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Norwegian Heat Pump Status and Policy Review

Refrigeration Engineering

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SINTEF Refrigeration Engineering

Address: N-7034 Trondheim, Norway
Location: Kolbjørn Hejes vei 1D
Phone: +47 73 59 39 00
Fax: +47 73 59 39 26
Telex: 55 620 sintf n

Enterprise no.: 948007029

REPORT

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Norwegian Heat Pump Status and Policy Review

AUTHOR(S)

Jørn Stene, Geir Eggen, Rune Aarlien and Kjetil Evenmo

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ABSTRACT

This report is *the Norwegian National Position Paper* on heat pumps prepared for the IEA Heat Pump Centre's 1994 analysis, "International Heat Pump Status and Policy Review". The main objectives of this analysis is to provide an authoritative assessment of: the achievements of policy measures regarding heat pumps, the current and expected penetration of heat pumps in all market segments, and the technological status of various heat pumping technologies.

The report includes the following surveys:

Important Basic Factors determining the impact of heat pumps including energy resources and energy use, energy prices in various market sectors, climatic conditions, building stock and prevailing heat and cold distribution systems with typical distribution temperatures.

The Norwegian Energy and Environmental Policies and the position of heat pumps therein including the accomplished Heat Pump Implementing Programme, the Norwegian Strategy Plan for the Heat Pump Sector, national regulations relevant to heat pumps, and national regulations/legislation with regard to refrigerants.

Heat Pump Technology Status and RD&D including the state-of-the-art heat pump technology, status on refrigerant use, and ongoing/accomplished research and development programmes and projects.

KEYWORDS	ENGLISH	NORWEGIAN
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NATIONAL POSITION PAPER

NORWAY

PRESENTED TO THE HEAT PUMP CENTRE

BY

THE NORWEGIAN NATIONAL TEAM

PREPARED BY SINTEF REFRIGERATION ENGINEERING

PREFACE

The Norwegian National Position Paper (NPP) on heat pumps is prepared for the IEA Heat Pump Centre's 1994 analysis, "International Heat Pump Status and Policy Review". The main objectives of this analysis is to provide an authoritative assessment of: the achievements of policy measures regarding heat pumps, the current and expected penetration of heat pumps in all market segments, and the technological status of various heat pumping technologies.

The NPP for Norway is worked out by M.Sc. student Kjetil Evenmo in cooperation with Mr. Jørn Stene, Mr. Geir Eggen and Mr. Rune Aarlien at SINTEF Refrigeration Engineering, and includes the following surveys:

Important Basic Factors determining the impact of heat pumps including energy resources and energy use, energy prices in various market sectors, climatic conditions, building stock and prevailing heat and cold distribution systems with typical distribution temperatures.

The Norwegian Energy and Environmental Policies and the position of heat pumps therein including the accomplished Heat Pump Implementing Programme, the Norwegian Strategy Plan for the Heat Pump Sector, national regulations relevant to heat pumps, and national regulations/legislation with regard to refrigerants.

Heat Pump Technology Status and RD&D including the state-of-the-art heat pump technology, status on refrigerant use, and ongoing/accomplished research and development programmes and projects.

The Norwegian Heat Pump Market including heat pump types in various market sectors, important market constraints, heat production from heat pumps and heat pump investment costs.

SINTEF Refrigeration Engineering
Trondheim, September 1993

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1. Basic Factors

1.1 Climate

The climatic conditions in Norway are presented in terms of degree day curves for 4 representative regions; Oslo (fiord climate - Southern Norway), Bergen (coastal climate - South Western Norway), Røros (inland climate) and Tromsø (coastal climate, Northern Norway), Figure 1.1.

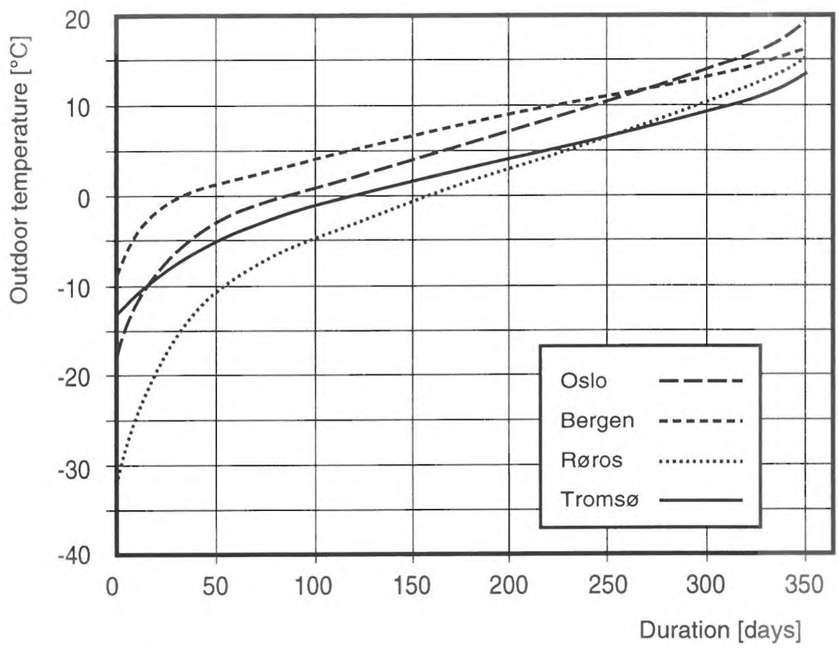


Figure 1.1: *Cumulative Degree Days for 4 representative climatic regions in Norway.*

The design outdoor temperature, DOT (three days minimum) and the seasonal average temperature, SAT for the same regions are listed in Table 1.1.

REGION	**DOT**	**SAT**
Oslo	-20°C	5.9°C
Bergen	-10°C	7.8°C
Røros	-40°C	0.5°C
Tromsø	-12°C	2.9°C

Table 1.1 *Design outdoor temperature (DOT) and seasonal average temperature (SAT) for 4 representative climatic regions in Norway.*

Appendix A : *Ground water temperatures in Norway*

Appendix B : *Sea water temperatures in Norway*

1.2 Energy Resources and Energy Use

Table 1.2 shows the annual domestic production and consumption of primary energy in Norway in 1992. The difference between domestic production and consumption represents the net export of primary energy. Norway's production of crude oil and natural gas in the North Sea is significant, and more than 90% of the oil and 95% of the gas is exported. Another import aspect is the electricity generation from hydro power, which comprise more than 60% of the total annual domestic energy consumption in Norway. About 10 TWh electricity is exported to Denmark, Sweden, and Finland.

	Annual Domestic Production	Annual Domestic Consumption
Oil [1000 metric tonnes]	118,866	5,481
Natural Gas [1000 Sm^3]	27,732,000	103,000
Pit Coal [1000 metric tonnes]	391	1,519
Hydropower [TWh_{el}]	117.7	96.6
Renewables (Windpower) [TWh_{el}]	0.007	0.007
Biomass (Fuelwood, black liquor, garbage) [TWh]	11.6	10.6

Table 1.2: *Primary energy resources and consumption - annual national consumption and production in 1992.*

The primary energy mix for electricity generation is presented in Table 1.3. Virtually all electricity in Norway is generated from hydro power, and most of the water turbines yield a high energy efficiency. About 0.4% of the electricity is generated by combustion of black liquor in paper mills, while a negligible share is generated in wind generators etc.

	Share [%]	Average turbine efficiency [%]
Hydropower	99.6	92
Renewables	0.006	-
Others (black liquor)	0.4	-

Table 1.3: *Primary energy mix for electricity generation in 1992.*

Final energy resources result from primary energy after transformation into forms suitable for use in industry, transport, buildings, agriculture etc. They include electricity, district heat, solid fuels and petroleum products. Table 1.4 on the following page indicates the final energy use in Norway in 1992, with particular reference to energy applications where heat pumps could be relevant, ie. space heating, space cooling, hot water heating and industrial processes operating below 200°C. The Higher Heating Value (HHV) is used to determine the energy content of fuels. Feedstocks are not included.

	Total Energy Consumption [GWh/yr]	Space Heating [GWh/yr]	Space Cooling [GWh/yr]	Hot Water Heating [GWh/yr]	Process Heat [GWh/yr]	
					< 200°C	> 200°C
Electricity	96,600	22,000	120	8,700	2,300	10,000
District Heat	1,016	726	0	290	0	0
Oil (based on H.H.V.)	66,100	11,700	0	1,600	6,400	2,800
Gas (based on H.H.V.)	0,800	0	0	0	0	0
Coal (based on H.H.V.)	12,800	400	0	100	1,500	8,600
Other (biomass etc.)	11,100	3,000	0	0	0	0

Table 1.4: *Final energy use in Norway (1992) - total, and use in areas relevant to heat pumps.*

Table 1.5 indicates the end use energy prices ($/kWh) in various market sectors (1993).

	Oil [US$/kWh]	**Coal [US$/kWh]**	**Electricity [US$/kWh]**		**District Heat [US$/kWh]**
			Low	**High**	
Homes	0.035-0.04	-	0.015	0.065	0.04-0.065
Commercial/Inst. Bldgs.	0.035-0.04	-	0.015	0.065	0.04-0.065
District Heating	0.04-0.065	-	0.04-0.065	0.04-0.065	0.04-0.065
Industrial	0.025-0.04	0.034	0.015	0.020	0.04-0.065

Table 1.5: *End use energy prices in various market sectors in 1993 (1US$ = 7 NOK). The Higher Heating Value (HHV) of fuels is used to determine their energy content. LOW= occasional power, HIGH =firm power.*

1.3 Houses and Buildings

Table 1.6 gives the size of the residential and commercial/institutional building stock, both new (ie. built in 1991), and existing. The average heat demand (including heat for hot tap water) and cooling demand is indicated for the various types of buildings.

	Building Stock [number of flats]		**Av. Heat Demand [MWh/yr]**		**Av. Cooling Demand [MWh/yr]**	
	New	Existing	New	Existing	New	Existing
Single Family Homes	7,000	972,000	19	20	0	0
Multi Family Homes	14,500	808,000	10	11	0	0
Commercial/Inst. Buildings (m^2)	$2*10^6$	$85*10^6$	1)	375 2)	1)	1)

Table 1.6: *Building stock and average heating/cooling demand in 1991. 1) There are no available statistics - total heat demand incl. hot tapwater 12.5 TWh, and total cooling demand 0.12 TWh. 2) MWh/year.*

Table 1.7 and 1.8 indicate the share of the prevailing heat and cold distribution systems in homes and commercial/institutional buildings in 1991, respectively. It is distinguished between *new* (1991) and *existing* homes/buildings.

		New Homes				Existing Homes			
		Heating[1)]		Cooling		Heating[1)]		Cooling	
		Temp. [°C]	Share [%]	Temp. [°C]	Share [%]	Temp. [°C]	Share [%]	Temp. [°C]	Share [%]
Heat Distribution System	Air	30-40	10	-	-	30-40	10	-	-
	Floor	30-50	10	-	-	30-50	5	-	-
	Radiators	50-80	20	-	-	50-80	10	-	-
Cold Distribution System	Air	-	-	-	-	-	-	-	-
	Water	-	-	-	-	-	-	-	-
Electric radiators		-	60	-	-	-	75	-	-
None		-	0	-	-	-	0	-	-
TOTAL:		-	100	-	-	-	100	-	-

Table 1.7: *Type, typical delivery temperature and percentage share of heat and cold distribution systems in homes. [1)] Most homes have a combination of heating systems (2.3 heating systems per house in average). 80% of the households have a combination of electric heating (electric radiators and/or electric boiler) and other heating systems (oil, firewood etc.), while 20% have electric heating only.*

		New Commercial/Institutional Buildings				Existing Commercial/Institutional Buildings			
		Heating[1)]		Cooling		Heating[1)]		Cooling	
		Temp. [°C]	Share [%]	Temp. [°C]	Share [%]	Temp. [°C]	Share [%]	Temp. [°C]	Share [%]
Heat Distribution System	Air	30-50	25	-	-	30-50	35	-	-
	Floor	30-50	35	-	-	30-50	5	-	-
	Radiators	50-80	25	-	-	50-80	40	-	-
Cold Distribution System	Air	-	-	15	30	-	-	15	30
	Water	-	-	13	70	-	-	13	70
Electric radiators		-	15	-	-	-	20	-	-
None		-	-	-	-	-	-	-	
TOTAL:		-	100	-	100	-	100	-	100

Table 1.8: *Type, typical delivery temperature and percentage share of heat and cold distribution systems in commercial/institutional buildings. 55% of the buildings have electric heating only (electric radiators and/or electric boilers), 40% have a combination of electric heating and oil fired boilers, while 5% have no electric heating at all.*

1.4 Industry

Table 1.9 lists energy intensive industry sectors, and indicates processes at moderate temperatures suitable for the application of heat pumps.

Industry Sector	Process	Temperature range [°C]
Aqua culture (fish farming)	• Heating of process water	5-15
Fish products	• Drying • Evaporative concentration	5-30 (100) 80-100
Pulp and paper	• Drying • Evaporative concentration	50-70 100-120
Leather	• Drying	40-60
Dairies	• Drying • Evaporative concentration	15-25 60-80
Chemical industry	• Steam production	110-120

Table 1.9: *Energy intensive industry sectors and processes suitable for the application of heat pumps.*

1.5 Future Trends

The most important basic factors in the future (other than policy measures), which are expected to affect the market penetration of heat pumps and competing heating system in Norway are expected to be:

- In new houses and buildings in all market sectors the insulation standard is constantly improved, consequently resulting in reduced spesific heating requirement [kWh/m^2]. Older buildings are also renovated to a large extent including improved insulation standard, new windows etc. Generally, a reduced specific heating requirement makes it less interesting to install heat pumps because the absolute energy saving potential is lowered.

- The indoor climate in both residential and commercial/institutional buildings has been given stronger priority the recent years, thus increasing the potential for exhaust air heat pumps in single/multi family houses and heat pumps for space conditioning (heating/cooling) in commercial/-institutional buildings. The market penetration of the latter type of systems is also influenced by the fact that internal heat gains in this kind of buildings is getting more significant due to increased use of heat emitting technical installations, such as computers and lighting systems. It is also a trend towards glass ceiling and glass front constructions in commercial buildings, which results in high specific heating and cooling requirements.

- Stipulated increase in oil prices, 1.6% per year. The oil price is expected to remain low in the coming 3-5 years. A low oil price favour use of oil fired boilers in central heating systems, both in industry and the commercial/residential sector.

- Stipulated increase in electricity prices, 3.5% per year. Norway has established a free market on electricity, which means that consumers in industry and commercial sectors (residential sector later) can buy electricity where they are offered the lowest price and the best conditions. This has contributed to *lower electricity prices* due to free competition between the various energy utilities (no regional monopoly situation). As a general consequence it has become more difficult to carry out energy saving measures by means of eg. heat pumps. A high electricity price will always favour heating with fossil fuels, while a very low electricity price will favour electric radiators and electro boilers.

2. Energy and Environmental Policy Relevant to Heat Pumps

2.1 General

This chapter gives a general overview of the Norwegian energy conservation and environmental policy relevant to heat pumps and competing systems. It is also describes the role of heat pumps in the national and utilities policy.

Norway is in general, strongly involved in energy and environmental policies both nationally and internationally. The authorities have given financial support for research and training on the energy conservation area since 1974. The most important strategies and objectives today are listed below:

- Loan- and subsidy arrangements for:
  - *Accomplishment of energy conservation attempts, including consultancy and analysis.*
  - *Research and development in the energy conservation area, including heat pumps.*
  - *Research and development of new, renewable energy sources, such as sun-, wind-, wave- and biomass energy.*

- In 1993 the Government distributed NOK 421 mill. ($ 60 mill.) in grants for activities within the energy conservation area.

- Financial support for establishment of Energy Conservation Centres.

- Introduction of a "free" electricity market. Due to the surplus energy this has resulted in lower electricity prices.

- The Energy Utilities are instructed to inform the consumers about the energy conservation attempts that possibly can be accomplished in their buildings.

- Today Norway is exporting electric power to Sweden, Finland, and Denmark, and is evaluating the possibilities for export of more power, eg. to Germany.

- The authorities are evaluating a new financial programme for energy conservation attempts where the value of the energy saving will be used to cover the financing. Hence, those who are selling the products are guaranteeing energy savings.

- The energy conservation attempts which are profitable today will be realised within 2005.

- Continued active participation and cooperation through the International Energy Agency (IEA).

The Authorities have in the recent years been giving improved frame requirements in the energy conservation area, namely for heat pumps. This is due to the fact that installation of heat pumps is considered to be a very important measure in saving energy and reducing environmental harmful emissions. *However, due to a general cut down in the Norwegian National Budget for 1994, the economic situation for heat pump research/development and promotion is considerably deteriorated, ie. very low budgets.*

2.2 Heat Pump and Energy Programmes/Policies

2.2.1 The Heat Pump Implementing Programme

The "Heat Pump Implementing Programme" was divided into 3 sub-programmes: HP-INFO (information, dissemination), HP-P&D (prototype and development) and HP-IEA (international activity through the International Energy Agency).

a) Goals of the programme:

- To promote the use of heat pumps as a part of an efficient, economic and environmentally acceptable energy system in Norway.

- To create a market for Norwegian suppliers and ensure that the suppliers deliver high qualitiy products which satisfy users' operating and maintenance requirements.

- To exchange information and cooperate in international fora in order to benefit from and contribute to international efforts to boost the use of heat pumps.

- To establish 3 major heat pump installations (over 5 MW), 10 medium-sized heat pump installations (2-5 MW) and 20 smaller heat pump installations (0.2-2 MW).

b) Type of programme: Technology transfer programme (promotion).

c) Total budget of NOK 23 mill. ($ 3.3 mill.)

d) Duration: 1989-1992 (4 years)

f) Results/achievements:

- About 20 heat pump courses with more than 600 participants from energy utilities, consultants, industry etc. were held during the programme period.

- Interest in heat pumps increased during the programme period, and suppliers reported a steady increase in sales of heat pumps in Norway.

- The programme has presented comprehensive reports on forty different heat pump installations monitored before or during the programme period.

- The programme has contributed to make the transition to approved refrigerants easier for everyone concerned.

- The programme has prepared comprehensive teaching material, including various text books, computer programmes, hand books, manuals, brochures etc.

- The heat pump programme has participated in the IEA's Implementing Agreement on Advanced Heat Pump Systems.

2.2.2 The Norwegian Strategy Plan for the Heat Pump Sector

This is a continuation of the Promotion Programme described in the previous section 2.2.1.

a) Goals of the programme:

ENERGY CONSERVATION:
- Technology and knowledge dissemination;
- Increase the number of heat pump installations;
- Heat supplied from heat pumps in 1996 - 3 TWh/year;
- Heat supplied from heat pumps in 2000 - 4 TWh/year.

ENVIRONMENT:
- Within year 2000 natural refrigerants including ammonia, CO_2, and hydrocarbons (propane etc.) should be the dominating refrigerants in new heat pump installations.

INDUSTRY DEVELOPMENT:
- Development and market introduction of at least two new export-related heat pump products by the end of 1996.
- Development of the Norwegian trade and industry for the heat pump sector.

b) Type of programme: Research, development and technology transfer.

c) Budget for 1993 is NOK 6.65 mill. ($ 1 mill.)

d) Duration: 1993 - 1996 (to be continued in 1997 - 2000).

Due to a general cut down in the Norwegian National Budget for 1994, the Heat Pump Programme is more or less postponed, and only a small activity will take place in 1994.

2.2.3 National Regulations Relevant to Heat Pumps

1) The energy prices are regulated by environment taxes and the new Energy Legislation (1991):
   - Environment taxes on fossil fuels (Appendix C).
   - The Energy Legislation introduced open competition on the Norwegian energy market. In a "normal year" Norway has surplus of electric power, and this leads to cheaper electricity (both firm and occasional power). This situation may easily change in the future.

2) The subsidy programme:
   - Energy conservation investments/projects are subsidised by 15-20%;
   - Heat pump investments in the private sector have been subsidised by 30% from 1993.1.1.

3) Environmental pollution regulations for the industry:
   - Infringement of this regulation will result in penalty.

2.2.4 Energy Policies and Programmes Indirectly Relevant to Heat Pumps

a) Programme for Cleaner Technology and Energy Conservation

a) Goals of the programme:

- To develop a methodology for integrated technical energy- and environment analyses.

b) Budget for 1992 : NOK 2.8 mill. ($ 0.4 mill.).

c) Duration: 1991 - 1994.

b) Programme for Trade Network

a) Goals of the programme:

- Reduce the specific energy consumption in the industry sector.
- Influence the industry groups in such a way that they set realistic energy-saving goals.
- Improve the communication between the industry and the authorities.

b) Duration : 1990 →

c) Results: Today it is 325 member achievements spread over 12 trades.

2.3 Environmental Programmes and Policies

2.3.1 Reducing the Emission of Environmental Harmful Gases

a) Goals of the programme:

CO_2 : Human affected emissions of carbon dioxide (CO_2) in the year 2000, shall not exceed the emission in the year 1989.

SO_2: Sulphur dioxide - 50 % reduction of 1980 level within 1993.

NO_x: Nitrogen oxides - 30 % reduction of 1986 level within 1998.

CFCs: ChloroFluoroCarbons - The Norwegian CFC-regulations from July 1991 bannes all installation and sale of *new* heat pumps using CFCs as refrigerants. From 1st of January 1995 all import of CFCs will be prohibited. A small amount of recovered/recycled CFC will be commercially available in a transition period.

HCFCs: Regarding HCFC-22, Norway has ratified the 1992 Copenhagen Amendment, but it is expected that more stringent regulations will be imposed in the coming years as in Germany (ie. accelerated phase-out schemes). This will include prohibition of HCFC-22 in *new* heat pump and refrigeration installations.

2.3.2 National Regulations and Legislations w.r.t. Refrigerants

As described in the previous chapter it will still be possible to buy recycled CFCs from retrofitted and scrapped heat pumps after 1995.01.01, but the amount available will be sufficient to cover only a minor part of the total CFC demand. Thus, most heat pumps using CFC-12, CFC-114, R-500 or R-502 have either to be retrofitted to non-CFC refrigerants or replaced with new equipment within a reasonable period of time (5 years).

The new national regulations on ammonia from 1993 are rather strict. Depending on the total refrigerant charge in the heat pump system and other system characteristics, special safety measures are required. This includes eg. two stage gas alarm system, enhanced ventilation system, sprinkler system etc. The use of ammonia in heat pumps is also prohibited in certain applications, eg. in *direct* ventilation systems in commercial buildings.

The use of flammables (eg. propane and HFC-152a) in heat pumps in Norway is still rare, and is only applied in installations with low refrigerant charge. The necessary safety precautions are stated in each case by the local fire station officer, following the more general regulations on flammables. Guidelines for handling of flammable refrigerants in heat pump installations have been worked out by SINTEF Refrigeration Engineering in cooperation with the Norwegian authorities.

3. Heat Pump Technology Status and RD&D

3.1 Heat Pump Performance

Table 3.1 gives typical seasonal performance factors (SPFs) for *heat pumps in buildings* (family houses and commercial/institutional buildings) as well as for heat pumps installed in district heating systems. District heating heat pumps utilize either sea water or untreated sewage as heat sources. In Norway the electricity is entirely based on hydro power, and *all heat pumps are electrically driven* due to relatively low electricity prices.

		Air source (ambient)	**Ground source** (soil, geotherm.)	**Water source** (sea water, rivers, lakes, groundwater)	**Waste Heat source** (sewage, ventilation air, industrial waste heat etc.)
Family Houses	**Electric**[1)]	2.0-2.5	2.5-3.5	3.0-4.0	3.5-4.0
District Heating	**Electric**	-	-	3.0-4.0	3.0-4.0
Commercial/Inst. Bldgs	**Electric**	2.5-3.5	3.0-3.5	3.0-3.5	3.5-7.0

Notes: 1) For Electric Heat Pumps: SPF defined as $\frac{\text{Heat Out } [MWh_{th}/yr]}{\text{Electricity In } [MWh_{el}/yr]}$

Table 3.1: *Typical SPFs for heat pumps installed in family homes, commercial/institutional buildings and district heating systems.*

Table 3.2 gives a range for typical performance factors (mean COP in the operating period) for *industrial heat pumps*. It is indicated a range of heat source temperatures and achieved temperature lifts. Industrial heat pumps in Norway are either mechanical vapour recompression (MVR) systems or closed electrically driven systems.

	Performance Factor Definition	**Source Temp. (range)** [°C]	**Temp. Lift (range)** [°C]	**Performance Factor (range)**
Open (M.V.R.)	$\frac{\text{Heat Out } [MWh_{th}]}{\text{Shaft Energy In } [MWh]}$	50-100	10-40	10-25
Closed - electric driven	$\frac{\text{Heat Out } [MWh_{th}]}{\text{Electricity In } [MWh_{el}]}$	10-70	20-70	3-10

Table 3.2: *Performance factors and temperature ranges for industrial heat pumps in Norway.*

3.2 Refrigerants (Working Fluids)

Table 3.3 gives an estimate of the various refrigerants (working fluids) used in installed compression type heat pumps in various market sectors (tonnes). In new heat pump installations *HCFC-22* and *HFC-134a* are the dominating refrigerants in the residential and commercial/institutional sector, while *ammonia* is frequently used in large heat pump installations. *Blends* are mainly applied when retrofitting existing heat pump and refrigeration plants using CFC-12 or R-502.

Market Sector	CFCs [tonnes]	HCFCs [tonnes]	HFCs [tonnes]	NH_3 [tonnes]
Residential	5	5	0	0
Commercial/Institutional	25	150	0.1	2
District Heating	20	0	0.2	2
Industrial	5	50	0	20

Table 3.3: Use of refrigerants in compression type heat pumps in various market sectors (total refrigerant charge, 1993).

Figure 3.1 shows the same figures as Table 3.3, presented as share in each market sector.

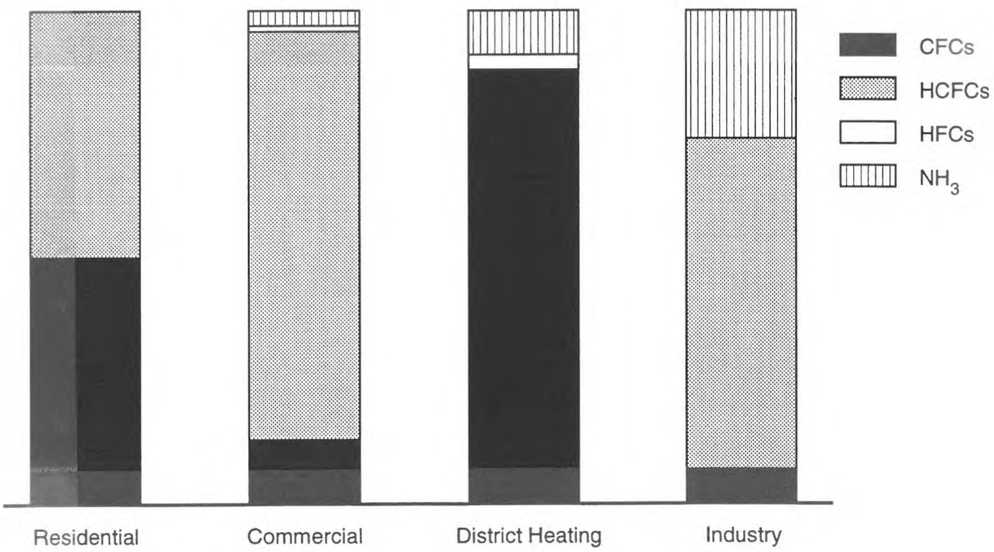


Figure 3.1: *Refrigerants used in existing heat pumps in various market sectors (percentage in each market sector).*

3.3 Research, Development and Demonstration (RD&D)

In Norway the focus is on the utilization of *natural substances* as refrigerants (working fluids), ie. *ammonia* (NH_3), *hydrocarbonss* (eg propane) and *carbon dioxide* (CO_2). The research and development activity is currently concentrating on low-charge ammonia heat pump systems and compact heat pumps with propane as refrigerant. Design rules for heat pumps using ammonia or flammables as refrigerants are being worked out as well.

The recent years a high-efficient air-conditioning system for automobiles using *carbon dioxide* as refrigerant has been developed. Carbon dioxide is also considered a very promising refrigerant in various refrigeration systems, hot water heat pumps and large heat pump applications.

17 heat pump installations using ammonia, propane and HFCs are built as prototype and demonstration plants, Table 3.4. The heat pumps are installed in commercial/institutional buildings, district heating systems, ice rinks and industry, and their thermal output range from about 30 kW to 2,500 kW.

PLANT	HP-OUTPUT (kW)	REFRIGERANT
SEA WATER BASED HEAT PUMPS:		
1. HP - district heating, Bodø	2,000	ammonia
2. Sjøkrigsskolen, Bergen	400	HFC-134a
3. Vallersund Farm	40	HFC-152a
4. The University of Bergen[1)]	2,500	ammonia
5. Research Centre of Statoil	900	ammonia
AIR BASED HEAT PUMPS		
6. Bjørnheim Borettslag	45	HFC-152a
7. Statens Kjølemaskinistskole	30	ammonia
GROUND COUPLED HEAT PUMPS		
8. Bølerskogen Borettslag	45	HFC-134a
9. Skaarsetlia church, Lillehammer	40	propane
10. Desentralized HP system, Birkenes[1)]	200	HP62
ICE RINKS		
11. Hamar Olympiahall	800	ammonia
12. Hamar Ishall	375	ammonia
13. Haakonshallen, Lillehammer	500	ammonia
INDUSTRIAL HEAT PUMPS		
14. TIMAR (fish farming)	585	ammonia
15. Tromsø Aqua Culture Research Centre	725	ammonia
15. Melbu Fiskeindustri (supercharge heat pump)	150	ammonia
16. Hallingsdalsbruket (drying of wood)	200	ammonia

Table 3.4: *Main data on R&D installations using non-CFC refrigerants. The heat pumps will be monitored in 1993/94. 1) To be built in 1994.*

Table 3.5 on the following page presents main data on 40 R&D heat pumps installations built and monitored by SINTEF Refrigeration Engineering in the period 1980-89.

PLANT	HP-output (kW)	HP energy prod. (MWh/yr)	Equivalent operating time (h/year)	Supply/ return temp. (°C)	SPF	Investment HP-system (1000 NOK)	Spes. inv. HP-system (NOK/kW)	Refrigerant
SEA WATER BASED HEAT PUMPS								
Marientek, Sandefjord	90	550	6,100	50/40	2.5	400	4,400	HKFK-22
Favusgården, Harstad	120	600	5,000	43/35	3.5	480	4,000	HKFK-22
Ljones Greenhouse, Hardanger	750	3,000	4,000	50/40	3.4	1,500	2,130	HKFK-22
Ålesund Townhall	310	800	2,600	43/35	3.0	1,050	3,400	HKFK-22
Royal Garden Hotel	800	3,200	4,000	50/40	4.0	1,185	1,500	HKFK-22
Hadsel Folkehøgskole	200	700	3,500	70/60	2.9	700	3,500	KFK-12
Gamvik Kommune	300	1,500	5,000	60/50	3.0	1,600	5,330	KFK-12
Polplast, Tromsø	70	122	1,750	50/40	2.1	395	5,640	HKFK-22
Hotal Maritim, Haugesund	310	1,000	3,230	70/60	2.9	300	1,000	KFK-12
Fylkesbåtane i Sogn- og Fjordane	45	195	4,330	45/35	3.2	247	5,500	HKFK-22
Protan, Haugesund	6,800	45,000	6,620	50/35	4.0	10,000	1,470	HKFK-22
Stokmarknes Hospital	400	2,300	5,750	70/60	2.7	1,700	4,250	KFK-12
Widerøes Airplane Hangar, Bodø	530	1,600	3,000	50/40	3.3	1,450	2,750	HKFK-22
HP district heating, Ålesund	6,000	27,000	4,500	90/60	3.5	27,000	4,500	KFK-12
AIR BASED HEAT PUMPS								
Sintef Adm. building	130	410	3,150	80/45	2.5	850	6,500	KFK-12
Common air/water-HP, Heimdal	16	61	3,810	60/50	2.5	150	9,400	HKFK-22
Air/air-HP, detach. house, Heimdal	3.5	11	3,150	-	2.4	30	8,600	KFK-12
Air/air-HP, detach. house, Heimdal	4.5	12	2,700	-	2.4	30	6,700	HKFK-22
Exhaust air HP - hot water prod.	1	4	4,000	50	2.4	10	10,000	KFK-12
Heat exch. + HP - hot water prod.	1	4	4,000	50	2.2	12	12,000	KFK-12
Grude Greenhouse	45	180	4,000	-	3.0	150	3,330	HKFK-22
Dalaker Greenhouse	108	410	3,800	-	3.0	224	2,070	HKFK-22
Medhus Greenhouse	28	142	5,070	30/20	3.9	52	1,860	HKFK-22
Gruben Road Station	56	175	3,130	50/40	2.6	374	6,680	HKFK-22
Mosjøen Road Station	90	360	4,000	-	2.5	713	7,920	HKFK-22
Air/air-HP, detach. house, Askim	4.7	19	4,000	-	2.4	35	7,500	HKFK-22
Alexandra Hotel, Loen	400	2,000	5,000	54/45	2.9	1,400	3,500	R-500
Bjørnheim B/L, Oslo	65	350	5,400	55	2.5	850	13,000	HFK-152a
GROUND COUPLED HEAT PUMPS								
Soil/water-HP, detach. house	12	18	1,500	55/45	2.4	80	6,700	HKFK-22
Holmin Greenhouse	250	1,000	4,000	55/45	3.3	430	1,700	HKFK-22
HP District heating, Målselv	52	207	4,000	55/45	2.7	530	10,000	HKFK-22
Sagen, Kristiansand	50	212	4,200	55/45	2.7	400	8,000	R-502
Brødrene Muhre, Jevnaker	12	34	2,800	40/35	2.9	100	8,300	HKFK-22
Søsterheimen B/L, Stord	18	66	3,700	55/45	2.3	148	8,200	HKFK-22
WASTE WATER BASED HEAT PUMPS								
HP District Heating - Skøyen Vest	2,200	12,000	5,500	90/60	3.0	-	-	KFK-12
HP Distr. Heat./Cool., Sandvika	13,000	65,000	5,000	90/60	3.8	-	-	R-500
Industriarbeidermuseet, Rjukan	240	820	3,400	45/35	5.6	1,465	6,100	HKFK-22
Matre Akva (fish farming)	490	1,925	4,000	-	6.6	520	1,100	HKFK-22
Timar, Slørdal (fish farming)	585	1,670	2,900	-	7.7	900	1,500	ammonia
Midt-Finnmark Smolt (fish farm.)	390	780	2,000	-	5.8	800	2,000	HKFK-22

Table 3.5: *Main data on 40 R&D heat pump installations built and monitored in the period 1980-89.*

Research and Development Programmes and Projects

Development of non-CFC Heat Pumps (Compact-Aggregate with HFC-152a)

The project was carried out in 1991. The main goals were: 1) To prove practical heat pump design with CFC-free refrigerants so they safely can be recommended for commercial use. 2) To test a compact-aggregate with HFC-152a (flammable/explosive) under normal and "stressed" operating conditions.

The main results achieved are: 1) After 1,200 hours in operation only moderate contents of acid in the refrigerant and lubricant was found. 2) Because of the explosion hazard, various safety measures have to be implemented in heat pump installations using HFC-152a.

CFC Reduction in Existing Heat Pump and Refrigeration Installations

The programme was carried out in the period 1991-92 (2 years). The main goals were: 1) To detect refrigerant leakage by means of adding tracer gases. 2) To reuse (recycle) CFC refrigerants.

The main results achieved are: 1) The refrigerants in ordinary installations are little polluted with the most harmful pollutions, namely acid, and this is favourable for the recycling process. 2) It is necessary to clean the refrigerants before reuse (remove oil and water), and the actual cleaning methods are filtration and decoction. 3) All tracer gases (smell substances) functioned well for leakage detection at the liquid side.

Development of a New Ammonia Technology for Small and Medium-sized Heat Pumps and Refrigeration Installations

The programme was started up in 1991 and will be accomplished medio 1994. The main goals are: 1) To develop an ammonia heat pump that fulfil the necessary safety demands, and which is able to compete technically with conventional heat pumps with CFC or HCFC refrigerants. 2) To minimize the refrigerant charge in heat pump installations.

The main results achieved are: 1) One ammonia-based prototype heat pump has been built (25 kW thermal output, 17 kW cooling capacity). Refrigerant charge in the region 50-100 gram/kW is practicable. 3) The physical size of the installation is, compared with eg. traditional heat pump installations using CFCs and HCFCs, considerably reduced.

4. Heat Pump Markets

4.1 Heat Pumps Installed, 1989 - 1992

Table 4.1 indicates the number of heat pumps installed in the period 1989 - 1992.

Market Sector	1989	1990	1991	1992
Single Family Homes	800	1,000	1,200	1,320
Multi Family Homes	20	20	20	25
Commercial/Institutional Buildings	300	300	300	310
District Heating Systems (< 100 users)	1	0	0	1
Industry	50	50	50	50

Table 4.1: *Number of heat pumps installed in various market sectors, 1989 - 1992.*

Figure 4.1 provides a more detailed overview of types and sizes of heat pumps sold in 1991 and the total number of heat pumps installed.

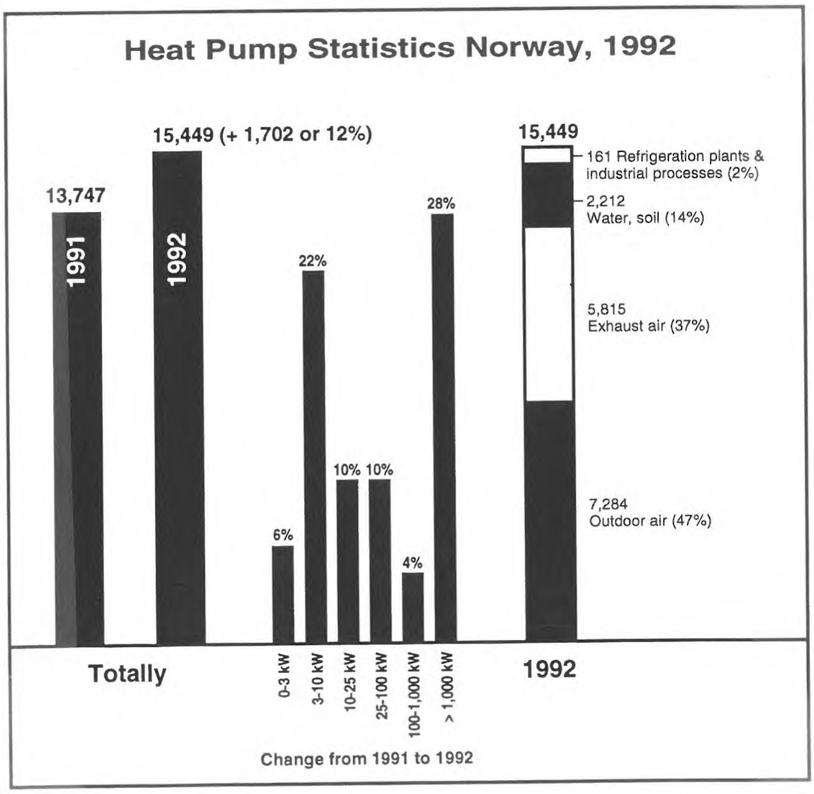


Figure 4.1: *Types and sizes of heat pumps sold in Norway in 1991 (1,702 installations), and the total number of heat pumps installed (15,449 inst.). It is distinguished between various sizes (0-3 kW, 3-10 kW, 10-25 kW, 25-100 kW, 100-1,000 kW and > 1,000 kW) and heat sources (industrial, water/soil, exhaust air and outdoor air).*

4.2 Heat Pump Types in Various Heat Pump Market Sectors

Table 4.2 indicates the number of various heat pump types currently installed in *homes* (1992). It is distinguished between heat sources and sinks, room or central heat pumps, water heater heat pumps, integrated systems, monovalent or bivalent installations, and new or retrofit installations (replacement of heating systems in existing buildings).

Heat Source		Air Source (ambient)	Ground Source (soil, geotherm.)	Water Source (sea water, rivers, lakes, groundwater, etc.)	Waste Heat source (e.g. ventilation air, sewage, industrial waste heat)
Heat Sink:	Air	2,500	0	0	2,300
	Water	200	1,000	100	2,900
Drive Energy:	Electric	2,700	1,000	100	5,200
	Room HPs	2,700	0	0	0
	Central	0	1,000	100	5,200
Water Heater Heat Pumps		0	10	0	2,700
Integrated Systems		100	900	80	0
	Monovalent	0	500	0	0
	Bivalent	300	500	100	5,200
	New	200	500	50	5,000
	Retrofit	2,500	500	50	200

Table 4.2: *Number of various types of heat pumps currently installed in homes in Norway (1992).*

All heat pumps in the residential sector are *electrically driven* and most of the systems are bivalent, using firewood, oil fired boilers, electro boilers or electric radiators as auxiliary heating (peak load). Room heat pumps are reversible air-to-air heat pumps, while central heat pumps using other heat sources than outdoor air are installed in central heating systems, ie. hydronic systems (radiators or floor heating) or ventilation systems. The vast majority of water heater heat pumps utilize ventilation exhaust air as heat source. Integrated systems are heat pumps combining tap water heating and space heating (no space cooling).

Table 4.3 on the following page indicates the number of heat pumps currently installed in *commercial/institutional buildings* (1992). It is distinguished between heat sources and sinks, whether a central, multi-zone or loop system is installed, and whether the heat pump is a stand-alone heater or not. All heat pumps in the commercial/institutional sector are *electrically driven.*

Heat Source		Air Source (ambient)	Ground Source (soil, geotherm.)	Water Source (sea water, rivers, lakes, groundwater, etc.)	Waste Heat source (ventilation air, sewage, industrial waste heat)	Other
Heat Sink:	Air	3,000	0	0	100	400
	Water	300	500	500	600	0
Drive Energy:	Electric	3,300	500	500	700	400
	Central	300	500	500	400	0
	Multi-Zone	3,000	0	0	300	0
	Loop	0	0	0	0	400
Water Heater Heat Pumps		0	0	10	50	0
Integrated Systems		200	200	200	100	0
	Stand-alone	0	100	100	100	200
	Combined with boiler	3,000	400	400	600	200
	New	300	250	250	600	200
	Retrofit	3,000	250	250	100	200

Table 4.3: *Number of various types of heat pumps in commercial/institutional buildings in Norway (1992).*

About 400 heat pumps are installed in swimming pools for dehumidification (loop systems), while 700 integrated systems provide combined tap water heating / space heating or combined tap water heating and space conditioning (heating/cooling). Bivalent, central heat pumps are installed in hydronic systems, and supply heat to radiators, floor heating systems and ventilation aggregates. Auxiliary heating (peak load) is provided by oil fired boilers and/or electro boilers.

Table 4.4 indicates the number of various types of district heating heat pumps. All heat pumps installed in district heating systems in Norway are *electrically driven*, and utilize either sea water or untreated sewage as heat source.

Heat Source		Water Source (sea water)	Waste Heat source (sewage)
Drive Energy:	Electric	3	2

Table 4.4: *Number of various types of district heating heat pumps in Norway (1992).*

Industrial heat pumps in Norway are either open mechanical vapour recompression (MVR) systems using process vapour as working fluid or traditional closed-cycle systems. All industrial heat pumps are *electrically driven.* Table 4.5 indicates the number of the main types of heat pumps in the most important industry sectors where heat pumps are used. Some 650 heat pumps are installed (1992), and they are mainly applied for various drying purposes (lumber, fish, leather), evaporation processes (dairies, paper mills), heating of process water i fish farms and for heat recovery from refrigeration plants, mainly in the fish industry.

Industry Sector:	Fish Farming	Fish Industry	Wood conver-sions	Meat products	Dairies	Leather
Open (M.V.R.)	0	3	5	0	10	0
Closed - electric	250	100	200	50	10	50

Table 4.5: *Number of various types of industrial heat pumps (1992).*

Figure 4.2 provides a more detailed graphical presentation of industrial heat pump installations in Norway.

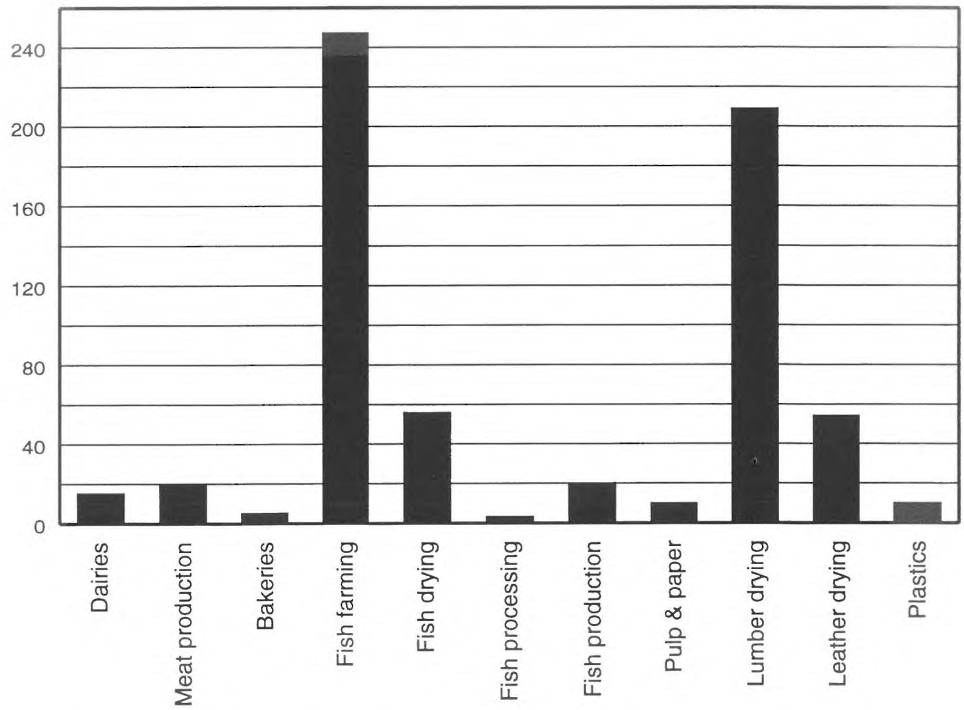


Figure 4.2 *Number of heat pump installations in various industry sectors (1992).*

4.3 Heat Pumps and the Total Heat Demand

Table 4.6 indicates the total heat demand in various market sectors in 1992 (residential, commercial/-institutional, industry), and the heat demand which is covered by heat pumps.

	Total Heat Demand [TWh/yr]	Provided by Heat Pumps [TWh/yr]
Single Family Homes	16	0.4
Multi-family Homes	10	0.4
Commercial/Institutional buildings	12	0.6
District heating systems (< 100 users)	1.016	0.12
Industry	15	1.2

Table 4.6: *Heat demand in Norway and heat delivered by heat pumps in various market sectors (1992).*

4.4 Heat Pump Investment Costs

Table 4.7 indicates the range of investment costs for heat pumps per kW installed thermal capacity for various heat pump sizes and for various applications (1993). The ranges are rather wide due to variations in heat sources (water/air), heat distribution systems (water/air), use of standard or tailored units, complexity of the plants etc. Extra costs for installing a possible new heat distribution system is not included in the figures.

	< 5 kW [US$/kW]	5 - 25 kW [US$/kW]	25 - 500 kW [US$/kW]	0.5 - 1 MW [US$/kW]	> 1 MW [US$/kW]
Residential	1,000-1,700	900-1,400	600-1,300	-	-
Commercial/Institutional	1,000-1,700	200-1,400	150-1,100	150-500	150-500
Industrial	-	700-1,200	150-900	150-400	150-500

Table 4.7: *Indication of the range of investment costs for heat pumps (1993). Extra costs for installation of a possible new heat distribution system is not included. 1US$ = 7 NOK.*

4.5 Market Constraints

The most significant market constraints are regarded to be:

In General for all Sectors:

- Heat pumps are still considered a "new" technology by consulters, contractors, building owners etc., and general statements as; "Heat pumps are expensive and they are less reliable in operation than traditional heating systems", are common. As a consequence oil fired boilers, electro boilers and resistance heating are normally the first (traditional) choice. This problem was one of the main tasks dealt with in The Heat Pump Implementing Programme (section 2.2.1).

- The low energy prices (electricity/oil) makes heat pumps less profitable than conventional heating systems.

- The Energy Utilities have an important position in implementing energy conservation in Norway. At the same time they are, however, in the energy business and they are interested in selling as much electricity as possible, and energy saving is given second priority.

- Uncertainty concerning refrigerants (CFCs and HCFCs).

Residential Sector:

- Roughly 60% of the households in Norway are single family homes. In most of the older, residential buildings, there are other energy conservation measures than heat pumps that first have to be accomplished, eg. improved insulation standard, installation of new windows etc.

- Residential heat pumps are in general very expensive (>1,000 $/kW output), and high investment costs (long pay-back time) is a limiting factor.

- The majority of residential heat pump installations in Norway are ambient air-to-air heat pumps for space heating or systems utilizing exhaust air as heat source for combined tap water heating and space heating. Most of the ambient air heat pumps in the market have unsuitable evaporator design for cold climates, insufficient defrosting systems (yields low COP) and last but not the least, they should only be installed in houses where proper air circulation is achievable. Moreover, exhaust air heat pumps require a ventilation system for being installed.

Commercial/Institutional Sector:

- The rather high investment costs is a limiting factor.

- About 80% of the existing buildings and 85% of the new buildings have installed central heating systems (hydronic systems). There is, however, a general problem with high temperature requirements, normally in the range from 60°C to 80°C, resulting in poor seasonal performance factor (SPF) for the heat pump installations and less profitability.

Industrial Sector:

- Industry have in general access to cheap occasional power (electricity), and this often implies in a too long pay-back period for heat pumps (> 3 years).

4.6 Market Trends

Residential Sector:

- The most common heat pump aggregates in the residential sector are small ambient air-to-air heat pumps, delivered as compact aggregates with low refrigerant charge (~0.2 kg/kW). Exhaust air heat pumps for combined tap water heating and space heating (integrated systems) are also popular.

Commercial/Institutional Sector:

- There is a general trend towards integrated space heating and space cooling systems (combined heat pump/chiller systems).

Industrial Sector:

- Integration of heat pumps in different industrial processes is becoming more and more common. The most common processes are drying and evaporative concentration. Fluidized bed drying at both high and low temperatures is also a promising technology.

5. Potential International Activities

In order to establish projects and programs between a group of several participants representing different countries, one needs good ideas. As soon as interesting *ideas* for joint projects pop up, there is no problem getting a group together with the purpose of solving challenges and problems.

Suggestions for potential international cooperation could be:

1) Heat Pump Reliability

   An annex on heat pump reliability with the aim of analyzing different causes for heat pump failures and breakdowns could be very interesting. All kinds of heat pumps should be investigated. The results from this annex would give answers that could be of invaluable benefit to heat pump designers and installers. Many experts maintain that the main problem with heat pump failures is located peripheral to the heat pump itself, and that poor workmanship done by installers and plummers is what really causes the trouble.

2) Cost Reductions

   An ever returning and strong incentive to forget about investing in heat pumps is their high investment cost. What it finally comes down to for most people, is economics, and perhaps is this the largest barrier for the heat pump industry today. Set a goal of 33 percent cost reduction, and create an annex around the question: How can heat pumps be produced with a price tag 33 percent lower than today, while at the same time the maintaining healthy profit margins for manufacturers?

3) Statistics

   The Heat Pump Centre could act as a resource center on heat pump statistics. Continuously updated, such information could be of importance to many countries in their argumentation for heat pumps in general. Among other things, there should be information on world total number of heat pumps (also broken down for the different countries), types and sizes of heat pumps, working fluids (types and volumes), manufacturers, etc.

The issue to be discussed here should not only be ideas for potential collaboration projects, but also, the issue of how we can ensure a constant flow of new ideas, that could result in new projects. In other words, how do we organize our work in order to encourage new ideas and innovation?

Suggestions on how to facilitate this could be:

4) Annual Idea Competition

   Ask people for suggestions and ideas regularly, and all the time. A critical issue here is that if one wants something in return, one also got to give something. Therefore, good suggestions must be rewarded. One could, for instance, institute a World Annual Heat Pump Award for the overall best idea contributing towards the Implementing Agreement objectives. This price should be handed out at a larger conference (for example, the International Heat Pump Conference).

5) "New Annexes": First Agenda Item at EXCO Meetings

If we really would like to stress the necessity of establishing new annexes, put "New Annexes" on top of the meeting agenda of each EXCO meeting, and make the delegates come prepared.

6) Brainstorming Sessions

Organize brainstorming sessions in connection with workshops, conferences, and other meetings, and demand *action* from *someone*, and reward action with benefits that could not be obtained otherwise (for instance, financial support to the meeting).

6. Discussion and Conclusion of National Situation

The conditions for using heat pumps in Norway are favourable. The climate yields a long heating season, the minimum outdoor temperatures are moderate in most of the country and a large part of the population is living along the coast, where the sea water is an excellent heat source (relatively high temperatures due to the Golf Stream). Because the electric power generation is entirely based on hydro power, only electric heat pumps are applied in Norway. Compared with electric or absorption heat pumps in countries where power generation is more or less based on fossil fuels, the overall efficiency of the energy system is considerably higher.

The penetration of heat pumps in Norway is closely linked to the electricity and oil prices. A generally high price level and similar prices between oil and electricity favour the use of heat pumps. Low oil prices and cheap firm electricity favour traditional heating systems such as oil fired boilers, electro boilers and resistance heating (electric radiators).

Another important aspect is the lack of knowledge among consultants, contractors, building owners etc. Heat pumps are still considered a "new" technology, and general statements as; "Heat pumps are too expensive and less reliable in operation than conventional heating systems", are quite common. As a consequence oil fired boilers, electro boilers or electric radiators are often chosen instead of heat pumps. It is therefore important to continue the work from "The Heat Pump Implementing Programme" (section 2.2.1) by means of general heat pump promotion, technology transfer, courses etc.

Norway has through international agreements set a limit for emission of various harmful gases, ie. CO_2, SO_2, NO_x and CFC's. One of the means to reach these objectives is to influence the use of heat pumps through favourable support arrangements. Investment in and installation of heat pumps are supported by 30 % from 01.01.93. These arrangements have not yet given the effects as expected, but by amended financial frame requirements (prices, taxes) this can change.

The uncertainty around the refrigerant situation, creates uncertainty about investments in heat pumps. It is therefore of great importance to develop environmentally benign refrigerants for heat pumps that neither affect the ozone layer nor the greenhouse effect (ODP=GWP=0). In Norway there is a considerable activity going on regarding natural refrigerants, ie. ammonia (NH_3), carbon dioxide (CO_2) and hydrocarbons (propane etc.). The ammonia heat pump technology is already highly developed.

Through the Heat Pump Implementing Programme it is built all together 40 prototype and demonstration installations. The aim of the activity was to test, survey and monitor the operation of various types of heat pumps in different parts of the country with different climatic conditions, and the program was proven successful. It has been performed many useful and important experiences regarding design, installation and operation of the heat pumps. These experiences are available in different reports.

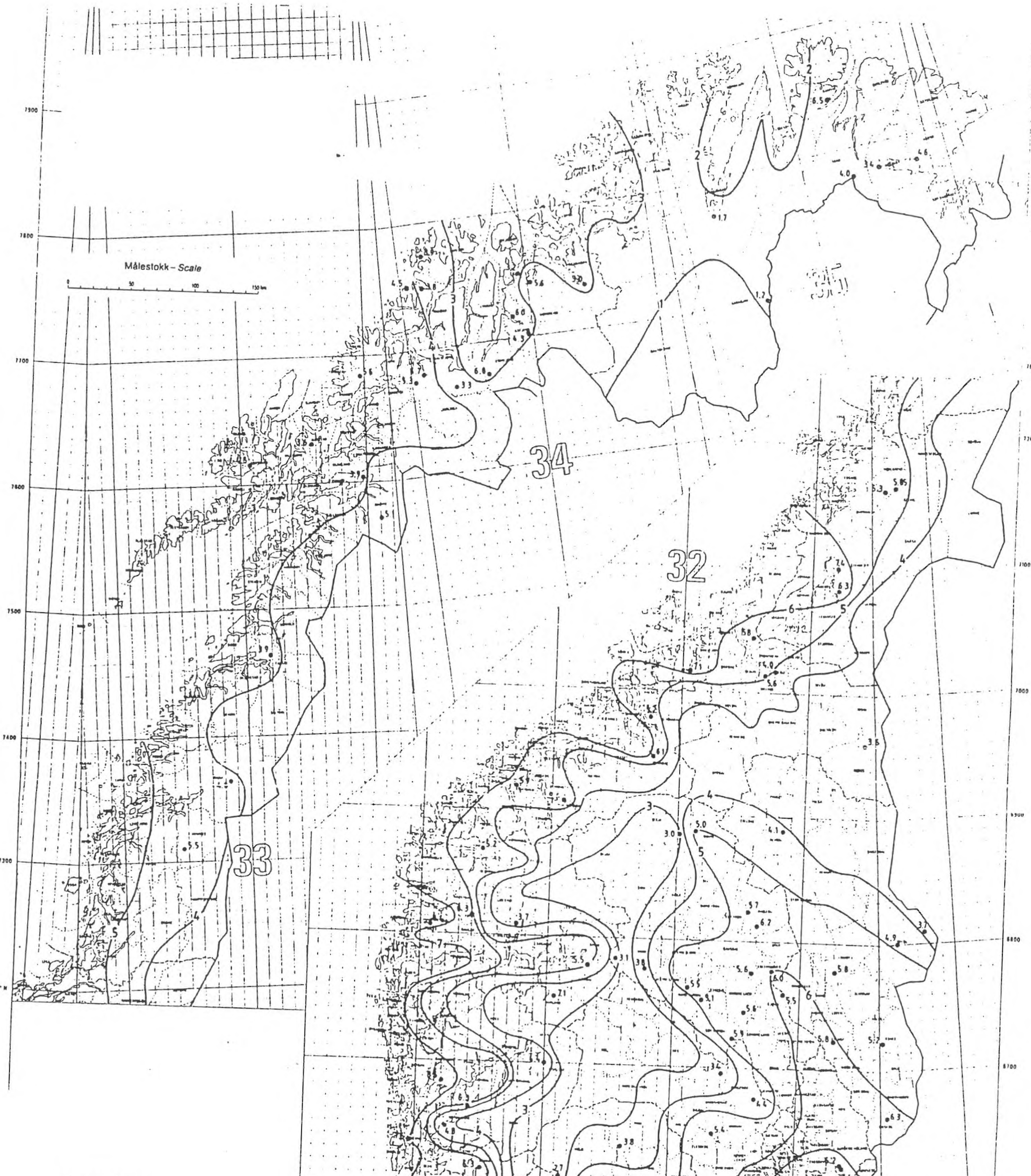
More than 60 % of the households in Norway are single family houses, where a heat pump investment will have a long pay-back period (10-15 years). At present price condition (investments and energy coditions), less than 5% of the technical heat pump potential (1 TWh) is stipulated to be profitable for the house owners. Stimulating attempts as investment subsidies and environmentally motivated taxes are already introduced to increase the heat pump rentability, but so far this has not resulted in a real breakthrough. A continued work in this region is necessary.

The buildings within the commercial/institutional sector often have a big and steady heat demand. Due to internal heat gains, external cooling is often required, and today about 30 % of this kind of buildings have space cooling installations. This enable heat pumps with excellent economy to be installed due to the combination of heating and cooling. As much as 35% of the technical heat pump potential (4 TWh) in this sector is stipulated to be profitable for the building owners.

Heat pumps for industrial applications become more and more common. In addition to space conditioning (heating/cooling) and heating of process water, this applies to drying and evaporation. The economy regarding these installations are generally good due to large, highly efficient heat pump units with long annual operating hours. A generally low price on occasional power (electricity) is, however, a market constraint. In the industrial sector almost 60% of the technical heat pump potential (2 TWh) is calculated to gain the companies economy.

APPENDIX A

Ground Water Temperatures



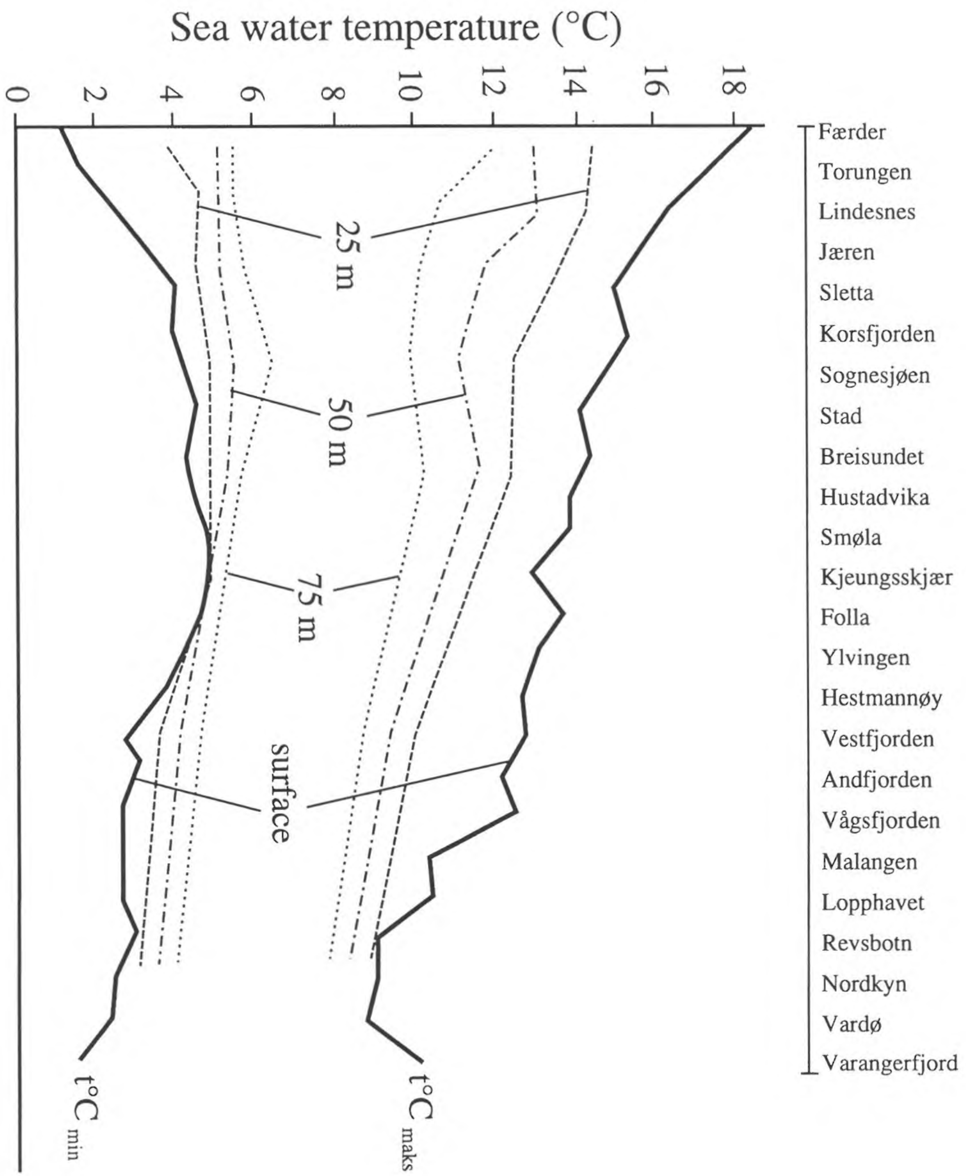
Appendix A

Isotherm map for the ground water temperature in Norway

Scale: 1:2,000,000

APPENDIX B

Sea Water Temperatures


Sea water temperature (°C)
0
2
4
6
8
10
12
14
16
18
25 m
50 m
75 m
surface
t°C min
t°C maks
Færder
Torungen
Lindesnes
Jæren
Sletta
Korsfjorden
Sognesjøen
Stad
Breisundet
Hustadvika
Smøla
Kjeungsskjær
Folla
Ylvingen
Hestmannøy
Vestfjorden
Andfjorden
Vågsfjorden
Malangen
Lopphavet
Revsbotn
Nordkyn
Vardø
Varangerfjord

APPENDIX C

Environmentally Motivated Taxes

Environmentally motivated taxes in affect in Norway 1993

Tax applies to	Type	Rate[1)]
Mineral oil	• basic rate	0 \$/litre
	• CO_2-tax	0.06 \$/litre
	• sulphur tax: \$/litre per 0.25% sulphur content	0.01 \$/litre
Continental shelf	• CO_2-tax natural gas	0.11 \$/Sm^2
	• CO_2-tax petroleum	0.11 \$/litre
Petrol tax	• basic rate:	
	- leaded	0.53 \$/litre
	- unleaded	0.44 \$/litre
	• CO_2-tax	0.11 \$/litre
Coal/coke	• CO_2-tax	0.06 \$/kg
Electricity tax	• production	0.002 \$/kWh
	• consumption	0.007 \$/kWh

1) 1 \$ = 7 NOK