let there be light

The shift to energy saving lighting will save vast amounts of electricity. But finding a true replacement for incandescent bulbs is proving more difficult – and more controversial – than anyone had expected. **Mark Harris** investigates.

THE UK is committed to moving towards more energy efficiency lighting. EU law already forbids the sale of 100W and frosted incandescent lamps, while in January 2010 many retailers will sweep the nation's favourite bulbs – 60W incandescents – from their shelves.

The energy saving lights are on then, but is anyone home? Labelling schemes are patchy and confusing, manufacturers' claims are often misleading and even the newest, most efficient technologies are dogged by technical problems. Above all, perhaps, consumer and media resistance to ditching traditional incandescent lights is ferocious.

Britain's love affair with the light bulb is nothing new. In 1881, London's Savoy Theatre became the first building in the world to be lit entirely by electricity. Owner Richard D'Oyly Carte enthused: "The greatest drawbacks to the enjoyment of theatrical performances are the foul air and heat which pervade all theatres. Each gas-burner consumes as much oxygen as many people and causes great heat beside. The incandescent lamps consume no oxygen and cause no perceptible heat."

RADIANT INCADESCENTS

Incandescent bulbs may be clean and cool compared to gas lamps but it has been decades since they were lighting's brightest idea. Incandescent (also called General Lighting Service, GLS) bulbs generate only about 11 lumens of light per watt of power, and have an average lifetime of just 1,000 hours in the UK. In comparison, compact fluorescent (CFL) lamps, invented by General Electric (GE) in response to energy crises in the 1970s, now average an efficacy of over 40 lumens per

watt and have lifetimes of 6,000 hours or more.

With lighting representing up to a fifth of a household's electricity consumption, the EU estimates that phasing out GLS lighting in favour of CFLs will save EU citizens 40 TWh a year. That's the equivalent of Romania's annual electricity usage – or a saving of around £45 a year for each UK household.

A comprehensive EU life cycle analysis in 2008 comparing lighting technologies showed that compact fluorescents are better for the environment, too. For both GLS and CFL bulbs, the vast majority of their total energy consumption (around 95 per cent) comes in the use phase. Even small increases in efficacy can justify the sophisticated electronic components and more complex manufacturing process required for CFLs. In fact, over the long term, the EU found that replacing a GLS bulb with a CFL leads to a decrease of 75 per cent for virtually all environmental impact indicators, including water use, greenhouse gas emissions, particulate matter, heavy metals and organic pollutants.

But if the economic and environmental benefits are so clear, why do CFLs currently account for less than 10 per cent of lighting in UK homes? Early CFLs were certainly clunky affairs. Bulky and expensive, many also suffered from perceptible flickering, unattractive blue-ish light, high-pitched whines, sluggish warm-up times and interference at infrared and radio frequencies. Years of product development, and especially improvements to the electronic ballasts found in every CFL, have eliminated most of these issues. But the fact remains that many consumers still perceive them as a poor replacement for GLS lighting.

A common complaint is that CFLs seem dimmer than incandescent bulbs. The Energy Saving Trust, the government's non-profit sustainability organisation, recommends that consumers compare lamp wattages when replacing bulbs, with CFLs requiring about a fifth of the power of incandescents. Its website suggests 11-14W CFLs to replace 60W GLS bulbs and 20-23W CFLs for 100W incandescents; advice that is echoed by most lighting manufacturers in the UK.

However, when actual light output is measured, a different picture emerges, according to the European CFL Quality Charter. The Charter is an EU initiative aimed at raising consumer confidence in CFLs by setting voluntary minimum standards, including light output in lumens (a measure of perceived brightness). It notes that all CFLs tend to lose brightness as they age, by as much as 20 per cent over their lifetime. Using the Energy Saving Trust's current 5:1 ratio, consumers could end up with a CFL nearing the end of its life that emits just 60 per cent as much light as a supposedly 'equivalent' incandescent bulb. To counter this, the Charter sets the minimum initial lumen level for CFLs at 120 per cent of the incandescent bulbs they are to replace.

This works out to a minimum CFL wattage of 16W to replace a 60W GLS and 26W for a 100W – around a 4:1 ratio. Other experts feel that even this is too optimistic. The Lighting Research Centre at Rensselaer Polytechnic Institute in New York recommends a 3:1 ratio: "You'll still use only a fraction of the energy, while avoiding the possible disappointment of a dim lamp."

PHASING OUT INCANDESCENTS, PHASING IN PROBLEMS?

The Energy Savings Trust has watered down other requirements of the European CFL Quality Charter. In order to qualify for the Trust's Energy Savings Recommended (ESR) scheme, CFLs must come up to 20 per cent of their full brightness within 2s, and 70 per cent within a minute. The EU Charter specifies 30 per cent and 80 per cent, respectively.

Some consumers are also concerned that switching CFLs on and off frequently can shorten their lifetimes. While the ESR was content with lamps that survived 3,000 on/off cycles over an 8,000 hour lifespan, the Charter requires a number of cycles equal to its rated life in hours; or 8,000 over the same period. The Energy Saving Trust has now dropped rapid cycle testing altogether, saying that it does not consider it 'proves a good representation of product quality'. However, similar tests in the US found that over a quarter of samples undergoing rapid cycle testing failed.

It might be tempting to characterise these discrepancies as just another battle between the British Government and the European Union, except for the fact that one of the organisations responsible for formulating the EU CFL Quality Charter was the UK Energy Savings Trust itself.

"I am confident our figures are correct and appropriate," says James Russill of the Trust. "Previously the Charter was useful for countries that did not have their own standards, but I don't see the need for it now that the EuP [Energy-using Products] Directive is here."

Russill is referring to European legislation that has just come into effect, specifying standards for CFL bulbs. ▶

GLS/incandescent		Compact flourescents			LED	
(Watts)	(lumens)	EST current recommendations (lumens)	EU law Sept 2010 (lumens)	EU CFL quality charter recommendations (lumens)	EU law Sept 2010 (lumens)	L Prize (lumens)
15	120		125	145	136	
25	220	180-300	229	265	249	
40	415	340-400	432	500	470	
60	710	530-730	741	850	806	900
75	930		970	1110	1055	
100	1340	1160-1830	1398	1610	1521	
150	2160		2253	2590	2452	
200	3040		3172	3650	3452	

'Labelling schemes are confusing, manufacturers' claims are often misleading and even the newest, most efficient technologies are dogged by technical problems'

However, the new EU directive actually downgrades minimum standards below even ESR levels. Bulbs currently need only last 6,000 hours, compared to the Trust's 10,000-hour standard; can warm up more slowly and lose more of their initial brightness after 2,000 hours; and have no requirements for maintaining brightness over their full lifetime.

The EU standards do get tougher over time but at even at their most stringent – a level that won't be reached until 2013 – they still fall short of the EU CFL Quality Charter in key areas, such as warm up time and end of life brightness.

Conflicting and changing standards make it all the more important that energy saving light bulbs are labelled clearly and correctly, so that consumers are able to make informed decisions for themselves. Unfortunately, the labelling system is also in a mess.

The Energy Saving Trust's voluntary ESR scheme requires participating manufacturers to disclose light output, lifetime and colour temperature on bulb packaging but the only obligatory label is the EU's energy efficiency rating. Even this applies only to non-directional lamps, thus excluding the spotlights and specialist bulbs that make up around 15 per cent of UK sales. Moreover, virtually all domestic CFLs already qualify for the highest A rating, giving consumers little help in distinguishing between different bulbs.

"It is not just in lighting that products are now mostly in the top classes," says a spokesperson for the Department for Environment, Food and Rural Affairs (Defra). "This is also a problem for cold appliances and washing machines. This is being discussed in the EU currently and is expected to be resolved in the coming months. The EU Energy label is also expected to be extended to directional lamps."

HOW MANY LIGHT BULBS DOES IT TAKE TO CHANGE A PERSON?

September 2010 will see the introduction of mandatory EU labelling for all CFLs in the UK, featuring a deluge of technical information including lumen output, colour temperature in Kelvins, switching cycles before failure, life time and warm-up time.

The potential for consumer confusion is immense, believes Mike Simpson, Technical and Design director at Philips Lighting UK: "The average man in the street doesn't understand what a lumen is. If he can't understand light output, trying to get him to understand colour temperature is going to be an uphill battle and I don't think you should even be talking

Philips Genie energy-saving lightbulb 11W BC

colour rendering index. I don't think you'll ever get that concept across to people. There needs to be a way of taking those technical terms out of the system."

The situation will be made more complex by new guidelines on CFL equivalency in the EU directive. Amazingly, a lamp that today is rated A for efficiency and is recommended to replace a 100W GLS bulb, could next September be rated B (or lower) and only labelled as bright enough to replace a 60W incandescent.

Defra is well aware of the problems that lie ahead but feels that its hands are tied. "The law will come into force in September 2010 and we can't enforce any changes before then," a spokesperson told *E&T*. "What we can do is raise consumer awareness and push for labelling that consumers can understand. I can promise you that the British government is pushing very strongly for the clearest, most concise label which is as easy for consumers to read as the current A to E rating."

Although CFL labelling might be finally moving in the right direction, consumers should not expect to see dramatic improvements in the lamps themselves, warns Simpson. "CFLs will have a peak when they take over from incandescents but in 20 years time they start to tail off and new technologies take over," he says.

"It takes five or six years to get a concept through to a manufacturable product. Even if you put a lot of research into CFLs now, in six years time you've only got another ten years or so before the market for them is dying. The majority of our development activity today is gearing in towards solid state lighting."

Solid state lighting, primarily based on light emitting diodes (LEDS), promises efficacies several times that of CFL (up to 100 lumens per watt), lifetimes measured in decades, tunable light frequencies, and fewer environmental concerns. The first LED products, mostly lower powered, directional 'mood'

	EU Stage 1	EU Stage 5	ESR	EU quality charter	Energy Star (US)
Lamp survival factor at 6,000h	≥0.50	≥0.70	>0.50 at 10,000	6,000hrs	
Lumen maintenance at 2,000h	≥85% (≥ 80% for lamps with second lamp envelope)	≥88% (≥ 83% for lamps with second lamp envelope)	88%	>88% (83% with external)	90% at 1,000hrs
At 6,000h	No requirement	≥70%	78%	>75% at 100% rated life	80% at 40% of rated life
Number of switching cycles before failure	≥half the lamp lifetime expressed in hours ≥10,000 if lamp starting time >0.3s	≥lamp lifetime expressed in hours ≥30,000 if lamp starting time >0.3s	3,000 at 8,000hrs. Now dropped.	=lamp lifetime in hours, ie 6,000 at 6,000hrs	
Starting time	<2.0s	<1.5s if P<10W, <1,.0s if P≥10W			
Lamp warm-up time	60% <60s or <120s for lamps containing mercury in amalgam form	60% <40s or <100s for lamps containing mercury in amalgam form	20% at 2s, 70% at 60s	30% at 2s, 80% at 60s	under 1s start-up, under 3 mins run-up

CFLS: CONFUSING FLUORESCENT LIGHTING?

Even if consumers do buy powerful enough CFLs, they may not be happy with the quality of the light they see, says Dr Steve Fotios, director of Lighting Research at The University of Sheffield: "The eye is really complex and we don't fully understand how it works. So to say that a certain wattage of CFL is equivalent to an incandescent based on lumens, is probably not what people perceive. With small fields like reading lamps we're OK, but we haven't yet got an agreed system for measuring or predicting large field responses like a room for brightness."

There are also lingering health concerns surrounding CFLs. The Health Protection Agency warns that some open CFLs (where the tube or coil is visible) generate levels of ultraviolet radiation similar to standing outside on a sunny summer's day – although only at a distance of 2cm or closer. Consumers also need to be aware that mercury is present in most CFLs. Broken bulbs should cleaned up quickly and carefully, while failed bulbs need to be recycled using the usual WEEE channels. CFL lighting's problems with mercury are occasionally overstated. Although each CFL contains up to 4mg of highly toxic mercury, life-cycle analysis shows that mercury emissions from coal-fired power stations mean that when compared per lumen and per hour, CFLs cause less mercury to be emitted than incandescent lighting.

lights, are already on shelves.

Sadly, the lighting industry seems to have learned little from the mistakes it made with CFL. "We're seeing reputable manufacturers providing data for LEDs that could be misleading about their performance," says Simpson of Philips Lighting UK.

"We are concerned about the technology getting a bad reputation before it's really had a chance to mature."

Kelly Gordon of the US Department of Energy (DoE) agrees. She manages the DoE's Lighting for Tomorrow scheme and follows the Department's LED testing programme, called Caliper, closely. "It's not uncommon in each batch of testing – say 30 to 35 products – for more than half of the products to have claims in their literature and packaging that are inaccurate, sometimes wildly so. They're simply not borne out in the testing," she says.

Official Caliper documents make for damning reading. "The majority of LED A-type replacement lamps do not meet manufacturer performance claims," says one report. "Testing reveals that these lamps produce only 10 to 60 per cent of their claimed light output, and often their directionality would not make them suitable replacements for nondirectional lamps. In addition, in many cases the products have colour characteristics that are not typical of the products they claim to replace, such as much colder colour temperatures or light that is not truly white."

CFL Candle

Philips' Bright Tomorrow Lighting Prize (L Prize) competition entry

The American scientists go on to criticise 'incorrect or misleading' energy efficiency data, low power factor, and dimmability information that was correct only about half the time. "In most cases," concludes Caliper, "purchasers would be best served by disregarding any manufacturer-published equivalency."

"The problem is that LEDs are quite a disruptive technology," says Simpson. "Everything we used to know about lamps – measuring, performance, temperature – all the ground rules have changed. But things like colour variation can be controlled. One technique we're using is a specialised multi-binning approach. On one silicon wafer you can have quite a wide variety of performance so the first thing is put them into controlled batches or bins. We take a range of chips from different bins and combine them to a give a consistent performance – like blending a wine or whisky."

Other aspects are less easily tested. "For consumer LEDs, you're talking about 20,000 hour lifespans – that's 15 to 20 years' usage," says Simpson. "Philips actually tests products over 6,000 hours, puts the data into a statistical function and predicts the life performance of the product from there. We have to do that because the speed of innovation is such that after 6,000 hours' testing – which is nine months – you've actually got the next generation of chip coming out."

CAN MANY HANDS MAKE (ENERGY-SAVING) LIGHT WORK?

It was partly to harness this flood of innovation that in 2008 the US DoE announced the L Prize: a $20m (£12m) race to find a high quality replacement for the most popular lighting products in the world, the 60W incandescent bulb and the PAR 38 halogen floodlight. Winning the L Prize won't be easy. Not only does it have ambitious technical targets – the 60W replacement must emit at least 900 lumens (70 per cent more light than the Energy Saving Trust's 'appropriate' minimum), at twice the efficacy of most CFLs – but the lamp must also be largely built and packaged in the US.

"We want to have an impact on the market," says Gordon of the US DoE. "Manufacturers have to demonstrate a commitment to actually manufacturing these products. We're asking for a high number of samples (2,000) because we didn't want the L Prize to be just one prototype that never gets built. It needs to be very close to commercialisation."

Philips is the only company so far to have submitted an entry to the L Prize and Simpson is confident about its chances. "We think our bulb ticks all the boxes," he says. "The L Prize has been a focus but it's not a million miles from where we were headed in any case. It's absolutely what we want to bring on board in Europe and the rest of the world. If you can crack the 60W equivalent – the most common incandescent bulb in the world – then you really have cracked the market."

But the contest is far from over, says Gordon: "There's now an extensive evaluation process that will take the better part of a year. There is most uncertainty in life testing because LEDs have such long potential lifetimes. We will be testing the whole lamp for at least 6,000 hours and we'll also be subjecting some lamps to stress testing with more extreme conditions: higher temperatures, higher humidity, frequent switching, higher voltage or voltage fluctuations.

"We are also disseminating some of the 2,000 samples to our utility and energy efficiency partners for field assessments. They'll put a couple of hundred lamps into hotels, multi-family housing or retail, to see how they fare under real world conditions. We want to anticipate failure modes and problematic applications before the lamps go out in the market."

Simpson even hints that we could even see Philips's bulb in the shops before an L Prize winner is declared: "It's probably got about 12 months in development to get it to the market but if we can get it out sooner then we will. We're certainly not waiting for the L Prize to be announced."

To a nation mourning 60W bulbs, disappointed by compact fluorescents and confused by tangled labelling schemes, the arrival of a true replacement for incandescents won't come a moment too soon. ■