DEVELOPMENT OF HEAT PUMPS IN NORWAY

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Abstract: The largest achievement in research and development for heat pump that has been carried out in Norway is in the field of heat pump systems with carbon dioxide (CO_2) as working fluid. Professor Gustav Lorentzen and his co-workers at NTNU and SINTEF Energy Research developed the concepts of the "transcritical" CO_2 heat pump cycle. The industrial group Norsk Hydro acquired all commercial rights to this technology in 1990. The CO_2 technology developed at SINTEF has e.g. been licensed to Japanese manufactures that are producing the “Eco-cute” heat pump water heating systems for residential and commercial applications. At the Institute for Energy Technology (IFE) in Norway they have developed a unique compression/absorption heat pump system for industrial applications.

The Norwegian heat pump market has been growing steadily since 2001. During the 1990s the annual sales figures were between 1000 and 2000 units/year. In 2006 the market reached 78,300 units which is an all time high. The most popular heat pump system in Norway is single unit air-to-air heat pumps. These heat pumps are replacing electric baseboard heaters and thereby reducing the dependency of electricity for space heating. In Norway there are also many medium- and large-scale heat pump systems with seawater, groundwater, rock or sewage as a heat source. One of the largest ground-source heat pump systems in the world for heating and cooling was installed in 2007 at the new hospital “Nye Ahus”. The largest heat pump system in Norway is a 28 MW sewage heat pump supplying 90ºC heat to a district heating grid.

The Norwegian Water Resources and Energy Directorate (NVE) has estimated that heat pumps will contribute with 10 – 14 TWh/year renewable ambient heat in Norway by 2020 compared with about 5 TWh today.

Key Words: ***heat pumps, R&D, market development, sales figures, Norway***

1 INTRODUCTION

Due to an abundance of hydro power and a government determination to keep prices low through regulations, electricity prices have been very low during the post-war period and up to the 1990s. In 1991, the government introduced the New Energy Act which deregulated the electricity market. In 1996, Norway and Sweden established a common market for electricity, which subsequently matured into a common market for all Nordic countries. The annual hydro power production in Norway, range from 90 to 150 TWh per year, depending on weather conditions. The average electricity consumption is about 120 TWh. The electricity supply in Norway, with indigenous production depending on weather conditions, benefits from connections to countries having power generation systems based on nuclear power, natural gas, coal or oil. The disadvantage for Norwegian consumers is that electricity prices increase significantly when it is necessary to import electricity. In 2002/2003, with a dry autumn and winter, prices rose to a maximum of up to about 250% for electricity during peak load periods.

In Norway, the price of primary energy, which for most consumers is electricity, is decisive for deployment of heat pumps and also influences the framework conditions from the government. In 2003 and 2006, when electricity prices rose significantly, the government gave private households subsidies for installing heat pumps. Research and development of heat pump systems in Norway is rather limited due to the lack of long-term perspective in the energy policy. In Norway, it has also been difficult for renewable energy systems to compete against the oil and gas industry with regard to funding of research and development projects.

2 RESEARCH AND DEVELOPMENT

The largest achievement in research and development for heat pump that has been carried out in Norway is in the field of heat pump systems with carbon dioxide (CO_2) as working fluid. Professor Gustav Lorentzen and his co-workers at NTNU and SINTEF Energy Research developed the concepts of the "transcritical" CO_2 heat pump cycle. The industrial group Norsk Hydro acquired all commercial rights to this technology in 1990. The CO_2 technology developed at SINTEF has for instance been licensed to Japanese manufactures that are producing the "Eco-cute" heat pump water heating systems for residential and commercial applications. At the Institute for Energy Technology (IFE) in Norway they have developed a unique compression/absorption heat pump system for industrial applications.

2.1 Research and Development with CO_2 as Working Fluid

CO_2 has been identified as an interesting working fluid in brine-to-water heat pumps for heating and cooling of non-residential buildings. SINTEF Energy Research is now involved in a project where the main goal is to design, install and monitor a prototype CO_2 heat pump system for heating and cooling of an office building. The heat pump unit will be connected in series with radiators and ventilation heater batteries providing a relatively low return temperature in the hydronic heat distribution system, and thus giving favourable operating conditions for a CO_2 heat pump. Computer simulations have demonstrated that CO_2 heat pumps for heating and cooling of non-residential buildings can achieve the same or higher seasonal performance factor (SPF) than that of heat pumps using conventional working fluids, as long as the heat distribution system is designed for a low return temperature.

Since 1997, SINTEF Energy Research has been investigating and developing reversible residential air conditioners (RAC) and heat pumps using CO_2 as a working fluid. A third-generation prototype CO_2 RAC split-type unit has recently been constructed and extensively tested in heating and cooling modes. The test results have been used for calculating the seasonal heating and cooling performance for two different climates; Greece (Athens) and Oslo (Norway). The results have been compared with manufacturer's data with verified rating points for the most energy-efficient Japanese R410A split-type units available on the market. In both the heating and the cooling mode, the calculated SPFs for the CO_2 and R410A units in the Oslo climate were more or less identical. However, in cooling mode in the Athens climate, the SPF of the CO_2 unit was about 17% lower than that of the R410A unit. Further development and optimization of the CO_2 unit will be necessary before CO_2 unit will be able to match or outperform the market-leading R410A units in terms of energy efficiency. However, since the CO_2 unit already matches many of the better R410A units on the market, CO_2 must be regarded as a promising working fluid in reversible air-conditioning and heat pumps for residential use.

2.2 Heat Pumps in Low-Energy Houses

Norway is participating in Annex 32 in the IEA Heat Pump Programme; "Economical Heating and Cooling Systems for Low-Energy Houses". The focus of the Norwegian national project is a study of heat pump systems suited for low-energy houses. This comprises an analysis whether state-of-the-art heat pump systems in low-energy buildings are feasible for Norwegian boundary conditions, e.g. the cold winter climate. In particular, ventilation air heat pumps will be evaluated. A 2.5 kW prototype propane water-to-water heat pump unit for space heating and hot water heating (integrated unit) will also be monitored during one year of operation in a low-energy house.

Investigations on the following subjects will also be conducted:

- Analysis of heat pump water heater systems for block of flats of passive house standard
- Analysis of compact units with heat pumps for low-energy houses and passive houses
- Analysis of a propane water-to-water heat pump system for a low-energy house

2.3 Compression/Absorption Heat Pumps for High-Temperature Industrial Applications

The development of a compression/absorption (hybrid) heat pump system for industrial applications was started at The Institute of Energy Technology (IFE) in 1996. In 2000, the first 60 kW hybrid heat pump installation was operated in the laboratory. In 2003 a full scale installation was running as planned in a Norwegian dairy. In June 2004, the company Hybrid Energy AS was established to design and build hybrid heat pumps. In June 2007, a single-stage 650 kW hybrid heat pump was put into operation at Nortura.

A hybrid heat pump combines the absorption cycle and the compression cycle. The hybrid heat pump uses the natural working fluids water and ammonia. The binary mixture of water and ammonia give a large flexibility in delivered temperatures and may be designed for high temperature glides. The system is based on a newly developed system of compression/-absorption technology. The system uses well-known components from state-of-the-art ammonia refrigeration and heat pump systems.

By adding water to a standard ammonia heat pump cycle and including a solution circuit, a high temperature heat pump concept can be obtained. Compared to conventional vapour compression type heat pumps, a combined absorption and compression heat pump has several advantages:

- For an ammonia/water system, the inclusion of water can increase the boiling point considerably. The heat can therefore be delivered at a much higher temperature using a standard 20-bar compressor.
- Due to the two-component mixture, the heat exchanging process will have gliding temperatures both at the heat source and the heat sink, and therefore reduce the heat exchanging losses for fluids with high temperature changes.
- The operation of the absorption/compression heat pump can effectively be tailored to the heat sink and heat source temperature fluctuations since the mixture’s component composition can be changed. The temperature glide performance may also be adjusted by changing the capacity of the compressor compared to the capacity of the liquid pump.

3 DEPLOYMENT OF HEAT PUMPS IN NORWAY

For many years, the Norwegian heat pump market remained stable at about 1,000 units per year, with only modest interest in the technology among politicians and the public. Even if there still are variations from one year to another, the heat pump market today has increased to a much higher level due to several positive factors:

- Higher energy prices, especially electricity and oil
- More efficient heat pumps and increased competition
- Subsidy schemes for heat pumps through Enova SF
- Awareness of climate change and environmental issues

The heat pump market in Norway first started to increase around year 2001. The main reason for this was that new distributors focusing on installation of more efficient air-to-air heat pumps with R-410 as a working fluid. These new products were introduced in the market at the same time as electricity prices started to increase in Norway due to a dry autumn and winter in 2002/2003. The increase in sale numbers was tremendous with an increase from 6,300 units in 2001 to 55,000 units in 2003. In 2006, we again experienced dry weather during the autumn with high electricity prices and a new peak in heat pump sale figures with 78,300 units.

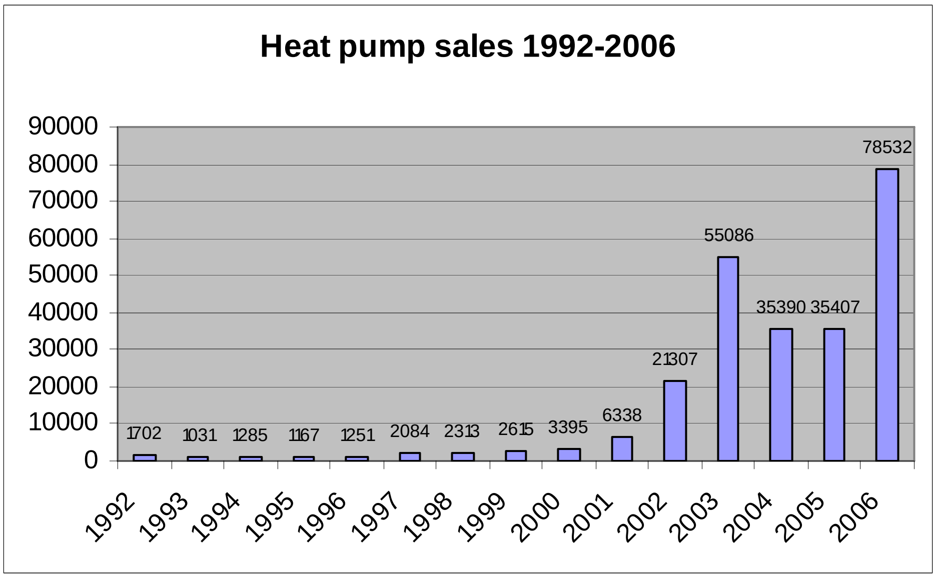

Figure 1: Sales figures for Heat pumps in Norway (NOVAP)

In Norway, there are, in addition to a large number of heat pumps in private households, also many medium- and large-capacity heat pump systems. One of the largest heat pumps in the world utilizing untreated sewage as heat source is supplying high-temperature heat to a district heating system in Oslo. The 28 MW heat pump has an annual heat supply of approximately 140 GWh. The installation costs for the plant was around € 11 million. The largest ground-source heat pump system for heating and cooling in Europe was installed in 2007 at the new hospital “Nye Ahus”. There will be around 350 boreholes each around 200 meters. The four ammonia (NH_3) heat pump units have a total heating capacity of 8 MW, and will supply about 20 GWh of renewable energy for heating and cooling each year. Due to the long coastline towards the North Sea there are many large-capacity heat pump systems in Norway utilizing sea water as heat source. The first seawater heat pumps were installed already in the 70s, and are still working properly.

In 2006 the, The Norwegian Water Resources and Energy Directorate (NVE) engaged an independent consultant company to estimate the development of the Norwegian heat pump market by 2020. The heat pump market was divided into private households, commercial, industry and district heating. The most promising market is the private households with more than half of the savings from installed heat pumps due to higher alternative energy prices. NVE have estimated that Norwegian heat pumps by 2020 will contribute with 10 – 14 TWh renewable ambient heat compared with about 5 TWh in 2007.

4 POLICY AND SUBSIDIES FOR HEAT PUMPS IN NORWAY

Six out of seven parties represented in the Norwegian Parliament have made an agreement about cutting the Norwegian greenhouse gas emissions. The agreement states that Norway shall reduce emissions by 15 – 17 million tones of CO_2 equivalents by 2020 compared with a reference scenario. The most important strategies include banning of fossil fuel heating as base load in new buildings, more insulation in new buildings, CO_2 capture and storage as well as more renewable energy for heating purposes and electricity generation.

Enova SF, as a public enterprise owned by the Royal Norwegian Ministry of Petroleum and Energy, is the most important instrument for the government to cut greenhouse gas emissions. The establishment of Enova signals a shift in Norway's organization and implementation of its policy to improve energy efficiency and implement renewable energy sources. By gathering strategic policy responsibilities in a small, flexible and market oriented organization, Norway has wanted to create a pro-active agency that has the capacity to stimulate energy efficiency by motivating cost-effective and environmentally sound investment decisions. Enova is not involved in the transport sector or in CO_2 capture and storage. Enova has different support schemes for all kinds of heat pumps except single unit air-to-air heat pumps. The support scheme for private households gives each household 20 percent of the investment or 10,000 NOK (approximately €1,200).

5 SYSTEMATIC EFFORTS BY THE NORWEGIAN HEAT PUMP ASSOCIATION

Another reason for the positive development of the Norwegian heat pump market is systematic efforts by market actors over several years to build a positive reputation of heat pumps as a reliable and energy saving technology. Especially, the establishment (in 1991) and undertakings of the Norwegian Heat Pump Association (NOVAP) are believed to have had a positive impact. One of NOVAP's main interests has been education and certification in order to increase the quality of heat pump installations. Other activities are information directed at the public and politicians for improving framework conditions for heat pumps.

Similarly, the activities undertaken by the regional energy conservation centres (established 1994) and continued by Enova (established 2001) are believed to have contributed to building a solid heat pump reputation. Typical activities for these organizations have been deployment of neutral and non-biased information, and providing answers to the public on demand, via for instance free telephone hot-lines.

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