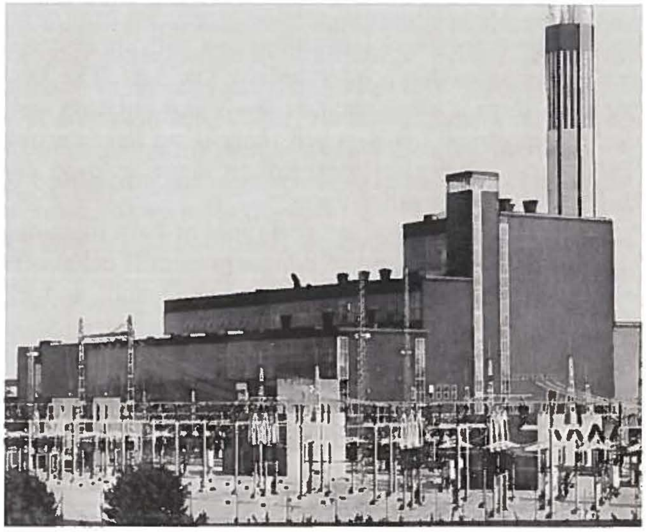

Fig. 1—Combined electricity and heat station, Orebro, Sweden. Outputs: 100 MW electrical, 200 MW heat at 90 C; hot water flow 7000 m^3/h; steam temperature 535 C; steam flow 130 kgs; return water temperature range 40-70 C.

There can be a temptation to forget energy conservation locally when new, valuable coal, gas and oil resources are discovered. The recent North Sea and Alaskan oil discoveries, for example, are immensely important economically to those concerned, but in the long term they have a comparatively short life and they will make only a 5% contribution to world oil output by the end of the decade. World coal reserves, including recent discoveries, are said to be so very considerable that they will outlast even nuclear fuels. Energy, like food, is needed by all now and in the future. Wasteful methods by some nations will not only endanger their own future, but will deprive others now and in the years to come.

Heat and Power Stations

A 500 MW_e combined heat and electricity station supplies roughly 1000 MW of heat, ample for a town with a connected heat load equivalent to 150 000 dwellings of average size. A 2000 MW_e station producing 4000 MW of thermal energy would nominally cope with several towns in a region. Electricity is the first priority, and the heat load in an established scheme is balanced by regulating the number of new connections, which are increased as more heat becomes available and as funds flow in from revenue.

There is a wide range of sizes. For example, combined heat and power turbines of 0.5 MW_e were once used, but 2 MW_e is now a minimum size. The maximum size in use in Sweden is 215 MW_e. There is design progress towards considerably larger sets in which the problem of the large volumes of exhaust steam has been overcome. There are cross-compound sets with three steam pressure stages—high, intermediate and low. The low-pressure stage is on a separate shaft and operates only at peak electrical loads, when there is no heat output. The steam from the intermediate stage is used for district heating at other times.

Combined generation uses all types of fuels including coal, gas, oil, refuse and of course nuclear. Fuel grades unsuitable for most boilers are used cleanly and efficiently in power stations. The SO_2 concentration in Västerås, Sweden, for example, is less than one-tenth of that in a town without district heating.

Gas turbine and diesel engine sets. Oil-engine-driven generators with heat recovery are used for estates, villages, islands and even for the transportable homes of nomadic peoples. The efficiency of a diesel-engine-driven generator increases from between 34 and 42% to between 68 and 75%, when heat is utilized from an exhaust waste heat boiler, and in larger sets from the cooling systems too.

Gas-turbine generating sets that are only 20 to 25% efficient have their performances raised to 70 or 85% with

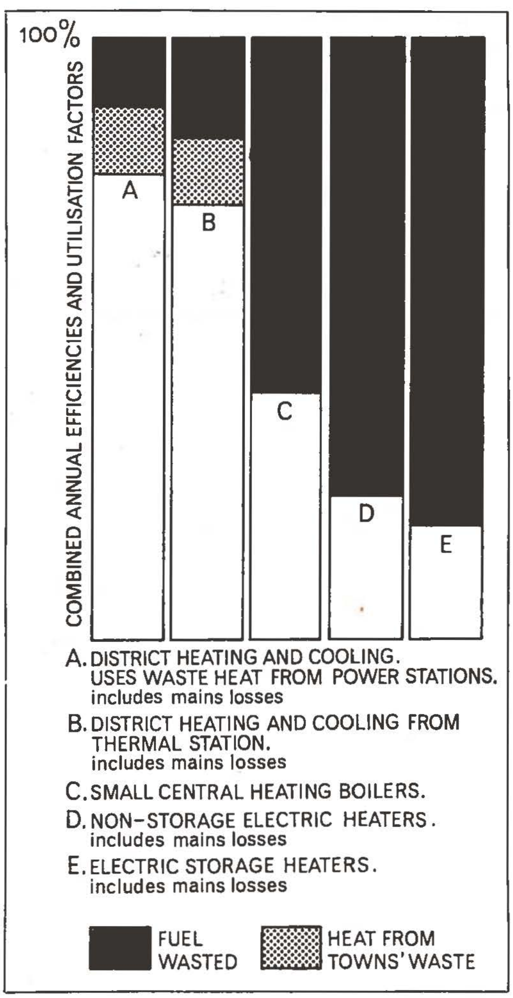

Fig. 2—Comparisons of fuel usage showing proportion of primary fuels wasted by alternative heating methods compared with combined heat and electricity production.

supplementary firing, when heat is reclaimed by means of exhaust heat boilers. These sets run continuously for thousands of hours, producing electricity and heat for heating and for process work, bulk drying,etc. The heat can be used in absorption chillers for air conditioning installations. The capital investment therefore brings a continuous financial return, especially as gas turbines can run on load for thousands of hours without the need for maintenance. The two largest gas turbines in the world, so it is claimed, supply some of the extensive district heating in Munich. They are 80 MW_e each, and supply 338 MW of heat.

Redundant power stations. Power stations declared redundant due to inefficiency, can be perhaps three times as efficient when the waste heat is utilized too. Existing plant, all or part, can be reused in a redesigned installation so saving materials, energy and national expenditure. An alternative method is to install heat and power gas turbine sets.

New power stations. In the urgent interests of saving fuel, no more electricity-only thermal power stations should be started. In fact, with the use of waste heat instead of electrical heating, the need for new stations is greatly reduced, which helps the national economy. The siting of stations far from population centres, in order to dump heat in rivers or the sea, is unnecessary when town buildings act as the heat sink. Cross-country single pipelines from remote nuclear stations cost less than the power lines.

Optimizing Energy Production

Turbine design. The cooling water from condensers in electricity-only stations is tepid. So to be able to use the considerable quantity of latent heat in its mass throughput, steam from the turbine has to be exhausted at a higher temperature and with a pressure higher than atmospheric. The alternative to this back-pressure method is to take off some steam from the turbine, at a suitable pressure and temperature for district heating condensers, at intermediate tappings. There are, in advanced designs, a number of tappings with automatic selection to maintain optimum total energy efficiency. Steam-turbine-generator design engineers in several countries including Sweden, Switzerland and USSR, have made great advances with techniques for maintaining optimum overall efficiency under all conditions of heat and power loads.

The best possible ratio of electricity to heat output, that is with the former as the priority, is the common objective for public or private energy-generating and supply authorities. There are of course some exceptions.

Selection of heat mains temperatures. One of the most important ways of obtaining the best power/heat ratio is by selecting the lowest possible return temperature, so that the water for the condensers is as cool as possible. This does not restrict the choice of the optimum Δt of flow and return mains temperatures, in order to reduce the capital and operating costs to a minimum. If 50 C is the Δt calculated to produce the most economical mains installations, then 90 C flow and 40 C return instead of say 120 C/70 C, increases the electricity output by 12½% without any technical or economic disadvantage to heat distribution. Whole town heating systems abroad are operating successfully at 90 C flow using heat transformer stations. The temperature is dropped to 80 C for normal operation. The return water can be cooled still further by the low temperature applications referred to in the introduction. The omission of insulation on return mains increases the station's electrical output, but it is not now acceptable deliberately to waste fuel for economic reasons.

The common design objective of maximum total energy from the fuel consumed, in addition to energy conservation, saves money and evidently produces the lowest costs of electricity and heat.

Telethermics

Telethermics, the long distance transmission and town distribution of energy in the form of piped hot or chilled fluids (usually water) is, like other pipeline applications, developing very fast and is a new high-grade sector of engineering.

District heating progress virtually stopped in Britain for two decades because the materials for, and the designs of, insulated underground mains were inadequate for the operating conditions. New materials and techniques have replaced them. The pipe-in-pipe coherent systems of prefabricated insulated pipes and fittings with presure-tight enclosures of the insulation have been introduced. These systems can be rapidly installed like cables, even in the wettest ground or under water. The heat losses have been measured over some years at maximum loads and temperatures and are extremely small. There is a British Standards specification, *BS 4508*, for some systems, and the latest performance specification is being circulated for comment. There is a code of practice, *BSCP 3009*.

There are about 50 cross-country insulated pipelines of diameters up to 1200 mm and lengths up to 100 km in use all over the world for telethermics. In all cases, the percentage heat losses on maximum load are in single figures, including one under 1%. Many other systems are either made in Britain or are being installed by British firms, including some long cross-country insulated mains overseas. Britain seems to be regarded as the leading authority in these techniques. A nuclear heat and power station is planned for Sweden, to serve three towns by means of a single insulated pipeline with a total length of 100 km.

The new coherent mains systems have made long distance heat transmission no serious difficulty and they have widened the scope of district heating down to lower load densities than ever before, including detached private houses at a few to the acre. This all helps to create adequate heat loads for the combined stations.

World Progress

Combined heat and power schemes were installed in Austria, Denmark, Finland, Germany, Hungary and USA late in the nineteenth and early in the twentieth century, since when the numbers have steadily increased. In recent years the growth rate has accelerated.

There are at least 22 large heat and power schemes in Western Germany where district heating increases by 20% per year. The objective is to have district heating in all towns as soon as possible.

There are six combined heat and power and 500 thermal only schemes in Denmark, with its small population. The figures suggest that Denmark has made the greatest progress per capita of all countries.

In Sweden electricity-only thermal stations will no longer be permitted, according to a self-imposed rule of the energy supply industry. The Swedish industry is half

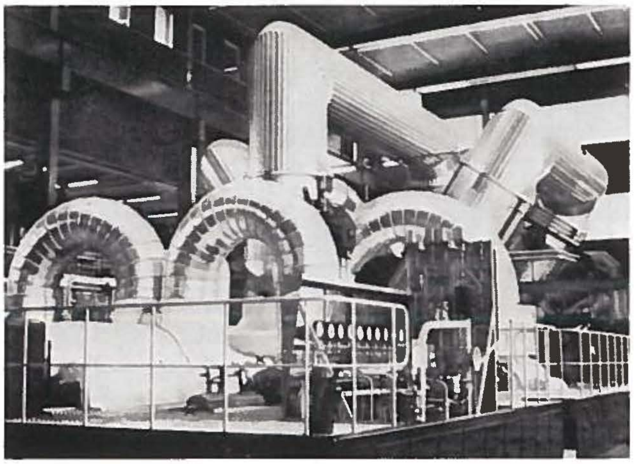

Fig. 3—Combined electricity and district heating turbine, Västerås, Sweden. Outputs: 215 MW electricity; 365 MW district heating at 90 C; hot water flow 6000 m^3/h; flow temperature range 85-120 C; return water temperature range 40-70 C. Actual annual efficiency in service, 85%.

private and half public. Its research and development, quality of design, extent of installations, and speed of progress, and the forward vision of all towns being district heated from combined stations and refuse incinerators by 1985, are remarkable. A 10 MW nuclear heat and power station near Stockholm has proved so successful that larger stations for whole regions are planned.

France does not seem quite so progressive with combined heat and power production so far. The use of district heating only is mandatory in new development areas, and there are hundreds of excellent schemes in towns and villages.

Finland has sophisticated district heating from large heat and power schemes, automatic peak heat stations, transportable boilers, gas turbines and total-energy refuse incinerators. The rate of progress and technological advance in heat and power generation is impressive, perhaps due in part to the fact that electrical and heating engineers work for a single authority.

Italy has good modern incinerator plants with energy recovery and a new power, heating and cooling installation in Naples.

Spain has a faster rate of progress than Britain with district heating.

Fig. 4—Transportable boiler plant, Finland, gives local heat supply for initial stages of district heating, pending build-up of load large enough for using power station waste heat when a number of such schemes are connected together.

Canada, USA, Hungary, Czechoslovakia, Belgium and the Netherlands all have some combined district heating and power schemes. Canada is very active with plans for energy conservation by the most modern methods.

The US energy plan includes district heating, refuse incineration, and combined heat and power generation. The US also has a few thousand total energy sets in use for all types of applications.

USSR has an enormous total of combined heat and power stations, and Japan has made great progress in only seven years. Poland, with its immense coal reserves, is expanding district heating. Central European countries also use much brown coal, and the trend is for heat and power production in some areas to use low-grade solid fuel.

The general rate of annual increase in district heating seems to be about 20%. Oil is used for most thermal only schemes. There is a discernible trend towards the ultimate supply of heat for population centres from combined heat and power stations, especially those using nuclear fuel or coal, and probably requiring cross-country telethermics single pipelines. Optimum total energy output and utilization is demonstrably the objective in design of turbines and of district heating systems, and it is interesting to observe the change, especially in the last year or two, from divided responsibilities and loyalties to the present cooperation of district heating and electrical engineers in the task of conserving energy.

A National Policy For Britain

Actions, such as the following, in the opinion of the author, need urgently to be taken. They would reduce national expenditure on capital programmes and imports. There would be considerable conservation of metals. Following an immediate national policy of centralised heat production wherever fuels would be saved by its full use, a reduction in oil imports of 25% would be the end reward. This is in addition to the vital economies from better insulation and controls such as thermostatic radiator valves.The risks to the nation of not following this action are increasing rapidly.

1. An urgent programme of top priority for energy conservation by the combined production of electricity and heat, and for the more widespread and rapid development of district heating to create the heat load.
2. A single authority responsible to Parliament for coordinating the production and utilization of district heating from thermal plants and combined heat and power stations, including nuclear. It should be responsible for the heat mains, including development, testing, standards and legislation. Parliament should quickly introduce an Enabling Act for district heating and telethermics.
3. 'Energy' instead of 'electricity' in the titles of the generating and supply authorities. Their charters to be modernized to cover laying of mains and sale of heat to consumers, owners, authorities or to heat service operators.
4. No new electricity-only thermal power stations. No power stations to be made redundant until the energy authority has examined the fuel economies of conversion to combined heat and power. Existing power stations to be surveyed with the objective of re-use of all or part of the heat at present rejected.
5. Schemes to be designed and supervised by consulting engineers selected for their experience, and that of their associates from overseas, of the combined production of electricity and heat.
6. All schemes involving large aggregates of heat energy loads, including building developments, upgrading schemes, existing and new towns, to have consulting engineers' reports at very earliest stage of planning on the comparison of optimum energy production and utilization methods including combined heat and power.
7. In schemes involving public or trustee funds, it should be a condition of approval by the energy authority that the use only of heat mains systems to British or equivalent overseas standard specifications and proved by independent tests should be used, and that they should be installed only by certified thermal mains jointers tested to national standards.
8. All heat producing appliances and plant should be labelled (the labels reproduced in any advertisements) with the certified quantity of primary fuel used, directly or indirectly, for their declared useful heat output. Wasteful methods should be penalized by taxation.
9. All refuse to be incinerated. No refuse incinerators without heat recovery and reclamation of metals. ✱

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