Effective water heating

for households, commerce and industry

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Heat pumps: the potential to reduce electricity consumption in major sectors of the economy

In an environment where electricity usage and costs are matters of increasing importance, the identification of technologies to lower electrical consumption is becoming critical, more so than ever before. In South Africa, this applies especially to industries such as mining where it is estimated that the amount of hot water used possibly exceeds the combined hot water consumption of all hotels, technikons and universities. Typically, an average-sized mining group can use more than 500 000 litres of heated water per day.

A significant technology that is simple and effective in lowering electricity usage is the deployment of heat pumps. Heat pumps offer both households and other major consumers of electricity a significant opportunity to reduce costs related to water heating. A heat pump can save up to 67% of energy consumption, and in some circumstances even more than that. In South Africa the primary users of hot water in the commercial sector are found in six major sub-sectors.

These, with their typical consumption, are illustrated in figure 1 below.

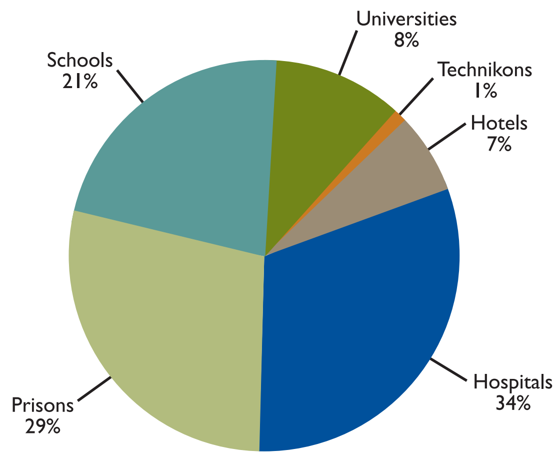


Figure 1: Distribution of sanitary hot water consumers in the commercial sector

Currently, most commercial enterprises, particularly those with major hot water demands for kitchens, laundries, restaurants, ablution facilities and industrial processes, heat their water with geysers and inline elements called calorifiers. Energy sources include gas, oil or coal.

The technology

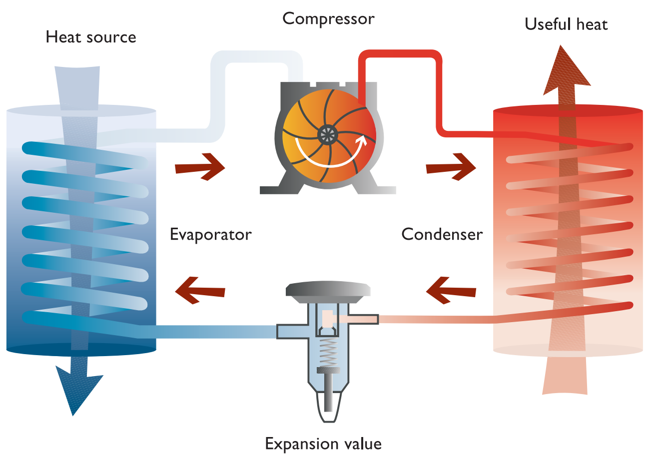
Heat pumps use the reverse cycle of a refrigeration plant to heat water. In effect, it transfers heat from a source such as air or water to the water which is to be heated. In general, it is the larger commercial units that use water as a heat source, however, for the purposes of this brochure only air sourced units will be featured.

As in other refrigeration equipment, the heat pump system employs an evaporator, a compressor, a condenser, refrigerant gas, and an expansion valve within a closed circuit. Latent heat is given off when the refrigerant gas is liquefied through the condenser and transferred to the surrounding water together with further "sensible" heat loss, effectively raising the temperature of the water to 65°C. In some circumstances even higher temperatures can be attained. Generally there is no need for a hot water booster pump to achieve this result.

In the case of a typical domestic heat pump, two types of configurations can be found. In the first case the entire system is contained in one unit that consists of a storage tank and a heat pump. In the second configuration the tank is separated from the heat pump. Heat pumps are typically mounted on the outside walls of buildings under the eaves or at ground level depending on the configuration of the system. It may seem strange that an electro mechanical device with moving parts - the electric motor driving the compressor - can be more efficient in heating water than a typical resistance-element geyser. In fact, a heat pump can be up to three to four times more efficient than a hot water system which is powered by a normal resistance element because for every kWh of electricity supplied to the heat pump, more than three kWh of thermal energy in the form of hot water is produced. A thermostat will keep the hot water at a constant temperature between 55°C and 65°C with 60°C being the most commonly used setting.

An additional benefit which is often used to increase the economic benefits of a heat pump, is that of the cooling system which can be utilised to simultaneously cool a building, or a specific area of a building. This is especially useful in the hospitality industry where cool air can be channeled into lobby areas thereby saving on the cost of a separate stand-alone air conditioning system. In a domestic situation the cooled air can be piped into the ceiling cavity to aid in keeping down interior room temperatures.

Functionality of a typical heat pump



The accompanying diagram represents the major components typical of a refrigeration system or heat pump where the refrigerant gas is circulated in a continuous cycle. The liquefied refrigerant, mostly R134A, passes under pressure through an expansion valve into a partial vacuum. The sudden expansion of the high pressure liquid into a low pressure area (the evaporator) cools the gas down. The refrigerant gas which is now at a comparatively low temperature is then suddenly pressurised by the compressor. The sudden increase in pressure raises the temperature of the refrigerant gas considerably. This heated gas is routed through a condenser and emits heat to the water that is to be heated in a storage tank near to the actual heat pump. It can also be emitted into the surrounding atmosphere in the case of a refrigerator or air conditioning system. A point worth noting is that an air conditioning system with a reverse cycle heating facility is one of the most efficient ways of heating your home or office in winter.

Heat pumps in major ablution facilities in mines

According to a survey commissioned by Eskom, about 580GWh of electrical energy is consumed per year to provide for the nationwide sanitary hot water usage in the entire commercial and industrial sectors.

In the South African mining sector one of the major consumers of electricity is the ablution, or change house facilities. These are found at most major shafts and high density residential facilities. Mining change houses nationally consume approximately 10.6 million litres of hot water.

This represents an average load of 66.2 MW which could be reduced by heat pumps as they use less energy to produce the volume of sanitary hot water required by a mine.

Heat pumps provide showering capacity for mine workers on a daily basis, each miner requiring about 45 liters of hot water heated to 60°C every day. This can account for 4% of all the electricity consumed by mines.

Currently in the majority of instances, electrical resistance heating elements in hot water storage tanks are used to supply hot water to between 40 and 1 000 workers at any one installation These elements are usually installed either inside the storage tanks or outside in an in-line heater vessel with the heated water supplied to the storage tank. Heat pumps can reduce this load on large water heating plants such as these by up to 66%, particularly in worker ablution facilities found on mines.

Normally electrical resistance type heaters in centralised heaters are sized to heat the daily hot water requirement for each 12 hour shift. At a typical inlet water temperature of 15°C, an amount of 26.5 Mega liters of hot water is required at 60°C, an installed capacity of 135 MW is needed, including typical heat transfer losses. If heat pumps are used to heat this amount of water it would require 46MW and result in a saving of 89MW.

Benefits of heat pumps

The major benefits of heat pumps apart from efficiency and cost savings include:

- Reduction of a building's carbon footprint because no combustible gas is burnt in the heating process. Sufficient use of the system reduces the need for either coal or nuclear power stations. This is mainly due to the significant co-efficient of performance (COP) improvement factor compared to that of conventional resistance-element boilers.

- The life of the boiler tank is lengthened due to the lack of chemical interactions between the element, and other metals such as copper used in the plumbing process.

- Because water heated in a heat pump seldom exceeds 65°C the risk of burns in showers is reduced.

- In cases where the cold side of the water heating system is used for air conditioning or HVAC (heating, ventilation and air conditioning) electricity consumption is reduced. By effective planning and use of both the hot and cold side of an installation, capital amortisation can occur over a much shorter period, especially in countries where energy costs are high. The payback period can be as short as 12 to 18 months from date of installation.

- The significant water heating efficiency combined with the cooling benefits favours the use of heat pumps in areas where there is a daily demand for hotwater. In hotels, for example, the cold side can be used to supplement cold water usually circulated through fan coil units in bedrooms and kitchens.

- Although initial equipment and installation costs are higher than those of gas or electric geyser systems, these are offset by lower operating costs. In South Africa, a typical payback period on a commercial system would be three to five years at the current electrical costs. As electricity costs increase this time frame will become shorter.

- Normal maintenance costs are reduced using heat pumps .

- As electricity demand is lowered, concomitant improvements in levels of environmental impact will be seen. Heat pumps are internationally recognised as eco-friendly contributing to a lowering of greenhouse gas emissions by between 200-400%. Their widespread use will reduce the demand for fossil fuels - a major factor in South Africa where most power stations are still coal-fired.

- Systems can vary in size from 125 litres domestic capacity units to very large commercial and industrial applications with heating and storage for thousands of litres of hot water.

- Although bulkier than traditional boilers, they can usually be accommodated within existing spaces and do not always require additional buildings to house them.

- Facilities which depend on standby generators can use heat pumps during power outages to produce hot water as they are more efficient than directly heating water with gas.

- The energy produced is usually three to four times the input. A unit consuming 30kWh will produce outputs of approximately 100kWh of water heating ability.

- Heat pumps can reduce the energy consumption of large water heating plants by up to 66% particularly in worker ablution facilities found in mines, where they can deliver the hot water needs of between 40 and 1 000 consumers on a daily basis.

Heat pumps case study at Zululand University (east campus)

In 2004 the University of Zululand asked Eskom to assist with the design of their new hot water system. The original hot water system consisted of resistance-element boilers and some very old heat pumps, and it was not coping with the hot water demands of the students. In order to meet the new requirements a resistance-element boiler system of 1.5MW was needed. The cost of such a system, with mild steel tanks, would have been approximately R3.6m. It was recommended that a centralised heat pump system with polyethylene tanks be installed at a cost of R4.2m. The cooling cycle of the heat pumps was used for air conditioning in the cafeteria. The hot cycle needed to heat over 220 000 litres of hot water required by the students. The annual savings realised by this system amounted to R310 000 per annum. This excluded the capital savings of a separate air conditioning system for the cafeteria.

Frequently asked questions

- **How much do heat pumps typically cost?**
  Costs vary from manufacturer to manufacturer, and according to the customers' specific needs. On a typical domestic unit of approximately 250 litres water capacity, the cost of the unit itself would be between 3 and 7 times the cost of an equivalent domestic resistance-element geyser. The actual installation cost should be about the same or, in some cases, marginally higher. The figure for commercial units is probably within the same spectrum, but with a shorter payback period. The costs of domestic units are more in line with a solar water heating system.

Notes:
It is advisable for plumbers to make use of the newer multi-layered plumbing pipes, and to use super insulation on longer runs. This eliminates the water wastage and delays in hot water reaching the hot water outlet. Heat pumps can also be used for underfloor heating within a building. They can also feed fan coil units with either hot or cold water.

- **What electricity source is required for installations?**
  The majority of large commercial heat pumps use a three-phase electricity supply, however, domestic units and smaller commercial units are all single phase. A small installation is defined as one with an output of up to 8kW.

- **Do heat pumps need servicing?**
  Yes. Suppliers will provide details of these requirements, however, they typically need less servicing than more conventional designs.

- **Are heat pumps noisy?**
  This depends on the size of the system and the design. Sources of noise in a heat pump system are usually produced by the compressor, in addition to air being blown through the evaporator radiator as air flows through the unit. Air noise is marginally higher than ambient background noise and is usually not distracting, especially as the heat pump is located away from work or sleep areas. On very large systems the noise level could cause distraction and therefore needs to be housed appropriately.

- **What factors affect the size of the heat pump I need?**
  The amount of heating needed will depend on the amount of hot water required, the average ambient air and municipal water temperatures, humidity, available storage and space constraints. Generally, heat pumps should be considered for producing hot water for showering purposes. This is usually an easy conversion, especially where there are no fan coil units or underfloor piping installations.

They should also be a major consideration for hotels and other applications where hot water is required. They become even more attractive where fan coil units are used to cool bedrooms, or conference areas, foyers and kitchens. These typical areas can be cooled by using the cold water produced by the heat pump on the cold side of the cycle.

To find out more

If you would like to find out more about heat pumps, and the benefits they could offer your business, browse through Eskom's website on www.eskom.co.za/dsm or contact Eskom's DSM help desk via telephone at (011) 800 4744 or e-mail dsmhelpdesk@eskom.co.za

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