LONG-TERM ENERGY SUPPLY STRATEGIES FOR STOCKHOLM COUNTY

Technical Report

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TABLE OF CONTENTS

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1. Objectives and Motivation

The nature of the energy problem today and the expected developments in the future show that greater ingenuity must be applied in order to secure future energy needs. Since Western Europe, and in particular countries such as Sweden, have only modest indigenous energy resources, most of the future energy supply will depend on import opportunities which are largely governed by the expected development of the world's energy exchange markets. All eventual developments cannot be predicted since this would be indeed an overwhelming and almost infinite undertaking. However, one can state already today that the dwindling supplies of cheap and clean crude oil will be replaced in the future by costlier and dirtier oil and other fossil energy sources. The availability of sustainable energy sources such as solar energy and nuclear energy in conjunction with breeder reactors, cannot be expected until the first half of the next century even if their widespread acceptance is reached. Large-scale introduction of these technologies is not possible before then, owing to long lead times connected with the development of adequate materials, increasing time requirements in the construction of complex and centralized systems, and last but not least, the sky rocketing investment costs. Thus, during the next two to three decades most of the national economies all over the world are faced with the problem of providing more energy services with decreasing amounts of more expensive energy. This imposes new political issues connected with the necessity to improve the efficiency of energy use and to decrease the dependency on energy exporting countries. Both higher energy use efficiencies and at the same time greater flexibility in energy use are conflicting objectives, and are therefore difficult to achieve simultaneously.

In the light of these rather general statements on the future evolution of the global energy system the legitimate question arises whether a very small (in relation to the globe) but exactly defined urban area, e.g. the Stockholm County, can develop an energy supply system which is characterized by high efficiencies and a certain robustness against drastic changes on the international energy markets. Stockholm County is not only dependent on the international energy situation but is also deeply embedded in the national energy supply system of Sweden. In particular, Stockholm

County depends on energy imports from abroad and the electricity delivered to Stockholm from indigenous hydroelectric and other power generation facilities within Sweden (one should note that the nuclear power plants depend on imported fuels also).

It is the Swedish electricity generation sector which lately has given reason for controversial deliberations. The forecasts of national electricity demand in the 70s were highly overestimated and have led to an excess electricity production capacity in Sweden. The abundance of production capacity is assumed to prevail until the late 90s. Thereafter, a serious squeeze on electricity supply is expected: Firstly, by that time the growing electricity demand will have hit the ceiling of existing capacities and will require full capacity utilization. Secondly, according to the last referendum with respect to the peaceful utilization of nuclear power, no additional nuclear power plants are permitted (except two plants already under construction). Thirdly, the service time of existing nuclear power plants is limited to 25 years. This means that the nuclear power stations which started production in the early 70s will have to go off line during the late 90s. Furthermore, the traditional source of electricity generation in Sweden, hydroelectric power, has almost reached its limit due to environmental considerations, and only minor capacity increases can be expected.

Thus, the Swedish electricity sector faces a twofold problem with direct repercussions on the overall energy supply system of Stockholm County. The first problem is rather short term and concerns the question of the most economical use of the excess electricity production capacity during the next 15 years while the second question is directed to the provision of long-term electricity supply. The real dilemma can be summarized as follows: The existence of excess electricity capacity in the short run suggests either promotion of the use of electricity e.g. for heating purposes or finding alternative fields of application which do not expand electricity demand. The promotion of electricity sales by means of appropriate pricing policies, however, given the constraints mentioned above, aggravates the envisaged problem of electricity supply in the long run. On the other hand, alternative fields of application e.g. the retro-fitting of thermal power plants for district heat supply create problems of their own. Firstly, by the turn of the century the so converted capacities would not be available since they would be required to meet electricity demand. The consideration of switching these power stations back to electricity production raises the question of future district heat supply alternatives.

In this context the temporary utilization of the Forsmark 3 nuclear power station which is partly owned by the Stockholms Energiverk is of interest when planning the energy future of Stockholm. Presently the Forsmark 3 power plant is under construction and its completion is scheduled for the year 1984. Between 1985 and 1998 the capacity of 1050 MW(el) is considered to be redundant due to the expected shortfall in the demand for electricity in Sweden. STOSEB, an association of the municipalities of the Stockholm County therefore investigated alternative fields of possible applications of Forsmark 3 during the period 1985 to 1998. Their analysis resulted in the STOSEB 80 report [1] which essentially favors and therefore suggests the retro-fitting of the Forsmark 3 power station for simultaneous generation of electricity (300 MW(el)) for the national grid and district heat (2000 MW(th)) for Stockholm County*. This proposal implies the construction of a heat transmission system (pipe line) over a distance of 120 km from the Forsmark 3 location to the Stockholm County area including the necessary infrastructure i.e. pump stations, heat exchangers and a 480 MW(th) oil-fired heating block serving as back-up capacity. The retro-fitting is assumed to be completed by 1988; the switch back to electricity production is envisaged for the year 1998. This leaves a service time of roughly 10 years during which the capital investments for the retro-fitting and the peripherial equipment should have paid off.

After 1998 two 500 MW(el)/1000 MW(th) coal-fired co-generation blocks located in the vicinity of the Forsmark site are planned to make up the drop in district heat production capacity caused by the switching back of the 2000 MW(th) of Forsmark 3 to electricity generation. The heat transportation system, therefore, would be utilized beyond the year 1998.

In light of the serious energy import dependence of Sweden and the Stockholm County in particular, it is desirable that the future energy system should be marked by intensified domestic energy production or at least by a higher import diversification. The Forsmark scenario as recommended in the STOSEB report implies a strong shift from

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* Other scenarios considered in the STOSEB report concern various centralized and decentralized coal strategies. By means of co-generation within the Stockholm County the demand for heat and electricity could be met to a certain extent. The remaining heat demand would be supplied by large-scale heat pumps. Forsmark 3--according to its original design--would then produce electricity only. In turn this electricity would be required to operate the large-scale heat pumps and supply the residual electricity demand.

oil to coal imports especially for the period after the temporary nuclear era in Sweden. The target of an import diversification has been achieved to some degree since the potential coal export countries are much more widespread over the globe and to a large extent belong to politically stable nations. This is certainly not the case with most of the major oil exporting countries. However, there are alternatives to the Forsmark scenario which offer an even higher degree of diversification with respect to energy imports. Such alternatives cannot be perceived analyzing primarily the heat production sector. Ideally, the entire energy system should be the center of attention including all energy demand categories as well as all energy supply sectors. For example, the fuel needs of the transportation sector amount to roughly 20 percent of all oil products consumed in Stockholm County. An energy supply system that in principle guarantees a district heat production similar to the Forsmark scenario but at the same time substitutes for oil and oil product imports in the transportation sector must also be considered along with the Forsmark scenario. The Nynäshamn Energy Complex represents such a promising possibility. Essentially, this complex would produce methanol by means of coal gasification. In the short run methanol is a suitable synthetic fuel admixture to eke out the traditional gasoline (and thereby oil) imports or in the long run a full substitute for gasoline. Further, the methanol production process necessitates significant cooling requirements. The integration of this "waste heat" into the Stockholm County district heat system could then in part meet existing demands. This would require the additional implementation of heat pumps which utilize the 60 degrees centigrade water returned to the energy complex by cooling it down to the technically desirable temperature of 20 degree centigrade. Up to the turn of the century the electricity required to operate these heat pumps could be supplied by the Forsmark 3 power station, while in the long run adequate co-generation power plants based on coal would have to replace the nuclear electricity generation.

The planned technical procedure of methanol production includes another feature which introduces additional degrees of flexibility for the future Stockholm energy supply system. In general methanol production comprises two major steps. Firstly, a carbon source is converted into a fuel gas, and secondly, this fuel gas is further processed and synthesised to become methanol. Therefore it is technically feasible to divert the fuel gas after the first step and utilize this synthetic fuel gas in a very conventional way, e.g. for heating or cooking purposes in residential areas, in industries or as a fuel in co-generation plants.

However, the Nynäshamn location requires the transportation of heat and gas over an average distance of 55 km. Thus, the problems attributed to the energy complex are similar to the Forsmark scenario but smaller in scale.

In summary, two basic weaknesses of the STOSEB report can be identified. The first refers to the methodological approach in planning the short-term energy future of the Stockholm region. The results of the STOSEB report are based on comparative cost analyses' of the various energy alternatives, but these comparisons were not made simultaneously for the whole energy system. Instead, options were compared one by one eliminating marginally costlier alternatives. However, it is possible that even marginally costlier alternatives could become attractive when the whole energy system of the Stockholm region is considered.

The second weakness refers to the relatively short planning horizon of the STOSEB report. It offers only a short-term solution to the excess electricity production capacity of the Forsmark 3 power plant and little else beyond that. In the report it is envisaged to utilize the district heat pipeline from Forsmark to supply district heat to Stockholm from coal co-generation plants after 1998 when the nuclear power plant would have to be switched back to electricity production. For the time period after 1998 no other alternative plan is offered. It is likely, however, that at that time most of the imported coal would be required to produce synthetic liquid fuels due to the lack of crude oil import opportunities. Instead of using coal to produce electricity after the 90s, Swedish indigenous biomass or hydroelectric power could be used to generate the required electricity. In such a case, the 120 km district heat pipeline from Forsmark to Stockholm is not likely to be used. Instead, hydroelectric power could produce electricity which could be converted into district heat in heat pumps, or biomass could generate electricity at point of collection and could again supply district heat via heat pumps. Further, it is not necessarily the case that nuclear power is out for ever in Sweden. Public opinion towards nuclear power may well change in the long run (as can policies). Provision for such eventualities is not given in the STOSEB report.

These three examples--of using nuclear energy, biomass and/or hydroelectric power to supply electricity and/or low temperature heat requirements--illustrate the inflexibility of the STOSEB proposal when a longer time horizon is adopted. It can be concluded that the two major weaknesses of the STOSEB report would have to be investigated further before this proposal could be used to make a binding decision for the implementation of the 120 km district heat pipeline and the conversion of the Forsmark power plant. It may well turn out that the STOSEB proposal is robust under such analysis e.g. when compared to the energy complex, but this is not obvious and must be investigated in detail.

The objective of a better understanding of Stockholm County's long-term energy future motivated the Regional Planning Office to fund the design and development of an energy supply model adequate to reflect the special case of a large urban area and the anticipated changes in its energy supply structure. In addition, the energy supply model was meant to fit into the set of models already or in due course being applied within the the "Regional Planning and Future Energy System (REGI)". Thus, the appropriate interfaces, i.e., the transfer of data etc. had to be kept in mind during the development phase of the energy supply model.

2. The Spatial and Temporal Frame

In principle, the spatial frame of this study was a priori determined--the Stockholm County. However, this is valid only when the future evolution of energy demand is considered. Energy supply facilities, as well as energy resources, are to a large extent located outside the Stockholm County area. The energy supply model, therefore, has to account for energy production and conversion facilities located in part far outside the Stockholm area--e.g., the Forsmark 3 nuclear power station or hydroelectric power installations in general. This also requires the inclusion of adequate representation of the energy transportation equipment from sites outside the County as well as the distribution inside the Stockholm area within the model. Thus, the spatial frame of the energy supply model frame covers the Stockholm County area plus the grids and the power plants which deliver secondary forms of energy to Stockholm.

The temporal frame covers 40 years, i.e., the period 1980 to 2020. In the analysis of future energy supply options for the Stockholm County a sufficiently long time horizon is an absolute prerequisite. The service time of power plants or energy distribution equipment ranges from 20 years in cases of block heating systems, up to 50 years and more (hydroelectric power plants etc.). This is to say that quantitative considerations in the planning of energy supply structures, which on one hand should be flexible enough to react to changes in the world energy situation and on the other hand are marked by a certain robustness towards surprises, have to be based on time horizons sufficiently long to encompass the effects of their implementation. In other words, the time horizon should match the service time of one generation out of most of the energy supply technologies considered. In light of the major future supply options available to Stockholm County the selected time horizon of 40 years appears appropriate.

3. The Basic Structure of the Energy Supply Model MESSAGE II

MESSAGE II is a dynamic linear programming model that reflects the essential stages of the energy chains which range from primary energy supply to the final energy requirements to meet useful energy demand. Given the absolute level and the types of useful energy demand, the model calculates the cost-optimal energy supply strategy for any predetermined area (metropolis, region, economy, etc.) subject to a number of constraints. The constraints limit the number of conceivable trajectories of the future energy supply system and compel the model's behavior to remain within the range of plausibility. Such constraints comprise restrictions on the speed of structural changes, availability of new technologies or simply energy import ceilings. Another important constraint concerns the often neglected prerequisite that the model's solution conforms to the existing energy supply system. A special feature of the MESSAGE II model is the detailed representation of end use technologies. As many as 38 different heating technologies were implemented to model the future possibilities of meeting the useful energy demand for heating purposes. Furthermore, the model changes and adjusts useful energy demand according to the endogenously calculated final energy supply costs, e.g., the model switches from one heating technology to another one when energy supply costs vary or it may decide to intensify retro-fitting efforts of the badly insulated building stock. In other words demand elasticities are explicitly implemented in MESSAGE II and are therefore endogenously determined. Another feature of MESSAGE II is the possibility of modeling mixed integer problems. This becomes necessary in cases where the problem under consideration requires an either/or solution, e.g., yes or no to a predetermined (in the sense of a fixed technical configuration) energy production facility.

Figure 1 shows a simplified, schematic representation of the current and envisaged energy supply structure for Stockholm County including all the technical options institutionally preferred or requested. The Värtan co-generation plant, the box labeled fossil power plants (oil

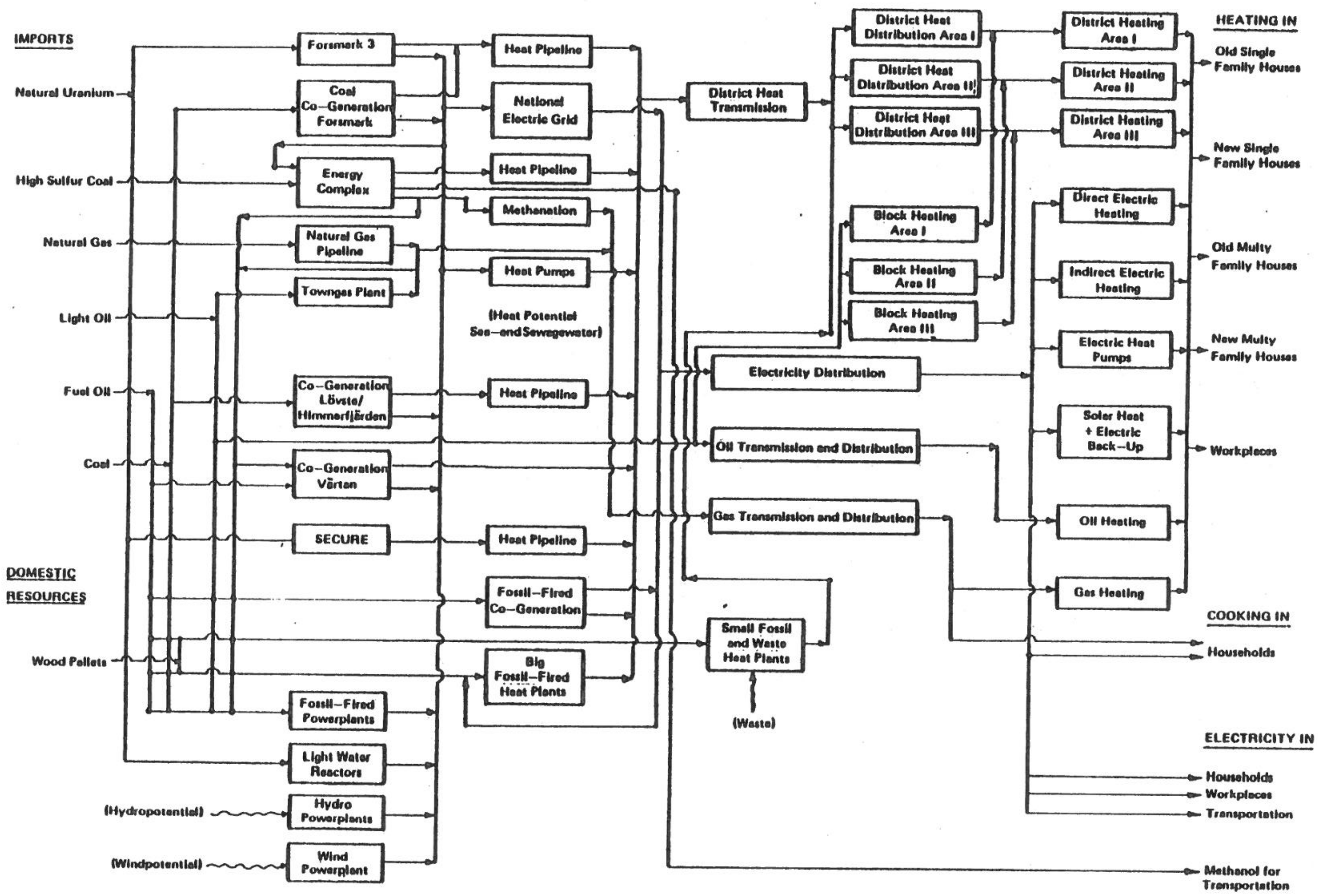


Figure 1: A Scematic Representation of the Energy System of Stockholm County

fired ones) or small-scale heat plants are examples of existing technologies while Forsmark 3 or the energy complex represent future supply options. Various transmission and distribution systems for different forms of energy complete the representation of the energy chain for Stockholm County. In a model, each of the diverse technologies considered are reflected by a set of input data. For example, the representation of an oil-fired co-generation plant requires the specification of the installed capacity, the capital cost per unit of capacity installed, the fixed and variable operation and maintenance costs, the plant factor, the availability due to unscheduled down times, the plant life time, the oil inputs, and the electricity and heat outputs as well as the range of variability within the output structure. A complete list of details describing each technology is given in Annex 1. The major characteristics of the "competing options", however, will be briefly discussed in the following section of this report.

4. The Energy Supply Options of Stockholm County

4.1 The Application of Forsmark 3

Table 1 summarizes the essential characteristics of the Forsmark 3 alternative as implemented in the energy supply model MESSAGE II. The data given in the following tables as well as in Annex 1 are based on the STOSEB report [1] and a report published by the AB Nynäs Petroleum [2] whereas deviations of various data quoted in this report stem from direct personal communication with staff members from REGI, STOSEB, STAL LAVAL or Nynäs Petroleum. Further, one should note that the data given in the main part of this report are incomplete and not sufficient even for a back of an envelope calculation. For example, efficiencies, the coefficients of performance or the allocation to distinct load regions highly influence the supply model's results. The alternative A of the two retro-fitting possibilities is marked by a condensation turbine (for the production of 300 MW(el) of electricity demanded by Vattenfalls) while the alternative B consists of a back pressure turbine. Apart from the different output structure the capital requirements are quite diverse in either case. Before going into the detailed comparisons of investment impacts of different output structures of the Forsmark 3 power plant one should be aware that the capital requirements for the normal operation of Forsmark 3 (electricity production only) have not been taken into

Table 1a : Forsmark 3 power production possibilities. The actual power rating amounts to 1050 MW(el) of which 300 MW(el) are not at the Stockholm County's disposal but required by the Statens Vattenfallsverk.

operation	electricity	heat	availability factor
normal	300 + 750 MW(el)	-	85 %
A	300 -	2000 MW(th)	88 %
B	300 + 200 MW(el)	1700 MW(th)	81 %

Table 1b : Investment requirements of retro-fitting, O&M costs of Forsmark 3 and investment requirements of heat transmission to Stockholm, in Millions of Swedish Crowns at 1980 prices.

operation	retro-fitting investments	fix O&M per year	heat transmission investments
normal	-	-	
A	900	20	3186
B	1500	35	2939

consideration in this analysis. It is argued that the expenditures for the construction of the power plant have been committed already a long time ago and therefore must not be taken as a criteria for the future mode of operation. However, the capital requirements of the retro-fitting for district heat supply and the heat transmission in particular do enter the cost-optimizing procedure of the energy supply model. According to Table 1b the condensation turbine requires 900 Million Skr at 1980 prices compared to 1500 Million Skr(80) in case of the back-pressure alternative for the on-site adaptation only. In addition to the retro-fitting capital requirements the necessary investments for heat transmission from Forsmark to the Stockholm area as well as the operation and maintenance costs have to be taken into consideration. The oil-fired 480 MW(th) back-up heat plant adds another 100 Million Skr(80) to the capital requirements of the Forsmark scenario.

The investment needs of the two coal-fired co-generation plants which ensure the supply of district heat after the year 1998 amount to 3900 Million Skr(80). The output structure is planned to produce 1000 MW(th) of heat and 500 MW(el) of electricity each.

4.2 The Nynäshamn Energy Complex

The planned production structure after completion in 1988, the energy input requirements and the investment needs of the Nynäshamn energy complex are given in Table 2. The output structure is organized so as to follow seasonal fluctuations of demands. For example, the gas output of the

Table 2a : Seasonal variation of the Nynäshamn complex production structure. All MW in thermal equivalent; the values in parentheses are the planned availability factors.

	winter	intermediate	summer
methanol	1500 t/d (.377)	2500 t/d (.221)	2500 t/d (.320)
gas	600 MW (.377)	269 MW (.221)	- (.320)
heat	382 MW (.377)	393 MW (.221)	274 MW (.156)

Table 2b : Average annual input requirements and average production (excluding return water heat pumps)

input		output	
coal	1 737 200 tons	methanol	700 000 tons
elec	600 GWh	gas	2.5 TWh
		heat	2.4 TWh

Table 2c : Investment requirements and annual O&M costs in Millions of Swedish Crowns at 1980 prices.

	Investments	O&M /year
energy complex	2500	137.5
heat pipe line, 400 MW(th)	500	12.5
pump stations, terminals etc.	300	6.0
gas pipe line, 600 MW(th)	100	1.0
retro-fitting Värtan	40	-
heat pumps, 250 MW(th)	370	11.1
Total :	3810	168.1

energy complex is supposed to contribute to the co-generation plant in Värtan which until now has been oil fired. During the summer period, peak electricity and heat demand is usually quite low and therefore no synthetic gas production is foreseen. On the other hand demand for methanol (i.e. for liquid fuels) in the transportation sector peaks in the summer periods and consequently the production follows this pattern also.

The investment costs of the energy complex itself, without the external infrastructure, amount to 2500 Million Skr(80). The heat transmission over 55 km to the Stockholm area plus the necessary pump stations, heat exchangers, etc. require another 800 Million Skr(80). The implementation of return water heat pumps (five 50 MW(th) units) adds 370 Million Skr(80) to the total capital requirements. Finally, one has to account for the gas transmission to the Värtan co-generation plant which amounts to 100 Million Skr(80). The retro-fitting of the Värtan plant from oil to oil-or-gas combustion costs about 40 Million Skr(80).

4.3 Large-Scale Heat Pumps

The third option of interest in this analysis concerns the installation of large-scale sea water and sewage heat pumps which would be integrated into the district heat supply system. Altogether a potential of roughly 1000 MW(th) of which about 700 MW(th) stem from sea water appears to be a reasonable magnitude for the Stockholm County. Table 3 summarizes the most important information on large-scale heat pumps.

Table 3 : Large-scale heat pumps for Stockholm County.

	sea water	sewage
potential in MW(th)	700	260
investment costs per 10 MW(th) unit in Millions of Skr(80)	22.3	22.3
heat pipe line per 10 MW(th) unit in Millions of Skr(80)	5.0	5.0
fix O&M costs per 10 MW(th) unit and year in Millions of Skr(80)	0.67	0.67
coefficient of performance	3.0	3.3

5. Energy Demand

Energy supply strategies can not be evaluated without close reference to the evolution of energy demand patterns. The absolute levels as well as the types of energy demanded significantly influence the energy supply system. On the other hand the quantities and types of energy purchased by consumers depend on the costs of energy offered by the suppliers. Thus, any analysis of the long-term evolution of the energy system has to account for the interdependence of energy demand and supply. A convenient point of departure with respect to the determination of future energy needs is provided by the analysis of energy demand densities. For example, the energy needs of an urban area without heavy industries such as the Stockholm County have been dominated by the demand for low to medium temperature heat. District heat supplied by co-generation is one of the most efficient ways to supply this demand category. However, the question with regard to the economic feasibility of constructing a comprehensive district heat network to a large extent depends on the given demand densities per hectar of urban area. In turn energy densities are determined by the building structure, the quantitative distribution on single and multi-family homes, apartment buildings, office buildings and so on. The age distribution of the different building categories determines the speed in the renewal of the housing stock. And last not least the various kinds of heating systems and their efficiencies in converting useful energy requirements into final energy demand complete this list of factors determining energy demand densities. Electricity needs other than for heating purposes (specific electricity) depend on the equipment of households and the service and business sectors (in this report they are referred to under the notion 'work places') with appliances.

Consequently, the energy demand analysis started with the investigation of the status quo of the existing building structure and the given heating systems of Stockholm County's subregions*. Together with energy consumption data per heated floor area it was possible to determine the various energy requirements for different building categories and heating systems. Finally, existing surveys on the degree of the equipment of households and offices with appliances and the actual electricity consumption permitted the determination of energy densities per hectar for each of the 105 subregions of Stockholm County.

The next step in the demand analysis required the definition of survival functions for the housing stock and the future rate of expansion of the heated floor area for each subregion. This is to say, that inputs from different regional planning disciplines were implemented into the procedure to determine future energy needs. Such inputs concerned changes in residential structures, newly opened up residential areas, information with respect to industrialization plans but also latest institutionally imposed regulations concerning insulation standards and so on.

The thus collected information then was grouped into five distinct demand categories for space and water heating, namely pre 1975 built single-family homes and post 1975 ones, pre and post 1975 multi-family homes, and work-places. The resulting useful energy demand for the period 1980 to 2020 is given in Table 4. The split of the planning horizon into 8 distinct time periods is a consequence of the complexity of the problem under consideration. A higher degree of disaggregation would have puffed up the supply model to a size beyond the capability of most commercially available computer systems. Further, the additional information gained would never correspond to the relative cost increases. The time periods selected for this study reflect the crucial points in time when new energy supply technologies are planned to go on-line or are phased out. Specific electricity demand of household, service and business sectors (work places) was aggregated into one demand category (see also Table 4). Modeling the relation between installed

* The demand calculations and the demand figures quoted in this report stem from the Regional Planning Office, Stockholm County Council. The essential steps of this analysis are presented in this report for reasons of completeness only. However, any misinterpretation of the work performed by the Regional Planning Office falls under the responsibility of the authors of this draft report.

capacity of a technology and the actually produced energy output requires the specification of a hierarchically organized load curve. The demand for heat and electricity in MESSAGE II is split into 5 distinct parts--so-called load regions. The load regions are represented by approximations into step-functions as shown in Table 5.

Table 4 : Useful energy demand Stockholm County in MW(th)yr/yr for Heat and in MW(el)yr/yr for Electricity.

category	time periods							
heat:	1980 1983	1984 1987	1988 1992	1993 1997	1998 2004	2005 2011	2012 2019	2020 2029
old-SFH	394.	388.	381.	370.	359.	341.	319.	290.
new-SFH	16.	27.	37.	49.	56.	71.	85.	105.
old-MFH	923.	908.	892.	869.	843.	801.	749.	678.
new-MFH	38.	61.	83.	107.	126.	154.	190.	235.
workpl	599.	596.	599.	609.	627.	661.	705.	766.
heat	1970.	1980.	1992.	2004.	2011.	2028.	2048.	2074.
spec.el	1084.	1151.	1213.	1273.	1314.	1346.	1357.	1356.

Table 5: Power levels relative to average load (lr = load region)

demand for	1. lr	2. lr	3. lr	4. lr	5. lr
heat	2.112	1.948	1.603	0.990	0.331
electricity	1.452	1.508	1.275	0.990	0.705

6. Energy Supply Strategies

6.1 The Overall Approach

In the following sections three distinct MESSAGE II runs provide the basis for the attempt to compare the energy supply options and to formulate energy supply strategies for Stockholm County. The three computer runs have been selected out of a total of more than 20 runs and in part represent extremes. Thus, the three strategies define the boundaries of a solution space within which all the other strategies are located also. The first scenario--labeled FE (Forsmark 3 Electricity)--represents the option of applying the Forsmark 3 power plant for electricity generation only. In the second scenario the model is forced to allocate Forsmark 3 primarily for heat production (the equivalent share in the capacity which is at the Stockholm County's disposal) and is labeled FH (Forsmark 3 Heat)*. The last case, NC (No Complex), excludes the Nynäshamn energy complex from the menu of supply options. In other words the NC scenario is a more constrained FH case.

After having discussed these three major energy supply strategies for the Stockholm County a fourth strategy will be presented. In the previous scenarios the one or other of the supply options was forced into the model solution while others were excluded exogenously. The linear programming

* In the initial MESSAGE II runs the total available capacity of 2000 MW(th) was allocated for the supply of district heat exclusively. In subsequent discussions with STOSEB representatives this strict allocation was modified. The planned technical set-up for the retro-fitting of Forsmark 3 was altered so as to permit continuous variation between heat and electricity generation. Maximum heat output remained at 2000 MW(th), but in case of varying demand loads the power plant's steam output would be diverted by means of a valve (in a figurative sense) to either heat exchangers and thus supplying district heat or to the turbine and generating electricity. The technical feasibility of such an arrangement was postulated by STOSEB. Further supplementary modifications affecting the principal analysis concerned the point of time when Forsmark 3 has to be switched back to electricity production. The introduction of the modification of the output structure of Forsmark 3 as just described makes the exactly determined switch-back to electricity production redundant. This implies that the full capacity of 2000 MW(th) is assumed to be available for heat production over the entire plant life i.e. up to the year 2013.

approach does not allow for endogenized 'if--then' operations. This implies that all conceivable combinations of the variables (technologies) are possible candidates of the solution space, i.e. the construction of half the capacity of a standardized technical unit and so on. By means of the appropriate arrangement of constraints and other methods within the linear programming approach the appearance of such 'solutions' can be kept to a minimum. Nevertheless, it is intriguing to investigate 'if--then' decisions in connection with the energy supply options for the Stockholm County. Therefore, in the determination of the fourth scenario use was made of the special feature of the MESSAGE II model--the possibility of modeling mixed integer problems. This is to say that all major supply or related technologies were set to integer variables. Thus, if a technology is selected to be part of the optimal solution the full capacity of e.g. the complete heat transmission system from Forsmark to Stockholm or the complete Nynäshamn energy complex has to be constructed. Of all energy supply strategies calculated the integer solution must be considered to be closest to reality given the constraints and the underlying assumptions. However, this does not necessarily mean that the integer solution is at the same time the cost-optimal one.

In all supply model runs the predetermined useful energy demand is the same. However, in cases where the costs of energy supply exceed a certain level, the built-in cost elasticities reduce energy demand endogenously. Thus, a reaction of consumers to varying energy cost structures is incorporated causing final energy demand not to be really identical throughout all model runs. The presentation of the major results is organized starting from the end use side moving along the energy chain towards primary energy supply. The results of the model runs are too complex to be presented in detail in this report. This is to say that the respective computer print outs containing the full and detailed information must be considered as a necessary complement to this report.

6.2 The Reaction of Useful Energy Demand to Diverse Final Energy Supply Costs

Surprisingly, in all supply strategies consumers appear to react quite uniformly to final energy supply. Figure 2 shows the evolution of useful energy demand for heating purposes in single-family homes. The heat demand in single-family homes is totally supplied by district heat, direct (thermal ventilation) and indirect (hot water and radiators) electricity. Thus, the complete substitution of oil and gas in the heat demand category can be achieved in all scenarios whereas the substitution process is slightly faster in the

Figure 2a: FE - FORSMARK ELECTRIC SCENARIO

HEATING IN SINGLE FAMILY HOUSES

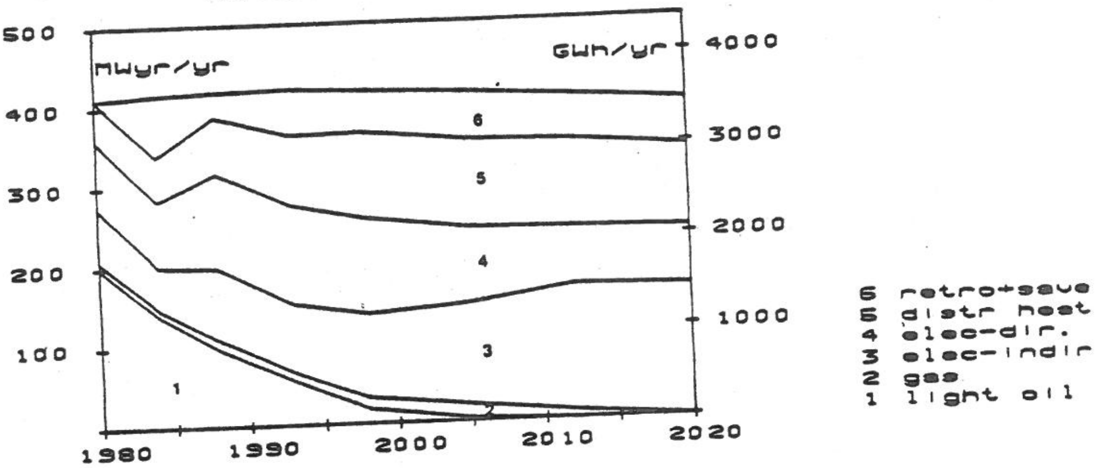


Figure 2b: FH - FORSMARK HEAT SCENARIO

HEATING IN SINGLE FAMILY HOUSES

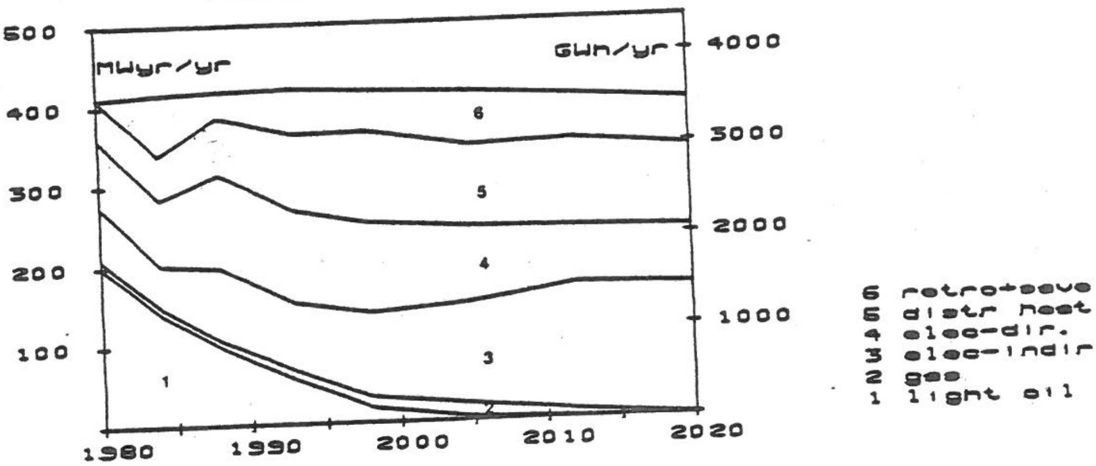
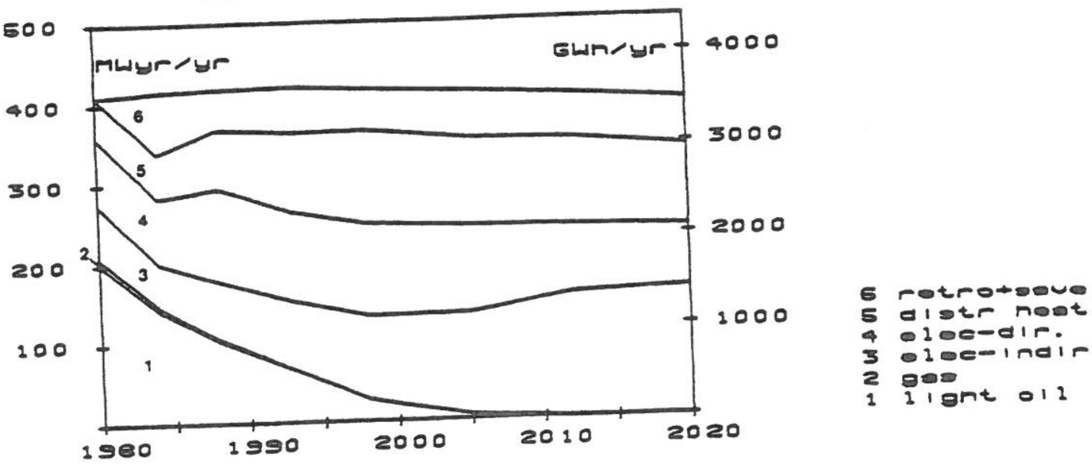


Figure 2c: NC - NO COMPLEX SCENARIO

HEATING IN SINGLE FAMILY HOUSES



cases of NC and FH than in the FE scenario. Again in all scenarios one may observe a significant plunge of final energy demand around the year 1984 which in later years is partly reversed again. This dip indicates a temporary saving in energy uses consisting of two diverse components which have distinct implications in the long run. The first component is a reaction to steadily increasing oil and gas prices leading to price induced conservation (see Table 6 for shadow prices for various forms of final energy demand). Consumers simply reduce energy purchases in the short run and as soon as the energy supply system is in a position to offer heat at a more favorable rate demand will jump back to the historically observed trends. The corresponding shadow prices of final energy demand are given in Table 6.

Table 6a : Shadow prices for final energy [Øre/kWh], FE - Scenario

	light oil	gas	electric	district heat: high	medium	low
1980	12.08	12.82	14.96	18.07	17.85	17.85
1984	13.73	14.65	18.05	14.57	15.72	15.72
1988	15.63	11.37	10.50	8.75	9.43	17.90
1993	18.41	15.15	15.90	12.23	12.91	14.18
1998	21.70	19.21	20.82	11.79	12.47	13.74
2005	26.74	28.83	31.03	13.28	13.96	15.23
2012	30.00	23.12	29.88	13.84	14.52	15.79
2020	41.64	43.69	46.66	18.62	19.43	20.96

Table 6b : Shadow prices for final energy [Øre/kWh], FH - Scenario

	light oil	gas	electric	district heat: high	medium	low
1980	12.08	12.82	14.96	18.07	17.85	17.85
1984	13.73	14.65	18.70	14.57	15.72	15.72
1988	15.63	14.89	11.43	5.40	6.08	17.90
1993	18.41	18.14	13.08	5.98	6.66	7.92
1998	21.70	22.15	22.74	10.76	11.43	12.70
2005	26.74	27.46	29.73	13.97	14.65	15.92
2012	22.76	25.00	32.14	13.09	13.77	15.04
2020	34.04	34.94	38.05	15.75	16.43	17.70

Table 6c : Shadow prices for final energy [Øre/kWh], NC - Scenario

	light oil	gas	electric	district heat: high	medium	low
1980	12.08	12.82	14.96	18.07	17.85	17.85
1984	13.73	14.65	18.25	14.57	15.72	15.72
1988	15.63	16.75	11.78	5.61	6.28	17.90
1993	18.41	0.	22.69	9.59	10.27	11.54
1998	21.70	0.	22.14	10.95	11.63	12.90
2005	26.74	0.	31.04	13.76	14.44	15.70
2012	32.70	0.	30.66	13.75	14.43	15.70
2020	49.51	0.	46.07	18.87	19.69	21.21

The second component, however, is long-term in nature and can be labeled substitution of capital for energy. Consumers invest in retro-fitting (enhanced insulation) of their existing homes and thus reduce their heat demand permanently. Figure 2 clearly reflects these two reactions. In the FE case the short-term reaction dominates while in the FH and NC scenarios the substitution effects set in on a larger scale. In the long run, however, the substitution of capital for energy is identical in all scenarios. By the year 2020 the heat demand pattern is identical also which actually is not too surprising. After the year 2012 when the service time of the competing alternatives (Forsmark versus Nynäshamn) has expired the energy supply system must have switched over to quite similar structures in all three scenarios. This, however, will be discussed later in this report.

The heating structure of multi-family houses shows an even more unified development than the single-family houses (see Figure 3). The only case that differs slightly is the FH scenario. Here the 1984 dip in heat demand (in useful energy terms) swings somewhat back after the Forsmark 3 power station has been put into operation. The immediate 2000 MW(th) heat supply in 1988 exceeds the absorption capacity of Stockholm County. Thus, heat is offered at considerably low costs to consumers and consequently they respond by a demand increase. In all scenarios by the year 2020 more than 95 % of heat demand is supplied by district heat; the remainder is met by gas and electricity.

The non-residential heat demand i.e. of the public and private service sectors in useful terms is given in Figure 4. In this demand sector renewable forms of energy are utilized to some extent for the first time towards the end of the planning horizon. The relatively dominating use of oil in

Figure 3a: FE - FORSMARK ELECTRIC SCENARIO

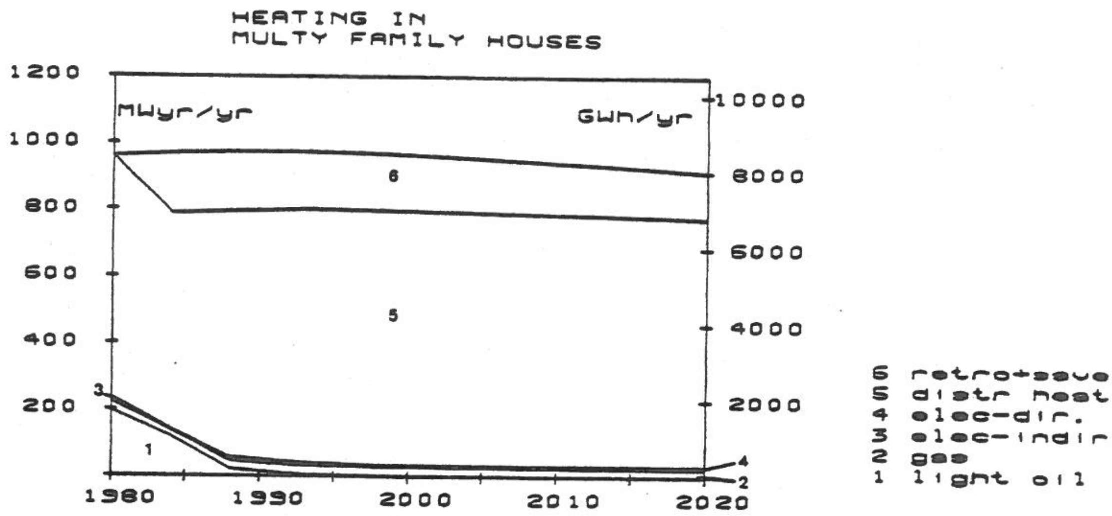


Figure 3b: FH - FORSMARK HEAT SCENARIO

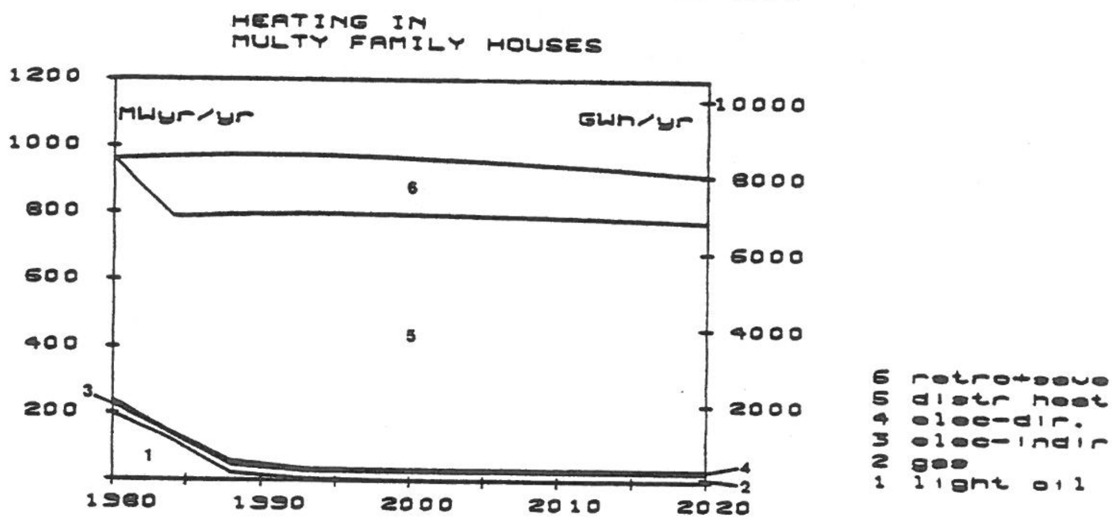


Figure 3c: NC - NO COMPLEX SCENARIO

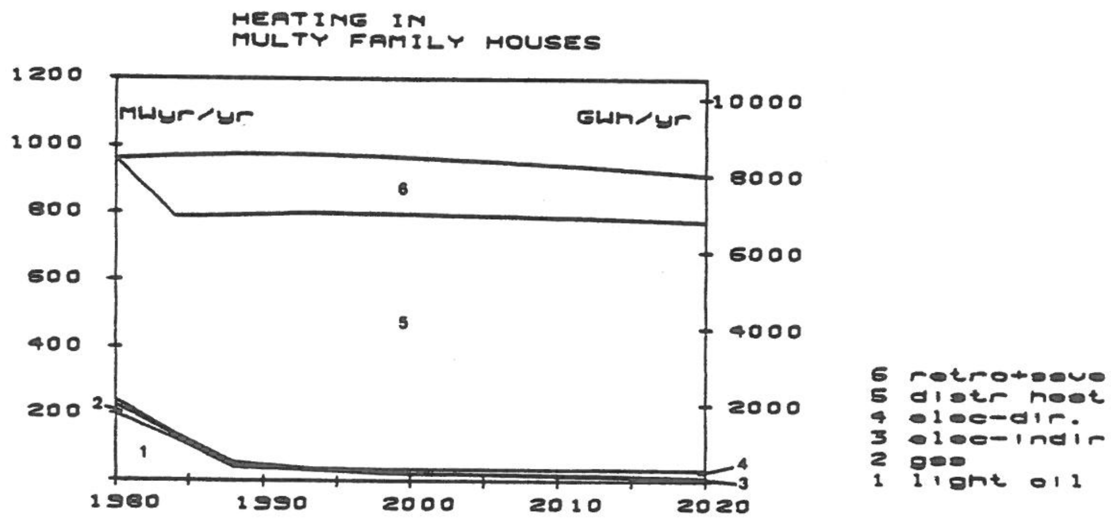


Figure 4a: FE – FORSMARK ELECTRIC SCENARIO
HEATING STRUCTURE FOR
WORK PLACES

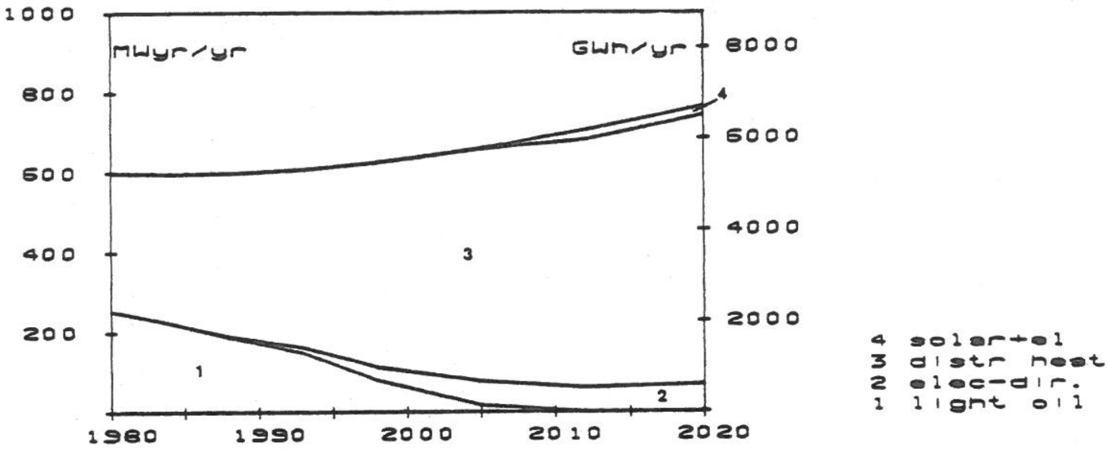


Figure 4b: FH – FORSMARK HEAT SCENARIO
HEATING STRUCTURE FOR
WORK PLACES

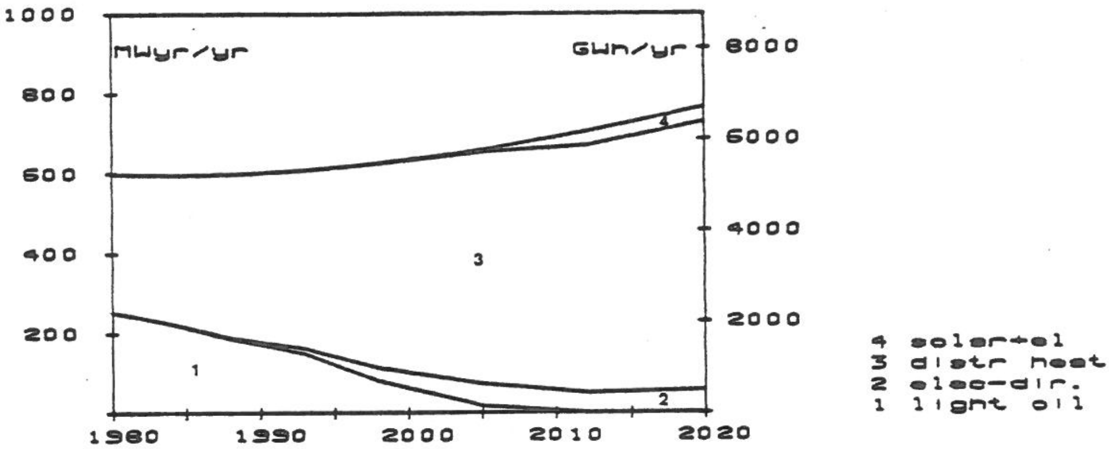
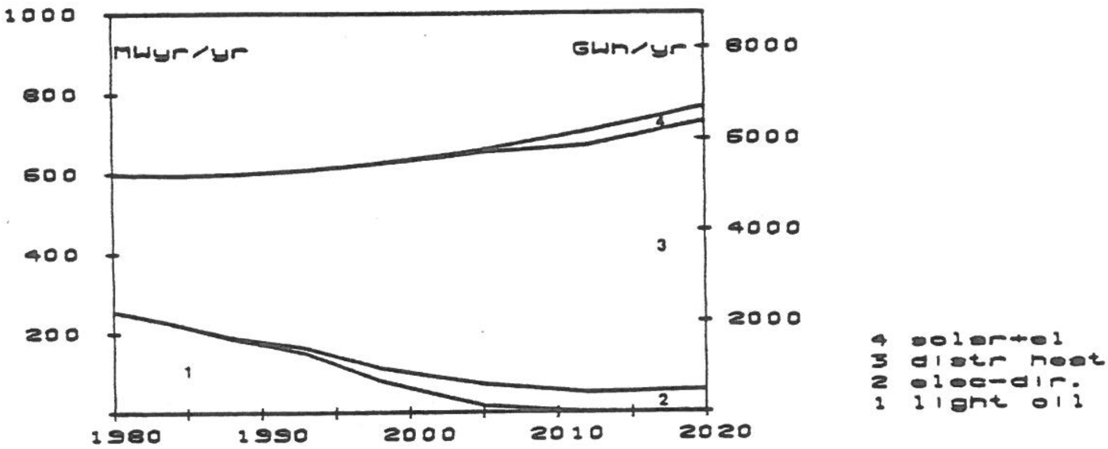


Figure 4c: NC – NO COMPLEX SCENARIO
HEATING STRUCTURE FOR
WORK PLACES



1980 is eliminated by the year 2010. Again the heat supply of this sector is increasingly dominated by district heat and the evolution over time is practically identical in all three scenarios. However, the electricity share in heat supply in the FH scenario is smaller than in the other two scenarios while with respect to the contribution of solar the converse takes place. This points to a diverse heat supply structure in the FE and NC scenarios. As will be shown later, in the FE and NC scenarios co-generation penetrates faster towards the end of the planning horizon than in the FH scenario and provides sufficient electricity at reasonable costs.

The final energy demand (and supply) evolution is given in Tables 7 to 9 which summarize the observations in the foregoing. The almost uniform development of final energy demand in all three scenarios and the fact that the potential of district heat is always fully utilized as fast as permitted by the build-up constraints (see Table 10) raises the question whether the supply costs of district heat are underestimated. In an international comparison the specific data concerning the district heat distribution costs for Stockholm appear to range at the lower end. For example, the distribution costs in comparable West German urban areas on the average are 1.6 times higher than the data adopted in this study. However, district heat distribution costs are not the crucial criteria in the determination of the mixture of district heat supply technologies. On the other hand relatively low costs may favor district heat within the whole energy system. For example, the model does not favor renewable forms of energy to contribute to the supply of residential heat demand at all.

Table 7 : Final energy demand, FE scenario, TWh/year

	light oil	gas	elec	district heat	block heat
1980	7.85	0.41	10.99	6.89	3.43
1984	5.83	0.29	11.73	8.84	1.06
1988	3.68	0.42	12.66	11.08	0.12
1993	2.50	0.44	13.23	11.95	0.
1998	1.19	0.48	13.88	12.74	0.
2005	0.24	0.50	14.43	13.34	0.
2012	0.	0.39	14.80	13.65	0.
2020	0.	0.26	14.93	13.98	0.

Table 8 : Final energy demand, FH scenario, TWh/year

	light oil	gas	elec	district heat	block heat
1980	7.85	0.41	10.99	6.89	3.43
1984	5.83	0.29	11.73	8.84	1.07
1988	3.66	0.37	12.65	11.11	0.14
1993	2.51	0.37	13.17	12.04	0.
1998	1.18	0.45	13.86	12.80	0.
2005	0.24	0.48	14.45	13.27	0.
2012	0.	0.39	14.79	13.65	0.
2020	0.	0.26	14.92	13.98	0.

Table 9 : Final energy demand, NC scenario, TWh/year

	light oil	gas	elec	district heat	block heat
1980	7.85	0.41	10.99	6.89	3.43
1984	5.90	0.22	11.73	8.84	1.08
1988	3.95	0.04	12.49	11.11	0.16
1993	2.95	0.	13.10	12.07	0.
1998	1.52	0.	13.93	12.83	0.
2005	0.46	0.	14.66	13.34	0.
2012	0.14	0.	15.00	13.65	0.
2020	0.05	0.	15.09	13.98	0.

Table 10 : The development of district heat in Stockholm County, TWh/year

year	heat demand	district heat: potential	use
1980	17.26	13.50	9.99
1984	17.35	13.97	11.01
1988	17.45	14.07	12.34
1993	17.55	14.18	13.02
1998	17.61	14.27	13.77
2005	17.76	14.45	14.45
2012	17.94	14.68	14.68
2020	18.17	14.98	14.98

Further, by 2020 the share of district heat in total final energy demand for heat has reached more than 80 % in all scenarios compared to about 40 % in 1979. This points to enormous institutional efforts to create an environment in which most consumers accept purchasing district heat (not to speak of the volume of construction activities to obtain an infrastructure that allows for an 80 % district heat share) and refrain from individualistic heating behavior. The almost uniform development of heating systems towards district heat and electricity in all scenarios permits concentration on the differences in district heat and electricity supply systems across the scenarios.

6.3 The Forsmark Electricity Scenario FE

6.3.1 Some General Remarks to the Representation of District Heat Supply and Electricity Generation in the Analysis

In MESSAGE II the various district heat generating plants are grouped into three categories. The composition of each category has been guided by the necessity to reflect differences in the requirements of infrastructures (i.e. with respect to the heat transmission and distribution systems) and the technological processes (e.g., co-generation versus heat production only). The three categories consist of heat production plants close to consumers (block heating plants, small-scale back-up plants, etc.) including heat production plants where the full capacity utilization requires a transmission system to deliver heat to the consumers*, co-generation of heat and electricity, and special plants requiring special transmission systems. The latter category comprises the directly competing Forsmark 3 plant, the Nynäshamn energy complex and large-scale heat pumps.

The electricity supply system of Stockholm County is closely interrelated with the national grid. The analysis of future electricity generation technologies of Stockholm, therefore, cannot be made without the incorporation of this interdependence with the national electric power system in at least some detail. On the other hand, a detailed consideration of the national grid would go beyond the scope of this analysis. The following compromise represents the national power system adequately for this analysis: The

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* The supply model distinguishes between transmission and distribution requirements explicitly. However, for reasons of a condensed representation these two systems have been merged into one category in this report.

existing and planned additions to the national electricity supply system are part of the input parameters of the MESSAGE II model. If in the model's solution the national grid is tapped for electricity supply of the Stockholm County (up to a certain ceiling which has to be specified) a proportional share of the costs will be charged. Such costs include the corresponding share in investments, fixed and variable operation and maintenance costs, etc. The Forsmark 3 reactor is considered as a 'Stockholm' plant, i.e. in the FE scenario the full capacity of 2000 MW(th) is allocated for the supply of Stockholm's electricity needs.

6.3.2 District Heat in the FE Scenario

In the first category--heat plants--the contribution of different kinds of heat production technologies varies significantly over the next 40 years (see Table 11). Although the existing capacities of oil-fired heat plants are more than sufficient to ensure the heat supply for at least the next 10 years, the model augments the heat production capacity during the period 1980 to 1984 by constructing a 400 MW(th) coal-fired plant and by installing electric boilers. In light of increasing oil import prices and the objective to diversify energy supply options, the build-up of non-oil capacity appears reasonable. Coal-fired heat generation produces on the average 310 MW(th)yr/yr from 1984 to 1988, while oil maintains its 1980 contribution of more than 590 MW(th)yr/yr but drops down to 120 MW(TH)yr/yr after 1988. During this period base load heat is supplied by coal while the intermediate and peak load regions are covered by oil. Of particular interest is the application of electric boilers for district heat. This technology complements the load curve of specific electricity demand. Off-peak periods in electricity supply serve as the principal times to operate electric boilers. The abundant electricity capacities therefore permit sufficient diversion of electricity for such purposes. In this configuration the model is in a position to cut out oil supplied intermediate heat production at an earlier point in time than without excess electricity capacity.

During the period 1988 to 1993 the heat supply pattern changes considerably for the first time. In general, the share of small scale heating plants in total heat supply drops from previously 86 % to 26 %. Specifically, the oil contribution in this category is reduced by 80 % and that of coal by 74 %. This reduction in fossil fuel combustion is offset in part by the utilization of electric boilers for heat production. This is a direct consequence of the setting to work of the Forsmark 3 nuclear power plant (in this

Table 11: Total District Heat Production, in [MWyr/yr], FE - Scenario

Technology or Fuel Used	1980-1983	1984-1987	1988-1992	1993-1997	1998-2004	2005-2011	2012-2019	2020- -
WASTE	40.00	13.45	0.	64.20	85.60	85.60	85.60	85.60
OIL	596.85	591.58	120.42	97.97	26.38	11.49	10.00	5.69
COAL	0.	310.94	79.70	79.70	50.17	9.11	0.	0.
WOOD	0.	0.	0.	0.	0.	0.	11.42	48.00
EL-BOILERS	20.35	83.35	189.39	156.27	0.	0.	0.	0.
HEAT PLANTS	657.20	999.32	389.51	398.14	162.16	106.20	107.01	139.29
OIL	186.30	21.97	5.46	13.77	2.18	0.	0.	0.
COAL	0.	66.00	49.50	79.63	478.65	617.16	1026.35	1151.01
GAS	0.	0.	0.	10.27	20.83	18.36	12.98	3.88
VARTAN	59.01	77.54	32.27	33.92	15.51	22.21	22.13	22.13
CO-GEN	245.31	165.51	87.23	137.59	517.16	657.73	1061.46	1177.03
EN-COMPLEX	0.	0.	343.20	381.25	371.07	353.39	315.28	265.71
HEAT PUMPS	0.	0.	658.27	675.99	650.55	664.34	338.67	284.20
SPECIAL	0.	0.	1001.47	1057.24	1021.61	1017.73	653.95	549.91
TOTAL	902.50	1164.83	1478.20	1592.97	1700.93	1781.66	1822.43	1866.23

scenario for electricity and not for heat generation)*. Again these boilers operate on the intermediate supply level while fossil fuels ensure peak supply as shown in Figure 5. The major factor causing the plunge in the use of fossil fuels stems from the shift in the heat production pattern from pure heating plants to the category of 'special plant', in this case to the application of large-scale heat pumps and the Nynäshamn energy complex. Due to the availability of sufficient electricity--again supplied by the Forsmark 3 power plant--the putting into operation of large-scale heat pumps is encouraged and by 1988 as much as 658 MW(th)yr/yr can be tapped from this heat production technology. The main mode of operation is base load supply except in cases of extreme peak demand for electricity.

Further, during the same time the energy complex goes into operation also. The mode of operation, however, does not meet the currently expected development as given in Table 2a. There is a definite hierarchy in the model's preference with respect to the output structure of the energy complex. The production of methanol is most profitable and consequently the methanol output is maximized. Over the period 1988 to 1997 the anticipated methanol production of annually 700 000 tons is exceeded by 17 % (on the average) reaching 98 % of the technically feasible maximum. This means that the energy complex operates the intermediate and summer mode exclusively (i.e. all around the year). The second profitable output is heat. Again almost the full potential heat output amounting to 3340 GWh or 381 MW(th)yr/yr (including the production of the return water heat pumps) is utilized. Gas, the third possible output of the energy complex is produced at a level of 1/3 to 2/5 of its maximum potential, which can be considered a residual of the intermediate operation mode. Figure 5b, showing the heat load distribution of the year 1988 provides the reasoning for the output structure of the energy complex. Large-scale heat pumps and the energy complex supply the total base load heat demand, while electric boilers cover the intermediate load region. Thus, gas can only be utilized in peak district heat supply or by meeting direct final energy demand for gas (roughly 1/3 of total gas consumption). Another reason for the reluctance of applying the winter operation mode might come from the lack of gas storage possibilities. Apart from meeting the gas demand of private households and the service sector, gas to a large extent is utilized in a specially built gas-turbine/steam-turbine co-generation plant and not so much in the Värtan station which continues to operate mainly on oil. Both types of plants supply peak heat/electricity demand and therefore constitute only a limited part of the energy complex's gas

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* In the FE scenario it is assumed that the equivalent of 2000 MW(th) of Forsmark 3 capacity is at Stockholm County's disposal.

potential. This situation would probably change if gas storage were available.

The heat supply pattern changes a second time around the turn of the century. Due to the 25 years service time limit imposed on nuclear power plants the first reactors have to be taken out of operation by the year 1998. This causes a bottleneck in the national electricity supply and consequently causes an impact on the Stockholm County's heat supply. Electric boilers are discontinued immediately and replaced by coal-fired co-generation plants which not only mitigate the squeeze on electricity production capacities but also guarantee sufficient heat supply. The briefly interrupted utilization of waste products is resumed again. The large-scale heat pumps are hardly affected by the reduced electricity supply from the national grid. The smooth build-up of coal-fired co-generation plants complements the discontinuation of the electric boilers and at the same time provides sufficient electricity for the sustained operation of large-scale heat pumps. The operation of the energy complex adjusts to the changes in Stockholm's heat supply market.. Since heat from waste products has penetrated the base load supply (see Figure 5c) the energy complex reduces heat output slightly by switching over to winter mode for short time periods.

The period beyond the turn of the century is marked by the necessity to construct sufficient electricity production capacity for the years after the shut down of the Forsmark 3 reactor in the year 2013. At the same time the first generation of large-scale heat pumps as well as the energy complex face the end of their service time. The model's reaction to this configuration is as follows: Coal-fired co-generation capacities are expanded significantly. Further, the utilization of wood for heat generation is introduced. The capacity of the new generation of large-scale heat pumps amounts to less than 50 % of the 1988 installed volume. The energy complex is reconstructed completely. The output structure, however, has shifted even more to summer operation. This means a continuously maintained demand for methanol and at the same time demand reductions for gas and heat. Figure 5d, the heat load curve for the year 2012, shows that heat from coal-fired co-generation has expanded its relative contribution to intermediate heat supply (a consequence of the necessity to meet electricity demand) compared to the year 1998. Thus, the flexibility of the energy complex to adjust the heat output by following the load curve is restricted to extreme base load only. This reduction in heat output for the periods after 2012 can be seen in Table 11. Since methanol continues to be produced at the full capacity level, the complex operates increasingly in the summer mode.

Figure 5a:

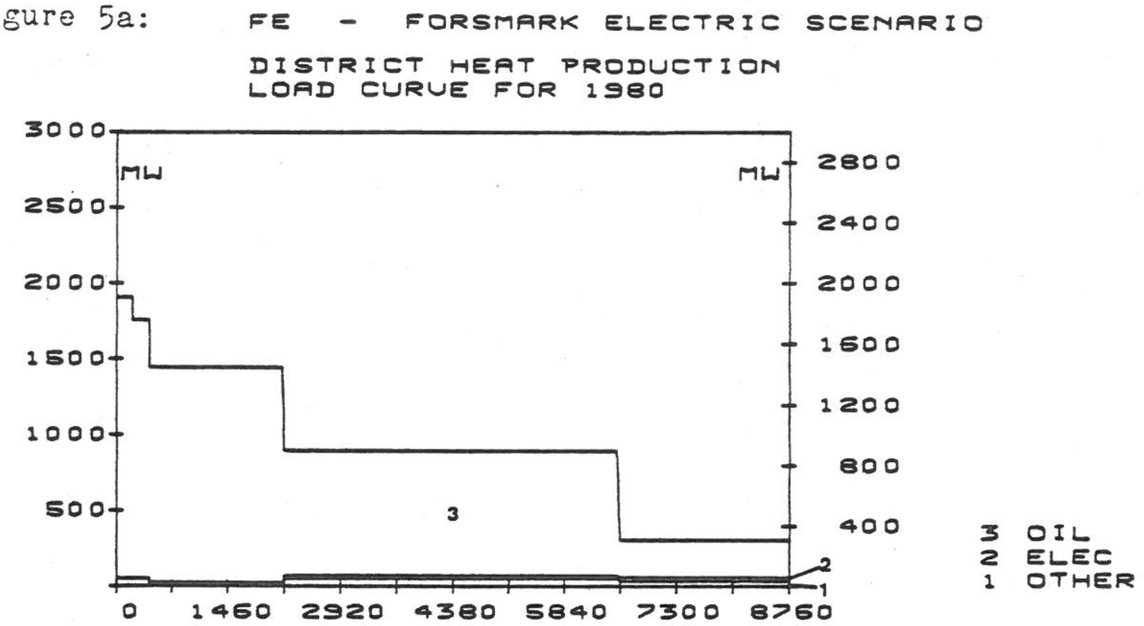


Figure 5b:

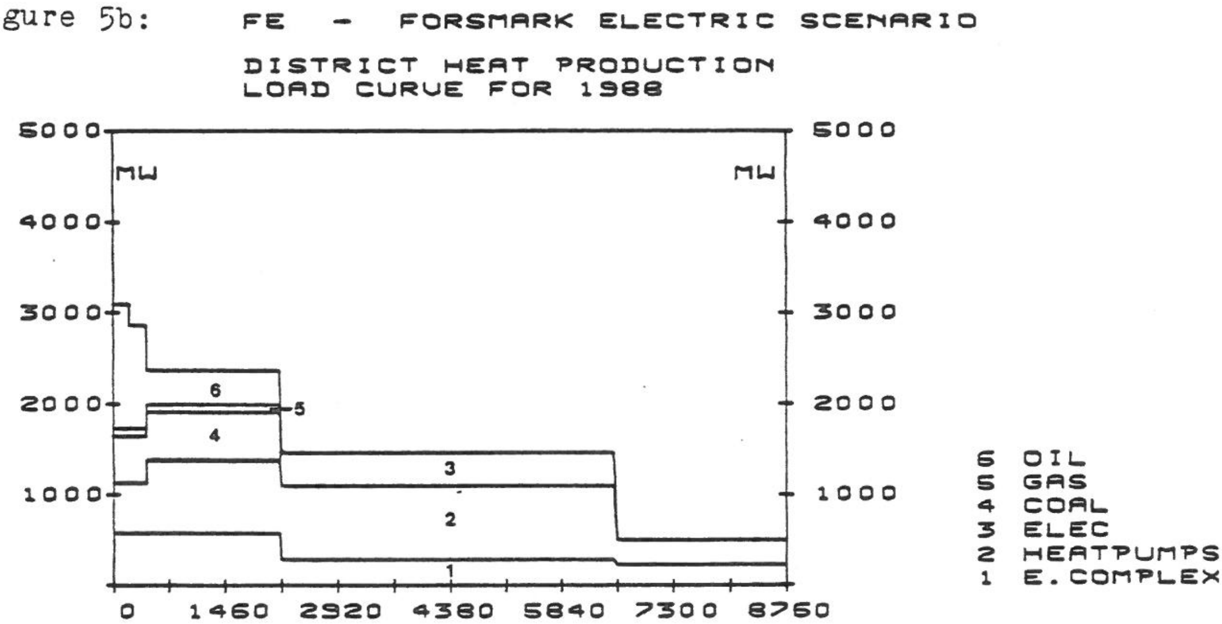


Figure 5c:

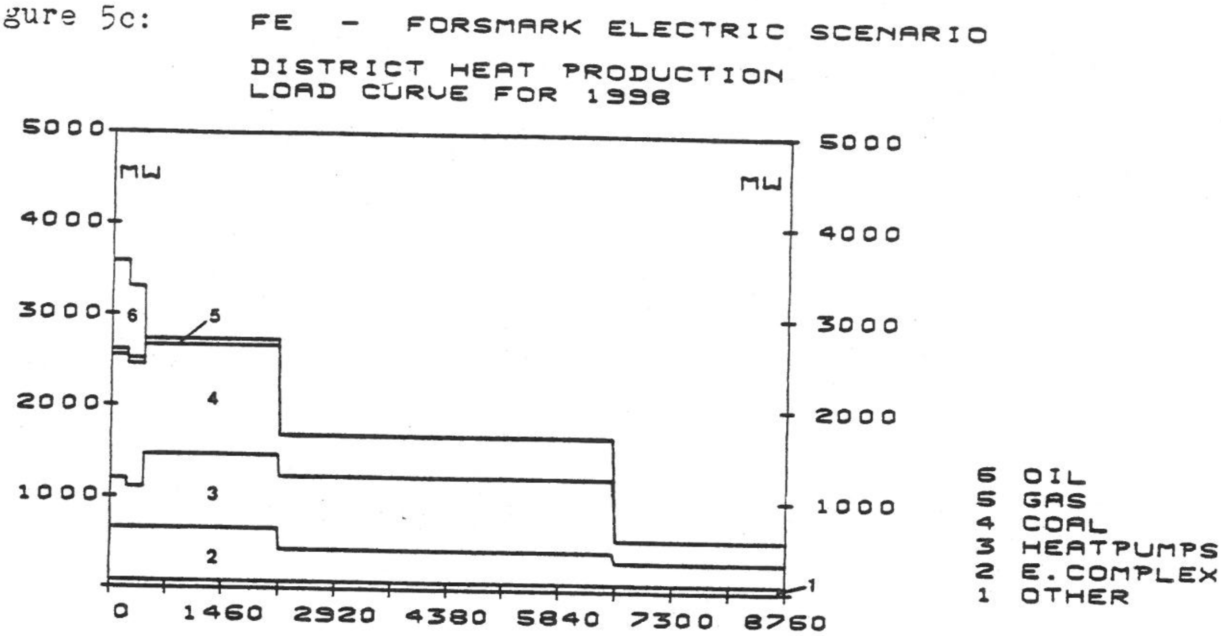
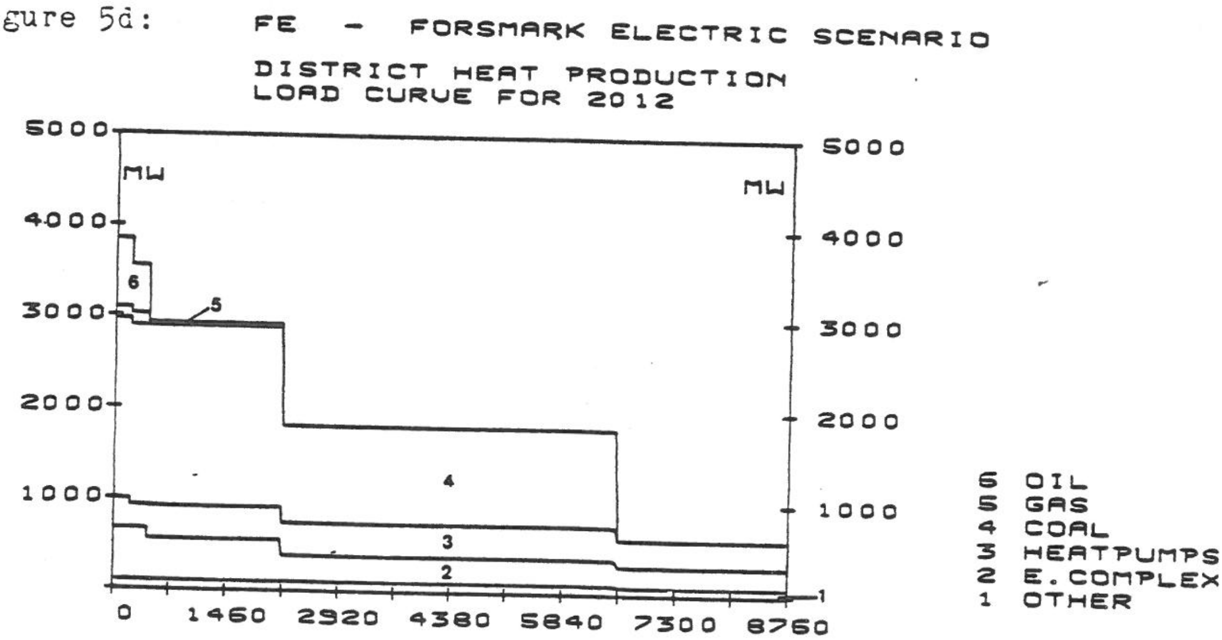


Figure 5d:



In summary, after 2012 and especially after the year 2020 coal-fired co-generation dominates the heat supply for Stockholm County. Other technologies contributing to heat supply consist of waste heat and wood combustion, a new generation of large-scale heat pumps and a new energy complex as well as some minor oil- and gas-fired peak co-generation plants.

6.3.3 Electricity Supply in the FE Scenario

According to Table 12 the electricity supply perspective of Stockholm County continues to be marked by imports from the national electricity grid. The dependence on the national grid, however, is steadily declining over time. This is a consequence of the significant shift in the heating supply structure from individual (oil based) heating towards district heat systems (based on co-generation) as described in the previous section.

In the initial periods of the planning horizon nuclear and hydroelectric power of the national grid supply almost 90 % of the electricity demand. The 10 % share in electricity generated by plants located in Stockholm County secure peak supply by means of oil combustion in co-generation and/or direct oil-fired electricity plants. As of 1984 the installation of coal-fired co-generation plants, of course, is identical to the heat supply sector but different in capacities. The 100 MW(th) of heat production capacity installed by 1984 is complemented by a capacity of 50 MW(el) for peak electricity production. The accelerated shift towards coal based co-generation sets in by 1998 only, since as of 1988 the electricity sector of Stockholm County is dominated by the Forsmark 3 generated electricity. Over the entire plant life the full capacity is utilized amounting to 582.27 MW(el)yr/yr of electricity production after deduction of transmission losses (output at bus-bar: 637.5 MWyr/yr). Figure 6b shows the load distribution of electricity supply for the year 1988. Base load is primarily supplied by the national grid (nuclear and hydroelectric power) while Forsmark 3 operates in the base and intermediate load regions. Almost 80 % of the electricity generated by Forsmark 3 is consumed by large-scale heat pumps, electric boilers and the energy complex.

In the period 1993 to 1998 gas from the energy complex in part substitutes for oil in peak electricity supply (not so much in the Värtan plant but in the special gas-turbine/steam-turbine plant). In 1998 the electricity supply picture changes drastically. Due to the shut-down of the oldest nuclear power stations of the national grid, electricity import possibilities decline. However, there

Table 12: Total Electricity Production, in [MWyr/yr], FE - Scenario

Technology or Fuel Used	1980–1983	1984–1987	1988–1992	1993–1997	1998–2004	2005–2011	2012–2019	2020– –
FORSMARK 3	0.	0.	582.27	582.27	582.27	582.27	72.78	0.
WIND	0.	0.	0.	0.	9.38	94.39	313.16	313.16
INDIGENOUS	0.	0.	582.27.	582.27	591.65	676.66	385.94	313.16
FUEL OIL	93.15	10.99	2.73	6.89	1.09	0.	0.	0.
COAL	0.	33.00	24.75	40.00	249.38	341.95	575.41	646.27
GAS	0.	0.	0.	10.27	20.83	18.36	12.98	3.88
VARTAN	33.67	44.24	18.41	19.35	8.85	12.68	12.63	12.63
CO-GEN	126.82	88.23	45.89	76.51	280.14	372.99	601.02	662.78
NUCLEAR	454.56	454.56	387.88	403.78	105.69	0.	0.	0.
HYDRO	750.49	938.11	938.11	938.11	938.11	938.11	938.11	938.11
OIL	9.28	10.69	6.37	8.31	5.51	0.	0.	0.
NAT GRID	1214.33	1403.36	1332.35	1360.47	1070.14	956.47	951.09	941.99
HEAT PUMPS	0.	0.	-211.54	-217.45	-209.08	-213.57	-105.02	-87.00
EN-COMPLEX	0.	0.	-61.88	-70.19	-67.97	-64.13	-55.80	-44.96
EL-BOILERS	-20.35	-83.35	-189.39	-156.27	0.	0.	0.	0.
TO: HEAT	-20.35	-83.35	-462.82	-443.92	-277.05	-277.70	-160.82	-131.97
TOTAL .	1320.81	1408.24	1497.70	1575.34	1664.88	1728.42	1777.23	1785.96

Figure 6a:

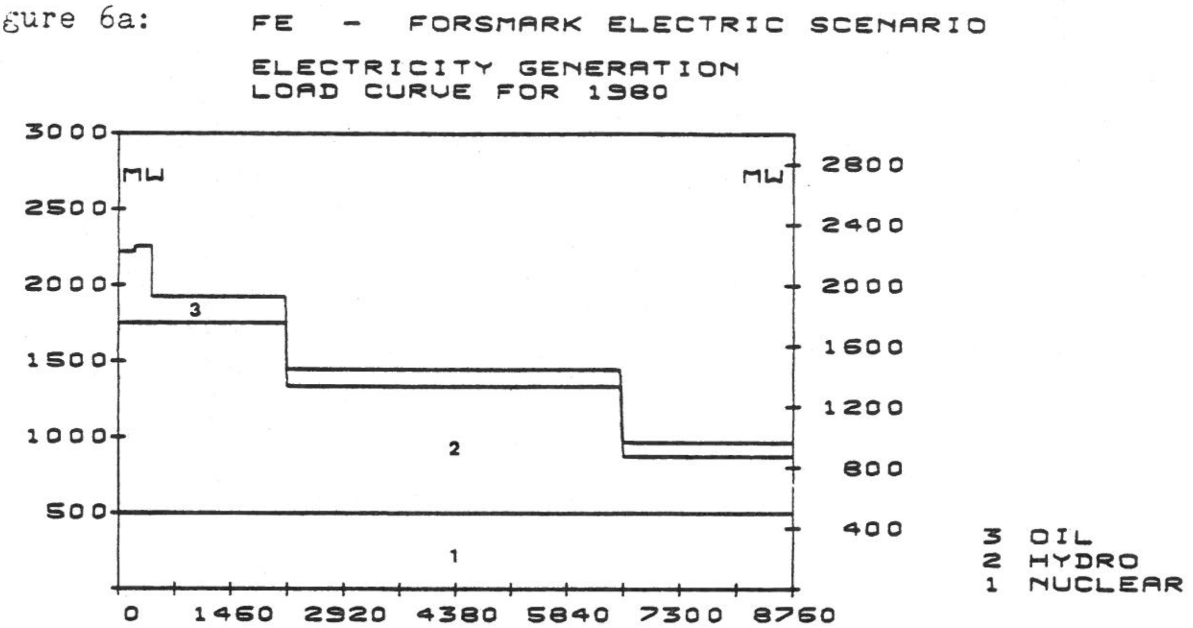


Figure 6b:

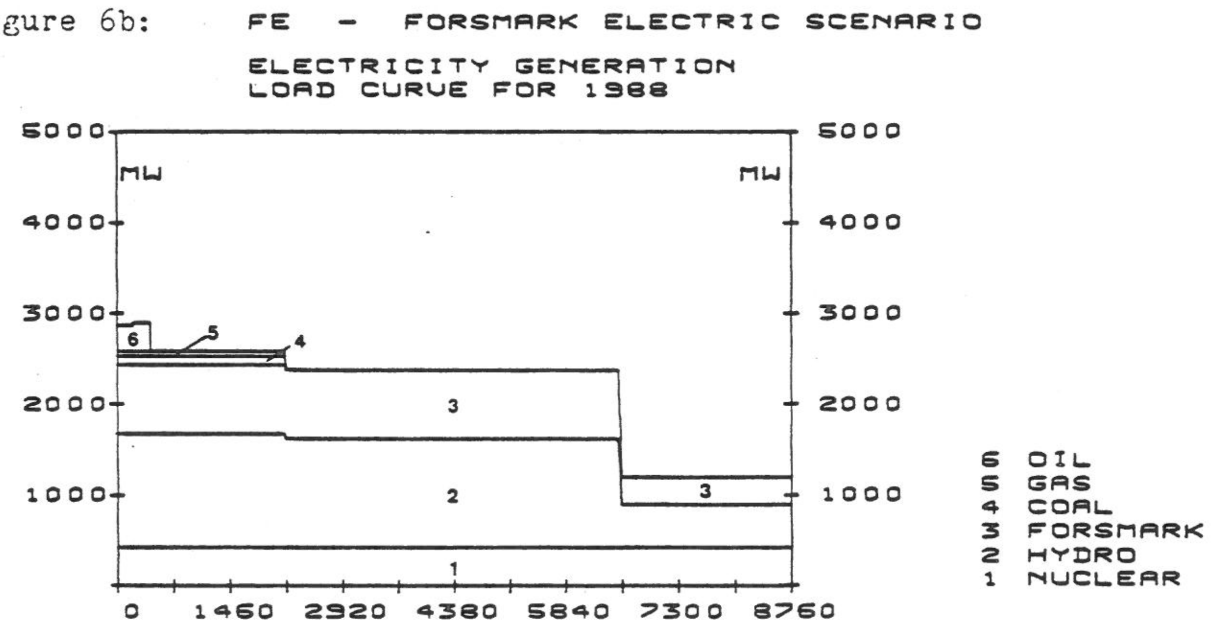


Figure 6c:

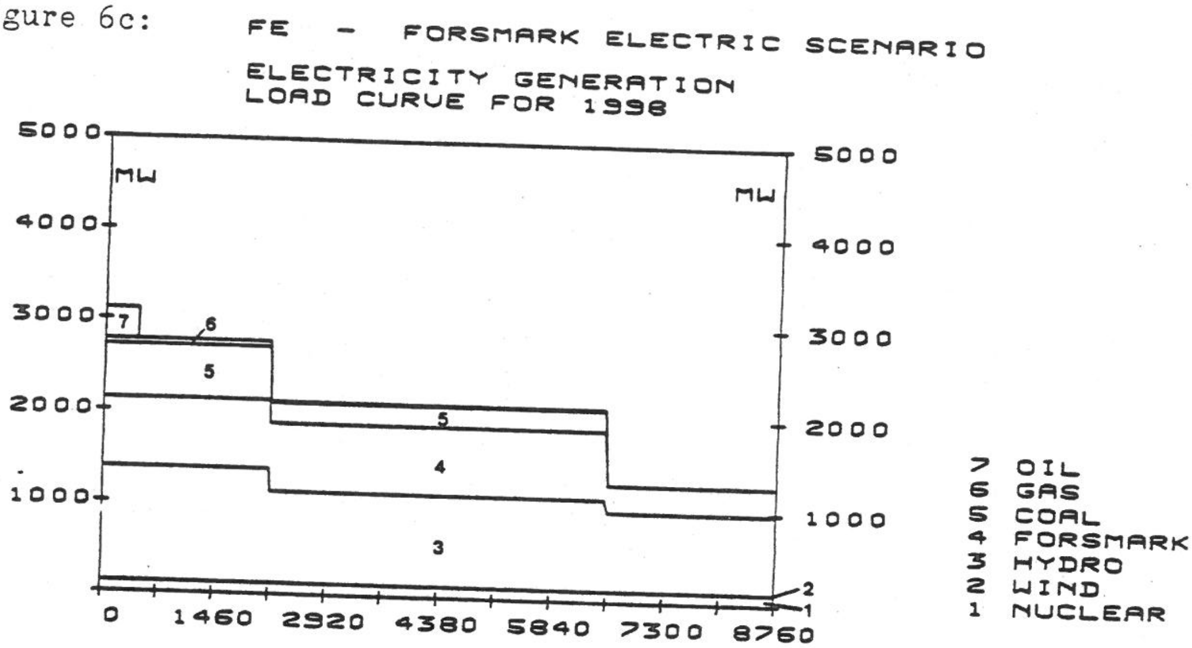
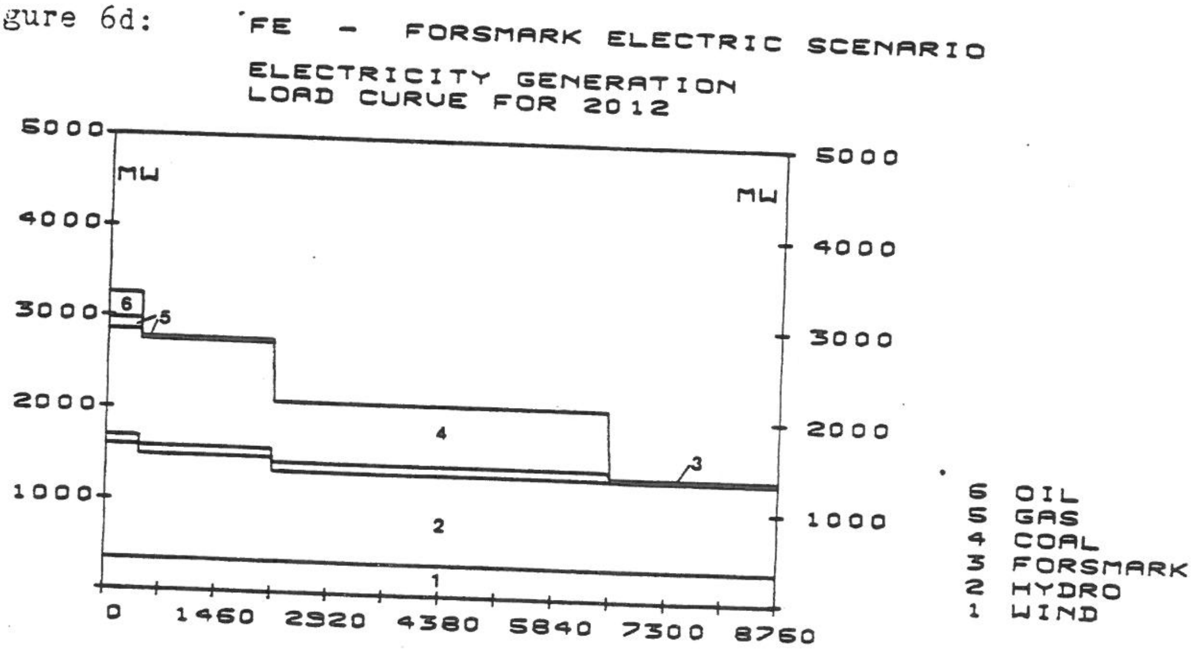


Figure 6d:



exists a somewhat peculiar configuration. The maximum nuclear power capacity of the national grid is not fully utilized by Stockholm County. According to present plans as much as 8.3 GW(el) of installed nuclear capacity will still be available for the national grid between 1990 and 1998. The ceiling for electricity imports of Stockholm County is fixed to 15 % of the national grid's electricity production. In other words Stockholm County could make use of more than 1 GW(el) of nuclear power capacity. The model, taking only the needs of Stockholm County into consideration, draws upon only 20 % of this potential. Three major factors are responsible for this situation. Firstly, there is the technical side of co-generation plants. The long run supply of district heat requires installation of sufficient capacities, especially for the period after the nuclear era. Heat production by means of co-generation means the provision of electricity capacities at the same time. Thus, existing co-generation capacities in the Stockholm vicinity reduce electricity import requirements. Secondly, wind power plants begin to penetrate base load electricity supply, forcing previous contributors to this load region out of the market. Thirdly, the cost-optimization of MESSAGE II comprises the total planning horizon. Therefore, the end of the nuclear era is anticipated by the timely diversification of electricity production capacities (in order not to conflict with capacity build-up constraints). Figures 6c and 6d, the load distributions of electricity production of the years 1998 and 2012, illustrate the shifts between various electricity supply technologies and their load contributions respectively.

Towards the end of the planning horizon hydroelectric power supplies the electricity procured from the national grid. The indigenous electricity is provided by wind, coal-fired co-generation (see also heat supply) and gas which is produced by the energy complex. Wind and hydroelectric power operate in the base load region, coal supplies the intermediate and part of the peak load regions, while gas serves the short duration peak load only.

6.4 The Forsmark Heat Scenario FH

6.4.1 District Heat Supply in the FH Scenario

In the FH scenario the oil-fired heating plants do not reduce their activity immediately, instead in 1984 the quantities of oil burnt by this technology increase slightly by 3 % compared to 1980 as shown in Table 13. The optimization feature of the supply model anticipates an abundant supply of heat from Forsmark 3. Therefore the cheapest solution to meet the heat demand in 1984 is selected--the application of the existing capacities of small-scale heating plants at the cost of temporary expensive oil imports*. The remaining heat demand is supplied by the utilization of waste products, some additionally installed electric boilers, and, as in the FE scenario, by a 400 MW(th) coal-fired heating plant. The electric boilers take advantage of the excess electricity supply in the intermediate load regions and their capacity expands by roughly 100 MW(th).

In 1988 the drop in the use of oil heating plant capacity is really striking--an output reduction of more than 90 %. The sudden 1626 MW(th) of heat supply from Forsmark and Nynäshamn energy complex to Stockholm County in 1988 practically forces all non-peak heating plants out of the market. Thus, after 1988, oil- and coal-fired heating plants provide peak heat supply only (see Figure 7b). The remaining block heating capacities then serve as back-up systems for eventualities. Electric boilers are switched off totally since the intermediate heat demand load region is supplied by the energy complex (see Figure 7b). The utilization of waste products for base load supply is also discontinued and replaced by Forsmark heat.

Before discussing the development of co-generation plants it is appropriate to capture the heat supply structure of the category 'special plants'. In the FH scenario the Forsmark 3 power station was forced to produce primarily heat. Thus, a potential heat supply of 1760 MW(th) (accounting for the actual availability due to shut down times for maintenance) could penetrate the Stockholm heat market. However, the Forsmark heat output exceeds total heat demand of the Stockholm County in 1988 (not considering the load variations) and of course the absorption capacity of the district heat distribution system. Further, nuclear power

* In the initial analyses for exactly the same reason this increase in oil consumption amounted to 35 %. At that time the 2000 MW(th) of Forsmark 3 capacity was completely allocated for heat production and not like now for either electricity and/or heat production.

Table 13: Total District Heat Production, in [MWyr/yr], FH - Scenario

Technology or Fuel Used	1980-1983	1984-1987	1988-1992	1993-1997	1998-2004	2005-2011	2012-2019	2020- -
WASTE	40.00	13.45	0.	0.	85.60	85.60	85.60	85.60
OIL	596.85	615.24	53.81	72.59	32.34	29.68	27.71	16.29
COAL	0.	287.37	14.37	71.84	23.39	8.21	0.	0.
WOOD	0.	0.	0.	0.	0.	0.	0.	48.00
EL-BOILERS	20.35	83.27	0.	0.	0.	0.	0.	0.
HEAT PLANTS	657.20	999.34	68.18	144.43	141.33	123.49	113.31	149.89
OIL	186.30	21.97	2.75	2.75	2.18	0.	0.	0.
COAL	0.	66.00	49.50	77.00	537.39	663.04	1049.91	1152.03
GAS	0.	0.	16.04	16.04	16.04	19.05	3.83	3.81
VARTAN	59.01	76.84	72.99	72.57	15.37	16.38	16.38	16.38
CO-GEN	245.31	164.81	141.29	168.36	570.97	698.48	1070.13	1172.22
FORSMARK 3	0.	0.	1288.79	1033.23	649.07	598.41	69.67	0.
EN-COMPLEX	0.	0.	336.89	337.29	347.06	350.64	291.88	265.72
HEAT PUMPS	0.	0.	0.	0.	0.	0.	276.89	278.06
SPECIAL	0.	0.	1625.68	1370.52	996.12	949.05	638.44	543.78
TOTAL	902.50	1164.15	1835.15	1683.31	1708.43	1771.02	1821.88	1865.90

Figure 7a:

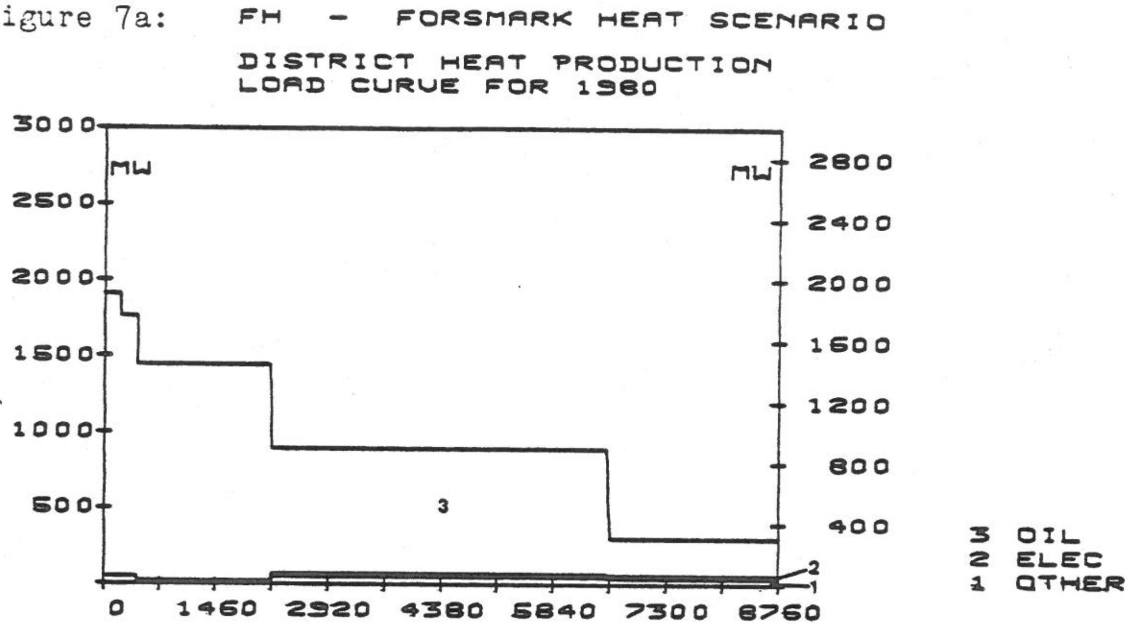


Figure 7b:

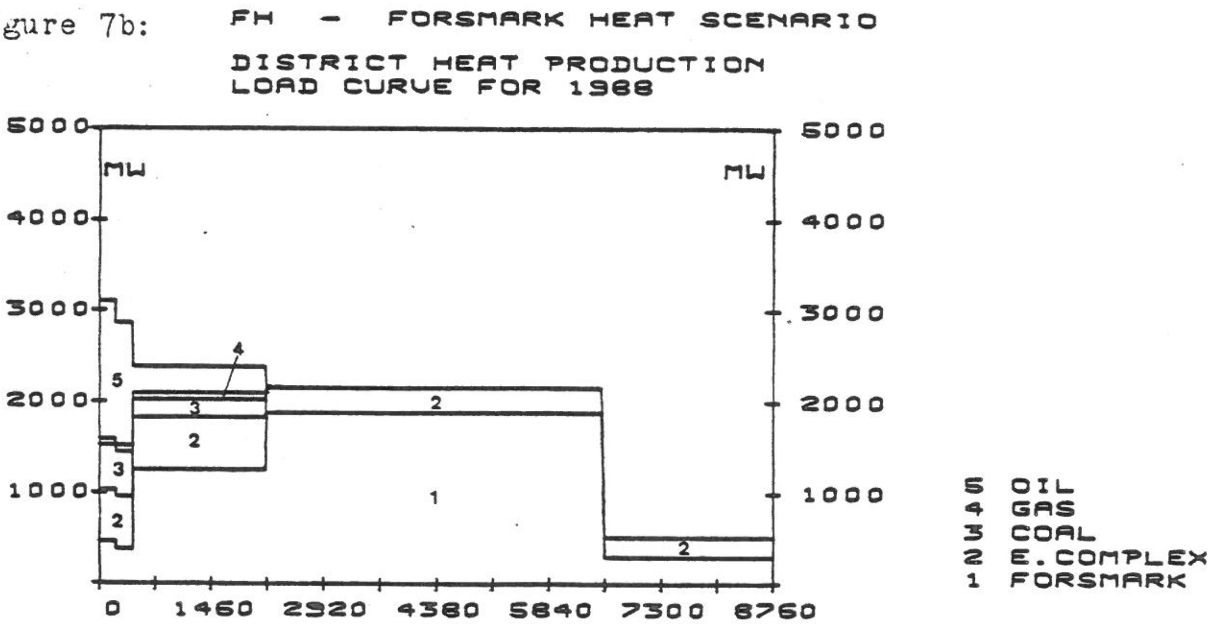


Figure 7c: FH - FORSMARK HEAT SCENARIO

DISTRICT HEAT PRODUCTION
LOAD CURVE FOR 1998

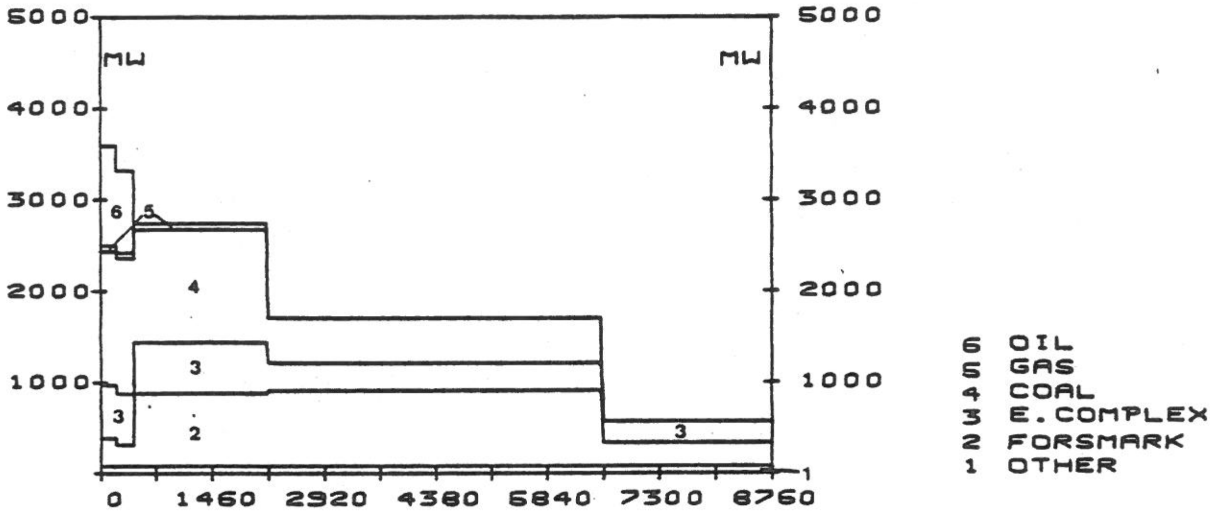
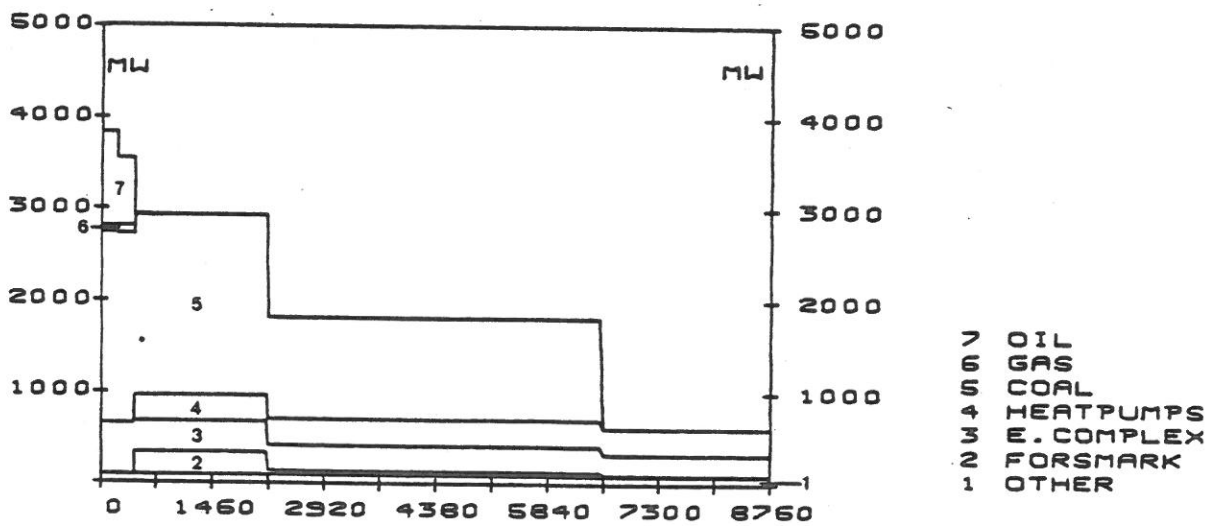


Figure 7d: FH - FORSMARK HEAT SCENARIO

DISTRICT HEAT PRODUCTION
LOAD CURVE FOR 2012



stations are inadequate (and also not suited) to supply peak demands and consequently Forsmark operates within the base and intermediate load regions exclusively. The application of Forsmark heat is further held back by the second technology in the category 'special heat plants'--the energy complex. This technology is installed in 1988 despite the given excess heat production capacity. The energy complex according to Figure 7b covers mainly intermediate and peak heat supply. Therefore, as in the FE scenario and for the same reasons, the complex does not meet the originally planned output structure. The winter operation--high gas and heat output, but reduced methanol production--takes place only in times of severe peak supply shortages of both heat and electricity. In these cases demand for gas rises sufficiently high (and so does the shadow price) to offset the losses in the so far profitable methanol production. That is why the energy complex prefers to utilize the intermediate/summer operation as much as possible. The other reason which explains the reluctance of the energy complex towards the winter operation stems from the excess capacities in heat production facilities.

The excess capacities in heat production facilities heavily distort the general picture of the heat market. Between 1988 and 1998 the 2000 MW(th) of Forsmark 3 capacity are not absorbed fully, neither in the heat nor in the electricity market. Due to the structure of the heat demand load curve the affluently produced heat is simply released or in other words wasted (see Figure 8 which contains the heat demand load distribution curve and the actual distribution of heat supply).

During the period 1993 and the turn of the century the changed electricity capacity situation of the national grid permits the so far wasted steam of Forsmark 3 to be utilized for electricity generation. After the year 1998 not only the excess steam is diverted in favor of stepped-up electricity generation but also part of the steam previously allocated for district heat supply. The reduction in base load heat supply is in part offset by the resumption of the combustion of waste products while in the intermediate load region coal-fired co-generation replaces Forsmark produced district heat.

Large-scale heat pumps do not enter the heat supply picture before the year 2012. Firstly, Forsmark and the energy complex deliver sufficient heat to meet most needs within the base and intermediate load regions. Secondly, electricity supply is somewhat tight after 1998 when the first nuclear power plants supplying the national grid have to go out of operation. Thirdly, the demand for electricity favors coal-fired co-generation and these plants penetrate heavily into the heat market in the late 90s. However, beyond

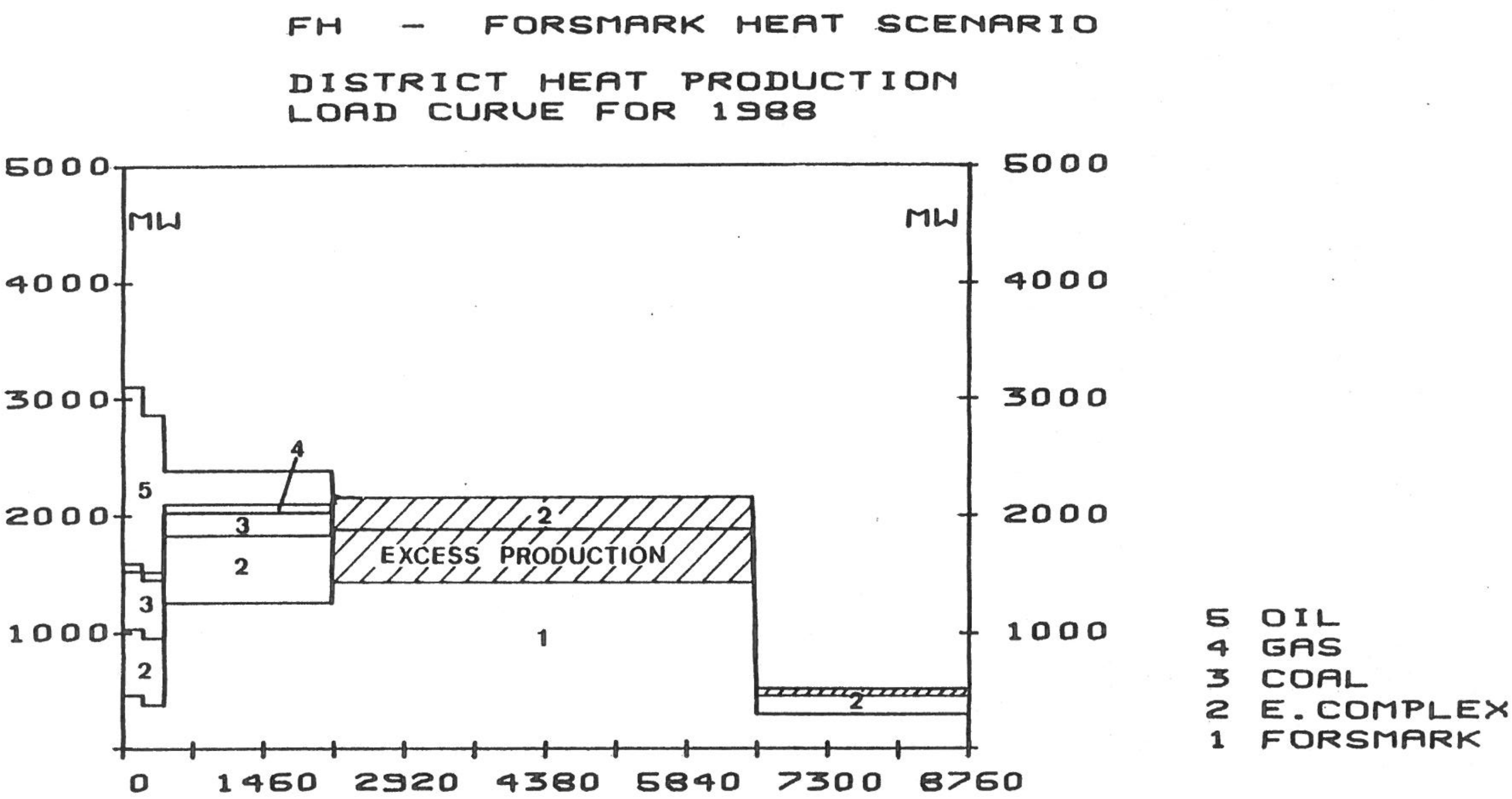


Figure 8 : District Heat Production load curve for 1988 and according district heat demand curve, Forsmark Heat Scenario.

the year 2012 an accelerated installation of these heat pumps is going to take place. By then sufficient co-generation capacity is available to provide the required electricity for their operation, i.e. 1.6 GW(el) for electricity generation and 2.63 GW(th) for heat production. Altogether 283 MW(th) of sewage water and 32 MW(th) of sea water heat pumps will be installed by the year 2012 and to a large extent supply base load heat.

The period after the shut down of Forsmark 3 is dominated by coal-fired co-generation. However, the location of these large coal-fired plants differs from the originally assigned Forsmark site. The timely completion of the required co-generation capacity by the year 2012 implies that the capacity build-up process has to be initiated well in advance. In order to avoid unnecessary and uneconomical slack capacity (actually the demand for electricity forces these newly installed co-generation capacities to go into operation immediately) these plants should be integrated into the heat supply system right after their completion. However, under the condition of the variable production mode (electricity and/or heat) of Forsmark 3 and the meanwhile extended service period for heat production until the end of the reactor's plant life excludes the Forsmark site as the principal location for the large coal-fired co-generation plants. Firstly, the economics do not agree and secondly, during the parallel operation of Forsmark 3 and the co-generation plants (i.e. 1998 to 2013) the capacity of the heat transmission system from Forsmark to Stockholm is not compatible with the heat demand load curves (see Figure 7c). Forsmark operates in the base load region while the co-generation plants operate within the intermediate and peak regions.

Further, in 2013 the energy complex is re-built. The output structure, however, shifts even more towards the summer operation mode. Co-generation capacities for electricity/heat production in connection with large-scale heat pumps are sufficient to secure most of the base and intermediate heat supply. Peak demand is met by direct oil combustion (i.e. 142 GWh per year), the utilization of wood products, gas from the energy complex and by one minor coal-fired co-generation plant.

6.4.2 Electricity Supply in the FH Scenario

The electricity supply structure of the FH scenario is given in Table 14 while Figures 9a to 9d contain the load curves for the years 1980, 1988, 1998 and 2012. Between 1980 and 1988 the development of the electricity supply structure is identical to the FE scenario. After the year 1988, however, a quite dissimilar evolution with respect to the indigenous electric power production is observed (the electricity imports from the national grid are almost identical again). The major differences in the electricity sector of the FH and FE scenarios depend directly on the heat supply structure. While in the FE scenario large-scale heat pumps are installed by 1988, the abundant Forsmark heat in the FH scenario suppresses the utilization of this technology until the end of the planning horizon. The large-scale heat pumps in the FE scenario consume more than 200 MW(el)yr/yr of electricity. This considerable quantity comes to nothing in the FH scenario. On the other hand the operation of the heat transmission from Forsmark to Stockholm calls for electricity inputs on the order of 68 MW(el)yr/yr (over the period 1988 to 1993).

Between 1988 and 1993 Forsmark 3 delivers 161 MW(el)yr/yr or 1.55 TWh/yr of electricity to the Stockholm County. For reasons discussed in the foregoing the contribution of Forsmark 3 to electricity supply increases steadily at the cost of reduced heat deliveries. The introduction of coal-fired co-generation capacity in the Stockholm vicinity is slightly higher than in the FE scenario. By the year 2020, however, the supply mix of electricity is practically identical in the FH and FE scenarios.

Table 14: Total Electricity Production, in [MWyr/yr], FH - Scenario

Technology or Fuel Used	1980–1983	1984–1987	1988–1992	1993–1997	1998–2004	2005–2011	2012–2019	2020– –
FORSMARK 3	0.	0.	161.33	248.83	380.35	397.70	51.47	0.
WIND	0.	0.	0.	0.	9.38	94.39	313.16	313.16
INDIGENOUS	0.	0.	161.33	248.83	389.74	492.09	364.63	313.16
FUEL OIL	93.15	10.99	1.38	1.38	1.09	0.	0.	0.
COAL	0.	33.00	24.75	38.50	295.72	365.37	588.31	646.68
GAS	0.	0.	16.04	16.04	16.04	19.05	3.83	3.81
VARTAN	33.67	43.85	41.65	41.41	8.77	9.35	9.35	9.35
CO-GEN	126.82	87.83	83.82	97.33	321.62	393.77	601.49	659.84
NUCLEAR	454.56	454.56	454.56	403.78	105.69	0.	0.	0.
HYDRO	750.49	938.11	938.11	938.11	938.11	938.11	938.11	938.11
OIL	9.28	10.69	0.	0.	0.	0.	0.	0.
NAT GRID	1214.33	1403.36	1408.71	1357.93	1059.84	957.16	941.94	941.92
HEAT PUMPS	0.	0.	0.	0.	0.	0.	-84.80	-85.15
EN-COMPLEX	0.	0.	-60.51	-60.59	-62.73	-63.53	-50.68	-44.97
EL-BOILERS	-20.35	-83.27	0.	0.	0.	0.	0.	0.
FORSM-PIPE	0.	0.	-68.31	-54.76	-35.69	-33.00	-3.95	-0.08
TO: HEAT	-20.35	-83.27	-128.81	-115.35	-98.42	-96.53	-139.43	-130.20
TOTAL	1320.81	1407.92	1525.05	1588.73	1672.78	1746.48	1768.63	1784.73

Figure 9a:

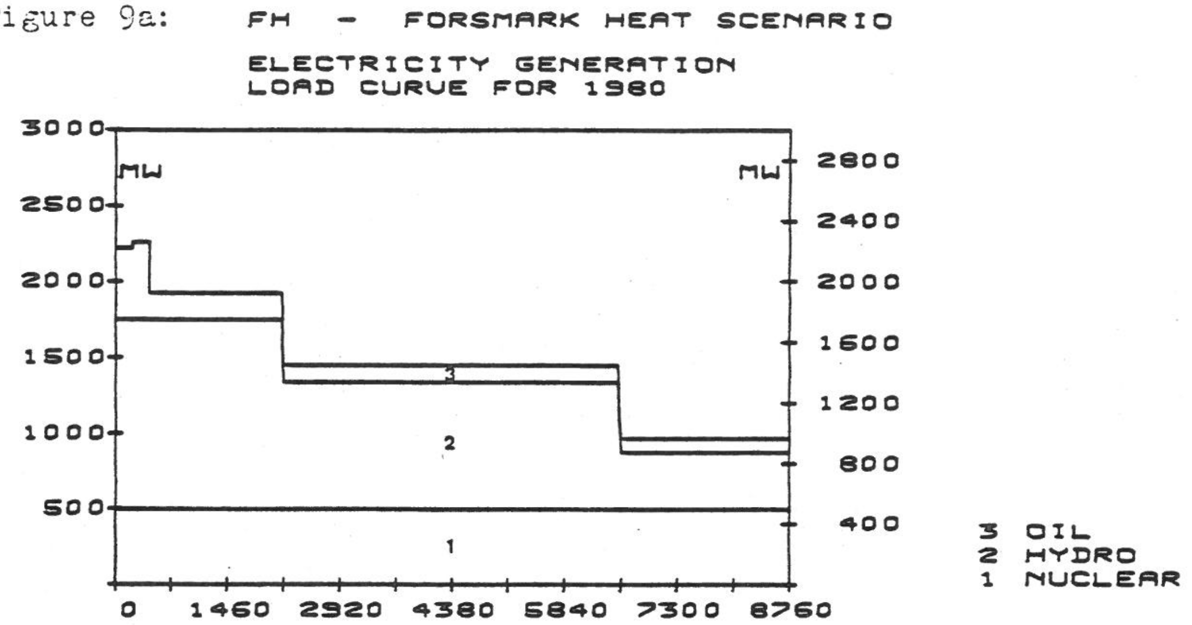


Figure 9b:

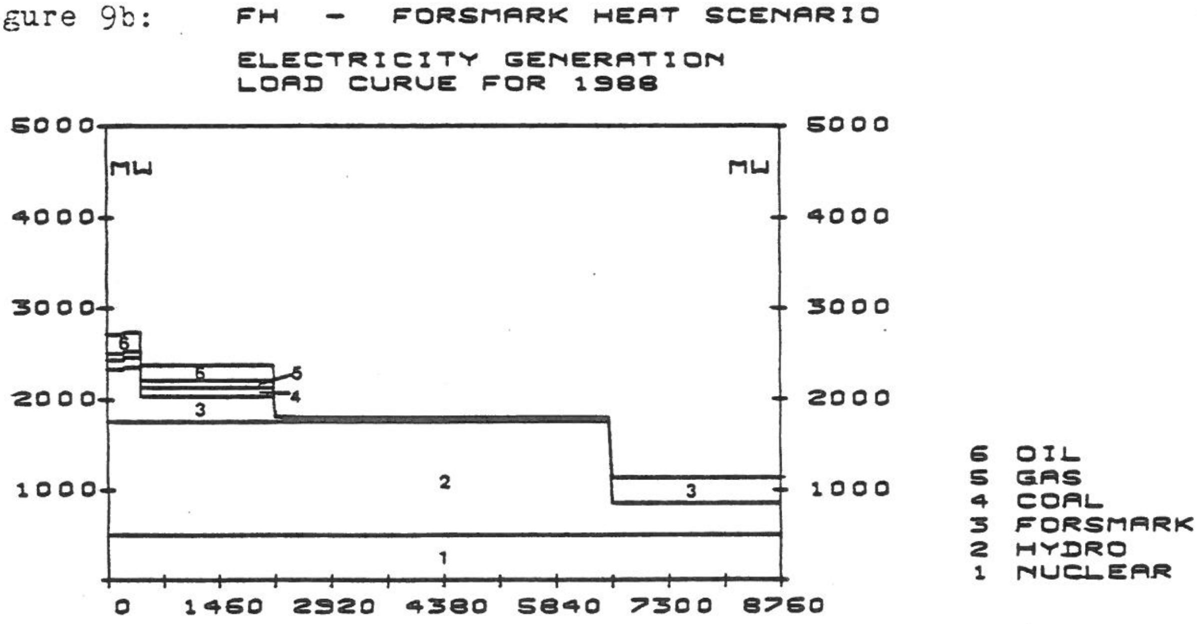


Figure 9c: FH - FORSMARK HEAT SCENARIO

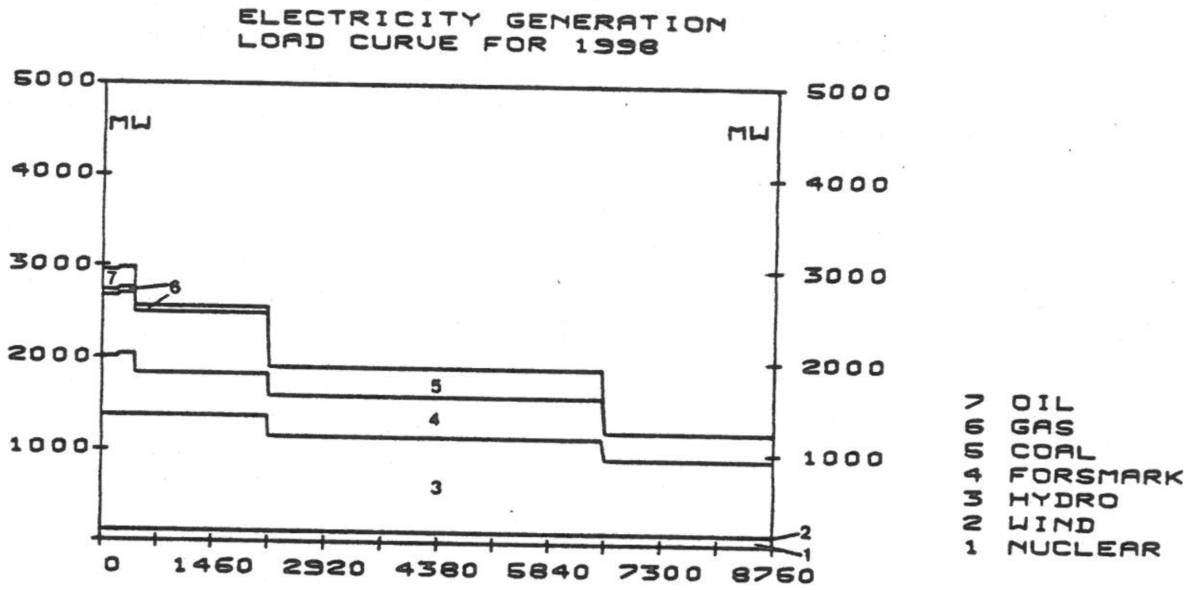
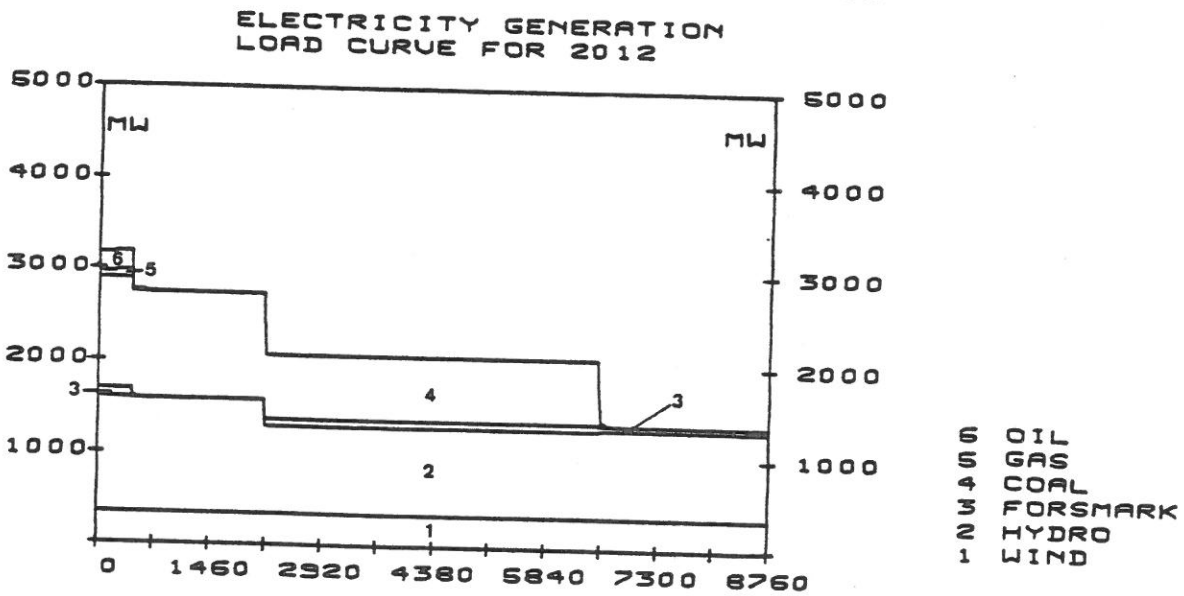


Figure 9d: FH - FORSMARK HEAT SCENARIO



6.5 The No-Energy Complex Scenario NC

6.5.1 District Heat Supply in the NC Scenario

The district heat supply structure of the NC scenario naturally compares very much with the previously discussed FH scenario. The exclusion of the Nynäshamn energy complex from the menu of supply options gives rise to the question of which technologies will be selected to fill the so created gap. Table 15 summarizes the district heat supply structure of the NC scenario. The category of small heating plants follows almost identically the development of the FH scenario with the exception of slightly increased contributions of oil and coal after the year 1988. This is especially the case during the period 1988 to 1993 when the missing energy complex forces the utilization of the existing capacities of coal and oil over longer periods per year. The general shift from base to peak supply and the future function of small heating plants as back-up capacities, etc. is common to all scenarios. Thus, the exclusion of the energy complex affects the development of the categories 'special heat plants' and 'co-generation plants' rather than the category of 'small heating plants'. Further, one should remember the fact that the energy savings activities in the NC (and in the FE) scenario are more permanent by nature than in the FH scenario (see section 6.2) which reduces the heat demand by 90 MW(th)yr/yr or 5 %.

The omission of the energy complex in this scenario reduces the heat quantities produced by Forsmark 3 and wasted thereafter due to the lacking market absorption capabilities over the period 1988 to 1993. Instead of 1289 MW(th)yr/yr of heat 1458 MW(th)yr/yr can be sold on the Stockholm market during that period. As of the year 1993 the shift from heat to electricity generation in the Forsmark 3 operation mode cuts the waste of steam down to zero. The reduction in Forsmark heat output is offset by a slightly increased combustion of oil in small heating plants as well as by higher contributions from oil- and coal-fired co-generation plants to heat supply. The additional contribution by these technologies is achieved by longer utilization of existing capacities and by the installation of new capacities. Gas has disappeared completely (no complex) which in turn means that the Värtan power station is fueled with oil over the entire planning horizon. Värtan again supplies peak heat demand but on somewhat longer periods per year than in the FH scenario.

Table 15: Total District Heat Production, in [MWyr/yr], NC - Scenario

Technology or Fuel Used	1980-1983	1984-1987	1988-1992	1993-1997	1998-2004	2005-2011	2012-2019	2020- -
WASTE	40.00	13.45	0.	0.	85.60	85.60	85.60	85.60
OIL	596.85	615.02	75.71	81.12	35.32	38.33	38.30	23.08
COAL	0.	287.37	71.84	71.84	33.97	8.21	0.	0.
WOOD	0.	0.	0.	0.	0.	0.	0.	48.00
EL-BOILERS	20.35	83.30	0.	0.	0.	0.	0.	0.
HEAT PLANTS	657.20	999.14	147.55	152.96	154.89	132.14	123.90	156.68
OIL	186.30	21.97	13.77	13.77	2.18	0.	0.	0.
COAL	0.	66.00	49.50	129.89	649.19	799.20	1129.36	1220.31
VARTAN	59.01	77.05	77.05	77.05	15.41	18.82	18.79	20.07
CO-GEN	245.31	165.02	140.32	220.71	666.77	818.02	1148.16	1240.38
FORSMARK 3	0.	0.	1457.89	1239.35	890.95	830.67	87.15	0.
HEAT PUMPS	0.	0.	0.	0.	0.	0.	462.35	468.63
SPECIAL	0.	0.	1457.89	1216.14	855.74	795.46	549.50	468.63
TOTAL	902.50	1164.16	1745.76	1613.02	1712.62	1780.83	1821.55	1865.69

The consequence of the exclusion of the energy complex on the activities of the co-generation plants causes a slight acceleration in the build-up of coal-fired plants which begins around in 1993. The operation mode of these plants complement the output structure of Forsmark 3. The omission of the energy complex forces Forsmark 3 to maintain the heat output on a level which ranges above the level of the previous scenario by 13 to 37 %. Thus, the shift from heat to electricity output cannot take place in the same way as well and the co-generation capacities help to avoid a shortage in indigenous electricity production capacities. Between 1998 and 2012 Forsmark 3 delivers almost all base load heat, the remainder stems from the utilization of waste products. Coal-fired co-generation meets the intermediate and part of the peak heat demand. The residual peak supply is delivered by small oil-fired peaking plants such as the Värtan power station.

The period after the year 2012 is marked by the substitution of Forsmark produced district heat supplying the base load region by large-scale heat pumps. Further, large-scale heat pumps have to make up for the non-existing energy complex as well. The heat contribution by this technology lies about 70 % above the level of the FH scenario (by 2020 the capacity of sewage water heat pumps amounts to 283 MW(th) and of sea water heat pumps to 224 MW(th)). The necessary electricity for the operation of large-scale heat pumps is supplied by the above mentioned increases in coal-fired co-generating capacity. In addition, the shut-down of Forsmark 3 releases more than 40 MW(el)yr/yr of electricity which earlier was required in the pump stations of the heat transmission system. Compared to the FH scenario there is another factor which in a figurative sense creates additional excess electricity capacity. The operation of the energy complex and the return water heat pumps also require a certain electricity input amounting on the average to almost 60 MW(el)yr/yr which in the NC scenario can be allocated to the operation of large-scale heat pumps. Coal-fired co-generation supplying mainly intermediate heat demand reaches a cumulative capacity of 2.7 GW(th) producing a total of 10.7 TWh per year (in 2020). Peak demand then is solely supplied by oil and the combustion of wood products.

6.5.2 Electricity Supply in the NC Scenario

The only notable difference in the electricity supply of the FH and NC scenarios is marked by the lower electricity contribution from Forsmark in the latter scenario. Between 1988 and 2012 the reduced indigenous electricity supply capacity is in part offset by the enhanced installation of coal-fired co-generation plants. Further, the omission of the energy complex causes overall electricity requirements to drop by approximately 60 MW(el)yr/yr. Before the year 1988 and after 2012 the electricity supply structure is almost identical to the FH scenario as shown in Table 16. As already mentioned in the discussion of the district heat supply structure coal-fired the co-generation capacities in the NC scenario exceed those of the previous one by 7 % which of course is directly applicable to electricity production capacities.

7. The Mixed Integer Scenario MI

The process of 'learning by doing' by means of the investigation of three distinct scenarios describing possible long-term and comprehensive energy supply strategies for Stockholm County has revealed the necessity of

- calculating and analyzing an integer solution and
- revising various essential assumptions.

The application of the mixed integer feature of the MESSAGE II model is meant to cast additional light on the cost competitiveness of the numerous energy supply technologies under consideration. So far exogenous manipulation has forced certain technologies into the solution or excluded others from the menu of supply options. Now all supply technologies will be confronted with each other simultaneously on the basis of integer solutions. This is to say that--in contrast to the linear or continuous solutions of the previous scenarios--a supply technology which is selected by the model must be installed according to its standard plant specification, i.e with respect to the specific capacity size etc. Any deviations from the exact specification is not permissible. Thus, a more realistic energy supply strategy is expected to be the result of this analysis, although it is still based on a host of assumptions and therefore represents only a plausible development path and by no means should be taken as a prediction.

Table 16: Total Electricity Production, in [MWyr/yr], NC - Scenario

Technology or Fuel Used	1980-1983	1984-1987	1988-1992	1993-1997	1998-2004	2005-2011	2012-2019	2020- -
FORSMARK 3	0.	0.	103.44	178.26	297.54	318.18	45.48	0.
WIND	0.	0.	0.	0.	9.38	94.39	313.16	313.16
INDIGENOUS	0.	0.	103.44	178.26	306.92	412.57	358.64	313.16
FUEL OIL	93.15	10.99	6.89	6.89	1.09	0.	0.	0.
COAL	0.	33.00	24.75	64.67	358.27	441.82	632.75	685.81
VARTAN	33.67	43.96	43.96	43.96	8.79	10.74	10.72	11.45
CO-GEN	126.82	87.95	75.60	115.52	368.15	452.55	643.48	697.27
NUCLEAR	454.56	454.56	454.56	403.78	105.69	0.	0.	0.
HYDRO	750.49	938.11	938.11	938.11	938.11	938.11	938.11	938.11
OIL	9.28	10.69	0.	0.	0.	0.	0.	0.
NAT GRID	1214.33	1403.36	1392.67	1341.89	1043.80	938.11	938.11	938.11
HEAT PUMPS	0.	0.	0.	0.	0.	0.	-146.26	-148.33
EL-BOILERS	-20.35	-83.30	0.	0.	0.	0.	0.	0.
FORSM-PIPE	0.	0.	-77.27	-67.55	-49.09	-45.89	-5.29	0.
TO: HEAT	-20.35	-83.30	-77.27	-67.55	-49.09	-45.89	-151.55	-148.33
TOTAL	1320.81	1408.01	1494.44	1568.11	1669.78	1757.34	1788.68	1800.20

The specific technologies set to integer variables in this scenario comprise the Forsmark 3 electricity option, the Forsmark 3 district heat/electricity option, the heat transmission system from Forsmark to Stockholm, the Nynäshamn energy complex, the Forsmark coal-fired co-generation plants, the special coal scenario plants, the Värtan co-generation plant, and the natural gas pipeline from Norway. All the other technologies are kept as linear variables. The commercially available plant sizes of these technologies are either variable (within certain limits of course) or of a relatively small scale.

The revision of some of the initial assumptions has become advisable at this point also. Firstly, the previous scenarios show a doubtful configuration of the electricity production sector. The allocation of the full electricity output of the Forsmark 3 power station to Stockholm County's disposal causes a partial de-coupling of what was an integrated national electricity system. The consequence of this has been discussed in the foregoing--Stockholm's participation in future development of the national electricity production system ceases (i.e. the replacement of capacities going out of operation as well as the general adaptation to future demand). In light of the large capacity of Forsmark 3, the assumed ceiling of electricity imports from the national grid appears to be too high. Therefore the following modifications are introduced:

- The ceiling of potential electricity imports from the national grid was lowered from 15 % to 12 % of the non Stockholm electricity production.

- In principal the electricity output of Forsmark 3 is fed into the national grid. However, 12 % of the Forsmark 3 produced electricity is at the Stockholm County's disposal. The corresponding costs of the transmission to Stockholm come upon the Stockholm utilities.

Further the option of small-scale heat pumps (i.e for operation in residential areas on an individual basis or for introduction in the private and public service sectors) was re-considered. In the initial MESSAGE II applications, the data concerning small-scale heat pumps were taken from the Jülich Data Hand Book [3] and Schiffer [4] which turned out to differ significantly from the Swedish market prices for this technology. On the average the Jülich data range below the Swedish investment cost data by a factor of two. Thus, in the previous model runs small-scale heat pumps had to be excluded until this cost discrepancy was resolved. In this scenario the revised set of input data including the Swedish characteristics of small-scale heat pumps is applied.

7.1 Useful Energy Demand in the MI Scenario

The investment cost revision concerning small-scale heat pumps causes some shifts in the structure of the supply of useful energy demand when compared to the previous scenarios*. The only really notable alteration occurs in the heating structure of the private and public service sectors (work places). After the year 1998 small-scale heat pumps begin to contribute to heat supply and expand their market share to more than 12 % by 2020 as shown in Figure 10. The penetration of small-scale heat pumps into this specific market takes place in part at the cost of solar technologies, which in contrast to the FE scenario do not enter the market at all. The remaining part of the service sector's heat demand supplied by small-scale heat pumps is covered by direct electricity (thermal ventilation) up until 1998. After that time, heat pumps substitute for direct electricity. By the year 2020 this process is completed and the entire market share formerly supplied by direct electricity is absorbed by small-scale heat pumps. However, the major share of almost 88 % of the heat demand (in useful terms) is taken on by district heat. This is exactly the same share as in the FE scenario.

A similar tendency, although on a much lower scale and occurring at a later point in time, can be observed in the development of heating structure of multi-family houses. Not until the year 2012 do small-scale heat pumps begin to substitute for direct electricity, reaching a minimum share of roughly 1 % of the heat supply in multi-family houses by 2020 (as a matter of fact heat pumps are installed only in buildings built after 1980). In the category of single-family homes the introduction of small-scale heat pumps does not cause any re-structuring in the end use devices for space and water heating at all. Of ultimate interest to the energy analyst are the consequences of changes in the heating structure on the development of final energy demand. The higher efficiency in the utilization of small-scale heat pumps (as opposed to direct electricity) reduces the electricity consumption for heating purposes by more than 16 % in the year 2020 when compared to the FE scenario. The overall effect on total electricity demand results in a reduction of more than 3 %. Table 17 summarizes development of final energy demand in the MI scenario for the period 1980 to 2020. As in the other scenarios, oil use steadily to zero by the year 2012. Heat from block heating systems is already totally substituted by district heat by 1993, while gas manages to sustain its 1980 level of 46 MW(th)yr/yr over most

* The primary energy supply structure of the MI scenario compares very much with the FE scenario. Therefore the FE scenario is used as the basis of reference in the following discussion.

Figure 10a : MI - MIXED INTEGER

HEATING IN
SINGLE FAMILY HOUSES

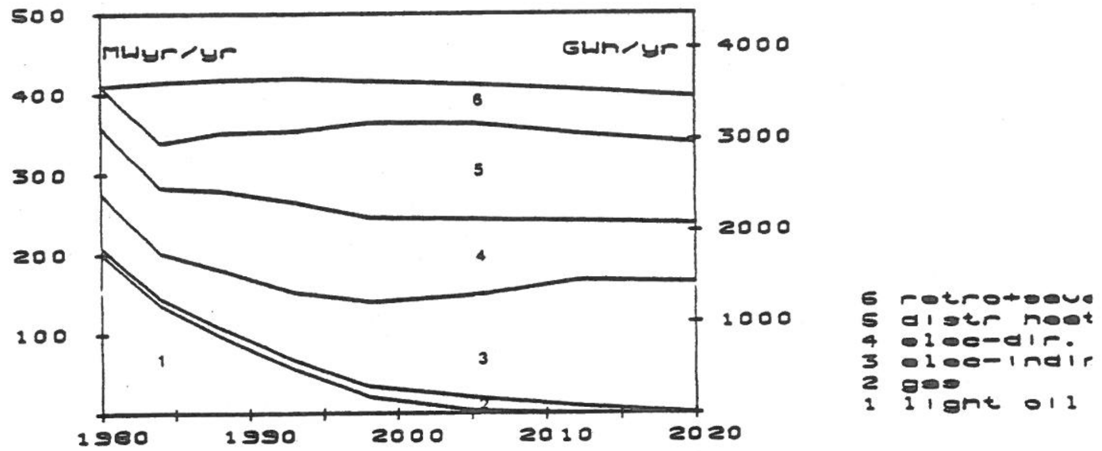


Figure 10b: MI - MIXED INTEGER

HEATING IN
MULTY FAMILY HOUSES

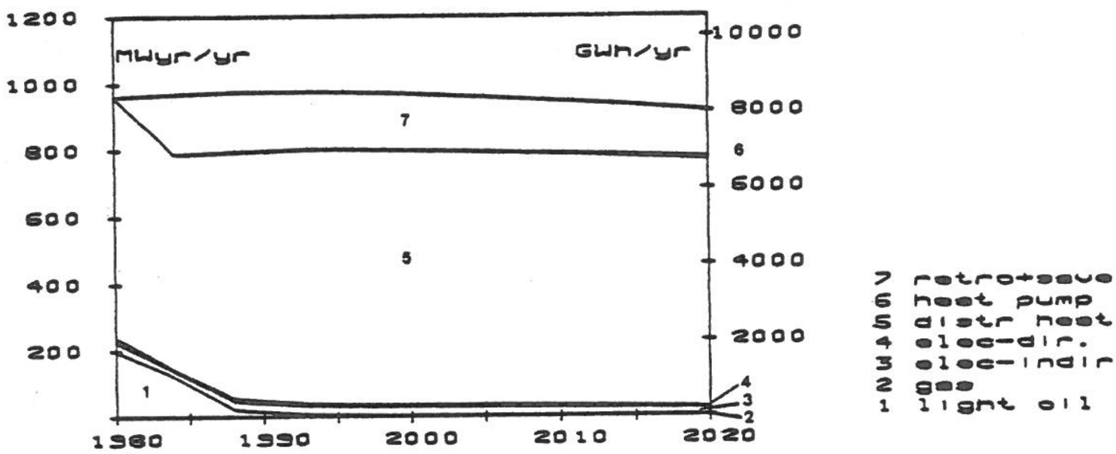


Figure 10c: MI - MIXED INTEGER

HEATING STRUCTURE FOR
WORK PLACES

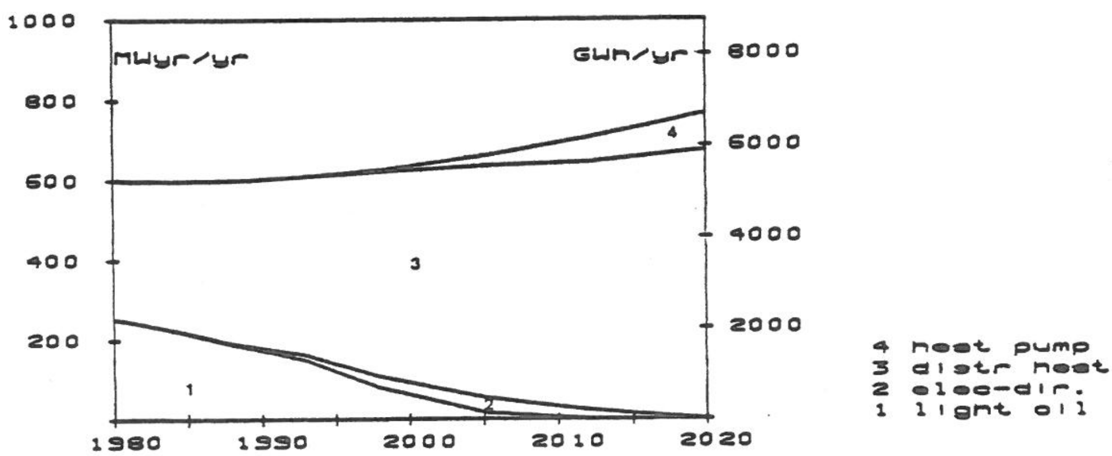


Table 17: Final Energy Consumption, MI Scenario in TWh/yr.

	Light Oil	Gas	Electr.	District Heat	Block Heat
1980	7.85	0.41	10.99	6.89	3.43
1984	5.79	0.29	11.36	8.84	1.07
1988	3.69	0.41	12.29	11.09	0.16
1993	2.51	0.43	13.12	11.98	0.
1998	1.21	0.48	13.73	12.86	0.
2005	0.24	0.50	14.31	13.44	0.
2012	0.	0.39	14.49	13.65	0.
2020	0.	0.26	14.44	13.98	0.

of the planning horizon. However, like in all scenarios, the category of final energy demand is totally dominated by electricity and district heat. Thus, it is again sufficient to concentrate further analysis with respect to the MI scenario on the supply of these two forms of final energy exclusively.

7.2 Energy Supply in the MI Scenario

Before going into the detailed discussion of the district heat and electricity supply structures it is appropriate to present a brief summary of the major results of the mixed integer solution. Principally, the cost-optimal solution of the MI scenario resembles the FE scenario. So far the FE scenario has been characterized by the lowest objective value which means that FE scenario represents the most economical solution of all scenarios. The resemblance of the solutions of the MI and FE scenario leads to the conclusion that based on the constraints and assumptions underlying the MI scenario the allocation of the Forsmark 3 power station to electricity generation appears to be the most reasonable policy to pursue. At the same time the Nynäshamn energy complex proves to be robust against all other competitors. The major impacts in the district heat and electricity supply menu as determined by the the cost-optimal solution of the MI scenario stem from modifications of some of the initial assumptions regarding the dependence of Stockholm County on the national grid. Without these modifications the outcome of the mixed integer approach is almost identical the FE scenario.

7.3 District Heat Supply in the MI Scenario

The general reduction in the electricity import ceiling from 15 to 12 % of the national electricity production results in a lowered electricity availability for Stockholm County. In turn, the decline in electricity deliveries from the national grid affects the structure of the district heat production significantly. The electricity supply situation is further aggravated by the second modification in the MI scenario. In the foregoing the total electricity output of the Forsmark 3 power station was considered to belong to the 'indigenous', i.e. Stockholm, power generation. In the MI scenario, similar to the arrangement with respect to the national grid, only 12 % of the electricity output of Forsmark 3 is directly allocated to Stockholm County. In summary the decline in the potential availability of electricity from these two sources for the years 1984 to 1993 is decreased by almost 40 % in comparison to the FE scenario.

The direct impacts of the reduction in potential electricity supply on the district heat supply structure can be derived from Table 18. For example, unlike in the FE scenario, the capacity expansion of electric boilers in the category of small heating plants does not occur. The application of this technology, although characterized by quite favorable investment costs, is phased out immediately. The other technologies of this category are marked by a quite dissimilar development as well. The capacity of pure oil heating plants, which in the FE scenario is reduced by the year 2020 to 20 % of its 1980 value, remains more than 40 % in the MI scenario. The shift from base and intermediate supply of heat demand to peak supply only, however, also takes place in the MI scenario, although towards the end of the planning horizon the utilization of oil capacities on the average range about 50 % above the FE scenario. Up to the turn of the century oil-fired heating plants serve as the principal back-up capacities. The combustion of waste products for district heat production purposes again reflects the situation of the electricity availability. In the initial periods this heat source is applied to a much larger extent than in any other scenario. Around the year 2000, however, there exists a brief period of excess electricity supply from co-generation (as will be shown later in the report), and the utilization of waste products is discontinued for this intermediate state. Towards the end of the study period waste products re-enter the heat supply market. By then wood products are utilized up to their maximum potential as well. As in the FE scenario, the 400 MW(th) coal-fired heating plant is installed to assume production by 1984. The operation mode of this power plant, however, is different, especially for the period 1988 to 1993. The lesser availability of electricity (for electric boilers) forces this technology to cover parts of the intermediate heat

Table 18: Total District Heat Production, in [MWyr/yr], MI - Scenario

Technology or Fuel Used	1980-1983	1984-1987	1988-1992	1993-1997	1998-2004	2005-2011	2012-2019	2020- -
WASTE	40.00	70.00	56.55	56.55	48.47	0.	85.60	85.60
OIL	596.85	557.60	178.32	143.51	25.04	23.62	17.54	18.76
COAL	0.	296.99	173.09	79.70	79.70	9.11	0.	0.
WOOD	0.	0.	0.	0.	0.	0.	30.73	48.00
EL-BOILERS	20.35	3.84	0.	0.03	0.	0.	0.	0.
HEAT PLANTS	657.20	928.43	407.95	279.79	153.21	32.73	133.87	152.36
OIL	186.30	65.91	13.77	13.77	2.18	0.	0.	0.
COAL	0.	88.00	264.51	555.33	1134.48	1337.72	1287.95	1315.02
GAS	0.	0.	37.30	43.41	16.37	15.22	4.20	3.81
VARTAN	59.01	81.71	59.17	27.58	15.37	4.75	4.75	4.75
CO-GEN	245.31	235.62	374.75	640.08	1168.40	1357.69	1296.90	1323.58
EN-COMPLEX	0.	0.	487.47	472.01	351.34	337.30	291.80	265.72
HEAT PUMPS	0.	0.	205.67	204.44	44.23	68.81	99.63	124.15
SPECIAL	0.	0.	693.14	676.45	395.58	406.11	391.43	389.88
TOTAL	902.50	1164.05	1475.84	1596.32	1717.19	1796.53	1822.19	1865.82

demand in addition to peak supply. In summary the reduction in the electricity import ceiling causes a general increase in the contribution of all non-electric small heating plants to district heat supply and an immediate exclusion of electric boilers.

Over the initial periods of the planning horizon the categories 'special heat plants' and 'co-generation plants' react in a similar way as the small heating plants, i.e electrically operated ways of district heat production are cut down in favor of non-electric district heat production technologies. Thus, coal-fired co-generation capacities are installed as of 1984 and expand rapidly in the periods thereafter. Table 19 compares this build-up of co-generation capacity with the FE scenario. In the MI scenario the construction activities become necessary at an earlier stage, firstly to provide the capacities for the substitution of electricity imports and secondly to compensate for the diminished contribution of large-scale heat pumps (and of

Table 19a : Installed Co-generation Capacity, FE Scenario, in MW.

	Electr.	Heat
1980	564.08	1041.01
1984	545.62	1003.30
1988	630.12	1172.29
1993	817.80	1492.14
1998	1637.48	2853.48
2005	2161.25	3689.99
2012	2878.87	4846.45
2020	3080.48	5209.21

Table 19b : Installed Co-generation Capacity, MI Scenario, in MW.

	Electr.	Heat
1980	564.08	1041.01
1984	542.58	998.01
1988	886.57	1531.96
1993	1368.06	2352.34
1998	2248.32	3812.29
2005	2727.17	4524.02
2012	2817.31	4713.08
2020	2815.55	4732.73

course oil in small heating and co-generation plants which is common in all scenarios) to district heat supply. By 1988 oil co-generation is reduced to super peak supply, and disappears altogether around the turn of the century. The Värtan co-generation station operates on oil most of the time. Preferably the gas from the energy complex is burned in a special small 100 MW(th) gas-turbine/steam-turbine co-generation plant. Only between 1988 and 1997 is the gas from the energy complex utilized by the Värtan plant when roughly 2/3 of the output is based on gas during this period. After the year 2005 the 334 MW(th) capacity of the Värtan station is replaced by a small 103 MW(th) peak oil-fired co-generation plant.

In the category of special heat plants the energy complex gains supremacy. The output structure of the energy complex is oriented to maximize methanol and heat output simultaneously. According to the planned output variations this implies that the intermediate operation mode is preferred by the energy supply model MESSAGE II, i.e. almost 80 % of the operation during the period 1988 to 1997. Altogether the heat output ranges between 472 MW(th)yr/yr and 487 MW(yh)yr/yr or 4.13 TWh/yr and 4.27 TWh/yr respectively (including the contribution of the return water heat pumps). Methanol output corresponds to the absolute feasible maximum of 819.000 tons per year, thus exceeding the planned output by 17 %. Almost 70 % of the gas output is consumed by the Värtan station and the gas-turbine/steam-turbine co-generation peaking plant plant, with the remainder being directly consumed by final users in the old single- and multi-family houses.

The second technology within the category of special heat plants in the MI scenario concerns the large-scale heat pumps. The installed capacity amounts to 225 MW(th) of the sewage water type. Sea water heat pumps are not installed at all. Compared to the FE scenario this means a reduction in the capacity of this technology in the order of 75 % which is a consequence of the curtailed electricity import volumes.

The contribution of the various technologies to district heat supply is illustrated in Figure 11b for the period 1988 to 1997. The utilization of waste products supplies the absolute base load heat demand, while the heat output of the large-scale heat pumps and in part of the energy complex complement the base load supply. The intermediate load region is about equally shared by the energy complex and coal-fired co-generation. Peak supply is provided by a little contribution of gas while the major share of this load has to be supplied by oil.

Figure 11a:

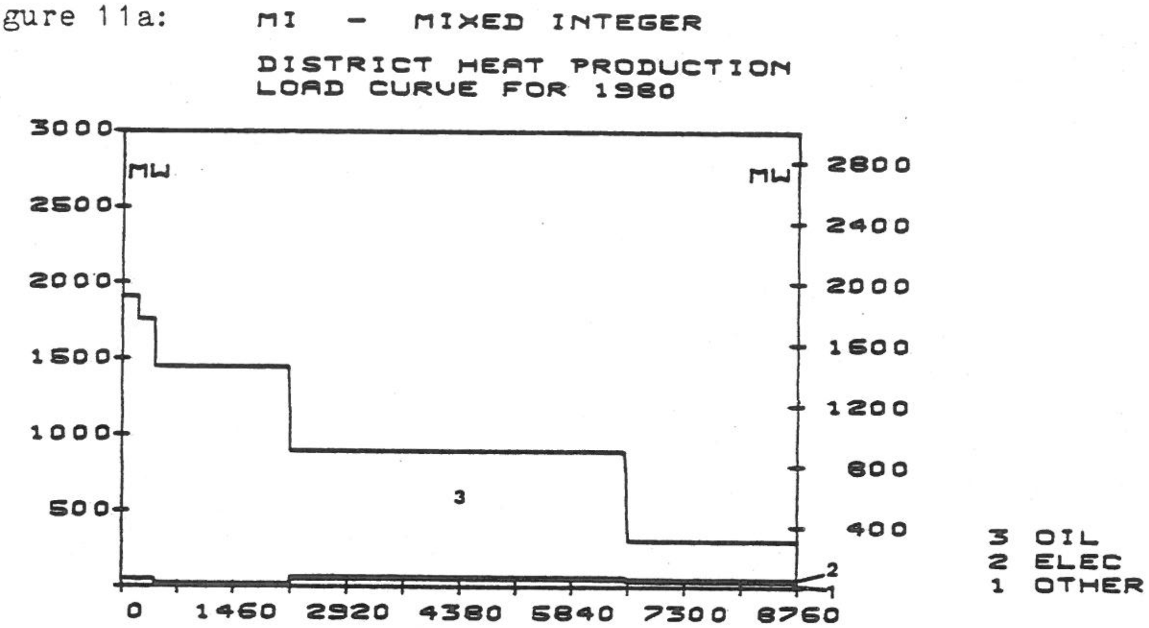


Figure 11b:

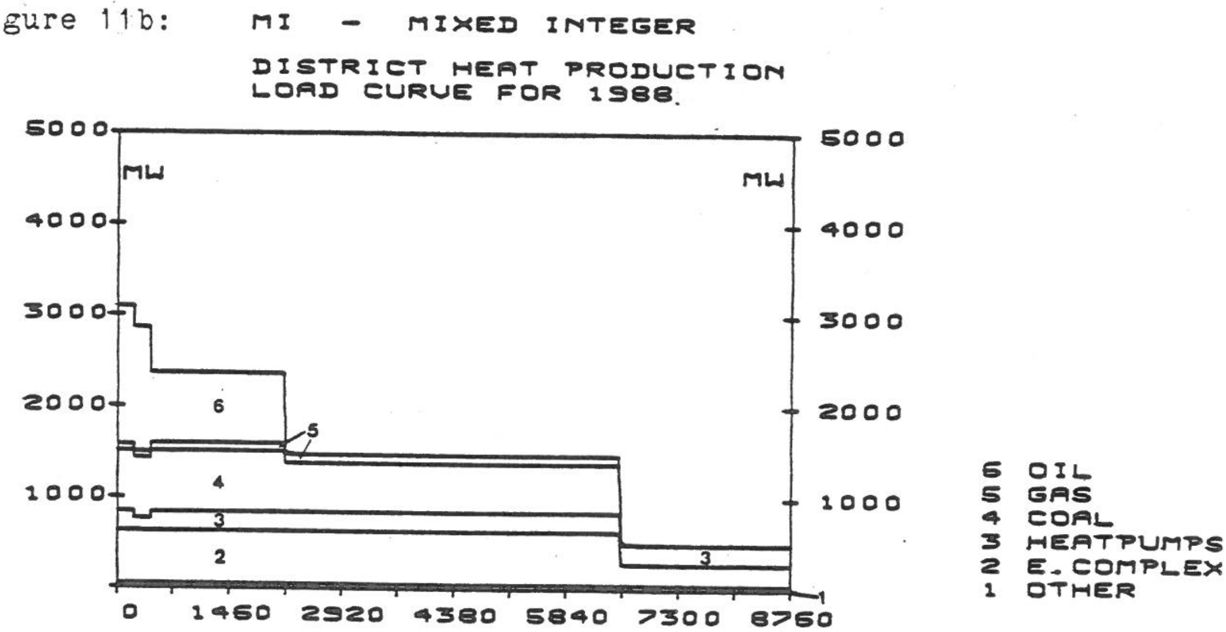


Figure 11c: MI - MIXED INTEGER

DISTRICT HEAT PRODUCTION
LOAD CURVE FOR 1998

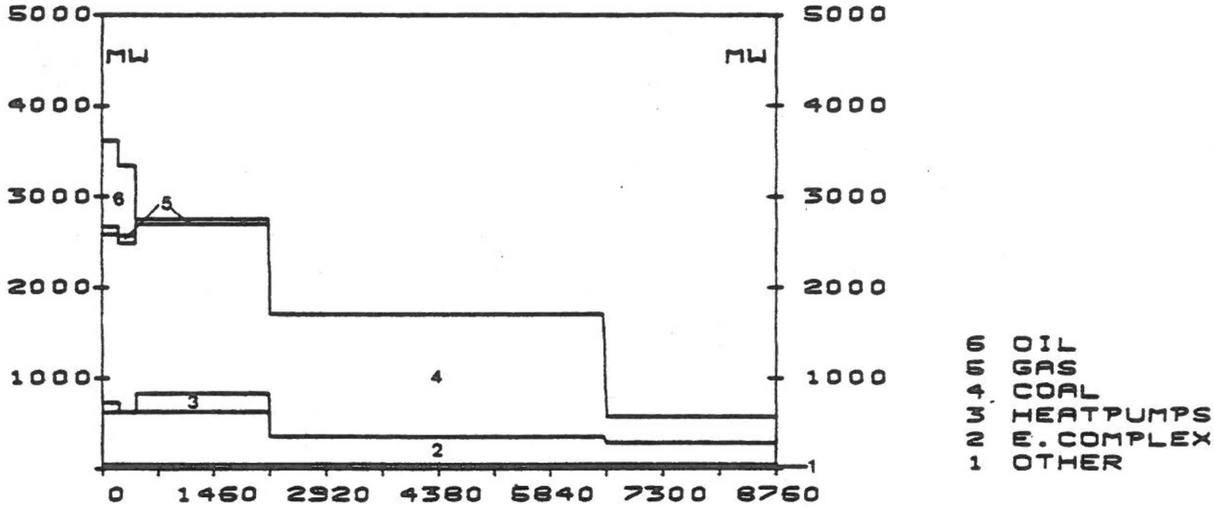
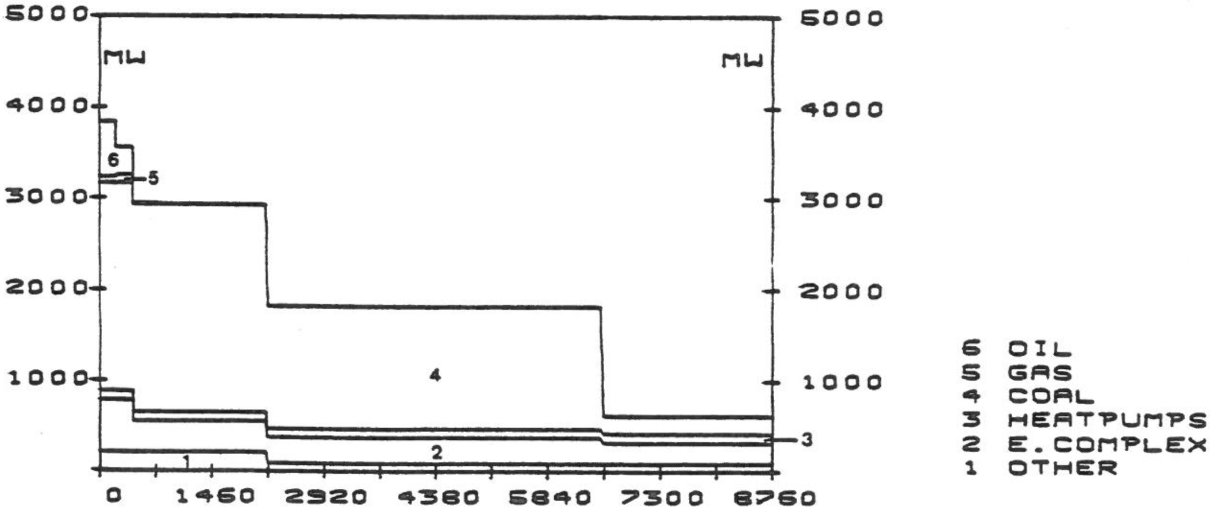


Figure 11d: MI - MIXED INTEGER

DISTRICT HEAT PRODUCTION
LOAD CURVE FOR 2012



After the year 1998 the heat supply picture changes notably. Co-generation capacities based on oil have reached a level of 1755 MW(th) and consequently expand their contribution to heat supply accordingly (see Table 18). The increase from 264 MW(th)yr/yr (or 2.3 TWh/yr) in 1988 to 1134 MW(th)yr/yr (or 9.9 TWh/yr) forces the large-scale heat pumps to cut down heat production considerably. However, there is another reason for the decline of this technology-- the squeeze on electricity supply caused by the phasing out of nuclear power stations supplying the national grid. The energy complex is affected by the enormous increase in co-generation as well, and adjusts its output structure by shifting from the intermediate to the summer operation mode.

The dominating role of co-generation also causes a re-arrangement in the load characteristics of the different technologies. According to Figure 11c heat pumps shift from base load to peak load supply and are replaced by coal in the latter load region. The energy complex sustains its contribution in base load supply but has to forfeit part of the former intermediate load supply. Again coal-fired co-generation takes over the major share in this load region. A similar substitution takes place in peak supply. About 40 % of oil is substituted by coal co-generation while gas from the energy complex maintains a minor share in this load region.

The institutionally enforced closing down of nuclear power stations in Sweden will be completed by the year 2013 and the total nuclear power capacity will have gone out of operation. However, the impacts on the district heat supply structure of Stockholm County is much less notable than in the previous scenarios. The modification of the maximum electricity import ceiling has forced the installation of adequate co-generation capacity at an earlier point in time as mentioned above. Thus, the transition to the post nuclear era appears to take place quite smoothly without any disruptions in the Stockholm County area. The period after 2012 is marked by the construction of a new energy complex replacing the aged old one. The mode of operation shifts even more into summer production; the heat capacity of the co-generation plants restricts the utilization of the energy complex for district heat purposes to base load supply. Further, the abundant co-generation capacity generates sufficient electricity for the operation of large-scale heat pumps. Thus, large-scale sewage water heat pumps are re-installed also, but on a 50 % lower scale than before.

According to Figure 11d another re-arrangement in the contribution of the district heat supply technologies to the variations of the demand load takes place. Large-scale heat pumps are shifted back to base load supply which indicates that around 1998 a minor electricity base load supply problem must have occurred. The other base load suppliers after 2012 are the energy complex, waste and wood products and coal-fired co-generation. The intermediate heat supply stems almost completely from co-generation while in the supply of the peak load region some oil and gas contribute in addition to coal-fired co-generation.

7.4 Electricity Supply in the MI Scenario

The most important characteristics of the electricity supply sector of the Stockholm County have been presented above. For reasons of completeness the dynamic development of this sector is summarized in Table 20. The striking differences compared to the FE scenario concern the electricity imports from the national grid. Due to the newly introduced 12 % limit on Forsmark 3 electricity, the model attempts to obtain additional electricity imports from the national grid. This is not straightforwardly possible since the electricity import ceiling is reduced to 12 % as well. Thus, the only possibility to draw additional electricity from the national grid is from enhanced active participation of the Stockholm utilities in the expansion of the national grid. Therefore, unlike in the previous scenarios where the completion of the nuclear power stations presently under construction is not supported by the Stockholm utilities (in the environment of the MESSAGE II model of course), the installation of these nuclear capacities is now favored. Consequently the full service time of the nuclear power capacities is utilized (see Table 20).

As of the year 1984 the coal-fired co-generation plant previously mentioned in the section describing district heat supply assumes its production. In the time periods that follow, co-generation capacity expands proportionally to the district heat production capacities. All normal oil-fired co-generation is steadily done away with by the turn of the century. Thus, the Värtan station remains the only oil-fired co-generation plant, although in part burning gas from the energy complex. The gas-turbine/steam-turbine supplies peak electricity, again a result of the interdependence of the heat and electricity supply by means of co-generation plants.

The drop in electricity supply from nuclear power stations belonging to the national grid causes a short-term bottle-neck in the supply of base load electricity around the year 1998. The consequences, however, are only marginal. The temporary shift of the electricity consuming large-scale heat pumps from base to peak supply is the only essential impact. Wind enters the indigenous electricity market in 1988 and expands to its maximum realizable potential by the end of the planning horizon.

Table 20: Total Electricity Production, in [MWyr/yr], MI - Scenario

Technology or Fuel Used	1980-1983	1984-1987	1988-1992	1993-1997	1998-2004	2005-2011	2012-2019	2020- -
FORSMARK 3	0.	0.	69.87	69.87	69.87	69.87	8.73	0.
WIND	0.	0.	0.	0.	15.80	98.35	313.16	313.16
INDIGENOUS	0.	0.	69.87	69.87	85.67	168.22	321.89	313.16
FUEL OIL	93.15	32.96	6.89	6.89	1.09	0.	0.	0.
COAL	0.	44.00	140.45	300.57	629.71	753.12	724.69	739.86
GAS	0.	0.	37.30	43.41	16.37	15.22	4.20	3.81
VARTAN	33.67	46.62	33.77	15.74	8.77	2.71	2.71	2.71
CO-GEN	126.82	123.58	218.40	366.60	655.93	771.06	731.60	746.38
NUCLEAR	454.56	484.15	571.25	520.46	222.38	104.00	10.89	0.
HYDRO	750.49	750.49	750.49	750.49	750.49	750.49	750.49	750.49
OIL	9.28	10.11	9.44	8.31	5.41	0.	0.	0.
NAT GRID	1214.33	1244.74	1368.47	1322.67	994.64	869.71	765.58	754.30
HEAT PUMPS	0.	0.	-62.32	-61.95	-13.40	-20.85	-30.19	-37.62
EN-COMPLEX	0.	0.	-93.39	-90.02	-63.67	-60.62	-50.67	-44.97
EL-BOILERS	-20.35	-3.84	0.	-0.03	0.	0.	0.	0.
TO: HEAT	-20.35	-3.84	-155.71	-152.00	-77.07	-81.47	-80.86	-82.59
TOTAL	1320.81	1364.48	1501.03	1607.13	1659.17	1727.51	1738.22	1731.25

Figures 12a to 12d contain the load characteristics of electricity supply. Between 1988 and 1998 base load electricity is produced almost entirely by imported nuclear and hydroelectric power. The remainder is made up by the direct contribution of Forsmark 3 electricity. Coal-fired co-generation, the Värtan station and the gas-turbine/steam-turbine plant supply intermediate and peak demand while the old oil-fired co-generation plants are operated in times of extreme peak demand only. After 1998 and especially after 2012 the major contributors to base load supply consist of wind and hydro electricity. The reduced and eventually phased out nuclear electricity is substituted to a large extent by wind and in part by coal-fired co-generation which on the other hand supplies the entire intermediate load region. Oil combustion in the successor of the Värtan plant and gas from the energy complex (in a re-built gas-turbine/steam-turbine) finally secure the supply of peak electricity demand.

8. Some Comparative Economic Remarks

The long-term energy supply strategies for Stockholm County are--among other factors--highly determined by the respective cost assumptions. Thus, it is appropriate to look briefly into the cost effectiveness of the various scenarios. The principal cost data which enter the energy supply analysis at various points (in the MESSAGE II model) concern the investment costs per unit of capacity, fixed operation and maintenance costs (again per unit of capacity), variable operation and maintenance costs per unit of output (excluding fuel costs) and fuel costs per unit of fuel consumed. The cost assumptions with respect to investments and the O&M costs for each technology (including further characteristics such as efficiencies, etc.) are summarized in the Appendix. One very essential ingredient in this analysis concerns the assumed development of the world market prices of various forms of primary energy, which certainly is of utmost importance for a relatively small economic entity such as Stockholm County which is without major indigenous primary energy resources. In Table 21 the assumed energy import price development for different primary energy carriers is given. These price assumptions are kept constant for all scenarios investigated. However, in addition to the scenarios presented in this report several additional supply strategies based on different energy import price assumptions were analyzed*.

* The sensitivity analysis with respect to energy import variations resulted in only minor consequences on the long-term energy supply picture for the Stockholm County. It appears that the envisaged system configuration is quite stable against surprises on the world energy market.

Figure 12a:

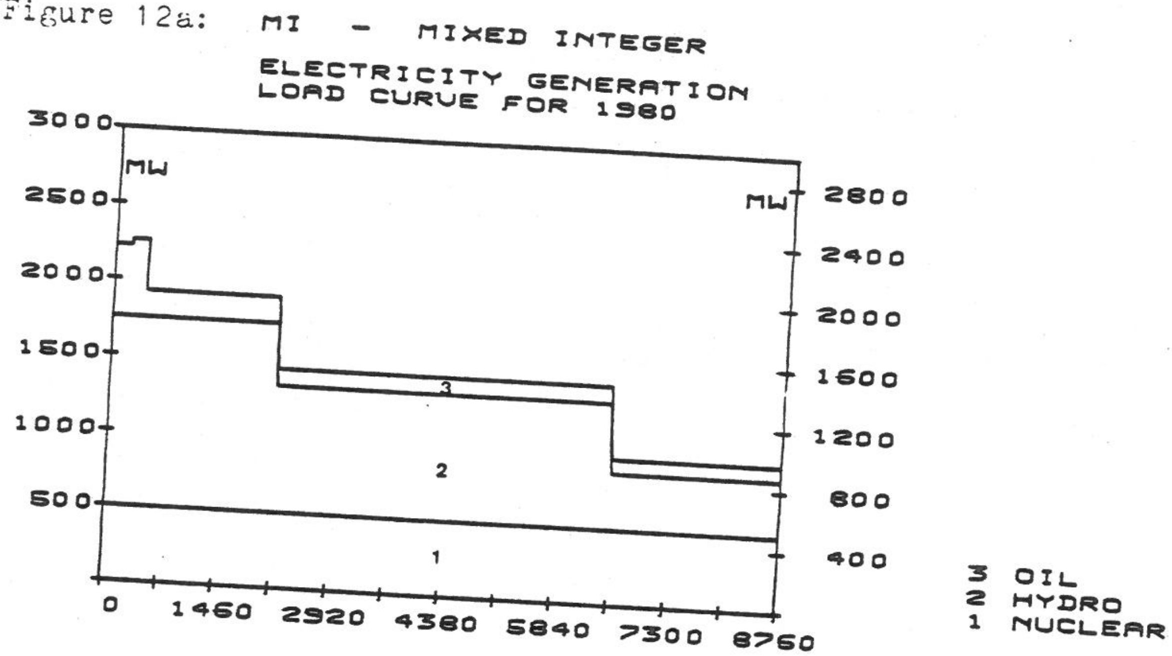


Figure 12b:

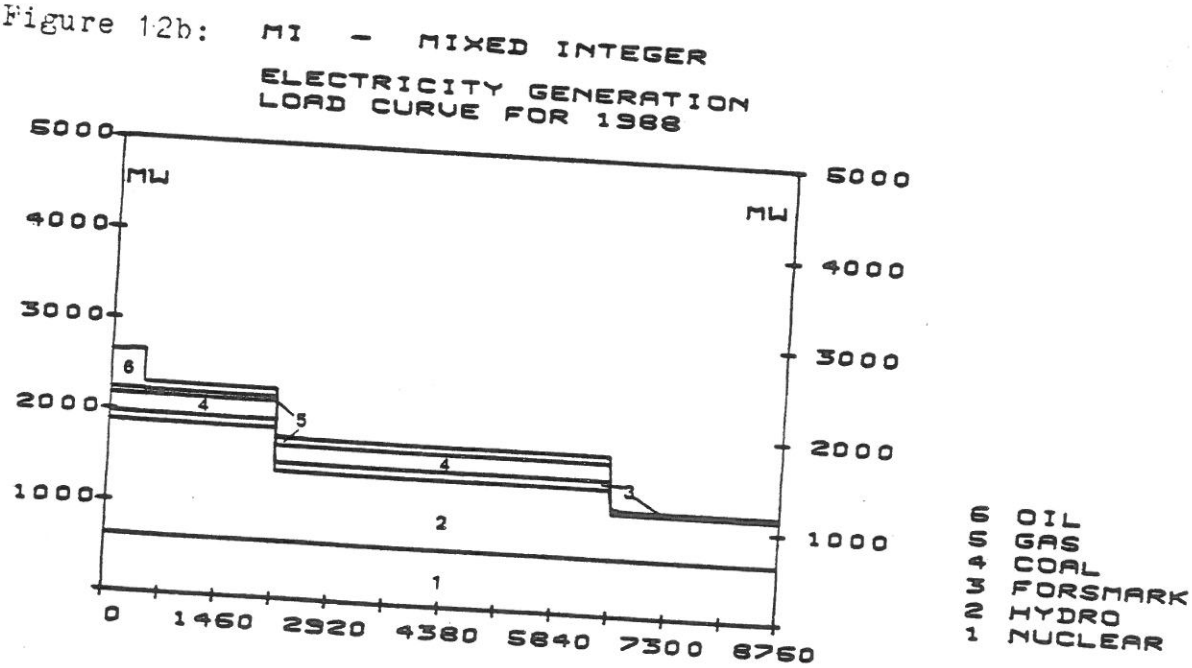


Figure 12c:

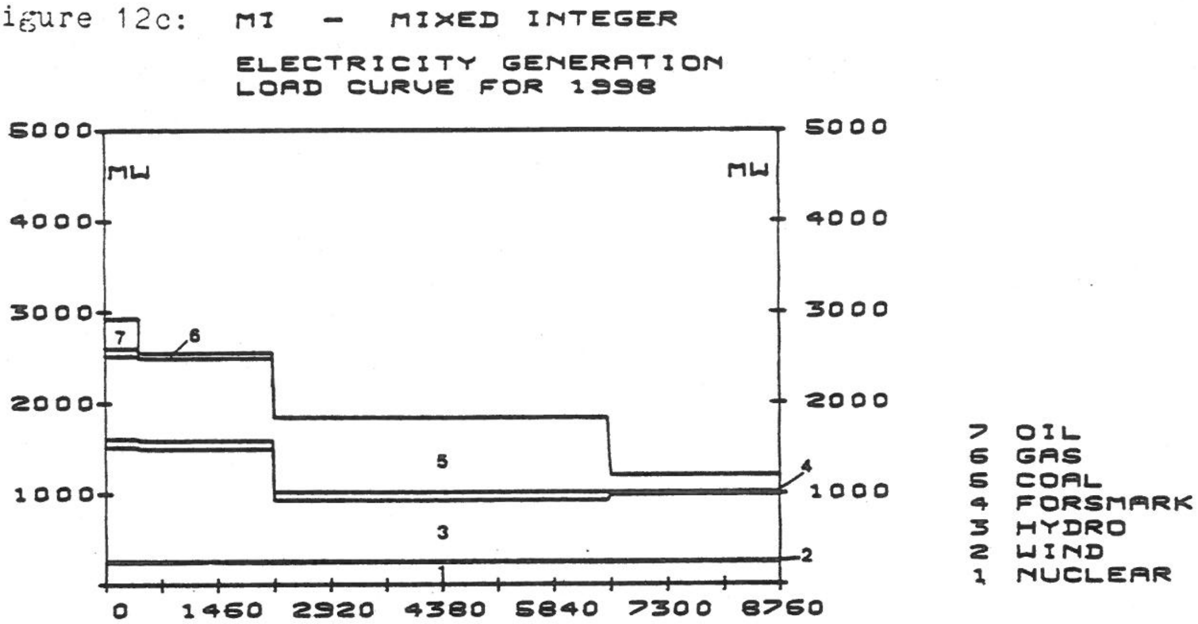


Figure 12d:

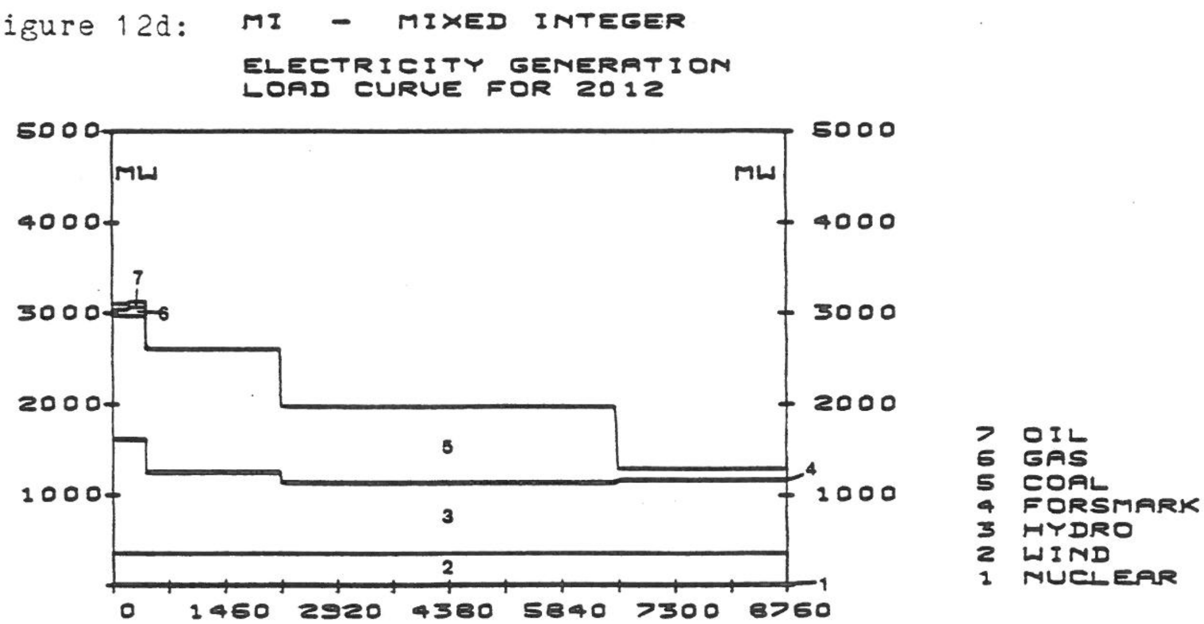


Table 21: Energy Import Prices in Skr(80)/KWyr.

Energy Form	Base Year (1980)	Cost Increases [% per year]		Last Year (2020)
		1980-2000	2000-2020	
natural gas	788.2	3.5	3.0	2832.6
light oil	964.0	3.5	3.0	3464.4
fuel oil	700.0	3.0	2.0	1878.7
hard coal	392.0	3.0	3.0	1278.7
h-sulf. coal	322.0	3.0	3.0	1050.4

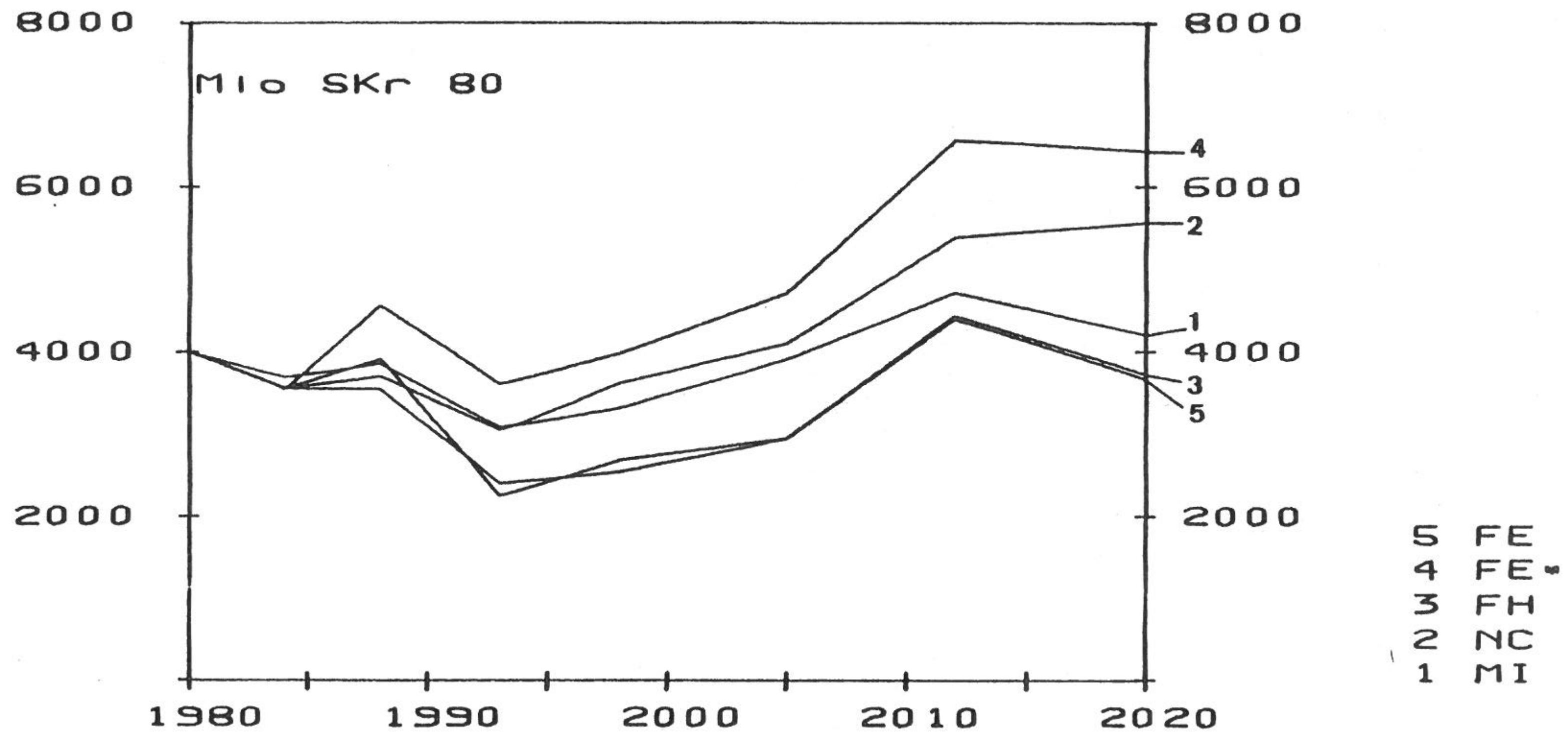
In general it has been assumed throughout this analysis that the price development of a specific type of energy on the world market is linked to the price development of its competitors. In this case all imported forms of energy must be considered direct competitors. This is to say that a diverse price development of different types of imported energy is not foreseen in this study.

The assumption concerning methanol revenues on the Swedish liquid fuel market is another critical variable in the determination of long-term energy supply strategies. The assumed revenue of 80 Öre at 1980 prices per liter of methanol is primarily based on the average 1980 world market price before taxation of refined oil products, which amounted to 130 Öre per liter. Further, the technically feasible admixture of up to 20 % methanol to gasoline leads to the same mileage as a purely gasoline operated vehicle (due to an improvement in the Second Law efficiency) [5]. In this case the lower calorific value per volume of methanol compared to gasoline does not matter. In this context the price per liter of methanol is directly comparable to gasoline (before tax) and appears to range at the rather conservative end of the liquid fuel price scale.

8.1 Total Expenditures in Long-Term Energy Supply Strategies for Stockholm County

The first question with respect to the economics of a large and complex system such as the energy supply system of Stockholm County concerns the total costs of its realization. The monetary expenditures over the next 40 years for the four scenarios analyzed in this report are displayed in Figure 13. The general development of total costs appears to follow a certain regularity in all scenarios whereas the actual

Figure 13: ANNUAL TOTAL COSTS



monetary quantities vary significantly. The dip in total costs around the year 1984 is a consequence of the anticipated availability of the 'special heat plants' as of the year 1988. Thus, utilities cut down their investment programs to absolute minimums, while consumers prefer to invest in long-lasting energy saving measures or to simply avoid the consumption of oil products as much as possible rather than pay the high oil market prices.

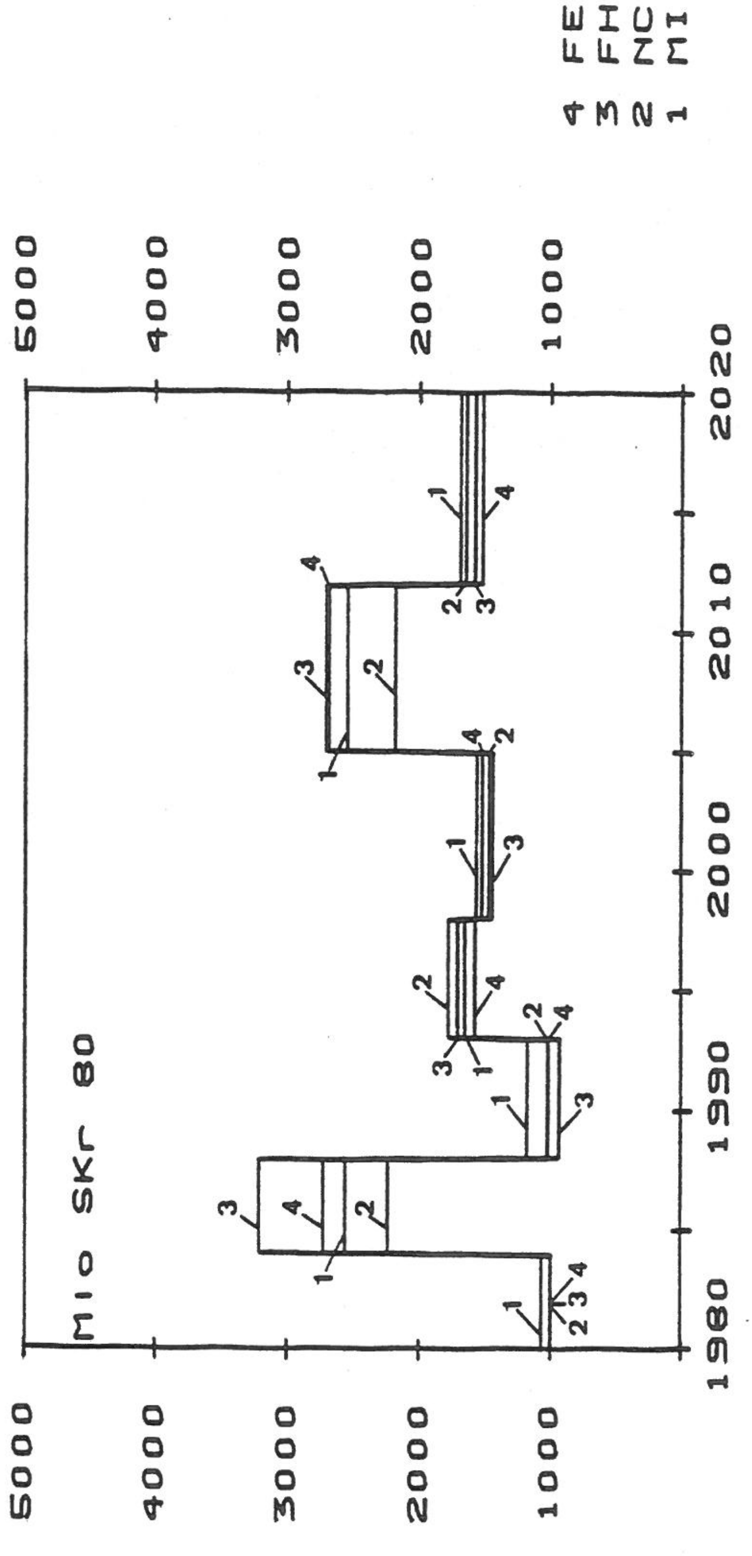
Between 1984 and 1988 the investment requirements for heat transmission system from Forsmark to Stockholm, the Nynäshamn energy complex, the large-scale heat pumps, and the district heat distribution system or the co-generation plants add considerably to the total costs. Thus, the first peak in total costs corresponds to this period. The FH scenario is marked by the highest total costs due to the parallel construction of the heat transmission system and the energy complex*. The dynamic development of the aggregate investment requirements for each scenario are given in Figure 14.

The peak in total expenses is followed by another plunge in total costs across all scenarios. Due to the completion of the installation of the special heat plants and the corresponding infrastructure, investment requirements drop significantly in the succeeding periods, as shown again in Figure 14. The FE and FH scenarios range at the bottom end of the costs bracket during the period 1989 to 1998. These scenarios profit from the revenues from methanol production in the order of 1000 Million Skr(80), pushing total costs considerably below those of the NC scenario. For purposes of comparison, the expenditures of the FE scenario without the bonus of the methanol sales is also given in Figure 13.

After 1998 total expenditures begin to rise again steeply. This is partly due to steadily increasing fuel prices which raise the energy import bill, and also to the energy supply facilities installed in the 70s nearing the end of their service lives. Consequently, expenditures for the replacement of the production capacities going out of operation contribute considerably to the step up of costs (see Figures 13 and 14). This is especially true between 2005 and 2012, when the energy production facilities constructed during the period 1984 to 1988 (i.e. the energy complex or the large-scale heat pumps) have to be replaced. Between the years 2012 and 2020 investment expenditures drop again for reasons similar to the drop following the previous peak. Total expenditures decline simultaneously with the reduction in investment activities for all cases but in the NC

* Only the costs of the FE, FH and the NC scenarios are directly comparable, since the MI scenario is based on a modified ceiling for maximum electricity imports.

Figure 14: ANNUAL CAPITAL COSTS



scenario. Although the NC scenario is marked by the lowest investment requirements during the peaking periods, the lacking methanol revenues turn this scenario into the most expensive one. A brief look at the objective function values given in Table 22 for the four scenario supports this conclusion. According to Table 22 the FE scenario is the most cost-effective solution while the NC scenario under such cost considerations appears to be the least preferable one. The objective value as well as the total expenditures do not include the costs for the additional oil imports which become necessary to replace the use of methanol in the NC scenario. Since the oil import expenditures range above the revenues for methanol the total expenditures would be even greater than indicated in Figure 13.

Table 22: Objective Function Values.

FE	1,029,436.4
FH	1,052,467.3
NC	1,223,934.7
MI	1,165,725.7

In spite of the lowered electricity import ceiling the MI scenario proves to be quite cost-effective also. The timely distribution of the investment requirements is different than in the other scenarios. The early build-up of co-generation capacities initiated by the modified ceiling on electricity imports reduces the capital demand during the peaking periods, when the special energy conversion facilities are scheduled for construction. In the MI scenario the higher level of total expenditures is a consequence of the lowered electricity imports which are offset by the combustion of coal in co-generation plants. The reduction in dependence of Stockholm County from the national grid takes place at the expense of an increase in the overall fuel costs.

The possible impacts of varying fuel prices on the long-term cost-effectiveness of the MI scenario can be derived from Figure 13. The gap in total expenditures between the MI and NC scenarios indicates that even at considerably lower methanol market prices (here revenues), the favorable environment for the pursuit of the MI scenario is not endangered. Variations in energy import prices matter only in the very unlikely situation that oil and coal prices on the respective world markets eventually diverge, favoring low oil prices but steeply rising coal prices.

The Tables 23 to 26 summarize the cost calculations of the MESSAGE II model for all scenarios. The expenditures are split into capital requirements for the installation of energy production facilities including the transmission and distribution systems, the operation and maintenance expenditures, fuel costs, the capital expenditures for energy conservation including heating technologies at the end use side and the methanol revenues. One should note that all cost figures are quoted excluding taxes, profits, etc.

Table 22: Total Annual Costs, FE Scenario, in Millions of Skr(80).

	Capital	O&M	Fuel	Retro&Sa	Methanol	Total
1980	1400.50	289.69	2293.29	0.	0.	3983.48
1984	993.97	366.81	1997.05	185.17	0.	3543.00
1988	2187.00	586.90	1659.94	127.85	-1022.06	3539.64
1993	1015.69	678.83	1748.62	156.70	-1214.14	2385.70
1998	1123.38	792.58	1909.79	152.92	-1439.14	2539.53
2005	1515.54	911.98	2120.25	158.69	-1762.37	2944.10
2012	2354.96	1101.15	2964.03	148.47	-2174.89	4393.72
2020	1215.10	1149.54	3919.41	144.83	-2779.56	3649.33

Table 23: Total Annual Costs, FH Scenario, in Millions of Skr(80).

	Capital	O&M	Fuel	Retro&Sa	Methanol	Total
1980	1407.95	290.13	2293.29	0.	0.	3991.37
1984	988.79	366.21	2005.97	185.17	0.	3546.14
1988	2572.59	573.88	1658.30	131.01	-1022.02	3913.76
1993	918.69	633.43	1742.14	162.37	-1213.45	2243.18
1998	1222.48	797.23	1947.98	152.92	-1439.15	2681.47
2005	1433.66	906.46	2207.36	169.56	-1761.77	2955.27
2012	2374.23	1126.54	2981.02	148.47	-2189.28	4440.97
2020	1259.15	1171.13	3924.65	144.83	-2780.12	3719.64

Table 24: Total Annual Costs, NC Scenario, in Millions of Skr(80).

	Capital	O&M	Fuel	Retro&Sa	Methanol	Total
1980	1407.95	290.13	2293.29	0.	0.	3991.37
1984	991.76	366.62	2005.27	185.17	0.	3548.83
1988	1794.95	418.83	1323.32	159.42	0.	3696.52
1993	1009.85	487.56	1373.31	163.36	0.	3034.08
1998	1272.52	664.41	1532.21	152.92	0.	3622.06
2005	1466.93	776.77	1703.55	158.69	0.	4105.95
2012	1918.55	998.37	2316.90	148.47	0.	5382.28
2020	1316.63	1045.14	3065.01	144.83	0.	5571.61

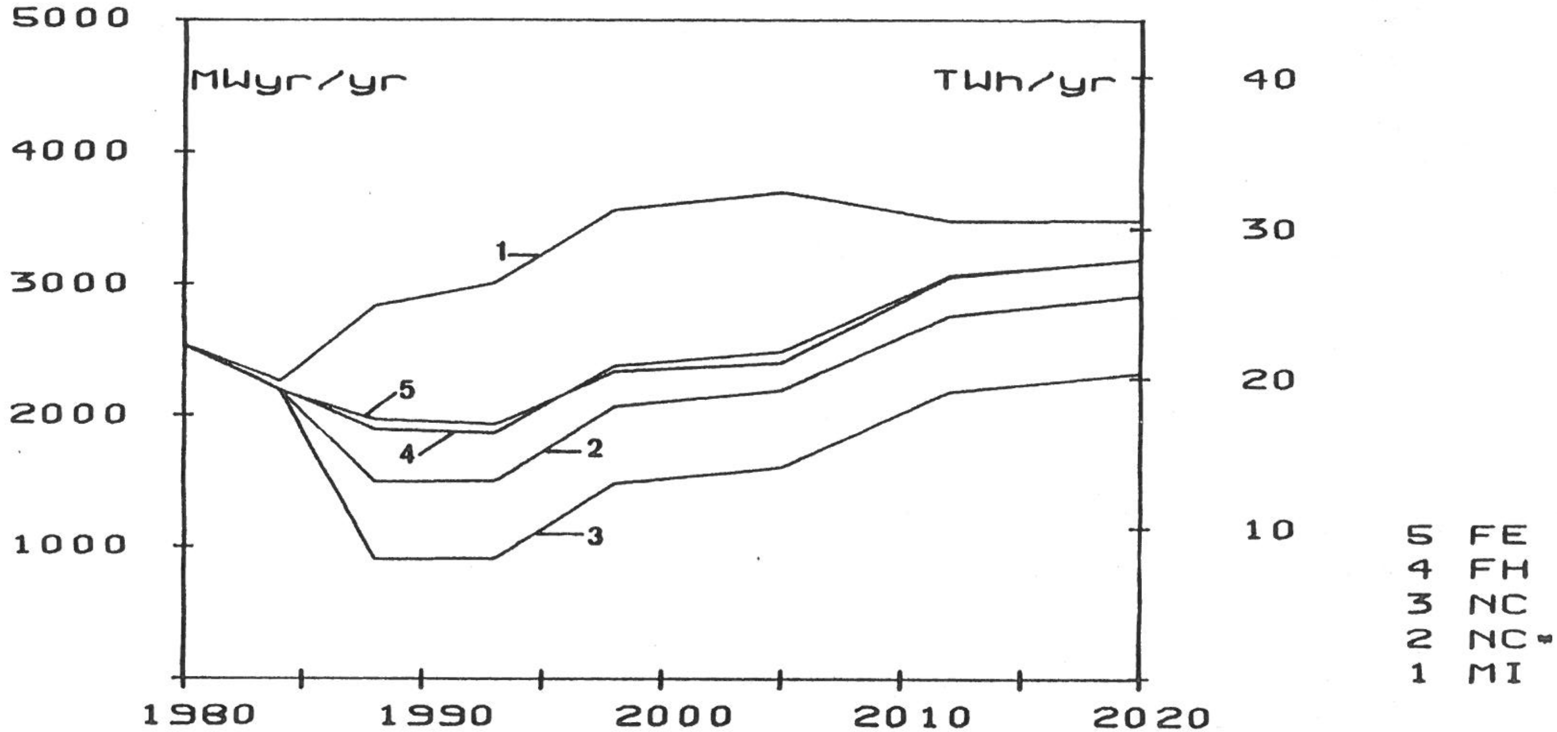
Table 25: Total Annual Costs, MI Scenario, in Millions of Skr(80).

	Capital	O&M	Fuel	Retro&Sa	Methanol	Total
1980	1399.42	289.62	2293.29	0.	0.	3982.33
1984	1067.78	384.31	2052.80	185.17	0.	3690.06
1988	2050.68	633.02	2017.49	174.87	-1022.87	3853.19
1993	1171.48	726.47	2215.72	168.41	-1212.21	3069.86
1998	1183.26	860.43	2561.60	152.92	-1433.80	3324.42
2005	1565.15	974.95	2981.79	145.11	-1754.45	3912.54
2012	2235.65	1151.47	3370.08	148.47	-2186.89	4718.77
2020	1350.96	1203.30	4280.28	144.83	-2780.12	4199.26

8.2 Energy Import Requirements

The picture of energy import requirements from abroad is distorted by the partial omission of the liquid fuel market, i.e the demand for liquid fuels in the transportation sector. Nevertheless, the energy import requirements in the different scenarios reveal some interesting insights. Figure 15 contains the aggregate fossil fuel imports for each scenario in physical terms. By the end of the planning horizon oil imports are negligible in all scenarios (less than 3 % but not accounting for liquid fuel consumption in the transportation sector and feedstocks). Energy imports consist of two types of coal--hard coal and high sulphur coal. According to Figure 15 the energy import requirements of the FE and FH scenarios develop almost identically, while the NC scenario involves considerably less imports than the previous

Figure 15: ANNUAL IMPORTS



scenarios. However, if one accounts for those energy import quantities which become redundant (by the substitution of methanol for liquid fuel products) the energy import volume of NC scenario is in the neighborhood of the other scenarios again. In general one may conclude that the objective of a most diversified energy import pattern is least satisfactorily met in the NC case. In the NC scenario oil imports for heating purposes and electricity generation are decreased to 0.6 TWh/yr by the year 2020 or less than 3 % of total imports for these demand sectors. The remaining 97 % or 19.8 TWh/yr are hard coal imports. The liquid fuel needs of the transportation sector still have to be imported fully. In contrast to the NC scenario the FE and FH scenarios are characterized by a more diversified import pattern. Oil use in the demand sectors considered in this study amount to less than 1.5 % of total imports, while coal is split into hard coal (67 %) and high sulphur coal(32 %). Further, the liquid fuel imports for the consumption in the transportation sector are reduced by at least 20 % in the case that methanol is used as an admixture. The remaining methanol would be admixed to the gasoline consumed outside the Stockholm County area, making Stockholm County almost a net exporter of liquid fuels.

9. Conclusions

The long-term energy supply options for Stockholm County analyzed in this report have one remarkable feature in common--by the end of the planning horizon, i.e. the year 2020, district heat production and electricity generation is almost identical in all scenarios. This is certainly not a totally unexpected finding considering the constraints, i.e. the institutionally enforced restrictions on the use of nuclear power and the poor energy resource situation of Sweden and Stockholm County in particular. In addition the desirable objective of shifting away from the serious dependence on oil imports determines a priori the principal feasible solution space which meets the objectives within the given constraints. Thus, since the long-term energy supply situation for Stockholm County is quite similar in all scenarios, the focus of attention rests to a large extent on the differences in the transitions from the present towards the future energy supply system. In other words, the eventual structure of Stockholm County's energy supply system is robust towards considerably diverse trajectories leading to this final structure. Therefore it appears reasonable to base the decision of how to arrive at this robust energy supply system on the cost-effectiveness of the feasible intermediate or transitory energy supply systems. Criteria other than pure cost considerations, e.g. the degree of energy import dependence, etc. should supplement this cost-optimal approach.

The analysis of future ways to supply the long-term energy demand of Stockholm County was conducted having in mind primarily the criteria mentioned above. Among the various proposals for utilization of the Forsmark 3 nuclear power station, the criterion of cost-effectiveness rejected the district heat alternative. Instead, the energy complex proved to be competitive even under very conservative assumptions regarding sales revenues from methanol. The objective of shifting away from oil to other forms of energy imports, thereby arriving at a more diversified energy import pattern, is achieved in all scenarios analyzed. However, again the most favorable energy import diversification is given in cases where the energy complex participates in the cost-optimal solution. In summary, this analysis has shown that under the criteria of cost-effectiveness and the long term robustness of the supply system with respect to surprises, the construction of the energy complex at Nynäshamn is strongly favored.

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APPENDIX

DESCRIPTION OF INPUT DATA TO MESSAGE II

DESCRIPTION OF INPUT DATA TO MESSAGE II

1. The Model

The energy supply systems model MESSAGE II (Messner,Strubegger (1982)) is a dynamic linear programming model with a mixed integer option for certain variables. The main objective of this model is to minimize or maximize the value of a function related to energy supply systems. This functional value may, as in the application described here, represent the total cost of energy supply, but might as well reflect other objectives, for instance minimization of energy import dependency or maximization of the overall system efficiency. Besides direct energy related goals the model also allowes to take into account objectives related to consumption of non-energy materials or aiming at a reduction of pollution caused by the energy supply system as a whole. The energy supply system is modeled by various constraints and interrelationships defining the feasibility region for the optimization.

As set up for this study, the model represents the energy supply system envisaged to supply the useful energy demands as forecasted for the Stockholm County over the next 40 years. The objective chosen was to minimize the total cost of energy supply and use for the time span under consideration. The most important constraints imposed on the system reflect limits on the amounts of different fuels used, on the availability of domestic resources, and on the maximum rate of introduction of new technologies. Figure 1 gives an overview of the structure of the energy supply system considered to meet all energy demands excluding the demand for liquid fuels used for other purposes than heating. The energy flows from primary energy to the final energy demand sectors represented in the model can be viewed as links between nodes of a two-dimensional grid. In the following these nodes are referred to by an energy form name and a number defining a so called energy form level (e.g.: secondary or final energy). This representation is specially useful for the tables describing the technologies included in the energy chain, where the energy forms being inputs and outputs of that technology are labeled in this sense. See Subsection 5.2 for all energy forms defined for the different levels. Each of the boxes in Figure 1 represents a technology characterized by various kinds of costs and technological parameters.

The next subsections will explain the general input data, outlining the scenario formulation, followed by the demand data used and by the set of data describing availability and costs of domestic and imported fuels. The various technologies included in the energy chain will be given in tabular form thereafter.

2. General Input Data Set

The total time span of 40 years is divided into eight time steps with the initial years being 1980, 1984, 1988, 1993, 2005, 2012 and 2020. All time varying parameters entering the model are expressed as step functions with constant values for each of the time peridos defined. An additional step function representing the annual load curves for electricity and heat is superimposed on the function. The latter divides the load curve into five load regions representing 2.5, 2.5, 20., 50., and 25. percent of a year respectively. The distribution of the energy demands to these load regions is shown in the next subsection.

One other important figure is the discount rate used to relate future costs to the base year. As we are dealing with a rather long time horizon of 40 years the discount rate was set equal to the interest rate. With the expectation of a reduced economic growth for at least some time to come, an interest rate of 4% per year was applied for the total time period under consideration.

3. Energy Demand Data

The energy demand data represent the expected requirements for useful energy necessary for space- and water heating, cooking and specific electricity needs in the Stockholm County. The space- and water heat demands are subdivided into separate time series for old and new single (SFH) and multy family (MFH) houses and for work places (WPL). The energy demand sector labeled specific electricity (SPEC.EL) comprises the demands for cooking, uses of electricity in households and at workplaces other than for heating, and the electricity demands in the transportation sector. Table 2 gives an overview of the demand figures used in this study.

Table 1: Energy Demands [MWyr/yr].

Demands	time periods							
from to	1980 1983	1984 1987	1988 1992	1993 1997	1998 2004	2005 2011	2012 2019	2020 2029
old-SFH	394.	388.	381.	370.	359.	341.	319.	290.
new-SFH	16.	27.	37.	49.	56.	71.	85.	105.
old-MFH	923.	908.	892.	869.	843.	801.	749.	678.
new-MFH	38.	61.	83.	107.	126.	154.	190.	235.
WPL	599.	596.	599.	609.	627.	661.	705.	766.
SPEC.EL	1084.	1151.	1213.	1273.	1314.	1346.	1357.	1356.

The total annual energy demands as given in Table 1 are distributed to five load regions (lr) of the lengths specified above. Table 2 shows the factors relating the power levels for each load region to the annual average load. These demand distributions were kept constant throughout the total time span under consideration.

Table 2: Power levels relative to average load.

demand sector	1. lr	2. lr	3. lr	4. lr	5. lr
heating	2.112	1.948	1.603	0.990	0.331
electricity	1.452	1.508	1.275	0.990	0.705

The heat demand in old houses is assumed to be reduceable through retrofitting. The anticipated costs of reducing the total demand by a certain percentage are expressed as annualized capital costs discounted over 50 years. The demand reduction possibilities are modeled as a step function allowing for three reduction levels. Table 3 shows the costs (cost) for reducing one kWyr of a demand by a certain percentage (red).

Table 3: Demand Reductions and Costs for Retrofitting.

demand	1.red [%]	cost [SKr]	2.red [%]	cost [SKr]	3.red [%]	cost [SKr]
old-SFH	10.00	133.00	20.00	266.00	25.00	805.00
old-MFH	10.00	42.00	20.00	126.00	30.00	266.00

4. Domestic Energy, Imports and Exports

4.1 Availability of Domestic Energy Sources

The domestic energy resources represent only renewable energy sources such as wood, waste, lakes whose thermal energy can be utilized by heatpumps and solar heating systems. Additionally one can view some of the electricity produced in Swedish hydro- and eventually also wind power plants as indigenous energy source. Another energy resource would be added through the utlization of natural uranium available in Sweden, however this resource was not considered to become available during the time span under consideration.

The amounts of energy to be produced from the indigenous energy sources and the costs related to the conversion to secondary or final energy can be seen from the tables describing the corresponding technologies. Constraints were imposed only on the annual availabilty of municipal waste and wood pellets used for district heat production and on the share of electricity produced in Swedish hydropower or wind power plants which are available to the Stockholm County. These limits as well as the potentials for heat pumps in sea- and sewage water can be seen in Table 5.

Table 5: Annual availabilty of renewable energy sources

energy source	wood pell.	waste	hydro power	wind power	sewage water	sea water
limit [MWyr/yr]	60.	85.6	1027.5	342.5	260.	700.

4.2 Energy Imports

In general the energy imports remaind unconstrained as the use of the various energy forms is constrained by limits on the technologies processing them in one way or another. Additionally the use of imported energy is controlled by cost increases. Table 4 shows the costs for energy imports for the base year (1980), the cost increases assigned to the different energy imports and the resulting costs in the last period under consideration (2020-2030).

Table 6: Energy Import Prices [Skr'80 / kWyr].

Energy form	base year (1980)	cost increases [% per year]		last year (2020)
		1980-2000	2000-2020	
natural gas	788.2	3.5	3.0	2824.4
light oil	964.0	3.5	3.0	3463.4
fuel oil	700.0	3.0	2.0	1880.6
hard coal	392.0	3.0	3.0	1287.7
h-sulf. coal	322.0	2.0	2.0	1050.4

4.3 Energy Exports

As the transportation sector was not modeled explicitly the methanol produced in the Nynäshamn energy complex is considered as a market product substituting gasoline. The selling price of methanol was assumed to be 80 Öre per liter in the base year. The price increases are assumed to be the same as shown for light oil and natural gas in Table 6.

5. Description of Technologies

This subsection summarizes the economic, technological and scenario related parameters describing the technologies included in the modeled energy supply system. For each technology this information is included in a number of tables whose entries are described in the following.

5.1 Economic and Technological Parameters

This table includes all costs involved in the construction and operation of the system as well as the most important technological parameters. All cost figures are related to the total energy output of the system and are expressed in constant Skr'80.

Table Entries:

invcost   Specific Investment Cost per kW Installed.
This item includes costs of:
-- components and material,
-- direct and indirect labour,
-- architect/engineers fee,

-- owners cost (site preparation, infrastructure, licensing, preliminary studies, etc.), and
-- interest paid during construction (5% per year over half the construction time).

var O+M Annual Variable Operation and Maintainance Cost per kWyr of energy produced.
This figure comprises:
-- labour cost,
-- cost of repair,
-- replacement of parts,
-- non-energy raw material consumption, and
-- waste disposal.

fix O+M Annual Fixed Operation and Maintainance Cost per kW installed capacity.
Includes the same items as stated above.

pllife Technical Life Time of Technologies.

plfctr Capacity Factor.
For end use technologies and technologies handling fuels without load regions this factor represents the time the system is actually working. For other technologies it represents the maximum availability factor.

avg cst Average Cost of Producing one Unit of Output.
This figure represents only the costs related to the technology itself. In order to determine the total cost per unit of energy output the fuel costs have to be added to the value stated here. The given value was calculated using an interest rate of 4% per year (equal to the discount rate used) and the maximum capacity factor. As the capacity factor can be lowered by the model these costs have to be interpreted as the minimum cost per unit of total output.

5.2 Energy Flows and Efficiencies

This list shows the amounts of energy inputs and outputs relative to one unit of main input (1. energy form in table) followed by a number indicating the energy form level on which this energy form is defined. Table 7 gives a summary of all energy forms defined in the model on each of the five energy form levels defined. The levels are numbered in decreasing order beginning with number 6 at the level of energy demand.

Table 7: LISTS OF ENERGY FORM NAMES

Energy Forms on Level 6:

heat-old-SFH	Total heat demand in single family houses buildt before 1975.
heat-new-SFH	Total heat demand in single family houses buildt after 1975.
heat-old-MFH	Total heat demand in multy family houses buildt before 1975.
heat-new-MFH	Total heat demand in multy family houses buildt after 1975.
heat-workplace	Total heat demand at workplaces.
electricity	Total electricity demand for specific uses in the household sector, at workplaces and for the transportation sector but excluding electricity use for heating.

Energy Forms on Level 5:

Remained unused.

Energy Forms on Level 4:

electricity	Final electricity deliverd by the grid.
d-heat-high	Final energy deliverd by district heat distribution to areas with a density of more than 60 w/sqm.
d-heat-medium	Final energy deliverd by district heat distribution to areas with a density between 15 and 60 w/sqm.
d-heat-low	Final energy deliverd by district heat distribution to areas with a density of less than 30 w/sqm.
gas	Final energy deliverd by the gas distribution system.
light-oil	Final energy (at the entrance of the house) as deliverd by a tank truck.

Energy Forms on Level 3:

electricity	Electricity at the border of the city.
heat-90deg	Heat coming from the small heating plants and district heat transmission links.
heat-120deg	Heat coming from the co-generation and heat plants at the border of the city and from the long heat pipelines.
methanol	Output of the energy complex (not used inside the modeled energy system).

Energy Forms on Level 2:

steam-FM	Steam produced in Forsmark nuclear reactor when the plant is used to produce heat and electricity.
heat-165deg-FM	Heat output of Forsmark (max. 2000 MW thermal energy output).
steam-coal	Intermediary product of big coal co-generation plants for the centralized coal scenario representing the steam which can be converted either to electricity or district heat.
heat-120d-coal	District heat produced in big coal co-generation plants for the centralized coal scenario.
elec-external	Electricity input to the Swedish grid.
gas	Gas coming from the gas pipeline, the methanation plant and the towngas plant.
lowbtugas	Low BTU gas from the energy complex.

Energy Forms on Level 1:

natgas	Natural gas bought from abroad.
light-oil	Light refinery products, imported from other parts of Sweden or abroad.
fuel-oil	Heavy refinery products, to be used for heat and electricity generation; imported from Sweden or abroad.
coal	Coal for heat and electricity generation.
hs-coal	Coal with high sulfur content for the energy complex.
wood-pellets	Pelletized wood.
uranium	Natural uranium imports.

Entries to the Technology Table:

input	Energy Inputs.
output	Energy Outputs.
initrequ	Initial Core Requirements for Nuclear Power Plants.
finalret	Last Core of Nuclear Power Plants.

If the load pattern of a technology is fixed exogenously an additional table shows the fraction of the energy in- or output per load region and the according power levels relative to the annual load average. Usually this fixing of the load pattern of an energy conversion technology is only necessary when because of technical reasons a certain technology is bound to produce base load or is, on the other hand, only allowed or able to work for a certain fraction of time as it is e. g. the case with solar power plants.

5.3 Scenario Parameters

The parameters shown in the following table reflect the dynamic constraints imposed on the capacity expansion. These bounds constrain the annual new capacity build-up Y(t) as a function of the new buildt capacity during the previous year Y(t-1)

$$Y(t) <= gam * Y(t-1) + g ,$$

gam   Annual Growth Factor,
g   Maximum Initial Capacity for new Technologies [MW].

To calculate the maximum annual biuld-up during a period (T) of n years this formula results in

$$Y(T) <= gam^{n} * Y(T-1) + g * (1 + gam +..+ gam^{n-1}).$$

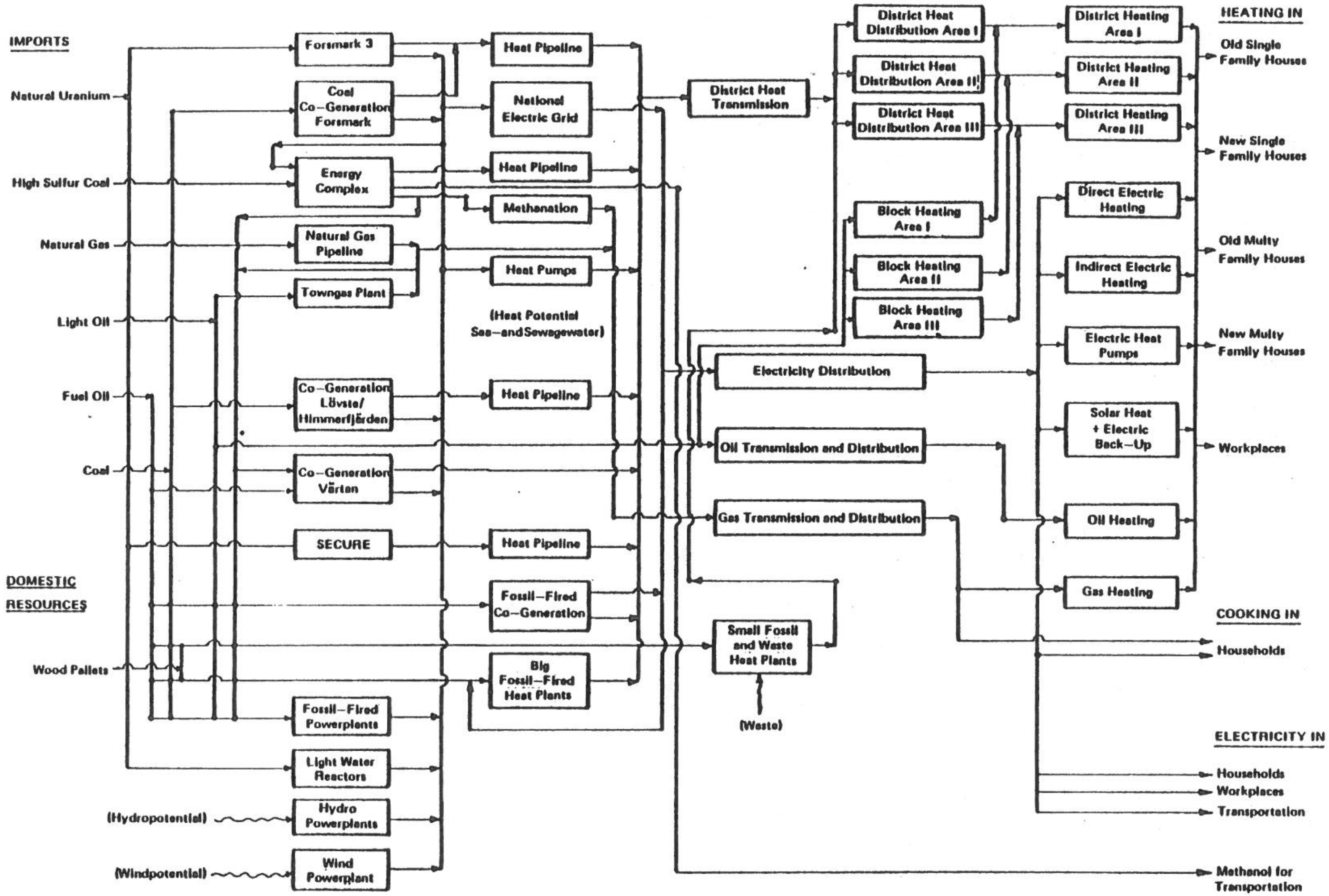

Figure 1: A Scematic Representation of the Energy System of Stockholm county

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TECHNOLOGY TABLES

Page

57	Oil Blockcent I
58	Oil Blockcent II
59	Oil Blockcent III
60	Heating Oil Distribution
61	Gas Distribution
62	Electricity Distribution
63	Dht I 90W/sqm
64	Dht II 60W/sqm
65	Dht III 30W/sqm
66	Oil-Dht 3*15MW
67	Coal-Dht 3*15MW
68	Wood-Dht 3*15MW
69	Gas-Dht 3*15MW
70	Waste-Dht 2*10MW
71	Dht Transmission
72	Wood-Dht 3*80
73	Gas-Dht 3*80
74	Elec-Dht 3*80
75	Oil-Dht 3*160
76	Coal-Dht 3*160
77	SECURE
78	Diesel Cogen 10/10
79	Oil Cogen 50/100
80	Coal Cogen 50/100
81	Gasturb 260/260
82	Oil Cogen VAERTAN
83	Coal Cogen 250/400
84	Towngas
85	Gaspipeline
86	Elec national
87	District Heat Transmission 120km
88	District Heat Coalscenario
89	FM Cogen 500/1000
90	Heatpump sewagewater
91	Heatpump seawater
92	LWR FORSMARK
93	FORSMARK ht
94	FM off peak
95	Heat Link FM
96	Energy Complex
99	Methanation
100	Coal Himmerfjaerden
101	Coal Loevsta
102	Co-Generation Turbine
103	Growian
104	LWR-conventional
105	Oil Powerplant
106	Diesel Powerplant
107	Gas-Steam Powerplant
108	Jetgas Powerplant
109	Hardcoal Powerplant
110	Run-of-river

1 Specific Electricity

Short system description:

Specific use of electricity in household, services, industry and transportation.
No costs are assumed due to variety of uses and lack of substitution possibilities.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
0.	0.	0.	0.	1.00	0.

energyforms	lev	input	output
Electricity	4	1.00	
Electricity	6		1.00

2 Gas for Cooking

Short system description:

Limited to present use (31 MWyr gas/yr)

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
0.	0.	0.	0.	1.00	0.

energyforms	lev	input	output
Gas	4	1.00	
Electricity	6		0.60

3 Oil SFH new

Short system description:

Light destillate oil heating system for new single family houses with heat distribution, 80/60 deg water circulation system.

If not stated differently the respective capacities of the heating systems are:

old SFH :	12.	kW
new SFH :	9.	kW
old MFH :	106.	kW
new MFH :	74.	kW
workplace:	98.	kW

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
5831.00	0.	67.20	27.	0.24	1767.84

energyforms	lev	input	output
Light-Oil	4	1.00	
Heat-New-SFH	6		0.65

Dynamic bounds on capacity build up

	gam	g
upper	1.20	1.00

4 Gas SFH new

Short system description:

Gas heating system for new single family houses with heat distribution, 80/60 deg water circulation system.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
4830.00	0.	56.00	29.	0.24	1418.29

energyforms	lev	input	output
Gas	4	1.00	
Heat-New-SFH	6		0.75

Dynamic bounds on capacity build up

	gam	g
upper	1.03	1.00

5 El indirect SFH new

Short system description:

Electric heating system for new single family houses with heat distribution, 80/60 deg water circulation system.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
5222.00	0.	49.00	28.	0.22	1647.22

energyforms	lev	input	output
Electricity	4	1.00	
Heat-New-SFH	6		0.95

Dynamic bounds on capacity build up

	gam	g
upper	1.03	1.00

6 El direct SFH new

Short system description:

Direct electric heating system for new single family homes. Each room has a separate thermal-ventilation unit.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
2443.00	0.	28.00	18.	0.22	1004.46

energyforms	lev	input	output
Electricity	4	1.00	
Heat-New-SFH	6		0.98

Dynamic bounds on capacity build up

	gam	g
upper	1.03	1.00

7 Dht SFH new I

Short system description:

District heating system for new single family houses in high energy density aareas (area I). Receives its heat from a water/water heat exchanger connected to the central grid, water circulates at 80/60 degrees.

The potential of district heat in new single houses in area I is set to 1% of the total heat in new single family houses.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
4613.00	0.	49.00	29.	0.22	1457.33

energyforms	lev	input	output
D-Heat-High	4.	1.00	
Heat-New-SFH	6		0.95

Dynamic bounds on capacity build up

	gam	g
upper	1.03	1.00

8 Dht SFH new II

Short system description:

District heating system for new single family in medium energy density areas (area II).

The potential of district heat in new single family houses in area II is 8% of the total heat demand in new single family houses.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
4613.00	0.	49.00	29.	0.22	1457.33

energyforms	lev	input	output
D-Heat-Medium	4	1.00	
Heat-New-SFH	6		0.95

Dynamic bounds on capacity build up

	gam	g
upper	1.03	1.00

9 Dht SFH new III

Short system description:

District heating system for new single family houses in low energy density areas (area III).

The potential of district heat in new single family houses in area III is 25% of the total heat demand in new single family houses.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
4613.00	0.	49.00	29.	0.22	1457.33

energyforms	lev	input	output
D-Heat-Low	4	1.00	
Heat-New-SFH	6		0.95

Dynamic bounds on capacity build up

	gam	g
upper	1.03	1.00

10 Heat Pump SFH new

Short system description:

Monovalent air heat pump for new single family houses. Data from JDHB Vol II adapted to cost figures compatible with data from VBB.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
9170.00	0.	266.00	20.	0.18	5226.36

energyforms	lev	input	output
Electricity	4	1.00	
Heat-New-SFH	6		2.35

Dynamic bounds on capacity build up

	gam	g
upper	1.03	0.30

11 Solar SFH

Short system description:

Solar heating system with electric back-up and a heat storage capacity of 24 m**3 for new single family houses. Low temperature system with 50/35 degrees centigrade water distribution.
The two-glass solar collectors (28 sqm) produce 9.8 MWh/yr. The total system (including energy from the back up system) produces
12 MWh/yr for space heat and
3 MWh/yr for water heat.
60% of space heat and 10% of water heat supplied by electric back-up system of 9. kW.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
16723.00	0.	441.00	23.	0.25	6266.44

energyforms	lev	input	output
Electricity	4	1.00	
Heat-New-SFH	6		1.58

Dynamic bounds on capacity build up

	gam	g
upper	1.03	1.00

12 Oil SFH old

Short system description:

Light destillate oil heating system for old single family houses with heat distribution, 80/60 deg water circulation system.

For all old houses the costs represent only the changing of boiler, burner and tank.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
1330.00	0.	39.90	15.	0.24	664.67

energyforms	lev	input	output
Light-Oil	4	1.00	
Heat-Old-SFH	6		0.68

Dynamic bounds on capacity build up

	gam	g
upper	1.03	0.

13 Gas SFH old

Short system description:

Gas heating system for old single family houses with heat distribution, 80/60 deg water circulation system.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
1169.00	0.	28.00	15.	0.24	554.76

energyforms	lev	input	output
Gas	4	1.00	
Heat-Old-SFH	6		0.75

Dynamic bounds on capacity build up

	gam	g
upper	1.03	0.

14 El indirect SFH old

Short system description:

Electric heating system for old single family homes with old water radiator system.
80/60 deg water circulation.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
1043.00	0.	23.10	15.	0.24	487.12

energyforms	lev	input	output
Electricity	4	1.00	
Heat-Old-SFH	6		0.95

Dynamic bounds on capacity build up

	gam	g
upper	1.03	0.

15 El direct SFH old

Short system description:

Electric heating system for old single family houses.
Each room has a separate thermal ventilation unit.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
2310.00	0.	26.60	18.	0.24	871.14

energyforms	lev	input	output
Electricity	4	1.00	
Heat-Old-SFH	6		0.98

Dynamic bounds on capacity build up

	gam	g
upper	1.03	0.

16 Dht SFH old I

Short system description:

District heating system for old single family houses receiving its heat from a water/water heat exchanger connected to the central grid.
For houses in high energy density areas (area I).
Water circulates at, 80/60 degrees.

The potential of district heat in old single family houses in area I is 1% of the total heat demand in old single family houses.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
917.00	0.	23.10	20.	0.24	377.39

energyforms	lev	input	output
D-Heat-High	4	1.00	
Heat-Old-SFH	6		0.95

Dynamic bounds on capacity build up

	gam	g
upper	1.03	3.00

17 Dht SFH old II

Short system description:

District heating system for old single family houses receiving its heat from a water/water heat exchanger connected to the central grid.
In areas with medium energy density (area II).

The potential of district heat in old single family houses in area II is 12% of the total heat demand in old single family houses.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
917.00	0.	23.10	20.	0.24	377.39

energyforms	lev	input	output
D-Heat-Medium	4	1.00	
Heat-Old-SFH	6		0.95

Dynamic bounds on capacity build up

	gam	g
upper	1.03	0.

18 Dht SFH old III

Short system description:

District heating system for old single family houses receiving its heat from a water/water heat exchanger connected to the central grid.
In areas with low energy density (area III).

The potential of district heat in old single family houses in area III is 15% of the total heat demand in old single family houses.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
917.00	0.	23.10	20.	0.24	377.39

energyforms	lev	input	output
D-Heat-Low	4	1.00	
Heat-Old-SFH	6		0.95

Dynamic bounds on capacity build up

	gam	g
upper	1.03	0.

19 Oil MFH new

Short system description:

Light destilate oil heating system for new multy family houses.
80/60 degr water circulation system.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
4081.00	0.	49.00	29.	0.18	1607.16

energyforms	lev	input	output
Light-Oil	4	1.00	
Heat-New-MFH	6		0.73

Dynamic bounds on capacity build up

	gam	g
upper	1.03	1.00

20 Gas MFH new

Short system description:

Gas heating system for new multy family houses,
80/60 degr water circulation system

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
3745.00	0.	42.00	29.	0.18	1458.36

energyforms	lev	input	output
Gas	4	1.00	
Heat-New-MFH	6		0.80

Dynamic bounds on capacity build up

	gam	g
upper	1.03	1.00

21 El indirect MFH new

Short system description:

Electricity heating system for new multy family houses, 80/60 degr water circulation system.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
3948.00	0.	42.00	28.	0.18	1549.62

energyforms	lev	input	output
Electricity	4	1.00	
Heat-New-MFH	6		0.95

Dynamic bounds on capacity build up

	gam	g
upper	1.03	1.00

22 El direct MFH new

Short system description:

Direct electric heating system for new multy family homes. Each room has a separate thermal-ventilation unit.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
1883.00	0.	21.00	18.	0.18	943.03

energyforms	lev	input	output
Electricity	4	1.00	
Heat-New-MFH	6		0.98

Dynamic bounds on capacity build up

	gam	g
upper	1.03	1.00

23 Dht MFH new I

Short system description:

District heating system for new multy family houses receiving its heat from a water/water heat exchanger connected to the central grid.
In high energy densitiy areas (area I).
Water circulates at 80/60 degrees.

The potential of district heat in new multy family houses in area I is 30% of the total heat demand in new multy family houses.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
2527.00	0.	30.80	28.	0.18	1013.63

energyforms	lev	input	output
D-Heat-High	4	1.00	
Heat-New-MFH	6		0.95

Dynamic bounds on capacity build up

	gam	g
upper	1.10	3.00

24 Dht MFH new II

Short system description:

District heating system for new multy family houses receiving its heat from a water/water heat exchanger connected to the central grid.
In areas with medium energy denstiy (area II).

The potential of district heat in new multy family houses in area II is 32% of the total heat demand in new multy family houses.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
2527.00	0.	30.80	28.	0.18	1013.63

energyforms	lev	input	output
D-Heat-Medium	4	1.00	
Heat-New-MFH	6		0.95

Dynamic bounds on capacity build up

	gam	g
upper	1.10	3.00

25 Dht MFH new III

Short system description:

District heating system for new multy family houses receiving its heat from a water/water heat exchanger connected to the central grid.
In low energy denstiy areas (area III).
The potential of district heat in new multy family houses in area III is 34% of the total heat demand in new multy family houses.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
2527.00	0.	30.80	28.	0.18	1013.63

energyforms	lev	input	output
D-Heat-Low	4	1.00	
Heat-New-MFH	6		0.95

Dynamic bounds on capacity build up

	gam	g
upper	1.10	3.00

26 Heat Pump MFH new

Short system description:

Monovalent air heat pump for new multy family houses. Data from JDHB Vol II adapted to cost figures compatible with data from VBB.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
6328.00	0.	170.80	20.	0.21	3030.60

energyforms	lev	input	output
Electricity	4	1.00	
Heat-New-MFH	6		2.07

Dynamic bounds on capacity build up

	gam	g
upper	1.03	0.30

27 Solar MFH

Short system description:

Solar heating system with electric back up for new multy family houses.
170 sqm one glass collectors.
The solarar system supplies 60 MWh/yr heat (28% of the total heat demand).
Costs includes water storage of 145 m**3 and radiator system for 50/35 degrees.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
11781.00	0.	158.20	24.	0.30	3102.93

energyforms	lev	input	output
Electricity	4	1.00	
Heat-New-MFH	6		1.32

Dynamic bounds on capacity build up

	gam	g
upper	1.03	1.00

28 Oil MFH old

Short system description:

Light destillate oil heating system for old multy family houses.
80/60 degr water circulations system.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
707.00	0.	23.10	15.	0.19	456.25

energyforms	lev	input	output
Light-Oil	4	1.00	
Heat-Old-MFH	6		0.75

Dynamic bounds on capacity build up

	gam	g
upper	1.03	0.

29 Gas MFH old

Short system description:

Gas heating system for old multy family houses.
80/60 degr water circulations system.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
686.00	0.	18.20	15.	0.19	420.52

energyforms	lev	input	output
Gas	4	1.00	
Heat-Old-MFH	6		0.80

Dynamic bounds on capacity build up

	gam	g
upper	1.03	0.

30 El indirect MFH old

Short system description:

Electric heating system for old multy family homes. Old water radiator distribution system is used.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
791.00	0.	16.80	15.	0.19	462.86

energyforms	lev	input	output
Electricity	4	1.00	
Heat-Old-MFH	6		0.95

Dynamic bounds on capacity build up

	gam	g
upper	1.03	0.

31 El direct MFH old

Short system description:

Direct electric heating system for new multy family homes. Each room has a separate thermal-ventilation unit.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
1750.00	0.	20.30	18.	0.18	880.77

energyforms	lev	input	output
Electricity	4	1.00	
Heat-Old-MFH	6		0.98

Dynamic bounds on capacity build up

	gam	g
upper	1.03	0.

32 Dht MFH old I

Short system description:

District heating system for old multy family houses receiving its heat from a water/water heat exchanger connected to the central grid.
In areas with high energy density (area I).
Water circulates at 80/60 degrees.

The potential of district heat in old multy family houses in area I is 33% of the total heat demand in old multy family houses.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
651.00	0.	14.70	20.	0.19	329.48

energyforms	lev	input	output
D-Heat-High	4	1.00	
Heat-Old-MFH	6		0.95

Dynamic bounds on capacity build up

	gam	g
upper	1.03	0.

33 Dht MFH old II

Short system description:

District heating system for old multy family houses receiving its heat from a water/water heat exchanger connected to the central grid.
In areas with medium energy density (area II).

The potential of district heat in old multy family houses in area II is 41% of the total heat demand in old multy family houses.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
651.00	0.	14.70	20.	0.19	329.48

energyforms	lev	input	output
D-Heat-Medium	4	1.00	
Heat-Old-MFH	6		0.95

Dynamic bounds on capacity build up

	gam	g
upper	1.03	0.

34 Dht MFH old III

Short system description:

District heating system for old multy family houses receiving its heat from a water/water heat exchanger connected to the central grid.
In areas with low energy density (area III).

The potential of district heat in old multy family houses in area III is 21% of the total heat demand in old multy family houses.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
651.00	0.	14.70	20.	0.19	329.48

energyforms	lev	input	output
D-Heat-Low	4	1.00	
Heat-Old-MFH	6		0.95

Dynamic bounds on capacity build up

	gam	g
upper	1.03	0.

35 Oil workplace

Short system description:

Thermal energy production for work places.

Light destillate oil heating system for work places, 80/60 degr water circulations system.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
3920.00	0.	49.70	28.	0.20	1424.75

energyforms	lev	input	output
Light-Oil	4	1.00	
Heat-Workplace	6		0.74

Dynamic bounds on capacity build up

	gam	g
upper	1.03	0.

36 Gas workplace

Short system description:

Gas heating system for work places.
80/60 deg water circulations system.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
3661.00	0.	44.10	28.	0.20	1319.04

energyforms	lev	input	output
Gas	4	1.00	
Heat-Workplace	6		0.80

Dynamic bounds on capacity build up

	gam	g
upper	1.03	1.00

37 El indirect workplace

Short system description:

Electricity heating system for work places.
80/60 degr water circulations system.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
3864.00	0.	42.70	28.	0.20	1372.95

energyforms	lev	input	output
Electricity	4	1.00	
Heat-Workplace	6		0.95

Dynamic bounds on capacity build up

	gam	g
upper	1.03	1.00

38 El direct workplace

Short system description:

Direct electric heating system for work places.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
1925.00	0.	21.00	18.	0.20	865.31

energyforms	lev	input	output
Electricity	4	1.00	
Heat-Workplace	6		0.98

Dynamic bounds on capacity build up

	gam	g
upper	1.03	1.00

39 Dht workplace I

Short system description:

District heating system for work places
receiving its heat from a water/water heat exchanger
connected to the central grid.
In high energy density areas (area I).
Water circulates at 80/60 degrees.

The potential of district heat in workplaces
in area I is 30% of the total heat demand
in workplaces.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
2625.00	0.	32.20	27.	0.20	964.76

energyforms	lev	input	output
D-Heat-High	4	1.00	
Heat-Workplace	6		0.95

Dynamic bounds on capacity build up

	gam	g
upper	1.03	0.

40 Dht workplace II

Short system description:

District heating system for work places receiving its heat from a water/water heat exchanger connected to the central grid.
In medium energy density areas (area II).

The potential of district heat in workplaces in area II is 30% of the total heat demand in workplaces.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
2625.00	0.	32.20	27.	0.20	964.76

energyforms	lev	input	output
D-Heat-Medium	4	1.00	
Heat-Workplace	6		0.95

Dynamic bounds on capacity build up

	gam	g
upper	1.03	0.

41 Dht workplace III

Short system description:

District heating system for work places receiving its heat from a water/water heat exchanger connected to the central grid.
In low energy density areas (area III).

The potential of district heat in workplaces in area III is 28% of the total heat demand in workplaces.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
2625.00	0.	32.20	27.	0.20	964.76

energyforms	lev	input	output
D-Heat-Low	4	1.00	
Heat-Workplace	6		0.95

Dynamic bounds on capacity build up

	gam	g
upper	1.03	0.

42 Heat Pump workplace

Short system description:

Monovalent air heat pump for work places.
Data from JDHB Vol II adapted to cost figures compatible with data from VBB.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
5782.00	0.	159.60	20.	0.20	2853.90

energyforms	lev	input	output
Electricity	4	1.00	
Heat-Workplace	6		2.30

Dynamic bounds on capacity build up

	gam	g
upper	1.03	1.00

43 Solar workplace

Short system description:

Solar water heating system for work places.
103 sqm two glass solar collectors and
5.5 m**3 hot water storage tank.
Total system supplies 36 MWh/yr for water heat.
Electric space heating system with water
distribution system 80/60 degr.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
5754.00	0.	114.80	26.	0.30	1582.71

energyforms	lev	input	output
Electricity	4	1.00	
Heat-Workplace	6		1.09

Dynamic bounds on capacity build up

	gam	g
upper	1.03	1.00

44 Oil Blockcentral I

Short system description:

Oil block heating plants
for high energy density areas (area I).

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
406.00	77.00	17.50	20.	1.00	124.37

energyforms	lev	input	output
Light-Oil	1	1.00	
D-Heat-High	4		0.86

output pattern fixed

energy:	0.05	0.05	0.32	0.50	0.08
power:	2.11	1.95	1.60	0.99	0.33

45 Oil Blockcentral II

Short system description:

Oil block heating plant
for medium energy density areas (area II).

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
406.00	77.00	17.50	20.	1.00	124.37

energyforms	lev	input	output
Light-Oil	1	1.00	
D-Heat-Medium	4		0.86

output pattern fixed

energy:	0.05	0.05	0.32	0.50	0.08
power:	2.11	1.95	1.60	0.99	0.33

46 Oil Blockcentral III

Short system description:

Oil block heating plant
for low energy density areas (area III).

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
406.00	77.00	17.50	20.	1.00	124.37

energyforms	lev	input	output
Light-Oil	1	1.00	
D-Heat-Low	4		0.86

output pattern fixed

energy:	0.05	0.05	0.32	0.50	0.08
power:	2.11	1.95	1.60	0.99	0.33

47 Heating Oil Distribution

Short system description:

Source:
Kostenfunktion der Energietraeger... ,
H.-W. Schiffer, Koeln 78
Schriftenreihe des Energiewirtschaftlichen Institutes
Band 23, Energiewirtschaftliches Institut an der
Universitaet Koeln, R. Oldenbourg Verlag

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
0.	74.20	0.	0.	1.00	74.20

energyforms	lev	input	output
Light-Oil	1	1.00	
Light-Oil	4		0.98

48 Gas Distribution

Short system description:

Includes pipes, main station and substations.
Investment costs of 2100 Skr/kW '80 (300 $/kW '75) are in the upper range of the Stoseb figures efficiency in '78: 91%, (eff. from Schiffer used).

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
2100.00	0.	42.00	50.	0.87	161.38

energyforms	lev	input	output
Gas	2	1.00	
Gas	4		0.99

Dynamic bounds on capacity build up

	gam	g
upper	1.06	0.30

49 El Distribution

Short system description:

Includes grid, main station and substations.
Efficiency in 78: 95%.
Growth of electricity consumption was:
6.2%/yr from 50 to 70, 1.6%/yr from 73 to 75
(source: IAEA energy and economic tables)
(used for growth of installed capacities).
Capital costs 900 Skr '80 per kW (source: Stoseb, medium range), fix O+M costs 2%/yr.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
903.00	0.	18.20	30.	0.83	84.84

energyforms	lev	input	output
Electricity	3	1.00	
Electricity	4		0.95

Dynamic bounds on capacity build up

	gam	g
upper	1.06	0.30

50 Dht I 90W/sqm

Short system description:

District heat distribution system for an area with more than 90 W/sqm (area I).
Production pattern fixed to distribution of demands to load regions.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
196.00	0.	3.92	60.	0.87	14.53

energyforms	lev	input	output
Heat-90deg	3	1.00	
D-Heat-High	4		0.88

output pattern fixed

energy:	0.05	0.05	0.32	0.50	0.08
power:	2.11	1.95	1.60	0.99	0.33

Dynamic bounds on capacity build up

	gam	g
upper	1.06	0.50

51 Dht II 60W/sqm

Short system description:

District heat distribution system for an area with 15 to 60 W/sqm (area II).

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
603.40	0.	11.90	60.	0.87	44.54

energyforms	lev	input	output
Heat-90deg	3	1.00	
D-Heat-Medium	4		0.88

output pattern fixed

energy:	0.05	0.05	0.32	0.50	0.08
power:	2.11	1.95	1.60	0.99	0.33

Dynamic bounds on capacity build up

	gam	g
upper	1.06	0.50

52 Dht III 30W/sqm

Short system description:

District heat distribution system for an area with less than 30 W/sqm (area III).

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
1358.00	0.	27.30	60.	0.87	100.84

energyforms	lev	input	output
Heat-90deg	3	1.00	
D-Heat-Low	4		0.88

output pattern fixed

energy:	0.05	0.05	0.32	0.50	0.08
power:	2.11	1.95	1.60	0.99	0.33

Dynamic bounds on capacity build up

	gam	g
upper	1.06	0.50

53 Oil-Dht 3*15MW

Short system description:

Oil Heatingplant, 3 x 15 MW.
Data source: STOSEB '81
Availability due to unsceduled downtime: 98%.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
340.20	66.50	15.40	25.	0.85	110.24

energyforms	lev	input	output
Fuel-Oil	1	1.00	
Heat-90deg	3		0.90

54 Coal-Dht 3*15MW

Short system description:

Coal Heatingplant, 3 x 15 MW.
Data source: STOSEB '81.
Availability due to unsceduled downtime: 92%.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
961.10	87.50	74.90	25.	0.80	258.03

energyforms	lev	input	output
Coal	1	1.00	
Heat-90deg	3		0.85

55 Wood-Dht 3*15MW

Short system description:

Wood Pellet Heatingplant, 3 x 15 MW.
Data source: STOSEB '81.
Availability due to unsceduled downtime: 90%.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
931.00	87.50	74.90	25.	0.78	259.93

energyforms	lev	input	output
Wood-Pellets	1	1.00	
Heat-90deg	3		0.80

56 Gas-Dht 3*15MW

Short system description:

Gas Heatingplant, 3 x 15 MW.
Data source: STOSEB '81.
Availability due to unsceduled downtime: 100%.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
340.20	70.00	15.40	25.	0.87	112.73

energyforms	lev	input	output
Low BTU Gas	2	1.00	
Heat-90deg	3		0.90

57 Waste-Dht 2*10MW

Short system description:

Waste Heatingplant, 2 x 10 MW.
Data source: STOSEB '81.
Availability due to unsceduled downtime: 80%.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
2821.00	201.60	135.10	20.	0.69	698.23

energyforms	lev	input	output
Heat-90deg	3		1.00

58 Dht Transmission

Short system description:

District heat transmission inside city.
Incudes all main pipes.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
301.00	0.	4.48	30.	0.87	25.27

energyforms	lev	input	output
Heat-120deg	3	1.00	
Heat-90deg	3		0.97

Dynamic bounds on capacity build up

	gam	g
upper	1.06	0.50

59 Wood-Dht 3*80

Short system description:

Wood Pellets Heatingplant, 3 x 80 MW.
Data source: STOSEB '81.
Availability due to unsceduled downtime 92%.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
700.00	87.50	44.80	25.	0.80	199.93

energyforms	lev.	input	output
Wood-Pellets	1	1.00	
Heat-120deg	3		0.80

60 Gas-Dht 3*80

Short system description:

Gas Heatingplant, 3 x 80 MW.
Data source: STOSEB '81.
Availability due to unsceduled downtime: 100%.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
285.60	43.82	9.80	25.	0.87	76.10

energyforms	lev	input	output
Low BTU Gas	2	1.00	
Heat-120deg	3		0.90

61 Elec-Dht 3*80

Short system description:

Electric Heatingplant, 3 x 80 MW.
Output in 78: 1.6 MWyr (14 GWh).
Data source: STOSEB '81.
Availability due to unsceduled downtime: 98%.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
254.80	8.75	9.80	20.	0.85	42.34

energyforms	lev	input	output
Electricity	3	1.00	
Heat-120deg	3		1.00

62 Oil-Dht 3*160 ds

Short system description:

Oil Heatingplant, 3 x 160 MW, with desulfurization.
Data source: STOSEB '81.
Availability due to unsceduled downtime: 96%.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
410.20	43.82	9.80	25.	0.83	87.26

energyforms	lev	input	output
Fuel-Oil	1	1.00	
Heat-120deg	3		0.90

63 Coal-Dht 3*160 ds

Short system description:

Coal Heatingplant, 3 x 160 MW, with desulfurization.
Data source: STOSEB '81.
Availability due to unsceduled downtime 92%.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
889.00	87.50	20.02	25.	0.80	184.02

energyforms	lev	input	output
Coal	1	1.00	
Heat-120deg	3		0.88

64 SECURE

Short system description:

Light water reactor SECURE.
Costs include heat pipeline of about 25 km.
Costs for nuclear fuel cycle are not included
(fuel cycle costs are approx 10 $/kWa).

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
2590.00	43.75	58.52	24.	0.95	284.16

energyforms	lev	input	output	initrequ	finalret
Uranium	1	1.00		0.31	0.16
Heat-120deg	3		18.00		

output pattern fixed

energy:	0.03	0.03	0.21	0.53	0.21
power:	1.05	1.05	1.05	1.05	0.84

65 Diesel Cogen 10/1

Short system description:

Diesel Co-generation, 10/10 MW.
Installed capacity: 10 MW electric and 10 MW heat.
Data source: STOSEB '81.
Availability due to unsceduled downtime: 88%.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
1550.50	109.55	50.05	25.	0.76	306.00

energyforms	lev	input	output
Light-Oil	1	1.00	
Electricity	3		0.40
Heat-120deg	3		0.40

66 Oil Cogen 50/100

Short system description:

Oil Co-generation, 50/100 MW, with desulfurization.
Data source: STOSEB '81.
Availability due to unsceduled downtime: 94%.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
1262.33	23.33	33.37	25.	0.81	164.29

energyforms	lev	input	output
Fuel-Oil	1	1.00	
Electricity	3		0.30
Heat-120deg	3		0.60

67 Coal Cogen 50/100

Short system description:

Coal Co-generation, 50/100 MW, with desulfurization
Data source: STOSEB '81
assumed to produce no peak energy

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
1738.33	38.03	46.67	25.	0.88	217.51

energyforms	lev	input	output
Coal	1	1.00	
Electricity	3		0.28
Heat-120deg	3		0.57

68 Gasturbine 260/260

Short system description:

Gasturbine, combined generaton of electricity and heat, 260/260 MW, with desulfurization.
Data source: STOSEB '81.
Availability due to unsceduled downtime: 94%.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
861.00	43.75	30.10	25.	0.81	148.95

energyforms	lev	input	output
Low BTU Gas	2	1.00	
Electricity	3		0.46
Heat-120deg	3		0.46

69 Oil Cogen VAERTAN

Short system description:

Base load oil co-generation plant in Vaertan, 250/400 MW, with desulfurization.
Can be retrofitted to operate on gas (according to Nynaes scenario).
Cost data for original plant from Stoseb.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
1098.46	20.19	30.69	25.	0.92	129.98

energyforms	lev	input	output
Fuel-Oil	1	1.00	
Elec-External	2		0.35
Heat-120deg	3		0.57

Alternative operation

Gas Cogen VAERTAN

Short system description:

Retrofitted co-generation plant in Vaertan.
Operating on gas from the energy complex.
Costs of retrofitting 27 $/kW.

var O+M Skr/kWa	avg cst Skr/kWa
23.58	133.37

energyforms	lev	input	output
Low BTU Gas	2	1.00	
Elec-External	2		0.35
Heat-120deg	3		0.57

71 Coal Cogen 250/400

Short system description:

Base to intermediate coal co-generation plant, 250/400 MW, with desulfurization.
Data source: STOSEB '81.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
1634.23	43.88	44.15	25.	0.88	212.93

energyforms	lev	input	output
Coal	1	1.00	
Elec-External	2		0.34
Heat-120deg	3		0.54

72 Towngas

Short system description:

Towngas station.
Produces SNG from naphta.
Efficiency from Stoseb report.
Output in 78: 72.8 MWyr (638 GWh).
Limited to present capacity of 350 MW (800000 m**3/day).
Costs assumed according to refinery.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
0.	35.00	0.	0.	1.00	35.00

energyforms	lev	input	output
Light-Oil	1	1.00	
Gas	2		0.90

73 Gaspipeline

Short system description:

Gas pipeline from abroad.
Investments in the range of the Stoseb data (average of all possibilities stated there).
Fix O+M costs 1.5%/yr.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
2450.00	0.	24.15	40.	1.00	147.93

energyforms	lev	input	output
Natgas	1	1.00	
Gas	2		0.92

Alternative operation

Gaspipeline

Short system description:

Linking technology for gas comming from outside the country to centralized heat production and co-generation plants.

var O+M Skr/kWa	avg cst Skr/kWa
0.	147.93

energyforms	lev	input	output
Natgas	1	1.00	
Low BTU Gas	2		0.92

75 Elec national

Short system description:

Stockholm's part of the national electricity grid to connect external powerplants.
Efficiency in '78: 91.3%.
Costs from Schiffer, 1978.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
1036.00	0.	14.70	60.	0.83	72.88

energyforms	lev	input	output
Elec-External	2	1.00	
Electricity	3		0.91

Dynamic bounds on capacity build up

	gam	g
upper	1.06	0.30

76 District heat pipeline 120km

Short system description:

District heat transmission from Forsmark :
length 120 km,
diameter 1500 mm,
heat temperature 165 deg,
capacity 2000 MW.

Electricity for pumping: 400 GWh/yr.
Efficiency 95%, losses replaced by pumping energy.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
1593.20	0.	11.90	40.	1.00	92.39

energyforms	lev	input	output
Heat-165deg-FM1	2	1.00	
Heat-120deg	3		1.00
Elec-External	2	0.05	

77 District Heat Coalscenario

Short system description:

District heat pipelines for the centralized coal scenario.
Electricity for pumps: .1 TWh/yr.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
686.00	0.	3.50	40.	1.00	38.16

energyforms	lev	input	output
Heat 120d-Coal	2	1.00	
Heat-120deg	3		1.00

78 FM Cogen 500/1000

Short system description:

Coal Co-generation, 2 x 500/1000 MW, with desulfurization.
Replacement of Forsmark reactor for heat production.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
1299.67	61.37	26.60	25.	0.88	186.13

energyforms	lev	input	output
Coal	1	1.00	
Elec-External	2		0.29
Heat-165deg-FM1	2		0.58

79 Heatpump sewagewater

Short system description:

Electric Heat Pump, 10 MW Heat.
Heat Source: Sewage water.
Costs data and cop from Stal-Laval
(318 $/kW for pump, 71.4 $/kW for heat
transmission).
Availability factor form Stoseb.
Potential according to Stoseb: 260 MWa/a:
=> 6.5 in 1st load region
=> 6.5 in 2nd load region
=> 52. in 3rd load region
=>130. in 4th load region
=> 65. in 5th load region.
Potential according to Stal-Laval: 400 MWa/a:
=> 10. in 1st load region
=> 10. in 2nd load region
=> 80. in 3rd load region
=>200. in 4th load region
=>100. in 5th load region.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
2730.00	0.	67.20	25.	0.92	262.99

energyforms	lev	input	output
Elec-External	2	1.00	
Heat-120deg	3		3.30

80 Heatpump seawater

Short system description:

Electric Heat Pump, 11.e7 MW Heat.
Heat Source: Lake surface.
Costs data and cop from Stal-Laval
(318 $/kW for pump, 71.4 $/kW for heat
transmission).
Availability factor form Stoseb.
Potential according to Stoseb: 700 MWa/a:
=> 17.5 in 1st load region
=> 17.5 in 2nd load region
=>140. in 3rd load region
=>350. in 4th load region
=>175. in 5th load region.
Potential according to Stal-Laval: 1000 MWa/a:
=> 25. in 1st load region
=> 25. in 2nd load region
=>200. in 3rd load region
=>500. in 4th load region
=>250. in 5th load region.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
2730.00	0.	67.20	25.	0.95	254.69

energyforms	lev	input	output
Elec-External	2	1.00	
Heat-120deg	3		3.00

81 LWR FORSMARK

Short system description:

Forsmark reactor as pure electricity generator.
No additional investment costs to the system.
Maximal production for Stockholm 750 MW.
Baseload production, maintainance in off-peak time.
The plant factor of 85% is accounted for in an additional accounting row.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
0.	42.91	0.	0.	1.00	42.91

energyforms	lev	input	output
Uranium	1	1.00	
Elec-External	2		5.88

output pattern fixed

energy:	0.03	0.03	0.24	0.59	0.12
power:	1.18	1.18	1.18	1.18	0.47

82 FORSMARK ht

Short system description:

Forsmark reactor with condensation turbine.
Maximal production 2000 MW heat.
Baseload production, maintainance in off-peak time.
Plant factor 88% (see above).
Costs include a 480 MWth oil heating plant.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
499.80	16.10	12.39	25.	1.00	60.48

energyforms	lev	input	output
Uranium	1	1.00	
Steam to FM-Tur	2		15.68

output pattern fixed

energy:	0.03	0.03	0.23	0.57	0.15
power:	1.14	1.14	1.14	1.14	0.59

83 FM off peak

Short system description:

Technology needed to model off-peak production of electricity in Forsmark 3 in case of heat production.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
0.	0.	0.	0.	1.00	0.

energyforms	lev	input	output
Steam to FM-Tur	2	1.00	
Elec-External	2		0.38

84 Heat Link FM

Short system description:

Technology needed to link
Forsmark 3 to the heat pipeline
in case of heat production.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
0.	0.	0.	0.	1.00	0.

energyforms	lev	input	output
Steam to FM-Tur	2	1.00	
Heat-165deg-FM1	2		1.00

85 Energy Complex-w

Short system description:

Nynaeshamn Energy Complex:
converts high sulfur coal to
heat, low btu gas and methanol.
For use in home heating this low BTU gas can be
converted to an equivalent to towngas in a
methanation station, in heating and co-generation
plants it can be used directly.

This technology includes: Energy complex,
District heat pipeline,
Gas pipeline, and
Heat pumps in backwater.
Electricity input is for heat pumps and pipeline.
Heat production includes heat from heat pumps.

Fix operation and maintainance costs of complex:
5.5 % of investments per year.

Gas pipeline from Nynaeshamn:
length 50 - 55 km;
diameter 500 mm;
capacity 600 MW;
O+M costs 1.% of investments / yr,

District heat transmission from Nynaeshamn:
length 50 - 55 km;
diameter 2 x 780 mm;
capacity 400 MW;
heat temperature 150 deg.

Heat pumps on return water:
215 MWth, cop = 3.9.

First part of the technology: Winter Production
gas: 600 MW
methanol: 394 MW (1500 tons/day)
heat: 382 MW + 239 MW.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
2332.33	0.	97.93	24.	0.90	278.77

energyforms	lev	input	output
hs-Coal	1	1.00	
Low BTU Gas	2		0.34
Elec-External	2	0.07	
Methanol	3		0.23
Heat-120deg	3		0.36

Alternative operation

Energy Complex i

Short system description:

Nynaeshamn energy complex.
Second part of the technology: Intermediate Production
gas: 269 MW
methanol: 657 MW (2500 tons/day)
heat: 393 MW + 246 MW.

var O+M Skr/kWa	avg cst Skr/kWa
0.	287.98

energyforms	lev	input	output
hs-Coal	1	1.00	
Low BTU Gas	2		0.16
Elec-External	2	0.07	
Methanol	3		0.38
Heat-120deg	3		0.37

Alternative operation

Energy Complex s

Short system description:

Nynaeshamn energy complex.
Third part of the technology: Summer Production
gas: 0 MW
methanol: 657 MW (2500 tons/day)
heat: 274 MW + 171 MW (runs 49% of summer).

var O+M Skr/kWa	avg cst Skr/kWa
0.	0.

energyforms	lev	input	output
hs-Coal	1	1.00	
Heat-120deg	3		0.22
Elec-External	2	0.03	
Methanol	3		0.66

88 Methanation

Short system description:

Methanation plant converting low BTU gas to towngas equivalent.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
225.40	0.	9.10	25.	1.00	23.53

energyforms	lev	input	output
Low BTU Gas	2	1.00	
Gas	2		0.82

89 Coal Himmerfjaerden

Short system description:

Steam generation part of coal fired heat or co-generation plants for Centralized Coal Scenario. Two blocks of 380 MWe + 690 MWth in Himmerfjaerden. The steam produced in this technology can either be used for district heat or in the co-generation turbine described below.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
1120.00	87.50	20.30	25.	0.92	187.49

energyforms	lev	input	output
Coal	1	1.00	
Heat 120d-Coal	2		0.87

Alternative operation

Altern Himmerfjaerden

Short system description:

Steam generation part of coal fired heat or co-generation plants for Centralized Coal Scenario. The steam produced in this technology can be used for the co-generation turbine described below (Himmerfjaerden).

var O+M Skr/kWa	avg cst Skr/kWa
87.50	187.49

energyforms	lev	input	output
Coal	1	1.00	
Steam Coal	2		0.87

91 Coal Loevsta

Short system description:

Steam generation part of coal fired heat or co-generation plants for Centralized Coal Scenario. One block with 205 MWe + 330 MWth in Loevsta. The steam produced in this technology can either be used for district heat or in the co-generation turbine described below.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
1288.00	87.50	31.50	25.	0.92	211.36

energyforms	lev	input	output
Coal	1	1.00	
Heat 120d-Coal	2		0.87

Alternative operation

Altern Loevsta

Short system description:

Steam generation part of coal fired heat or co-generation plants for Centralized Coal Scenario. The steam produced in this technology can be used for the co-generation turbine described below (Loevsta).

var O+M Skr/kWa	avg cst Skr/kWa
87.50	211.36

energyforms	lev	input	output
Coal	1	1.00	
Steam Coal	2		0.87

93 Co-Generation Turbine

Short system description:

Co-generation Turbine for the Centraliced Coal Scenario. Combines the production of electricity and haet for the plants in Himmerfjaerden and Loevsta (This is only a modeling trick to reduce the matrix size).

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
406.63	0.	13.99	25.	1.00	40.02

energyforms	lev	input	output
Steam Coal	2	1.00	
Elec-External	2		0.37
Heat 120d-Coal	2		0.63

94 Growian

Short system description:

Wind power plant (JDHB 15) ("GROWIAN" system).
Capacity factor expressed as availabilty factor.
Fixed to baseload production.

Maximal output according to Stoseb:
1990: 1TWh, 2000: 4TWh.

Potential used in 2000 : 1 TWh/yr
maximal : 3 TWh/yr.

Data source for central conversion stations labelled JDHB1 nn (nn = technology number):
Energy Technology Data Handbook,
Volume I - conversion technologies
Juel-Spez-70, Januar 1980

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
7875.00	0.	288.75	25.	0.46	1723.57

energyforms	lev	input	output
Elec-External	2		1.00

output pattern fixed

energy:	0.03	0.03	0.20	0.50	0.25
power:	1.00	1.00	1.00	1.00	1.00

Dynamic bounds on capacity build up

	gam	g
upper	1.05	3.00

95 LWR-conventional

Short system description:

Light water reactors.
Costs for fuel cycle of approximately 30 $/kWyr are not included.

Reactors in Sweden (IAEA '79):

Location	1.yr	capacity [MW]
OSKARSHAMN-1	1972	460
OSKARSHAMN-2	1974	570
RINGHALS-2	1975	800
BARSEBAECK-1	1975	570
RINGHALS-1	1976	750
BARSEBAECK-2	1977	570
RINGHALS-3	1979	912
FORSMARK-1	1979	900
RINGHALS-4	1980	912
FORSMARK-2	1980	899
FORSMARK-3	1984	1060
OSKARSHAMN-3	1986	1060

12% to 15% of the production is available for Stockholm.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
5138.00	42.91	255.50	25.	0.75	822.10

energyforms	lev	input	output	initrequ	finalret
Uranium	1	1.00		0.31	0.16
Elec-External	2		5.88		

output pattern fixed

energy:	0.03	0.03	0.20	0.50	0.25
power:	1.00	1.00	1.00	1.00	1.00

96 Oil Powerplant

Short system description:

Heavy destillate oil base load steam power plant (JDHB 3).

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
2170.00	63.00	126.00	30.	0.85	358.87

energyforms	lev	input	output
Fuel-Oil	1	1.00	
Elec-External	2		0.37

Dynamic bounds on capacity build up

	gam	g
upper	1.05	2.00

97 Diesel Powerplant

Short system description:

Light destillate oil peak power plant.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
1400.00	154.00	140.00	30.	0.85	413.96

energyforms	lev	input	output
Light-Oil	1	1.00	
Elec-External	2		0.30

Dynamic bounds on capacity build up

	gam	g
upper	1.06	1.00

98 Gas-Steam Powerplant

Short system description:

Natural gas medium load steam power plant.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
2030.00	63.00	122.50	30.	0.85	345.23

energyforms	lev	input	output
Gas	2	1.00	
Elec-External	2		0.34

Dynamic bounds on capacity build up

	gam	g
upper	1.05	2.00

99 Jetgas Powerplant

Short system description:

Natural gas peak load power plant.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
1365.00	133.00	126.00	30.	0.95	348.72

energyforms	lev	input	output
Gas	2	1.00	
Elec-External	2		0.32

Dynamic bounds on capacity build up

	gam	g
upper	1.06	1.00

100 Hardcoal Powerplant

Short system description:

Advanced hard coal base load power plant (JDHB 6). Hard coal conversion to low BTU gas and coke, electricity produced through a combined gas turbine and coke steam cycle process.

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
4228.00	308.00	126.00	25.	0.75	836.86

energyforms	lev	input	output
Coal	1	1.00	
Elec-External	2		0.43

Dynamic bounds on capacity build up

	gam	g
upper	1.05	20.00

101 Run-of-river

Short system description:

Run of river hydropower plant.
Capacity in '80 1320 MW (12% of public Swedish plants).
Plant factor decreasing, .45 in '78.
Production limit imposed via an accounting row
(see section 4.1 of this appendix for the figures).

capcost Skr/kW	var O+M Skr/kWa	fix O+M Skr/kW/a	pllife years	plfctr fr	avg cst Skr/kWa
8855.00	0.	292.60	60.	0.95	720.01

energyforms	lev	input	output
Elec-External	2		1.00