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IEA – Energy conservation in buildings and community systems

Program for community systems
Swedish report

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CONTENTS

1. INTRODUCTION

At the International Energy Agency Executive Committee meeting in Amsterdam, held in June 1982, the decision was made to start a Research, Development and Demonstration Programme for Community Systems.

One of the reasons stated for the creation of such a programme was that too much interest had been directed towards the development of annex-agreements for the housing area even though a great potential exists for the development of Community Systems.

The task of co-ordinating the effort was entrusted to the vice-chairman of the executive committee: Mr. Lars E. Sundbom, Windborne International AB.

This paper is a first attempt at making a presentation of the Swedish proposal for what will be the main theme of the work. It is also meant to assist the parallel discussions conducted in other countries on the best method of carrying out their own work.

The Swedish report has been prepared by:

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2. DEFINITION OF COMMUNITY SYSTEMS

A general definition of Community Systems could be "the infrastructural supply-systems essential to the proper operation of a town, i.e., the transportation systems for people and goods, the supply of water and removal of sewage, and the refuse-handling systems with their implications for energy requirements and potential energy sources".

Community Systems, as a subject for further development within IEA, has also been defined to include models for optimization of energy supply and conservation at the community level.

For reasons of priority, parks and green areas were not taken into account during the first stage, even though they are considered to be an element of Community Systems. However, it should be borne in mind that green areas, tree-planted spaces etc, do provide protection from the sun and the wind for buildings.

The transportation sector has been excluded also since it generally falls within the working spheres of other Executive Committees.

The energy system will, however, be considered within the range necessary for developing water, sewage and refuse-handling systems as a waste derived source. Especially, small-scale technologies for the local use of waste heat will be considered.

The co-ordination of plans developed within IEA for district heating will be deployed at a later stage.

3. OBJECTIVES AND AREAS OF STUDY

The programme work should contribute to an increase in the international exchange of knowledge, ideas and products, all with the objective of achieving a reduction of energy and oil consumption within the IEA states. This involves a broad committment of research and development resources as well as resources of the industrial sector to realize the programme goals.

Possibilities are limited for systems within existing settlements, whilst there are completely different degrees of freedom in the establishment of new settlements.

The differences are so great that a division of the programme into two parts is warranted:

* Existing settlements
* New settlements

As mentioned earlier, within this framwork the following systems will be taken up for discussion first:

* Water supply and sewerage
* Refuse handling
* Small-scale energy systems

The study will deal with the following subactivities:

1. A survey of the technology and organizational principles most frequently used in Community Systems.
2. A compilation of data regarding direct and indirect use of energy in Community Systems.

3. A description of circumstances which are relevant to the use of Community Systems as a source of energy (temperatures, quantities etc).

4. A survey of ideas for new technical and organizational solutions which could diminish the use of energy in Community Systems

5. A survey of ideas for new technical and organizational solutions which makes it possible to use Community Systems as a source of energy.

6. A discussion regarding the introduction of the techniques mentioned in item 4 and 5 depending upon the specific situation in different countries and the economics of these techniques.

7. A discussion regarding changes in the Community Systems as in item 4 and 5 depending upon organization and investment capacity.

8. A discussion about what techniques can be suitable in the development of international co-operative efforts and what techniques are already available in some countries but may be of interest to other countries.

For small-scale energy systems the following topics are relevant:

A. The most suitable energy system for the utilization of waste heat; specification of demand.

B. Low temperature techniques and waste heat utilization.

C. Technical systems for utilization of waste heat.

The recovery of material from refuse and drainage systems will not be included, since this is not a primary energy issue.

It is suggested that the points mentioned above should be carried out by all participating countries. Sweden is prepared to arrange in systematic order the incoming contributions for the project report.

This draft mainly deals with points 1 to 3. A presenttation of a synopsis of point A to C will be included later.

Finally, to give an idea of the logic behind the analysis and assessment of the obstacles is enclosed in Appendix 1.

4. ENERGY CONSERVATION IN SOLID WASTE MANAGEMENT SYSTEMS

4.1 Introduction

A developed, industrialized society generates a large amount of waste products in conjunction with production and consumption. Waste is assembled and processed in a variety of ways which require energy for handling and disposal. Many possibilities exist for recovering energy from waste.

Waste has considerable energy content. For example, the direct energy recovery that can be achieved from incineration of the waste products generated each year in Sweden has been estimated to be about 10 per cent of the country's total energy requirements. However, this concept of "waste" also comprises waste oils, bark, chips, straw and other similar products which are not normally dealt with by public-operated management of waste products. The potential which is recoverable in practice is smaller, but this by no means implies that it is of no interest.

This chapter discusses first of all energy economy in conjunction with the treatment of solid wastes produced by household, commercial and industrial sources, i.e. the types of waste products which make up the bulk of municipal waste treatment and disposal in built-up areas. The yearly amounts generated in Sweden are stated in Table 1.

Table 1
Swedish Industrial and household solid wastes, 1981.

Types of waste normally[1] processed in a conventional municipal waste disposal system	Amount in metric tons per year	Specific amount Tons per inhabitant and year
Industrial waste from manufacture and commerce including construction waste and rubble	4,500,000	525
Household waste and comparable waste from shops, offices etc.	2,500,000	290

[1] Neither agricultural, forestry waste products, fish-processing offal, mining industry, refuse nor hazardous chemical waste, sludge etc, is included.

This chapter is intended to direct attention to those parts of the waste management process which are of most interest in terms of energy, and to outline various possibilities for future development.

4.2 Legislation and organization

To what extent the design and operation of waste treatment systems as well as the use of waste products are subject to change and improvement depends upon its organization and upon existing legislation.

The basic attitude taken by society to the question of wastes is of particular importance. Should wastes be regarded as a problem of disposal or as a natural resource?

The Swedish government has clearly stated that wastes are to be considered primarily as natural resources which should be recovered to the greatest extent possible. This view thus characterizes Swedish legislation relating to waste products. In order that the intention of the law be fulfilled, it will for example be necessary to co-ordinate the resources available for waste management. This responsibility for the most part has been put into the hands of local government.

Therefore, the municipalities in Sweden carry great responsibility for the management of waste products, and also have a large say in the manner in which waste product management is conducted.

4.3 Technical aspects of solid waste management systems

The expression "waste management" is the collective concept for:

* Refuse collection	Assembly Storage Collection Transport Compaction
* Waste treatment	Comminution Separation Composting Incineration

* Waste disposal — Deposition, Dispersal

* Recovery — See below

Recovery, i.e. the exploitation of waste, can be effected in most of the stages of the waste management system. Starting with the energy aspect, energy can be recovered primarily in two ways:

* Direct energy recovery by conversion of the calorific value of the waste into energy as a result of incineration.

* Indirect energy conservation by materials recovery, wherein energy bound materials can be exploited for the production of new raw materials.

4.31 Energy consumption in processing waste

Processing waste energy above all in the form of fuel for transport, fuel for heating and electric energy for machinery, lighting, etc. To permit comparisons of energy consumption between the different stages of the processing chain and the energy bound in the waste, a comparable energy measure has to be introduced.

The energy coefficient "e" has been chosen as the energy measure: it is defined as specific energy amount in MJ per metric ton of waste which expresses the energy amount that is required or that can be recovered in a certain operation of the waste management process under certain given conditions.

The specific energy amount (e^T) at transport in MJ/ton can be expressed, in a simplified manner, by the following relation:

$$e^T = \frac{\textit{Vehicle fuel consumption (MJ/km)} \cdot \textit{Transport distance (km)}}{\textit{Waste load (ton)}}$$

On transfer and treatment of waste the corresponding coefficient (e) can be obtained by direct measurement taken at the plant.

The energy coefficient for various processing operations of the waste management systems is shown below in Table 2. The figures are based upon Swedish conditions, i.e. and efficiently organized refuse collection and modern waste processing operation.

Table 2
Specific energy consumption in MJ/ton of waste in various processing operations.

Processing operation	Energy consumption (e) in MJ/ton of waste
Transportation in the building assembly	0 – 50
Collection in built-up areas	50 – 150
Transport 20 km and empty return	50 – 200
Transfer	20 – 50
Compactor deposition on landfill	50 – 100
Comminution – separation – composting	100 – 250
Incineration	100 – 200
Gas recovery	100 – 200

Waste-product management, as a rule, is fashioned according to certain requirements placed on hygienic standard, and good local and working environments. It seems difficult, without lowering standards, to effect essential economies of the energy demand in waste management.

It should also be observed that waste management is not primarily optimized with respect to energy consumption, since the energy cost in most cases constitutes a small part of the total cost of waste management.

4.32 Energy recovery in conjunction with waste management

Energy can be recovered from waste both directly by incineration or gas recovery, and indirectly by materials recovery. On direct incineration, the energy yield is influenced by two decisive factors:

* The calorific value of the waste, which in turn is dependent on the composition of the waste, the moisture content and the ash content.

* The incineration efficiency.

Swedish household waste contains a large proportion of paper and plastic and is relatively dry, which gives the waste a lower calorific value[1] of <u>about 10,000 to 11,000 MJ/ton</u>.

The incineration efficiency is about 60 to 65 per cent, which means that the energy yield can, on average, be estimated at about 6,500 MJ/tons of waste.

Concerning gas recovery, the energy yield will generally be lower, whereas indirect energy conservation by materials recovery can give considerably higher values, which are dependent on how many times the material can be recycled. Material that has been recovered one or more times can in addition be incinerated in a final stage.

Summerizing, it may be established that:

* The energy consumed in the waste management processes is small relative to the calorific value of the waste.

- Energy economy in conjunction with waste management should be concentrated to different ways of exploiting the inherent energy content of the waste.

[1] When calculating the lower calorific value it is assumed that the water content escapes in the gaseous phase together with the flue gases.

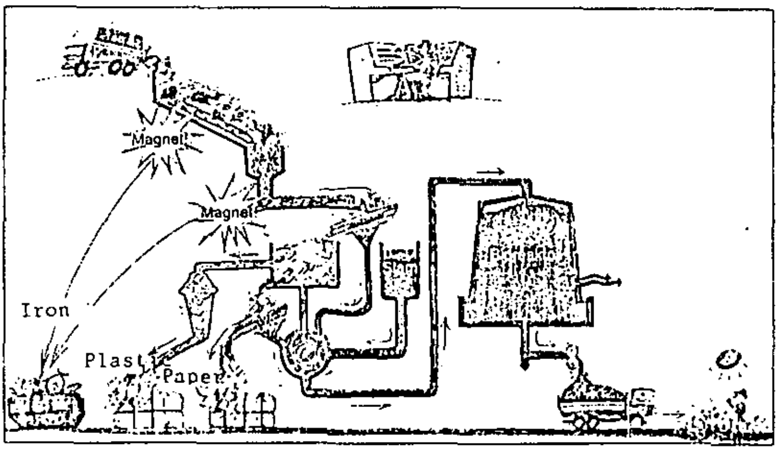
4.4 Methods of energy conservation

4.41 Materials recovery from solid waste

The type and composition of the waste can vary greatly owing to industrial structure, patterns of consumption, standard of living, etc. In an industrialized country with a high standard of living, the waste consists, to a great part, of paper, plastic, metal, etc. Household waste also contains a sizeable proportion of organic (degradable) matter in the form of food remains and the like.

If these materials are recovered for renewed use in production and consumption, then great indirect energy savings can be made.

Table 3



Separation and treatment of solid waste.

Table 3, by the way of an example, shows the amount of energy saved when waste paper, iron and plastic are recycled once.

Table 4
Gross energy savings as a result of recovery of three materials from one ton of waste.

Source: L.G. Lindfors, Institute for Waste-Handling Technology.

Material	Assumed proportion in the waste % by weight	Theoretically recoverable material from the waste % by weight	Gross energy savings in MJ/ton of waste in one recycling operation
Paper	45.0	35.0	2800
Iron	5.5	5.0	500
Plastic	7.0	6.5	5300
Total MJ per ton of waste			8600

As it should be possible to recycle the material several times (5 to 7 times for paper should be possible) the total energy savings may amount to multiples of value given in the table. In any case, paper and plastic may in addition be incinerated after final recycling.

Thus the energy potential is high when materials are recovered from waste. Hitherto however, great practical difficulties have been experienced at the recovery stage.

The difficulties of recovering pure materials from waste generally increase with the distance from the source of waste. With central separation of household waste it has thus proved difficult to obtain material qualities acceptable to industry. Today, one makes one's way, but falls short of the goal.

As for pre-separation at source the problems associated with information, storage and assembly must be duly considered. In Sweden, a certain amount of trial activity is underway using both central separation and pre-separation at source. A great many experiments have been made to date.

The following questions should be elucidated as a step in the improvement of recovery of usable materials from waste products:

* How is the separation equipment to be operated and, if necessary, complemented in order that quality requirements be satisfied?

* Which additional equipment is needed in industry in order to permit the use of recovered materials?

* Is it possible to convert in a simple way existing but inoperative industrial plant into reprocessing centres for recovered products?

* Which products are best suited to incorporate recovered raw materials?

* How could industry be persuaded to increase the use of its own waste materials, which today are discarded?

* Which method for storage, assembly and collection are suitable for household waste pre-separated at source?

* How can households be motivated to pre-separate their waste?

* Can a system of fees be used as a control instrument?

* How should the profits derived from materials recovery be distributed to the various parties concerned?

* How can materials and goods production be encouraged to facilitate materials recovery?

4.42 Fuel production from solid waste

The difficulties encountered in recovering materials of a satisfactory quality by the central separation process have focussed interest instead to the production of a refined fuel product (RDF) from waste. When producing RDF, one endeavours to concentrate as much as possible of the combustible material from the waste into a single fraction.

A waste fuel (RDF) can be created by separation, at times in combination with pelletization, which has a lower calorific value of 12,000 to 14,000 MJ/ton of RDF. The RDF fraction normally constitutes about 45 per cent of the waste content (if one starts from household waste), for this reason the fuel energy quantities per ton of waste are reduced to <u>about 6,000 MJ/ton (e)</u>. The efficiency of RDF incineration can be estimated at about 65 to 70 per cent, the energy yield thus being about 4,000 MJ/ton of waste.

The advantages gained by using RDF as a fuel compared with unseparated waste are, principally:

* RDF should be able to be used in simple, solid fuel plants.

- RDF, in certain forms (for example, pelletized), should be able to be stored for, say, a summer period.

* RDF is easier to transport.

* RDF should produce less emission and therefore require only simple equipment for the collection of flue-gas dust.

A great many RDF fuel producing plants are already in operation in Sweden.

However, RDF combustion is more difficult than expected, and for this reason only a small proportion of RDF is currently used, mainly in plants that rely upon conventional waste incineration.

The following questions should be answered, if RDF is to be put to greater use in the future:

* How should the fuel be classified and what requirements should apply?

* How should the grinding and separating functions be optimized in order to provide as "good" a fuel as possible?

* How should the hydrogen chloride and metal content of RDF be reduced even more?

* Would the pelletizing processes be modified or simplified?

* Which distribution and storage methods would be most suitable?

* Which furnace types would be most suitable for RDF combustion?

Should RDF combustion take place in smaller plants? (an interesting furnace type at present being developed in Sweden is the gas turbine which is based on a simple pyrolysis process, combined with combustion of the gas generated).

4.43 Gas recovery from household waste (Direct energy recovery)

Technically, gas recovery from waste can, principally, be carried out in two different ways:

* By pyrolysis, which implies that the waste is gasified by heating, wholly or partly in the absence of oxygen.

* By anaerobic fermentation of the organic content of the waste.

Pyrolysis of unprocessed waste has been tested in different parts of the world, but the experience gained has been definitely negative. This technique will not, therefore, be discussed further (for pyrolysis of RDF, however, see the preceding chapter.

The method of anaerobic fermentation is based on the fact that the organic content of waste under anaerobic conditions produces methane gas. In natural concentrations (about 50 per cent methane) the gas can be directly used for combustion in a gas-fired furnace, but could also, after purification, be distributed as city gas.

The prerequisites for gas recovery from household waste by a controlled digestion process in reactors or rock caverns, are at present being investigated in Sweden.

It is estimated that the amount of energy made possible by controlled gas recovery would be from about 1,000 to 2,000 MJ/ton of waste.

The following questions have attracted attention during the development phase:

* How should the operation of the process be optimized?

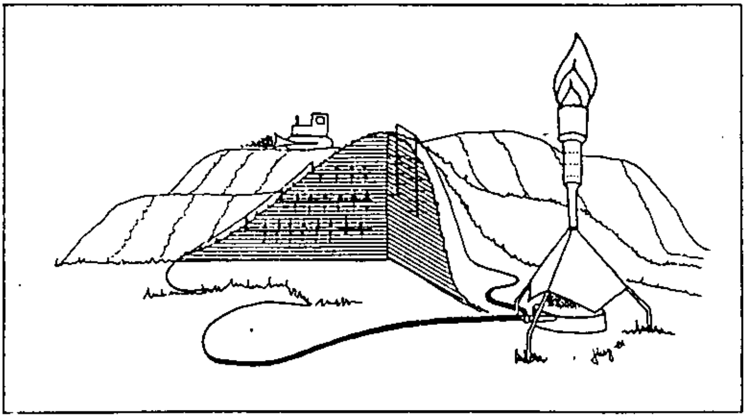
* To what pre-treatment should the waste be subjected prior to gasification?

* How is the residual product of the gasification processed?

* What gas quality should one aim at?

* Which safety aspects must apply to the process?

Another gas recovery method, the development of which has been driven considerably further, is the recovery of gas directly from landfill sites.



Principles of gas production in a sanitary landfill

The anaerobic process in a landfill site takes considerably more time than when a reactor is used, but considering that waste was earlier deposited for long periods of time, the sites contain a not insignificant potential energy source. It is estimated that waste deposit on landfill sites can produce gas up to 15 years. On this basis, the energy amount can be estimated to be 1,000 to 2,000 MJ/ton of waste.

This method is interesting insofar as the natural discharge of gas from landfill sites in many cases creates moisture problems and disturbs the surrounding vegetation.

Apart from the interest in a purely technical follow-up of the method, some interesting questions have been framed with a view to increasing the possibilities for gas recovery:

* How should the waste be pre-treated prior to deposition?

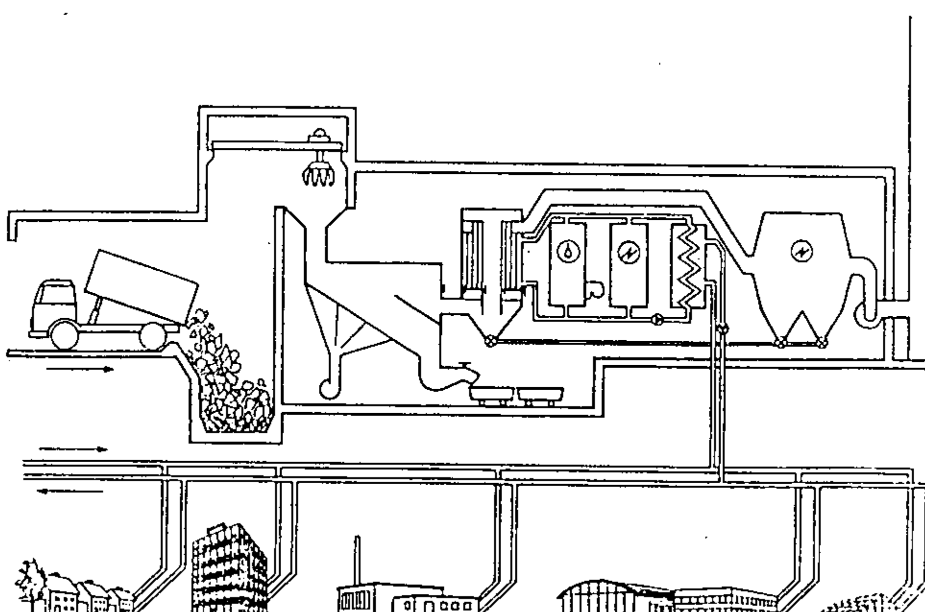
* Should fixed gas pipe-works be installed in connection with the deposition?

* Can the anaerobic degradation be accelerated by watering and which consequences, for example, may this have for the leachate formation?

* How could the waste deposition be operated in the best way?

4.44 Incineration of solid waste combined with energy recovery (Direct energy recovery)

Incineration of household waste and combustible industrial waste in conventional furnaces is a well-developed and well established technique in Sweden. It is estimated that in 1985 about 50 per cent of all household waste will be processed by incineration. The energy produced is exploited substantially for the production of hot water for municipal district heating networks. Of the total district heat production in Sweden in 1981 (about 125 PJ), waste-produced district heat amounted to about 4.5 per cent (5.5 PJ). Only about 10 per cent of the energy produced had to be removed by cooling in the summer-time when heating requirements are low.



Recovery of heat from an incineration plant for district heating.

The lower calorific value of household waste is from 10,000 to 11,000 MJ/ton. With the current efficiency of the plants (about 60-65 per cent) the energy yield is about 6,500 MJ/ton. The lower calorific value of industrial waste is considerably higher than that of household waste and is estimated to be about 14,000 to 16,000 MJ/ton. Combustible industrial waste in Sweden amounts to around 1,500,000 tons per year. At present, approximately 10 per cent is incinerated.

The relatively low efficiency of waste incineration is above all due to the large flue gas losses because:

* Incineration is subjected to a high air factor (a large excess of air leads to large flue gas quantities).

* The temperatures of the escaping flue gases are kept high as otherwise there is a risk of corrosion in filters and chimneys.

* Evaporated water is emitted together with the flue gases.

While there is substantial unexploited energy potential in household and industrial waste, which at present does not go to incineration. We are also, nevertheless, interested in trying to reduce flue gas losses, and thereby to increase the efficiency (energy yield) of the plants. It should be fully possible to achieve an efficiency of 75 to 80 per cent.

Energy obtained through incineration means a correspon-ding reduction in the demand for fuel oil; a useful way of describing the energy potential of waste is to express it as an equivalent quantity of oil, as in the figure below:

Table 4
Waste as a potential source of energy.

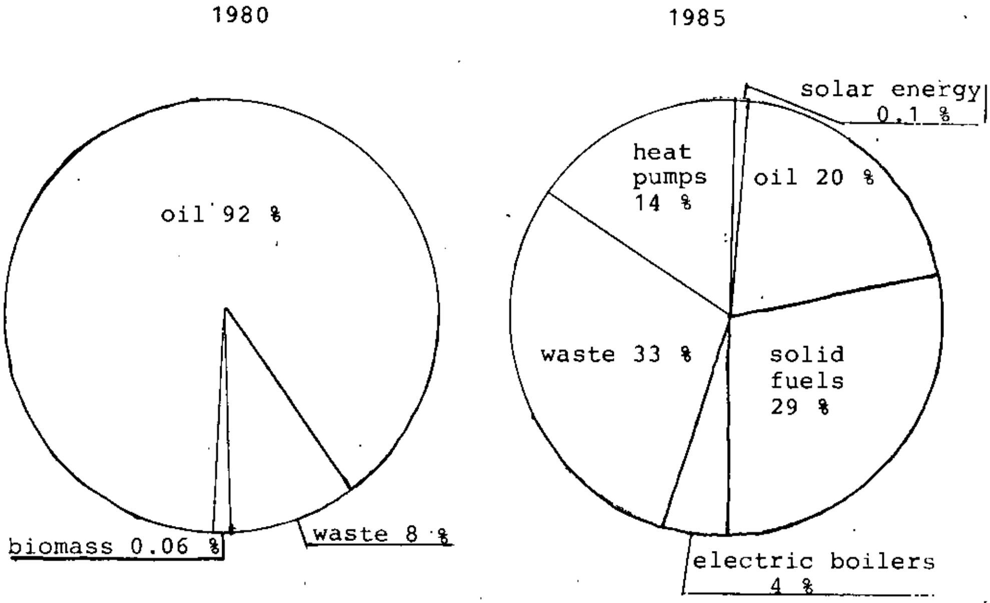
Type of waste	Quantity metric ton/year		Energy potential	
	gross	net	PJ/year (1)	toe/year (2)
Household waste	2,500,000	2,500,000	19	530,000
Industrial Waste	4,500,000	1,500,000	18	500,000
Total	7,000,000	4,000,000	37	1,030,000

(1) Assumed degree of efficiency 75 per cent
(2) toe = one equivalent ton of fuel oil with a net energy content of 36 GJ.

The total potential is estimated to be 37 PJ per year. In 1981, the energy that could have been derived from waste, expressed as a percentage of the heat produced in the (mainly oil-fired) district heating stations in Sweden, would have amounted to as much as 30 per cent of all fuel requirements for heating.

There are examples of individual municipalities who have in a short period of time greatly reduced their dependency upon it through an increased use of waste as energy source.

The town of Uppsala decreased its reliance upon oil from 92 to 20 per cent, in great part due to an effective utilization of the energy to be found in the supply system of public utilities. Waste-derived energy will in 1985 account for a third of the energy requirements, while heat pumps at the sewage works will supply an additional 14 per cent.



Sources of energy for district heating production in Uppsala, 1980 and 1985 (total 6.3 PJ).

The environmental questions relating to waste incineration have broad public interest and have often acted as limiting factors. However, an operational study which is now being carried out in Sweden has shown that a correctly chosen purification technique combined with strict process-monitoring measures considerably reduces the combustion emissions.

In addition, more detailed studies should be devoted to the following factors in order to ensure an increase in energy production through the use of waste incineration.

* The optimization of existing incineration plants.

* The framing of suitable control parameters.

* The devising of auxillary instruments necessary for process direction and monitoring.

* The development of methods of operation and charting the links between various process parameters, treatment results etc.

* The determination of the lowest practical flue gas temperatures that do not risk operational breakdown or environmental disruption.

* The study of absorption heat pumps for wet flue gases.

* The improvement of furnace controllability.

* The training of personnel.

* The development of control systems to improve the quality of waste products.

4.5 Suggested fields of R & D on energy conservation in solid waste management systems

Two proposals for co-operative ventures initiated by the Swedish firms Studsvik Energiteknik AB and Gunnar Hofsenius AB/Liser AB are presented below. Both firms are willing to participate in co-operative ventures, project supervision or other similar undertakings.

4.51 Operationally optimal energy extraction from waste

The following reasons can be stated for the increase in recent years of energy generation through the incineration of waste:

* The volume of a typical batch can be reduced in volume by about 90 per cent to an inert product, relatively easy to handle.

* The energy content of waste is high (around 10 to 16 MJ/kg) and energy extraction can normally be co-ordinated with other forms of energy generation.

* Environmental aspects can be better controlled due to improved methods of operation and flue-gas purification.

Unfortunately, waste incineration plants are often complicated installations. Moreover, waste varies in quantity and composition. For these reasons waste incineration may be considered a difficult process.

The difference between properly done and a poorly done incineration of waste is clearly measureable in both economic and environmental terms. It is very important, for example, to be able to control the supply and distribution of air for combustion.

In economic terms, too great an air supply lowers efficiency, i.e. there is less energy generated per ton of waste. From an environmental point of view, an increase in the volume of air means more dust transmitted, greater demands upon filtration and a poorer combustion of organic compounds. Optimal operation presumes s knowledge of which factors are important for the control of combustion and of how these factors affect each other in the combustion process.

Proceeding from operational studies of waste combustion, Swedish firms have derived a computer-adapted operation programme that can be used in a variety of types of waste-fueled heating stations. The programme applied to Swedish installations has shown itself to bring about an increase in efficiency of up to 70 to 75 per cent as well as reducing the amount of flue-gas emissions.

4.52 Possibilities of reducing Mercury emissions

The emission of not easily soluble mercury compounds can be reduced if their capacity of absorbing solid particles can be improved. This possibility is often restricted, however, due to the risk of corrosion. Moreover, to reduce only Swedish emissions would lead to but marginal improvements.

The easily soluble types can be reduced by means of wet or semi-wet processes. Several such systems are under development. A wet method, especially adapted for waste or other moist fuels, is briefly described below.

Brief description of a wet method of cleaning flue gases of hydrogen chloride

Flue gases resulting from the incineration of waste have high contents of water vapour, as is apparent in the accompanying diagram. By cooling the flue gas down to around 40^{o}C, the quantity of precipitant required for the absorption of easily soluble mercury compounds can be generated. Cooling is accomplished by the water condensated from the flue gas, which after passing through a heat pump, is recirculated. To a certain extent, the cooled condensation water is used in the gas-cleaning stage proper where it is brought into contact with the flue gas. Because of the high hydrogen chloride content of the gas, the precipitant will be acidic; the mercury will then be dissolved, forming volatile chloride compounds.

The resulting solution is drawn off. Lime is then added to produce a basic reaction, thereafter an easily soluble suphide is added, forming a mercury sulphide which is very difficult to dissolve and thereafter is a form of mercury suitable for deponation.

The system described above could possibly be put into operation at a pilot level at the Högdalen waste incineration station in Stockholm. Work is now under way to secure tenders for the supply of equipment, while programme clarification and definition concerning the norms that will affect emissions is under preparation. The intention is to request a grant during the first quarter of next year for such a pilot project.

4.53 Sorting of household refuse at source

A number of regional refuse collection and treatment stations were built in Sweden with state grants during the 1970s. Here waste and refuse are separated into different categories of recoverable materials. Results however have not turned out as expected. The separated material is not of such a quality that it is attractive for recycling purposes. To date the project has been a financial loss; moreover, state subsidies have ceased.

The expection of just such a high technology installation being constructed in northwest Skåne was encouragement enough for the Norra Åsbo Sanitation Company to begin an experiment based upon sorting out refuse at source, that is, in the households. Financial risks are but minimal compared with the investments necessary for a technologically advanced refuse handling and treatment plant.

Today, in a densely built area of detached housing in the three townships of Klippan, Perstorp and Örkelljunga – paper, textiles, glass and metal are collected separately. Individual storage of each category of material takes place in glassfibre sacks distributed to each household. These are collected every fourth week. The sacks are emptied into a specially constructed vehicle with four compartments, one for each type of refuse. The sacks are then returned to the households. Glass, metal and textiles are stored at the plant for later sale. Paper is sent on to a depot.

Even rural areas are included. Beginning in 1982, sorted material has been collected four times a year from around approximately 300 houses in the countryside. To lower costs, a system was devised for next year in which recoverable material according to the following schedule will be collected at the same time as ordinary refuse:

first collection,	refuse	plus	waste	paper
second "	"	"	"	glass
third "	"	"	"	paper
fourth "	"	"	"	tin cans
fifth "	"	"	"	paper
sixth "	"	"	"	textiles.

The intervals are therefore:

household refuse,	14 days
waste paper,	1 month
" glass,	3 months
" tin cans,	3 months
" textiles,	3 months

For the time being, only paper is being collected in residential districts consisting of multi-family housing units.

The experience acquired to date in Skåne reveals very positive results. The quantity of material collected per person has been very high, and steadily increasing. For waste paper the figures are 17 kg per person in 1980, 26 in 1981 and 30 kg per person in 1982. As an economic venture the undertaking may be considered to be a success.

The figures below (for 1982) can provide an illustration of the distribution of costs and receipts.

	Costs	Income
Capital costs	90 000	
Operational costs	40 000	
Labour	140 000	
Collection of paper (multi-family housing districts)	40 000	
Transport: intermediate store to depot	50 000	
Hire of containers	18 000	
Depot handling, 1280 tons at 130 SKR/ton	166 000	
Distribution of sacks and informative material to rural areas	3 000	
Glassfibre sacks, 10 000 at 2.40 each	24 000	
Public relations	2 000	
Advertising	15 000	
Construction costs (pick-up installations in multi-family housing districts)	10 000	
Hire of containers for paper (multi-family housing districts)	37 000	

Illustration of the distribution costs and receipts – continued . . .

	Costs	Income
Sale of materials collected, 1280 tons at 355 SKR/ton		454 000
Better utilization of refuse depot, 6300 m^3 at 30 SKR/m^3		189 000
Expected profit	8 000	
Total / Swedish Crowns	643 000	643 000

Concerning refuse, i.e. unsorted waste, there are plans underway of using a relatively simple method of extracting combustible elements and using the remainder as compost.

4.6 Summary

Both production and consumption in an industrialized society, with a high standard of living, produce large quantities of waste.

The content of recoverable products and combustible materials in waste products conceals an important energy source which is but partly exploited at the present time.

For the proper management and utilization of waste in conjunction with refuse collection and processing, energy is consumed in the form of fuels and electricity. This energy consumption may, however, be considered as negligible compared with the potential amount of energy that may be derived from various types of recovery methods.

In order to compare the amounts of energy available between different processing stages and recovery methods, a comparative energy coefficient (e) has been chosen, which expresses the energy amount in MJ per ton of waste. The energy coefficient should be used with caution, but should in prinicple be of use as a factor which permits potential energy amounts to be estimated.

The energy coefficients discussed in this report are compiled in Table 5.

Table 5

Specific energy amounts in MJ/ton of waste that may be derived from processing recovery.

Processing operation or Recovery method	Specific energy amount (e) in MJ/ton of waste Consumption	Recovery
Processing operation		
Internal management	0 – 50	
Assembly (built-up areas)	50 – 150	
Transport (20 km)	50 – 200	
Transfer	20 – 50	
Recovery method		
Deposition by compactor	50 – 100	Gas[1)] 1,000-2,000
Gas recovery in reactor	150 – 250	Gas[1)] 1,000-2,000
Comminution, separation, composting 2)	100 – 250	Material[3)] A x (5,000-10,000)
Incineration	100 – 200	RDF[1)] 5,000-7,000 Household waste [2)] 10,000-11,000 Industrial waste [2)] 14,000-16,000

1) Energy coefficient indicated as lower calorific value. The net yield varies with the incineration efficiency.

2) Material recovery can also be realized by pre-separation at source.

3) A = Number of possible recyclings of the material.

The energy recovery from waste products can be increased considerably by application of known methods which in many cases may be improved upon, and by the exploitation of innovations, to which more attention should be devoted.

Finally, it should be pointed out that the report discussed wastes exclusively with the view to potential energy conservation. When assessing whether particular recovery methods may be realized or not, attention must also be paid to a series of other factors such as the environment, economics, the market, development trends and the like.

5. ENERGY CONSERVATION IN WATER SUPPLY AND SEWAGE SYSTEMS

5.1 Introduction

A large part of the total energy used for heating and production of hot water in households, offices etc, is lost in the water and sewage disposal. In Sweden the energy consumption in the water supply and sewage systems amounts to between 15 and 25 TWh/year, which is roughly 25 per cent of the total energy consumption for heating and hot water production. The potentials of energy conservation are considerable, and will briefly be discussed in this chapter.

This study is confined to Community Systems in urban areas, and will not deal with energy problems in rural areas or in industry. Potentials for energy conservation in both existing water supply and sewage systems, and in future systems, will be discussed. There are basically three types of energy in water: potential energy; chemical – biological energy; and heat energy. The largest by far type of energy is heat energy, and the study will be focussed on the possibilities of utilizing this heat.

5.2 Legislation and organization

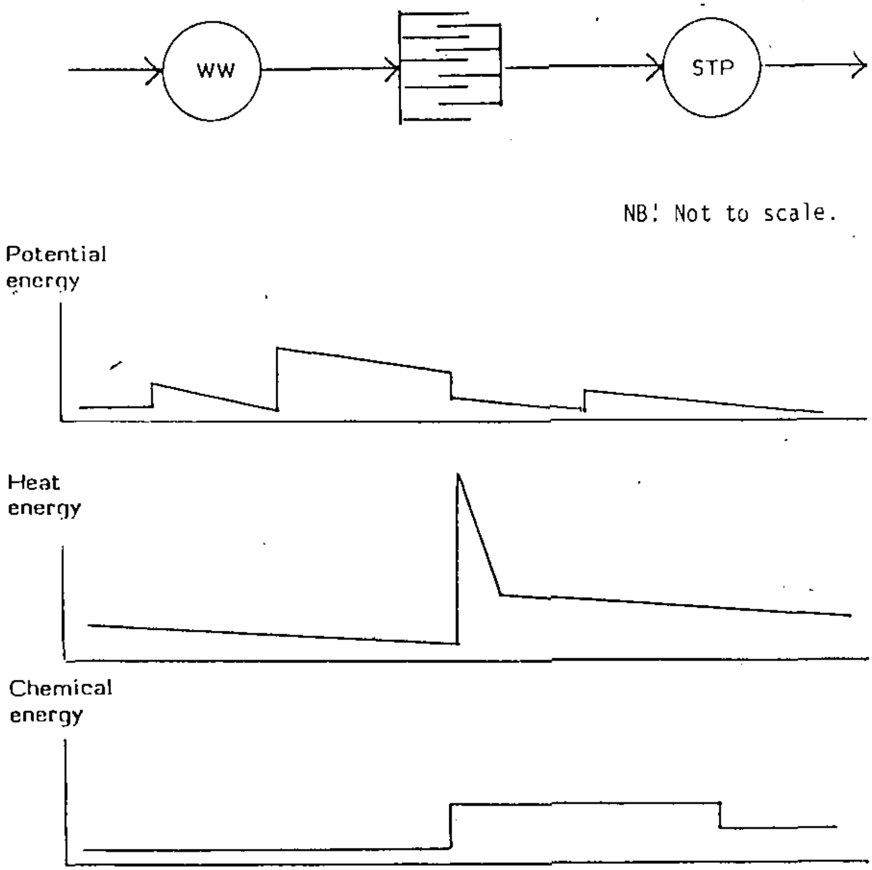
In Sweden public water supply and sewage is the responsibility of the local township or municipalities. In some of these, the water-works or sewage treatment plants are owned and operated by private or municipally-owned companies, selling their services to the town. In principle, the consumer buys the water at the building boundry and "owns" the water as long as it stays inside the building. As soon as it is discharged to the sewage system it becomes public property again. This applies to most industries as well. Large industries often have their own water supply and sewage, including sewage treatment plants.

The issue of "who owns the energy content of the water and sewage?" is not clearly covered by existing legislation in Sweden. The energy contained in water and sewage during treatment and distribution logically belongs to the owner of the water, that is the municipality. But which restrictions should be imposed on the energy content of the sewage that is discharged from a building? What temperature of the drinking water should the consumer demand? These and associated questions are not covered by Swedish legislation, nor in practice. There is a great need for a study of these issues to be made.

5.3 Technical aspects of water supply and sewage systems

A conventional water supply and sewage system in an industrialized city is composed of a water-works, a water distribution system, a sewage system and a sewage treatment plant. Below a simplified system is outlined, together with typical relative energy potential levels in the different parts of the system.

Figure 5.



The energy potential curves in Figure 5 will naturally look quite different under different circumstances, but the curves illustrated above are believed to be typical for a Swedish city.

A water supply and sewage system may be constructed in many ways. In order to discuss the possibilities of energy conservation in more detail, we have to distinguish the different parts of the system, and describe the technical aspects of the different elements that constitute the system. The four systems: water-works, water distribution, sewage, and sewage treatment plants will be discussed separately.

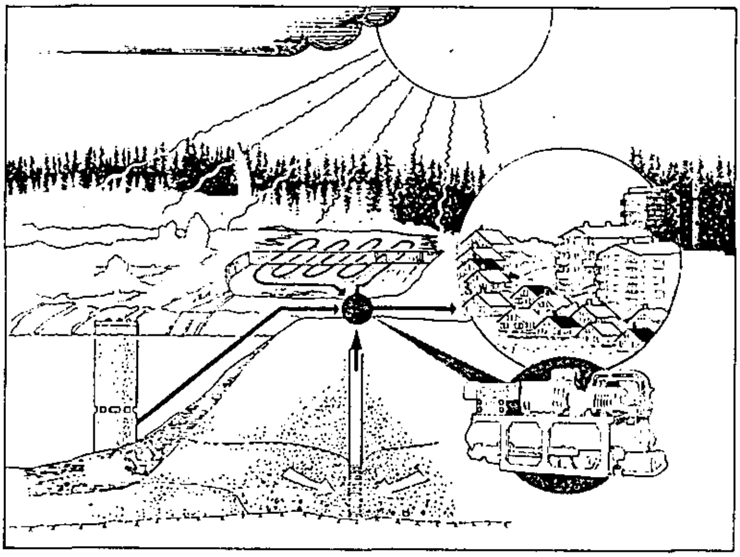
5.4 Methods of energy conservation

5.41 Energy conservation in waterworks

In surface water treatment works the temperature of the raw water can usually be increased some degrees. An increase of 1^{o} K saves as much energy as the total energy consumption for the production and distribution of the water. In most cases it is more advantageous to extract this energy with a heat pump in the waterworks, rather than to distribute a warmer water.

This possibility exists in most surface water treatment works. Techniques for the utilization of the energy are available. Problems may arise for the operation of the waterworks, and in the distribution systems, but these are considered to be of little account in view of the potential energy savings.

In groundwater treatment works the temperature of the water is higher than in a surface water treatment works during the winter-time. Thus, it is generally better, from an energy point of view, to use groundwater. The temperature of the groundwater may, if the geohydrological conditions are suitable, be further increased by a re-charge of warm water in the summer. In some aquifers a seasonal storage of the water may be possible, causing a substantial increase of temperature. The heat energy may, as for surface water treatment works, be further re-fined by heat pumps. Groundwater recharge is a common technique and no problems of a technical nature are expected. Conflicts may, however, arise if the need for water does not coincide with the need for heat.



Ground water as a heat source for heat pumps.

It is not uncommon that Swedish municipalities hold a water supply in reserve of the normal supply. This reserve water supply may be utilized as a heat source for a heat pump. The techniques of recharge may also be used here.

There are basically two ways of utilizing the heat in drinking water:

a) by extracting the heat with a heat pump in the works or elsewhere, or,

b) by distributing a warmer water to the households in order to reduce their energy consumption.

In the second case no new investments will be necessary if the temperature of the raw water can be increased. In the first case, new investments will be necessary not only for the heat pump, but also for a distribution system for the heated water. This also limits the use of this technique, since the consumption of the energy must not be too far away from the waterworks. Local conditions will set these limits. The possibilities for utilization of waste heat from any industry near the waterworks should always be investigated.

5.42 Energy conservation in water distribution systems

In existing, conventional water distribution systems there are always heat losses to the ground during the winter. The decrease of temperature may be several degrees. The risks of freezing is a factor that must be carefully investigated before heat is taken from the water before distribution.

For water distribution systems that are to be built, the technique of insulation and utilization waste heat from other pipe systems (electricity, sewage, district heating) might prove successful. First, the heat loss from the water will be diminished, or the water will even increase its temperature. Secondly, the trench does not have to be as deep as is normal. It is today not unusual to place the pipes only half a metre below ground level under an insulating cover, even in the north of Sweden. Some mechanical and hygienic questions remain to be answered before this technique can be used on a broader scale.

5.43 Energy conservation in households

The largest consumption of energy in the water and sewage system takes place in the households, for the production of hot water. Several ways to decrease this consumption have been studied, but will not be further discussed here. The households are also responsible for the loss of potential energy, and the addition of chemical-biological energy to the water.

The loss of heat from the sewage occurs to a great extent immediately after it has left the building. Therefore, the heat ought to be recovered in the buildings. This can be done by storing the sewage (excluding the waste-water from water-closets) in the cellers of the building, using a heat pump of a heat exchanger. The problems of maintaining and operating such a device would probably be too great for the residents. However, effort should be made to develop automatic, self-cleaning heat exchangers and/or pumps for use in single buildings.

In or adjacent to a building there are also other heat sources available, for example ventilated air, outdoor air, groundwater, soil, and drinking water. A heat pump may very well use alternative heat sources, and for example revert from outdoor air to drinking water depending on the temperature of the heat source. Other factors also influence the choice of heat source. The possibilities of discharging the cold water which has passed through a heat pump must be carefully studied. The discharge of very cold water from many buildings in an area to the sewage system might be crucial for the operation of the systems. This fact implies that the possibilities of using heat pumps with water as a heat source in residential areas are restricted. For out-of-the way buildings or elsewhere, cold water need not to be discharged to the sewage system, and heat pumps for water are a realistic alternative.

In Sweden there is a clear tendency towards a decrease in the use of water in households as well as industry. This could affect the potentials for energy conservation in two ways:

* by reducing the waste heat in drinking water and sewage,

  and

* by increasing the available capacity in the water supplies, thereby allowing for heat pumps either in the waterworks or in households.

5.44 Energy conservation in sewage systems

Sewage systems may be

* combined (all types of wastewater in one pipe);

* duplicated (sewage from households in one pipe and stormwater and drainage water in another pipe),

  or

* separated (sewage in one pipe and stormwater in ditches or open trenches).

In combined sewage, the sewage, with a temperature of 8-14^{o}C will be cooled by stormwater and meltwater during the cold seasons. This may considerably reduce the available heat in the sewage. Much better, from an energy point of view, are the duplicate or separate systems, in which a steady, uniform temperature is available during the entire year. Because of heat losses to the trenches, the heat should be taken as immediately in the system as possible, which indicates pumping stations and storage points as potential locations for heat pumps. The techniques of exploiting the heat in raw sewage have been tested in a few places, and no serious operational problems have been noted. Still, this technique has to be refined and evaluated.

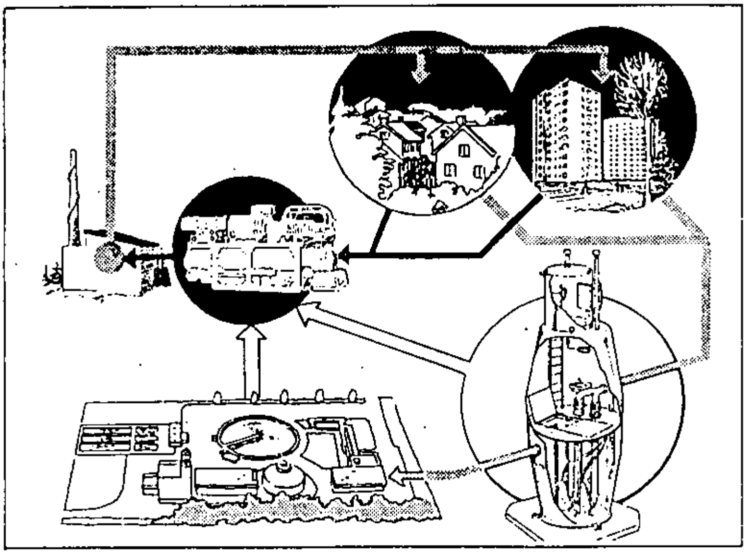
If there are risks for freezing in the sewers (or in the water mains), the pumping stations are not suitable locations for heat pumps. Also, the effects of a low temperature on the processes in the sewage treatment plant should be considered.

An alternative to transporting the sewage in long pipelines to a treatment plant is to infiltrate the sewage in the ground. This is today an accepted method in Sweden, and has been applied in hundreds of small and middle-sized communities. This alternative allows the storage of warm sewage in the aquifer from one season to another, if geohydrological conditions permit.

The heat losses in the trench may be decreased by the new technique of insulating the pipes, but also by better design of the storm sewers. These pipes sometimes act as ventilating shafts, and extract the heat from the trench and from the sewage. The stormwater also infiltrates into the sewage in winter-time. The possibility of utilizing the waste heat from district heating systems and electrical systems should be investigated.

5.45 Energy conservation in sewage treatment plants

The sewage treatment plants in Sweden are the most-used locations for heat pumps in the water supply and sewage systems. If the heat is recovered after leaving the plant, the processes are not affected. The effects on the receiving water are small, and may in some respects even be favourable. In all cases the heat from the heat pump can be used for internal heating of the plant, the sewage or the heated water can be transported there. Rough estimates indicate that heat pumps in a sewage treatment plant can supply about one-tenth of the heating needs in the area.



Recovery of waste heat from a sewage treatment plant or a pumping station.

In a sewage treatment plant the chemical–biological energy of the sewage can be recovered. This energy is contained in the organic material and the nutrients of the sewage. There are several different ways to recover the energy, of which the most-used way today is sludge digestion and the production of methane. A technique that will allow better recovery of the energy is irrigation with treated sewage. By this technique, which has not been used in Sweden at full scale, the nutrients of the sewage are utilized on the fields as a substitute for commercial fertilizers. Furthermore, the need for tertial treatment, which is very common in Sweden, will decline. The potential for extracting the chemical energy of sewage, depending on the method of calculation used, is 1/10 to 1/2 of the available heat energy of the sewage.

5.5 Suggested fields of R & D on energy conservation in water and sewage systems

5.51 Algae Cultivation

The cultivation of algae as a means of treating sewage biologically has become a very popular method in many places throughout the world. Japan has today 100,000 hectares of algae at work; China started late but has already 20.000 hectares. The United States and Canada have also begun to cultivate algae.

Denmark pursues a dual-purpose programme for algae cultivation: it performs as the final, biological stage of sewage treatment, and it provides raw material for biogas – a useful source of energy. The town of Odense has set out aquatic plant life in a sealed-off inlet of the sea that serves as a wastewater recipient. This particular solution was preferred rather than the alternative one of constructing a testiary treatment at the sewage treatment plant.

Algae quickly absorbs the nitrogen and phosphorus contained in wastewater, partly in order to create and nourish new cell growth, partly to store away for future needs. The algae is harvested every ten days by an amphibious vehicle equipped with a mulching pump. Part of the mulched material is returned to the water in order to renew the proecess, and the rest is pumped ashore.

This method has succeeded very well in Odense. An experiment is even being planned to allow the harvested algae to ferment, thereby creating a supply of methane gas for the biogas production constitutes a not insignificant portion of the municipal heat supply. The remainder (after degestion) is moreover an excellent fertilizer.

The algae cultivation project is a co-operative undertaking between the town of Odense and the Institution of

Marine Botany at the University of Lund, in Sweden.

Experiments in algae cultivation are also underway in Sweden – Falsterbo and among the islands off the coast of the province of Östergötland; both under the direction of Lund University. Experiments will also soon begin on the west coast. It is expected that within 5 to 10 years, Sweden will have several large biomass installations in operation.

The cultivation of algae for energy purposes has the advantage over similar projects involving the cultivation of energy plantations in that they require less space. Algae doubles its volume in 4 to 10 days and can be cultivated eight months of the year. At Lund University work is in progress to develop a type of algae able to grow quickly even in the winter, an improvement which would permit production and harvesting the year round.

Suitable locations for the cultivation of algae are enclosed inlets and other coastal waters. Algae are capable of absorbing 75 to 80 per cent of the nitrogen and phosphorus they come into contact with.

Algae is also a promising raw material as energy source. Preliminary estimates indicate that the price of algae-generated energy will be less than 0.2 SKR per kWh. Algae may also be useful in the restoration of polluted lakes. Lake algae can extract the nitrogen and phosphorus stored in bottom sediments.

Just now an investigation is being conducted to determine whether or not algae can be used to restore Ringsjön, a lake in the southern part of Sweden. This lake is subject to constant pollution from the surrounding farmland. The goal here is to reduce the entry of nutrient salts by 70 per cent by setting out algae cultivations in the streams that feed the lake, and even in the open spaces in the lake itself.

5.52 Sludge

The city of Gothenburg is conducting experiments using sewage sludge to fertilize energy plantations on marginal land. The particular piece of land used in the experiment is a strip about two hectares in all, that formely was agricultural land, now inaccessible and unsuitable for farming.

In Gothenburg, as in many other towns and cities, there are many such inaccessible pieces of land next to motorways, for example, that can be used for little else. If sewage sludge could be used as a fertilizer for energy plantations on this kind of land, then the municipal heating stations would have access to a domestic source of fuel. The wood products obtained from the piece of land in question amounts to between 20 and 30 tons of dry substance, which corresponds to around 10 tons of fuel oil, or 5 tons of oil per cultivated acre.

The energy plantation in Gothenburg will be harvested every fourth year. A prototype of a specially designed harvester is now under construction.

The College of Agriculture at Ultuna is also conducting a series of experiments with energy plantations fertilized by different types of municipal wastewater and sludge. Other experiments are taking place in the town of Hässleholm, using wastewater, and in the northern part of Uppland where digested sludge fertilizes and energy plantation. The agricultural college is also investigating the possibility of growing energy plantations on refuse dumps and using leachates for irrigation.

Research is also being conducted at Ultuna to determine the most practical size that cultivated areas should have, factors that affect growth, ecological effects etc. Research results are expected in about two years time and after that it is believed that energy plantations will begin on a large scale in Sweden.

5.53 Irrigation

The town of Sölvesborg began in 1978 an experiment using mechanically and biologically treated wastewater for irrigation purposes. The project consists of a 300 hectare large section of farmland west of Mjällby in Blekinge. The aim of the experiment is to determine the possibilities for and consequences of the utilization of the wastewater as a resource.

The township and the local farmers are thereby able to conserve their groundwater supplies, reduce their need of artificial fertilizers for agriculture and chemical agents for sewage treatment (i.e. the testiary treatment will no longer be necessary) as well as reducing sludge transport.

Test installations are made up of pumping stations, transfer conduits, extraction wells and land to be irrigated. Ten or so farmers are engaged in the project and each has access to a share of the available wastewater. Each farmer is to decide for himself when, where and how much to irrigate.

There is in Scandinavia at present no definite norms that govern irrigation with wastewater. Such norms do exist however in other countries – the United States, West Germany and Israel, for example – where this kind of irrigation has been in use for some time.

Preliminary norms have been laid down for the Sölvesborg project, to apply during the time required for the experiment. In addition, a control programme consisting of extensive sampling has been decreed by the Blekinge County Council.

Several aspects of wastewater irrigation are now being studied:

- the extent and need of irrigation
- irrigation systems and methods
- long and short-term storage possibilities
- energy balance and gains
- risks to public health
- environmental consequences
- economic advantages and restrictions

5.54 Drinking water as heat source

Hässleholm is the first township in Sweden to sell drinking water as a source of heat for detached housing. This is a way of disposing of surplus water and saving house-owners money. The town has lowered the cost of this service but still increased its income.

Beginning in 1982, the town offered for sale at special rates drinking water for heating purposes. The requirements were that house-owners heat their homes using heat pumps that extract heat from both water and air. This scheme is made possible because the Hässleholm waterworks, like many others in Sweden, produces a surplus of drinking water in the winter. Storm drains are also empty whenever the temperature falls below freezing point.

Storm drains can therefore be used to remove the cooled water leaving the heat pumps. House-owners must pay a small fee for this privilige. When the temperature rises above freezing, the heat pumps switch automatically to the extraction of heat from the air - storm drains will then be needed for their normal purpose.

It is estimated that house-owners whose house would ordinarily require 3 cubic metres of fuel oil annually, will be able to save as much as 3000 Skr a year, providing a heat pump is installed at a cost of around 25,000 Skr.

The township also benefits. At the present level of capacity the water treatment works can supply water as a source of heat for 600 houses. Moreover, an additional 200 houses that have their own wells can also use the storm drains. The town's income increased by 700,000 Skr, at the same time as Sweden's oil imports declined by 2400 cubic metres.

Hässleholm does have specially advantageous circumstances that permit the scheme described above. Water is purified by the process of artificial infiltration of surface water; this water is warmed in the summer, and in late autumn and winter when the underground magazine is filled will maintain a higher temperature than would ordinary groundwater.

An inventory made has shown that there are many municipal groundwater catchment areas in Sweden where artificial infiltration is a method used to complement underground water resources.

5.55 Digestion tank gas as heat source

Many municipal sewage treatment plants in Sweden use the gas produced in digestion tanks to heat the plant itself. A disadvantage is that a surplus occurs during the summer months and this must be burned off.

If however, the digestion tanks are connected to the district heating station of a nearby housing area, then the gas can be utilized both winter and summer, because households will need hot water the year round.

The town of Eslöv recently built a biogas installation for the digestion of sludge; the gas by-product is used in a housing area in the negihbourhood, thereby replacing 600 cubic metres of fuel oil per year.

The interesting feature about this installation is that the main part of the energy of heat between the warm digested sludge and the raw sludge. This exchange takes place in newly constructed heat exchanger expecially adapted for raw sludge. A certain amount of energy is also obtained from the wastewater by way of heat pumps. These serve as complementary heat sources and are protected from direct contact with the wastewater through intermediary heat exchangers.

In order to heat 550 cubic metres of sludge over a twentyfour hour period, a total power supply of 1000 kW is required – obtainable in the following way:

- 700 kW are derived with the help of heat pumps

- 100 kW are acquired from the electricity that powers the heat pumps

The total costs of investment for the biogas installation amounted to 10.5 mSkr (in 1982 prices). Costs of operation are estimated at 300,000 Skr per year.

When the biogas installation began operation, the volume of dewatered sludge fell from 18,000 to 7000 cubic metres per year due to the reduction of organic material and the improved characteristics of the sludge. All digested sludge is used for soil improvements.

The savings made possible as a direct result of the biogas installation operations are as follows:

Partial cost	Cost without Biogas installation	Cost with biogas installa- tion	Savings as a result of sewage digestion
Polymers	500 000	200 000	300 000
Transport	450 000	140 000	300 000
Deposition	700 000	-	700 000
Labour	160 000	70 000	90 000
Total	1 810 000	410 000	1 400 000

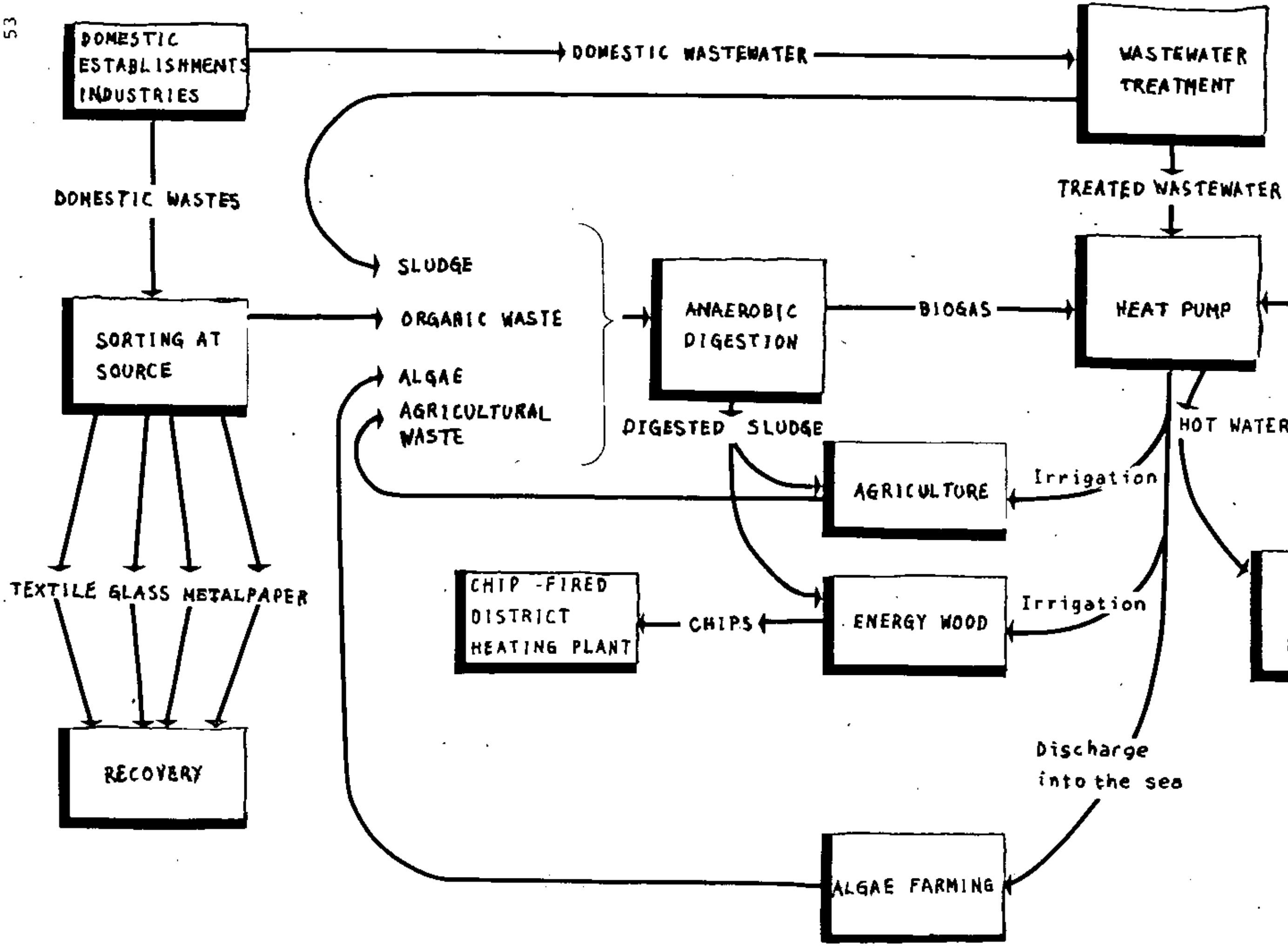
Moreover, a savings each year of 1.3 mSkr can be attributed to the replacement of otherwise essential fuel oil. Total overall savings will thus be 2.4 mSkr per year, permitting amortization in four years.

The installation works on the principle of mesophilic/thermophilic processes, which means that digestion takes place first at 35°C, thereafter at 52°C. The process in each digestion tank requires from 7 to 10 days. To sum up, the advantages of this system are:

- the production of gas is increased by 10 to 15 per cent compared to a two-stage mesophilic process alone

- the dewatering characteristics of the sludge are improved

- the sludge is sanitized.


DOMESTIC ESTABLISHMENTS INDUSTRIES
DOMESTIC WASTEWATER
WASTEWATER TREATMENT
TREATED WASTEWATER
DOMESTIC WASTES
SLUDGE
ORGANIC WASTE
ALGAE
AGRICULTURAL WASTE
SORTING AT SOURCE
ANAEROBIC DIGESTION
BIOGAS
HEAT PUMP
HOT WATER
DIGESTED SLUDGE
AGRICULTURE
Irrigation
TEXTILE GLASS METAL PAPER
CHIP -FIRED DISTRICT HEATING PLANT
CHIPS
ENERGY WOOD
Irrigation
MUNICIPAL HEATING NETWORKS
RECOVERY
Discharge into the sea
ALGAE FARMING

5.6 Summary

Energy in existing water and sewage systems may be conserved by:

- better operation and maintenance of the works and the pipe systems,

- installation of more efficient equipment,

- a change in habits of energy consumption in households and industry,

- recovery of the potential, chemical, and heat energy contained in water and sewage.

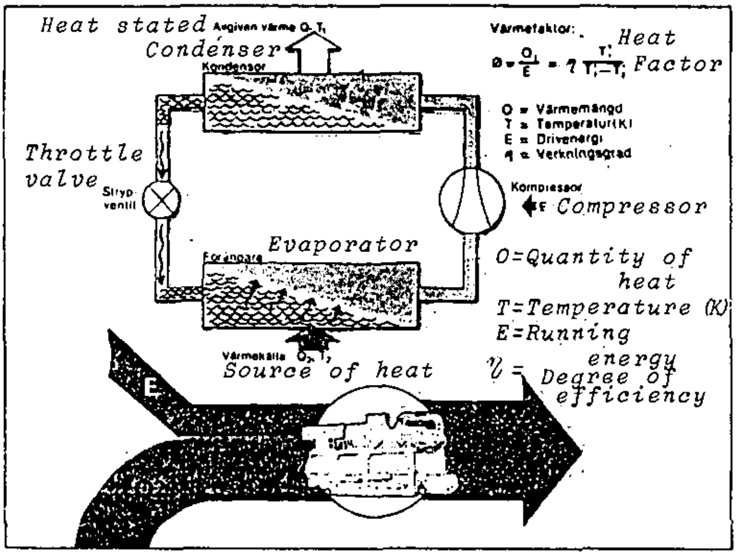
All these methods of energy conservation should be tried, and in combination will contribute to substantial energy savings. The largest by far source of energy in water is heat energy. Today the modern heat pump has made it possible to regain most of the heat brought to water in households by hot water production, or already cheap and reliable heat pumps has totally changed the possibilities for utilizing the waste heat of water and sewage. The location of a heat pump in the system will depend on a number of factors, but generally, for Swedish conditions, the following locations are recommended:

* In the waterworks – especially if the raw water temperature can be increased.

* In sewage pumping stations – provided that the remaining heat will be enough to prevent freezing in the sewers and to ensure satisfactory operation of the sewage treatment plant.

* After the sewage has been treated, where in principle all available heat can be recovered.

Cominations of heat sources for the heat pumps may prove advantageous, for example outdoor air/drinking water or lake water/sewage.



It is not recommended to recover sewage heat from individual building in an entire urban area, because of the obvious risk of freezing in the trenches. Nor is the discharge of cold water on a broader scale from heat pumps into the sewer system recommended. There is an exception for single buildings where these methods may be utilized.

Moreover, the possibilities of utilizing ground water aquifers in existing systems for the storage of heat should be investigated. Aquifers may be recharged either by surface water or by sewage.

In future urban areas, additional opportunities for energy conservation will be possible, besides the ones already accounted for:

- The insulation of water and sewage pipe systems to reduce heat losses and allow for a shallower trench.

- The placement of water mains, sewers and district heating pipes in the same trench in order to utilize the waste heat.

- Local infiltration or separate discharge of stormwater in order to:

  a) reduce heat losses in the utilities trench, and
  b) permit the discharge of cold water from heat pumps.

- Installation of energy and water conserving pipe systems and other fixtures and equipment in buildings.

The potential for energy conservation represented by some of the measures mentioned above are unknown, and should be studied further.

6. THE DECISION-MAKING PROCESS, SYSTEMS CO-ORDINATION AND ECONOMY

6.1 Introduction

Various alternatives for energy conservation in Community Systems were presented in preceeding chapters. It was seen that from a technical point of view, there are several system solutions worthy of regard. The suitability and practical application of these systems are discussed in two case studies.

The question now to be asked are: how can these alternatives be adapted into an overall system, how can their economic efficiency be rendered reliable, and how can the information necessary for the making of decisions be compiled and put in order?

The inherent ideas of these systems must be promoted if the technical possibilities for energy conservation in Community Systems are to be realized. A prerequisite of the successful promotion of system-ideas (the technical concepts) is that they are seen to be credible, i.e. that they represent biable alternatives of complements to existing systems without threatening to diminish the value of previous material or inmaterial investments.

It is essential that the infrastructural preconditions for energy related policies concerning Community Systems must be clarified. In addition the methods of describing the system-situations in which the technical alternatives of energy conservation can be incorporated are of great importance. On the whole the result should be improved conditions for technical and economic rationality (perhaps optimality) in the decision-making process.

The co-ordination of systems which may be necessary in connection with the use of different methods of energy conservation in Community systems is a complicated matter.

However, methods of compiling complicated technical and economic system-characteristics in a comprehensive and adequate form to facilitate decisions are being developed today, and good reasons exist for the application of such models in connection with problems of policy that arise concerning energy conservation in Community Systems.

As an example of the conceivable utilization of large computerized policy models that may be used to help determine various ways of energy conservation in Community Systems, section 6.2 present an application study carried out with a dynamic linear programming model – MESSAGE II – within the framwork of another IEA annex. This model in application illustrates a study for the town of Sundsvall that had the goal of minimizing the total costs of energy supply during a specified period of time.

The principle of the Sundsvall energy system is presented in section 6.23. It will be seen that the model can take into consideration the various technical system alternatives proposed in a previous chapter.

The model for Community Systems in question in section 6.2 takes up for study purposes only the large waste-fueled boiler intended for the supply of heat to the central district heating network, and at the local level a sewage-primed heat pump, but the model can of course be complemented also with other technical system alternatives of interest for Community Systems.

Models type MESSAGE II are especially helpful when it is necessary to select a technically optimal system solution for a given set of circumstances. The models can cope with relatively complex conditions, – modern computer technology permits different solution alternatives to be presented in a way that ought to be of considerable pedagogigal worth in many practical selection situations.

In spite of advantages of models in the above respects, it must however be noted that even large and comprehensive models also under-absorb information. The policy maker must personally be familiar with the model's structure, working procedure and application in order to understand which type of information is under-absorbed. Model, of course, are always simplifications of any given model are acceptable in a practical policy situation, cannot be determined without a consequence analysis, which in many cases can be difficult for a policy maker to personally carry out. Even if a policy model does generate practicable alternatives, it can naturally have difficulties in handling the particular set of conditions which apply in the case in question etc.

With these restrictions in mind, the models specified should nevertheless be capable of broadening the rational basis of decisionmaking in a complex technical system and in this way serve as practical tools useful in the policy development process.

6.2 Case-study Sundsvall [1)]

6.21 Introduction

Our work began with the search for a long-term energy planning model that could integrate planning for energy supply and conservation. At IIASA (the International Institute for Applied Systems Analysis) in Vienna we found dynamic linear-programming model – MESSAGE II – which could minimize the total costs of energy supply in a given period of time.

This model was initially constructed to minimize costs at a national or regional level. We decided, however, to determine if the model could be useful if applied at a local level. A large-scale test was made of the model as a part of the REGI project in Stockholm carried out in 1981.

The town of Sundsvall, north of Stockholm, was selected as an appropriate site for the test. The town already had a well-developed system of energy planning and is fortunate in the respect that it has the option of being able to select from a variety of different energy supply alternatives.

The following sections present in more detail the town's energy problems, the model itself and the results obtained.

6.22 Energy questions

The township, or municipal district, of Sundsvall is located on the coast in the northern part of Sweden. Municipal districts in this part of the country can be quite large – in Sundsvall's case 3219 square kilometres. The total number of inhabitants is 94 500, of which 54 per cent live in the town of Sundsvall proper.

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1) An exserpt from "Case-study Sundsvall: A Model for Long-term Energy Planning" (IEA annex VII, subtask C)

The town of Sundsvall is the largest industrial centre in the northerin part of Sweden; the dominant industries are paper and pulp, chemical, and metal works. 25 per cent of the labour force is employed in the industrial sector, while 60 per cent is employed in trade or service. Its coastal location and three harbours make Sundsvall an important shipping town.

Survey area

The area regarded in this study is the main urban area of Sundsvall. The number of inhabitants and dwellings is listed in table 6.1, the age distribution of dwellings in table 6.2, and the types of heating units in table 6.3.

Table 6.1
Number of inhabitants and dwelling units in Sundsvall, 1980.

Dwelling type	number of dwelling units	Number of inhabitants
Single-family houses	5 600	17 393
Multi-family housing	18 648	33 611
Total	24 248	51 004

Table 6.2
Age distribution of dwellings.

Year of construction	Number of dwellings Single-family	multi-family
- 1920	489	767
1921 - 1940	889	1 033
1941 - 1960	1 453	5 849
1961 - 1975	2 106	9 529
1976 - 1980	569	1 318
unknown	94	152
Total	5 600	18 648

Table 6.3
Heating systems, 1980.

Type of building	Heating demand GWh	Energy supply: Oil %	Electricity %	district %	other %	sum %
Single-family	141.1	56	31	12	1	100
Multi-family	274.1	25	1	73		100
Other	290.2	17		83		100
Total	705.2	28	6	66		100

Existing and future energy supply systems.

1. The central district heating system.

The town of Sundsvall already had a satisfactory district heating system. In 1980 280 MW were supplied, and possibilities are good for increasing this load.

Some of the important topics concérning future district heating systems are:

- the size of future networks

- technical design

- the size and integration of heat-generating stations

- measures to reduce oil consumption

Some possibilities for reducing oil comsumption that have been investigated:

- the use of solid fuels in the existing co-generation station (coal and/or peat)

- the construction of a new solid fuel plant built to use refuse derived fuel, peat and wood chippings (20MW)

- an increase in the use of industrial waste heat

- an increase in the number of heat pumps.

2. Group heating stations with a capacity larger than 1MW.

Only a small amount of heat is today generated in local, or group stations. The largest one at present (of a total of 12) has a capacity of 10MW (Ljustadalen). All existing units use oil; three of them in combination with electricity.

In the future it will be quite possible to use fuels other than oil, for example, wood chippings, peat, natural gas, electricity and various types of refined fuel. Another interesting alternative is the use of heat pumps to extract heat from air or water.

3. Individual heating systems

In 1980 the existing systems were based upon the use of oil and electricity (table 3). Some possible alternatives would be:

- heat pumps, available in a variety of types
- combined systems, ones that use oil, electricity and solid fuels in combination.

4. Energy conservation

Parliament declared in 1981 that the reduction of oil consumption would be a primary national goal. More specifically, the current annual import volume (of oil) is to be reduced by 45 per cent before 1990. The two principal methods of obtaining this reduction are:

- an increase in the number of energy conservation measures taken, this is expected to account for 25 per cent
- the substitution of oil by other fuels, including domestic solid fuels and an increased use of heat pumps.

An important factor in the national energy policy is the integration of heat supply and oonservation measures, especially as regards district heating.

5. Co-operation with industry

10MW of waste-derived heat have been delivered since 1980 from the paper and pulp plant at Ortviken to the central district heating system. A further 7MW may be obtainable from the Gränges sluminium works in the future. Some other alternatives are:

- a 40MW heat pump to retrive low temperature heat from the aluminium works

- a 30MW heat pump to retrieve low temperature heat from the paper and pulp plant.

6.23 The Energy planning model

MESSAGE II

As mentioned before, MESSAGE II is a dynamic linear programming model designed to minimize total costs of energy supply in a given period of time. Some features of the model are as follows:

* All energy technologies to be considered are specified and the corresponding technical and economic data are assemblied.

* All technologies are linked together in a logical scheme from primary energy source to final user. The energy system in Sundsvall is illustrated in figures 1 and 2. See also the map of the survey area.

* Expected demand is calculated.

* Restrictions are introduced into the system, e.g. the energy potential of local, regional and national sources.

- Load demand variation is introduced into the model, i.e. load curves describing daily and seasonal variation.

- Prices of energy sources (oil, coal, peat, wood chippings etc) are specified.

* The model is programmed to respond to a specific period of time.

- A basic scenario is evaluated and programmed. After that it is possible to alter any variables for a new test run in order to investigate any scenario thought desirable.

The energy system in Sundsvall

An energy system can be described as a linear scheme, with the following stages:

* primary energy sources
  (national and regional electricity supply grids and gas supply networks, heat co-generation stations, surplus industrial energy, large hot-water production plants, large heat pumps)

* secondary energy sources and main distribution network
  (local district heating networks in each area, local electricity supply and gas networks, local oil and solid fuel distribution services)

* supply systems
  (district heating, direct electrical heating, indirect electrical heating, oil-fired boilers, gas-fired boilers, solid fuel boilers, combination boilers)

- recipients
  (energy demand in housing and other buildings).

Figure 6.1 illustrates the various technical options possible in the energy supply system of the survey area.

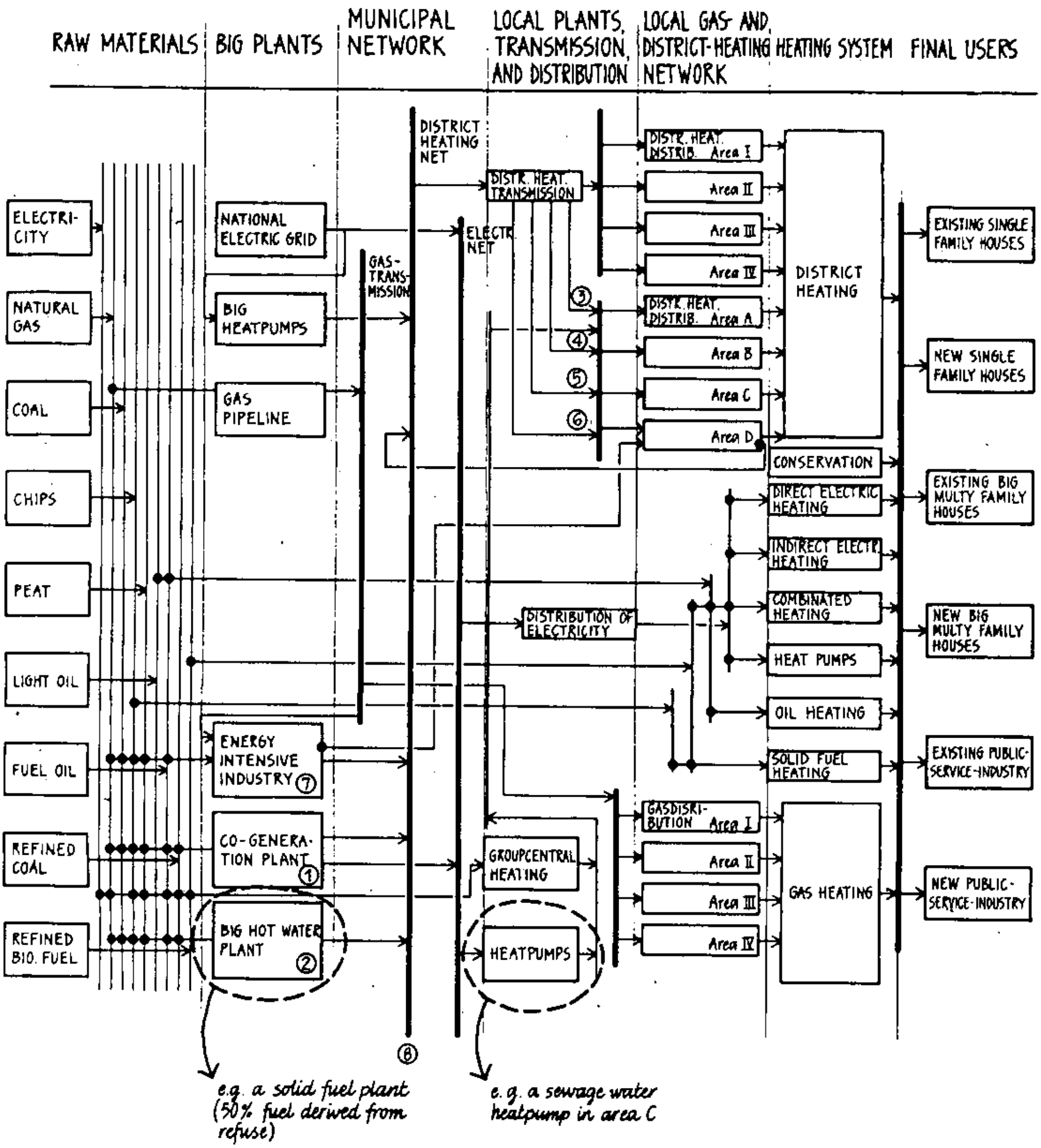


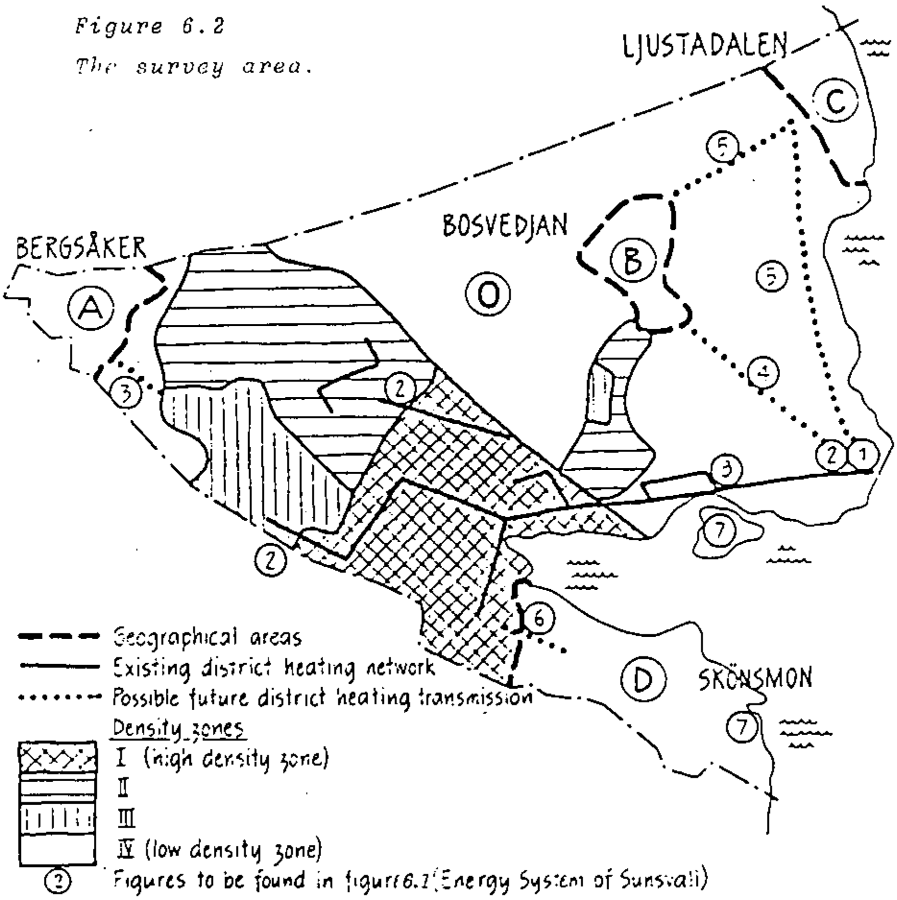
Figure 6.2 is a simplified version of the survey area. The circled figures refer to figure 6.1. As a first step the survey area is divided into 5 geographical areas:

A. Bergsåker
B. Bosvedjan
C. Ljustadalen
D. Skönsmon

O. Potential district heating area to be supplied by the central district heating system.

In second step area O is divided into 4 different zones from high to low density.

Figure 6.2
The survey area.



6.24 Results obtained from the model

The central district heating system

The type of heat generation in the central district is an important aspect of the future energy supply system in Sundsvall.

Figure 6.3 illustrates the optimal and cost minimizing mix of energy inputs for the central district heating system.

S1 (base case)	the base scenario
S2 (co-gen free)	a scenario in which the present co-generation plant need not necessarily exist
S3 (co-gen fix, coal cut)	a scenario in which the present co-generation plant is assumed to exist, but is not allowed to use coal
S4 (co-gen free, dht distribution cost doubled)	A scenario with the assumptions of S2 but with costs of district heat distribution doubled as compared to other scenarios.

The above scenarios represent four of the above twelve generated.

Local district heat generation

Another aspect to consider is whether each geographical area is to be supplied by energy from the district heating system or from local heating plants.

Figure 4 is a chart of the optimal solutions using the scenarios listed above for all of the geographical areas taken together.

Total heating structure

The optimal total heating structure for the scenarios mentioned above are presented in figure 6.6. The figure reveals that central district heating will be the most important supply in the future and that the use of individual systems (using oil or electricity) will decline gradually. Another important point is that energy conservation measures (up to a certain level) should be carried out as quickly as possible.

Cost minimizing solution

If the present value of total costs of the system are taken into account (for the period 1980-2010) then scenario S2 (co-gen free) will be the most inexpensive.

Scenario	Present value (1980 prices)
S1 base case	4 330 million Sw. Cr.
S2 co-gen free	4 250 " " "
S3 co-gen fix, coal out	4 540 " " "
S4 co-gen free, district heating distribution cost doubled	4 320 " " "

As the heat co-generation plant does already exist, scenarios 2 and 4 cannot be realized. Therefore scenario 1 must be compared with number 3 (co-gen fix, coal out). Of the two S1 is the most inexpensive with respect to present value. If the entire goal duration is taken into consideration, the coal out alternative will be 5 per cent or 200 million Swedish Crowns more expensive than the coal in. alternative.

Figure 6.3
Central district heat generation by type.

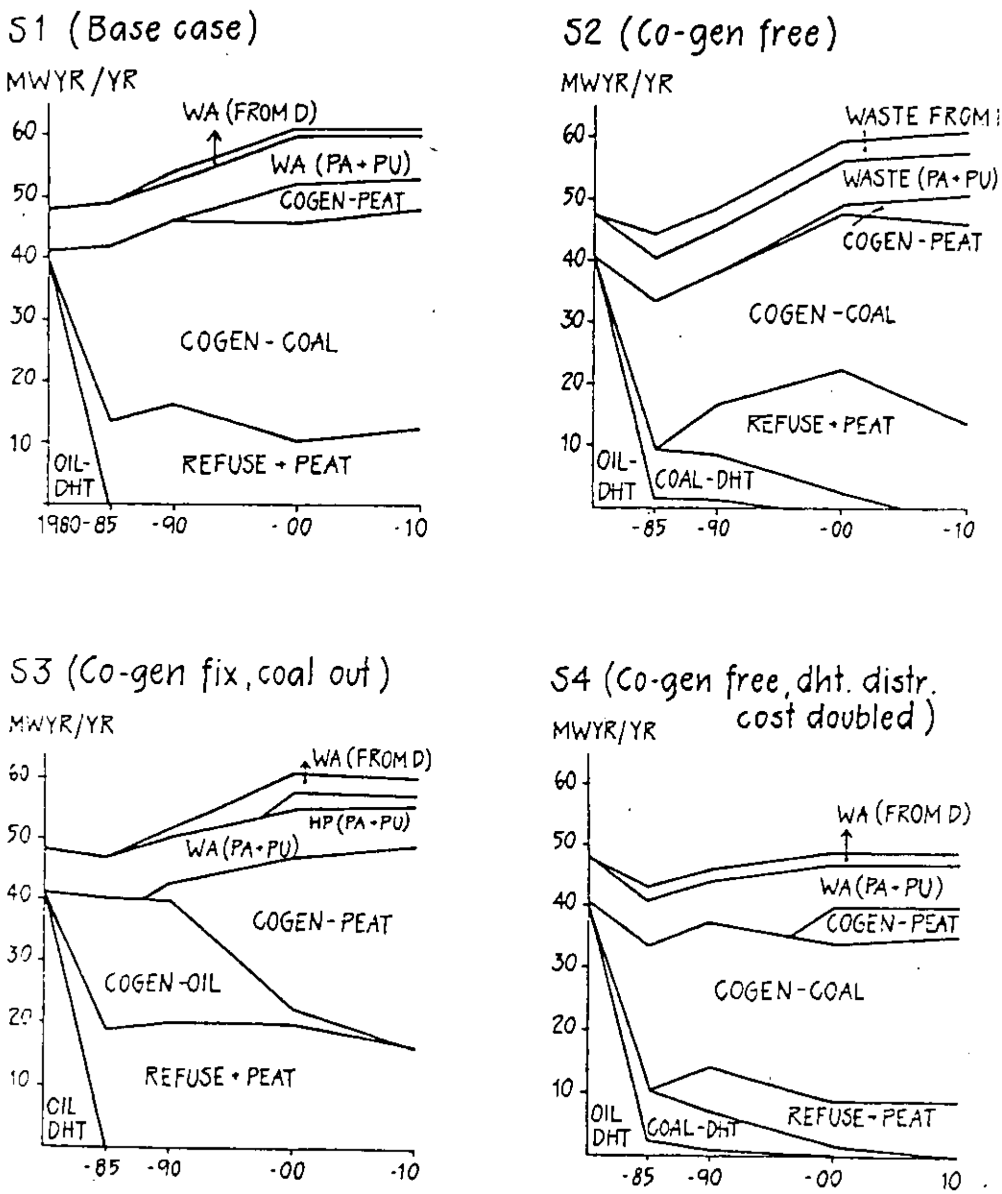


Figure 6.4
Local district heat generation by type.

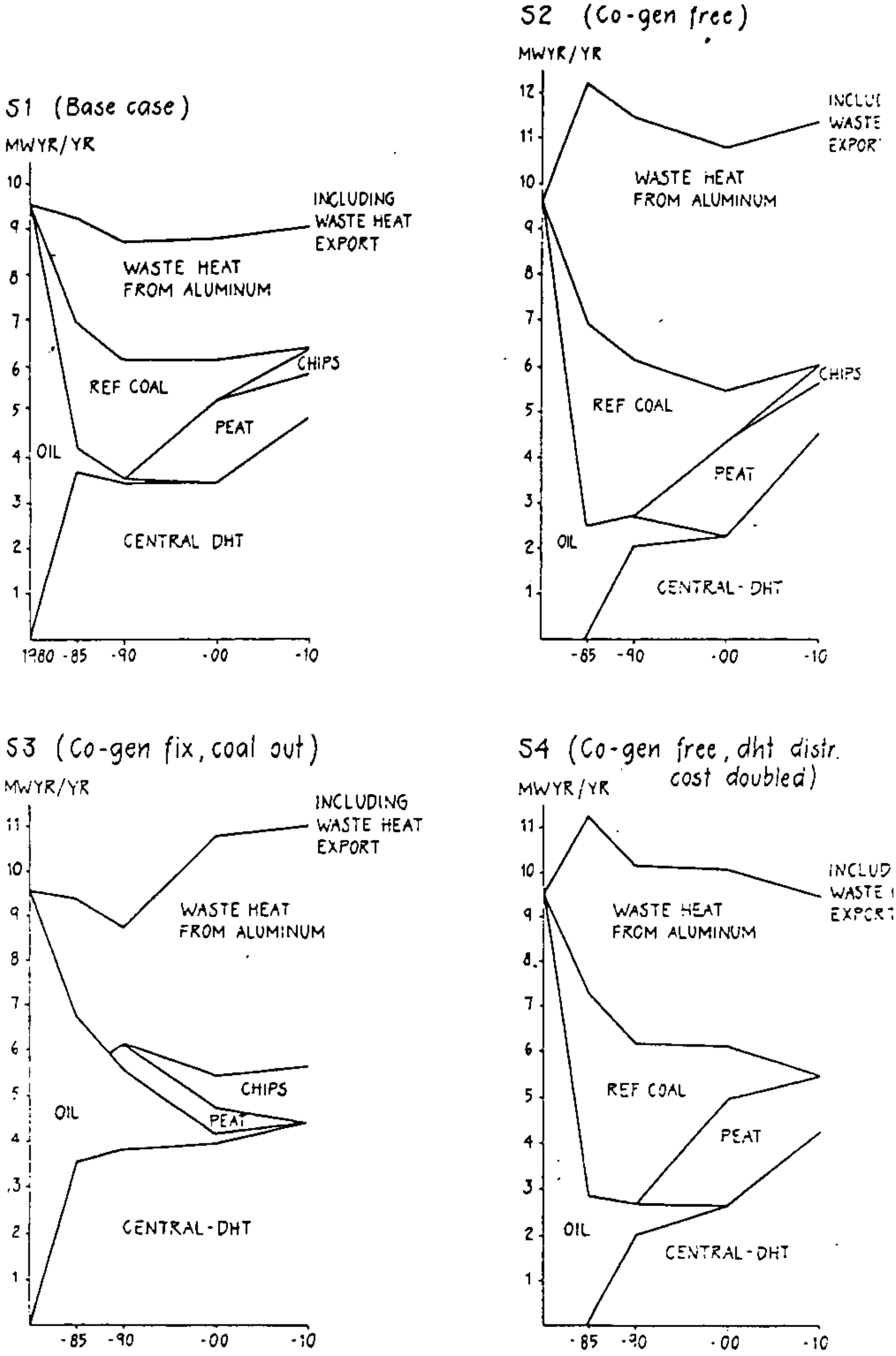
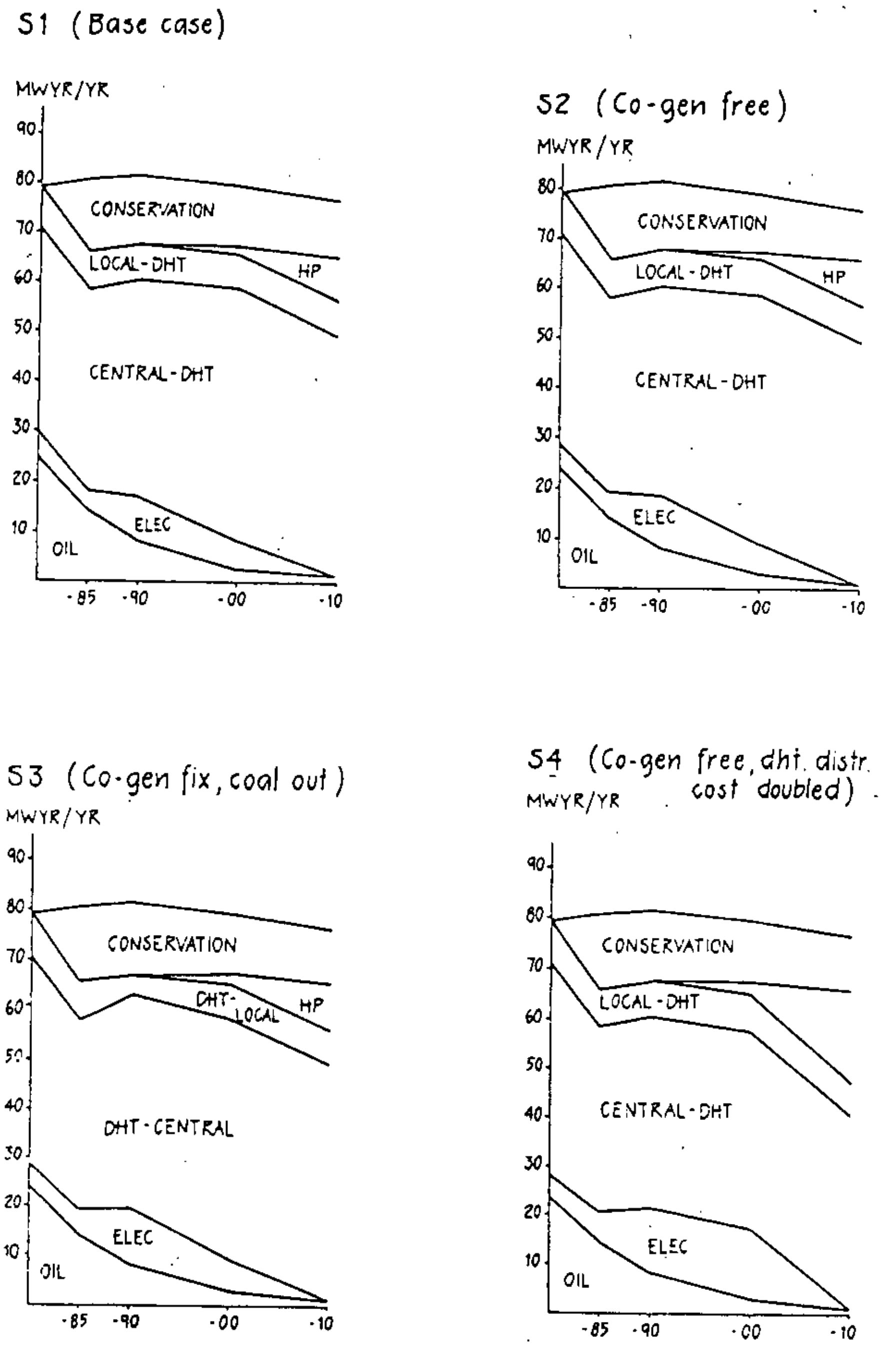


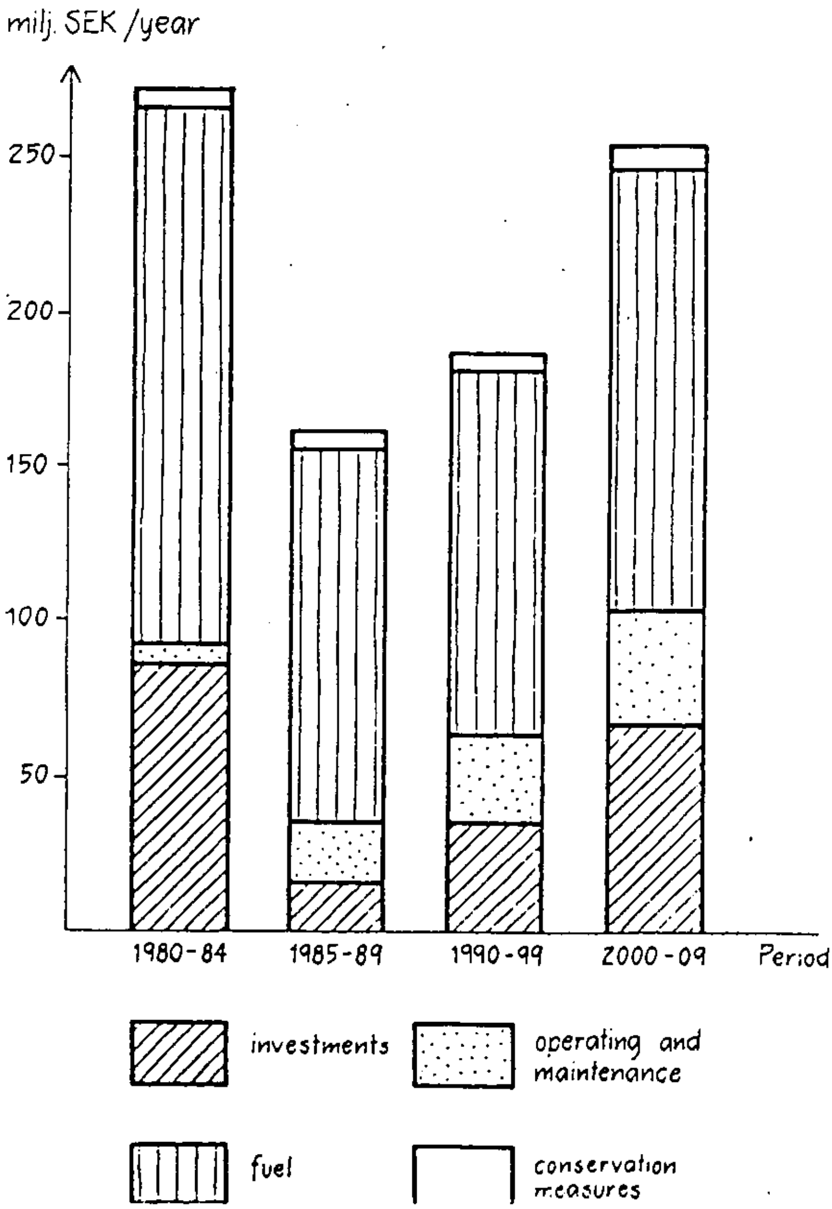
Figure 6.5
Total heating structure.



System costs

The system of the optimal base-case scenario are illustrated below.

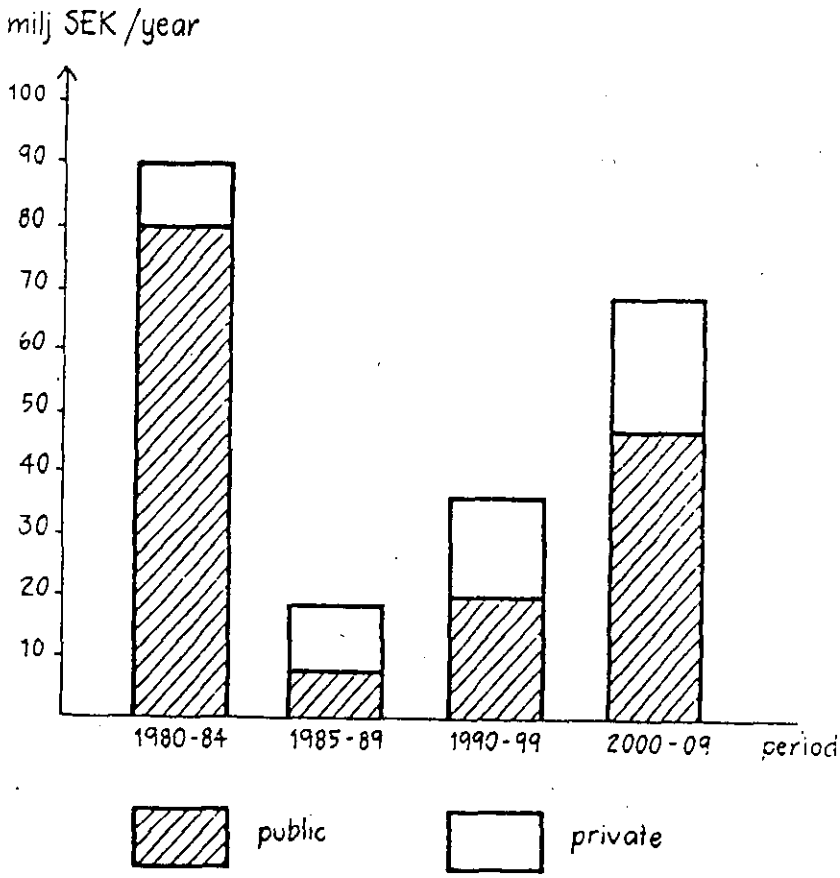
Figure 6.6
System costs (base case).



Investments by category of investor

The diagram below calls attention to the preponderance of public investment over private in the initial states of the goal period. Private investments are estimated to remain almost constant throughout the entire period. More than 50 per cent of the necessary public investments before 1985 will be for the construction and fitting out of heat co-generation plants.

Figure 6.7
Investments by investor (base case).



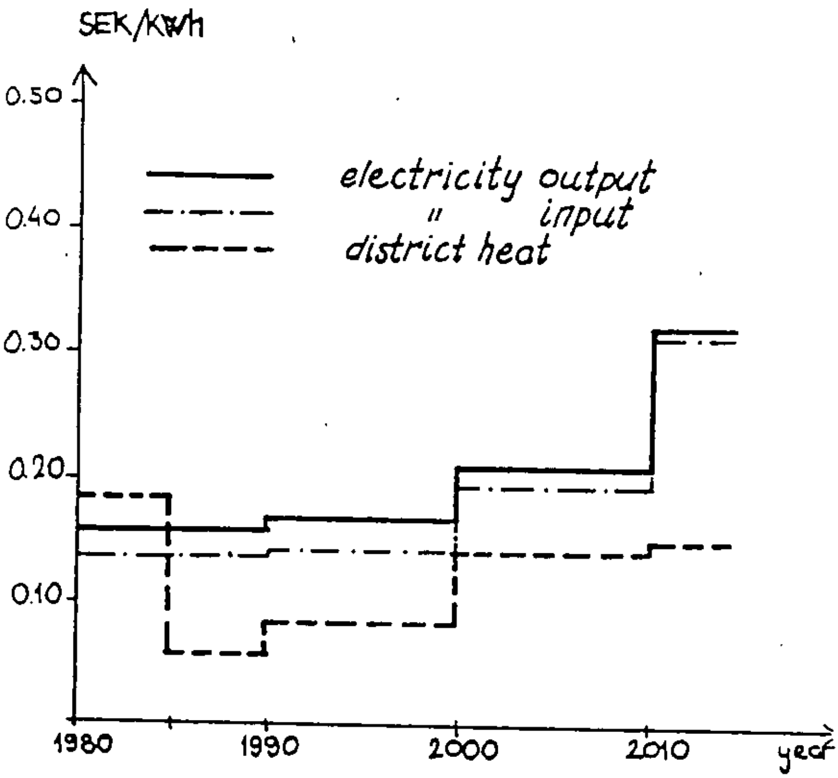
Average energy shadow prices

The average shadow prices of energy illustrated in the diagram below reveal the marginal costs of the last energy unit produced for district heating and electricity supply.

The costs differ from period to period and indicate the price levels of energy output for operating the collective systems without deficit.

For electricity, the price development if shown relative to the input price of electricity into Sundsvall. The district heat price is generated internally and reflects the change in mix of fuel inputs over periods of time.

Figure 6.8
Average shadow prices of final energy.



6.25 Summary

The purpose of this study was to determine if MESSAGE II, a linear programming model designed to minimize the total costs of energy over a given period of time at a regional or national level, could also be made to serve the needs of an energy supply system at the local level.

The town of Sundsvall was found to be an appropriate location for a case study.

The results obtained from the study showed that the total system costs over a period of 30 years for a variety of supply alternatives, when interest rates and prices of energy inputs are constant, only differ by 5 to 7 per cent with regard to the present value. To some extent this is due to the presence of the large co-generation plant.

Of course, the interest rates and future price relationships of competing energy sources are of great importance and will very much affect the final choice of energy systems.

With help from the model it is possible to demonstrate the influence of different energy input prices and energy rates on the total system and its costs over a long time-span.

It is our conclusion that the model is a most valuable tool for policy makers at the local level. Its major attraction is its ability to identify and compare alternative system solutions in order to ensure the best possible selection.

7. TWO SWEDISH CASE STUDIES: GOTHENBURG AND MORA

One of the goals of Swedish energy policy is to lower the country's total energy requirements by 30 per cent before 1990, mainly by reducing the consumption of oil.

This chapter will describe how two Swedish municipalities have initiated an effective energy planning programme designed to achieve the stated goals. In both cases, energy resources found in the municipal sanitation services are being put to use. The most popular methods of energy extraction are (a) the use of waste as fuel, and (b) the use of heat pumps to extract heat from wastewater.

7.1 Gothenburg

The city of Gothenburg is situated on the west coast at the mouth of the Göta River. It is a very important harbour and industrial centre; with its population of approximately half a million people, it is the country's second largest city.

Gothenburg is the site of Sweden's largest port as regards importation of oil and petroleum products, accounting for about 35 per cent of the total import figures. Moreover, there are three refineries in the vicinity (Shell, BP, and Swedish company, Nynäs).

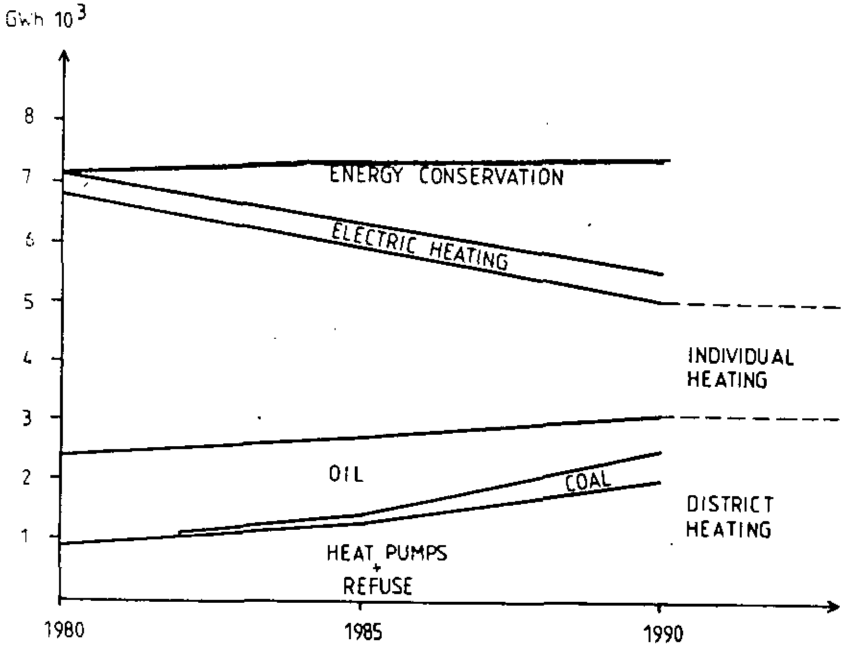
By issuing and distributing information to the public about energy conservation matters and encouraging technical improvements to buildings and houses it is believed that energy consumption for heating purposes can be reduced by a third. In absolute figures this means a reduction of energy demand from approximately 20.8 PJ in 1979 to 18.4 PJ by 1990. 608,000 cubic metres of oil were used to heat buildings and houses in 1979. It is hoped to lower this figure by 78 per cent or 130,000 cubic metres by 1990.

After reviewing various alternatives for the replacement of oil, among others coal, the city of Gothenburg decided first of all on a mximum utilization of locally available energy sources such as:

- heat pump extraction of heat from wastewater
- energy extraction from waste
- surplus heat from the refineries

The figure below illustrates the planned development for the period 1979 – 2000.

Heat generation in Gothenburg 1979 – 2000.



The availability of surplus heat in great quantities in the Gothenburg area enhances the prospects for the storage of energy during the summer months. A study made indicates that at least 6000 cubic metres of oil could be saved annually through heat storage.

7.11 Solid waste management

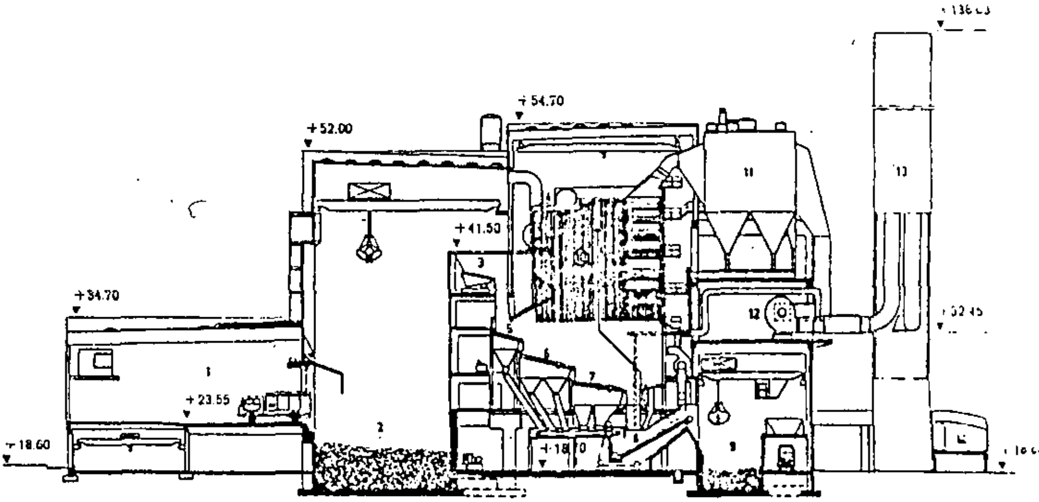
The waste fueled heat generating station in Gothenburg is owned by GRAAB, the Gothenburg regional Sanitation Company, which in turn is owned by the city of Gothenburg and other townships in the area. The installation began operations in 1872 and uses waste collected from households and industry. 239,000 tons of waste were burned in 1982, producing a quantity of heat amounting to 1500 TJ. The heat energy exchange consisted therefore, on average, of 6400 MJ per ton of waste.

1200 TJ were delivered to the Gothenburg Power Company in 1982, or 14 per cent of the heat supplied by the municipally owned district heating stations. The income from the sale of energy made it possible to lower the charges for handling waste.

Of the energy produced, 180 TJ was lost because of the lack of demand in the system during the summer months. The network is being expanded however so that by 1966 new customers will ensure that all energy produced can be used.

The waste-fueled heating station consists of three oven units (Von Roll) each with a capacity of 15 tons of waste per hour. The heat of combustion is collected in flue gas boilers (Generator) which use heat exchangers to transfer hot water to the district heating network.

The figure below shows a cross-section of the installation as it was in 1981. Since then economisers for the preliminary heating of circulation water have been added to the three flue gas boilers.



The GRAAB heat generating station in Gothenburg:

1. discharge hall
2. waste containers
3. vibration hopper
4. oven
5. dehydrofication grate
6. main grate
7. combustion grate
8. fire trough
9. slag hopper
10. flue gas boiler
11. electrofilter
12. exhaust gas fan
13. chimney
14. entrance ramp

There is a demand for the energy produced during most of the year, GRAAB has therefore extended a great deal of effort in optimizing the combustion both from the economic and environmental points of view.

The addition of the economizers led to an improvement in efficiency as the temperature of the flue gases were lowered from 290 to 225°C. As the temperature of the gas is lowered its volume becomes less, reducing the load upon the electrofilter. Although the effect produced has been increased by 6 MJ the dust content of the flue gases has been greatly reduced.

Furthermore, a mini-computerized control and guidance system for the ovens was installed in 1982. Such equipment ensures a more even rate of combustion which means that the oven, boiler and filter now work under much more advantageous conditions. The economisers and other measures taken to improve operational performance have meant that the degree of efficiency for the plant as a whole could be increased from 66 to 75 per cent. Energy production, because of the above mentioned improvements, will be raised by 290 TJ annually beginning this year.

At present an enlargement of the preliminary handling section is underway to receive industrial waste. Preliminary treatment improves the combustability of the waste and reduces the risk of interruptions to operations in the ovens. This too should result in an increase in energy production in the long run.

7.12 Water supply and sewage systems

There are two conditions for making a heat pump installation economic:

* the heat source must have a constant and not too low a temperature, and

* there must be a district heating distribution net nearby.

Both these conditions are fulfilled in the sewage treatment plant of Ryaverket, which receives sewage from the Gothenburg region (about half a million inhabitants). The sewage flow, and the temperature, at the Ryaverket permits the installation of heatpumps for delivery of about 135 MW. The installation is carried through at three steps of 27, 27, and 80 MW, respectively.

A temperature-duration curve for the sewage at Ryaverket is shown in the figure on the next page. The temperature will be lowered about 1.3^{o}C by the first heat pump. When all three pumps are installed, the discharged sewage will have a minimum temperature of 0.5^{o}C.

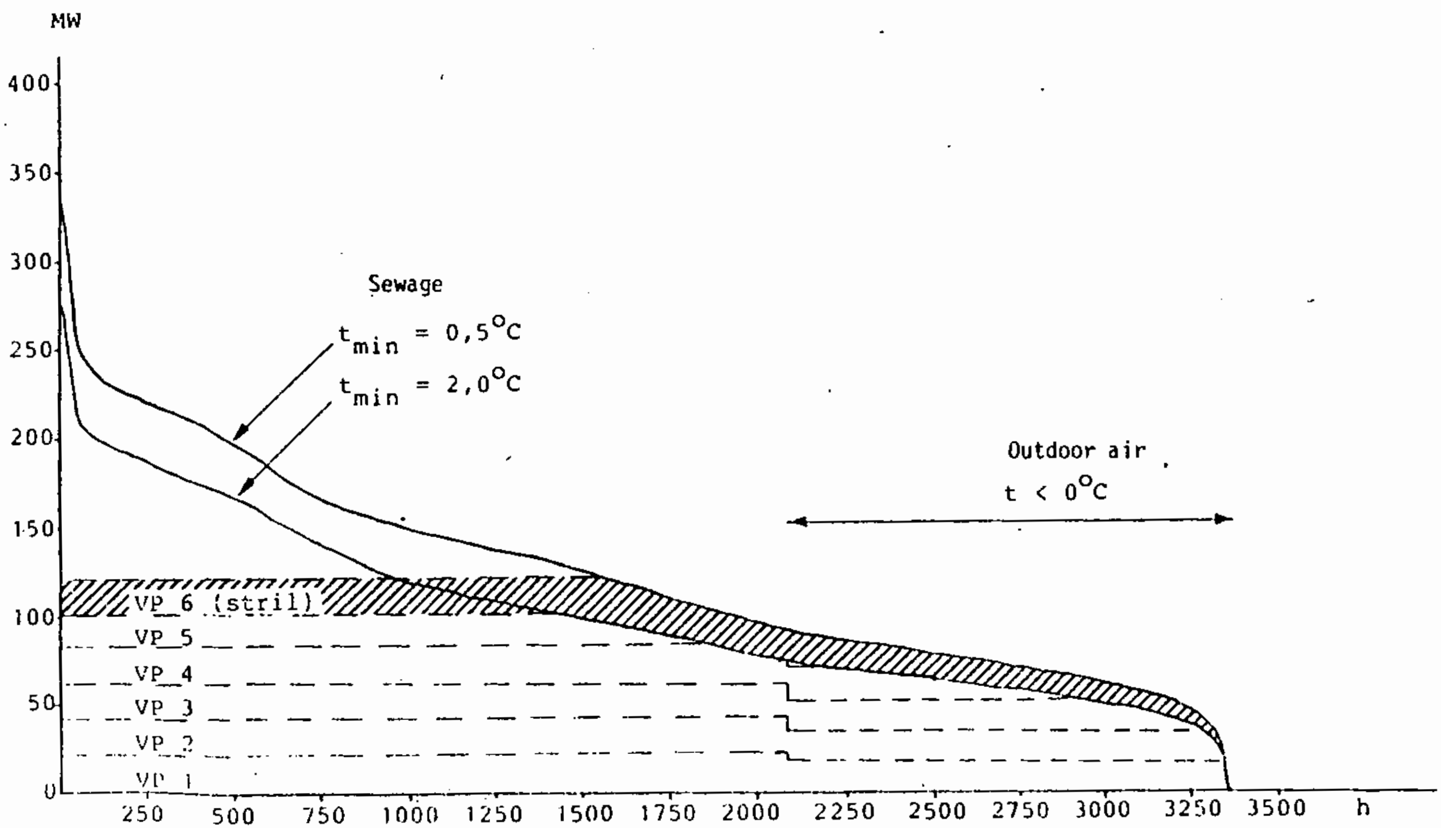
The first heat pump will be operating by the winter of 1983/84, delivering about 150 GWh heat, which approximately corresponds to 15.000 m^3 of heavy fuel oil, or the annual heat consumption of 12,000 dwellings. The investment cost bill is about 44 M Skr (6 million $), and the cost is estimated to be regained in 4 years.

The second heat pump has equivalent data, but is estimated to pay off in 2.7 years. The third heat pump has not yet been decided upon. The decision depends on whether certain residential areas, which receive their heat from private companies will be connected to the public district heating system. Furthermore, the district heating distribution network will have to be extended.

In the Gothenburg region there are also 5 large sewage pumping stations, and a considerable number of smaller pumping stations. A heat pump has been installed at one of the larger stations, with untreated sewage as the heat source. The pump has been operating for some years, and performs satisfactorily, provided daily maintenance is kept up. The time required for investment pay-off has been estimated to be 10 years. A filter would decrease maintenance needs, but would also considerably increase the pay-off time.

EFFEKT GRYAAB

1/1--31/3 samt 1/11--31/12 1979

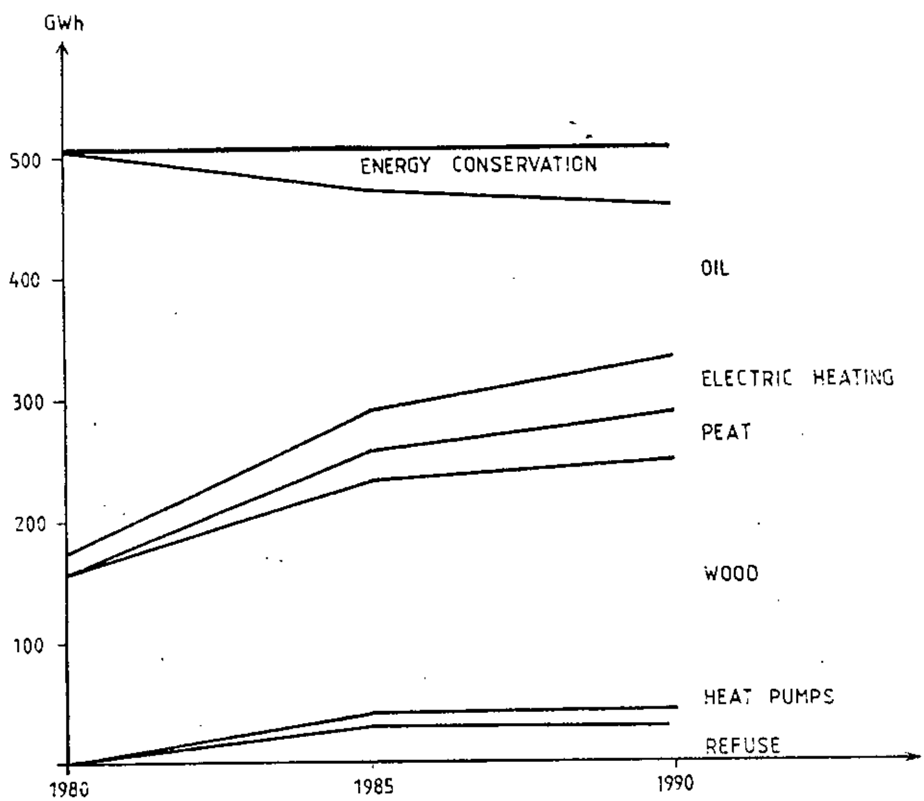


Temperature-duration curve at Ryaverket sewage treatment plant (1979).

7.2 Case II: MORA

Mora is a town of 20,000 inhabitants, situated in the province at Dalarna in the middle of Sweden. About 70 per cent of the inhabitants live in one-family houses. Small and medium-sized industries, mainly manufacturing engineering industries, employ about 40 per cent of the working population. Annual mean temperature is + 3.4°C.

The heat supply for the town during 1980, and anticipated heat supply for 1985 and 1990 is displayed in the figure below:



Heat supply in Mora 1980 – 1990.

From the figure it can be seen that the heat supply already by 1980 to a relatively large extent was based on wood fuel, mostly in the one-family houses situated outside the main urban centre.

From a total heat supply of 503 GWh in 1980, 113 GWh was supplied via the district heating network. The fuels used for district heating were oil (92 GWh) and wood (21 WHh).

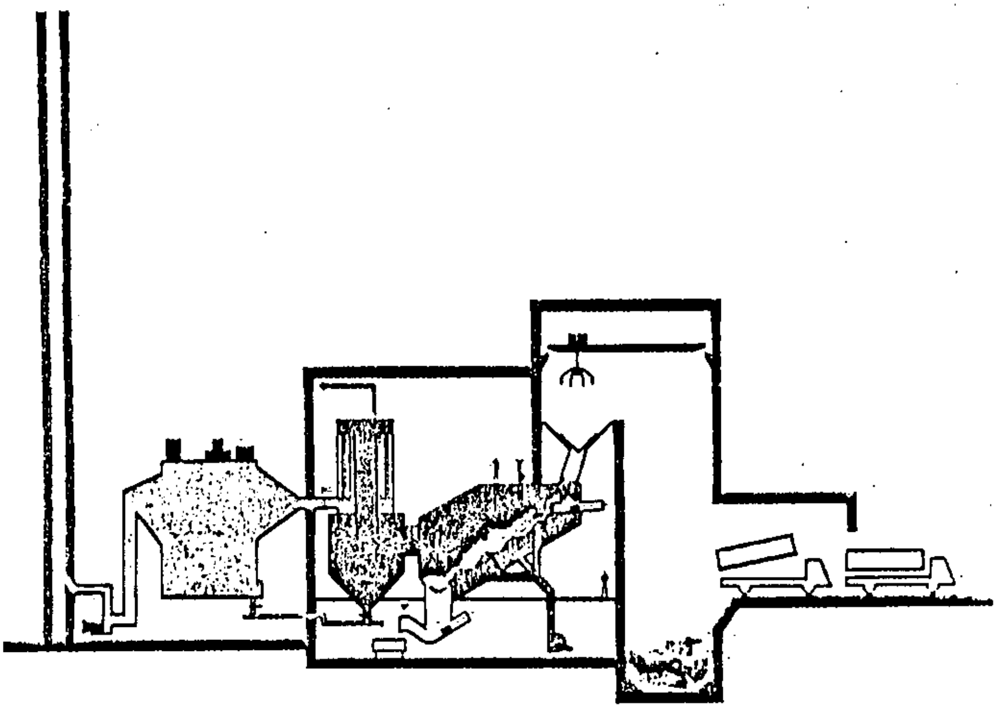
The potentials for energy conservation in the municipal heating systems will be utilized only partially. A new refuse incineration was constructed in 1981, which should deliver about 30 MWh annually when fully utilized. A heat pump has been installed in the largest sewage treatment plant, but only for heating the plant itself. The plant is situated outside the town proper, and the distance to the district heating distribution network is considered to be too long for en economic utilization of the sewage-derived heat. There has so far been no discussion on the possibilities of installing heat pumps in the waterworks or in the sewage pumping stations. The reasons for this is that the heat produced in the refuse incineration plant well covers the heat produced in the refuse incineration plant well covers the demand in the summer. A heat storage facility - there are potentials for aquifer storages – would increase the possibilities of utilizing the local waste heat sources. The economics of an aquifer heat storage has however not been calculated.

7.21 Energy extraction from the combustion of waste

The waste-fueled heat generating station in Mora is wholly owned by a municipal corporation. The installation began its operations in 1981 and uses mainly household refuse, but also some office and industrial waste. 15,000 tons of waste were incinerated in 1982, producing 90 TJ of energy (1.8 TJ had to be dissipated). The net energy exchange amounted to 6000 MJ per ton of waste.

The energy produced is used for district heating and the deliveries from the heat generating account for 25 per cent of Mora's present district heating supplies.

The heat generating station consists of an oven unit (Bruun & Sorensen AB) with a capacity of 3.15 tons of waste per hour. Final combustion takes place in an afterburner connected to the fule gas boiler. The figure below shows a cross-section of the plant.



The Mora heat generating station:

1. refuse silo
2. automatic loader
3. combustion oven
4. afterburner
5. flue gas boiler
6. conveyor belt for removal of slag
7. electrofilter

The maximum capacity of the plant is 25,000 tons of waste per year. This means that the production of energy from the heat generating plant, at its present mode of operation, can be as high as 140 TJ per year. An optimization of the combustion process should however make it possible to raise this figure to 150-170 TJ per year.

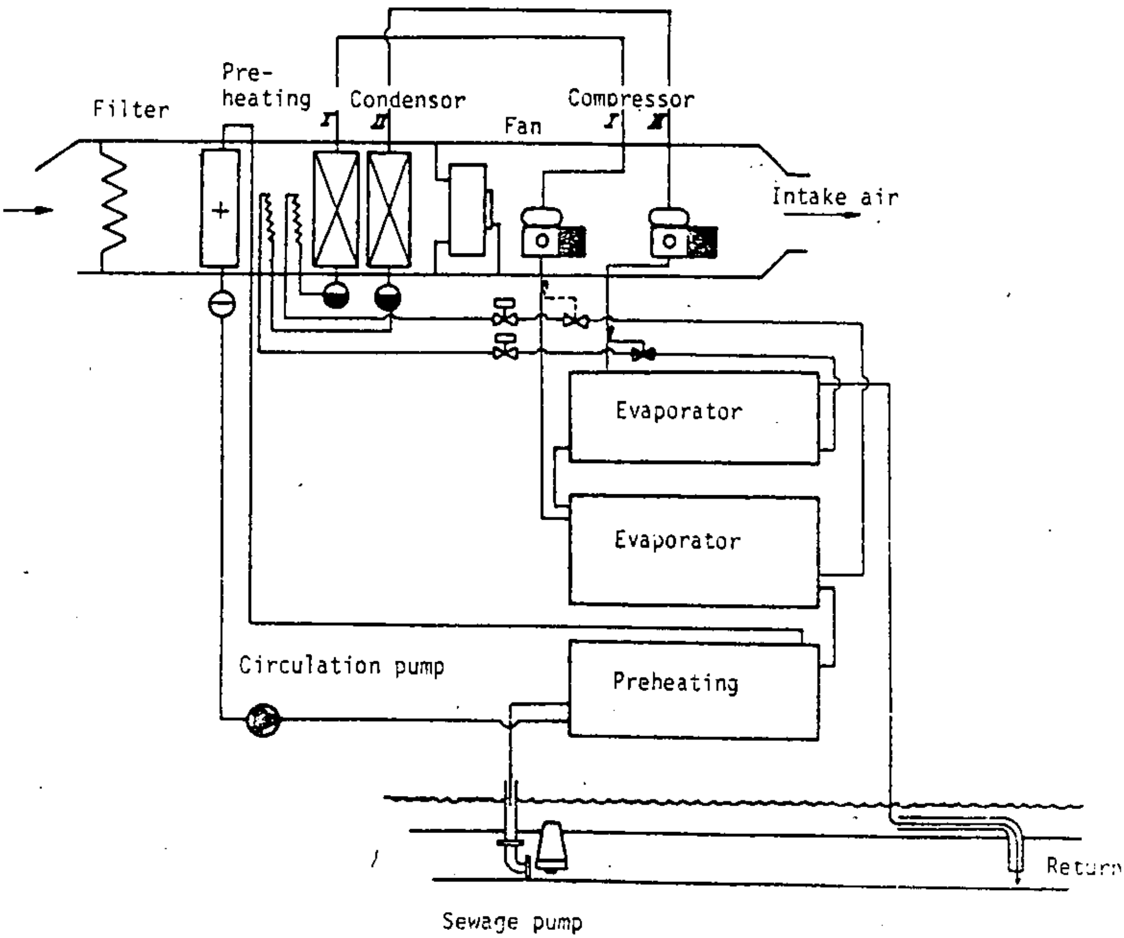
All of this energy is not required at the present time in the district heating network. However, the town of Mora has built a factory for the manufacture of peat and woodchip fuel pellets and it is technically feasible to use the surplus energy in the factory's process dryer.

7.22 Water supply and sewage systems

A heat pump has been installed in the sewage treatment plant of Solviken, which receives sewage from the central parts of the town. The heat pump uses about 60 MWh of electricity annually, and delivers about 500 MWh. Delivered effect is 110 kW. The heat from the treated sewage is brought to a specially designed heat exchanger, which delivers heat to the heat pump, in turn heating the ventilation system for the sewage treatment plant.

The heat pump has been operating for about a hear, and has been functioning well. The temperature of the sewage has been decreased by about 1°C; from 12 to 11°C during most of the year, and from 6 to 5°C in ths spring, when large volumes of water flow to the plant.

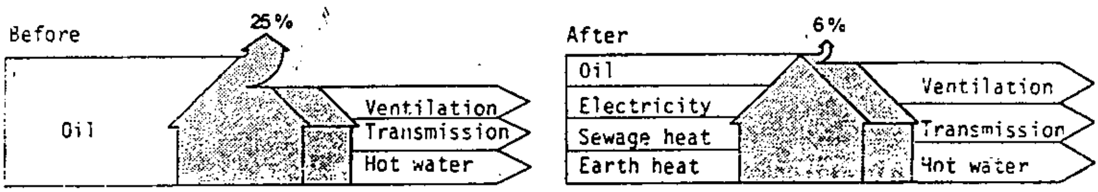
A layout of the heat pump system can be seen in the figure below:



The installation has cost about 500,000 Skr (about 60,000 $), and it is expected to be amortized within 5 years.

A heat pump has also been installed in Mora for the heating of dwellings. A residential area of about 170 dwellings and some other buildings, uses, alternatively, waste heat from the untreated sewage and earth heat. The heat pump installation accounts for about 75 per cent of the annual heat demand. The installation is currently under revision by the Swedish Council for Building Research.

The reduction of oil consumption for the area can be seen in the following figure:



Energy conservation in water supply and sewage systems may also be achieved by using alternative techniques for the construction of distribution systems. In the residential area of Balder-Lisselsby in Mora, the trenches for the water and sewage pipes have been made relatively shallow, and insulated. The district heating pipes have been placed in the same trench, thereby benefiting from the heat loss in these pipes. This technique makes it possible to construct considerably less expensive distribution systems, especially in the northern regions, and where rock blasting would otherwise have been necessary. The system of Balder-Lisselsby has been in use for some years, with encouraging results.

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