Action Research: My Change Toward Improving My Sustainability

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During the last few months, I have embarked upon a plan to reduce my electrical & gas energy consumption. I must admit that I was already thinking of doing so in the face of a very high energy bill after Christmas, but the requirements for this essay meant that I could combine saving money with getting coursework done which seems like a win-win deal. This essay summarises my progress, the realisations that I have made and how hidden energy consumption is so easy to miss.

Background

Like most people, unless it affects me in the pocket with a "wow" factor (as in, "wow that's more expensive than I thought"), I don't much consider how I consume energy. Sure, one knows that a disposable plastic bottle requires however many kilograms of fossil fuels, or a glass bottle so many kilojoules for processing & transporting the silica, but one does not realise just how much they are or indeed how important (or not) such a consumption might be. After all, consuming a lot of renewable energy might even be worse in the big picture than a small amount of non-renewable energy, but our price mechanism does not show any of the "back story".

I did however get "wowed" with our first electricity & gas bill from Scottish Gas, especially with historically high energy prices thanks mostly due to deregulation of the energy market in the UK. We, like most students, live in rented accommodation and so cannot change our utilities provider nor make structural improvements to our house (e.g.; installing a condensation gas boiler, or improving insulation). However, we can change our behaviour and because we can read our own meter readings, have feedback on how well we are doing. Indeed, having the house as a constant allows direct interpretation of changing behaviour.

Our House

Our terraced house is just below Tom Morris Drive as part of a complex of council houses built after the Second World War. After Thatcher's introduction of the "Right to Buy" policy, most of these houses have been bought by their tenants. The quality of these houses is high for council housing, and our house has been refurbished with modern double glazed windows, new attic insulation and a modern central thermostat controlled heating system with individual thermostats on each of the radiators. It contains two bedrooms and a bathroom upstairs and a dining room plus kitchen downstairs.

There is no insulation between ground and first floors, so heat tends to rise easily from the kitchen and dining room. Upon moving into the house, during a number of days I adjusted the individual thermostats to ensure that the top floor radiators were minimally activated while the dining room radiator was fully on (and thus relying on the central thermostat). Initially we had the kitchen being heated like the dining room, however we discovered that leaving the kitchen door open created a draft and by keeping the kitchen door closed, we could eliminate almost all the heating in the kitchen (which also improves the efficiency of the fridge and freezer). We chose 17°C for the central thermostat which while not warm was not cold – we used a spare duvet on the sofa if we wanted extra warmth. We used a separate digital temperature monitor throughout and found that the temperature ranged between 16°C and 19°C.

We had the heating also running on a timer: 8am-10am and 6pm-11pm but we sometimes overrode the timer if it was particularly cold during the daylight hours or we were studying in the house all day.

Date	Electricity	Gas	Used Electricty (kWh)	Used Gas (m3)	Days	kWh Electricity Per Day (left scale)	m3 Gas Per Day (right scale)
01/09/2006	29072.6	1127.525					
08/12/2006	29963.8	1216.973	891.2	89.448	98	9.093877551	0.91273469
03/04/2007	31176.9	1475.32	1213.1	258.347	116	10.45775862	2.22712931
23/04/2007	31378.1	1479.95	201.2	4.63	20	10.06	0.2315
30/04/2007	31443.7	1480.58	65.6	0.63	7	9.371428571	0.09

Table 1: Electricity & Gas Consumption 1st September 2006 to 30th April 2007

Table 1 shows the meter readings for Electricity and Gas since we moved into our house. One can see a noticeable spike during the winter period and a trailing off thereafter, most obviously for gas – yet our electricity consumption has remained fairly constant with an average of 9.84kWh per day.

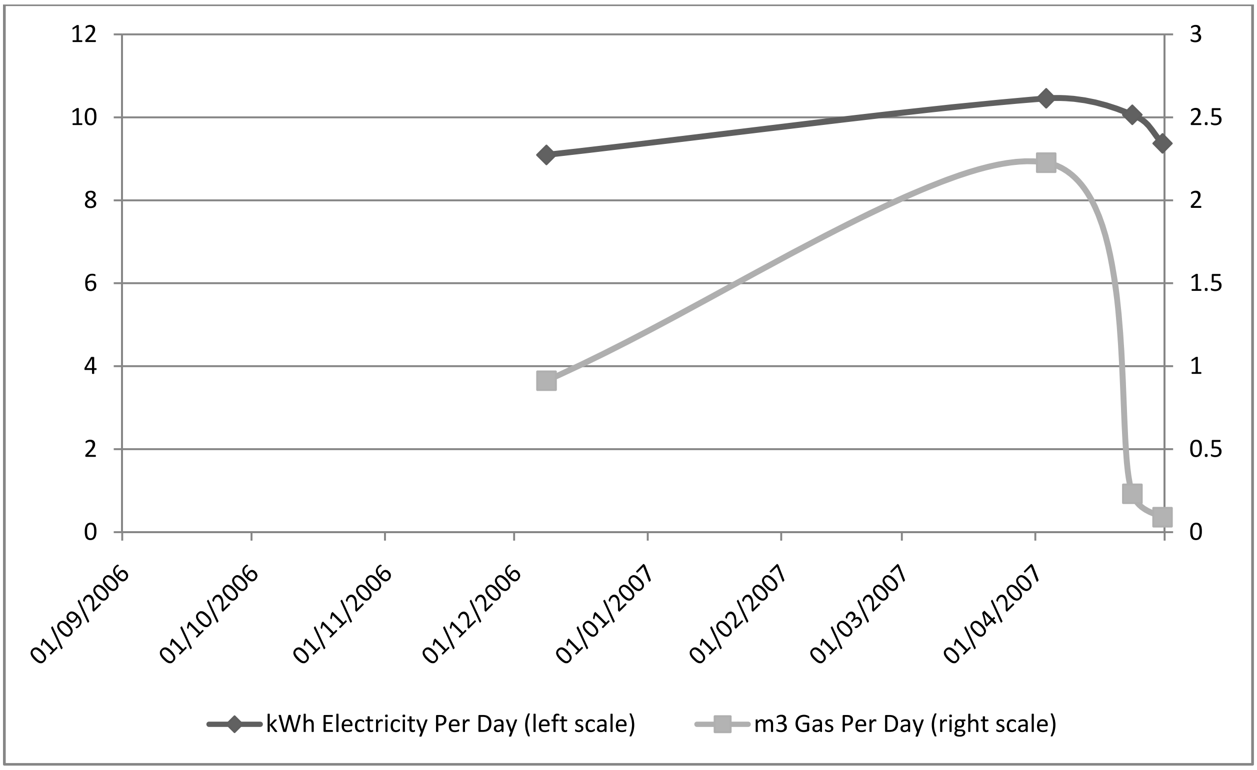


Figure 1: Per Day Electricity & Gas Consumption 1st September 2006 to 30th April 2007

Before The Change

Due to being unable to make structural changes to our house, we cannot do much past what we have done to reduce gas consumption but we surely could with electricity consumption. I had thought before this semester that one of the main reasons that we had such a high, regular consumption of electricity was that my personal computer is running 24/7. I had no idea just *how* much it contributed, but for the purposes of this essay I determined to find out.

This is not to say that it would be more responsible if I just turned it off all the time. This computer is permanently connected to the internet and is always doing something – also, hard drives have a vastly lower failure rate if they are never heated up and cooled down repeatedly and as a former Computer Science student, I have a great deal of valuable data (currently a quarter of a Terabyte) plus all our audio-visual entertainment is served from this computer via a wireless network to other computers throughout the house. One still might deem this unnecessary, but bear in mind that a computer is basically a fancy electric bar heater – all the energy it consumes is converted into heat, and that extra heat made a noticeable difference to the top floor of our house when the heating was off. So effectively it was a form of heating the top floor of our house.

Nevertheless, that computer was relatively ancient being year 2000 technology. Substantial improvements have been made in power efficiency since then, and as I needed to upgrade it anyway, I determined to find the most power efficient parts possible for a reasonable price. After all, extra heating is a waste during the summer and furthermore, the hotter a computer, the more noisy it usually is – which is a problem when it's in my bedroom!

Before all that though, I needed to find out *specific* power consumptions so I bought a digital power meter from Maplin for £15 which is pictured on the left. This is a very useful device because you can test individual items to see how much they contribute. Table 2 summarises the power consumption for various left-on items around the house.

Item	Subitem	Power Factor	Off	Idle/ Standby	Busy/ On
BT Phone		0.53	-	-	3W
Wireless Internet		0.6	-	-	15W
Fridge		0.55	-	0W	89W
Old Computer	16" TFT Monitor	0.53	0W	1W	16W
	Epson Printer	0.5	2W	-	2W
	Speakers	0.4	8W	-	13W+
	Dual Athlon 1700	0.62	4W	228W	221W
	Total	**0.58**	**14W**	**242W**	**252W**
Total 24/7 usage	**Minimum: 255W**				
Used Daily:					
Lighting		?	0W	-	37W
Entertainment	Laptop	0.9	8W	38W	83W
	19" TFT Monitor	0.58	1W	1W	33W
	Speakers	0.71	8W	21W	38W+
	Total	**0.78**	**17W**	**60W**	**154W**

Table 2: Power Consumption for various often used household items

Some explanation is required here. Firstly, "Off" means that the item appears to be turned off – its switch is turned off. "Idle/Standby" means that the item has entered some sort of power save mode e.g.; the computer is idle, the monitor has gone into standby etc. Lastly "Busy/On" means that the item is working e.g.; the computer is crunching some numbers, music is playing out of the speakers etc. Where there is a + after the number it means that it can go upwards e.g.; speakers will consume more power the higher the volume is.

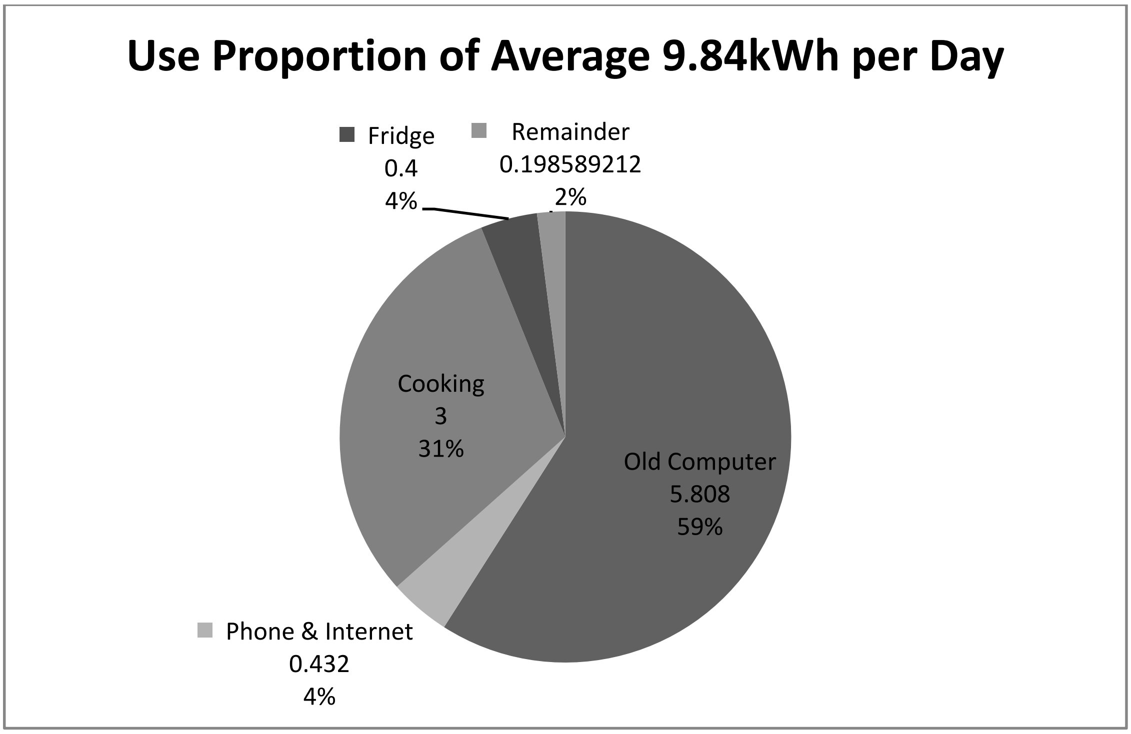


Figure 2: Categorised Electrical Consumption Per Day

Another interesting measurement is that we use about 2kWh each time we cook using the oven & hob and a little less than 1kWh when just using the hob which I average out as 3kWh per day. We can therefore decode our electricity consumption of around 10kWh per day into the pie chart depicted in Figure 2.

One can see that the old computer represents a good majority of the total electricity consumed. This at the time was quite a surprise, but a bigger surprise was how much cooking consumes and how little things such as using the dryer (which we use for 30 minutes and leave to rack dry thereafter), the fridge, the electric shower or lighting.

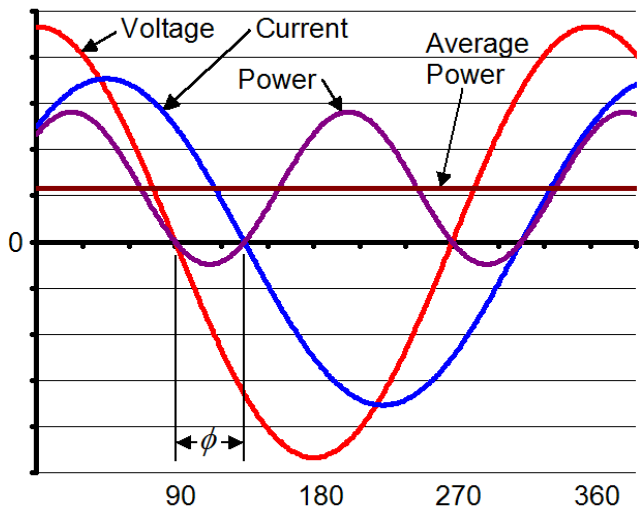
After The Change

The new computer consists of the latest technology as of 2007, and I also bought an expensive Power Supply Unit with guaranteed >0.9 power factor and 85% efficiency (the old one could barely break 60% despite being the best-in-class at the time of purchase). The very latest technology can dynamically alter its running speed and thus power consumption depending on what the computer is doing, so unlike the old computer which expended the same energy no matter how idle it might have been, the new one can throttle back its CPU clock and voltage to run more slowly when not in use. It can also adjust its fan speeds according to heat production via an internal thermostat, so this yields idle and busy power consumption of 115W and 227W respectively with the fans spinning down to inaudible when idle.

This should result in a 113W*24=2.712kWh reduction in daily consumption. As one can see from Figure 1 above, since the new computer was installed at the start of April, there has been a noticeable drop of around 1kWh per day but this is less than half of what it should have been. My unverified as yet hypothesis for why is that the computer will easily jump up to 150W-170W of consumption even if I am just typing on it or it's doing anything at all which would mean only a 1.3-1.7kWh reduction.

Power Factor

Mains power is in alternating current form (AC) but many electrical items require direct current (DC) which requires an AC to DC conversion. The quality of this conversion can vary widely depending on the method used and the quality of the components. The two most important factors determining quality conversion are straight efficiency (how much of the input energy is converted to heat in order to produce the output energy) and power factor (how much the AC sinusoidal wave is deformed by the converter). The latter is particularly important because consumers do not pay for it and therefore the supply company takes it as an overhead.



An example will help. Any heating appliance, say a (conventional) bulb or electric oven, simply passes the electricity through a resistor which reduces the voltage and consumes current across the resistor at the same time. Therefore its power factor is 1.0 – the electricity required to expend say 100W of heat is exactly 100W. However, an AC to DC converter will skew the waveform, making it no longer correctly synchronise voltage with current. The figure on the right shows how a power factor of 0.71 causes the bottom of the power waveform to dip below zero, thus causing average power to be lower than it is supposed to be. In this case, the power company must supply 100W/0.71=141W to expend 100W. Let us put this more clearly: Any equipment doing an AC to DC conversion requires the power company to supply more power than the equipment appears to use at the electricity meter.

Needless to say, as the number of DC using household appliances skyrockets, more and more power consumption is being moved off the consumer's electricity meter. This led the EU via IEC 61000-3-2 to introduce minimum power factor requirements for new electrical appliances: as of January 1st 2001, anything drawing more than 75W must have a minimum power factor of 0.7. As you can see from the table above, this has had a noticeable effect on newer goods as the speakers for the Entertainment computer have a power factor of 0.71 whereas the older speakers for the old computer have only 0.4 despite being from the same manufacturer.

The Impact

Now that we understand Power Factor, we can calculate the real effects on sustainability of our changes. Figure 3 shows power factor corrected values for electricity usage.

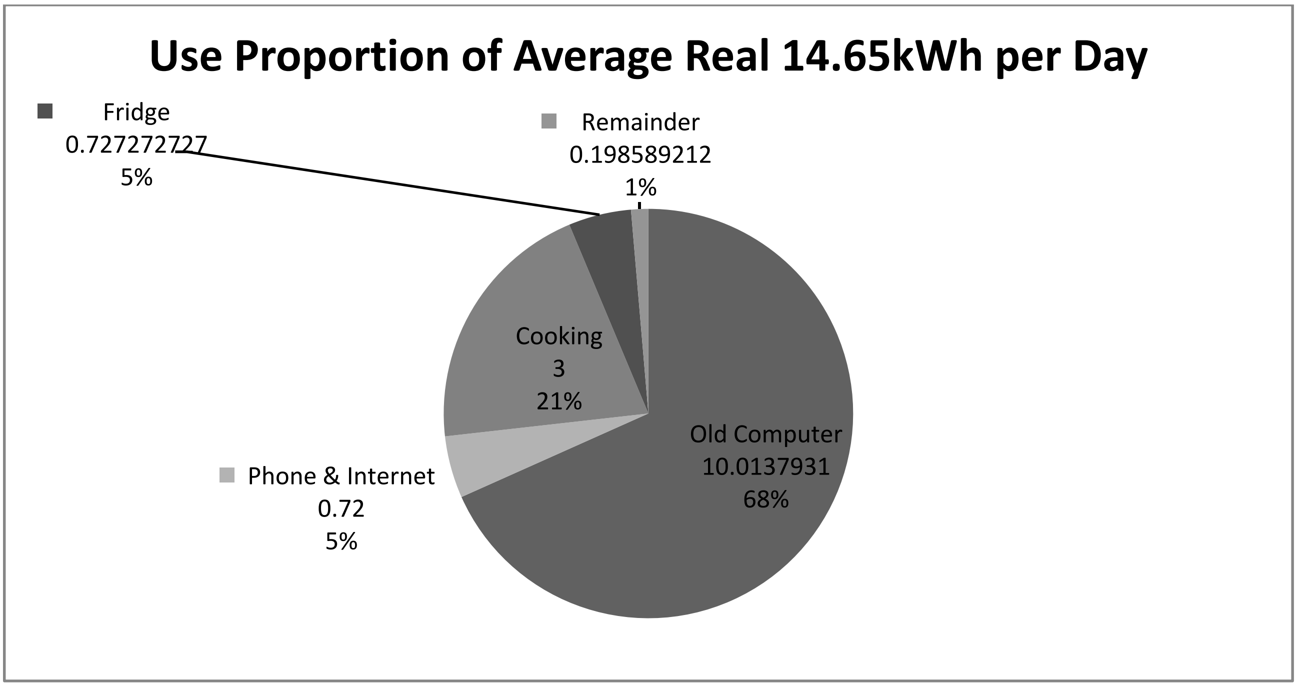


Figure 3: Power Factor corrected Electrical Consumption with Old Computer

The real electricity usage has jumped to 14.65kWh per day, a 48.9% increase. The old computer now consumes **68%** of real daily electricity usage!

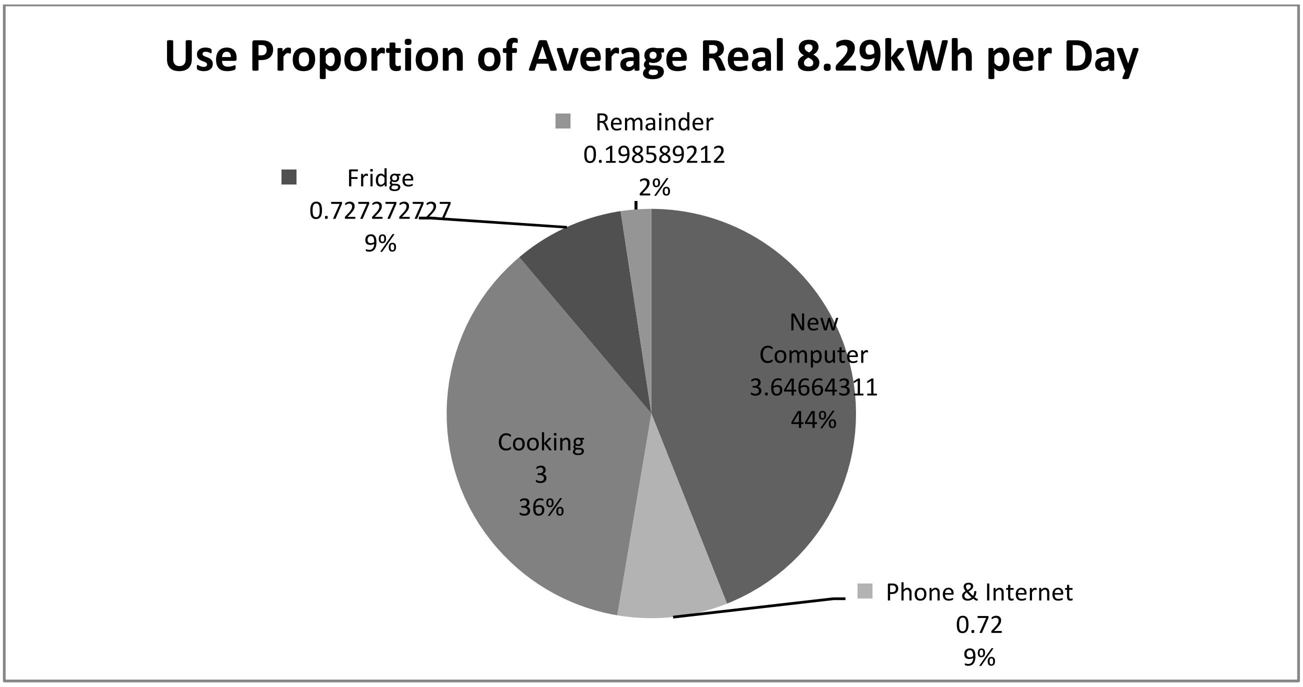


Figure 4: Predicted Power Factor corrected Electrical Consumption with New Computer

With the new computer, total daily real usage should shrink to 8.29kWh which is a 43.4% decrease, not far from half – much of which is power factor improvements. The New Computer no longer consumes most of the real electricity usage and should indeed now be nearly a **third** of the old computer.

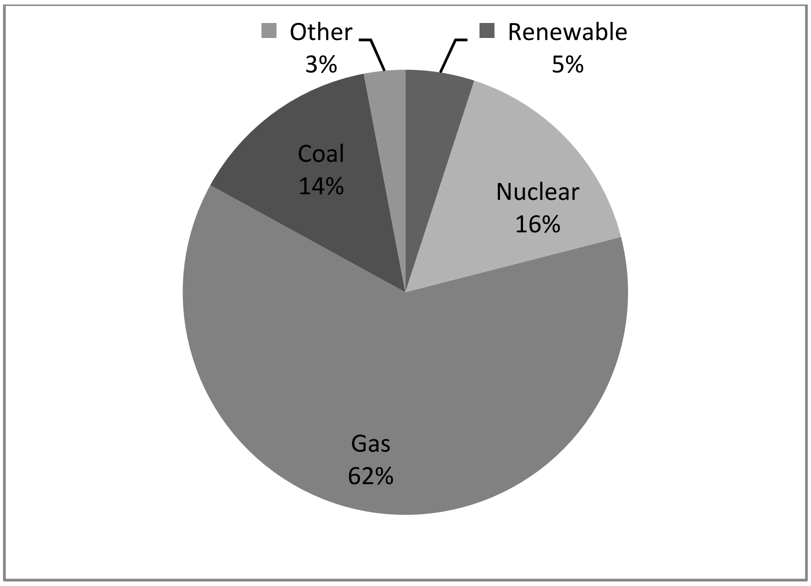


Figure 5: Scottish Gas Fuel Mix in 2006

According to the DTI, figure 5 shows the fuel mix for Scottish Gas in 2006. This results in 0.354kg of CO_2 and 0.00262kg of nuclear waste per kWh. Even if we only have saved 1kWh per day at the meter instead of the predicted 2.712kWh, this through improvements in power factor translates into 1.46 real kWh per day which is 188kg of CO_2 and nearly a kilogram and a half of nuclear waste saved per year. Of course, we probably have expended a lot more than that in the manufacture and transport of the new computer parts, and indeed none of this accounts for the pollution effects of say burning coal instead of gas or any form of mining etc, but it will almost certainly have paid for itself in raw CO_2 output terms within the five year expected lifespan of this new computer.

Conclusion

The new computer may only save us about £36 per year at the meter, but it should save considerably more for the power company and thus the planet. It is amazing how actual power consumption is so hidden from us – a DC power supply grid would eliminate all need for AC inefficiencies and indeed it was only due to a fluke of history that we got lumbered with AC at all[1]. Due to IEC 61000-3-2, Europe will cut her electricity consumption substantially over the next few years yet due to deregulation, UK consumers are unlikely to see any of the cost savings. Only a few extra euros worth of cost per unit is required to bring all AC to DC converters up to better than 0.9 power factor – indeed, that was the original IEC proposal, but it was watered down by the EU commission – but such legislation could cut European electricity usage by up to a third. Even better, if Europe implemented a 24V DC supply, it is directly compatible with solar panels and all the waste (min 15%) necessary from even best-in-class AC to DC conversion would be avoided never mind completely avoiding AC power line transmission waste which can be a lot.

For me personally, I have found that while it is not easy becoming more green, it is far easier than in the past. When I bought the old computer in 2001 I did so then with power efficiency in mind, but there simply was not any information available from the manufacturers – I had to rely on geek webpages on the internet who did their own testing. In 2007, this process has been vastly easier and there has also been a very noticeable improvement in getting hold of the data as well as power efficiency being considered in their design – even two years ago, that £15 power meter from Maplin was costing well over £100 and so it would have been impossible to do the detailed survey of my house that I have done for this essay. Best-in-class power supply units are now over twice as efficient and CPU's can dynamically adjust themselves to use up to a third of their maximum power draw. It would be even better if we had some environmental impact figures available for the manufacturing of the computer components themselves, but sadly these are not accurately available outside industry campaigns against the RoHS directive which are hardly objective.

[1] AC vs. DC was the first modern standards war and is substantially treated in Jonnes (2004).

I would wholeheartedly recommend that everyone own their own power meter – not only is it fun to find out how much power we use, it breaks down how we use our electricity – one can literally test the difference between boiling just enough water for a cup of tea or too much as many people do. I look forward to owning my own house where I can install my own 24V DC power rails and thus increasingly move the house to energy self-sufficiency via a water wheel and solar panels. My research for this essay shows just how much easier all this is becoming, and I hope it keeps on becoming easier.

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