



Bruno de Wachter

bruno.dewachter@forte.eu

Clothilde Wattel

clothilde@copperbenelux.org

Combining heat pumps with a PV system

A comfortable zero-emission house

<http://www.leonardo-energy.org/drupal/node/2083>



Figure 1 - The family before the house

Kurt works as an electricity and instrumentation designer for BNS Engineering. He lives with his wife Lieve and their two children, Ella (7 years old) and Pablo (5 years old), in a new house in Laarne near Ghent, in the Flemish part of Belgium.

It is a spacious home of 180 m² with all of the usual appliances: an electric cooker, a fridge, a freezer, a dishwasher, a washing machine for laundry, a computer, and a television. The house even has a private sauna as a bonus. The tap water is supplied to the house from a rainwater cistern by an electric pump. Despite all of these electrical appliances, the total monthly energy bill of Kurt and his family is only €76. How can that be?

For Kurt Hellemans, electricity is as much a passion as a profession. His technical know-how goes hand in hand with a strong environmental consciousness. His own home is a perfect example. He has installed two heat pumps, a ventilation system with heat recuperation, and photovoltaic panels. The complete system reduces the energy purchased from the grid to one quarter of what the average Flemish household uses. By buying ‘green electricity’ generated by renewable resources, he has reduced the carbon emissions of his house to zero.

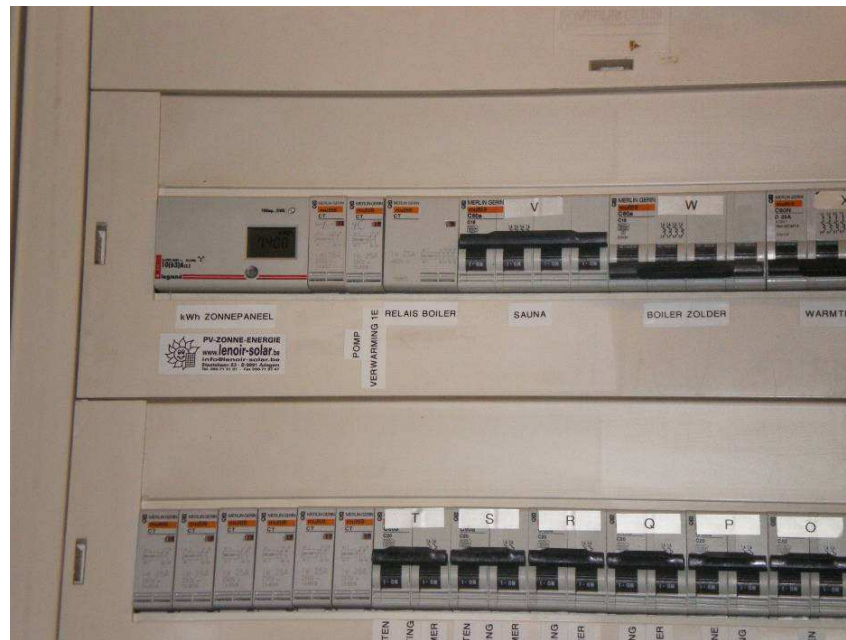


Figure 2 - The electricity distribution panel

Retaining heat from groundwater

‘The whole concept came into being gradually,’ recalls Kurt. ‘When we started building the house in 2000, the street was still without a natural gas network. I did not like the idea of heating our home by fuel oil, the most common alternative for natural gas. So I started looking around for residential heat pump systems. I finally bought a system from Nordic, a Canadian brand. The installer was a geologist, which was perfect since I could handle the electrical part of the installation myself.’

‘The system uses a closed circuit that consists of four 35 meter deep wells. In actuality, it does not retain heat from the ground but from a groundwater pool that has a more or less constant temperature. This is different from most heat pump systems in Europe. They usually have a long snake-like tube just below the surface of the ground. This results in a lower installation cost, but also in a lower efficiency since the temperature of the ground close to the surface is not constant.’

Little or no maintenance

The heat pump circuit consists of copper tubes filled with Freon. In the low pressure, low temperature section of the circuit, the Freon flows into the wells and retains heat from the ground water (6 °C). It is then compressed by a 5.5 kW screw compressor to high pressure and high temperature. After giving off heat to the house, the Freon is expanded again and flows back into the wells.

‘In the beginning we had some problems with the pressure safety valve switching the installation off. We then discovered that the installer had simply injected too much Freon into the circuit. Since correcting this, everything has worked perfectly. In the past six years we have not had any operational or maintenance problems whatsoever. It is true that a heat pump has certain inertia; you cannot raise the temperature in a house from 12 °C to 20 °C in one hour. But since our house is very well insulated, the interior temperature seldom, if ever, drops that low.’



Figure 3 - The heat pump

Forced ventilation with heat recuperation



Figure 4 - The ventilation system

Since the heat pump is combined with low temperature convection heating, good insulation is essential. To minimize the heat losses, Kurt opted for a system of forced ventilation with heat recuperation. Air is exhausted from the toilet, the bathroom, and the living room. Fresh air is injected, after being heated by the exhausted air, into the living room, the kitchen, and the bedrooms.

‘The result is that we rarely need to put on the heating in the

bedrooms,’ explains Kurt. ‘In the beginning, we had to get used to never opening the windows in wintertime. The ventilation system works a bit slower compared to wide open windows, but when I come home from work in the evening, bedrooms smell freshly ventilated and very little heat has escaped. During summer months we turn the ventilation system off and enjoy the pleasure of open windows.’ The ventilation system fans have been soundproofed to avoid noise nuisance.

Combining various subsidies

When the Flemish Government started granting subsidies for photovoltaic (PV) systems in 2005, Kurt did not hesitate and decided to install his own PV system. He also got a small extra grant from the community of Laarne, a tax exemption from the Federal Belgian Government, and his system yields *green certificates*. He could only receive subsidies for 2,400 W as a residential customer, but he opted to immediately install 3,840 W.

‘During the design phase of the house, I had already decided to eventually install a PV system on the roof,’ says Kurt. ‘As you can see, the sloping sections of the roof are not directed towards the street and the garden as you would normally expect, but rather towards the side of the house. One of the slopes faces south with only 2° of deviation.’



Figure 5 - The PV panels on the roof

A three-phased PV system

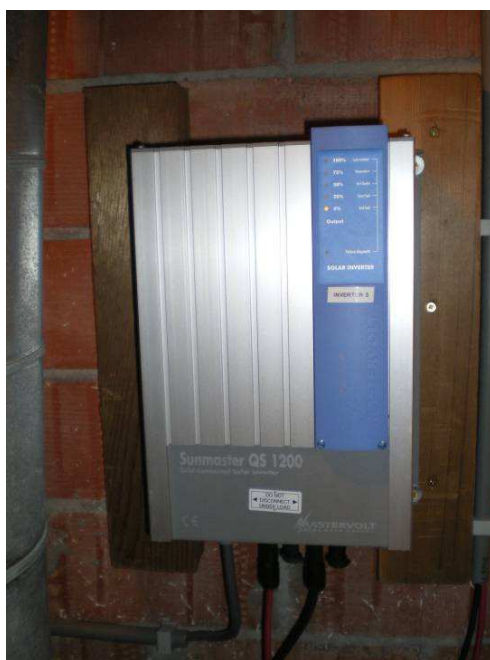


Figure 6 - The inverter

The PV system, installed on the south facing roof, consists of 24 panels of 160 W each from Shell and covers 30 m². The cells are made of polycrystalline silicon and have a 25 year guarantee.

Kurt Hellemans: ‘The most delicate parts of the system are the invertors. If their power is too low, they become too hot and will have a shorter life span. If their power is more than necessary, their efficiency goes down. I divided the panels into three sections and installed three invertors to generate three-phased electricity. That was the best option to keep my residential network balanced, since the heat pump compressor is also three-phase. The invertors have an efficiency of 95-98 per cent. I installed them in the attic to be as close to the PV panels as possible, because the DC side of the system has higher losses.’

‘The system reaches its maximum production between eleven o’clock in the morning and three

o'clock in the afternoon from April to September. On a nice sunny day, it can yield 22 kWh.'

Generating his own electricity does not mean he is spared from power cuts on the grid. 'I can not use my photovoltaic system as an Uninterruptible Power Supply', says Kurt. 'It simply is not worth the additional cost to provide a UPS function. When the grid goes down, a safety switch cuts my system off and we are in the dark just like our neighbors.' And what if a power cut happens on a cold winter's day? 'Then the heat pump turns off and we have to do without the heating system. But thanks to the excellent insulation of our house, temperature goes down very slowly. In the past six years, we have never had any problems with that.'

A second heat-pump for sanitary water

In the beginning, Kurt was still providing the hot-water supply for the kitchen and the bathroom by two stand-alone electrical boilers. In the meantime he has exchanged the boiler in the bathroom for a second heat pump. 'It is a small air-to-air heat pump that I installed in the attic,' explains Kurt. An air-to-air heat pump is basically a reversible air-conditioning unit that cools the surrounding air to heat water. 'I used the vessel of the old electrical boiler and connected it to the heat pump. In this way I created a buffer stock of 200 liters of hot water at 55°C. I am presently investigating whether I can also use this air-to-air heat pump to pre-heat the water for the electrical water boiler in the kitchen and for the dishwasher. It should be possible.'



Figure 7 - The second heat pump

Cutting consumption

Kurt is not only putting effort in optimizing the energy technology. He also tries to adopt good habits to minimize consumption. By installing a few kilowatt-hour meters, he is able to monitor the consumption of each energy function in the house. 'This awareness helped us cut our consumption from 13,000 kWh per year to 9,500 kWh per year,' he explains.

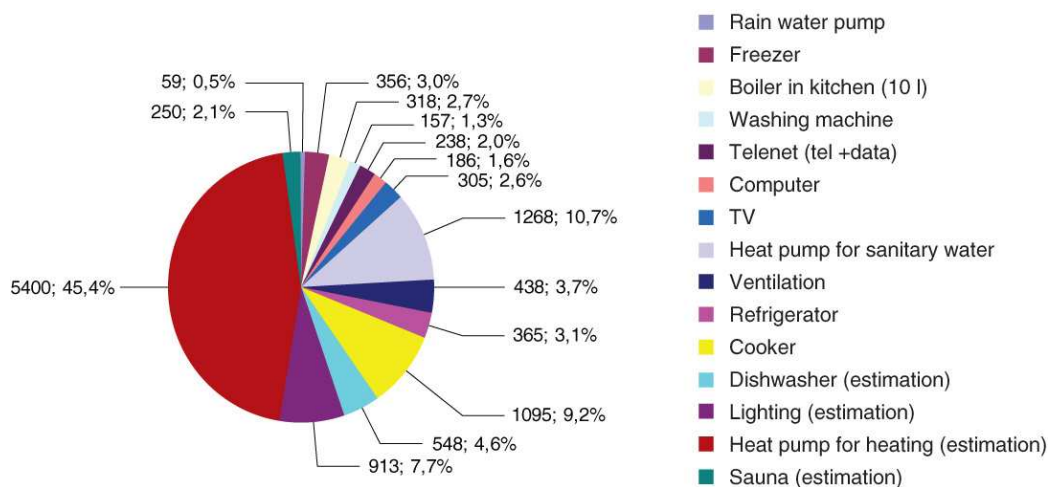


Figure 8 - The consumption of the various energy systems

Of this energy, he can generate 3,500 to 3,600 kWh with his own PV system. The remaining 6,000 kWh is supplied by the grid. This is less than one fourth of the 24,880 kWh the average Flemish household is buying from the electricity and natural gas utilities. And by purchasing 'green electricity' from Nuon, which is generated by wind and hydro power, Kurt assured that his house is completely free of carbon emissions.

'Our total energy bill is only 76 € per month', he says. 'For the PV system, I calculated a pay-back period of 17 years. With the new incentives of the Flemish Government (without subsidies but with a higher price for green certificates) the pay-back period would only have been 10 years.'

Dreaming of going off the grid

On the question if he would do anything differently if he could restart building his house, Kurt's answer is clear: 'I would have installed a larger PV system. Apart from that, I would do everything the same.'

'Upgrading the PV system now would require new invertors and that is a substantial investment,' he explains. 'But maybe I'll do that one day. I designed everything in such a way that I could go off the grid quite easily. That was another argument to make

the PV system three-phased. Providing my own renewable energy autonomously from the grid would be a dream come true for me.'



Figure 9 - The house

As the interview ended, Kurt's wife Lieve was leaving for a tennis match. By car. 'The fact that we are still driving those oil-fueled cars with all their carbon emissions bothers me,' she says. 'I'll be happy if one day we'll be driving plug-in hybrids.'

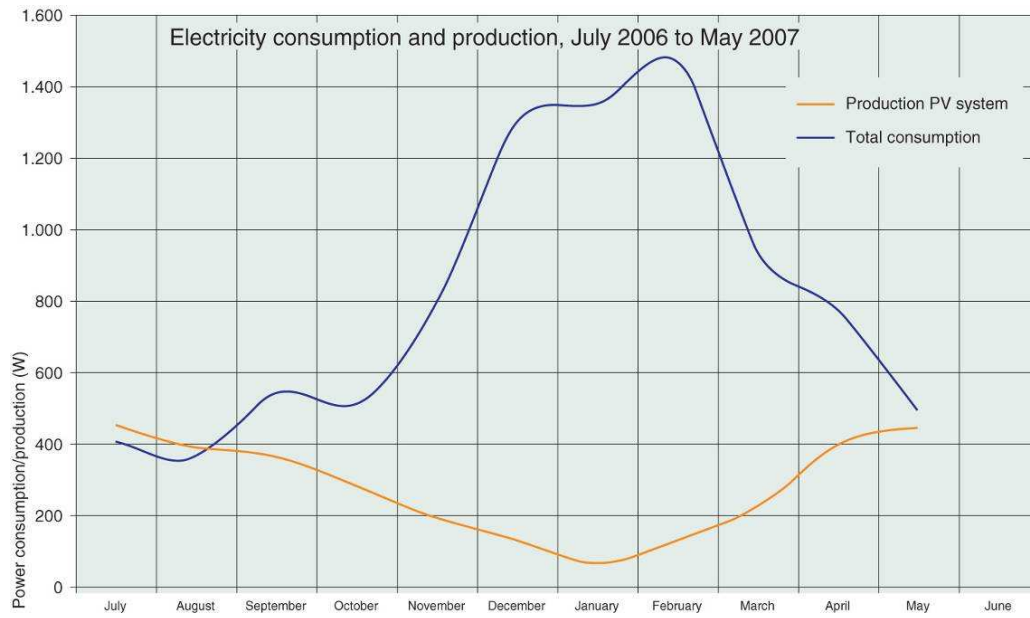


Figure 10 - Total electricity generation and consumption in the house