Heat pumps replace electrical heating

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Retrofit with energy-efficient inverter heat pumps replaces electrical night storage heating in multi-storey flats in Essen, Germany. Monovalent air-to-air heat pump heating using aerothermal renewable energy represents 72% savings on tenants' energy bill in Essen retrofit project which is labelled with 30kWh/m² without extra exterior wall insulation.

Making energy choices when retrofitting

Tenants are increasingly reluctant to live in flats heated with expensive and inefficient electrical night storage heating. Hence, multi-storey housing investors and landlords are continuously faced with questions concerning the alternatives available to replace their old heating system. Is an oil or gas-fired boiler preferable to a heat pump based system? And is there a proven system or technology that can do the trick without costly and disrupting refurbishments?

State-of the-art heating system without low temperature distribution system?

Heat pump based systems must be taken seriously in the case of renovation and new housing projects for multi-family housing units. Landlords are increasingly under pressure by tenants to install modern, cost- and energy-efficient low temperature heating systems. In addition, the once popular electrical night storage heating is no longer an option since residences equipped with this type of heating are increasingly more difficult to rent out due to the system's high operating costs, poor environmental performance and the presumed presence of asbestos even though builders stopped using asbestos in the late seventies.
With heat pumps, there is no need for expensive, complex hot water distribution systems (such as underfloor heating). Plus the existing electrical infrastructure can be reused. And tenants do not need to be convinced of the energy efficiency of heat pumps, since energy labelling on heat pumps is mandatory (and similar to other electrical appliances) [1].

Decentralised air-to-air heat pumps

In buildings without hot water heat distribution systems, inverter heat pumps can be used for monovalent heating. 'Inverter' means variably adjusting the operating frequency of a heat pump, thereby providing highest efficiency at partial load operation. The PID control algorithm controls accurately heating, and results in high comfort and efficiency.

Comfortable

Prof. Dr.-Ing. Fritz Steimle of GH Essen University conducted thermodynamic research in rooms equipped with inverter heat pumps. His research shows that the air movement in the room easily was on a par with a conventional fossil fuel boiler system [2]. The constant temperature distribution in the room (at different heights) thus meets the high requirements, as demonstrated in the graph below. Moreover, the integrated air cleaning function contributes to enhanced comfort compared to conventional heating systems.

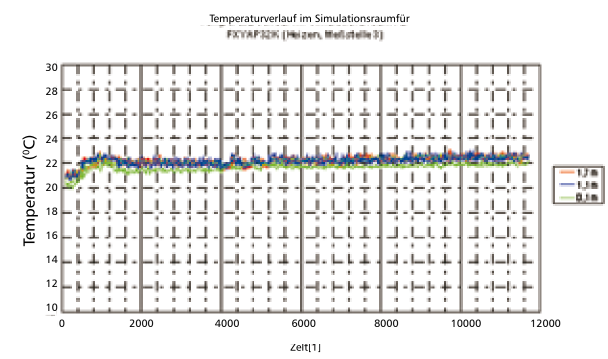

Figure 1. Temperature variation in room equipped with inverter heat pumps

Efficient

The decisive factor in the low operating costs is the inverter heat pumps' high COP values, which are achieved thanks to their good partial load efficiency [3] and [4]. Efficient partial load is of utmost importance to the annual energy use of heat pumps since they will only operate a limited number of hours at full load. The low operating costs are detailed below in the Essen retrofit example.

How does inverter heat pump work?

Unlike conventional heat pumps, the cycle of an inverter heat pump is constantly controlled based on actual heating demand. Using swing compressors with frequency controlled motors and electronic expansion valves, the heating energy produced is adapted to the room's requirements.

Rooms can be directly heated with inverter heat pumps, with the condenser releasing heated energy directly into the indoor air **(Figure 2)**. Thus, there are no losses in efficiency due to the transfer of heat to an intermediary circuit. Nor are there heat distribution losses as is the case with conventional ground-to-water or air-to-water heat pumps, district heating systems or gas- or oil-fired central heating.

The simplicity of this type of heat pump results in increased efficiency and reduced operating costs. Installation is also easy thanks to the system's exploitation of aerothermal renewable energy: ambient air outside the building. First, the heat pump extracts energy from the outdoor air via the evaporator. Then this energy is transported via the compressor to the condenser of the indoor heating unit.

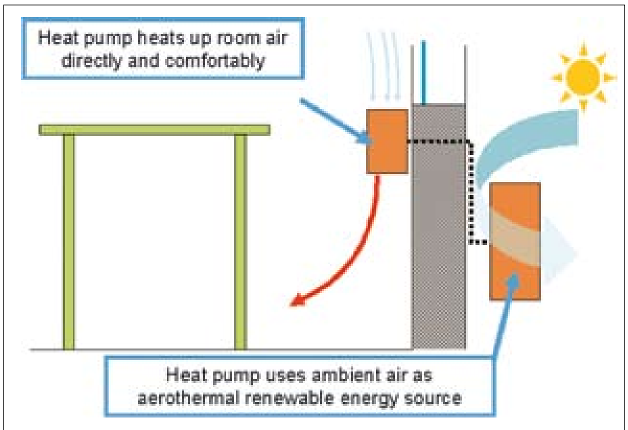

Figure 2. Heat pump with indoor heating unit below window for comfort (warm air on the floor) and efficiency (drawing convection flow cooled at glass surface) [5]

An inverter heat pump consists of a unit outside the building and an indoor heating unit (condenser) in the room that requires heating **(Figure 2)**. This configuration is known as a split system. The outdoor unit contains the evaporator with electronic expansion valve and a swing compressor. The indoor heating unit is equipped with an integrated air filter, which – depending on the manufacturer – can also remove allergens and other pollutants from the room air. Some systems also contain integrated movement detection, thus reducing unnecessary energy use and contributing to automatic energy savings. Good systems also have a night mode, enabling further energy savings when system demand is lower.

The cycle on inverter heat pumps is fully reversible, which means they can also offer cooling and/or dehumidification. This is especially good news for the rooftop floors, which benefit from enhanced comfort in summer.

The indoor and outdoor units are connected by a single control circuit, and two copper pipes with a diameter of 6mm and 10mm for the heat pump circuit. Thus, installation is easy and clean: drilling one approximately 50mm-hole for the piping and the mains connection is sufficient. This hole can be concealed behind the indoor unit, which is usually located below the window and thus benefits from local air circulation. Moreover, the indoor unit takes up very little space, certainly far less space than the older night storage heating systems.

A single inverter heat pump can meet the heating requirements of one to five rooms **(Figure 3)**. Consequently, when used for monovalent heating in multi-family housing units, a larger number of decentralised heat pumps need to be installed. As indicated in the following example, this presents a number of advantages in renovation projects.

Multi-family housing units with 10 flats in Essen

The present example is one of the case studies collected during work of International Energy Agency's HPP Annex 30 on 'Retrofit Heat Pumps for

Buildings' which was lead by IZW e.V., Hannover. It shows a multi-family housing unit which is very similar to many other buildings built after the war. First heated with coal, these buildings were switched to night storage heating decades ago. Subsequent renovations included adding balconies on the garden side, painting the façade, the (partial) joining of apartments and dismantling of the night storage heating systems. The housing units are now heated with monovalent inverter heat pumps, and differ with respect to size and number of rooms. There are five flats with 50m² of living area, three apartments with 70m² of living area and two apartments with up to 90m² of living area. The smaller flats have two indoor units, the larger apartments a maximum of four.

The choice of inverter heat pumps was primarily due to the easy installation together with low operating cost. In addition to this main measure, balconies were attached to the building in order to improve attractiveness of these dwellings.

A special benefit compared to other heating systems is the fact that inverter controlled heat pumps have a high boost capacity, allowing a room to be heated very quickly. Thanks to this powerful mode, the temperature can be lowered during the day in unused rooms, without loss of comfort.

Another benefit of this system is the accurate energy bill (precise to the kWh) that the power supply companies submit directly to the tenants, substantially reducing paperwork and sparing tenants the trouble of meter reading.

Low investment cost

Only two weeks were required from the start of installation to commissioning of the system,

Figure 4. Multi-storey housing unit in Essen, viewed from the street

including training the tenants on how to use their system. The housing units were retrofitted in sequence, room by room. The investment cost for the heat pump systems and their installation in the abovementioned 600m² multi-family housing units was a modest €52.000, including all required extras and VAT.

This compares favourably to the investment required for other modern heating systems. In the case of heat pumps, however, the tenant is spared the time and hassle required when installing hot water heat distribution systems, to say nothing of the additional masonry or painting touch-up work. Another marked benefit is the fact that the building no longer needs a dedicated heating room, which would have been the case with other modern heating systems.

Low operating cost

The Essen retrofit project allows accurate cross-comparisons of the energy consumption and operating costs of inverter heat pumps and the previous night storage heating system, since the building's passive thermal insulation remained unchanged.

Installing inverter heat pumps not only requires little energy, energy costs are also low due to energy-efficient technology and cost-effective heat pump rates offered by the power companies. The local utility guaranteed a by 25% reduced heat pump rate for a period of 10 years. In return, the power company has the right to switch off the heat pumps for a short period during the day; this fact was taken into account when dimensioning

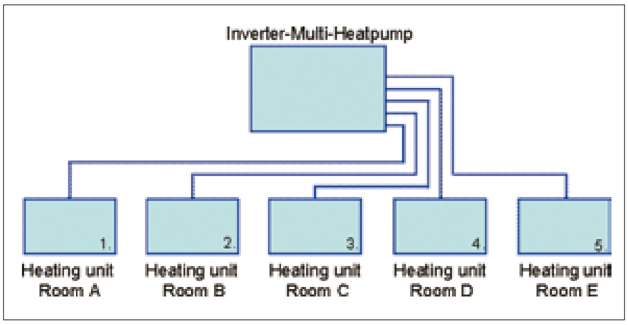

***Figure 3.** Inverter heat pump can serve up to five indoor units*

the systems and acceptable from the background of thermal storage mass of the building structure. The inverter heat pumps in the housing units achieve seasonal efficiency of 3.4 to 4.3 (ratio of heat provided to electrical energy used – see also **table 1**). With a COP of 3.8, one kWh of heating energy at the heat pump rate costs only €0.0179, including all taxes **(Table 2)**

Energy savings over 70%

Energy consumption for the multi-family housing units in Essen with night storage heating averaged around 94kWh/m² per year for all housing units (heating season 2001/2002). The housing unit that consumed the least energy needed around 85kWh/m² per year, while the highest consuming unit required around 100kWh/m² per year. Since the electric storage heating system was still in operation at that time, these values were equivalent to the heating requirements.

Inverter heat pumps, however, need only around 26kWh/m² per year on average (operating period 2002/2003 incl. summer). The minimum value can be as low as 20kWh/m² per year, as can be seen in **table 1.** These values include also the energy use for cooling during the summer of 2002. Installing inverter heat pumps thus yielded energy consumption savings of over 70%.

Energy cost reduced over 70%

Energy consumption costs for the multi-family housing units in Essen with night storage heating averaged around €6.7/m² per year for all housing units **(Table 3)**. Additionally, a €72 'measuring and connecting fee' was owed each year per housing unit **(Table 2)**.

With heat pumps, energy consumption costs are only €1.80/m² per year, with a €42.6 'measuring and connecting fee' owed per housing unit. Thanks to the excellent energy performance and the special heat pump rate, energy cost savings of well over 70% were possible compared to night storage heating.

Conclusion

When renovating or building new multi-family housing projects without a heat distribution system, inverter heat pumps offer an economical,

Table 1. Energy use before the retrofit (electrical night storage heating) and after (inverter drive heat pumps).

Energy consumption	Night storage heating 2001/2002		Inverter heat pumps* average 2002-2008: 26kWh/(m²/year)			
			2002/2003		2004-2006	
Average	**94**	kWh/(m²/year)	**26**	kWh/(m²/year)	**30**	kWh/(m²/year)
Minimum value	**85**	kWh/(m²/year)	**20**	kWh/(m²/year)	**26**	kWh/(m²/year)
Maximum value	**100**	kWh/(m²/year)	**34**	kWh/(m²/year)	**36**	kWh/(m²/year)
* Inverter heat pumps incl. summer months						

Table 2. Electricity cost for heating in the case building

Rates, all taxes included				
Type	Night storage heating systems		Inverter heat pumps	
Measuring and connecting fee	**72.00**	€/year	**42.60**	€/year
NT (Night rate)	**7.122**	Cent/kWh	**6.786**	Cent/kWh
HT (2 h/day)	**10.974**	Cent/kWh	--	Cent/kWh

Table 3. Heating cost before the retrofit (electrical night storage heating) and after (inverter drive heat pumps).

Energy consumption (Energy consumption x Rate)				
Housing units	Night storage heating systems*		Inverter heat pumps	
Average	6.69	€/(m²/year)	1.79	€/(m²/year)
Minimum value	6.05	€/(m²/year)	1.40	€/(m²/year)
Maximum value	7.12	€/(m²/year)	2.33	€/(m²/year)
* With night storage heating systems, only the night rate was taken into account				

hassle-free, state-of-the-art and proven solution using aerothermal renewable energy. They permit unprecedented savings on the operating cost, while offering functions that conventional heating systems simply don't have.

The measured savings in the Essen project amounted to more than 70% for both energy consumption and energy cost, and clearly show the advantages offered by heat pump technology. These energy savings also translate into annual CO_2 savings of more than 28 tonnes per year. The effectiveness of inverter heat pumps is documented by the energy performance certificate for this not insulated building: 30kWh/m².

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Key Facts Essen project	
Building	3-storey multi-family housing units with garden
Location	Living area only; low-traffic street
Number of flats	10
Heated floor area	around 600m²
Heated floor area using inverter heat pumps	completely monovalent (roof area partly retrofitted)
Required number of heat pumps	26
Models used	DAIKIN FTXD25/RXD25+ DAIKIN FTXD35RXD35

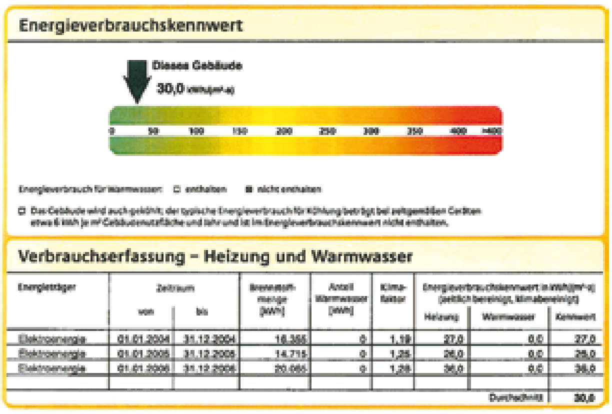

Figure 6. *Energy performance certificate (Energieausweis) of Essen project per 23.9.2008*

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The Mine Water Project Heerlen - Low Exergy Heating and Cooling in Practice

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Abstract

In Heerlen, the Netherlands, warm and cold water volumes from abandoned mines will be used for heating and cooling of buildings, based on a low exergy energy infrastructure. The combination of low temperature heating and cooling emission systems, advanced ventilation technologies and integrated design of buildings and building services provide an excellent thermal comfort and improved indoor air quality during 365 days/year, combined with a CO2 reduction of 50% in comparison with a traditional solution.

Abandoned and flooded mines can be reutilized for a new sustainable energy supply for heating and cooling of buildings. The Minewater project in Heerlen shows that temperatures of ~30 °C can be found at 700 m; the temperature of the shallow wells is to be expected 16..18 °C at 250 m. These temperatures can be used for heating and cooling of buildings if these buildings are very well insulated, have energy efficient ventilation systems and have emission systems suitable to operate with moderated temperatures like floor heating or concrete core activation. Despite the rather high investment costs such projects can be economical profitable avoiding additional cooling systems and by integrated design and if energy exploitation is organised by the investors. Although the project is more or less an experiment, the project is already scaled up to extra buildings to make it commercial profitable. This requires a reliable and efficient distribution system that lasts for at least 30 years and therefore extra measures have to be taken to prevent scaling and corrosion in the piping. For the post-pilot period also extra measures will be taken, like oversized, insulated transportation pipes with leakage detection.