A fridge that takes only 0.1 kWh a day?

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There is no mistake in the title. This article describes an inexpensive fridge that is 10 to 20 times more energy efficient than an average fridge on the market. It also demonstrates that the biggest limitations are our habits and mediocre attitudes, not technology or cost.

My dream is to live a near-zero emission life. Step by step I come closer to bring this dream to reality. After all, the rainforest here at Mt Best is so beautiful and so unique that I hesitate to disturb it with any kind of pollution.

Insulating and double-glazing my RAL home reduced my winter energy requirement to about 20 Watt per square meter of floor area. I do not like “star ratings”. I think they are misleading and promote ignorance rather than understanding of energy efficiency.

Reflective solar heating (described in issue 88 of Renew) nearly halved my heating energy (and the firewood) needs in winter. However, to achieve a near-zero emissions I needed to find a clean renewable source of energy to replace the firewood altogether. The system of choice became a geothermic storage heat pump system that will be described in my next article. However, since I generate my own electricity from wind and sun, I needed to save some energy to run the heat pump.

For almost 2 years I tolerated the fridge that I did not like a little tiny bit. The list of things I did not like about it is too long to mention here. If I could eliminate this fridge, I would have enough energy to run the heat pump…

Chest fridge

Comparing the energy consumption of various refrigeration devices available on the market I noticed that well-designed chest freezers actually consume less electricity than fridges of comparable volume, even though freezers maintain much colder temperatures inside. While chest freezers typically have better thermal insulation than fridges, there is another reason for their efficiency.

Vertical doors in refrigeration devices are inherently inefficient. As soon as you open a vertical fridge door – the cold air escapes, simply because it is heavier than the warmer air in the room. When you open a chest freezer – the cool air stays inside, just because it’s heavy. Any leak or wear in a vertical door seal (no seal is perfect) causes significant loss of efficiency. On the other hand, even if you leave the chest freezer door wide open, the heavy cool air will still remain inside. Have you ever wondered why chest freezers in supermarkets have their doors either wide open or not thermally insulated?

Designing refrigeration devices with vertical doors is clearly an act against the Nature of Cold Air. Shouldn’t we cooperate with Nature rather than work against it?

I become really curious just how efficient a chest fridge can be. After contacting some leading fridge manufacturers and discovering that no one has ever made and tested a chest fridge, I decided to make my own test. I bought a good chest freezer and turned it into a fridge.

Turning a chest freezer into a chest fridge

The main difference between a freezer and a fridge is the temperature maintained inside. Freezers maintain sub-zero (freezing) temperatures down to -25^{o} C, while fridges operate somewhere between $+4^{o}$ and $+10^{o}$ C.

Hence, turning a freezer into a fridge meant changing the temperature control. Rather than interfering with mediocre thermostat of the freezer, I decided to install an external thermostat to cut the power off when the temperature of my choice has been reached.

For my research I bought a Vestfrost SE255 chest freezer with 600a refrigerant and a $40 battery-powered thermostat equipped with digital temperature display and an internal 5A/240V latching relay. The main feature of the latching relay is that it consumes battery power only during actual switching so that the thermostat equipped with it is a true micro-power device and its 2 AAA batteries last for many months.

Connection diagram (Fig 1.) is really simple. Thermostat relay cuts the power to the freezer, much like a light switch cuts the power to a lamp. Thermistor (the temperature sensor) is placed inside the freezer at the end of a thin 2-wire flexible cable. I used the freezer drain hole to pass the thermistor cable inside the cooling compartment. An alternative is to insert it from the top via the chest door. If the thermistor is left near the bottom of the chest fridge – the minimum fridge temperature is controlled by thermostat. If the thermistor is located near the top of the cooling compartment – the thermostat will control the maximum temperature there. The best position for thermistor is somewhere in the middle.

It took me about 30 minutes to make all connections. The most time consuming part was removing the thermistor from inside the thermostat (I cut it out from the circuit board using wire clippers) and soldering it at the end of a thin 2-wire flexible cable. I protected the thermistor from moisture and mechanical damage using shrink-wrap tubing and a tiny bit of silicone.

The external thermostat can be installed anywhere on the fridge or outside it. I have decided to place it on the wall behind the fridge, so that the temperature display was easy to read at the eye-level.

I have also removed the interior light bulb, rated 15 Watts, because I avoid using energy wasting devices as a matter of principle. I will consider installing a LED interior illumination if I find a reason for opening my fridge in the dark.

When I finished my connections I had a chest fridge with a digital temperature display and a temperature control at my fingertips.

Performance

I set the thermostat to $+7^{o}$ C and switched on the AC power via energy measurement gadget called Sparometer. After about 2 minutes my thermostat displayed $+6.5^{o}$ C and the power to the freezer was cut off. The temperature continued to drop down to about $+4^{o}$ C. I thought that there was something wrong with the digital display, because everything happened too quickly. I took another thermometer and to my surprise, it confirmed readings of the thermostat.

I watched the system for a few hours and then decided to move the content of my old fridge to the new one that I have just made. Since I have never had a chest fridge in my life – it took me some time to arrange baskets and their content inside. I placed the most frequently used items in top baskets that slide on top edges of fridge walls. It turned out to be a very practical idea. Not only they are very handy there, but also I can take out the entire basket, rather than taking out one item at a time (a typical case with a vertical door fridge).

In the first 24 hours my new chest fridge took 103 Wh (0.103 kWh) of energy. About 30% of this energy was consumed during the initial power up and re-arranging of the fridge content. The room temperature varied from 21^{o}C during the day to 15^{o}C at night. The fridge interior temperature was kept between $+4^{o}$ and $+7^{o}$ C. The fridge compressor was working only for about 90 seconds per hour. When the thermostat intervened – the fridge consumed ZERO power. The only active part was a battery powered temperature display.

Results of my experiment exceeded all my expectations. My chest fridge consumes as much energy in 24 hours as a 100W light bulb does in just an hour. Not only it is energy efficient. I have never seen a fridge that was SO quiet. It only works 90 seconds or so every hour. At all other times it is perfectly quiet and consumes no power whatsoever. My wind/solar system batteries and the power sensing inverter simply love it. With my new chest fridge I have power to spare and I can use it to warm up my house in winter with a heat pump. I wonder why no one has ever thought of a chest fridge controlled by a digital thermostat…

What performance can I expect from my chest fridge during hot summer days? In principle, the energy consumption should be proportional to thermal losses of the fridge, which in turn are proportional to the temperature difference between the inside and outside of the fridge. A vertical door fridge has large additional losses caused by opening the door and the associated loss of cold air

The power consumption data for my chest fridge was measured for average 5^{o}C internal and about 18^{o}C average ambient temperature (13^{o}C difference). If the average ambient temperature rose to 31^{o}C, the temperature difference will double to 26^{o}C. This in turn should double the thermal losses and hence the energy consumption. In this case I expect my fridge to work about 3 minutes per hour.

In reality, doubling the temperature difference causes slightly more than doubling of the energy consumption, due to the reduced thermal efficiency of the fridge heat pump (compressor system). The larger the temperature difference between the heat source and the heat sink, the less efficient is the heat pump.

Fortunately for those who rely on solar power, in hot summer months there is also more solar energy to power the fridge...

It is obvious that a truly energy efficient fridge does not cost any more money than a mediocre one. It actually costs less. It also has extra features, such as a digital temperature display that gives you full control over the temperature settings. So - WHY mediocre fridges are being made? Why people continue to buy and use energy wasting devices? Does anyone care?

Nearly every household on Earth has a fridge that totally wastes at least 1 kWh of energy a day (365 kWh a year). How much reduction in greenhouse emissions can we achieve by banning just ONE inefficient household device in just ONE country? How many politicians debating for how many years will it take to achieve such a ban? Rather than waiting for someone to do something I would like to volunteer to supply modified chest freezers and/or freezer modification kits to environmentally conscious people of Australia. Let's do something in the right direction right now.

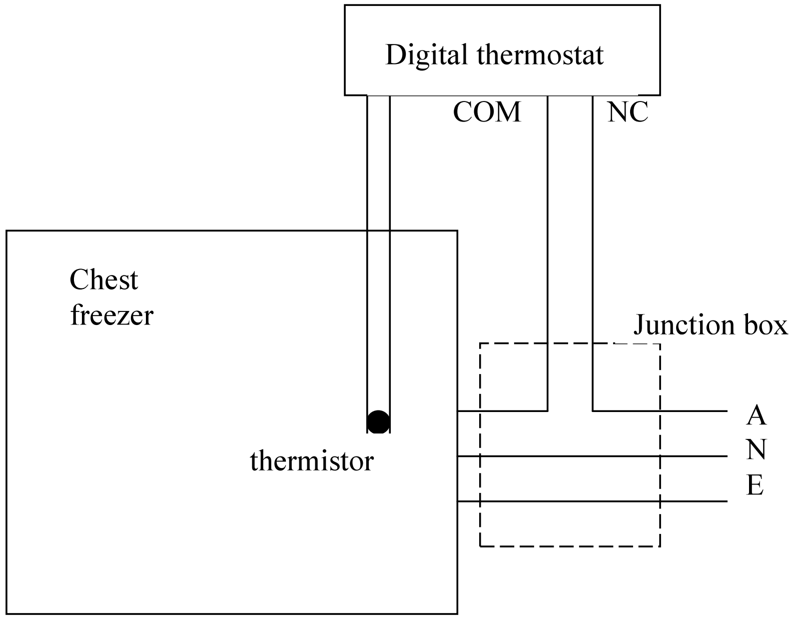

Fig. 1. Wiring diagram of the chest freezer turned into chest fridge. The junction box is not required if all connections are made inside the fridge service compartment. Active (A) connection passes via latching relay terminals inside the thermostat.

Fig 2. Fully installed chest fridge with thermostat on the wall. Note energy measuring gadget at the bottom left.