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The Norwegian National Team's Contribution to the IEA Annex 21, "Global Environmental Benefits of Industrial Heat Pumps"

Refrigeration Engineering

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REPORT

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The Norwegian National Team's Contribution to the IEA Annex 21, "Global Environmental Benefits of Industrial Heat Pumps"

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ABSTRACT

This report is the contribution from the Norwegian National Team to the IEA Annex 21, *"Global Environmental Benefits of Industrial Heat Pumps"*. The annex has four objectives:

- Heighten industry's awareness of large energy savings associated with industrial heat pumping;
- Broaden the information base to industry to help further development of industrial heat pumps (IHPs);
- Estimate the market potential for various types of IHPs and illustrate the opportunities for their use;
- Estimate the global environmental benefits for IHPs resulting from energy savings and emission reductions.

There are about 700 industrial heat pumps currently in operation in Norway, with a total heating capacity of 170 MW, and an annual heat production of approximately 1.1 TWh. More than 230 heat pumps are installed in fish farming plants, and about 50 heat pumps utilize condenser heat from large refrigeration plants. Heat pumps are also applied for various drying purposes, and more than 280 heat pumps are currently in operation, notably for drying of timber, leather and fish. Most MVR systems are applied in the dairy industry, while several large systems are installed in the wood processing industry.

KEYWORDS	ENGLISH	NORWEGIAN
GROUP 1	Refrigeration Engineering	Kuldeteknikk
GROUP 2	Heat	Varme
SELECTED BY AUTHOR(S)	Heat Pumps	Varmepumper
	Industrial Applications	Industrial Applications
	IEA Annex 21	IEA Annex 21

TABLE OF CONTENTS

1 INTRODUCTION

This report is the contribution from the Norwegian National Team to the IEA Implementing Agreement on Advanced Heat Pump Systems, Annex 21, *"Global Environmental Benefits of Industrial Heat Pumps"*. The annex has four objectives:

- Heighten industry's awareness of large energy savings associated with industrial heat pumping;
- Broaden the information base to industry to help further development of industrial heat pumps;
- Estimate the market potential for various types of industrial heat pumps and illustrate the opportunities for their use;
- Estimate the global environmental benefits for industrial heat pumps resulting from energy savings and emission reductions.

The main products from the annex will include a comprehensive report on global environmental benefits of industrial heat pumps (IHPs), guidelines for IHP applications, a detailed IHP design manual and an expert computer programme to assist IHP implementation.

The Norwegian heat pump analysis has been executed by SINTEF Refrigeration Engineering.

Operating agents of Annex 21 are:
Chalmers Industriteknik, Sweden
RCG/Hagler Bailly, USA

2 INDUSTRY,- ENERGY AND ENVIRONMENT

2.1 Energy Use

Final energy consumption in Norwegian *industry* in 1991 was approximately 87 TWh (42% of Norway's total, final energy consumption) /1/. The figure includes use of energy goods as raw materials. Table 2.1 shows current and estimated energy demand in industry for the period 1990 to 2010 /2/.

Table 2.1 *Final energy use in industry in 1990, and estimated figures for the year 2000 and 2010. The figures include use of energy goods as raw materials /2/.*

Type of Energy	**Energy Demand [TWh/year]**		
	1990	**2000**	**2010**
Electricity - Firm power	42.4	42.2	42.1
Electricity - Occasional power	0.7	0.7	0.8
Light Fuel Oil	2.5	2.8	3.1
Heavy Fuel Oil	9.4	10.5	11.5
Natural Gas[1)]	13.8	13.6	13.4
Coal and biomass[2)]	16.3	15.8	15.3
Black Liquor[3)]	1.7	2.0	2.4
TOTAL	86.8	87.6	88.6

1) Mainly used as raw material *2) Includes wood, wood waste, refuse etc.* *3) For heating and electricity production in the wood processing industry*

The total energy demand for hot water heating and space heating/cooling in the Norwegian industri in 1990 was about *5.3 TWh*, while the process heat demand at temperatures below 200°C was approximately *10.5 TWh* /2/. The latter includes heating of process water and steam, evaporation processes, drying processes, etc. It is distinguished between process heat demand above and below 200°C, since current industrial heat pumps maximum can achieve output temperatures of 150 to 200°C.

Figure 2.1 and Table 2.2 on the following page provide more detailed information on the total energy demand and energy mix for heating purposes below 200°C /2/. About 2.2 TWh (41%) and 1.7 TWh (31%) of the energy demand for hot water heating and space heating/cooling was covered by electicity and oil, respectively. With regard to the process heat demand below 200°C, the respective figures for electicity and oil was 2.2 TWh (21%) and 5.3 TWh (50%). Since coal and notably natural gas are scarely used for heating purposes in Norwegian industry, they are not taken into consideration in this analysis.

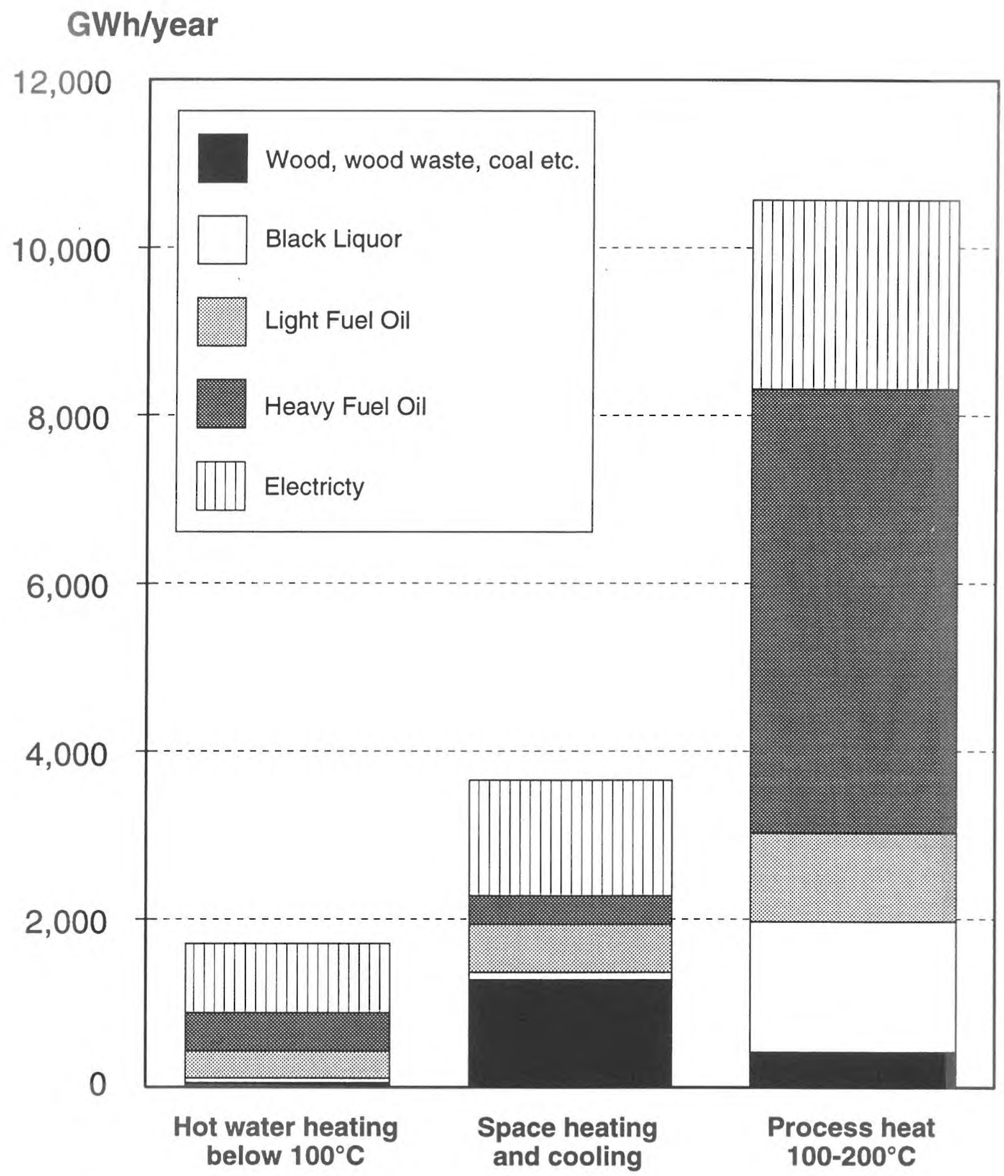

Figure 2.1 *Total energy demand [GWh/year] and energy mix for hot water heating, space heating/cooling and process heat below 200°C in Norwegian industry in 1990 /2/.*

Table 2.2 *Total energy demand [GWh/year] and energy mix for hot water heating, space heating/cooling and process heat below 200°C in Norwegian industry in 1990 /2/.*

Energy Demand [GWh/year]	Coal & Biomass	Black Liquor	Light Fuel Oil	Heavy Fuel Oil	Electricity[1)]	**Total**
Hot Water Heating	51	55	323	457	819 / 3	**1,709**
Space Heating/Cooling	1,276	88	577	337	1,376 / 3	**3,656**
Process Heating/Cooling (< 200°C)	417	1,551	1,057	5,290	1,616 / 640	**10,571**
Total	1,744	1,694	1,957	6,084	4,457	**15,936**

1) Firm and occasional power , respectively

2.2 Emissions to Air

Table 2.3 shows total industrial emissions of air pollutants in 1990 /1/.

Table 2.3 Industrial emissions to air of various pollutants in Norway (1990) /1/.

POLLUTANT		**Emissions [thousand tonnes]**
SO_2	Sulphur dioxide	31
NO_x	Nitrogen oxides	9
CO	Carbon monoxide	60
CO_2	Carbon dioxide	7,000
VOC	Volatile organic compounds	114
Pb	Lead	0.008

3 INDUSTRIAL HEAT PUMPS

3.1 Introduction

Industrial heat pumps utilize waste heat sources in the range from 20 to 100°C for space heating, tap water heating, heating of process water and steam production or they are integrated in drying, evaporation and distillation processes. Industrial heat pumps are generally large in capacity with a thermal output in the range of 100 kW to several MWs. Moreover, the units are often custom designed for specific applications. Evaporation temperatures are generally higher than for residential and commercial applications, and condensing temperatures are often found in the 80°C to 150°C range.

Industrial heat pumps generally have much higher coefficient of performance (COP) than space heating heat pumps. This is mainly due to small temperature lifts and generally large and highly efficient units operating at more or less constant loads.

The majority of industrial heat pump installations in Norway are applied for:

- Heating of process water in fish farming plants
- Drying of timber, fish and leather
- Evaporation in dairies, wood processing industry and fish industry
- Heat recovery from refrigeration plants

The heat pumps are either closed-cycle vapour compression systems or mechanical vapour recompression (MVR) systems. All heat pump installations in Norway are *electrically driven*, and there are no absorption heat pumps (type 1) or heat transformers (type 2) currently in operation.

3.2 Closed Cycle Vapour Compression Heat Pumps

The majority of industrial heat pump installations in Norway are closed cycle vapour compression heat pumps. About *670 units* are currently in operation, and they utilize heat sources in the temperature range from 0 to 70°C, and work with temperature lifts from 20 to 70°C. The COP typically ranges from 3 to 10. The heat pumps are mainly used for drying purposes, heating of process water and heat recovery from refrigeration plants.

The current use of working fluids in industrial heat pumps is estimated to be /6/:

HCFC-22:	50 tonnes
NH_3:	20 tonnes
CFC-12:	5 tonnes

Example 1: Closed Cycle Compression Heat Pump in Fish Farm

The fish farm at *"TIMAR"* in Slørdal, produces 1 million smolt/year. The main components of the heating system are two heat exchangers for direct heat recovery from waste water to fresh process water. Two heat pump aggregates are installed to heat the waste water in order to maintain a driving temperature difference over the heat exchangers. The heat pump, which applies ammonia as working fluid, has a total heating capacity of 585 kW. 2,000 kW is delivered from the heat exchangers. Annual heat production for the heating system is 5,440 MWh/year, including 1,670 MWh/year produced by the heat pump /7/.

Figure 3.1 provides a principal scheme of the heating system.

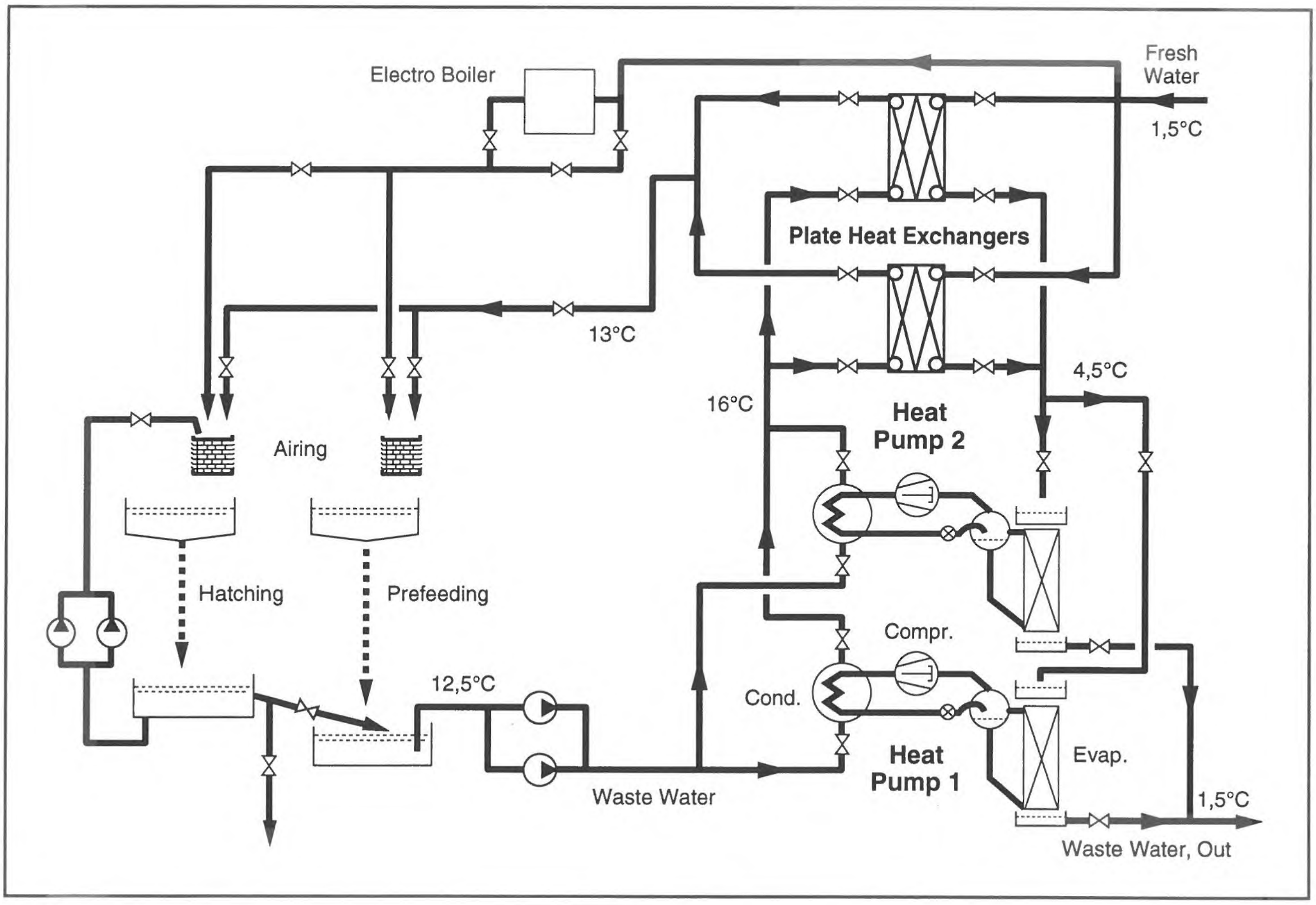

Figure 3.1 Principal scheme of the heat pump at TIMAR in Slørdal /7/.

3.3 Mechanical Vapour Recompression (MVR)

Mechanical vapour recompression (MVR) systems are classified as open or semi-open heat pumps. In open systems process vapour is compressed, and the steam is used directly in the process. In semi-open systems, heat from the recompressed vapour is transferred to the process via a heat exchanger.

Since the evaporator and/or condenser are eliminated and the temperature lift generally is low, the performance of MVR systems is high, with COPs ranging from 10 to 30. Current MVR systems work with heat source temperatures from 50 to 100°C, and deliver heat in the temperature range from 75 to 150°C.

There are about *20 MVR systems* in operation in Norway, mainly in dairies and the wood processing industry. The MVR installations in dairies use turbo compressors, and typically have a heating capacity in the range from 300 to 3,000 kW. The temperature lift is typically 10 to 25°C. A few MVR's are installed for drying purposes in the fishmeal industry.

Example 2: Mechanical Vapour Recompression Heat Pump in Dairy

"L/L Sunnmøre Meieri avd. Ørsta" are treating 90,000 litres of milk daily. The dairy produces white cheese, brown cheese and milk. The total annual cheese production is 1,700 tonnes, including 600 tonnes of brown cheese. MVR is used for evaporation in the brown cheese production. Annual energy saving compared to traditional equipment is 5,300 MWh/year, and the pay-back time is 4.5 years /7/. Figure 3.2 shows a principal scheme of the heat pump.

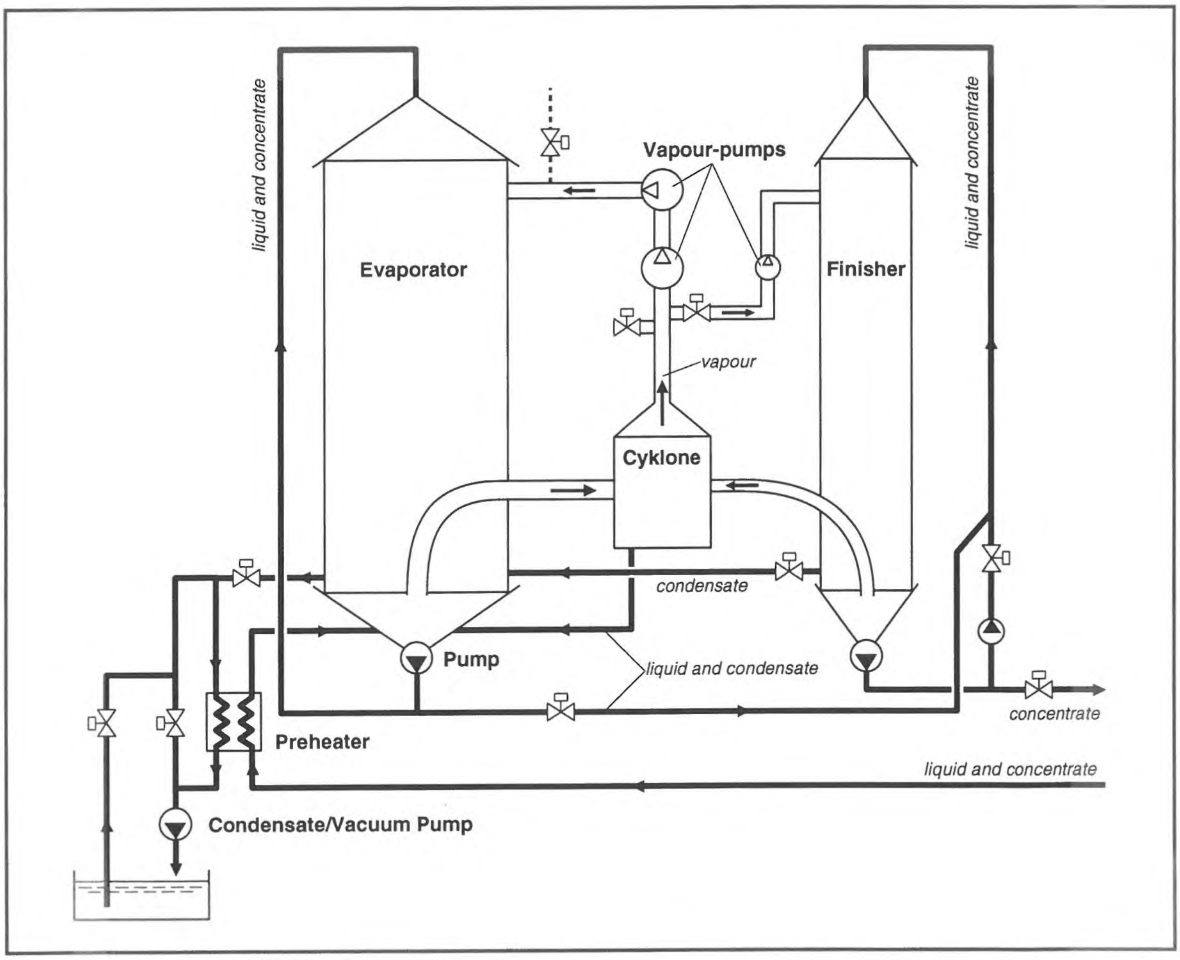

Figure 3.2 Principal scheme of the heat pump (MVR) installation at Sunnmøre meieri avd. Ørsta /7/.

4 CURRENT STATUS ON INDUSTRIAL HEAT PUMPS

4.1 Current Installations

In 1993 there were about *700* industrial heat pumps in operation in Norway, with a total heating capacity of *170 MW* and an annual heat production of approximately *1.1 TWh/year*. From 1989 about 50 industrial heat pumps have been installed annually, which gives a market growth rate of approximately 7%.

Table 4.1 shows estimated number of heat pump installations in 1992, installed capacity and annual heat production in the most significant industry sectors where heat pumps are applied.

Table 4.1 Industrial heat pump installations in various industry sectors in Norway (1992), including closed cycle vapour compression heat pumps and MVR systems. "Heat recovery" means heat recovery from refrigeration plants by the use of heat pumps, and direct heat recovery of condenser heat is not included.

Industry sector	Process	Temperature Range [°C]	No. of IHP (1993)	Installed Capacity [MW]	Heat production [GWh/year]
Fish Farming	• Heating of process water	5 - 15	230	55	280
Fish Products	• Evaporative concentration • Drying • Heat recovery	80 - 100 5 - 30 -	3 MVR 60 30	tot. 21	- 45 22
Timber and Wood Products	• Evaporative concentration • Drying	100 - 120 50 - 70	5 MVR 170	55 8	600 30
Dairies	• Evaporative concentration • Heat recovery	60 - 80 -	13 MVR 18	tot. 12	22 27
Leather	• Drying	40 - 60	50	2	3
Meat Products	• Heating of process water • Heat recovery	60 - 90 -	15 10	tot. 14	20 15

Figure 4.1 and 4.2 on the following page provide a graphical presentation of industrial heat pumps installations in Norway with regard to number of installations and installed heating capacity in various industry sectors (1992).

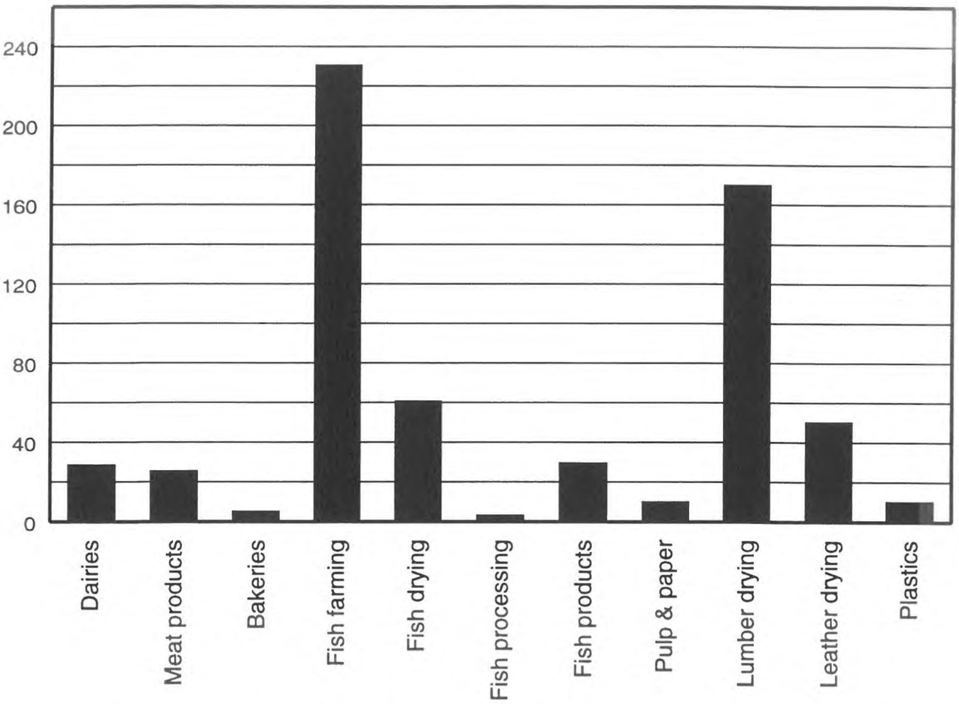

Figure 4.1 Number of heat pump installations in various industry sectors (1992).

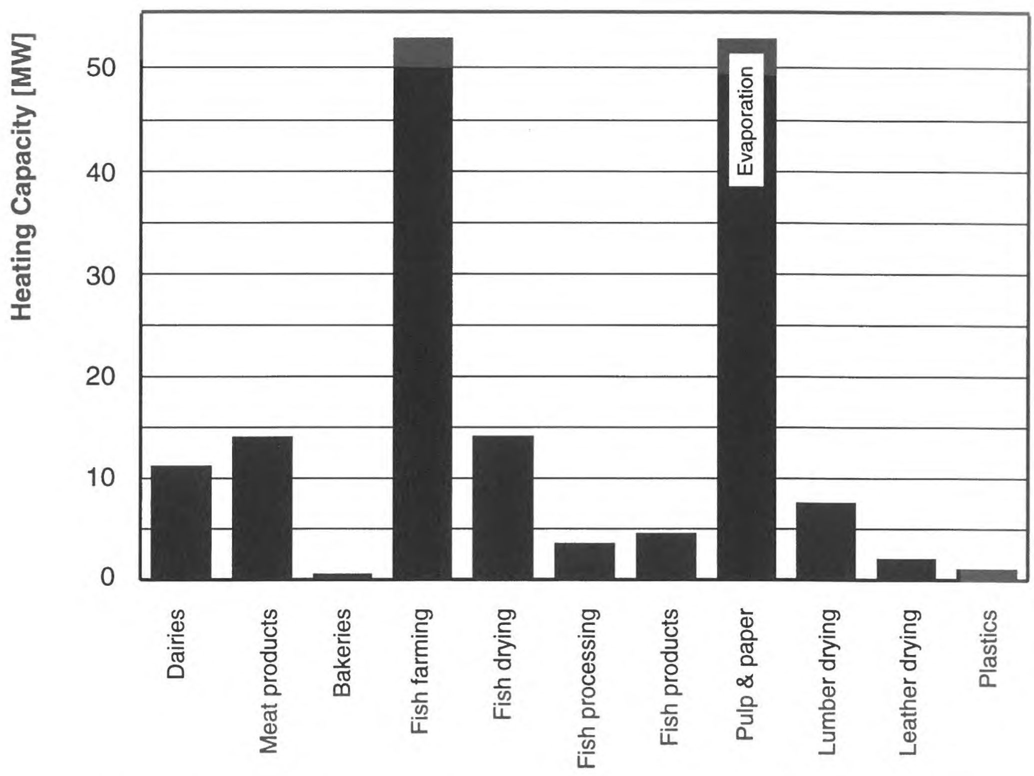

Figure 4.2 Installed heat pump heating capacity [MW] in various industry sectors (1992).

4.2 Norwegian Heat Pump Manufacturers

Traditionally there has been several small manufacturers of refrigeration equipment in Norway, but there are only a few left. Some has been incorporated in foreign companies, like Sabroe Refrigeration, Carrier, etc. Others have closed down local production and are selling equipment for leading multinational manufacturers. There has also been a mergering tendency in this industry. At the moment *7 companies* in Norway are manufacturing industrial heat pumps. Norwegian manufacturers has long tradition in tailor-making industrial heat pumps rather than series production.

For the dairy (MVR's) and fish farming sector, almost all units are produced in Norway. Also with regard to equipment for drying of fish and heat recovery from refrigeration plants, Norwegian equipment is cost competitive.

Norwegian manufacturers of industrial heat pumps are (1993):

- Aquaterm Energi AS
- Bodø Kjøl og Frys AS
- Energi og Prosesskontroll AS
- Frostmann Kulde AS
- Industrikulde AS
- Kværner Eureka AS
- Nobø Electro AS

5 FUTURE MARKETS FOR INDUSTRIAL HEAT PUMPS

5.1 Market Potential

The application of heat pumps is increasing in industry, especially for drying and evaporation processes. In addition to energy saving and reduction of environmentally harmful emissions, heat pumps are advantageous regarding product quality. By using adapted drying programmes, optimum characteristics for the products can be obtained. Fluidized bed drying is also regarded a promising technology.

The *technical potential* for industrial heat pumps in Norway was in 1990 estimated to be approximately 3.5 TWh /2/. The following estimates on the current and future *market potential* for industrial heat pumps in the most important industry sectors, are mainly based on two sources: 1) The two computer programmes which has been developed in Annex 21; Chalmers Programme and the Market Assessment Spreadsheet (Section 6), and 2) Investigations on market possibilities for industrial heat pumps in Norway by Institute for Energy Technology (IFE) /3/.

Table 5.1 shows IFE' estimated market potential for heat pumps in various industry sectors in Norway /3/. Estimated number of industrial heat pumps from the Market Assessment Spreadsheet for the years 1995 and 2000 (Annex 21 - average profit scenario), is shown in the two right hand columns.

Table 5.1 Estimated market potential for industrial heat pumps.

Industry Sector	Heat Pump Application	Heat Pump Market Potential - IFE (1993)		Heat Pump Market Potential - Annex 21	
		No. Units	Heat Prod. [GWh/year]	No. Units 1995	No. Units 2000
Fish farming	Heating of process water	20	24	17	80
Fish products	Heat recovery from refr. plants Drying	70 30	50 22	- 5	- 25
Timber/wood prod.	Drying	80	75	-	-
Dairy products	Heat recovery from refr. plants Evaporation (MVR)	30 6	44 13	2 -	8 -
Meat products	Heating of process water Heat recovery from refr. plants	40 6	46 8	- -	- -
TOTAL		~ 280	~280		

When estimating market potential of industrial heat pumps, it is important to emphasize that the data presented are *rough estimates*, since the results are much dependent on basic factors such as future energy prices, environmental regulations, industrial growth, general economic activity, etc.

Another important factor is the time aspect. The Annex 21 analysis includes both short-, medium and long-term estimates, and it is obvious that estimates made for the year 2000 include more uncertainties than estimates made for the year 1995. Long-term estimates made by Energidata in 1990, concludes with a potential of *2.5 TWh/year* produced by industrial heat pumps by the year 2000 /2/.

IFE's market assessment takes into account economy, competing technologies, future market trends and general attitudes towards heat pumps in each industry sector. The economic calculations are based on 15% nominal interest rate, 4% inflation and 15 years economic lifetime for the heat pump installations. Possible grants, subsidies etc, are not included in the estimate. A macro economic real interest rate of 7% has been used when comparing heat pumps with competing technologies. The profitability demand in the various industry sectors expressed in terms of *internal rate of return*, range from 15 to 25% /3/.

5.1.1 Fish Farming

The Norwegian Government has registered over 500 licences for fish farming /3/. A lot of fish farms were established during the 1980s, and about 230 heat pumps are currently in operation in this market sector. Heat pumps in fish farming plants have favourable operating conditions with low distribution temperatures (15°C), and long annual operating hours (up to 6,000 h/year).

The aqua-culture sector has experienced a market stagnation during the last few years, and uncertainties about the European Community, trade deals and duty regulations for export of fish reduces the potential for new heat pump installations in near future. This also applies for other industrial heat pump processes related to the fish processing industry.

There is a current market potential for 20 heat pumps in this market sector, with an annual heat production of about 25 GWh/year /3/.

5.1.2 Fish Products

About 300 companies in the fish processing industry have refrigeration plants, and the economic heat recovery potential is estimated at 50 GWh/year for the coming years /3/.

90 factories have facilities for drying of stockfish or clipfish. There are installed 60 heat pumps for drying purposes, most of them for clipfish. These heat pumps deliver 45 GWh of heat annually, and the average heating capacity is about 300 kW. All heat pumps have been installed during the last 15 years. There is expected a market stagnation the coming years, since many factories already have installed heat pumps, and there are concerns regarding future market development within the fish processing industry.

Except for the energy savings, the main advantage with heat pump driers is the high product quality achieved. The product is dried with a temperature programme where the drying period depends on the temperature, and volume and quality can be controlled in a better way than with traditional driers /9/. For this reason, heat pumps are the far most used heating system in new drying plants.

There is a current market potential for 30 heat pump driers, with an annual heat production of about 20 GWh/year. In addition there is an economic potential of 70 heat pumps for heat recovery from refrigeration plants, with an annual heat production of 50 GWh/year /3/.

Drying of fishmeal is not included in the estimated market potential for heat pump driers. There are about 14 fishmeal factories in Norway, and three heat pumps were installed in the late 1970s. There is a potential heat demand of 220 GWh/year which can be covered by heat pumps /3/. The implementation of heat pumps in the fishmeal industry is very much dependant on the operating experiences of a new fluidized bed heat pump dryer. The heat pump prototype uses ammonia as working fluid, and can reach condensing temperatures of 100°C /9/.

5.1.3 Timber and Wood Products

There are 260 timber mills and 500 woodwork and furniture manufacturers in Norway. The total energy demand for electricity, heating, drying and evaporation is about 1,400 GWh/year /3/. Most of the energy demand, (60%) was in 1991 delivered from biomass fueled incinerators. A few companies are still using the "natural" drying method, sun and wind.

At the moment, 5 MVR's are installed in paper mills. Approximately 170 closed cycle compression heat pumps are installed for drying of timber, woodwork and furniture materials, and they annually supply 30 GWh of heat. Most of the installations are small drying aggregates in the furniture industry.

The wood processing industry has the last years suffered from the general decline in building construction activity. A future recovery in the building sector as well as in export of timber, will encourage investments.

A new concept for high temperature heat pump drying of wood and wood products has recently been developed. The heat pump, which uses ammonia as working fluid, is designed for 40 bar operating pressure, and drying temperatures up to 75°C can be achieved. A demonstration plant is installed in a timber mill, and the operation experiences so far are good. Similar heat pumps are under installation.

There is a current market potential for 80 heat pumps in drying of wood and wood products, with an annual heat production of 75 GWh/year /3/.

5.1.4 Dairy Products

Heat pumps are applied in dairies for recovery of waste heat from refrigeration plants, and for evaporative concentration in cheese production. In December, 1993, there were 120 dairies in Norway, with a total heat demand of 361 GWh /3/. 11 MVR's and 20 closed cycle compression heat pumps are currently in operation, with an annual heat delivery of about 50 GWh.

The demand for cheese in Norway is slightly growing, and there is a tendency to centralize the production of cheese and other dairy products in few and larger factories. An extensive growth in heat pump installations for the dairy industry can not therefore be expected.

There is a current market potential for 6 MVR's and about 30 closed-cycle compression heat pumps for heat recovery, with an annual heat production of approximately 55 GWh/year /3/.

5.1.5 Meat Products

270 enterprises were active in the meat production business in 1991, and they had a total annual energy demand of 450 GWh. 50% of the energy was used for refrigeration and water heating purposes /3/.

Heat recovery from refrigeration plants can be achieved by utilizing the condenser heat directly, or by installing a supercharge heat pump. Heat pumps for water heating, which utilizes ice-water for air-conditioning as heat source, is also an alternative.

There is a current market potential for about 45 heat pumps in this market sector, with an annual heat production of 55 GWh/year /3/.

5.2 Market Constraints

The main impediements for futher market penetration of industrial heat pumps in Norway are:

- Heat pumps are regarded to be more expensive, less reliable and more difficult to operate than more traditional heating systems. However, these barriers are stronger in the residential/commercial market sectors than the industrial, since the knowledge about heat pumps tend to be higher among consultants, contractors and owners in industry. Still, there is a considerable lack of knowledge regarding heat pumps among decision makers in industry.

- Industry has access to cheap electricity (occasional power). Low prices, both on electricity and oil, make heat pumps less profitable compared to traditional heating systems.

- Uncertainty regarding the future working fluid situation, since CFC's as well as HCFC's will be phased out within a few years.

5.3 Energy Prices

The increase in oil prices is stipulated to be 1.6% per year /2/. The oil price is expected to remain low in the coming 3-5 years. A low oil price will favour use of oil fired boilers.

Stipulated increase in electricity prices is 1.2% per year /2/. Norway has established a free market for electricity, which means that consumers in industry and commercial sectors can buy electricity whereever they are offered the lowest price and the best conditions. This has resulted in lower electricity prices due to free competition between the various energy utilities.

Table 5.2 shows the energy price estimates for the years 1995, 2000, 2005 and 2010 /2, 10/.

Table 5.2 *Energy price estimate for electricity and oil for the period 1995 to 2010 [$/kW, $/GJ]. The local exchange rate applied is 7.5 NOK per US$ (1994.02.01) /2, 10/.*

Energy prices	**1995**		**2000**		**2005**		**2010**	
	$/kWh	$/GJ	$/kWh	$/GJ	$/kWh	$/GJ	$/kWh	$/GJ
Oil	0.052	14.4	0.056	15.6	0.06	16.7	0.065	18.3
Electricity	0.029	8.1	0.032	8.8	0.034	9.6	0.037	10.4

Since there are several difficulties in predicting the energy prices for the next 15 years, the estimates are to be considered as quite rough:

- Virtually 100 % of the electricity in Norway is generated from hydro power, and the availability and hence the electricity price depends on inflow/rainfall.
- Norway trades electricity with Sweden, Denmark and Finland, and energy prices in these countries will influence the electricity price in Norway.
- Oil prices worldwide has a significant effect on the oil and electricity prices in Norway.
- Political decisions can influence the energy prices in any direction (eg. CO_2 and environmental taxes).

5.4 Heat pump Investment Costs

Table 5.3 indicates the range of investment costs for industrial heat pumps per kW installed heating capacity [NOK/kW]. The ranges are rather wide due to variations in heat sources (water/air), heat distribution systems (water/steam/air), complexity of the plants, etc. /5/.

Table 5.3 *Investment cost for industrial heat pumps [$/kW] /5/ The local exchange rate applied is 7.5 NOK per US$ (1994.02.01).*

Heating Capacity	Investment Costs ($/kW)
5 - 25 kW	665 - 1,130
25 - 500 kW	135 - 800
0.5 - 1 MW	135 - 400
> 1 MW	135 - 400

6 ANNEX 21 - RESULTS FROM DATA PROGRAMMES

Two computer programmes have been developed under Annex 21:

Chalmers/ETA
The programme examines industrial processes suitable for industrial heat pumps.

Market Assessment Spreadsheet
The spreadsheet uses inputs from the Chalmers/ETA programme, and provides estimates on future market penetration of industrial heat pumps as well as energy and emission savings per process.

The following industrial processes in Norwegian industry have been examined by Chalmers' computer programme and the market assessment spreadsheet:

A) Aqua Culture - fish farming

B) Fish products - drying of stockfish and clipfish

C) Dairies - creamery, evaporation and heat recovery

Economic Boundary Conditions:

Cost of heat source:	The heat pumps are using free waste heat
Cost of saved energy:	Electricity or oil price
Annuity factor:	0.25, based on 5% real interest rate and 4-5 years payback period

The results are presented in detail in Appendix A, B and C.

When estimating projected number of industrial heat pumps and energy and environmental benefits, it is important to emphasize that the data presented are *rough estimates*, since the results are much dependent on basic factors such as future energy prices (oil/gas/electricity), environmental regulations, industrial growth, general economic activity, etc. Another important factor is the time aspect. The analysis includes both short-, medium and long-term estimates, and it is obvious that estimates made for the year 2010 include more uncertainties than estimates made for the year 2000.

Moreover, it is important to stress that the number of heat pump installations projected includes *replacement installations* (retrofitting) as well.

6.1 Aqua-Culture - Fish Farming, Heating of Process water

The average specific investment cost for the entire energy system is 1,000 NOK per kW installed heating capacity. A lot of fish farms were established during the 1980s, and heat pumps are the dominating heating system, with oil boilers as an alternative/back-up. The aqua-culture sector has experienced a market stagnation during the last few years, which reduces the potential for new heat pump installations.

Annual operation hours	: 3-6,000
Number of plants with the process	: 500
Estimated industry growth	: 1%
Existing plants with HP already installed	: 230
Tot. process heat demand for all plants (GWh)	: 600 (2,160 x 1,000 GJ/year)
Heat delivery from existing HP plants (GWh)	: 280

<u>From Chalmers' computer programme:</u>

Process no.	: 643
Heat pump type	: El. driven motor closed-circuit compr., no.1
Annual Profit	: See attachments
Payback	: "
Energy delivered (energy produced by the heat pump)	: "
Drive energy (energy consumed by the heat pump)	: "
Global dT	: 1°C
Working fluid	: HCFC-22

<u>Example from a typical fish farming heat pump plant, from IFE's analysis /3/:</u>

Heat pump type	: El. driven motor closed-circuit compr.
Annual Profit	: 90,666 $
Payback	: 1.5 years
Energy delivered by the heat pump	: 2,730 MWh
Drive energy (energy consumed by the heat pump)	: 350 MWh
Working Fluid	: HCFC-22

IFE has estimated a short-term economic potential for 20 heat pumps with an annual heat delivery of 24 GWh/year /3/.

Results from the market spreadsheet are attached. The average profit scenario concludes with 17 heat pumps and 10.3 GWh energy saved in year 1995, and 80 heat pumps and 45.6 GWh energy saved in year 2000. The projected emission reduction for CO_2 in year 1995 and 2000 are approximately 2,322 and 13,362 metric tonnes/year. Total projected emission reductions are 2,339 and 13,450 metric tonnes/year, including SO_X, NO_X, CO_2, CO, CH_4 and PM.

The *average profit scenario* estimates heat pumps with 50% heat capacity compared with the *maximum profit scenario*. Therefore, the saving per heat pump is less than in IFE's studies /3/.

6.2 Drying of Fish Products

There are installed 60 heat pump dryers in Norway, most of them for clipfish, with an average heating capacity in the range from 250 to 300 kW. For stockfish, the alternative drying method is by means of sun and wind. For clipfish, the alternative drying method are oil-fired heating systems. Clipfish is Norway's 2nd largest fish export product, after fresh salmon. The average drying temperature is in the range from 20 to 30°C.

Clipfish:	
Number of plants with the process	: 80
Estimated industry growth	: 5%
Existing plants with HP already installed	: 60
Annual operation hours	: 8,000
Heat delivery from existing HP plants (GWh)	: 45
Stockfish:	
Number of plants with the process	: 10
Estimated industry growth	: 5%
Existing plants with HP already installed	: 0
Both Stockfish and Clipfish:	
Total process heat demand for all plants (GWh)	: 67.5 (243 x 1000 GJ/year)
From Chalmers' programme:	
Process no.	: 644
Heat pump type	: El. driven motor closed-circuit compressor
Annual Profit	: See Attachment
Payback	: "
Energy delivered (energy produced by the heat pump)	: "
Drive energy (energy consumed by the heat pump)	: "
Global dT	: 18°C

IFE has estimated a short-term economic potential for 30 heat pump dryers, with an annual heat production of 22 GWh/year /3/.

Results from the market spreadsheet are attached. The average profit scenario concludes with 5 heat pumps installed and 2.8 GWh energy saved in year 1995, and 25 heat pumps installed and 14.4 GWh energy saved in year 2000. The projected emission reduction for CO_2 in year 1995 and 2000 are approximately 969 and 4,877 metric tonnes/year. Total projected emission reductions are 976 and 4,909 metric tonnes/year, included SO_X, NO_X, CO_2, CO, CH_4 and PM.

6.3 Dairies

Dairies are using heat pumps for recovery of waste heat from refrigeration plants, and also for evaporative concentration in cheese production. In December, 1993, there were 120 dairies in Norway, with a total heat demand of 361 GWh.

The demand for cheese in Norway is slowly growing, and there is a tendency to centralize the production of cheese and other dairy products in few and larger factories. An extensive growth in number of heat pump installations in the dairy industry can therefore not be expected.

6.3.1 Heat Recovery from Refrigeration Plants

Milk are pasteurized at 75°C, and then cooled and stored at 4°C. All dairies are using large amounts of hot water for washing at 40 - 50°C, and also steam for sterilisation at 90°C. Waste heat from the refrigeration plants can be used to cover this heat demand, either by direct heat exchange, or by raising the temperature by a heat pump.

There are already installed some closed cycle compression heat pumps for waste heat recovery, and the existing heat pump plants have a heat delivery of 27 GWh/year. Oil fired boilers are the most common alternative to heat pumps in these processes.

Number of plants with the process	:	105
Estimated industry growth	:	3%
Existing plants with HP already installed	:	18
Tot. process heat demand for all plants (GWh)	:	158 (569 x 1,000 GJ/year)
Heat delivery from existing HP plants (GWh)	:	27

IFE has estimated a short-term economic potential for 30 heat pumps for heat recovery from refrigeration plants, with a total annual heat production of 44 GWh/year /3/.

The following data are collected from an analysis of a typical dairy with heat pump for heat recovery /8/. The plant has been calculated with maximum size heat pump, and with 4,500 hours annual operation time:

Heat pump type	:	Electrical driven heat pump, closed circuit
Energy delivered (energy saved by the heat pump)	:	1.5 GWh (5,400 GJ)
Drive energy (energy consumed by the heat pump)	:	0.3 GWh (1,080 GJ)
Working Fluid	:	HCFC-22

Year	1995	2000	2005
Annual profit ($/year)	47,773	50,933	52,533
Payback period (years)	4.9	4.6	4.4

Results from the market spreadsheet are attached. The maximum profit scenario concludes with 2 heat pumps installed and 2.5 GWh energy saved in year 1995, and 8 heat pumps installed and 9.7 GWh energy saved in year 2000. The projected emission reduction for CO_2 in year 1995 and 2000 are approximately 852 and 3,408 metric tonnes/year. Total projected emission reductions are 858 and 3,430 metric tonnes/year, including SO_X, NO_X, CO_2, CO, CH_4 and PM.

6.3.2 Evaporation in Cream/Cheese Production

About 25% of the Norwegian dairies produce cheese in addition to the processes mentioned above. For evaporation in cheese production, 13 dairies has installed mechanical vapour recompression (MVR) systems. The installed MVR's are using turbo compressors, with an approximately temperature lift of approximately 25°C. They are open on the heat source side, and have a heating capacity ranging from 300 to 3,000 kW. A few dairies have installed closed-cycle compression heat pumps for evaporation, using CFC-12 as working fluid, e.g. Østlandsmeieriet Alvdal and Lom/Sjåk, and Nordlandsmeieriet Sortland /11/.

The remaining dairies are using conventional multi-stage oil-fired evaporators. The process is not analyzed with Chalmers' computer programme.

Number of plants with the process	: 28	
Estimated industry growth	: 5%	
Existing plants with HP already installed	: 10	
Total process heat demand for all plants (GWh)	: 62	(223 x 1,000 GJ/year)
Heat delivery from existing HP plants (GWh)	: 22	

From IFE's report /3/:

Heat pump type	: El. driven, closed circuit, no. 1	
Annual Profit	: 560,000 NOK	
Payback	: 8.0 years	
Energy delivered (energy produced by the heat pump)	: 2.2 GWh	(7,900 GJ)
Drive energy (energy consumed by the heat pump)	: 0.2 GWh	(700 GJ)
Working Fluid	: CFC-12	

IFE has estimated a short-term economic potential for 6 MVRs in this market sector, with a total annual heat production of 44 GWh/year /3/.

References

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ED 90-110	Summary Report
ED 90-111	Main Report
ED 90-112	Appendix 1 - Heating Demand
ED 90-113	Appendix 2 - Heat Pump Data
ED 90-114	Appendix 3 - Boundary Conditions
ED 90-115	Appendix 4 - Calculation Results

3. IFE, Institutt for Energiteknikk: *Markedsmulighetene for varmepumper (Market Possibilities for Heat Pumps).* IFE-report no. IFE/KR/F-93/126 Revidert. 1993.

4. NED, Nærings- og Energidepartementet (The Norwegian Ministry of Industry and Energy): *Fossile brenslers plass i det norske energimarkedet (The Position of Fossil Fuels in the Norwegian Energy Market).* 27.09.1993

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6. Tokle, T., Aflekt, K., Grandum, G.: *Brukeroversikt - Kuldemedier i Norge (Refrigerant Use in Norway).* SINTEF Report no. STF11 A93051. Trondheim 1993.

7. Stene, J.: *Varmepumper - Industrielle Anvendelser (Heat Pumps - Industrial Applications).* SINTEF Report STF11A 93009. ISBN 82-595-7162-5. Trondheim 1992.

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11. Sabroe, Personal communication, February 1994.

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Appendices

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Appendix A

Aqua Culture - Fish farming

SECTION 6 - SUMMARY OUTPUT

PROCESS: Aqua Culture - Fish Farming, Heating of Process Water

Current No. of Plants	500
Projected Industry Growth	0%
# Existing Plants w/IHPs	230
Total Process Heat Demand (1,000 GJ/year)	2.160

	1995	2000	2005
Projected Process Heat Demand (1,000 GJ/year)	2.160	2.160	2.160
Supplied by Non-IHP Technologies	0%	0%	0%

IHP Data		Maximum Profit Scenario				Average Profit Scena		
		1995	2000	2005	2010	1995	2000	2005
El. motor driven closed-cycle compression								
Refrigerant Used	HKFK-22							
Payback		2,0	1,8	1,8	1,8	3,0	2,8	2,7
Market Share		100%	100%	100%	100%	100%	100%	100%
Projected Penetration		4%	20%	45%	48%	3%	16%	36%
Projected # of IHPs		20	101	226	239	17	80	181
0								
Refrigerant Used		0						
Payback		0,0	0,0	0,0	0,0	0,0	0,0	0,0
Market Share		0%	0%	0%	0%	0%	0%	0%
Projected Penetration		0%	0%	0%	0%	0%	0%	0%
Projected # of IHPs		0	0	0	0	0	0	0
0								
Refrigerant Used		0						
Payback		0,0	0,0	0,0	0,0	0,0	0,0	0,0
Market Share		0%	0%	0%	0%	0%	0%	0%
Projected Penetration		0%	0%	0%	0%	0%	0%	0%
Projected # of IHPs		0	0	0	0	0	0	0
0								
Refrigerant Used		0						
Payback		0,0	0,0	0,0	0,0	0,0	0,0	0,0
Market Share		0%	0%	0%	0%	0%	0%	0%
Projected Penetration		0%	0%	0%	0%	0%	0%	0%
Projected # of IHPs		0	0	0	0	0	0	0
0								
Refrigerant Used		0						
Payback		0,0	0,0	0,0	0,0	0,0	0,0	0,0
Market Share		0%	0%	0%	0%	0%	0%	0%

SECTION 6 - SUMMARY OUTPUT

PROCESS: Aqua Culture - Fish Farming, Heating of Process Water

	Maximum Profit Scenario				Average Profit Scena		
	1995	2000	2005	2010	1995	2000	2005
Total Projected IHP Penetration	4%	20%	45%	48%	3%	16%	36%
Total Projected # of IHPs	20	101	226	239	17	80	181
	Maximum Profit Scenario				**Average Profit Scena**		
	1995	2000	2005	2010	1995	2000	2005
Net Energy Savings/IHP Energy Delivered (1,000 GJ/year)							
Natural Gas	0	0	0	0	0	0	0
Coal	0	0	0	0	0	0	0
Oil	59	362	857	862	30	171	409
Electricity	12	-26	-148	-157	7	-7	-59
Other	0	0	0	0	0	0	0
Total	71	336	709	705	37	164	350
Net Energy Savings (Million $/year)							
Natural Gas	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Coal	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Oil	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Electricity	0,1	-0,2	-1,4	0,0	0,1	-0,1	-0,5
Total							
-- Million $/yr	0,1	-0,2	-1,4	0,0	0,1	-0,1	-0,5
-- Local Currency	0,7	-1,7	-10,2	0,0	0,4	-0,5	-4,1
(Million/yr)	7,5	NOK per U.S.$					
Projected Emission Reductions (metric tons/year) [excluding IHP refrigerant use]							
SOx	22	117	238	239	11	55	113
NOx	10	58	120	120	5	28	57
CO2	4.583	28.298	66.909	67.290	2.322	13.362	31.944
CO	1	5	13	13	0	3	6
CH4	0	0	1	1	0	0	0
PM	1	5	12	12	0	2	6
Total	4.616	28.485	67.292	67.675	2.339	13.450	32.127
Projected Emission Reductions (tons/year) [excluding IHP refrigerant use]							
SOx	24	129	263	265	12	61	126
NOx	11	65	133	133	5	31	63
CO2	5.073	31.326	74.068	74.490	2.571	14.792	35.362
CO	1	6	14	14	0	3	7
CH4	0	0	1	1	0	0	0
PM	1	6	13	13	0	3	6
Total	5.110	31.533	74.492	74.916	2.589	14.889	35.565

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Appendix B

Fish Products - Drying of Stockfish and Clipfish

No.	Data	Process name	Interval pinch (°C)	Current heating (kW)	Current cooling (kW)	Operation hours/year
643	Simple	Fish Culture	1.	.	.	Unknown

Simple	Fish Culture	Norwegian NT, SINTEF Kuldeteknik	Stene Jorn, Heat Pumps - Industrial Applications, Report no STF11A 93009, ISBN 82-595-7162-5,		
The waste water is used as heat source in a heat pump to heat process water for the fish farming	By heating the process water to 12 - 14 °C it is possible to reduce the growth time for smolt from 2 - 5 years to 15 month.	Explain	Explain	Explain	Explain
Operation hours/year	Current heating (kW)	Current cooling (kW)	Global temperature diff (°C)	Pinch temperature (°C)	
Unknown	0	0	0	1.499994	
Supply temperature (°C)	Target temperature (°C)	Heat load (kW)	delta T contribution (°C)	Heat transfer coefficient (kW/m**2 K)	Comments
12.49999	1.619989	220	0	0	Waste wter
1.499994	12.99999	250	0	0	Process watei
-	-	-	-	-	-
-	-	-	-	-	-

No editing in predefined processes!
Save as new user process and edit.

OK | Cancel | Quit

SECTION 6 - SUMMARY OUTPUT

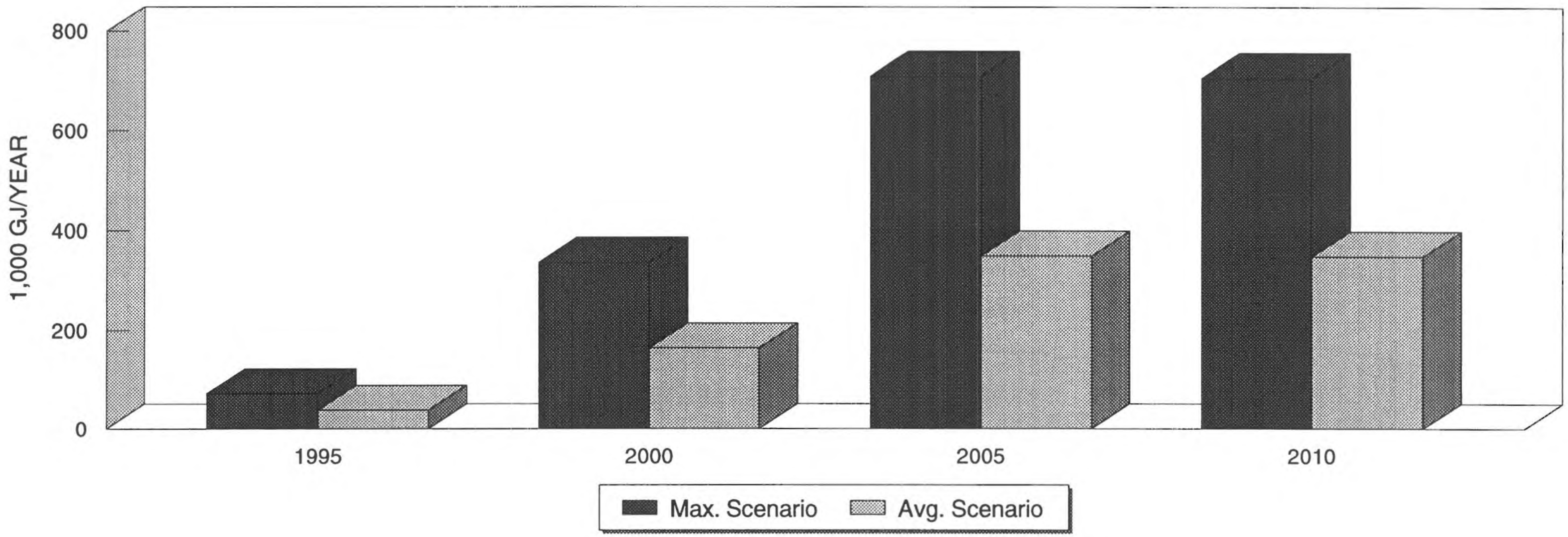
PROCESS: Drying of stockfish and klipfish

Current No. of Plants	90
Projected Industry Growth	5%
# Existing Plants w/IHPs	60
Total Process Heat Demand (1,000 GJ/year)	243

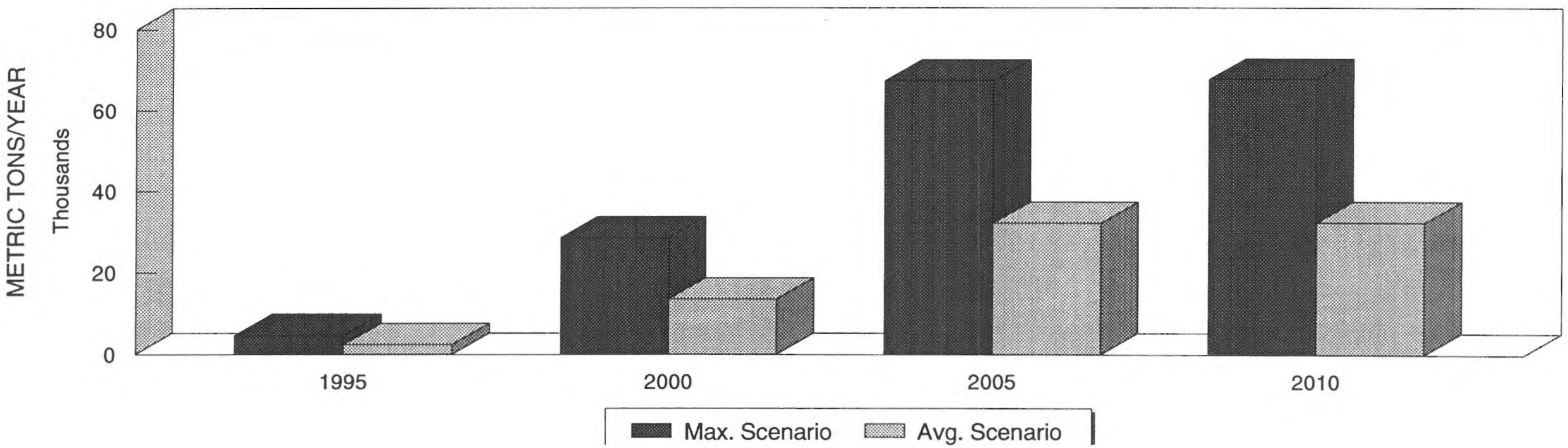
	1995	2000	2005
Projected Process Heat Demand (1,000 GJ/year)	268	342	436
Supplied by Non-IHP Technologies	0%	0%	0%

IHP Data	Maximum Profit Scenario				Average Profit Scena		
	1995	2000	2005	2010	1995	2000	2005
El. motor driven closed-cycle compression							
Refrigerant Used HKFK-22							
Payback	1,3	1,2	1,2	1,2	1,9	1,8	1,8
Market Share	100%	100%	100%	100%	100%	100%	100%
Projected Penetration	5%	20%	45%	48%	5%	20%	45%
Projected # of IHPs	5	25	73	98	5	25	73
0							
Refrigerant Used	0						
Payback	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Market Share	0%	0%	0%	0%	0%	0%	0%
Projected Penetration	0%	0%	0%	0%	0%	0%	0%
Projected # of IHPs	0	0	0	0	0	0	0
0							
Refrigerant Used	0						
Payback	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Market Share	0%	0%	0%	0%	0%	0%	0%
Projected Penetration	0%	0%	0%	0%	0%	0%	0%
Projected # of IHPs	0	0	0	0	0	0	0
0							
Refrigerant Used	0						
Payback	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Market Share	0%	0%	0%	0%	0%	0%	0%
Projected Penetration	0%	0%	0%	0%	0%	0%	0%
Projected # of IHPs	0	0	0	0	0	0	0
0							
Refrigerant Used	0						
Payback	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Market Share	0%	0%	0%	0%	0%	0%	0%

Net Energy Savings



Projected Emission Reductions



No.	Data	Process name	Interval pinch (°C)	Current heating (kW)	Current cooling (kW)	Operation hours/year
643	Simple	Fish Culture	1.	.	.	Unknown

No	Heat pump type	Heat output (kW)
1	Electrical motor driven closed-cycle compression. Reciprocating, R22.	40 to 2400

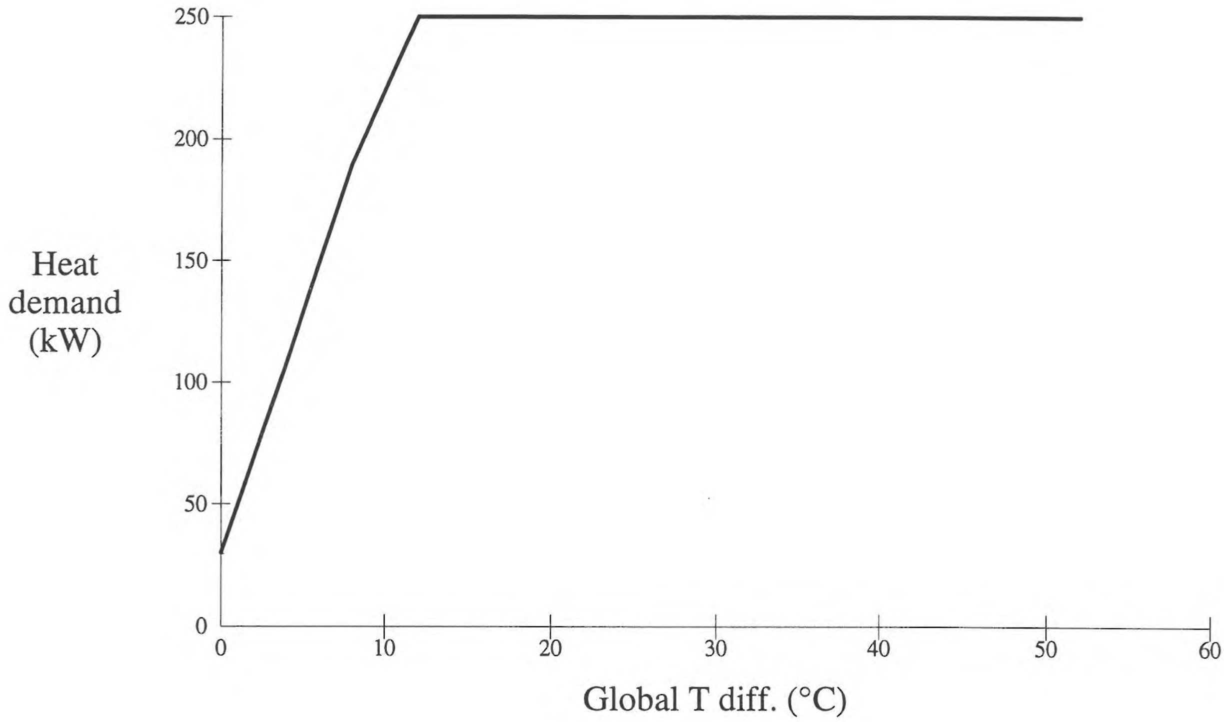
Cost of heat source ($/MJ)	0
Cost of saved energy ($/MJ)	.0081333
Cost of electricity ($/MJ)	.0081333
Annual operation time (hour/year)	8000.
Annuity factor (1/year)	0.25
HE cost: (constant * size ^ 0.6) constant: ($/kW)	1500.
Annual maintenance cost ($/kW)	6.
Optional factor to adjust total installation cost	.5

IHP for maximum energy saving	
Heat delivered (kW)	178.84
Heat del./min. hot utility (%)	71.54
Electricity (kW)	22.75
Payback period (years)	2.0
Annual profit ($)	17782.53
Estimated total investment ($)	70828.3

IHP for average energy saving	
Heat delivered (kW)	89.42
Heat del./min. hot utility (%)	35.77
Electricity (kW)	11.37
Payback period (years)	3.0
Annual profit ($)	4254.66
Estimated total investment ($)	53960.57

OK Cancel Quit

Minimum heat demand. Process no 643



Results valid for process no 643 and IHP no 1	Maximum saving.	Average saving.
Annual heat delivered by the heat pump (MJ)	5150551.	2575275.
Annual electricity consumption (MJ)	655125.8	327562.9
Annual value of heat delivered ($).	41890.97	20945.49
Annual cost of electricity. ($)	5328.33	2664.17
Annual cost of source energy ($).	0.	0.
Estimated heat pump installtion cost ($).	70828.3	53960.57
Estimated number of additional heat exchangers.	0.	0.
Estimated cost of additional heat exchangers ($).	0.	0.
Estimated annual maintenance cost ($).	1073.03	536.52
Payback period (years).	2.0	3.0
Annual profit ($).	17782.53	4254.66
COP (-).	7.86	7.86
Delivering temperature (°C)	20.00	20.00
Extraction temperature (°C)	-1.33	-1.33

1995

OK Cancel Quit

Results valid for process no 643 and IHP no 1	Maximum saving.	Average saving.
Annual heat delivered by the heat pump (MJ)	5150551.	2575275.
Annual electricity consumption (MJ)	655125.8	327562.9
Annual value of heat delivered ($).	45324.84	22662.42
Annual cost of electricity. ($)	5765.11	2882.55
Annual cost of source energy ($).	0.	0.
Estimated heat pump installtion cost ($).	70828.3	53960.57
Estimated number of additional heat exchangers.	0.	0.
Estimated cost of additional heat exchangers ($).	0.	0.
Estimated annual maintenance cost ($).	1073.03	536.52
Payback period (years).	1.8	2.8
Annual profit ($).	20779.63	5753.21
COP (-).	7.86	7.86
Delivering temperature (°C)	20.00	20.00
Extraction temperature (°C)	-1.33	-1.33

2000

OK Cancel Quit

Results valid for process no 643 and IHP no 1	Maximum saving.	Average saving.
Annual heat delivered by the heat pump (MJ)	5150551.	2575275.
Annual electricity consumption (MJ)	655125.8	327562.9
Annual value of heat delivered ($).	47385.07	23692.53
Annual cost of electricity. ($)	6027.16	3013.58
Annual cost of source energy ($).	0.	0.
Estimated heat pump installtion cost ($).	70828.3	53960.57
Estimated number of additional heat exchangers.	0.	0.
Estimated cost of additional heat exchangers ($).	0.	0.
Estimated annual maintenance cost ($).	1073.03	536.52
Payback period (years).	1.8	2.7
Annual profit ($).	22577.8	6652.3
COP (-).	7.86	7.86
Delivering temperature (°C)	20.00	20.00
Extraction temperature (°C)	-1.33	-1.33

2005

OK Cancel Quit

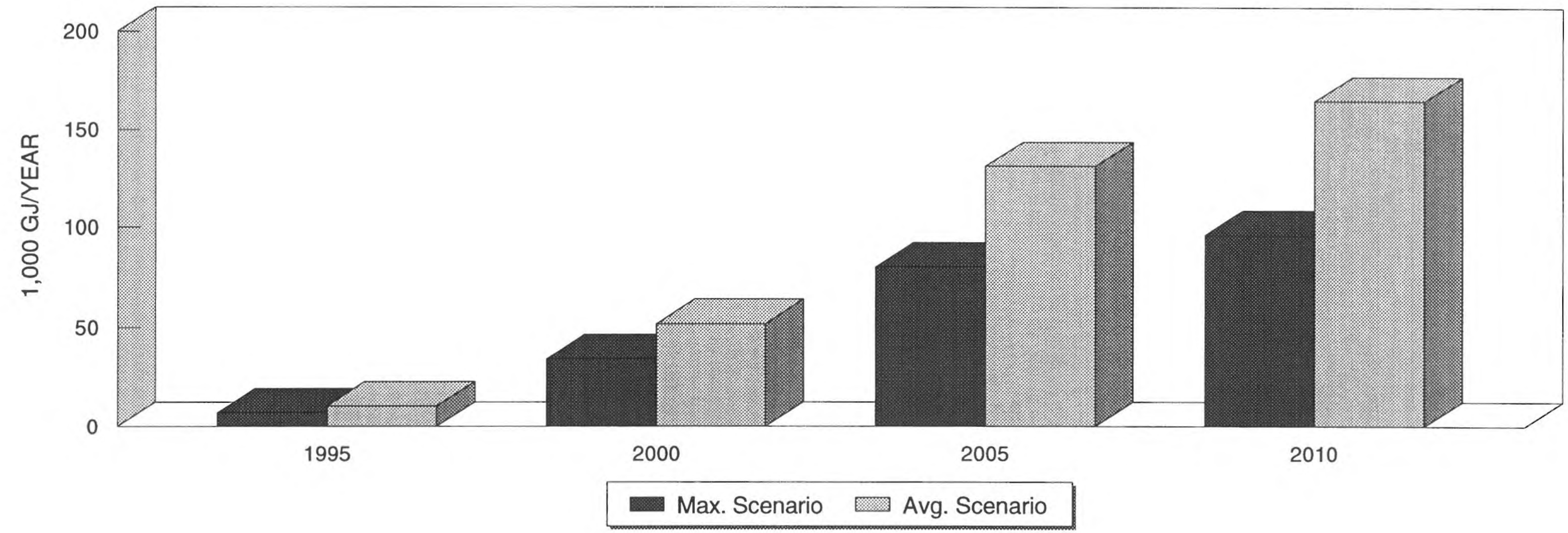
SECTION 6 - SUMMARY OUTPUT

PROCESS: Drying of stockfish and klipfish

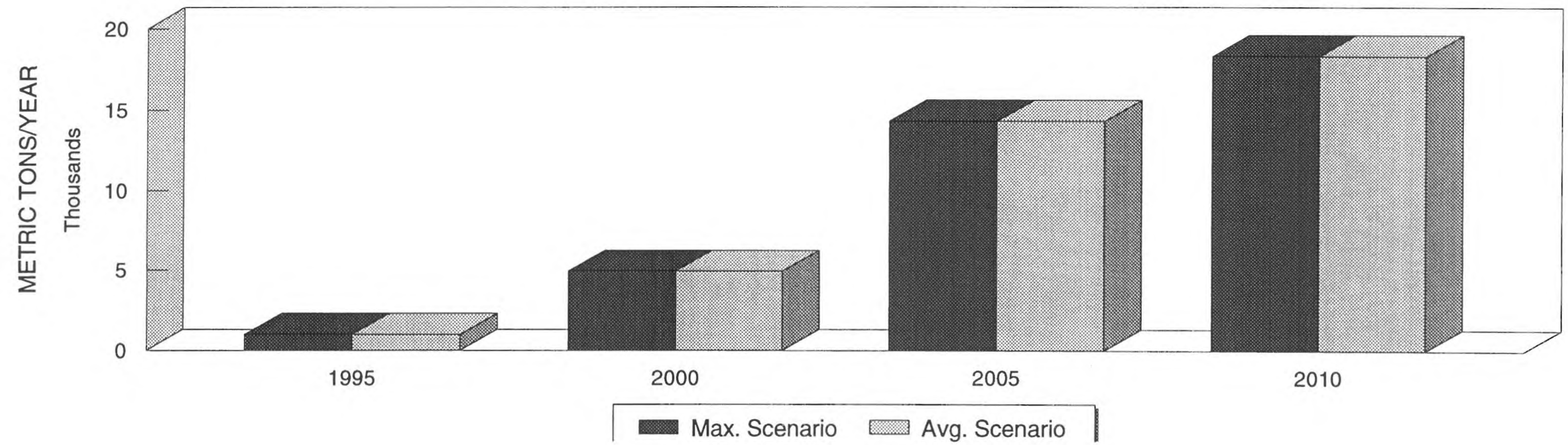
	Maximum Profit Scenario				Average Profit Scena		
	1995	2000	2005	2010	1995	2000	2005
Total Projected IHP Penetration	5%	20%	45%	48%	5%	20%	45%
Total Projected # of IHPs	5	25	73	98	5	25	73

	Maximum Profit Scenario				Average Profit Scena		
	1995	2000	2005	2010	1995	2000	2005
Net Energy Savings/IHP Energy Delivered (1,000 GJ/year)							
Natural Gas	0	0	0	0	0	0	0
Coal	0	0	0	0	0	0	0
Oil	12	62	182	233	12	62	182
Electricity	-7	-35	-102	-137	-3	-17	-51
Other	1	7	0	0	1	7	0
Total	7	34	80	96	10	52	131
Net Energy Savings (Million $/year)							
Natural Gas	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Coal	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Oil	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Electricity	-0,1	-0,3	-0,9	0,0	-0,0	-0,2	-0,5
Total							
-- Million $/yr	-0,1	-0,3	-0,9	0,0	-0,0	-0,2	-0,5
-- Local Currency (Million/yr)	-0,4	-2,3	-7,0	0,0	-0,2	-1,2	-3,5
	7,5	NOK per U.S.$					
Projected Emission Reductions (metric tons/year) [excluding IHP refrigerant use]							
SOx	5	20	51	65	5	20	51
NOx	2	10	25	33	2	10	25
CO2	969	4.877	14.238	18.220	969	4.877	14.238
CO	0	1	3	4	0	1	3
CH4	0	0	0	0	0	0	0
PM	0	1	3	3	0	1	3
Total	976	4.909	14.320	18.324	976	4.909	14.320
Projected Emission Reductions (tons/year) [excluding IHP refrigerant use]							
SOx	5	22	56	72	5	22	56
NOx	2	11	28	36	2	11	28
CO2	1.073	5.399	15.762	20.170	1.073	5.399	15.762
CO	0	1	3	4	0	1	3
CH4	0	0	0	0	0	0	0
PM	0	1	3	4	0	1	3
Total	1.080	5.434	15.852	20.285	1.080	5.434	15.852

Net Energy Savings



Projected Emission Reductions



Results valid for process no 644 and IHP no 1	Maximum saving.	Average saving.
Annual heat delivered by the heat pump (MJ)	11626070.	5813033.
Annual electricity consumption (MJ)	1399432.	699715.9
Annual value of heat delivered ($).	167415.33	83707.66
Annual cost of electricity. ($)	11382.	5691.
Annual cost of source energy ($).	0.	0.
Estimated heat pump installtion cost ($).	198952.5	146921.3
Estimated number of additional heat exchangers.	0.	0.
Estimated cost of additional heat exchangers ($).	0.	0.
Estimated annual maintenance cost ($).	2422.1	1211.05
Payback period (years).	1.3	1.9
Annual profit ($).	103873.1	40075.29
COP (-).	8.31	8.31
Delivering temperature (°C)	25.00	25.00
Extraction temperature (°C)	4.80	4.80

1995

OK Cancel Quit

Results valid for process no 644 and IHP no 1	Maximum saving.	Average saving.
Annual heat delivered by the heat pump (MJ)	11626070.	5813033.
Annual electricity consumption (MJ)	1399432.	699715.9
Annual value of heat delivered ($).	176716.19	88358.09
Annual cost of electricity. ($)	12315.	6157.5
Annual cost of source energy ($).	0.	0.
Estimated heat pump installtion cost ($).	198952.5	146921.3
Estimated number of additional heat exchangers.	0.	0.
Estimated cost of additional heat exchangers ($).	0.	0.
Estimated annual maintenance cost ($).	2422.1	1211.05
Payback period (years).	1.2	1.8
Annual profit ($).	112241.	44259.22
COP (-).	8.31	8.31
Delivering temperature (°C)	25.00	25.00
Extraction temperature (°C)	4.80	4.80

2000

OK Cancel Quit

Results valid for process no 644 and IHP no 1	Maximum saving.	Average saving.
Annual heat delivered by the heat pump (MJ)	11626070.	5813033.
Annual electricity consumption (MJ)	1399432.	699715.9
Annual value of heat delivered ($).	181366.6	90683.3
Annual cost of electricity. ($)	12874.77	6437.39
Annual cost of source energy ($).	0.	0.
Estimated heat pump installtion cost ($).	198952.5	146921.3
Estimated number of additional heat exchangers.	0.	0.
Estimated cost of additional heat exchangers ($).	0.	0.
Estimated annual maintenance cost ($).	2422.1	1211.05
Payback period (years).	1.2	1.8
Annual profit ($).	116331.6	46304.54
COP (-).	8.31	8.31
Delivering temperature (°C)	25.00	25.00
Extraction temperature (°C)	4.80	4.80

2005

OK Cancel Quit

No.	Data	Process name	Interval pinch (°C)	Current heating (kW)	Current cooling (kW)	Operation hours/year
644	Simple	Drying of Stockfish and klipfish	18.	.	.	Unknown

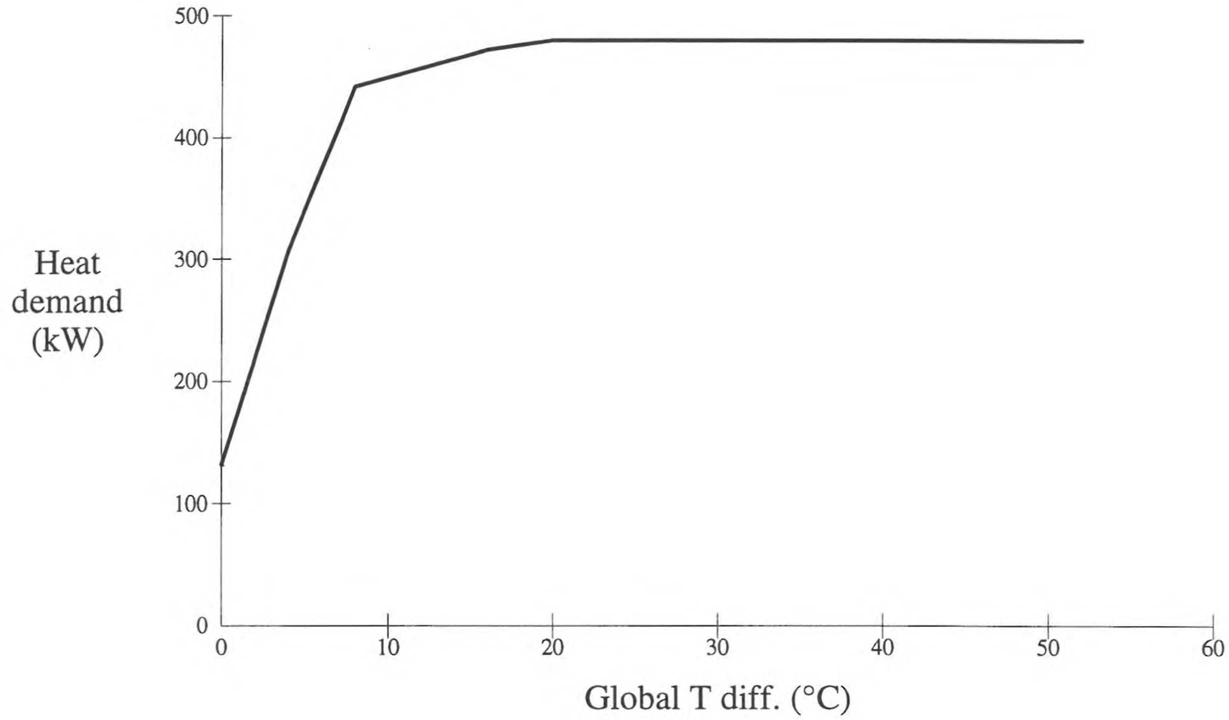
No	Heat pump type	Heat output (kW)
1	Electrical motor driven closed-cycle compression. Reciprocating, R22.	40 to 2400

Cost of heat source ($/MJ)	0
Cost of saved energy ($/MJ)	.0144
Cost of electricity ($/MJ)	.0081333
Annual operation time (hour/year)	8000.
Annuity factor (1/year)	0.25
HE cost: (constant * size ^ 0.6) constant: ($/kW)	1500.
Annual maintenance cost ($/kW)	6.
Optional factor to adjust total installation cost	1

IHP for maximum energy saving	
Heat delivered (kW)	403.68
Heat del./min. hot utility (%)	84.1
Electricity (kW)	48.59
Payback period (years)	1.3
Annual profit ($)	103873.1
Estimated total investment ($)	198952.5
IHP for average energy saving	
Heat delivered (kW)	201.84
Heat del./min. hot utility (%)	42.05
Electricity (kW)	24.3
Payback period (years)	1.9
Annual profit ($)	40075.29
Estimated total investment ($)	146921.3

OK Cancel Quit

Minimum heat demand. Process no 5



No.	Data	Process name	Interval pinch (°C)	Current heating (kW)	Current cooling (kW)	Operation hours/year
5	Simple	Drying of Stockfish and klipfish	18.	.	.	Unknown

No	Heat pump type	Heat output (kW)
1	Electrical motor driven closed-cycle compression. Reciprocating, R22.	40 to 2400

Subcooling in condenser (°C)	5
Super heating in evaporator (°C)	5
Temperature difference between heat sink streams and condenser T (°C)	4
Temperature difference between heat source streams and evaporator T (°C)	6

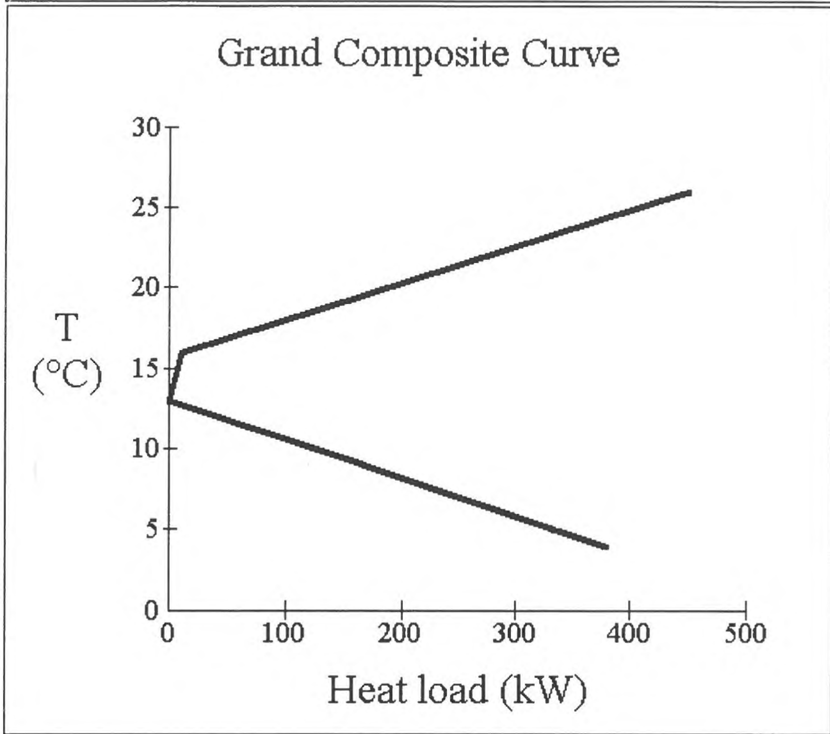
Global minimum T difference 1[illegible]

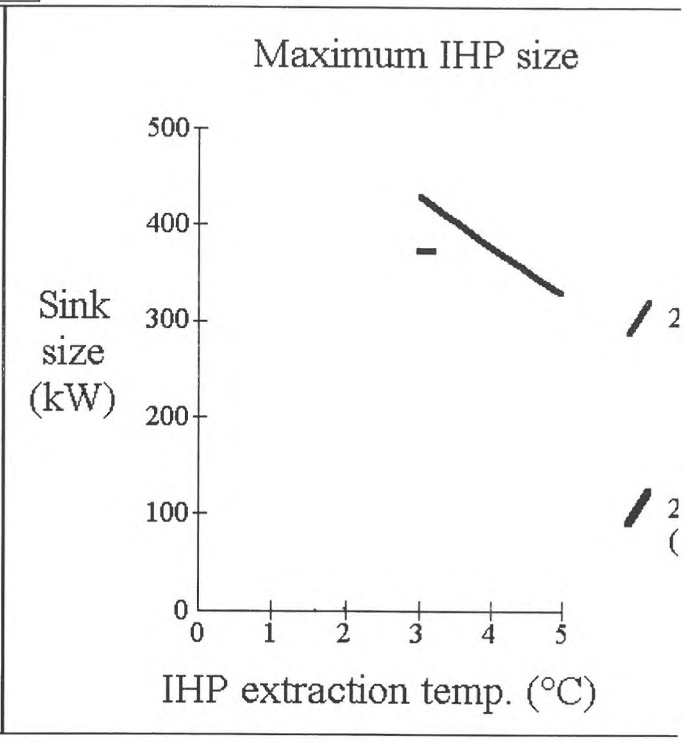
Change or accept values and press 'OK'.

OK Cancel Quit

No.	Data	Process name	Interval pinch (°C)	Current heating (kW)	Current cooling (kW)	Operation hours/year
5	Simple	Drying of Stockfish and klipfish	18.	.	.	Unknown

No	Heat pump type	Heat output (kW)
1	Electrical motor driven closed-cycle compression. Reciprocating, R22.	40 to 2400





OK Cancel Quit

SINTEF

Appendix C

Dairies - Creamery, Evaporation and Heat Recovery

No.	Data	Process name	Interval pinch (°C)	Current heating (kW)	Current cooling (kW)	Operation hours/year
602	Full	Creamery	30.	1008.	.	2000

No	Heat pump type	Heat output (kW)
1	Electrical motor driven closed-cycle compression. Reciprocating, R22.	40 to 2400

Hot streams pinch T	35.	°C
Cold streams pinch T	15.	°C

Cost of heat source ($/MJ)	0
Cost of saved energy ($/MJ)	.0144
Cost of electricity ($/MJ)	.00813333
Annual operation time (hour/year)	2000.
Annuity factor (1/year)	0.25
HE cost: (constant * size ^ 0.6) constant: ($/kW)	1500.
Annual maintenance cost ($/kW)	6.
Optional factor to adjust total installation cost	1

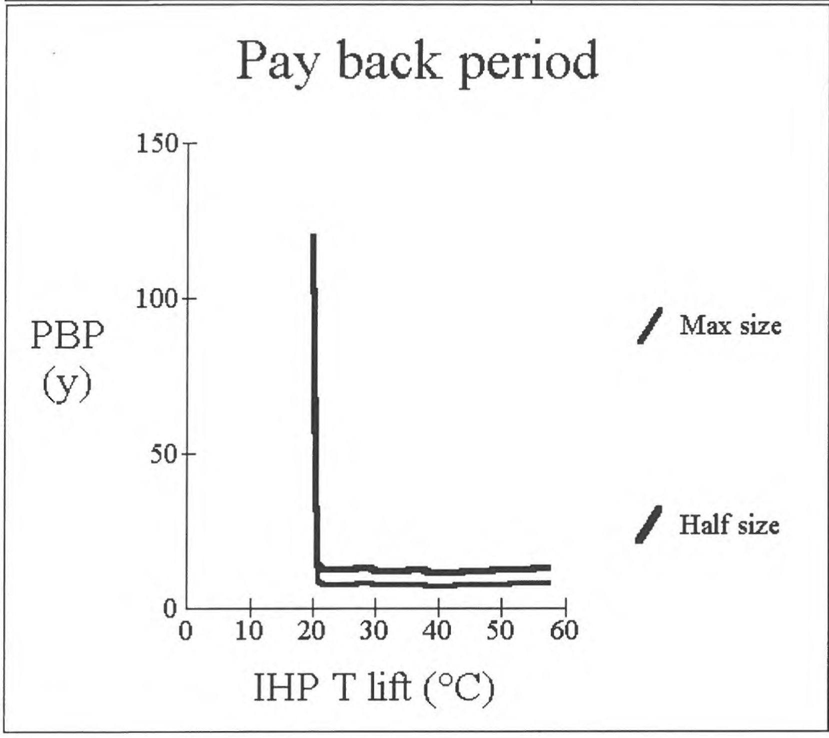
IHP for maximum energy saving	
Heat delivered (kW)	280.96
Heat del./min. hot utility (%)	42.54
Electricity (kW)	39.31
Payback period (years)	7.8
Annual profit ($)	-23922.64
Estimated total investment ($)	196259.2
IHP for average energy saving	
Heat delivered (kW)	140.48
Heat del./min. hot utility (%)	21.27
Electricity (kW)	19.65
Payback period (years)	12.4
Annual profit ($)	-26302.55
Estimated total investment ($)	155494.5

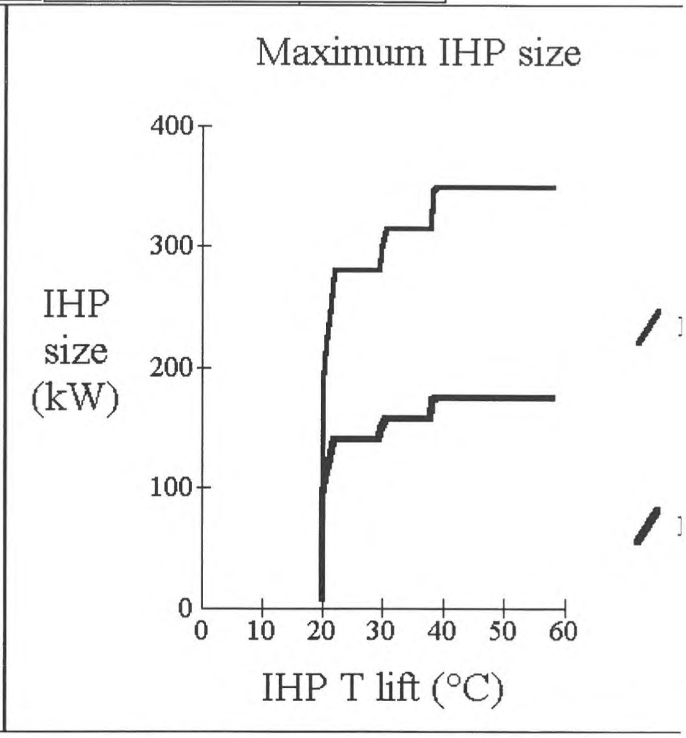
OK Cancel Quit

No.	Data	Process name	Interval pinch (°C)	Current heating (kW)	Current cooling (kW)	Operation hours/year
602	Full	Creamery	30.	1008.	.	2000

No.	Heat pump type	Heat output (kW)
1	Electrical motor driven closed-cycle compression. Reciprocating, R22.	40 to 2400

Hot streams pinch T	35.	°C
Cold streams pinch T	15.	°C





OK | Cancel | Quit

No.	Data	Process name	Interval pinch (°C)	Current heating (kW)	Current cooling (kW)	Operation hours/year
602	Full	Creamery	30.	1008.	.	2000

No.	Heat pump type	Heat output (kW)
1	Electrical motor driven closed-cycle compression. Reciprocating, R22.	40 to 2400

Hot streams pinch T	35.	°C
Cold streams pinch T	15.	°C

Cost of heat source ($/MJ)	0
Cost of saved energy ($/MJ)	.0144
Cost of electricity ($/MJ)	.00813333
Annual operation time (hour/year)	2000.
Annuity factor (1/year)	0.25
HE cost: (constant * size ^ 0.6) constant: ($/kW)	1500.
Annual maintenance cost ($/kW)	6.
Optional factor to adjust total installation cost	.6

IHP for maximum energy saving	
Heat delivered (kW)	280.96
Heat del./min. hot utility (%)	42.54
Electricity (kW)	39.31
Payback period (years)	5.2
Annual profit ($)	-7285.95
Estimated total investment ($)	129712.5

IHP for average energy saving	
Heat delivered (kW)	140.48
Heat del./min. hot utility (%)	21.27
Electricity (kW)	19.65
Payback period (years)	8.4
Annual profit ($)	-13742.33
Estimated total investment ($)	105253.7

OK Cancel Quit

SECTION 6 - SUMMARY OUTPUT

PROCESS: Dairy Cream Production Evaporation

				1995	2000	2005
Current No. of Plants	28		Projected Process Heat Demand			
Projected Industry Growth	3%		(1,000 GJ/year)	237	274	318
# Existing Plants w/IHPs	15		Supplied by Non-IHP Technologies	0%	0%	0%
Total Process Heat Demand (1,000 GJ/year)	223					

IHP Data	Maximum Profit Scenario 1995	2000	2005	2010	Average Profit Scena 1995	2000	2005
MVR, open on source side. Screw							
Refrigerant Used	0						
Payback	4,5	0,0	0,0	0,0	0,0	0,0	0,0
Market Share	100%	ERR	ERR	ERR	ERR	ERR	ERR
Projected Penetration	2%	ERR	ERR	ERR	ERR	ERR	ERR
Projected # of IHPs	1	ERR	ERR	ERR	ERR	ERR	ERR
0							
Refrigerant Used	0						
Payback	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Market Share	0%	ERR	ERR	ERR	ERR	ERR	ERR
Projected Penetration	0%	ERR	ERR	ERR	ERR	ERR	ERR
Projected # of IHPs	0	ERR	ERR	ERR	ERR	ERR	ERR
0							
Refrigerant Used	0						
Payback	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Market Share	0%	ERR	ERR	ERR	ERR	ERR	ERR
Projected Penetration	0%	ERR	ERR	ERR	ERR	ERR	ERR
Projected # of IHPs	0	ERR	ERR	ERR	ERR	ERR	ERR
0							
Refrigerant Used	0						
Payback	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Market Share	0%	ERR	ERR	ERR	ERR	ERR	ERR
Projected Penetration	0%	ERR	ERR	ERR	ERR	ERR	ERR
Projected # of IHPs	0	ERR	ERR	ERR	ERR	ERR	ERR
0							
Refrigerant Used	0						
Payback	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Market Share	0%	ERR	ERR	ERR	ERR	ERR	ERR

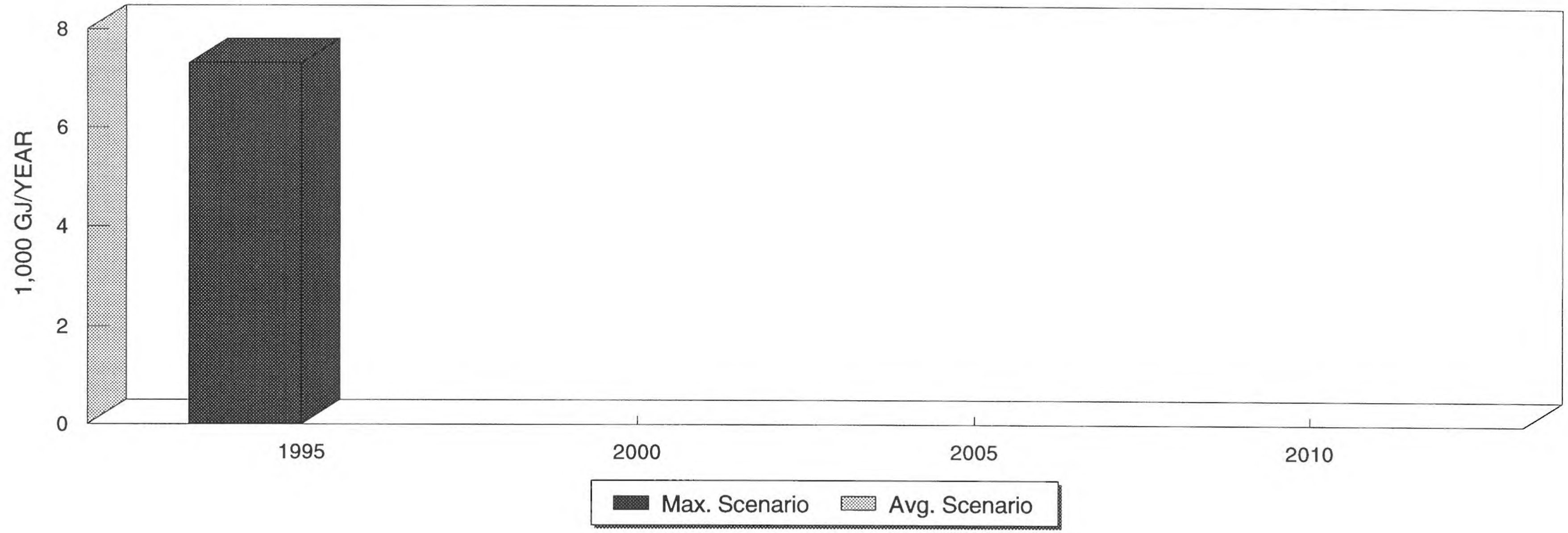
SECTION 6 - SUMMARY OUTPUT

PROCESS: Dairy Cream Production Evaporation

	Maximum Profit Scenario				Average Profit Scena		
	1995	2000	2005	2010	1995	2000	2005
Total Projected IHP Penetration	2%	ERR	ERR	ERR	ERR	ERR	ERR
Total Projected # of IHPs	1	ERR	ERR	ERR	ERR	ERR	ERR

	Maximum Profit Scenario				Average Profit Scena		
	1995	2000	2005	2010	1995	2000	2005
Net Energy Savings/IHP Energy Delivered (1,000 GJ/year)							
Natural Gas	0	ERR	ERR	ERR	ERR	ERR	ERR
Coal	0	ERR	ERR	ERR	ERR	ERR	ERR
Oil	0	ERR	ERR	ERR	ERR	ERR	ERR
Electricity	7	ERR	ERR	ERR	ERR	ERR	ERR
Other	0	ERR	ERR	ERR	ERR	ERR	ERR
Total	7	ERR	ERR	ERR	ERR	ERR	ERR
Net Energy Savings (Million $/year)							
Natural Gas	0,0	ERR	ERR	ERR	ERR	ERR	ERR
Coal	0,0	ERR	ERR	ERR	ERR	ERR	ERR
Oil	0,0	ERR	ERR	ERR	ERR	ERR	ERR
Electricity	0,1	ERR	ERR	ERR	ERR	ERR	ERR
Total							
-- Million $/yr	0,1	ERR	ERR	ERR	ERR	ERR	ERR
-- Local Currency	0,4	ERR	ERR	ERR	ERR	ERR	ERR
(Million/yr)	7,5	NOK per U.S.$					
Projected Emission Reductions (metric tons/year) [excluding IHP refrigerant use]							
SOx	ERR	ERR	ERR	ERR	ERR	ERR	ERR
NOx	0	ERR	ERR	ERR	ERR	ERR	ERR
CO2	0	ERR	ERR	ERR	ERR	ERR	ERR
CO	0	ERR	ERR	ERR	ERR	ERR	ERR
CH4	0	ERR	ERR	ERR	ERR	ERR	ERR
PM	0	ERR	ERR	ERR	ERR	ERR	ERR
Total	ERR	ERR	ERR	ERR	ERR	ERR	ERR
Projected Emission Reductions (tons/year) [excluding IHP refrigerant use]							
SOx	ERR	ERR	ERR	ERR	ERR	ERR	ERR
NOx	0	ERR	ERR	ERR	ERR	ERR	ERR
CO2	0	ERR	ERR	ERR	ERR	ERR	ERR
CO	0	ERR	ERR	ERR	ERR	ERR	ERR
CH4	0	ERR	ERR	ERR	ERR	ERR	ERR
PM	0	ERR	ERR	ERR	ERR	ERR	ERR

Net Energy Savings



Projected Emission Reductions