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Australian (Worldwide?) Ban on Incandescent Lamps

Should There be a Ban on Incandescent Lamps?

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PLEASE NOTE: My apologies for the length of this article, but this has turned into something of a horror story. Only a short while ago, I thought that the power factor issue was most important, then that a vast number of enclosed light fittings (probably hundreds of millions worldwide) cannot be used with CFLs was critical. Now, it turns out that dimmers are a far bigger issue that first imagined. What happens in houses where dimmers are fitted? These *must* be removed completely, not simply set to maximum and left there. Who's going to pay to have millions of dimmers worldwide removed by electricians? You, the homeowner - that's who.

Power factor is still very important ... while you only *pay* for the actual energy used (as shown on the packaging), power companies have to *provide* the full voltage and current (also shown on many packages and/or other literature). The relatively poor power factor increases distribution losses and therefore the cost of getting electricity to your house.

Now, we also have the European Union (EU) singing the same silly song. It was recently announced that the 490 million citizens of the 27 member states will be expected to switch to energy-efficient bulbs after a summit of EU leaders yesterday told the European Commission to "rapidly submit proposals" to that effect. I wonder just how much research was done before this piece of lunacy was announced? None, perhaps?

Speaking of the EU, these mental giants have recently decided to ban mercury altogether. Apart from the considerable annoyance to people who use it for manometers, barometers, certain antique clocks, etc., the ban is inconsistent. While they will probably eliminate a few tonnes of mercury from those who would use it responsibly, there will be hundreds or perhaps thousands of tonnes (in CFLs and conventional fluorescent lamps) in the hands of the general public. Most will end up in landfill unless there is a very comprehensive education campaign for the householders throughout the EU and elsewhere. So far, there appears to be little or no effort anywhere to ensure that the public are made fully aware of the risks involved. As of early 2010, there are still people who remain blissfully unaware that CFLs contain mercury!

Nothing in this article is conjecture or CFL bashing (I *like* CFLs used sensibly, and have installed them wherever possible in my home and workshop), merely simple facts that a great many people have overlooked. The reasons are described below (yes, it's mostly technical), and for those who want to know more about power factor, the use of CFLs in existing luminaires, or any of the other factors involved, please read on ...

(External links in this article are for information only, and do not necessarily reflect the opinions of the author of this page.)

Contents

Several sections have been moved to separate sub-pages to try to reduce the size of this article. For the links to work properly, you must have JavaScript enabled on your browser. The sub-pages use script to create popup windows with a "close" button. You can open the files in a new window by right-clicking the link if you prefer.

Introduction

It is now illegal for anyone to import conventional incandescent lamps (light bulbs) into Australia, except for a few specialty types. In most shops, there isn't an incandescent lamp to be seen, although some have small fancy types as might be used in some specialty chandeliers or similar fittings. Insanely, halogen downlights are still readily available because they pass the MEPS (Minimum Energy Performance Standards) criteria ... just. They have also caused a number of house fires because ceiling insulation was too close to the fitting (there are special clearance requirements for downlights and any type of insulation).

So far, it's fairly safe to say that few households will have seen a dramatic reduction in their power bills, and the governments (local, state and federal) have remained stoically silent regarding any form of mandatory recycling scheme to prevent a build-up of mercury in land fill waste disposal facilities. The Copenhagen conference came and went with no firm commitment by anyone.

No-one seems to have noticed that it is immaterial if global warming/ climate change is man-made or not. The fact is that we cannot continue the way we are because the resources we are depleting will eventually be gone. It won't have a major impact on those who are around now, but future generations will have good reason to curse us to eternal damnation for the massive waste of valuable resources over the last hundred years or so. And rightly so - what we have done (and are still doing) is nothing short of shameful. Governments are more interested in being seen to be doing something (large, highly visible projects) than *actually* doing anything ... like switching off unused lights in government buildings at night.

Meanwhile, the cry to ban the humble incandescent lamp (also known as GS - general service or GLS - General Lighting Service) may not seem like such a bad idea at first glance, but there are a number of issues that have not been addressed (or even thought about, based on what has been heard so far). Incandescent lamps are inefficient, typically over 95% of all energy consumed is converted into heat - not light. By comparison, the CFL (compact fluorescent lamp) has a dramatically higher efficiency, although it falls well short of a full sized (18W or 36W) standard fluorescent tube. The latest tube-type fluorescent lamp is the T6 - thinner than the traditional T8 we mostly use, and can only be used with an electronic ballast. These have greater efficiency (more lumens/Watt) than all earlier fluorescent tubes, and use a ballast that *doesn't* get thrown away with the tube.

Many people have tried CFLs in any number of locations, but they are not always liked because of their colour rendition (many colours look wrong under all forms of fluorescent lighting), and because they are considered by many to be rather ugly. These dislikes are not necessarily major issues of course, although there are many users who would disagree.

Lighting is actually a very complex topic, and although it seems pretty simple on the surface, there are many factors to consider that proposed legislation will utterly fail to address. Just look at the European RoHS (restriction of hazardous substances) legislation as an example of how wrong things can get when governments become involved in things they don't understand.

This article is not intended to be a complete and final discussion - because lighting *is* so complex, I am bound to miss things, and I can only rely on the information I can get my hands on. There is undoubtedly a great deal that I won't find. Hopefully though, this article may get a few people thinking of the long term implications of the proposed ban (which is almost completely meaningless in real terms).

As a side issue, although I have (mostly) used the term "efficiency" in this article, this is actually relatively meaningless for lights. The correct term is luminous efficacy, usually expressed in lumens / Watt. While not strictly accurate, comparing the relative efficiency of different light sources does make it easier to comprehend - few people outside of the lighting industry will really have a proper grasp of the concept of luminous efficacy, so I have elected to keep the term "efficiency" in the interests of making the article as easy to understand as possible.

LED Lamps

The nice people at LV Lighting saw this article some time ago, and sent me a LED lamp to trial. The lamp is excellent, and I would have no hesitation recommending these to anyone. The colour temperature is good, and the lamp doesn't get excessively hot in use. This is not to say that it runs cool - it doesn't. The front bezel is a heatsink, and this gets quite hot after it's been on for a while. Now over three years later, it's just as good as when new (it gets used for up to 4 hours a day), and I now have quite a few LED lights around the house too.

As with CFLs, the current crop of LED lamps need good ventilation, because the electronics (and

LEDs) must always be kept cool in order to obtain maximum life. With a minimum rated life of 20,000 hours (up to 50,000 hours is also claimed on the pack, 80,000 to 100,000 hours elsewhere on the Net), no CFL can even come close. There's also no mercury involved, so disposal is less of an issue. While it pains me to see perfectly good electronic parts being thrown away, reality indicates that it will happen whether I like it or not - at least there's no risk of contaminated landfill.

LED PAR20 Lamp

The lamp I was sent is a PAR20 style. PAR (Parabolic Aluminised Reflector) lamp sizes are based on the number of units of 1/8 inch that indicates the diameter, so this lamp is 2½ inches in diameter (or 63mm in real measurements). The metal section around the front is the heatsink for the LEDs, and given that the lamp's rating is only 8W, it dissipates a surprising amount of heat. The main difference between this and a CFL is that the heat is predominantly external, and the electronics are not subjected to the main heat source (with CFLs, the source of most heat is the tube filaments, and these are inside the tiny housing that holds the electronics). The light source is 6 x 1.3W Cree XRE LEDs, and the LEDs are powered by a fairly conventional (but very nicely built) switchmode power supply (yes, I've had the lamp apart).

There seems little doubt that this is the way of the future. By comparison, the CFL that's presently installed in the same lamp standard comes a rather poor second place, even though it's also rated at 8W. At around $50-70 each, the biggest disadvantage with the LED lamps is their cost, however that can be expected to fall as production and demand increase. Even at the current price, the LED lamp is actually a better (although not yet cheaper) choice than a CFL. While it may not appear so at first glance, the LED based lamps can be expected to outlast up to eight CFLs, but they suffer few of the disadvantages.

Lamp Type	Power	Life	Cost	Total Cost	Per Hour
Incandescent	75W	1,000 Hours	$0.50	$11.75	1.175 Cents
CFL	8W	10,000 Hours	$4.00	$16.00	0.16 Cents
LED	8W	50,000 Hours	$60.00	$120.00	0.24 Cents

> Total cost is purchase price plus electricity cost based on $0.15 / kWh for the total rated hours of operation. Per hour cost is total cost divided by rated life in hours. Should a CFL or LED lamp last less than the rated number of hours, the cost per hour will increase. It should be noted that the actual cost of electricity has risen dramatically since this article was written, but I have not updated every calculation for obvious reasons.

While the LED lamp appears more expensive, remember that unlike the CFL, it is immune from premature failure due to switching cycles and does not need to be on for up to 5 minutes while you wait for the light output to reach the normal level. LED lamps are also not bothered by low temperatures, so extremely low light output (or none at all if it's cold enough) isn't an issue. As the price falls, expect the total cost to fall significantly. Also, note that only a "mid priced" CFL was used for this comparison. A premium brand may actually last as long as claimed, but will be more expensive than shown above. So far, I seriously doubt that any CFL I've used has lasted (or will last) the rated number of hours

Overall, there is good reason to expect that CFLs are merely an interim solution. While they are presently very cheap (unrealistically so in my view), the ever-increasing demands from environmental groups to force proper recycling will ultimately drive up the cost, while the LED lamps will get cheaper as production methods and technology improve their cost effectiveness. In Europe, the WEEE directive will apply regardless, but recycling LED lamps will be far cheaper than recycling CFLs, because there is no requirement for capturing and storing mercury and mercury vapour.

However, even LED lamps fail to address all the issues. Just like CFLs, they can't be used in very hot environments (such as oven lights), and at present they can't be used in completely sealed luminaires as are required for outdoor or hazardous/explosive atmosphere lighting. However, LEDs are so easy to use (no fragile glass or high voltages) that these problems can be solved by producing specialty lamps with provision for external heatsinks (for example).

Speaking of heat, there's a bold warning on the pack that the LED lamp must not be used in sealed light fittings. Just like CFLs, the electronics don't take kindly to being overheated, and doing so will cause premature failure. Although I didn't test it, I expect that this lamp would also be completely unsuitable for use with a dimmer (even turned to the maximum setting). I didn't run a test because of the fact that the SMPS (switchmode power supply) is rated for use with any voltage from 100 to 240V - so reducing the voltage with a dimmer will have little or no effect.

Power factor (see below for more on this topic) is still an issue. The SMPS used in LED lamps has around the same power factor as typical CFLs, so the peak current drawn will be of a similar order. This means that mains waveform distortion remains a problem, but this can be solved. Nothing will happen until supply companies start charging residential customers for Volt-Amps (VA) used, rather than power.

Because LEDs are low voltage devices, the SMPS used to drive them is very easily made to have complete isolation to double-insulated standards. The LEDs and their heatsink can be accessible without fear of electric shock, making the construction of LED based lamps far more flexible that can ever be achieved with CFLs or even traditional incandescent lamps. I don't know how the sample lamp I was given provides electrical isolation between the mains through to the heatsink, but if it fails before I do I'll find out.

$2,000 Clean-Up Bill

Many people would have seen the story circulating the Net (some time ago) about a woman in

Maine (US) who broke a CFL in her daughter's bedroom, and was quoted $2,000 to clean up the mercury. This is what happens when bureaucrats become involved in things they don't understand (like lighting for example). This story is scare-mongering at its lowest. While I have no doubt that the figure is correct, it would be plain stupid to involve bureaucrats in something as trivial as a broken CFL.

Yes, mercury is a potent neurotoxin, but metallic mercury is relatively safe. The real danger comes from the vapour and various salts and compounds (particularly methyl mercury as may easily be created in landfill for example) ... not from 5mg of mercury buried in the carpet. Having said that, I'm not sure I'd be happy letting a small child play on the floor where any fluorescent lamp had been broken. Kids have enough things to cause them damage or injury without adding tiny glass shards and mercury to all the other concerns.

Perhaps governments and CFL manufacturers could provide the necessary cleanup procedures that should be undertaken to ensure that the area is reasonably safe after "contamination". At present, you will find a great many conflicting opinions as how best to clean up after a breakage, but almost no usable information about the possible risk from the mercury itself. For myself, I'd probably not be at all concerned, but my kids are grown up and have their own homes. With small children around, I'd want to know with reasonable certainty that a recommended cleanup process would make the area safe enough for them to play on.

Speaking of clean-up, I have finally had confirmation of something I had always expected would be the case. I was contacted by someone from a European lighting manufacturer with some scary information (I don't want to be too specific about his job function lest he lose his job for speaking out).

He has visited Chinese factories where CFLs are made, and tells me that mercury spillage is common during the manufacturing process, and that the workers have zero protective clothing, masks or anything else to safeguard their health. This means (as many could easily have predicted) that while *our* environment may benefit by using CFLs, the Chinese environment and factory workers most certainly do not.

In years to come, there will be massive clean-up bills to decontaminate factories and surrounding areas where CFLs were made, and with spillages happening regularly the long term health of the workers is certainly at risk. This is not confined to just one factory either - the same thing has been seen in several facilities visited by my corespondent.

It seems that no-one cares (or wants to care) about things they cannot see. Until governments *world-wide* can ensure that proper safeguards and decent safe working conditions are a requirement for "environmentally friendly" products, these products should simply be banned from sale.

It is also well known that Chinese test houses will cheerfully fake test results that are required information for the certification of products in the countries where they are sold (Australian Standards, UL, CSA, VDE, etc., etc.). On Australian TV only recently, it was shown that Chinese made air conditioners (with full test documentation) were found to fail the mandatory Australian "Minimum Energy Performance" criteria - despite Chinese lab test results that clearly showed that it passed. Does anyone *really* think that all products that come from China will match the test results that come from Chinese laboratories? I certainly hope not, because one would have to be extremely naive to believe that these overseas labs will be as rigorous and thorough as those in the target importing country.

Incandescent Surcharge

There is one thing that *could* have been done, and it could easily have been implemented. Needless to say, nothing was done that was even remotely sensible. A surcharge (indexed each year) on all lamps below a given luminous efficacy can be used to finance a carbon 'offset' programme, with all money collected devoted 100% to planting trees or other viable efforts towards reducing our "carbon footprint". The extra (and increasing) cost of low efficiency lamps of all types will encourage people to use CFLs (or other high efficiency lighting) wherever it is sensible to do so, and will help to ensure that as light fittings are replaced by new ones (during remodelling or because of breakage etc.), the replacements will be designed to be CFL friendly. Some people may even want to use tinted glass to recover the 'warm' glow they are used to. We also get more trees, something that many areas throughout the world have depleted to depressingly low and aesthetically unappealing numbers.

Such an approach causes the minimum disruption, minimises waste from CFLs that fail prematurely because of inappropriate light fittings, and is a far more sensible approach than imposition of a blanket ban that will cause many people much grief. The surcharge can be altered as CFL (or better still, LED) technology improves (allowing better dimming ability for example), and eventually, only a few lamps in most households will use incandescent globes because CFLs cannot be used (see the rest of the article to find out why CFLs cannot be used in some areas).

This approach is sensible (one good reason for government avoidance) , and over a period of only a few years has the potential to exceed the (claimed) benefits of an outright ban by an order of magnitude. Such a programme will have real and immediate results - something that is suspect at best (and possibly substantially negative) with the present plans to simply ban incandescent lamps.

Eventually (my guess is within 5 years, but see above if you missed it), LED lighting will have improved so much that the whole mess may be resolved anyway. However, even LED (light emitting diode) lamps cannot be used at high temperatures (such as oven lights), so the incandescent lamp will never really die. They do allow full dimming ability though, but this capability needs to be included in the circuitry. There are already some LED based lamps available that are not just a usable alternative - one I was given is excellent, and I'm highly impressed.

For Australian readers, Silicon Chip magazine had an article on the same topic (and with much the same conclusions) as the material here. See the Silicon Chip website.

Consider too that lighting is normally used at night (this will surprise no-one). In Australia, electricity companies offer very cheap rates at night, because they have Megawatts of capacity just spinning around with not much to do (known as spinning reserve). The lights that we use domestically offer very little loading, so where's the saving in greenhouse gases? The alternators aren't just shut down, because it takes up to 12 hours to get a large coal-fired alternator on-line. Incentives are offered to get people to use the spare capacity at night for storage hot water systems (for example). This isn't to say that electricity should be squandered, but merely to put it into some perspective. (Note that the off-peak system does not operate in many parts of the world.)

Wherever possible, sensible and safe, I highly recommend using CFLs. You will reduce your power bill, and you will save electricity. If you are mindful of the limitations, there are real benefits and these should be embraced. As noted in several places, I use CFLs everywhere I can, both in the house and my workshop. Much of my main lighting uses conventional fluorescent lamps, which gives the maximum efficiency for domestic lighting.

CFL Vs. Incandescent Trial

If the powers that be (wherever in the world they are) are serious, then the obvious answer to working out if there are any genuinely worthwhile benefits to a ban on incandescent lamps is fairly simple. Conduct a trial. Select a small town, and choose 50% of randomly selected dwellings to continue the way they are already, and get the other 50% to use CFLs exclusively. No modifications to light fittings, no changes to anything other than the type of lamps used.

With careful monitoring of both sets for lamp failures, total energy usage (electricity, gas, heating oil, etc.) and overall satisfaction or otherwise, a realistic set of statistics can then be developed to show exactly what the outcome of a wholesale ban would achieve. This is real science, using a controlled test environment to gather information that can be expected to be reasonably representative of the benefits to the area tested and anywhere else that has similar climate. Data may be extrapolated to determine a realistic potential outcome for other localities.

While businesses may be included, many (if not most) will be found to be using conventional tube fluorescent lamps, because of the necessity for good lighting in most areas of business (cinemas, nightclubs and many restaurants being notable exceptions).

Such a trial needs to be run for 1 year, and at the end, people will have real data from real homes in a realistic environment. This is a far cry from the situation at present, where we have a few zealots sprouting figures that either make no sense, are often obviously false, or are simply the same as the (often wrong) figures sprouted by other zealots. I'm getting rather fed up with some of the claims, as they seem to be based entirely on fantasy. One I saw claimed that "*Changing one incandescent lamp for a CFL will save £9 in one year, or £100 over the life of the lamp*." (or along those lines - I can't find the quote this time around). Based on those figures, the lamp has to last for over 11 years - a fairly unlikely scenario. In common with many such claims, the lamp power wasn't mentioned, what it replaced wasn't mentioned, and no supporting data was mentioned either. In other words, the figures claimed have no substance at all - pure horse-feathers.

Ravens are Black ...

Because most of this section seemed to create more distraction than benefit, it has been removed. However, some sections are still worthy of inclusion.

One thing I have seen in countless forum sites, blogs and other areas is especially disconcerting. Some people seem to have a completely black and white approach to many things related to CFLs. There is often a complete refusal to accept that anyone else's experience is valid, because it either disagrees with published data, the experience of others, or for reasons unknown.

Some people may delude themselves, albeit unintentionally. They may grossly overestimate the life of the lamp ("*Well, it says on the package that it lasts 10,000 hours, so it must have done.*") - in fact, the lamp may have lasted a great deal less than its rated life. In reality - unless you keep a log - how does *anyone* really know how many hours of use any lamp in their house has actually lasted if it's switched on and off? We don't. We make estimates, based on what seems to be the case, tempered by expectations and boosted by advertising (or other) promotions. After a year or more, we are very unlikely to remember when it was changed last.

The same 'logic' has been used to proclaim that CFLs work "just fine" with motion detectors and/or timers. Others have claimed that they don't work at all. Neither is right ... see below for more information.

Similar arguments are applied to colour rendering index, the "human friendliness" of the light and almost any other area that pertains to the debate. This topic - like any other of importance - needs to be examined dispassionately. The points laid out below are a combination of measured data, simple and demonstrable facts, and information from manufacturers and lighting professionals. Passion and personal preference carry little weight (either for compact fluorescent or incandescent lamps) in what follows here. This article has its basis in facts, not any personal vendetta against one technology or the other.

You can find more information at any number of sites on the Net, and if anyone doubts that there really are problems, then a web search should disabuse you of such notions pretty quickly. Make sure that the information has basis in reality - anyone who simply raves or rants (for or against) with no technical information is not a source of useful information.

Luminous Efficacy

As noted above, the term 'efficiency' is fairly meaningless for lighting. Luminous efficacy is a measure of how much light one obtains for a given power input. If one uses the maximum theoretical luminous efficacy figure (683 lumens / Watt) as a starting point, then an approximate efficiency figure can be worked out easily enough. The following table is condensed from that shown on Wikipedia [1]. Click here for the full article.

Lamp Type	**Power**	**Luminous Efficacy (lu/W)**	**Efficiency ¹**
Tungsten incandescent	40W	12.6	1.9%
Tungsten incandescent	100W	17.5	2.6%
Quartz halogen	n/a	24	3.5%
Fluorescent (compact)	5W - 24W	45 â€“ 60	6.6% - 8.8%
Fluorescent tube (T8 120cm / 4 ft)	36W	93 (max, typical)	14% (max, typical)
Fluorescent tube (T5 115cm / 45 in)	28W	104	15.2%
Xenon arc lamp	n/a	30 - 50 (typical)	4.4% - 7.3%
High pressure sodium	n/a	150	22%
Low pressure sodium	n/a	183 - 200	27% - 29%
Ideal white light source		242.5	35.5%
Theoretical maximum		683.002	100%

¹ - The term "efficiency" is actually fairly meaningless. This is a measure of the "overall luminous efficiency", and is included as a comparative figure only, calculated such that the maximum possible efficiency is 100%

Where the power rating is indicated as "n/a", this indicates that luminous efficacy is not affected significantly by the power rating. Many lamps become more efficient as their power rating increases, with incandescent and CFLs being good examples. While it is easy enough to imagine that this will be so with traditional lamps, it is a little more subtle with a CFL. Essentially, the electronic circuitry has limited efficiency, and will consume some current just to operate. For low power lamps, this basic operating current is a higher percentage of the overall, so the effective efficiency of the assembly is reduced accordingly.

As becomes readily apparent from the above, even a CFL with a reasonably high efficiency still discards over 90% of the energy supplied as heat. While the total input energy is less than for an equivalent incandescent lamp, the maximum temperature to which the lamp may be subjected is also a great deal lower because of the electronic components. This means that CFLs can only be used successfully with well ventilated fittings (see below for more information on this topic).

CFL Equivalence

Interestingly, there is a "standard" table of equivalence for CFLs vs. incandescent lamps (supposedly accepted worldwide). It is interesting in that the figures claimed are much less than the above table would lead one to believe. The table is shown below. For example, a 100W incandescent is shown as having an output of 1,246 lumens, yet the above table indicates that it should be 1,800 lumens, and a 40W incandescent should provide 504 lumens, yet is downgraded to 386 lumens. The problem is that no-one seems to disagree that 17.5 lu/W is reasonable for a 100W incandescent lamp, so how did it get changed? I find this kind of deception very annoying (to put it mildly). The US Energy Star programme has a different standard, as well as a set of standards that few CF lamps will meet (of those sold in Australia, at least). See ENERGY STAR (Criteria, Reference Standards and Required Documentation for GU-24 Based Integrated Lamps) to read the requirements in full. Their equivalence table is more in line with reality than the previous reference, but other Australian government departments (see below) and CFL manufacturers seem to prefer the other.

One maker may claim their 13W CFL to be the equal of a 60W incandescent, another says their 13W CFL is equal to 75W - the lack of any standardisation allows huge leeway for makers and advertisers (as well as politicians). The consumer loses out by getting less light than expected, tarnishing their opinion of CFLs in general.

Power (W)	150	100	75	60	40	25
Lumens	2009	1246	874	660	386	214
Lumens (Energy Star)	2600	1600	1100	800	450	250

Incandescent Lamp Luminous Efficacy Tables

So who decided on the "standard" equivalence table? Why are the figures so different from what we should expect? I would be very interested to know who decided to downgrade a 100W lamp from 17.5 lu/W to 12.46 lu/W - could it have been the CFL manufacturers perchance? This is but one of many anomalies that you'll come across when you start to look into the subject carefully. Even the Energy Star ratings have been criticised as too low! Luminous efficacy does increase with reduced operating voltage (120V vs. 230V for example), and this is because the filament is thicker and stronger and can be run at a higher temperature (12V halogen downlights are a good example).

Many people have complained that CFLs that supposedly replace various incandescent lamps are not as bright as expected (these gripes can be found all over the Net). Remember too that CFLs lose light output as they age - the effect is sometimes very noticeable, and I've replaced several that were too dim to be useful, but had no more than around 500-1000 hours of use.

A couple of documents from Australian government groups (see EnergyAllStars and National Appliance and Equipment Energy Efficiency Program both use the table shown above. Based on any tests that anyone might want to perform themselves, these figures inflate the light output from CFLs compared to incandescent lamps. Most people who have used a CFL know that the light output is not equivalent to the claimed "equal" incandescent lamp. There are (supposedly) perfectly good reasons for the discrepancies, but so far I remain unconvinced.

CFL vs GLS Equivalence as a Product

Most industry websites claim that the CFL is simply an equivalent product to the GLS (General Lighting Service) incandescent lamp. This is extremely misleading. The only "equivalence" is that both are designed to produce light, but the technology involved in CFLs makes them an altogether new product. As a new product they should be subjected to new tests, based not only on their ability to produce light, but also on the impact of the new technology on safety - electrical and environmental. This has not been recognised by politicians, and appears to have also been missed by the regulators - whether intentionally or otherwise is unknown.

As one unfortunate homeowner (see Fire Risk below) pointed out to the press ... "I don't read light bulbs, I wouldn't think I'd ever have to.". This is in large part because no-one has ever had to do so before, and since the CFL is marketed (and promoted) as simply a more efficient light bulb, it is assumed to be equivalent in all significant respects. The marketing has concentrated almost exclusively on the advantages of power savings and less heat, but has never explained that this is new technology (from the consumer's perspective), and that there are major differences that must be considered. A CFL is not simply a different type of lamp - given the amount of technology embedded in the small housing, it's an appliance in its own right.

Because this isn't explained, people are expected to read the packaging (which no-one ever did before), and decipher often cryptic symbols that indicate certain criteria that determine the life and possible safety of the product. People don't. They are sold an "equivalent" product that they are told will save them money, and lacking any detailed knowledge of what is involved in the replacement will commonly assume that this "new" lamp can be used in the same way as the old.

Because CFLs run at much lower temperatures, possible risks are no longer obvious. A CFL (even connected to a dimmer) may operate apparently normally for weeks or months before it fails, and it's impossible to predict exactly *how* it will fail. The ultra-cheap electronic ballast is a new development, and is something that 99% of the populace is unaware even exists. Lamps are such commonplace commodities that the average consumer will simply assume that they are all equivalent products - indeed, the lighting industry and government bodies alike insist that the CFL *is* an equivalent to a normal GLS light bulb.

If there was ever any doubt, this article should disabuse you of that notion pretty quickly. That CFLs have their place is obvious - everyone likes to save money and help the environment if they can do so with little or no sacrifice, and there are many applications where CFLs are perfect replacements for GLS lamps. There are also many situations where CFLs are absolutely *not* appropriate, but this is rarely stated other than occasionally in fine print on the packaging (that almost no-one reads anyway). Even though this article has been on-line for 1½ years, it's hardly mainstream.

About 2 months before these latest amendments were written, a local TV station raised a fuss about CFLs. They had only just "discovered" that CFLs contain mercury. This is information that is readily available, but you'd need to know what to look for in order to find it. Put another way, if you already knew that CFLs contain mercury you'd have no difficulty finding out that they do, *but*, if you didn't know, the information hardly leaps out at you. Even if you are the type to read the packaging, in most cases (none that I found amongst my collection of CFLs) there is no mention of mercury on the packaging.

The CFL is not simply a different type of light bulb - it's an entirely new product, with an entirely new set of rules for safe operation.

Incandescent Lamp Basics

Although it appears simple, the modern incandescent lamp is the result of many years of research. Small but important improvements have been made over the years, and considering the minimal cost of a typical 75W lamp, they are quite remarkable value for money. There is a veritable feast of available information on the development of the incandescent lamp, and it would be foolish of me to even attempt to cover the topic. A web search is recommended for those who want to know more. I only intend to cover the topics that I feel are important to the discussion at hand ... should they be banned?

The light source is simply a filament - a coil (or a coiled coil) of thin tungsten wire. This is supported on a pair of wires, and the whole is enclosed in a glass bulb. When an electric current passes through the filament it gets hot, in fact it gets to such a high temperature that it glows white - the operating temperature (closely related to colour temperature) is typically around 2,400 - 3,100 K (about 2,130 - 2,830°C). It is standard practice to rate colour temperature in Kelvin (the term 'degree' is not used). Zero Kelvin is about -273°C, and represents the complete absence of heat (absolute zero).

In the early days, the bulb was evacuated (a vacuum), but this leads to the tungsten 'boiling off' and being deposited on the glass. Because of the loss of metal, these early lamps had a short service life, and most standard lamps are now filled with a low pressure inert gas (argon, nitrogen, etc.). The use of an inert gas does not prevent the liberation of molecules of tungsten, but it does slow the process significantly.

Because of the presence of the gas, modern lamps usually have a section of the support deliberately thinned to act as a fuse. When the filament breaks, it can cause an arc or fall across the support wires, and the fuse prevents excessive current flow.

By using a halogen (typically either iodine or bromine gas), an interesting phenomenon occurs - the halogen causes vaporised tungsten to be re-deposited on the filament. This is one of the main reasons that quartz-halogen lamps last so long (as well as usually having much thicker filaments than conventional high voltage lamps). As a side issue, quartz is used because ordinary glass would soften or melt at the typical operating temperature of a quartz-halogen lamp. Halogen lamps are usually far more efficient than traditional incandescent lamps, and may reach 9-10% efficiency. Not wonderful, but better [1].

Because incandescent lamps are pure resistance, they have unity power factor. This means that the electricity meter registers exactly the power drawn by the lamp. A 75W incandescent lamp (traditional or halogen) draws 75W from the mains (313mA at 240V). Where any electrical device has reactance, the power factor will be less than unity. This means that it may draw 75W (and that's what you will be charged for), but might draw a current of 626mA (again at 240V). This is 150VA, and although you don't pay for the extra current, the supply utility still has to generate and supply that current through the entire grid. This 2:1 ratio of VA to Watts represents a power factor (PF) of 0.5 - generally considered to be the lowest acceptable PF for normal usage.

The constituent materials in a standard incandescent lamp are all used in small quantities, and nothing is toxic by normal definitions. The basic ingredients are ...

- glass
- steel
- tungsten
- inert (and naturally occurring) gas
- a small amount of high temperature plastic insulation
- (lead free?) solder
- plating material for exposed metal, probably nickel

Although it is possible to recycle incandescent lamps, the small amount of all material and lack of anything even remotely toxic probably makes the process uneconomical. IMO this is a pity, because I prefer to recycle everything I can, but economics must intrude somewhere I suppose 😃.

Incandescent Lamp Characteristics
Benefits ...

- Low purchase price
- Simple, low technology manufacturing (minimal energy usage to manufacture)
- Excellent power factor (unity)
- Easily dimmed with simple and cheap TRIAC dimmers
- Pleasant, "human friendly" colour rendition (and colour temperature)
- Colour Rendering Index (CRI) of close to 100 (100 is optimal) [6]
- No hazardous materials used in manufacture
- Can be used at any temperature, freezers and ovens are no problem (~-18°C and ~250°C respectively)
- Relatively modest initial (inrush) current when switched on (~10 to 20 times running current)
- Recycling (although it would be nice) is not really needed because of small amount of materials used
- No electro-magnetic interference problems

Deficiencies ...

- Low efficiency, far more heat than light (typically less than 5% efficient)
- Relatively short life (typically 500-2,000 hours)
- High running cost for a given light output

In may be premature to write off the poor old incandescent lamp anyway. General Electric (GE) is apparently developing an incandescent lamp that matches the efficiency of typical CFLs [4], and no doubt others will follow before too much longer.

One site I looked at claimed that it takes about 1kWh to manufacture an incandescent lamp. No further details were given.

CFL Basics

The Compact Fluorescent Lamp (CFL) also seems simple from the outside - you can't see what's inside, but there is quite a bit of technology involved (see below).

The tube itself contains around 5mg of mercury, mercury vapour (mercury is an *extremely* potent neurotoxin), and various phosphors that emit visible light when stimulated by the intense ultraviolet radiation emitted by a mercury arc discharge. There is still some conjecture regarding the toxicity of the phosphors, with various claims and counter-claims. It is generally better to err on the side of caution with any chemical compound, so a designated recycling program is essential before the mandatory use of CFLs becomes a reality. Such a program should be in place now to deal with standard fluorescent lamps, as these also contain the phosphors *and* the mercury. In Europe, the WEEE Directive (Waste Electrical and Electronic Equipment) has already addressed the issue of recycling, but it has not been mentioned so far for Australia. Interestingly, some CFL manufacturers have even stated that the expected boom in CFL sales will create problems with the mercury (it's true - look it up).

Proponents of the anti-incandescent lamp stance will point out that the reduction in energy usage by using CFLs will prevent far more mercury entering the atmosphere than will be liberated by the (inappropriate) disposal of defunct CFLs. While this may be true at present, there are serious moves afoot to reduce mercury emissions from coal-fired power stations [2], so the point may be lost to scientific advances before too long. Consider too that mercury from power stations is distributed, not concentrated in landfill.

The CFL is not as efficient as a standard full-size fluorescent lamp, but still manages to achieve quite respectable performance. An efficiency of around 6-10% seems to be indicated, but there are so many factors that influence the apparent efficiency that direct comparisons are difficult.

The technology used in modern CFLs is quite astonishing for a throw-away product. The incoming mains is rectified to obtain DC, and there is some degree of ripple reduction by a filter capacitor. A switchmode inverter is then used to obtain the necessary voltage to strike the arc within the tube, and additional circuitry is included to limit the current to the nominal value needed to produce the required power. All of this must fit into the base of the lamp itself. Dedicated lamp housings are becoming available so that only the tube itself needs to be replaced (at present they seem aimed primarily at commercial applications).

The disadvantage of all this is that the power factor is far worse than an incandescent lamp. You don't pay for the extra current drawn, but the power utility must still provide cabling, transformers and generating plants that can handle the total load *current*, regardless of the power factor. There is still a significant saving, but this could easily be eroded because of two significant failings of CFL technology as it exists at present.

Readily available CFLs cannot be dimmed effectively with a normal wall-plate dimmer, so must run at full power at all times (some provide a low power setting by switching off and back on quickly). Incandescent lamps are often dimmed to very low power levels for extended periods (while watching TV for example), so their power usage will be perhaps 20% of the rated power, in some cases even less.

CFLs will fail prematurely if switched on and off many times a day. Many people already know this, so may be tempted to leave lights on that would otherwise be switched off, so a household might have 4 or 5 CFLs running for hours at a time, where they may have had only 1 or 2 incandescent lamps switched on (and possibly on dimmers, thus reducing power significantly).

Another area where CFLs cannot be used is at very low or very high temperatures. Most will not start at all at temperatures below -20°C, and a lot will refuse to start (or will have very low light output) at even higher temperatures. Because of the electronics in the base of the lamp, temperatures above around 50°C will shorten their working life considerably. Electronics components have highly accelerated failure rates as temperature goes up from the standard 25°C 'reference' ambient.

The constituent materials in a typical CFL vary widely, because there are many technologies that can achieve the same (or at least similar) results. In general though, the basic ingredients are ...

- glass
- steel
- silicon (in ICs, transistors, MOSFETs, diodes, etc.) *
- mercury + mercury vapour **
- fibreglass and epoxy resins (PCB, semiconductor cases) *
- aluminium (electrolytic capacitor) *
- various plastics (main housing, film capacitors) *
- ferrites / ceramics (resistor bodies, choke cores) *
- copper wire and PCB traces *
- phosphors **
- a small amount of high temperature plastic insulation
- (lead free?) solder
- plating material for exposed metal, probably nickel

Items marked with * are in addition to the basic ingredients for an incandescent lamp. Although it is possible to recycle CFLs, there is little or nothing in Australia geared towards any form of recycling of these (or any other) fluorescent lamps. This *must* be addressed and fully functional before any ban on incandescent lamps can be implemented.

Items marked ** are in addition to materials used in conventional lamps, but are either toxic, or may be toxic when mixed with other chemicals in landfill and/or when heated to high temperatures.

Compact Fluorescent Lamp Characteristics
Benefits ...

- Low energy usage
- Relatively efficient
- Long life (typically 8,000 - 15,000 hours claimed)

Deficiencies ...

- Comparatively expensive
- Medium to high technology
- Wide variety of non-reclaimable materials used in manufacture
- Poor Colour Rendering Index (CRI) - typically 60 - 70
- Commonly fail prematurely if subjected to repeated switching cycles *
- Cannot be used at very low temperatures (< -20°C, but often higher)
- Cannot be used at high temperatures (> 60°C, but often lower)
- Relatively poor power factor (around 0.52 seems typical for better versions)
- Cannot be dimmed with common light dimmer circuits (see important details above)
- May suffer instantaneous failure with moisture ingress (condensation, etc.)
- Disliked by many people (not always for valid reasons)
- Will not fit (and cannot be made to fit) many fittings designed for miniature lamps
- Unsuitable for totally sealed light fittings (they will get too hot, and the electronics will fail)
- Moderately high initial (inrush) current when switched on (20-100 times operating current !)
- *Must* be recycled, or no tangible environmental benefit can be claimed
- May (will?) cause local interference on AM radio and possibly TV picture (analogue TV only) because of EMI

Note that premature failure (* above) is very difficult to judge unless the switching is logged. Some makers quote switching cycle data, most don't. Some newer models of CFL use active inrush current limiting, so will not stress switching systems when CFLs are used in large numbers (from the same switch). A standard CFL has the potential for an inrush current of up to around 4 to 5A, since it is limited only by the equivalent series resistance (and to a lesser extent the capacitance) of the filter capacitor, along with any series resistance. Series resistance will usually be kept to a minimum, as it contributes nothing more than heat (and reduces overall efficiency).

From much of the above, the reader could be excused for thinking that I dislike CFLs - I don't! I use them wherever possible (or practical), and for the most part I will never change back to incandescent lamps in the places where CFLs are ideally suited. At the same time, I will not change to CFLs where it is obvious that traditional lamps are more practical (such as the lights in my house that have dimmer controls). My workshop is almost exclusively standard fluorescent lamps, but with CFLs used in most of the desk lamps I use for drill presses, lathe, milling machine, etc. Many other light fittings in my home are also fluorescent - there are actually only a few incandescent lamps used (about 9 at a rough count, excluding outdoor quartz halogen floodlights - which are used only when absolutely necessary). This may seem like quite a lot, but most are hardly ever used. I strongly recommend that others use fluorescent or CF lamps wherever possible - the modern CFLs are considerably better than the originals that people may have tried, and they should be used wherever it is *sensible* to do so.

An outright ban on incandescent lamps is simply foolish - as has been demonstrated in the UK and California, where calls for a ban have been largely met with the contempt they deserve. However the moronic government in Australia has simply trampled on our rights to choose without even asking us.

The site I mentioned above that claimed 1kWh to manufacture an incandescent lamp also claimed 4kWh for a CFL. I would expect this figure to be less than half the real (total) energy usage. The ceramics and semiconductors alone would easily account for that figure. My guess (and that's all it is) is that somewhere between 10 to 20kWh would be needed to produce all the materials used and make the lamp. Distribution cost is higher because the CFL weighs more.

CFLs in Existing Luminaires

A very common question in forum sites is along the lines of "My light fitting says that the maximum lamp power is 60W. Can I use a 20W CFL that has the same light output as a 100W lamp?"

The standard answer given in Q&A sites is an unqualified "yes", however there is one major factor that must be considered but rarely gets a mention. Some CFL packaging states that the lamps *must not* be used in fully enclosed light fittings, but in reality, no CFL is suitable. The reason is temperature. Because of the electronic circuitry, all CFLs can only be used where they have reasonable ventilation to prevent overheating. Excess heat doesn't bother an incandescent lamp, and temperatures well in excess of 100°C won't cause them any problems at all. Remember that the filament is already operating at around over 2,000°C, so a bit more won't hurt (although wiring insulation and even the lamp socket itself will be damaged eventually). Some sealed light fittings use high temperature wire internally, because they get too hot inside for ordinary PVC insulation - which will fail quite quickly at elevated temperatures.

Because of the electronic circuitry, the maximum ambient temperature for a CFL should remain as low as practicable, with most manufacturers warranting their products to a maximum of 50°C. This has forced a complete re-design for recessed downlights [7], and many other light fittings are completely unsuitable. If the heat from the tube and the electronics cannot escape, the temperature will potentially rise to well over 50°C, and the lamp's life and light output will be badly affected.

There are far too many factors that need to be considered to even try to answer the question here, but as a guide, if the light fitting is completely sealed (or recessed into the ceiling with no way for hot air to escape) then the answer is **no**. Not simply "no" to the question, but no to the use of *any* CFL in a completely sealed (or even just poorly ventilated) light fitting.

Many of the sites that offer advice have zero technical expertise, and a lot seem to assume that CFLs emit almost no heat at all. Anyone who has used one knows that this most certainly is not the case. This is shown very clearly below ...

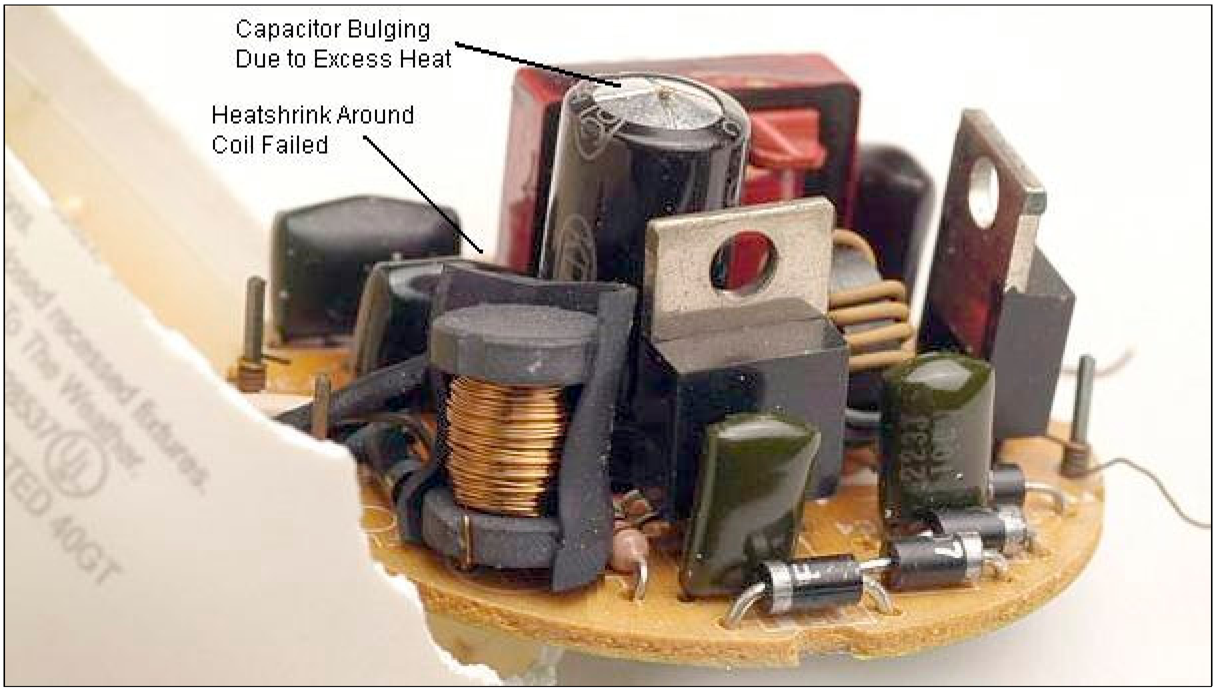


Figure 2 - CFL Killed by Overheating [A]

This is a perfect example of what happens. The photo was sent to me from the US, and the lamp failed after about 200 hours - somewhat shy of the typical claimed life (to put it mildly). You can see that the electrolytic capacitor is bulging at the end, and it had ruptured its safety seal and leaked electrolyte. The heatshrink tubing around the inductor got so hot that it split, and the "Greencap" capacitors are all seriously discoloured.

So, what would cause this? Simple. Most existing home light fittings are designed for conventional incandescent lamps, and have little or no ventilation. Many of the popular fittings typically have no ventilation at all - especially the "oyster' style, which has a glass dome clipped over a metal ceiling mount unit. There are many other styles of light fittings (luminaires) that are either fully enclosed, or are open only at the bottom.

The heat will build up quite quickly, and because it has nowhere to go, will remain in the fitting. Since the maximum ambient temperature for an operating CFL is 50°C, it will only take a few minutes to reach this temperature. Test results for this are shown below. The result is quite clear, although (for whatever reason) *some* CFLs will manage to survive in *some* enclosed fittings. Unfortunately, quite a few people who have commented on this particular topic seem to think that because *they* have not had a failure, that this somehow implies that no-one else will either. One word sums up my response to these claims ... bollocks!

Do not use CFLs in fully enclosed light fittings !

As an example of the ratings of one of the key components in any CFL electronic ballast, we can examine the typical specifications for aluminium electrolytic capacitors. These are supplied in either 85°C or 105°C temperature grades, and the manufacturers usually claim a "typical" life of 1,000 - 2,000 hours when operated at the maximum temperature. This is obviously far shorter than the "typical" life of most CFLs, and the *only* way the capacitors can be made to last longer is to operate them at a lower temperature. Should the temperature exceed the maximum rated, then the life of the capacitor will be reduced dramatically. The same principle applies to most of the other components used too.

Semiconductors (transistors or MOSFETs) will run fairly hot in most CFL circuits - in fact they are responsible for a fair proportion of the total losses within the system as a whole. These components must never be allowed to exceed a junction temperature of (usually) 150°C - and this means that the case temperature must be somewhat lower than the maximum permissible. The *only* way to get the maximum life from any CFL is to keep the electronics as cool as possible - preferably well under the manufacturers' recommendation of 50°C.

Ultimately, this is the biggest downfall of the technology, and means that if incandescent lamps are banned, there will be an enormous consumer backlash when long-life lamps fail well before their supposedly short lived incandescent predecessors ever would. The environmental impact of thousands of prematurely failed compact fluorescent lamps is also a disaster - especially when you consider the energy that went into making them. This will (not *might*) result in exactly the reverse of what governments are "planning" - with a net energy loss and a huge consumer outcry.

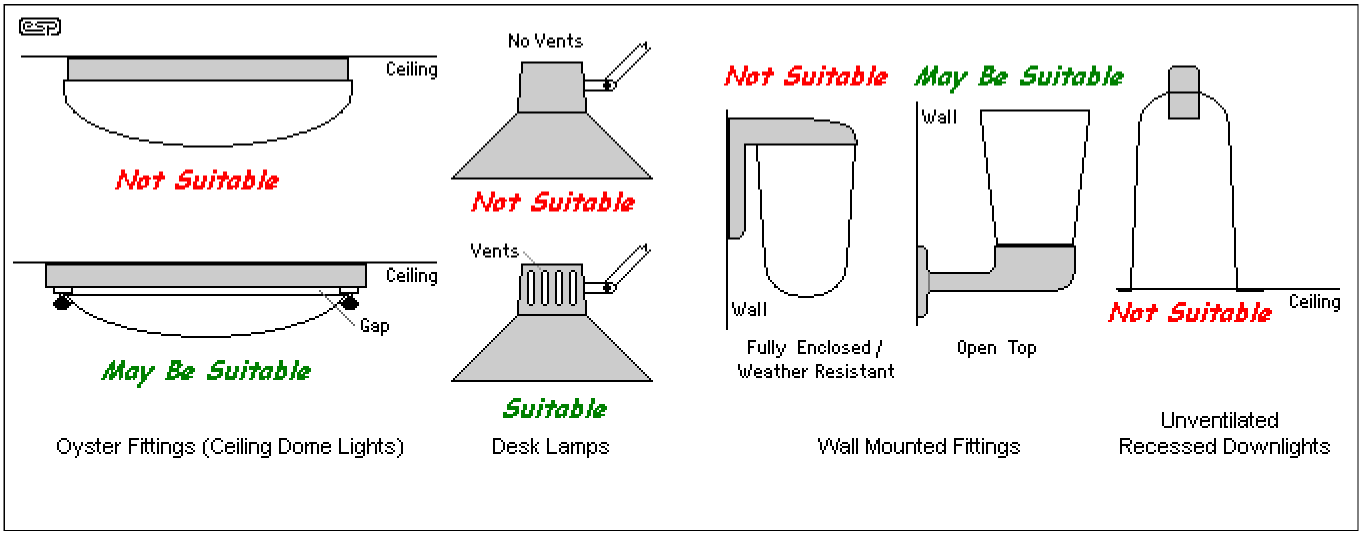


Figure 3 - Light Fitting Suitability

The above is a small example of fittings that are (or may be) suitable, and some of those that are not. Needless to say, there are hundreds of different styles, and only a full inspection (and perhaps a controlled test) will reveal if the fitting is or is not capable of being used with a CFL. The key factor is ventilation. Any fully sealed fitting is almost certainly unsuitable, because there can be no air circulation, and the temperature will rise sufficiently to cause premature failure. Elevated temperature also reduces the light output, so you will not be able to get as much light as you hoped for, as well as shortening the life of the electronic circuitry (probably drastically).

There isn't a technological breakthrough around the corner that will fix this - electronic equipment cannot be made to function properly and reliably at severely elevated temperatures. Householders will be faced with the rather daunting (and *very* expensive) requirement to replace all non-ventilated light fittings with new ones that have sufficient airflow to maintain a safe temperature. Because the fittings must be installed by a licensed electrician in most countries, this is yet another expense.

Any potential saving in energy bills is gone ... for quite a few years, until the cost of the fittings and their installation is amortised. There is also the enormous waste of replacing perfectly good light fittings with new ones, so the environmental impact is also negative - probably by a large margin. It will take many, many years before the household or the environment start to get any real benefit, because of the vast waste that was created to impose an "environmentally friendly solution".

In the UK, the Market Transformation Programme (MTP) stated that ...

> *The availability and the current stock of light fittings heavily influence what types of lamp are being used in the domestic sector. Research showed that less than 50% of the existing light fittings are suitable to fit a compact fluorescent lamp.*

This means that, on average, householders will have to replace more than half of all their light fittings to accommodate CFLs. I doubt they will be pleased if this is forced upon them, either in the UK, Australia, Europe, or anywhere else! It is also likely that lighting retailers will be rather annoyed, since a great deal of their existing stock will have to be scrapped. Doesn't sound quite so environmentally friendly now, does it?

One other area has been pointed out as well - spot lamps. While these are primarily decorative and it can be argued that they are not essential, the fact remains that people use them, and will want to continue doing so. Because of the large radiating surface of a CFL, it is not possible to focus them to anything like the same degree as a bi-pin quartz halogen lamp. These are almost a point source, and are easily focused to a very narrow beam. Even a conventional incandescent lamp can be focused fairly well - far better than any CFL.

For displays and in some home decorating schemes, designers use the 'sparkle' effect that one can get with point source lighting. This simply cannot be achieved with CFLs because of their large area. While LED lamps can achieve point source sparkle effects, they are not seen as a mature technology yet, and luminous efficacy is only marginally better than incandescent lamps for the majority. Colour temperature and colour rendering index of LEDs are currently not well controlled, and in general are far worse than CFLs. While one can argue that none of these special effects are needed to sustain life as we know it, people have expectations. They get very annoyed if they can no longer do what they want - or used to be able to do. Whether this is important or not depends entirely on your job or personal tastes.

CFL In Sealed Luminaire Test

This is an important area, and tests were conducted to find out just how hot a CFL would get in a sealed enclosure. I fabricated a test jig that would show the effects and ran two versions of the test simultaneously, using two temperature sensors. The temperature was measured at 10 minute intervals. The main test had the CFL set up as shown in the sub-page, with a bead thermocouple taped to the lamp socket. This was installed in a housing. The second set of test results were obtained with a probe thermocouple that was used to measure the air temperature inside the test fitting, with the very tip of the probe just touching the metal top cover. The probe was inserted into the hole where the bead thermocouple lead exits the housing. Measured temperatures were ...

Time	Temperature (°C)	
(minutes)	**Bead**	**Probe**
0	23	23
10	48	34
20	55	39
30	58	40
40	58	42

Sealed Fitting Temperature Test

This is not a good result. A 10W CFL in a 3 litre enclosure is over temperature in just over 10 minutes. The full test details and a photo of the test jig used have been moved to a sub-page ... Click Here to View.

The temperature inside the plastic housing of the CFL's electronics will be 20-25°C higher than measured by either probe or bead thermocouple. A higher power CFL in a smaller (or even the same size) housing that is completely airtight (as required for outdoor use) will get far hotter (and faster) than shown in the table. Any claims that more than 50% of existing light fittings are unsuitable for use with CFLs is completely justified on the basis of this test.

Explosive CFL Failures (Things That go **BANG** in the Night)

There have been a few reports of CFLs literally exploding when switched on. While it isn't really possible to give a detailed analysis without having such a unit in my possession, there are a few reasonable explanations that may cover the issues.

Moisture: If a CFL is operated where it is exposed to outside air and/or moisture, there is a chance that condensation may collect on the PCB. Because of the high operating voltages (360V DC for 240V mains), even a small amount of moisture may be enough to cause significant current between PCB tracks. This is commonly called "tracking" and the initial discharge carbonises parts of the printed circuit board substrate - commonly a paper-epoxy or paper-phenolic material.

Once an arc is started, it will continue until enough material has been burnt away that there is no longer a conductive path - this means that PCB tracks, components, or anything else in the circuit can be blown apart - often quite violently and usually with lots of black soot and at least some smoke.

Insects, Dust, Etc.: Small insects can get into most CFL housings easily enough, and are more than capable of starting an arc. This will have the same results as moisture, with a violent cascade of failures within a few milliseconds.

Component Failure: Because the CFL is a throwaway product, the cheapest components that will work with the voltages involved are used. For example, the CFL intestines shown in Figure 3 (below) includes a 150nF, 400V DC capacitor directly across the mains. This device is *absolutely* not designed for direct connection across 240V AC, and it will fail. Usually, specifically designed mains film capacitors die quietly, simply losing capacitance as more and more of the metallised layer is damaged. Most CFLs use non-mains rated capacitors, and these commonly fail with acrid smoke and pyrotechnics - especially since they are often used well above their safe current ratings.

Inrush Current: As noted above (and below), most CFL electronic ballasts have a rather high initial inrush current, which can easily exceed 5A and often a lot more. This current is limited in some electronics by one component - the main filter capacitor. If it has a relatively high ESR (equivalent series resistance), this will hopefully be enough to limit the current to a safe value. The problem is that as an electrolytic capacitor gets hot, the ESR *falls*. When the lamp is cool, the ESR should be high enough to prevent problems, but if the lamp is switched on while still hot, the ESR will be very much lower - as little as one tenth of its original value. A much higher initial current flows (it could easily reach 20A or more), and may cause a diode to fail, for example. One diode failure in a bridge rectifier circuit will always be followed by another, and within milliseconds, the filter capacitor may be connected directly across the mains. Spectacular failure is guaranteed within well under 100ms (one tenth of a second).

The failure modes described above are educated guesses, but the lamp failures are not. The possible causes listed are all quite plausible, and all can be demonstrated. Which is the most likely or most common is unknown at this stage, and will remain so until one of mine fails so it can be analysed, or I find some additional information ... either by more searching on the Net, or if some kind reader lets me know what was found in a few failed CFLs.

On this basis, use of CFLs in bathrooms is obviously not a good idea - some manufacturers warn against using CFLs in bathrooms, most don't. Lots of water vapour from hot showers is likely to cause condensation that could cause spontaneous failure. Likewise (well apart from the known problems of CFLs not even starting if it is cold enough), outdoor use means that water may enter the lamp itself, or insects, small spiders and other matter may also get inside. As detailed above, using a fully sealed housing will shorten the life of the lamp dramatically , so our options are very limited.

"Normal" CFL Failure Modes

It seems that as far as many manufacturers are concerned, melted plastic, evil-smelling smoke and other similar issues are considered normal modes of failure at the end-of-life of a CFL. According to EnergyIdeas, one manufacturer stated that "*some overheating after a lamp fails and the ballast remains energised may cause minor melting of plastic and leakage of non-toxic glue.*" He indicated that there is a fuse that will blow before fire danger develops. The implication is that this kind of failure is within normal expectations.

A so-called "normal" failure is shown in the image - I must say that I do not consider such damage to be normal by any definition of the word. More information may be seen here. There are a couple of photos of failed CFLs, some additional information, and technical data that was moved from this page.

These claims make the CFL the only consumer product ever made that is *expected* to fail in a comparatively spectacular manner. When any other product fails, smoke, melted plastic and/or small fires (whether seen or not) are considered abnormal - protection devices are fitted to ensure that any normal failure is "silent" - the device simply stops working, and you don't need to ventilate your house afterwards. There will be exceptions, but these should be rare, and triggered by an abnormal failure - not by a reasonable percentage of units that have simply reached their end-of-life.

Various bodies have reported consumer concerns about CFL failures, and we know for a fact that a significant number of these lamps have not failed silently, but have advertised their demise by making noises, emitting smoke, or other behaviour that is simply not expected of any normal consumer product. None of this is helped by the fact that most packaging fails to make it absolutely clear whether the lamp is suitable for various light fittings (luminaires), if it can be used outdoors, or even state that the lamp must not be used with a dimmer ... even if set to maximum.

There are countless examples of failed CFLs at Doug Hembruff's site, and some of the photos and descriptions are sufficient to make one think that perhaps it is the CFL that should be banned. Because of misleading advertising and packaging, and a number of zealots insisting that CFLs can (or must!) be used anywhere at all (but *never* citing any proof or documentary evidence), users often have unrealistic expectations. No-one expects the lamp to fail and burn - this is simply not anticipated with *any* consumer product, and nor should it be.

Above, it was indicated that CFLs are fitted with a fuse. Unfortunately, the most commonly used "fuse" is a fusible resistor, and these are simply not suited at all when in close proximity to a thermoplastic enclosure. The photo on the right is a 10 ohm 1W fusible resistor, subjected to 8W. That this is more than capable of melting and charring plastic is pretty obvious - the temperature is roughly the same as a car cigarette lighter, and will easily set fire to any flammable material that comes in contact with the resistor body. (Please note that the resistor is not quite as hot as it looks in the photo. It was enhanced a little so everything was more visible, and that makes it look hotter.)

The ESA (Electrical Safety Authority, Canada) is concerned that it can be difficult for consumers to distinguish between what is normal and what may be a precursor to fire or some other hazardous condition. As a safety precaution, they encourage consumers to replace CFLs at the first sign of failure or aging - not always easy with a lamp in a light fitting on the ceiling! The early warning signs to look for include flickering, a bright orange or red glow, popping sounds, an odour (typically a burning smell), or browning of the ballast enclosure (base). The ESA has pointed out that CFLs should not be used in exactly the same places as indicated elsewhere in this article, and I suggest you read their information on the topic.

The ESA is well ahead of Australia (as well as many other countries), and there's not even talk of an incandescent ban in Canada. They are encouraging product manufacturers to review packaging information to support consumers in making safe product decisions. The ESA also has plans underway to update the existing Canadian safety standard for CFLs to address consumers' end-of-life product issues.

Many of the parts used in CFLs are simply not suited to the purpose. There is more technical detail in the sub-page, along with the failed CFL photos.

It has to be said that the current situation is not merely intolerable, it is a disaster waiting to happen. Many people use lights (often on timers) when they are away, so that it looks like there's activity in the home. I wouldn't use *any* CFL as supplied for unattended use, because there is no way to know when (or how) it will fail, or what exactly will happen when it does fail. I'd be perfectly happy to use a conventional fluorescent lamp in this role, as I have never seen one "crash and burn" when it fails. Likewise, an incandescent lamp will fail silently - no smoke, fire or brimstone - they just stop working. Unattended operation may not pose a big risk, *but it's something we never had to worry about before*.

Some Technical Data

There's a surprising amount of information that needs to be understood to realise the full implications of a complete ban of incandescent lamps, and more information will be supplied as it comes to hand. In the meantime, as I continue research, I hope that the amount I have been able to supply so far helps you to understand some of the potential problems.

It's interesting to see how much electronics has been packed into such a tiny space. It is also worthwhile to perform some measurements. I also recommend a web search - there is much to learn and a vast amount of information is available.

It is worthwhile to look at the circuit (or equivalent circuit) of a CFL and an incandescent lamp ...

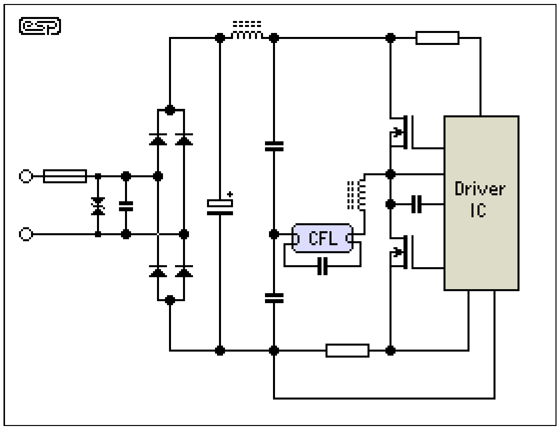


Figure 6 - CFL Simplified Circuit [3]

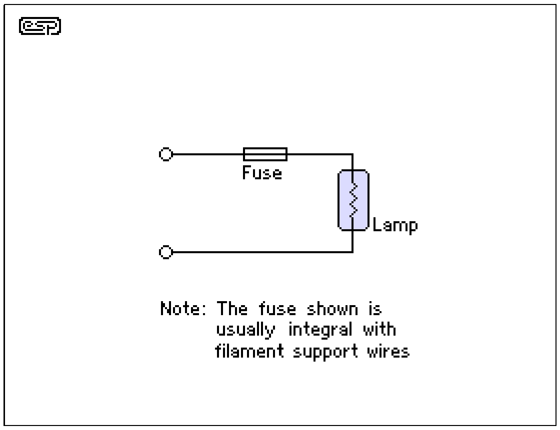


Figure 7 - Incandescent Equivalent Circuit

The level of technology for the CFL (even simplified) is quite clearly vastly greater than for a conventional lamp. Likewise, the potential waste material at the end of its life means that recycling is not optional for CFLs. Suitable initiatives should be put into place immediately, if not sooner, and should be mandatory for all forms of fluorescent lamp.

Visual Comparisons

It is interesting to look at the guts of a typical CFL. The photo in Figure 8 was sent to me, Figure 9 is a standard incandescent lamp.

Figure 8 - Inside a modern CFL **Figure 9 - Typical Incandescent Lamp**

There is some additional info and another photo in a new sub-page ... Click to View. The newer CFL featured has some measure of power factor correction - not perfect, but a lot better than most. The old one shown (formerly Figure 10) is purely for interest's sake.

As you can see, there's no contest as to which takes more energy to produce, and look at all the parts that will be discarded when a CFL fails. The incandescent lamp uses so few materials (and so little of them) that it weighs only 31 grams, vs. 98 grams for a 15W CFL. The incandescent lamp shown is 100W, so is a little heavier than a lamp with claimed equal light output to that of a 15W CFL.

A Few Facts About Dimmers & Other Electronic Switching Devices

Most CFLs cannot be dimmed, so I tried an 8W, 10W and a 15W CFL (plus a few others) attached to a Variac (variable voltage transformer). Using this, they *can* be dimmed, but the effect is generally completely unsatisfactory. Some CFLs claim that they *can* be dimmed, but only with "rheostat" type dimmers, which should have been phased out worldwide many, many years ago. Although the measured light output is approximately linear, our vision (like our hearing) is logarithmic. A dimmed CFL varies (visibly) from 'bright' to 'a bit less bright' to 'off'. Below around 90V on most I tested, they become erratic and/or go out. So, even using expensive dimmers intended for use with CFLs, the user's experience will probably not be a happy one. The 15W unit I tested would function down to a bit less than 80V and actually dimmed quite well. This is the first I've seen that will do so, but it can't be used with a normal wall-plate dimmer.

Judging from some of the bizarre comments I have seen when the topic of dimmers is raised, this is something that needs to be addressed. Modern (i.e. less than ~30 years old) conventional lamp dimmers use a TRIAC (bi-directional thyristor), in a phase control circuit. The dimmer works by preventing any voltage from getting to the lamps filament until a certain point is reached, when it switches on. As the applied AC passes through zero, the TRIAC switches off again, and waits for the next pulse to turn on. This process takes place 100 times a second (120 / second for 60Hz countries). The circuitry is very simple, but also very effective, allowing lamps to be dimmed from almost nothing right through to full brightness.

The losses in the dimmer itself are very low - typically around 1W or so for a 100W lamp, since it is either on or off. The intermediate states (the transition between off and on) are so fast that power loss is minimal. The voltage waveform is shown below, and there is a great deal more information available on the Net. I did run a simulation and run a test with a real lamp though, because it is important that people understand that a dimmer does reduce the power consumption of an incandescent lamp, and does so very effectively. There is significant waveform distortion though, and this remains cause for concern.

I used a circuit simulator to see the effect of changing the phase angle, and was easily able to measure the power, VA and power factor. The results are shown here for those who are interested to know more.

With an incandescent lamp, there is a complication ... the resistance of the filament changes depending on its temperature. At low settings of the dimmer, the filament is cooler, so has a lower resistance. Like most metals, tungsten has a positive temperature coefficient of resistance, so resistance increases with higher temperatures. This means that at low dimmer settings the lamp draws more power than the table may indicate (the table is based on a constant resistance).

Nevertheless, it is obvious that the power delivered falls as the phase angle is reduced and the lamp is dimmed. A setting that just gives a slight glow (a bit less than a candle) is pretty much ideal for watching TV, and that will correspond to about 18W for a 100W lamp (from measured data below).

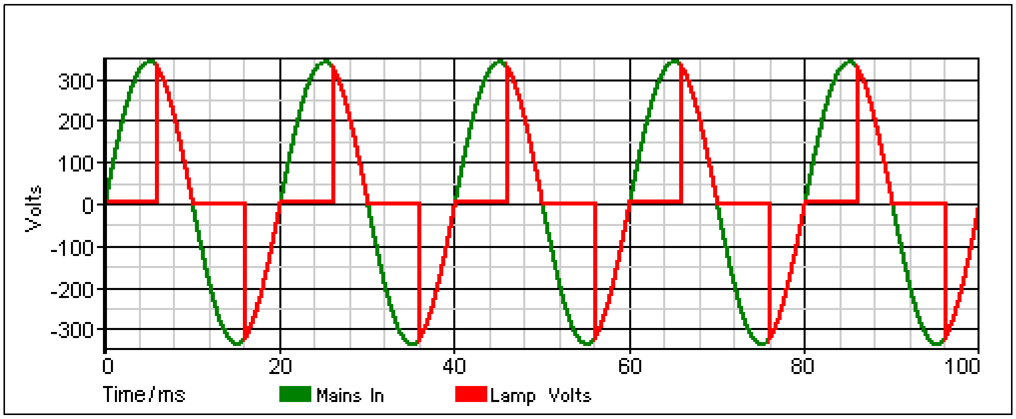


Figure 10 - Phase Angle Control of Lamp Voltage

Although this section is not intended to be a complete lesson on dimmers or how they work, I have included Figure 10 to show the incoming (mains) voltage, and the voltage applied to the lamp. The phase angle is set at 72°, so the lamp gets 132V RMS from a 240V RMS incoming mains supply. The dimmer works as a switch, and blocks the incoming voltage for a number of milliseconds, at which point it turns on. The 'switch' automatically turns off as the current to the lamp falls to zero.

This example that shows quite definitively that dimming incandescent lamps most certainly *does* reduce their power consumption, your electricity bill, and greenhouse emissions. Anyone who claims otherwise is talking through their hat - the effects can be simulated or measured easily, and the results are perfectly clear.

Brightness	**Volts RMS**	**Current RMS**	**Power**	**Resistance**
Off	0	0	0	44 Ohms
Just On	42 V	167 mA	7 W	252 Ohms
Dull Glow *	79 V	231 mA	18 W	342 Ohms
Half Brightness **	169 V	350 mA	59 W	483 Ohms
Fully On	239 V	433 mA	103 W	552 Ohms

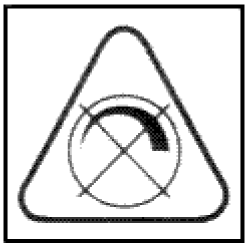
Measured Voltage & Current for 100W Incandescent Lamp

The above table shows measured data, using a TRIAC dimmer and a 100W (nominal) incandescent lamp. The total power is higher than the simulation (on the sub-page) shows, because the tungsten filament has a strong temperature dependence, so the resistance varies with the lamp's brightness. Even so, at a dull glow (marked *) typical of the level we use when watching TV, a 100W lamp is using just over 18W, or less than one fifth of the rated power. The level marked as 'Half Brightness' (**) is a visual estimate, but corresponds well with the setting that gives a conduction angle of 45° - power at this conduction angle is just under 60W as shown. It is also worth noting that using an incandescent lamp at a slightly lower voltage than rated will give significantly increased life. Operation at around 90% of rated voltage will increase life by a factor of 3, but light output is reduced to about 70% of the normal level [9]. The overall efficiency of a filament lamp is reduced even further by using a dimmer, but there are very few options that provide the versatility offered by the combination ... and you do still save power.

Dimmers can reduce the power consumption of incandescent lamps significantly, and are a (reasonably) environmentally sound proposition if lighting needs to be adjustable. Conventional dimmers cannot be used with CFLs, and dimmers designed for CFLs cannot come even close to the range available from a traditional lamp and dimmer with the current basic CFLs available to consumers. Dimmable CFLs do exist, but are more expensive and don't work very well according to my own experiences and many forum posts worldwide (this will probably change though).

Dimmer + CFL Test Results

This is not an area that anyone seems to have looked at closely, so some tests were run to find out exactly *does* happen if a CFL is connected to a dimmer. The results were a complete surprise. The assumption is that the CFL probably won't work at all, but most do (although they don't dim). What you can't see is the RMS and peak current drawn from the mains!



The symbol on the left means "no dimmers", but may or may not be understood by users - most of whom are normal householders with little or no technical know-how. I don't think it's clear enough, and it certainly doesn't make the point as strongly as it should.

Warning! ... If one decides to test what happens if a CFL is used with a dimmer, at some settings (with possibly most CFLs) it may actually appear to work perfectly normally. One could easily be excused to imagining that there is no problem, as long as the dimmer is set to the maximum and left there. There's no visual clue, with normal light output and no nasty noises. Certainly, the lamp can't be dimmed, but that may not *seem* a major concern. I have seen this done - the dimmer knob was taped to hold it at the maximum setting.

Don't do it! While it may appear to work normally, the current drawn by a typical CFL used this way increases up to 5-fold, to the point where it is potentially very dangerous. The current spikes are very narrow, but can exceed 8A with an 18W CFL. The RMS current drawn can be as high as 0.5A - over 5 times that drawn with no dimmer in the circuit (and that's with dimmer set to maximum!).

Where the CFL has a fusible resistor at the mains input, this is present to limit the maximum (peak) current, and prevent internal short-circuit failures from blowing the main circuit breaker or fuse. Fusible resistors do not react (fuse) with excessive dissipation, so if the lamp is used with a dimmer (even if set to maximum), there is a very real chance that the fusible resistor (and/or other parts) will overheat due to the massively increased current, possibly leading to a (hopefully) small fire. The fusible resistor value can vary widely. Some have a very low resistance, so the chance of serious overheating is small. Others can use values ranging from 10 ohms up to 22 ohms. Some don't use one at all, but you don't know from the outside.

This is also a potential issue with electronic timers, motion sensors and home automation systems as discussed below. One thing is of great concern in all cases - either the lamp will have a very short life (assuming it doesn't choose to catch on fire), or the dimmer or other switching circuit will be severely damaged - or both !

While many CFL packages do state that they should not be used with dimmers, some don't, and others use a rather cryptic symbol (shown above) that users may or may not understand. While we still have a choice there isn't a major problem, because people will use incandescent lamps where they have dimmers (after all, that's why the dimmer is there). Once the choice is taken away, people no longer have a choice. Those in rented premises can't remove dimmers without the owner's approval, and those who own their home (or have permission) will usually have to get an electrician to remove the dimmer and its wiring and blank off the hole. Many will find that the lamp seems to work fine, so will leave it there. The consequences are potentially very dire, if seemingly somewhat remote at first glance.

At anywhere between 3 to 5 times the normal current, the chance of a fire may seem pretty small, but even if only *one* house burns down or is badly damaged as a direct result, what if it's yours? Will your insurance even cover it ("*You caused the fire yourself by using a CFL with a dimmer*")? What if someone dies? This isn't idle speculation - several CFLs have been tested, and the same problem has shown up with all of them. The chance may be 1 in 1,000,000 but with several million CFLs being forced upon people following a ban, we have far too many opportunities for a disaster.

Tests I ran showed that the operating (RMS) current could easily increase from a normal current of 90mA up to 300mA, with peak currents as high as 3A measured. Other tests run [10] showed higher currents because a different dimmer was used, namely a standard wall-plate dimmer, as used in most households. The one I used is a unit I built many years ago and is designed for heavy loads. These measurements (tabulated below) also showed current spikes of around 4.4 amps worst case, reduced to 2.2 amps with the dimmer on full (peak currents are not shown). The RMS current measured 0.42 amps at 75% and 0.24 amps at 100% dimmer setting - this equates to 110 VA and 59 VA respectively.

CFL Power	**Current Drawn (RMS)**		
	Nominal	**Dimmer 75%**	**Dimmer 100%**
13 W	83 mA	450 mA	245 mA
11 W	80 mA	420 mA	240 mA
8 W	80 mA	330 mA	190 mA
5 W	40 mA	260 mA	200 mA

These test results are from real CFLs, connected to a dimmer set to 75% and 100%. Why test at 75%? Because it *will* happen - people (especially children) will fiddle with the dimmer, and they may be highly amused by the CFL becoming a flashing lamp at some settings (although not all do). If the dimmer is in circuit, a setting of 75% looks alright, in that most CFLs don't flicker or flash, and have more or less normal light output, so it could easily remain like that for some time. Even if the dimmer is glued, taped or nailed at the maximum setting (not that I recommend the latter 😃), the current is still much, much higher than it should be. At the very least, lamp life will be reduced, at the worst ... ?

Just look at the current drawn! The average increase is 5 times, which means that 25 times more heat is generated in any current limiting resistor in the lamp's ballast circuit. It is inevitable that this will cause a failure, and probable that the circuit board will be badly charred or set on fire. While there is no guarantee that the lamp will catch on fire, *there is likewise no guarantee that it won't*. The waveform of a CFL with a dimmer in circuit is shown below, along with the normal waveform for comparison.

If the fusible resistor is rated at 1W (fairly typical) and has a value of 15 ohms (also not uncommon), it will normally dissipate about 100mW - a perfectly safe power level. In the worst case shown above, the same resistor with 450mA through it will dissipate 3W, so it will get *extremely* hot. Certainly hot enough to cause failure in adjacent components, hot enough to melt the solder holding it into the PCB, and very likely hot enough to cause the PCB to catch on fire. I've seen boards that have caught alight because of overheated resistors enough times to know that there is a real possibility of the same thing happening in a CFL drawing 5 times its normal current.

To reiterate ... *never* use a CFL with a dimmer in the circuit, even if it is set (and kept) at the maximum setting. Doing so places you at risk of fire, and at the very least will dramatically shorten the life of the lamp *and* the dimmer. Remember that these figures were all measured using a normal dimmer and with a variety of different CFLs - nothing is guessed, surmised or imagined - *this is real data* !

Although you probably won't find information this detailed anywhere else on the Net (although there is a brief mention of just this topic here and here), that's because almost no-one has done the tests (although many people *have* experienced burn-outs, melt-downs and even fires).

If tests have been done, the results have not been publicised. Anyone with the skills and test equipment can verify the results, and I encourage those who are able to do so. Your results will almost certainly be slightly different because of differing mains voltage and lamp types, but the general trend will be the same. These results are compiled from tests run independently by two people, using different lamps and test gear, but with very similar results. Again, a total lack of any form of comprehensive mandatory standards means that no-one knows which lamps will just die quietly and which ones may exit in a blaze of glory (see below for suggested standards).

Timers, Motion Sensors & Home Automation Systems

Firstly, it is important to understand that the above section on dimmers may also apply with any electronically switched lighting circuit. Unless you have extensive electrical and electronics experience, there is no way to know for certain, and the packaging or instructions will probably not say whether the switching system is suitable for use with CFLs. Unless it is *specifically* stated that the equipment is designed for use with CF lamps, it is far safer to assume that it is *not* suitable. While it may appear to work fine, you can't normally measure the current, so excessive current may be drawn and you'd never know.

Several articles, many people, and some CFL packaging claim that CFLs *cannot* be used with time switches, motion sensors or other automated switching systems. This is only partially true - many auto-switching systems will work perfectly with CFLs, while many others will not. Some may *appear* to work, but will have the same problems as described above when a CFL is used with a dimmer (because of simple TRIAC switching circuits).

Any switching system that uses a relay (an electro-mechanical switch) or a contact closure to operate the load will work with CFLs. Unfortunately it is not always easy to know, but the following might help ...

- Old style mechanical timers with little pegs around the outside of a time wheel are almost all mechanically switched, and should work fine.
- If your motion detector makes a faint 'click' sound when triggered, it probably uses a relay, and therefore should be alright.
- Modern electronic timers with a display commonly use electronic switching, and will probably not work with CFLs.
- Motion detectors that make no noise at all (or have any fancy switching abilities) will most likely use electronic switching and may not work.
- Touch lamps almost certainly pose a serious risk - do not use CFLs in touch lamps!
- Light sensitive lamps (on at night, off in daylight) must not be used with CFLs - especially those that fade the lamp on and off.
- Remote controlled or home automation systems should not use CFLs unless the maker specifically states that they will work with the system.

The above is nearly all "should", "may" and "probably" for a reason. Because of the vast range of motion switches, timers home automation systems, etc., it is very difficult to know whether they will work with CFLs or not, unless it is specifically stated on the packaging or in the instructions. This is a very grey area, and it is simply impossible to provide a simple way to know beforehand whether CFLs will work with a particular auto-switching system. The only way is to test it - but even if it appears to function there can still be a potential serious risk. Either get a new switch that specifically states that it is suitable for low energy lamps, or use incandescent lamps.

You may not know if your system is really working properly, or only seems to. Unfortunately, there is no easy way to determine if any given electronic switching circuit is causing the problems referred to in the dimmer section. This is a very insidious and potentially dangerous area, usually with no tell-tale signs that anything is wrong. If there is *any doubt whatsoever*, please do yourself and your family a favour and stay with traditional lamps.

Power Factor

With any AC load, there are two things that can influence the power factor (the difference between the actual power used, and the volts and amps (VA) drawn from the mains). Most of the formulae available only deal with sinusoidal voltage and current waveforms, because the maths are simple and the result is quite clear. To refresh the memories of those who 'used to know this stuff' and to help those who never did, the following should help ...

- A pure capacitance across an AC supply causes the current waveform to be 90° out of phase with the applied voltage, with the current waveform 'leading' - i.e. the current occurs before the voltage. This seemingly impossible feat really does happen, but it takes a few cycles for the steady state conditions to be set up. This is called a *leading* power factor, and although there is voltage and current (VA), no power is consumed (PF = 0, Power = 0)
- Pure inductance has the reverse effect, in that the current lags the voltage (lagging power factor), but current and voltage are still 90° out of phase, and no work is performed. Again, voltage and current are both present (VA), but there is no power. In reality, an inductive circuit will *always* have some resistance, so power factor will never be zero.
- If the power factor is less than unity, your electricity meter will only cause you to be charged for the power consumed. The power company still has to provide the full voltage and current though (VA), so naturally enough they don't like low power factors. With PF = 0.5, a load may consume 20W, but will pull 40VA from the grid. For more information, do a web search, or look at Reference 5.

I recommend that anyone who doubts that power factor is an issue reads (and understands) the information from Integral Energy ...

Harmonic Distortion in the Electric Supply System

This technical note describes the ramifications of harmonic current and its implications for all power supplies that have a poor power factor caused by the non-linear current waveform. As more and more switching power supplies are added to the network, the problem simply becomes worse.

At the power station, the alternators produce power in Watts (or more commonly Megawatts). A 1MW alternator can provide 1MVA (a million Volt-Amps), and that is its maximum. A bad power factor means that the maximum power available from the alternator is reduced, because some of the energy produced is VA rather than true Watts. If an alternator is faced with a power factor of 0.5, its output *power* is reduced to 500kW, but it will get just as hot as it would if generating 1MW. Like all electrical machines, the alternator is heated by losses in the wiring, and if the maximum current is 1,000A at 1,000V (1MW), a poor power factor will still cause 1,000A to flow, but the power delivered is reduced in proportion to the power factor. In theory, less input power is needed, but now we need more machines.

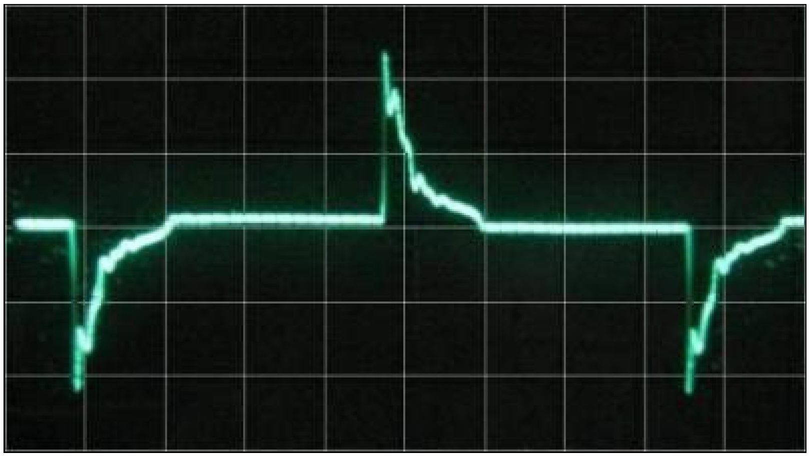
While we can be sure that the power companies will have measures in place to correct the power factor wherever possible, they *cannot* correct for waveform distortion caused by 'discontinuous' load current. This is an harmonic component of the mains waveform that is extremely difficult to correct once it has been distorted. Harmonic waveform distortion can only be fixed by using power factor correction in the power supply of the offending appliance(s).

Every transmission line and every transformer in the grid is subjected to resistive losses in the wire that are related to the current being drawn by every customer attached to the power grid. A bad power factor increases the losses by a ratio that is inversely proportional to the total power factor of the attached loads. A total PF of 0.5 means that twice the current is drawn for the power delivered, and the losses are not merely doubled, they are *quadrupled*. This is in addition to the reduction of the capacity of the alternators as described above. Because of the transmission losses, in order to deliver the same power to the customers, more power must be delivered to the grid.

This is not a trivial issue.

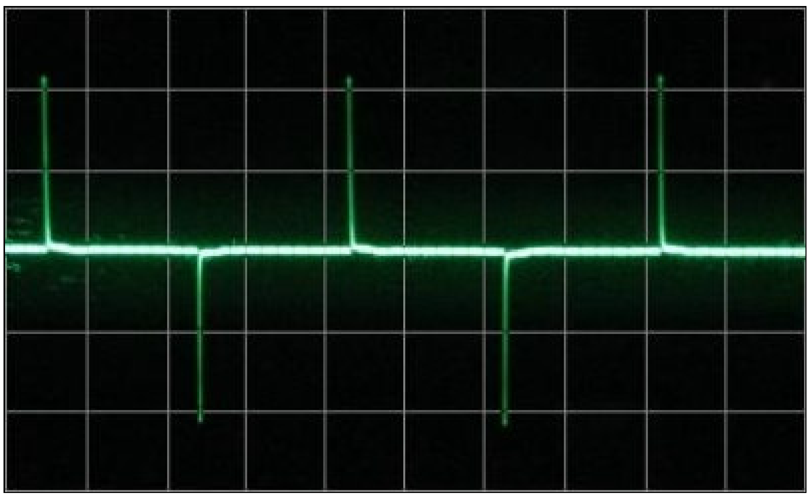
Most CFLs have a claimed power factor of around 0.52 (where the figure is given at all), so a 15W CFL will actually draw just under 29VA. Because the load is not linear, the current waveform is in phase with the applied voltage, but is discontinuous. This simply means that current is only drawn at the peak of the waveform, and this effect causes a poor power factor just as readily as a phase shift between voltage and current. It's actually quite easy to obtain a power factor of less than 0.35 with a simple rectifier and filter cap circuit, but how many CFLs are that bad? I don't know, but the almost complete lack of any form of standard doesn't help matters.

Remember, the supply companies must provide the total load in **VA**, not Watts. Based on a reasonably typical quoted PF of 0.52, each CFL in use requires almost double its rated power, because of the poor power factor. Therefore, rather than talking about a 15W CFL, we *should* be thinking in terms of a 30VA CFL. Just because we don't have to pay for the power doesn't mean that coal, uranium or some other fossil or non-renewable fuel isn't being used up to cover the total RMS voltage and current distribution losses caused by each and every load. You won't find this mentioned in too many articles (and none by politicians lobbying for green votes), but it is true nonetheless. Since these distribution losses can reach 20% easily (and I have even heard as high as 50% in some cases where extremely long feeders [several hundred kilometres] are used), the power factor is very important. A poor power factor will also reduce the capacity of power generating equipment, so more machines are needed to provide the same total load power.



13W spiral CFL Peak current = 410mA I_{RMS} = 93mA Crest Factor = 4.4 VA = 22.4 PF = 0.58

Figure 11 - Current Waveform of a Modern CFL



13W spiral CFL Peak current = 2.2A I_{RMS} = 245mA Crest Factor = 9.0 VA = 59 PF = 0.22

Figure 12 - Current Waveform With Dimmer In Circuit

The waveform shown in Figure 11 above gives a power factor of around 0.58, so the 13W CFL tested will actually draw 22.4VA - not as big a saving as is usually claimed in real terms. As you can see, it is a great deal worse if a dimmer is in circuit. Sure, you don't pay for the extra current, but the power company and the environment most certainly do. Larger transformers and heavier gauge distribution cables are needed to handle the extra current, plus more coal (or whatever) to generate the volts and amps needed to overcome the distribution losses.

The arguments assume that the number of CFLs used is the same as with incandescent lamps, but this may not be the case. There is a very real chance that the load will increase by the use of many more CFLs than anticipated. Because CFLs are known by many to be adversely affected by switching them on and off all the time, we may find that users decide to leave them on for much longer 'in case' they may need to go into the room later - the loo (dunny/toilet/restroom etc.) is a prime candidate for just that. Silly though it may sound, the widespread use of CFLs could actually *increase* the power generating requirement unless people are convinced that the lamps can be switched on and off repeatedly without damage. The only way people will be convinced is when manufacturers actually solve the problem. Note that just because *you* don't have a problem switching CFLs on and off, that doesn't mean that others don't. When it's cold, CFLs are rather dim when first turned on - yet another reason to leave them on rather than put up with very low light levels when you next go to the loo.

The nasty waveform created by CFLs is another thing that is going to come back and bite us on the bum. Any spike waveform means that significant harmonics are added to the mains waveform, and although CFLs are only a small percentage of 'nasty waveform generators' at present, the situation will get a lot worse. Power factor correction is possible (some up-market CFLs have it now, and have done for some time), but it does add to the cost - *plus* more electronics to end up in landfill.

Harmonics generated by non-linear loads are causing major problems in power distribution, as well as increasing the overall level of RF energy that surrounds us all. Many people think this is dangerous, others say there is no problem - exactly the same situation that existed when global warming/climate change was first raised as an issue. While older people may not need to concern themselves, what of small children? No-one *really* knows, but caution is well advised.

There is a little more on this topic here.

It is worth noting that mains waveform distortion is now becoming big business. There are more and more companies selling large inductors for use as mains filters for critical applications. Likewise, complete filter units are becoming more readily available than ever before, because the cost of replacing motors that fail because of high harmonic currents is considerable ... both the cost of the motor and machine down-time make failures very expensive.

This topic is of sufficient importance that a new article will be written to describe the problems and their impact on equipment. It's high time that governments stopped messing about with things that will only annoy people, and started making rules that will have a positive effect on the whole power grid. The potential savings are a great deal more significant than banning incandescent light bulbs!

Some Additional Measurements

I measured the 8W CFL referred to above. I also measured a 10W version from the same manufacturer. Interestingly, both claim 80mA at 240V, and they can't both be right! Since some people have complained about strobing (which can make a moving machine *appear* stationary), I also measured the light modulation ('flicker') frequency. The results were tabulated so we can get a better idea of what's happening ...

Power	Claimed Current	Measured Current	Peak Current	VA	Power Factor
8W	80mA	70mA (RMS)	270mA	16.8	0.48
10W	80mA	80mA (RMS)	338mA	19.2	0.52

Measured Characteristics of Two CFLs

The 'flicker' frequency of the 10W lamp I measured was 38kHz, so strobing is very unlikely. The light intensity was modulated at 100Hz (this will be 120Hz in 60Hz mains countries) to a depth of about 50%. I say 'about', because it is difficult to measure accurately because of the nature of the light waveform. In general, strobing is not a problem with modern compact fluorescent lamps, although it may get worse as the lamp ages.

The 38kHz flicker frequency has caused infrared remote controls to malfunction - a reader described this exact issue to me some time ago. While this is hardly a common gripe, it can and will happen in some instances, and will most likely be intermittent. Sometimes the remote will work, other times not. Most users will not make the connection, because they will be unaware that CFL electronic ballasts and IR remote controls operate at similar frequencies.

I also measured inrush current - the current drawn at the instant the lamp is switched on. Inrush current always varies, depending on the exact moment the lamp is switched on, but the measurements I took showed that the minimum was 2.6A, and the maximum (that I saw) was 5.8A. If you had (say) 20 CFLs in a festoon (using multiple lamps all attached to a single cable), the average current will only be 1.6A for 20 x 10W CFLs, but the peak inrush current could easily be as high as 116A for a couple of milliseconds. Your circuit breaker may or may not allow you to turn the lamps on - it will probably be intermittent.

Fire Risks

As noted above, there is a definite fire risk with so-called "normal" failure modes using CFLs (although it is much, much lower than with 12V halogen downlights for example). There are several news reports on the Net that have described fires (or the imminent danger of fire), with the worst so far being a description of a US$165,000 fire apparently caused by a CFL that had been connected to a circuit with a dimmer in circuit. The details in the article are somewhat sketchy, and it's rather unlikely that a follow-up will be done when the real cause has been identified. Fortunately no-one was hurt in this case, but there will undoubtedly be a fatality at some stage (if not already). It's not possible to have tens of millions of products such as CFLs being sold without any incidents, but it would be nice if someone actually took the risk seriously.

Part of the problem is that a CFL is a time bomb - the house fire above happened around 12 months after the CFLs were installed. While fires have been caused by incandescent lamps is not disputed - they get hot enough to cause fires quite easily, but in most cases the likelihood of a fire is almost immediately apparent.

Any GLS lamp installed where it's in contact with flammable materials will only take a few minutes before the risk is obvious, and corrective action can be taken before a serious fire ensues. Fairly obviously though, the risk may not be present at the time when the lamp is installed, but can occur at any time thereafter. Yes, incandescent lamps are a potential fire hazard, but most people are aware of this because the heat is delivered immediately, and nearly everyone is aware of the risk because they know that traditional lamps get very hot.

The press and most of the websites that talk about CFLs often mention heat - but usually only the relative lack of it compared to incandescent lamps. There's almost no information about using CFLs with enclosed fittings, dimmers, light/movement activated switches or home automation systems, other than in articles such as this. The websites that extol the virtues of the energy saving lamps are hardly going to discourage people by disclosing the facts - largely because they don't even know. Since governments either don't understand the risks or choose to ignore them, no-one's about to be prosecuted for misleading advertising when governments and their own agencies are providing exactly the same misleading "information" to consumers.

As always, be careful with news stories and comments you find on the Net. Unless the article has good technical details and really does describe the problem in detail, it's often best to ignore it. Too many such stories are based on hearsay or journalistic "license", and few have sufficient real information to be credible.

Disco Lighting?

Well, not really, but another issue has been raised. I ran some tests, and sure enough, you can have your own little disco strobe lamp given the right (or wrong) set of circumstances. Although the flashing effect is usually quite faint, it certainly won't look faint if you are trying to sleep! In a bedroom, even the smallest amount of flashing light may disturb sleep patterns, and is definitely not recommended.

In many households, you will find ceiling fans with a light under the fan. Ignoring the fact that these are usually fully sealed (so will overheat the lamp as described above), some have remote control units. This usually means that the switching is performed using a solid state switch (typically a TRIAC). When a TRIAC is used for switching, it is customary to add a small (typically 47nF or so) capacitor in parallel with the TRIAC to suppress extremely fast pulses that can cause the TRIAC to "spontaneously" trigger. Capacitors may also be connected in parallel with relay switching systems to help prevent arcing.

Where used, this capacitor will cause quite a few CFLs to flash at a rate between around 2Hz to 6Hz - as noted, the flash is very dim and may not even be visible in bright lighting, but you most certainly will see it if the room is dark. I tested 3 CFLs I had in my workshop, and 2 of those flashed quite cheerfully. The other seemed immune (I tried a range of capacitor values). This tallies with the test details I was given, and means that there will be installations where a CFL simply cannot be used because of the low-level flashing. On the basis of the two sets of tests run, I would guess that around 50-60% of CF lamps may be affected to some degree.

Further reports (including a response from an Australian CFL distributor to someone who had the problem) acknowledge this issue, and in some cases CFLs will flash simply because of the cable capacitance or the way the switch is wired. Some have described the effect as a bright flash, but this seems unlikely - it probably just seems bright in a dark room.

It isn't known if this will shorten the life of the lamp - my guess is probably not, because the energy is so low. Even so, it represents a tiny amount of wasted energy, and it may transpire that lamp life *is* reduced by means not yet understood. Most certainly, the flash will be sufficiently irritating in a dark room to force its removal - especially in a bedroom. That fact that many lamps will flash if there is a capacitor in parallel with the switching device (or because of the way their house is wired) means that there are further applications where CFLs cannot be used at present. While the number of people so affected will probably be small, if incandescent lamps *are* ever banned, users will have to search for a lamp that doesn't flash, or have their ceiling fan(s), home automation system or house wiring modified or replaced. I doubt they will be amused.

It is likely that CFL manufacturers will fix this problem once it becomes well known to the public - it is already known to many (most?) of the manufacturers. In the meantime, it is a real issue, and will affect a lot of people who want to do the right thing. I have CFLs installed in my main bedroom (in a 3-lamp fitting), and had to install a small incandescent lamp in one socket to prevent the flashing at night.

Health Issues?

The most recent information to hand (from a reader whose wife has Lupus) indicates that there most certainly *are* health issues. There are several auto immune diseases (Lupus being one of them), where UV light and/or light flicker cause sometimes extreme physical pain. See Wikipedia (Fluorescent Lamp, Other Health Issues) for more on this. A web search will quickly show that there are several conditions that create extreme sensitivity to UV light ... once you know what to look for.

For the remainder of the population, there is no evidence to suggest that humans are adversely affected by high frequency modulated light, but there is also no evidence that there are *no* long term effects. There is a great deal of concern (and a certain degree of conjecture) that fluorescent lamps of all types may contribute to health problems, in particular cancer. Try a web search for many articles that describe possible reasons in some depth.

Of particular concern is the amount of UV (ultraviolet) light that *all* discharge lamps emit - it is significantly higher than that from an incandescent lamp. Are these claims real or just scare mongering? Based on the information above, it seems that the claims are indeed real, and will affect a considerable number of people. Some additional scientific study certainly wouldn't go astray - preferably *before* government lunatics impose any bans on GLS lamps. This is a fairly hot topic on the Net, and a search finds a great many sites (over 1.2 million results) discussing the link between artificial lighting and breast cancer in particular.

Ultimately, it is better to err on the side of safety, but modern realities can make that extremely difficult. This information has been included in the interests of completeness, and the reader is advised to read the available information and make any decision based on that. It may prove that incandescent lighting is no better (or worse) than fluorescents in this respect, but it is not my intention to discuss this in any more depth than has been done in this section. I have neither the research material nor the medical skills needed to be able to make any recommendations, but it seems plausible that the claimed link between lighting and cancer may have some credibility - what we can do about it is another matter altogether.

If a lamp decides to fail and let the magic smoke out, there is definitely a serious health risk. Despite claims that the smoke poses no danger, it depends entirely which component it comes from. A burning polyester capacitor is very bad news - the smoke is toxic, as with most burning plastics. This also applies if the PCB is severely overheated and smokes or burns. Although it is uncommon for electrolytic capacitors to catch on fire, it has happened ... I've seen the results on a number of occasions. The fumes from burning ethylene glycol (part of the electrolyte in electrolytic capacitors) should not be inhaled - ethylene glycol itself is toxic, and the smoke is unlikely to be beneficial.

Never use a CFL as an all-night light for small children. Lamp failure could result in toxic fumes and possible serious injury.

Another health related issue is where a CFL is used to illuminate a stairwell or similarly potentially dangerous area. The light output from CFLs is often very low when the lamp is first turned on, and the colder it is, the worse the effect. If it's cold enough, the lamp may not even start at all. Should a CFL be used to light an area where you really do need lots of light immediately, this poses an accident risk because of inadequate lighting. Falling down a flight of stairs is definitely hazardous to your health. The young and elderly are most at risk, because they may not fully appreciate the hazards.

This problem is well known - even a politician supporting the ban commented that the CFL in her hallway didn't give enough light when first turned on, and this made it "difficult to find something dropped on the carpet" (this was the (then) E.U. Council president Angela Merkel !). The solution is easy - just leave the light on for 5 minutes, right? An incandescent lamp may need to be on for no more than 30 seconds while one descends stairs or finds something dropped on the carpet, so its energy usage will be (say) 30s x 100W = 0.8Wh (Watt Hours). Leave a 23W CFL on for 5 minutes until its light is adequate for the task, and you use 5m x 23W = 1.9Wh - *more than twice as much as the incandescent*! Not so energy efficient now, is it?

Scare Mongering

It must also be considered that there are some websites that are guilty of serious scare-mongering. While the material presented may have some (often tenuous) basis in fact, it is often exaggerated to the point of being somewhere between "quite silly" to "insane". One such site has made the most outrageous claims I've ever seen, and this kind of idiocy will only make it harder for people to have a sensible argument on the topic.

It should be remembered that we've been using fluorescent lighting for a very long time, and the CFL is simply a compact version of the traditional tubes that are ubiquitous in offices and shopping centres. Despite the use of fluoro tubes, the world has not ended, and huge sectors of the population do not have panic attacks nor get serious UV burns as a result of working beneath them. I have 2 x 1,200mm (4') tubes directly above my workbench (as well as a LED tube), and they are no more than 500mm from me while I'm working. My eyesight has not been ruined and I've never even had the tiniest sunburn as a result of working so close to them. Likewise CFLs - I use lots of them in my workshop!

Dirty Electricity

A favourite for a while (and it's still a topic) is so-called "dirty electricity". The CFL electronics supposedly pollute the normal mains sinewave and this is claimed to have serious health issues. This seems on the surface to be utter bollocks! Digging deeper doesn't help either.

I have never seen any technical data that describes the "scientific" meter that is used to measure this "dirty electricity", and as far as I'm concerned the entire topic is just nonsense. I'm sure that some frequencies above 50Hz (or 60Hz for North America) can be measured, but most will probably be barely above the frequencies that are typical for audio equipment. All countries have strict rules about the amount of RF interference that electronic products can produce.

No claim for this "dirty electricity" causing harm has been proved to my knowledge, and I'd be very surprised if anyone managed to show any connection whatsoever. This is exactly the kind of disinformation that makes any attempt at credible criticism very difficult. There may actually be a connection somewhere, but no-one is going to try to look for it or defend their results against the nonsense that's being generated by these pseudo-scientific purveyors of snake-oil.

In short, there are some issues, there is a small amount of UV that may affect some people, and CFLs do contain mercury. They don't contain enough so that one broken CFL will pollute the water supply of a small city, and "dirty electricity" is a myth until someone explains what they are measuring. They won't do that though, because their claims can then easily be challenged. As long as they keep their tests in the realms of magic, no-one can level any sensible complaint against them.

Wasted Heat

A topic commonly raised by proponents of a ban on incandescent lights is that the generated heat is wasted. In many areas (even in Australia), the heat is not wasted at all. It is in addition to other heat sources (radiators, reverse-cycle air conditioners, convection heaters, etc.).

Even in temperate regions like Sydney, the little bit of extra warmth is perhaps usable for about 5 months of the year, or around 7 months in places like the UK. Small though it may be, having a 100W lamp switched on for a few hours will probably make some difference, even if only to make up for heat lost through window glass, ceilings, etc. In colder climates, the heat will hardly ever be 'wasted' - it is a usable form of additional heating for the home. Not much, but a number of people have brought this up on forum sites and elsewhere.

Because this really is (or seems to be) a relatively trivial issue, the original material from this section has been moved. Click here to see the entire topic. It turns out that it's no so trivial after all though - see "*However*" below for more.

Two links in the sub-page may look a bit silly if launched from the popup window, so you can access them here ...

Building Research Establishment
Lighting Industry Federation

As noted in the introduction, the *only* way to prove or disprove the wasted heat argument is a properly conducted trial. Humans don't normally apply maths and science to their everyday activities, so using these tools to prove a subtle point is, well ... pointless. It may turn out that the heat from conventional lamps *is* completely wasted, it could be that it makes more difference than anyone thought, or it may not make any difference either way. This can only be determined by testing real people in a real environment - not by someone dragging out reams of data and using maths to prove a point one way or another.

However, halogen downlights must be mentioned specifically, because they usually involve having holes in the ceiling. This has only recently been addressed, and the results are far from encouraging. Apart from the fire risk (50 in Melbourne alone in 2007 [The Age], there is often not only wasted heat, but a serious *increase* of heat loss due to convection through the hole in the ceiling. See Australian Government Free Insulation Program for some of the issues.

There are now special non-combustible "hats" available that can be placed over the downlight that prevent heat loss (or heat gain during summer) due to convection, but in my opinion this is a stop-gap measure only. While these devices can make a very big difference, the traditional 50W halogen downlight is likely to fail the next round of energy performance standards amendments, and because the enclosure is now sealed it may not be suitable for CFL or LED downlights.

Life Span & Standards

Australia is *way* behind the US in this area. At this stage it's only a draft but I recommend you read ENERGY STAR (Criteria, Reference Standards and Required Documentation for GU-24 Based Integrated Lamps) to see the requirements in full. While Australia has adopted the Energy Star system, there appears to be little or no activity with CFLs.

Although the packaging may claim 10,000 hours or more for a CFL, there is usually no guarantee that this will ever be achieved. I've used quite a few CFLs in the house and workshop, and I seriously doubt that the claimed life is/will be ever reached. While some manufacturers will provide detailed technical data sheets, most don't, and even for the ones that do you have to really search for the information. The stated lifespan is generally taken as that where 50% of lamps are still working - in other words, half are not still working. What is not stated is the light output at end-of-life - it may be as little as half that when the lamp was new. Claims that incandescent lamps also get dimmer as they age are complete rubbish. When was the last time you saw a (mains operated) filament lamp that was blackened on the inside of the glass, but was still working? It can happen, but I haven't seen one for many years. The old style inductive ballast CFL shown in the sub page above still works, but its light output is uselessly low compared to when it was new.

We can reasonably safely assume that the life is 'typical', based on other similar products, and with the lamp running continuously. Manufacturers are not going to test lamps for over a year before selling them to verify that the claimed life is accurate. It is well known that switching reduces life, but there is usually very little (or no) information provided on the pack, the maker's website or anywhere else.

Standards covering these important questions appear to be somewhere between few to none. Likewise, there appear to be no standards (at least in Australia) that specify what 'warm white' actually means. It is not at all uncommon to have a number of 'warm white' CFLs from different makers all having quite different colour temperature and colour rendition. Even lamps of different vintages from the same manufacturer (and with the same claimed colour temperature) can be quite different from each other - especially those from supermarkets or department stores, which will nearly always be at the low end of the price range.

Actually, there *are* standards, but they are completely voluntary. The only mandatory standard that applies is electrical safety, because CFLs are a "prescribed product" in Australia. Two sets of standards (also referenced earlier) from Australian government groups (see EnergyAllStars and National Appliance and Equipment Energy Efficiency Program describe minimum energy requirements and other standards, but there is no obligation for these products to comply. According to these documents, a CFL should retain 80% or more of its light output after 2,000 hours - that is obviously a joke if a lamp is claimed to last for 10,000 hours or more. According to these "standards", at end of life for a CFL, you'd be better off with a candle.

Mandatory standards that specify minimum performance criteria should be in place now - waiting until incandescent lamps are banned (as has already effectively happened in Australia) is too late. At the minimum, these mandatory standards should cover the following ...

- Expected life in hours, based on reasonable switching cycles (e.g. 3 times / day)
- Luminous efficacy, in lumens / Watt (can range from 45 to 60 for CFLs)
- Equivalent light output referred to an incandescent lamp. People are starting to make very ambitious claims
- Luminous efficacy at 'end of life' (can be as little as ½ the claimed output for CFLs, at present it is not stated)
- Colour temperature equivalent
- Colour Rendering Index (CRI)
- Power factor (actual and measured, *not* just made up by someone in the marketing department)
- All packaging must be recyclable, and must also contain recycling information for the lamp itself
- Strong and unambiguous labelling of any limitation (not safe with dimmers, sealed luminaires, wet areas, etc.)
- Proper fire rating information (currently available in some countries, not in others)
- Proper sensible (and correct) advice as to clean-up procedures in case of breakage

Of these, only colour temperature is commonly provided, but this is not meaningful without the CRI figure. For example, low pressure sodium vapour lamps have a colour temperature of perhaps 2300K (my guess, but it's actually an irrelevant figure for these lamps), but have a CRI of almost zero (they are the most efficient lighting source currently available, but are an orange/yellow colour, and are typically used for street lighting).

A (now empty) CFL pack I have states the colour temperature as 3500K, and says that the lamps are 8W (equivalent to 40W). It also claims the current to be 80mA (but I measured it as 60mA, a rating of ~17VA ... *not* 8W at all, giving a power factor of 0.47). The actual generating capacity needed is therefore closer to ½ that of the 40W incandescent lamp, not ¼ as claimed. People are being seriously mislead by the term 'power' - as noted above, this may be what you pay for, but is *not* what must be generated and distributed.

If it seems that I'm really pushing the power factor issue, that's because I am!. It is important, and almost no-one has commented on it (or even seem to know the problem exists). Power factor is real, and reduces the claimed savings in CO2 generation to significantly less than that claimed.

For power savings, we've all seen wide variances for apparently equivalent CFLs. A 100W incandescent lamp gives a total of around 1,800 lumens. Assuming 60 lu/W for a CFL, that means you need a 30W compact fluorescent lamp to replace a 100W incandescent. My maths tells me that the CFL uses 30% of the energy of an incandescent - not 25%, not 20% and definitely not 12.5%. Anyone claiming that an 18W CFL is equivalent to a 100W incandescent lamp is trying to trick you - a 100W incandescent lamp will provide around 1,800 lumens as noted above ... *not* 1,350 lumens or thereabouts as is often stated in various websites and other so-called 'information'.

As a side issue, the claimed colour temperature of all fluorescent lamps is meaningless, because they are not 'black body' radiators of light (look it up 😃).

Packaging and ...

Many CFLs used to come in a plastic 'blister' pack with a thin cardboard sheet with printed details. This has now changed (for the most part) to thin cardboard boxes similar to those that were common for incandescent lamps. Almost none has a recycling symbol or disposal warning to be seen anywhere. Some show a wheelie bin with a cross through it - that's pretty clear, but there is no information about disposal. Presumably we simply hoard the old lamps until someone offers a means of disposal.

Dedicated end user recyclers could potentially reclaim the steel (and possibly the glass) from incandescent lamps, but the quantities produced by the average household are so small that it would take a very long time to make the effort worthwhile. As noted above, this same thin cardboard package is becoming more popular for new CFLs, which is s step in the right direction.

Many people all over the world have commented that the push to use CFLs really has little to do with the environment and a lot to do with consumption. I don't necessarily agree with this (it is rather cynical), but sometimes you wonder when you see all this packaging and electronics, with no indication as to whether it can be recycled or not. It becomes even harder to disagree when you consider the millions of existing fittings that will ruin a perfectly good CFL in as little as a couple of hundred hours, because so many light fittings are inadequately ventilated. Almost no-one who is pushing for a ban of incandescent lamps even *mentions* the limitations of CFLs, or any precautions that users should observe to get the maximum life from them. Now, to me, *that* is cynical beyond belief.

As noted above, recycling is imperative, and can do a great deal to reduce CO2 production and waste. With CFLs, it must be mandatory, but what are those supporting bans on incandescent lamps doing about it? Bugger all as near as I can find.

The latest from governments (in Australia at least) is the claim that we need to reduce our consumption of electricity to minimise "carbon pollution". A figure of 33% was mentioned recently ... pie-in-the-sky (with sauce) if ever I've heard it. It's unclear exactly how we will be able to reduce consumption by such a massive amount - many home appliances are already reasonably efficient, and the remainder can never reach the gains expected. It's really easy to make a blanket statement like that, but much harder to implement it. In this case, I'd suggest that it's impossible unless our lifestyles are drastically modified, and that simply is not going to happen other than by catastrophe.

I have no idea who is advising governments these days, but they are undoubtedly either seriously over- or under-medicated.

References & Acknowledgments

1. Incandescent Light (Wikipedia)
2. Mercury in Coal
3. STMicroelectronics
4. Incandescent Lamp Matches Efficiency of CFLs
5. Power factor (Wikipedia)
6. Colour Rendering Index (Wikipedia)
7. CFLs in Recessed Downlights
8. Refutation of claims that heat is not wasted
9. Gilway - Tungsten Filament Lamps

10. My thanks to Phil Allison for the photos used in Figures 8 and 11, and for various other bits of information used in this article - in particular the information about the use of a CFL with a dimmer.
Thanks too to Ron Sawyer in the US for the photo used in Figure 2 (overheated electronics)

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Page created and copyright © 22 Feb 2007./ Updated 25 Mar 07./ 30 Mar - disco lights, health addition (stairwell etc), burnt neutral link./ 02 Apr 07 - dimmer+CFL./ 09 Apr - "Normal" failure, page re-format./ 21 Apr - Page clean-up./ 05 May - added info on standards, clean-up procedures./ 26 Jun - EU to ban mercury./ 08 Oct- included T5 tube data and footnote to "efficiency" table./ 16 Jan 10 - several minor updates (wasted heat, halogen downlights, etc)./ 12 Oct 10 - added scare mongering and dirty electricity sections, and amended final section.