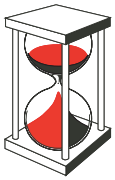

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Mapping knowledge on low energy lamps and health

A report for Megaman® by the Association for the Conservation of Energy

The Association for the Conservation of Energy is a lobbying, campaigning and policy research organisation, and has worked in the field of energy efficiency since 1981. Our policy research is funded independently, and is focused on three key themes: policies and programmes to encourage increased energy efficiency; the environmental, social and economic benefits of increased energy efficiency; and organisational roles in the process of implementing energy efficiency policy.

Contents

1) Introduction

The energy and carbon savings that can accrue by replacing incandescent lamps with low energy lighting have led governments to push for their installation. In the UK, this started through the inclusion of compact fluorescent lamps (CFLs) in the Supplier Obligation, resulting in the delivery of over 260 million lamps to households under EEC1, EEC2 and the first three quarters of CERT. This has been strongly reinforced by a voluntary agreement between Government and major retailers to implement a stepped phase-out of all incandescent lamps by not replenishing stocks. It began in 2008 with lamps over 100W; greater than 60W lamps will not be replenished from 2009, greater than 40W from 2010, and the agreement will extend to all incandescent lamps by 2011 (EST, 2009). An EU-wide ban on incandescent lamps is likely to begin in 2012 (Europa, 2008).

Such policies have placed considerable attention on CFLs, which, in the short term at the very least, will be the successors to incandescent lamps. Such attention has concentrated both academic and interested minds on the subject and resulted in a flurry of reports and accounts, both expert and non-expert, which link the use of CFLs to potential health issues. The evidence base to support and refute such claims is continually growing.

Two other low energy lamps, metal halides and light emitting diodes (LEDs), are receiving far less academic and media attention, since, in the case of the former, the lamps are unlikely to be used in a domestic setting thus reducing public concern, and in the case of the latter, because the technology is not yet widely commercially available at competitive prices.

This study reviews the current literature and maps the existing knowledge on the links between these three types of low energy lamps and health, in order to establish the level of understanding and illustrate the broad areas where further research may be considered.

2) Methodology

2.a) Scope

This study comprises of a literature review and subsequent assessment to identify the status of data, evidence, thought, understanding and perception surrounding the relationship between three types of low energy lamp (CFLs, LEDs, and metal halides) and health. The whole spectrum of evidence is included from academic to anecdotal sources.

Only health issues associated with the point of use, not during the manufacture or transport of the lamps, are included. Where the risk to health is posed by a chemical hazard (e.g. mercury), the potential health implications associated with this chemical have not been documented as these are adequately covered elsewhere.

The study has concentrated its focus on sources from the UK (particularly for anecdotal sources) and Europe but has also included useful references from other countries that have undertaken a phase-out of incandescent bulbs (in particular Australia, Switzerland, Canada).

2.b) Approach

The team used a strategic approach to develop knowledge and cover the material. First, a briefing on lamp technology and study of technical material was undertaken to develop an understanding of the lamps in question.

The literature review began with the most recent major studies in this field: a review from the European Commission's 'Scientific Committee on Emerging and Newly Identified Health Risks' on Light Sensitivity (SCENIHR, 2008), and a Health Protection Agency (HPA) study entitled 'Optical Radiation Emissions from Compact Fluorescent Lamps' (Khazova and O'Hagan, 2008). These studies presented an overview of some of the key issues and provided a starting point for further investigation.

References within these two studies were followed in order to probe deeper into the reviewed material. Then key references within these secondary papers were also followed up, providing a fuller picture of the issues surrounding health and lamps. References to medical or technical studies were also sourced from health sufferers' organisations via websites and research pages, and from studies carried out in other countries that have phased out incandescent lamps. The team also contacted lighting specialists within the Department for Environment Food and Rural Affairs (Defra) and the Department of Health (DH) to determine their current areas of activity.

The academic papers reviewed fall into both technical and medical categories, with medical papers including both provocation studies (*in vivo* as well as *in vitro*) and epidemiological studies. Technical or medical papers on fluorescent light written before the 1990s have largely not been included unless in special circumstances. This decision was made in order to avoid

including too many studies that focus on older style fluorescent lamps, which use a different technology to that used in modern CFLs.

Following the detailed study of the academic literature, the team reviewed less formal sources of information. Charities and organisations associated with each of the health issues identified were reviewed for their own research and position statements. A list of these organisations has been included in Appendix 2. From this exercise it has been possible to gauge which organisations are most active on the issues (a possible indicator of strength of feeling) and where organisations representing the same sufferers differ in opinion on low energy lamps.

Google searches were used to locate media articles, blogs and forums that comment on the relationship between health issues and low energy lamps. Where more formal sources were quoted, they were followed and their validity assessed.

All relevant references and sources identified have been entered into a database that is presented as a supplement to this report.

2.c) Typology

The team considered three alternatives for categorising the health issues found in the review: listing the health issues by lamp type (CFL, LED or metal halide); listing the health issues by the lamp property to which they have been linked, or listing the health issues by source type (academic study, media article, blog etc).

The early literature review found that the vast majority of health issues are linked to a specific property of a lamp. Therefore to categorise health impacts by technical lamp property was the natural choice (section 3.a). In the next section, this categorisation was then reversed, with each health issue presented in association with the technical property or properties with which it has been associated (section 3.b).

A large number of health issues have been identified (along with a much smaller number of potential health benefits). In order to give some structure to this list and prioritise issues, the health issues been grouped according to the number and range of sources that refer to the issue. Three groups have been created – from Group 1 which contains commonly and academically referenced health issues, to Group 3 which contains health issues only documented in anecdotal sources. These groupings highlight the degree of prominence an issue holds in the literature and anecdotal sources: they do not reflect an analysis of the significance of the link between lamp property and health, nor represent an analysis of health risk. No attempt has been made to comment on the significance of a particular health issue.

Group 1: Commonly referenced. Health issues referenced by more than one expert (medical or technical expert) source and less formal sources. For conditions that have very low prevalence, fewer sources are required for inclusion into this group to reflect the condition's lower priority in both academic and popular fora.

Group 2: Less commonly referenced. Included in this group are health issues or conditions that are referenced by one expert source, with or without less formal sources.

Group 3: Anecdotal. Health issues in this group have only been referenced by non-expert sources. Conditions referred to by health sufferers' organisations have been included here if no expert information is used in reference.

3) Findings

The narratives below collate and summarise the findings of the literature review.

From the initial mapping of information, five technical lamp properties emerged through frequent reference. These are common to one or all of the three lamp types in the study. The first section in this chapter (3.a) presents references and sources on each of these five technical lamp properties. The focus in these technical property sections is on presenting informed sources and the risk factors identified are outlined and areas of consensus or disagreement are highlighted.

A summary of the health issues that have been associated with each technical property is then presented using the three groupings outlined in the methodology (section 2.c). This section of findings (3.b) first presents a summary of the sources that make reference to the health issues and symptoms that fall into Group 1 (Commonly referenced health issues); second, it presents shorter summaries of the health issues that have been less frequently referenced (Group 2) or only anecdotally referenced (Group 3).

The main focus of this review has been on the potential health risks associated with the three lamp types but a smaller number of potential health benefits have also been identified. Section 3.c) outlines the potential health benefits, almost exclusively associated with LEDs.

It is not within the remit of this study to provide conclusions on the relative risk posed to health by the technical properties or lamp type. ACE does not have the medical expertise to assess the relative significance of these findings. Instead the references and sources collated serve to give an indication of the prominence of each issue in academic and public spheres.

Appendix 3 contains a visual illustration of the links that have been made in the sources reviewed between technical lamp properties and health issues.

Appendix 4 contains tables of all sources and references reviewed, presented by technical lamp property and by health issue. Citations in the text of this report refer to references in these tables and the accompanying database. Footnotes are also included in the text of this report. These make note of references that are not included in the tables as they contain supporting material that is not directly relevant to the connection between low energy lamps and health (e.g. prevalence data).

3.a) Technical property

The five technical lamp properties identified in the review – electromagnetic fields, flicker, light spectrum, mercury and UV – their risk elements and their associated health issues, are identified and summarised below. Fuller accounts of the evidence on each of the health issues can be found in section 3.b).

By far the greatest number of sources found concentrate on CFLs, due perhaps to the mainstream presence in the domestic market that LEDs have not yet achieved and in which metal halides are not promoted. Where specific reference has been found to LEDs or metal halides it has been noted.

(i) Electromagnetic fields (EMF)

CFLs emit electric and magnetic fields in two ranges: 0-300Hz (50 Hz and harmonics thereof, e.g. 150 Hz, 250 Hz etc in Europe), and in the range of 30-60 kHz (SCENIHR, 2008). Zero to 300Hz is commonly known as the Extremely Low Frequency (ELF) range and fields within it are emitted by CFLs and incandescent lamps alike (BFE, 2004; SCENIHR, 2008). The higher range, 30-60kHz, is rather inconsistently referred to in the reviewed sources as High Frequency (HF) (SCENIHR, 2008), Intermediate Frequency (IF) (SCENIHR, 2007) and Radio Frequency (RF) (BFE, 2004) which gives an indication of the lack of clarity and consistency around this issue in the reviewed material. We refer to this as the 'high range'. This higher range is not emitted by incandescent lamps. There is some evidence to suggest that different types of CFLs produce different frequency fields (SCENIHR, 2008).

Relatively little attention has been focused on EMF from lamps, the issue being dwarfed by concerns about mobile phone base stations (see for example the work of the Electromagnetics and Health Research Team at the University of Essex), overhead power lines and to a lesser extent visual display units (VDUs). It is of note that interest in, and concern around, EMF varies across different European countries. Concern appears particularly strong in Sweden (Irvine, 2005), France (personal communication Steven Mills, 2nd March 2009 and the work of CRIIREM[1]) and Switzerland (Roosli, 2004).

From the few studies that have looked at CFLs and EMF, there is some consensus that CFLs emit stronger EMF than incandescent lamps (EMF Solutions, no date; BFE, 2004; SAEFL, 2005; Havas, 2008). However, two Swiss studies referenced (BFE, 2004; SAEFL, 2005) conclude that fields and frequencies from lamps are not a cause for concern. The Swiss Federal Office for Energy (BFE, 2004) found that magnetic fields from CFLs in the low EMF range were weaker than those from incandescent lamps, and in the high EMF range were also very weak and within Swiss guideline levels. Electric fields in the low EMF range, though slightly stronger than those from incandescents, were found to be weak compared to other household appliances, and fields in the high EMF range were also found to be well within Swiss guideline levels. The Swiss Agency for the Environment, Forests and Landscape (2005) also confirmed that although the magnetic fields emitted by low energy lamps are stronger than those of incandescent lamps, they disappear at a distance of around 50cm.

It should be noted that the International Commission on Non-Ionizing Radiation Protection (ICNIRP) guidelines for limiting exposure to EMF (up to 300GHz) have been criticised as inadequate by a range of academics and health sufferers' organisations (Maisch Wollongong University, no date; Cherry, 1999; BioInitiative Working Group, 2007; Cech *et al*, 2007; Right to Light, 2008; Response to SCENIHR from various authors, 2008; and list of appeals in Havas,

[1] http://criirem.ouvaton.org/

2008). Some countries have developed strict national guidelines for EMF, for example the Swedish guidelines on VDUs[2] that have also been taken up in Switzerland.

An offshoot from EMF is the issue of 'dirty electricity' which is defined by its main proponent – Magda Havas of Trent University, Ontario, Canada – as "*electromagnetic energy that flows along a conductor and deviates from a pure 60-Hz sine wave. It is generated by electronic equipment such as computers, plasma televisions, energy efficient appliances, dimmer switches...as well as arcing on electrical conductors*" (Havas, 2008). Havas' work is largely the only body of evidence relating to this issue. The work links 'dirty electricity' to a very wide range of ill-effects including asthma, diabetes, Multiple Sclerosis, tinnitus, migraine, skin irritations, joint pain, sleep problems, dizziness, fatigue, headaches and eye strain, nausea and cancer.

Many of the symptoms Havas refers to are consistent with those collectively referred to as symptoms of electromagnetic hypersensitivity (EHS) (see health issue section 3.b)(i)E). A few studies have shown a link between EHS and EMF (Rea, 1991) or identified physical differences in EHS sufferers that might indicate a vulnerability (Johansson, 2006; Langrebe *et al*, 2008), whilst others have been unable to show causality (review of studies in Rubin *et al*, 2005). A number of studies present self-identified links made by sufferers between their symptoms and lighting (Granlund-Lind and Lind, 2004; Roosli *et al*, 2004; Irvine, 2005).

No sources were found making reference to the relationship between EMF and either metal halides or LEDs, though electric and magnetic fields will be generated by the use of either of these lamps. As such, an impact on health from these lamps cannot be ruled out.

Conclusions

- Relatively little attention has been focussed on EMF from lamps, the issue being dwarfed by concerns about mobile phone base stations and overhead power lines
- There is very little available informed research on the effect of the electromagnetic fields produced by CFLs and even less that considers the long term effects of exposure
- No references could be found to the relationship between EMF and either metal halides or LEDs, though an impact on health cannot be ruled out.
- The available studies indicate that the frequencies and intensities of fields emitted by the CFLs tested are not above those emitted by household appliances.
- There is concern around the issue of EMF generally as is indicated by the call from a range of sources for a revision of the international protection guidelines.
- There is a fairly large body of self-reported evidence that links CFLs to the still ill-defined and ill-understood condition of electromagnetic hypersensitivity (EHS).
- Very few sources of evidence that we would consider popular or purely anecdotal were found on EMF. There are few press references from the UK and the issue of EMF and lighting does not appear frequently in blogs (though it should be noted that there

[2] Swedish Confederation for professional employees
http://www.tco.se/Templates/Page2___2319.aspx

is a lobbying body[3]). This is perhaps an indication that, unlike in countries such as Sweden, Switzerland, France and to some extent Canada, EMF is not an issue of popular concern in the UK.

Associated health issues

Group 1:

Commonly referenced health issues

- Electromagnetic hypersensitivity (EHS) encompassing a range of symptoms, most commonly skin reactions and systemic disturbances, such as to the nervous system
- Cancer

Group 2:

Less commonly referenced health issues

- Miscarriage
- Diabetes
- Multiple Sclerosis
- Asthma
- Migraine
- Alzheimer's

Less commonly referenced symptoms

- Sleep problems
- Headaches, eye strain
- Fatigue and confusion
- Nausea
- Dizziness and ringing in the ears
- Joint pain
- Behavioural changes

(ii) Flicker

Two ranges of modulation are distinguished in the academic studies on the issue of flicker: low-frequency luminous modulation (~100 – 120 Hz) from the operation of fluorescent lamps on magnetic ballasts; and high-frequency operation, with an operating frequency in the order of 40 kHz when electronic ballasts are used (Veitch, 2006).

There is a body of older work that notes the effect of flicker at the lower end of the range (from 50-120 Hz) produced by old style fluorescent strips. These references have largely been excluded from this study to avoid confusion between old fluorescent and new CFLs, which generally have electronic ballasts and are modulated in the higher frequency range. There is

[3] www.powerwatch.org.uk

some consensus that the higher frequency flicker (around 20 – 60 kHz) produced by electronic ballasts does not pose a risk (e.g. Veitch and McColl, 1995; Kasteleijn-Nolst *et al*, 2004; Goldsworthy, 2008; Australian Department of the Environment, Water, Heritage and the Arts, 2008; Migraine Trust, 2008).

However, the recent HPA study (Khazova and O'Hagan, 2008) found that a significant proportion of CFLs that they tested exhibited flicker in the lower range at around 100Hz. This undermines the assumption that modern CFLs are all modulated on the higher frequency range, thus not posing a risk. The study reports that "whilst a 100 Hz flicker will not be perceptible to most people, some will be aware of it if the light is in the periphery of their vision" (Khazova and O'Hagan, 2008).

Academic studies have found negative health impacts associated with flicker in this lower range relating to, amongst others, visual performance (Veitch and McColl, 1995), eye strain and headache (Wilkins *et al*, 1991), autism (Gluskin *et al*, 2006) and epilepsy (Kasteleijn-Nolst *et al*, 2004). A proven negative reaction in epileptics has been found at the relatively low frequencies of >3Hz (Harding *et al*, 2005), 15-18Hz (Hughes, 2008), 8-30Hz (Australian Department for the Environment, Water, Heritage and the Arts, 2008) and in some cases at 50Hz (Binnie *et al*, 1979). These studies are supported by a number of anecdotal reports of ill-effects of the 'imperceptible flicker' of CFLs (see relevant health issue sections for anecdotal references).

Many of the health issues associated with lamp flicker are characterised by the abnormal sensory profile of the sufferer, which means that they respond to flicker in different ways to the general population. For example, Evans *et al* (1994) and Ben-Yehudah *et al* (2001) found that dyslexics show impaired flicker detection, whilst Gluskin *et al* (2006) found that 50% of autistics are sensitive to flicker of fluorescent lights due to impaired ability to filter out 'brain noise', and Kowacs *et al* (2004) make reference to an abnormal flicker fusion threshold described in migraineurs. The extent to which the stimulus response differs from the general population is not constant amongst all sufferers. For example Ridder *et al* (1997) found that not all dyslexic groups respond in the same way to flicker stimulus.

Although generally the eye cannot see flicker above ca 50Hz (Seitz *et al* 2006), some studies have shown that the normal eye or brain responds to flicker at frequencies much higher than those that are visible to the general population. For example, Bergman *et al* (1991) recorded visual pathway responses to flicker at up to 145Hz. The indication here is that the effect of flicker at 'imperceptible' frequencies of around 100Hz and above is not fully understood, both for those with particular sensitivity to stimulus and for those with 'normal' sensory profiles. Until more is known, particularly about abnormal sensory profiles, it is difficult to rule out the effect of flicker in the lower frequency ranges. Similarly, more information is required about the extent to which currently available CFLs flicker in these lower ranges.

It should be reiterated that studies have not illustrated ill-effects at the higher range (~40 kHz).

We have found no sources that relate flicker produced by metal halides to health issues. However, metal halides feature similar properties to CFLs: older versions with magnetic ballasts operate at around 60Hz, newer lamps at much higher frequencies. Therefore it is possible that older metal halide lamps can be connected to health issues.

Conclusions

- The frequency produced by an electronic ballast CFL is widely accepted to not cause ill-effects.
- Studies reveal a wide range of different frequencies produced by lamps currently on the market. This makes it impossible to rule out any negative effects from flicker in CFLs and may cause confusion and mistrust amongst those who are sensitive to flicker.
- Some health sufferers have abnormal sensory profiles which make them more or less sensitive to flicker of different frequencies (evidence only in the Hz range, not in kHz or above). Until more is understood about these different sensory profiles, risk to these groups cannot be ruled out.
- Health problems have not been associated with flicker in metal halide lamps. However, older lamps that use magnetic ballast operate at a frequency that some studies on CFLs or fluorescents have found problematic.

Associated health issues

Group 1:

Commonly referenced health issues

- Epilepsy
- Migraine
- Autism
- Irlen Syndrome (perceptual problems and forms of dyslexia)

Group 2:

Less commonly referenced health issues

- Conditions affecting balance (Vestibular Disorder and Ménière's Disease),
- Retinal diseases linked to HIV/Aids

Less commonly referenced symptoms

- Headache /eye strain
- Visual performance

Group 3:

Anecdotal health issues

- Hyperactivity
- Irritability
- Accidents and misjudgements

(iii) Visible light spectrum

Concerns around the visible spectrum of light emitted by lamps fall into two main areas: first, concerns around the colour temperature of the light (with a low temperature indicating warm or red light and a high temperature indicating a cold or blue light); second, concerns about the colour rendering index of the light which affects visual performance and the way in which colours are perceived. CFLs and LEDs are the most commonly referenced lamp types when looking at light spectrum.

The recent HPA study (Khazova and O'Hagan, 2008) into 73 CFLs currently on the market found that all of the lamps emitted light in just a few narrow peaks within the visible spectral range rather than light evenly distributed throughout the range. It notes that very low or negligible emissions were found in the parts of the range between the peaks. The HPA deduce that this may result in distorted colour perception of an environment. The low or negligible emissions in such large parts of the spectral range could also result in the need for an increase in brightness of a CFL to perform a visual task compared to an incandescent.

The spectral property of light has been connected to different pre-existing health conditions ranging from those affecting the autoimmune system (Lupus [Sarkaney, 2008]) to skin conditions (Eczema [Sarkaney, 2008]), neurological syndromes (Migraine [Maine *et al*, 2002; Migraine Trust, 2008; Right to Light, 2008]), and forms of dementia (Alzheimer's [South Illinois University, 2005]).

Most commonly, the blue part of the spectrum is named as being the most problematic in connection with CFLs (though this could conceivably be expanded to other lamp types), particularly for sufferers of Lupus (ELCF, 07), cutaneous porphyrias (SCENIHR, 2008), Irlen Syndrome (SCENIHR, 2008), retina damage (Sarna *et al*, 2003), and anecdotally for Asperger's Disease sufferers (Patricia, 2009).

Whilst all other conditions named here are pre-existing conditions which may be negatively influenced by parts of the light spectrum, retinal damage is reported to be directly caused by exposure to blue light, though only at very high intensities (Rózanowska *et al*, 1995 and 1998; Sarna *et al*, 2003; Okuno *et al*, 2002).

For this technical property there is also a body of evidence that looks at the benefits of light. Light therapy is an area of research that provides references related to light spectrum. Whilst, as mentioned above, SCENIHR (2008) found the blue part of the spectrum to be problematic, high temperature light 'with a bluish tint' is used in 'bright light therapy' (see references in Sloane *et al*, 2008) indicating that the blue part of the visible light spectrum might offer some potential health benefits insofar as it has been deemed to be effective in suppressing melatonin secretion. Melatonin is the hormone that regulates the human circadian system and thus may be effective in regulating sleep/wake patterns (Sloane *et al*, 2008 and references therein). Studies investigate the use of light therapy for a number of conditions including

seasonal affective disorder (Thalén *et al*, 1995), depression (Tuunainen *et al*, 2004) and sleep patterns, especially in Alzheimer's or Dementia sufferers (Figueiro, 2008; Forbes *et al*, 2004).

At the other end of the visible light spectrum – near-infrared red light – other effects on the human physiology have been asserted and/or observed. LEDs are particularly relevant and frequently used or cited in this sphere, as they are able to deliver this part of the light spectrum at lower temperatures than other lamps (Sloane *et al*, 2008). Most of the assertions are based on laboratory observations that near-infrared light gives a brief boost to cellular mitochondrial activity, an as yet poorly understood process. The inference is that this supports cellular regeneration, with numerous subsequent assertions made. For example, studies make connections between near infra-red light (particularly from LEDs) and the treatment of non-malignant skin melanomas (Smith *et al*, 2008), reduced risk of skin erythema (Barolet and Boucher, 2008), reduction of skin wrinkles (Sommer and Zhu, 2008; University of Sunderland, 2005), healing of wounds (Eells *et al*, 2004) and the reversal of dementia (University of Sunderland, 2008).

Conclusions

- Light spectrum is the technical property in this review found to be connected to the greatest number and widest range of health issues (see Appendix 3 for a summary map illustrating this).
- Knowledge on the effects of incomplete spectrum of lighting (or non-full spectrum lighting) and on the effect of particular ranges of the light spectrum is incomplete.
- Most commonly the blue part of the spectrum from CFLs has been connected with health issues
- Particular ranges in the spectrum have been connected with both positive and negative effects on health, depending on application and/or pre-existing conditions; blue light in particular has been connected with negative effects.

Associated health issues

Group 1:

Commonly referenced health issues

- Retina damage
- Migraine
- Lupus
- Alzheimer's (designing for / improving sleep)
- Skin erythema (risk reduction)
- Skin ageing (reduction)

Group 2:

Less commonly referenced health issues

- Photosensitive skin conditions (cutaneous porphyria and eczema)

Group 3:

Anecdotal health issues

- Autism
- Asperger's
- Irlen Syndrome
- Alzheimer's (treatment)

(iv) Mercury

The EU Reduction of Hazardous Substances Directive (2002/95/EC) allows for the use of mercury in lamps not exceeding 5mg per lamp (European Lamp Companies Federation, 2007).

Popular concern over the mercury content of lamps is evident from a variety of sources including press (The Week, 2009; Booker, 2009; Derbyshire, 2009a; Tomkins, 2008; Stretton, 2009; Hanlon, 2009), blogs ('Ellie', 2009 and 'Gwyn', 2009, *Layman.org.uk*, no date; 'Helen', 2009; 'Daz', 2009; 'June E Kiger', 2009; 'Carol', 2009) and at least one Member of Parliament (Heathcoat-Amory, 2009). Generally there are more informal, press, or anecdotal sources concerned with mercury than informed ones.

The two main issues emerging from the review around mercury are: localised effects of mercury release through lamp breakage in the home, and the effect of mercury release on the global environment.

On localised pollution, sources from two Governments that have already put in place an incandescent phase-out (USAid, 2008; Australian Department for the Environment, Water, Heritage and the Arts, 2009), as well as the UK's Energy Saving Trust (EST) and Department for Environment, Food and Rural Affairs (Defra), all confirm that if disposed of correctly by recycling, handled with care, and cleaned appropriately when breakages occur, then CFLs pose no risk to public health.

A study of mercury levels in the home during and after the cleanup of broken CFLs, and using various cleaning methods, has been widely referenced (Maine Department for Environmental Protection, 2008). This study found that mercury concentration in the air often exceeded the Maine Air Ambient Guidelines for a period of time after the breakage of one lamp. However, it found that a short period of ventilation can reduce these levels and that Maine's cleanup guidelines are generally sound – guidelines that were slightly amended as a result of the study, and which the UK's clean up guidelines (Defra, 2008) are in line with. The neutral to positive conclusions of this study have been reported in popular sources in a more negative light (*Consumercidal Happenings*, 2008; Adamkiewicz, 2008).

On global pollution, there is a general consensus in the informed sources that mercury released into the environment is higher with the widespread use of incandescent lamps than CFLs. This is because of the electricity generation that is displaced by CFLs. Electricity generated from coal releases mercury into the atmosphere, and the generation of extra

electricity required to run an incandescent lamp over its lifetime results in a greater release of mercury than through the domestic use of CFLs (European Lamp Companies Federation, 2007; MEP Peter Liese, 2009; Defra, 2008; Australian Department for the Environment, Water, Heritage and the Arts, 2009).

The University of Yale have recently published a set of calculations which give a less conclusive answer. They modelled energy generation, chemical makeup of fuel, and recycling schemes for 130 countries and confirm that mercury release is higher for incandescent use when electricity generation is coal-based (Eckelman *et al*, 2008). However, this does mean that areas of the world where coal is not the dominant source of electricity generation – including much of South America, Africa, the Middle East, parts of Europe, and some US states – have the potential to increase their mercury emissions through the widespread use of CFLs. We should note that this calculation does not assume total recycling of CFLs that is common in Europe and available in every local authority in the UK.

Metal halide lamps also contain mercury but in much greater quantities than CFLs, ranging from 20mg in a 75 Watt lamp to 250 mg in a 1500 Watt lamp (Purdue University, 2003). However, this review has not found any press or anecdotal sources that document the risks for mercury exposure from metal halide lamps. This perhaps is not surprising – metal halides are not generally designed for domestic lighting (though they are used by some in fish tanks) and hence the public may not be as concerned about mercury exposure.

Conclusions

- There is clear popular concern over the mercury content of CFLs, though no references were found to link metal halides (that also contain mercury) to exposure issues
- The informed sources reviewed do not consider that mercury release from CFL breakage in the home will cause health risks if clean up guidelines are followed
- Attention has been placed by both informed and informal sources on the importance of following cleanup guidelines and recycling lamps at the end of their life.

Associated health issues

Health issues related to mercury exposure were not in the remit of this study.

(v) Ultraviolet (UV) light

The issue of UV light from CFLs is summarised by Khazova and O'Hagan (2008): "CFLs generate ultraviolet radiation (UVR) from a discharge in mercury vapour. The energy in the ultraviolet photons is converted into visible optical radiation in the phosphor coating inside the glass envelope of the lamp. Ideally, the conversion would be 100% efficient. However, in reality, some UVR is transmitted through defects in the phosphor coating and the glass envelope."

UV radiation is divided into three bands: 315 to 380–400 nm is UV-A, 280 to 315 nm is UV-B, and 100 to 280 nm is UV-C. Wavelengths below 180 nm are of little practical biological significance since they are readily absorbed in air (ICNIRP, 2004).

Recent studies indicate that CFLs emit UV at levels and in ranges that could pose a risk to the general population (Khazova and O'Hagan, 2008; Sayre *et al*, 2004). The HPA study (Khazova and O'Hagan, 2008) provides the most up to date and thorough investigation of the optical radiation emissions of CFLs currently on the market (73 tested). It found that single envelope CFLs emit UV-B, and traces of UV-C at a wavelength of 254nm while double envelope CFLs emit only a low level of UV-B. This finding is confirmed by Sayre *et al* (2004) who noted wavelengths emitted as short as 280nm.

The HPA study also found that 20% of lamps exceeded the ICNIRP UV radiation exposure guidelines at close proximity (2cm) in ten minutes, whilst half exceeded guidelines at the same distance in 30 minutes. At a larger distance of 20cm, eight per cent of lamps tested exceeded exposure guidelines after eight hours. Therefore, precautionary advice was issued for the general population on close proximity to CFLs.

ICNIRP guidelines give limits for exposure to the skin and eyes but the ICNIRP notes that, since CFLs are too bright to comfortably stare at, the main risk is to the skin. The guidelines outline that "the exposure limit for skin is conservative for the general population and, if it is exceeded, the immediate risk is for skin reddening, similar to sunburn" (ICNIRP, 2004). The connection with skin reactions or skin damage has been variously made elsewhere (Sayre *et al*, 2004; Freeman, 2008; Khazova and O'Hagan, 2008; Havas, 2008; Stretton, 2009).

The ICNIRP (2004) warn of "a small increased risk of skin cancer associated with [the skin reaction]". The SCENIHR (2008) confirm the risk to the general population from cancer and DNA damage associated with UV emissions in the range emitted by CFLs (SCENIHR, 2008).

Aside from the risk to the general population identified, there is also evidence of a connection between UV from CFLs and a large number of light sensitive conditions, mainly photodermatoses (Polymorphous Light Eruption, Idiopathic Solar Uticaria, Chronic Actinic Dermatosis, Actinic Prurigo, Xeroderma Pigmentosum (XP), Cutaneous Pophyria and photosensitive Eczema), but also Lupus and Irlen Syndrome. Many of these conditions have quite low prevalence (apart from Polymorphous Light Eruption) but associations with much more common conditions like eczema have also been made (see section on relevant health issues for references).

A review by the Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR, 2008) indicates that "the use of double skin CFLs or similar technology would largely or entirely mitigate the risk of approaching workplace limits...and the risk of aggravating the symptoms of light-sensitive individuals." However, this finding has been challenged (Response to SCENIHR from various authors, 2008) and there is evidence to suggest that some light sensitive diseases can be triggered by emissions in the UV-B range that is emitted by double-skinned lamps (e.g. Mastalier *et al*, 1998, on PLE; SCENIHR, 2008, on Chronic Actinic Dermatosis and XP; Lehmann *et al*, 1990, and Rihner and McGrath, 1992, on Lupus).

UV exposure from metal halide lamps has also received wide coverage. UVR is emitted by metal halide lamps alongside visible light from an inner arc tube. When the outer shell of a metal halide lamp is damaged, older lamps continue to function but do not protect against UV exposure. Since metal halide lamps have often been installed in school gymnasiums, there have been several reports of large numbers suffering from UV exposure due to damaged metal halide lamps (*News Review Today*, 2005; Silverman, 2007). Exposure in these cases has led to Photokeratitis (Kirschke *et al*, 2004).

As a result of these occurrences, the US Food and Drug Administration (US FDA) issued guidance to schools in the US on the use of metal halide lamps. They recommended that schools replace all non-self-extinguishing type metal halide lamps with newer self-extinguishing products that switch off if the outer shell is broken to prevent UVR exposure (US FDA, 2006).

Conclusions

- The HPA study indicates that there is a range of different CFLs currently available that emit UV in different bands and intensities. This lack of homogeneity could cause confusion and uncertainty for those concerned about UV exposure or who are light sensitive.
- UV emissions from many of the CFLs available exceed the INCIRP's "conservative" guidelines.
- There are health risks associated with UV emissions from CFLs for both the general population (at close proximity) and light sensitive disease sufferers.
- Double skinned CFLs may mitigate some of the risk for the general population but many light sensitive disease sufferers may still be at risk.
- UVR is also produced by metal halide lamps, with older varieties continuing to emit UVR once the outer shell is damaged, risking exposure.

Associated health issues

Group 1:

Commonly referenced health issues

- Lupus
- XP
- Photosensitive eczema
- Idiopathic photodermatoses: PLE, Idiopathic Solar Uticaria, Chronic actinic Dermatosis, Actinic Prurigo
- Skin damage
- Photokeratitis

Group 2:

Less commonly referenced health issues

- Cutaneous Porphyria
- Cancer
- Irlen Syndrome

(vi) Other

It is accepted in the literature that a small number of metal halide lamps can rupture and explode at the end of their life (National Electrical Manufacturers Association, 2004). This occurs in lamps with a quartz arc tube, where the arc tube wall is weakened due to heat and vibration. Under high pressure from within (90 psi), the arc tube can crack, and if this occurs at full wattage and pressure the tube may shatter (Houghton, no date).

Responding to this risk, the US National Electrical Code was updated in 2005 to only allow metal halides to be installed if they are enclosed, or of the 'O' type and feature an additional outer shell to capture falling glass (National Electrical Code, 2005).

Associated health issues

Health issues related to falling glass as a result of metal halide rupture were not in the remit of this study.

3.b) Potential Health Risks

The health issues described below have been grouped into three clusters, based on the frequency and the source of references, as outlined in the methodology. Within these groupings the health issues have been listed alphabetically, not in order of any significance. For most conditions, a connection has been made with one or more technical lamp properties. The majority of health issues covered are pre-existing conditions that are reportedly exacerbated by a technical property of a lamp type, but where a health risk is potentially caused by a light property this has been highlighted.

For health issues in Group 1 (section 3.b (i)) each chapter begins with a summary indicating the lamp types and technical lamp properties with which it has been associated. Where a technical issue appears in brackets, the association is reported in only one less formal source. This summary also gives an indication of the health issues' prevalence (in the UK where possible).

(i) Group 1: Commonly referenced issues

These are health issues that have been referenced by both expert (medical or technical) *and* less formal sources. For issues that have very low prevalence, fewer sources are required for a health issue to be included in this group since the health issue is likely to be of lower priority in both academic and popular fora.

(i)A Autism

Linked to lamp property/properties: Flicker, (light spectrum)
Linked to lamp type(s): CFLs
Prevalence: 0.2% of population[4]

Pre-1990 studies have established a tentative link between increased repetitive behaviours in children with autism, and exposure to fluorescent light (modulated at around 60Hz) in comparison to incandescent lighting (Colman *et al*, 1976; Fenton and Penney, 1985). Gluskin *et al* (2006) have brought this body of research up to date with a theory that the high incidence of sensitivity to fluorescent light in autistic people (50%) is due to the 100Hz flicker of fluorescent lamps being the same frequency as the frequency of the micro saccades (eye muscle tremor). (A recent UK Health Protection Agency study (2008) found that a significant percentage of modern CFLs tested flicker in the 100Hz range.) Gluskin *et al* claim that normal brains can adjust to this coincidence but autistics cannot filter out the 'brain noise'. The abnormal sensory profile is a common characteristic of health issues that are negatively affected by flicker – Casanova (2008) for example links migraine and autism by common sensory overstimulation. The lack of understanding of these sensory differences indicates that a negative effect of stimulation on these groups of health sufferers cannot be ruled out.

[4] http://www.orpha.net/consor/cgi-bin/Disease_Search.php?lng=EN&data_id=312&Disease_Disease_Search_diseaseGroup=autism&Disease_Disease_Search_diseaseType=Pat&Disease(s)%20concerned=Autism&title=Autism&search=Disease_Search_Simple

The health sufferers' coalition, *Right to Light*, report (2008) that the National Autistic Society have received complaints from carers that significant aggravation of health and behavioural symptoms have occurred with use of CFL lighting. This is a concern that has been picked up by MEP John Bowis and reported in the online press (*EurActiv*, 2008 and 2009).

Anecdotally, the spectrum of light emitted by CFLs has also been connected to Autism and the related condition Asperger's Disease (Patricia, 2009).

(i)B Cancer

Linked to lamp property/properties: Electromagnetic field and UV
Linked to lamp type(s): CFLs, metal halide
Prevalence: N/A

Cancer has been connected in the evidence to both the UV emitted by light (skin cancer) and the electromagnetic fields emitted by lamps (multiple cancers). It should be noted that whilst the majority of health issues identified in this study are ***pre-existing*** (that is they are claimed in the sources reviewed to be aggravated or have symptoms induced by exposure to a technical lamp property), the risk has been identified that cancer may be ***caused*** by one or more of the technical properties of low energy lamps.

The SCENIHR (2008) review confirms that UV radiation is a major environmental risk factor for skin cancers. It notes that the UV-B and UV-C ranges are especially effective in damaging DNA, and in causing gene mutations and cancerous formation of cells. The HPA in the UK recently carried out tests on 73 currently available CFLs and found that single skin models emit UV in both the B and C ranges, with double skinned models emitting in the UV-B range (Khazova and O'Hagan, 2008). The SCENIHR (2008:27) report refers to wavelengths emitted by CFLs in the UV-C range as both "unnecessary and undesirable". It goes on to say, "it is important from a public health viewpoint that the exposure to UV radiation, particularly UV–C is limited".

Given the identified link between UV radiation and skin cancers, there is an issue regarding exposure to damaged metal halide lamps that continue to function once their outer shell is broken. Whilst sources link such UV exposure to skin burns (US FDA, 2006), there is no documented direct causal link between acute exposures such as these and skin cancer (Kirschke *et al*, 2004).

Similarly, there is little direct causal evidence to prove the link between skin cancer and CFL exposure which is partly due to a general lack of evidence on the long term effect of these lamps. Serdlow *et al* (1998) have shown that skin cancer risk was slightly but not significantly raised in those exposed to fluorescent light at home or at work, but other statistically significant studies are few and present problems with illustrating direct causality due to the impact of other environmental or biological factors.

It should be noted that skin cancer is a risk factor associated with photosensitive skin diseases that sources reviewed have linked to low energy lighting (see for example section on Xeroderma Pigmentosum).

Links have also been made between cancer and electromagnetic fields (EMF), though little work has been done on the EMFs emitted by CFLs. A report by the SCENIHR on *The Possible effects of Electromagnetic fields on human health* (2007) concluded that extremely low frequency fields, found to be emitted by CFLs (SCENIHR, 2008), are possibly carcinogenic to humans but resolves that the evidence is not conclusive.

Amongst many inconclusive or un-replicable studies, the report references one successful replication study illustrating that low intensity 60Hz frequency **magnetic** fields (in the extremely low frequency band) inhibit the anti-proliferative effect of an anti-breast cancer drug on a specific sub-clone of human breast cancer cells (Blackman *et al*, 2001; Ishido *et al*, 2001; Girgert *et al*, 2005 all referenced in SCENIHR, 2007), therefore reducing the effectiveness of the drug. CFLs have been found to emit low frequency **magnetic** fields, though these are weak (BFE [Swiss Federal Office for Energy], 2004).

A number of studies have been carried out on cancer rates in communities exposed to strong EMF, for example near mobile phone base stations or under overhead power lines, but as these sources of EMF emit in frequencies that have not been shown to be emitted by CFLs they have not been reviewed here.

Dr Goldsworthy (2008), an academic in the Department of Biological Sciences, Imperial College London, claims that electromagnetic radiation causes the decalcification of cell membranes which leads to cancer and genetic damage. This source does not specify the range of EMF that causes the cell decalcification.

An American study (Milham and Morgan, 2008) of cancer rates in teachers showed a positive correlation between cancer rates in one school and cumulative exposure to high frequency voltage transients, also referred to as 'dirty electricity'. These high frequency voltage transients are caused by an interruption of electrical current flow. The authors name power-saving CFLs as one of the appliances that use power switching and cause an interruption of current flow.

(i)C Chronic Fatigue Syndrome (CFS)/ME

Linked to lamp property/properties: unknown
Linked to lamp type(s): CFL
Prevalence: 0.2 – 2% (Wyller, 2007), 0.41% of UK population[5]

A number of references have been made by both informed and anecdotal sources to the impact of all types of light, particularly fluorescent light, on CFS/ME sufferers. Anecdotal sources make direct connections between CFLs and CFS/ME.

[5] http://www.meassociation.org.uk/content/blogcategory/38/83/

Soderlund *et al* (2000) and Action for ME (2007) confirm that CFS/ME sufferers feel a sensitivity to light. The connection with fluorescent light is made by Professor Pinching (2008), an immunologist, who reports the consistency with which a proportion of CFS patients have adverse experiences in settings lit by fluorescent light. He states that it is not yet clear how widespread these reactions may be to newer types of low energy lamps, and confirms that the relationship with physical properties of the light is unclear.

Pinching's concerns have been taken up by light sensitive coalitions *Right to Light* and SPECTRUM Alliance (2008) and reported in the press (*BBC News*, 2008). Direct connections between CFLs and negative reactions in CFS/ME sufferers have also been reported in blog articles (*Janet Love*, 2008; *Layman.org.uk*, no date).

(i)D Eczema

Linked to lamp property/properties: Light spectrum and UV
Linked to lamp type(s): CFLs
Prevalence: 8% of adults and 20% of children in the UK[6]

Evidence collected by the health sufferers' organisation, *Right to Light*, by two prominent dermatologists (Sarkaney, 2008 and Hawk, 2008) makes the link between eczema and different kinds of fluorescent light. The medical experts cannot be precise about the cause for the negative reactions in eczema sufferers, but make connections with atmospheric ionization, UV and the spikiness of the spectrum of light emitted.

The evidence of these medical experts is supported by references in the press to the effect fluorescent light can have on eczema sufferers (Rosenfeld, 2008; Stretton, 2009) and more specifically the effect of CFLs (*BBC News*, 2008; Freeman, 2008).

(i)E Electromagnetic Hypersensitivity (EHS)

(also termed electrical sensitivity, electromagnetic sensitivity, electrical/ electrohypersensitivity, electrical oversensitivity, electrical hypersensitivity)

Linked to lamp property/properties: Electromagnetic fields
Linked to lamp type(s): CFLs
Prevalence: estimates vary widely[7], European estimated between 1.5-5%[8]

[6] http://www.eczema.org/eczema.html
[7] http://www.who.int/mediacentre/factsheets/fs296/en/index.html
[8] Swedish study found prevalence of 5%.
http://www.springerlink.com/content/q5n731u88v6m1642/
Stockholm population based study found prevalence of 1.5% and more prevalent in women
http://cat.inist.fr/?aModele=afficheN&cpsidt=13478173
An Austrian study showed an EHS prevalence of 3.5%. UK survey 2007 aimed at a randomly selected group of 20,000 people found a prevalence of 4% for symptoms attributed to electromagnetic exposure.
http://www.radiationresearch.org/pdfs/20090224_eileen_eu_presentation_text.pdf

EHS is a condition in which people experience medical symptoms which they believe to be as a result of exposure to electrical fields. EHS is therefore linked exclusively to the electromagnetic field property of a lamp.

The existence of EHS is not universally recognised, nor has causality between exposure to electromagnetic fields and the symptoms thereof been proved. It should be noted however, that concern around this issue is significant even in the absence of proven causality. The Radiation Protection Division of the UK HPA (Irvine, 2005) initiated a review of the literature around EHS from the starting point that EHS needs to be considered in terms other than its aetiology.

It should be noted that studies on EHS and lighting are few compared to research around exposure to mobile phone base stations, overhead power cables and VDUs. Much of the available information on EHS comes from Sweden where this condition is recognised as a functional impairment (Johansson, 2006). A few studies have shown a link between EHS and electromagnetic fields (Rea, 1991) or identified physical differences in EHS sufferers that indicate a vulnerability (Langrebe *et al*, 2008; Johansson, 2006), while others have been unable to show causality (review of studies in Rubin *et al*, 2005).

The difficulties in defining and proving the existence of EHS may be due in part to the wide variety of reported symptoms, differences in trigger sources, the variable time period between exposure and presentation of the symptoms and differences in individual tolerance levels.

Reported symptoms of EHS are many and varied, but can largely be grouped into: skin, and other systematic symptoms. Skin symptoms include redness, burning, itching and forms of dermatitis (see the work of Johansson 2004-2006). Neurological symptoms like headache and fatigue predominate in the second of these groups (accompanied by dizziness, nausea, pain, and concentration difficulties). Irvine (2005) and Roosli *et al* (2004) provide useful lists of reported symptoms.

Links have been made between lighting sources and EHS symptoms (Roosli *et al*, 2004) and between CFLs and EHS symptoms specifically (Irvine, 2005; Grandlund and Lind, 2004; Havas, 2008; Goldsworthy, 2008).

Lighting appears to be of relatively lower significance than other sources of exposure. Roosli *et al* (2004) report on the results of a survey of 430 EHS sufferers in Switzerland. Lighting is identified as a trigger but by less than 10% of respondents, making it a far less significant trigger than, for example, mobile phone base stations, reported by 74% of respondents, and mobile phones, reported by 36%. However, in one survey of electro-sensitive individuals' reaction to different light sources, CFLs were named as second only to fluorescent strips as sources of sensitivity (Havas, 2008).

(i)F Epilepsy

Linked to lamp property/properties: Flicker
Linked to lamp type(s): CFLs
Prevalence: 0.74% of world population[9]; 0.76% of UK population[10]. An estimated 5% of epileptics are light sensitive (Epilepsy Action, 2007)

Photosensitivity in epileptics is scientifically proven (SCENIHR, 2008) and the link to flashing or flickering light has been established (Harding *et al*, 2005). A proven negative reaction in epileptics has been found when exposed to flicker at the relatively low frequencies of >3Hz (Harding *et al*, 2005), 15-18Hz (Hughes, 2008), 8-30Hz (Australian Department for the Environment, Water, Heritage and the Arts, 2008) and in some cases at 50Hz (Binnie *et al*, 1979).

Kasteleijn-Nolst *et al* (2004) suggest that three per cent of epilepsy patients are sensitive to flicker of up to 110Hz though there is evidence to suggest that lamps modulated above this range will not negatively affect epileptics (Binnie *et al*, 1979 and Ricci *et al*, 1998 studies on computer screens). Further work indicates that CFLs with electronic ballast that are modulated at a much higher frequency of 20-60kHz should not pose a risk (Kasteleijn-Nolst *et al*, 2004; Australian Department for the Environment, Water, Heritage and the Arts, 2008).

The findings of the UK HPA study (Khazova and O'Hagan, 2008) into CFLs shows a significant proportion of the 73 lamps tested for flicker in the 100Hz range, and indicate there is some potential for modern CFLs on the market to affect epileptics.

A good deal of anecdotal and press evidence indicates that epilepsy sufferers are adversely affected by CFLs (Derbyshire, 2009; 'David', 2009; *BBC News*, 2008; 'L Hayes', 2009; 'Tim', 2007). In addition, a recent online survey conducted by Epilepsy Action (2007) indicated that four per cent of 174 respondents thought their seizure had been caused by a CFL. Just one respondent reported a seizure brought on by an incandescent lamp.

(i)G Idiopathic Photodermatoses

Linked to lamp property/properties: UV
Linked to lamp type(s): CFLs
Prevalence:

- Polymorphous Light Eruption: European estimate is 10-20% (increasing with distance from the equator and with altitude. It affects two to three times more females than males) (SCENIHR, 2008)
- Chronic Actinic Dermatitis: mainly in males over 50 years old, prevalence in Scotland 0.017% (Dawe, 2008)
- Idiopathic Solar Uticaria: estimated at 0.0031% (Beattie *et al*, 2003)
- Actinic Prurigo: well known in native American populations but rarely seen in Europe and Asia (SCENIHR, 2008)

[9] http://www.who.int/mediacentre/factsheets/fs999/en/index.html
[10] http://www.epilepsysociety.org.uk/AboutEpilepsy/Whatisepilepsy

Photodermatoses are a group of skin conditions in which negative reactions are induced by light. The four reviewed below are all idiopathic, or of unknown mechanism, as opposed to other groups of dermatoses that are induced by drugs or chemicals (not included in this review), are genetically determined (Xeroderma Pigmentosum [XP] is covered by this review), or are in the group known as porphyrias which are conditions, both inherited and environmentally induced, that result as an accumulation of photosensitive porphyrin in the skin (SCENIHR, 2008) (also included in this review).

The four photodermatoses covered below are all idiopathic (of unknown mechanism) but are believed to have an immunological basis (SCENIHR, 2008).

The most prevalent of this group, **Polymorphous Light Eruption (PLE),** has been proven through provocation studies to produce symptoms after exposure to UV light in the UV-A and UV-B ranges (Stratigos *et al*, 2002; Mastalier *et al*, 1998). Both double and single-skinned CFLs recently tested emit UV in the UV-B range (Khazova and O'Hagan, 2008). The recent SCENIHR review (2008) of the literature confirmed that CFLs could provoke an eruption in those severely affected by PLE although it is recognised that data are lacking in this area (Bock *et al*, 2005).

Sources reviewed making reference to **Chronic Actinic Dermatoses (CAD)** are fewer than those for PLE, but the recent SCENIHR (2008) review confirms that photosensitivity in CAD sufferers can be severe and broad extending from the UV-B (emitted by single and double skin CFLs) to the visible range. This review concludes that there may be a problem with CFLs for CAD sufferers.

Beattie *et al* (2003) establish that **Idiopathic Solar Uticaria (ISU)** sufferers are negatively affected by both UV-A and UV-B, with 63% of cases reacting adversely to one or other wavelength. The SCENIHR review indicates that reactions are more UV-A than UV-B dependent but does not exclude the effect of this wavelength. The recent HPA study (Khazova and O'Hagan, 2008) found that both UV-A and UV-B is emitted by double and single skinned CFLs which are currently available.

Actinic Prurigo (AP) is very rare in Europe and Asia, which is perhaps an explanation for the dearth of information available on the disease and its potential response to artificial light. The condition is reported in the SCENIHR review (2008) to react adversely to sunlight and to repetitive UV provocation. It concludes that severe cases may potentially be at risk from CFLs.

(i)H Irlen Syndrome/perceptual problems and Dyslexia

(also known as Irlen Meares or Meares Irlen – linked to dyslexia and Scotopic Syndrome)

Linked to lamp property/properties: Flicker, light spectrum and UV
Linked to lamp type(s): CFLs

Prevalence: Irlen syndrome: 12-15% of UK population[11], rising to 46% of those with dyslexia, attention deficit disorders and learning difficulties (Nandakumar and Leat, 2008).

Irlen Syndrome is a perceptual problem that affects the way the brain processes visual information. It is not an optical problem. For those with Irlen Syndrome, the brain is unable to process full spectral light. This results in a range of distortions in the environment and on the printed page, with physical and behavioural symptoms (Irlen UK, 2008c).

Firm links have been made between the properties of light and the condition (SCENIHR, 2008), and more specifically with fluorescent light both formally and anecdotally ('Laura', 2007; Nandakumar and Leat, 2008; Irlen UK, 2008; 'Lola', 2009). It not entirely clear which properties associated with low energy lighting aggravate the perceptual problems associated with Irlen Syndrome. The SCENIHR Review (2008) makes a connection between UV, blue light and Irlen but the source used is anecdotal.

As with photosensitive epilepsy (Wilkins *et al*, 1999), coloured tints used as overlays and in lenses have been used as a treatment (Nandakumar and Leat, 2008; Irlen UK, 2008). The Irlen UK website (2008), in describing the coloured tint treatment, indicates that selectively reducing the input of specific wavelengths of light produces benefits. This may indicate that certain wavelengths or parts of the colour spectrum are more problematic than others. However, there is some indication that the problem wavelengths are highly individual to each sufferer (Nandakumar and Leat, 2008).

More generally, much research has been carried out on the ability of dyslexics and others with perceptual problems to detect flicker (Evans *et al*, 1994; Ridder *et al*, 1997; Ben-Yehudah *et al*, 2001). These studies outline that sufferers from the group of conditions collectively known as dyslexia have different perceptual or sensory profiles to the general population (see references in Nandakumar and Leat, 2008). Some studies have found that dyslexics have an impaired ability to detect flicker (Evans *et al*, 1994; Ben-Yehudah *et al*, 2001) but importantly, Ridder *et al* (1997) found that not all dyslexic groups respond in the same way to stimulus.

(i)I Lupus

Linked to lamp property/properties: UV and light spectrum
Linked to lamp type(s): CFL
Prevalence: estimated at 0.027 in the general population, though higher in Afro-Caribbean females (Hopkinson *et al*, 1993, Johnson *et al*, 1995 referenced in SCENIHR, 2008). Lupus UK estimate 0.08% in the UK[12].

Lupus is a chronic auto-immune disease that may be affected by both the UV content of light and the light spectrum emitted.

[11] http://www.irlenuk.com/
[12] Lupus UK http://www.lupusuk.org.uk/qanda.asp

Although there is relatively little research on Lupus compared with the more prevalent diseases like migraine and epilepsy, the effect of UV on Lupus sufferers has been established. Provocation studies (Rihner and McGrath, 1992; Lehmann *et al*, 1990) have shown that the action spectrum of UV that induces lesions in Lupus sufferers is within the range emitted by CFLs. Lehmann *et al* (1990) recorded reactions in 33% of patients to UV-B, a frequency range that is emitted by both single and double-skinned CFLs (Khazova and O'Hagan, 2008).

In contrast to other studies referenced here (Sayre *et al*, 2004; Khazova and O'Hagan, 2008), Chingwell *et al* (2008) found that the spectral irradiance emitted by a 14W CFL was similar to a 60W incandescent (and no weaker than 365nm). The authors also found that the photosensitisation index, an indication of the potential of the lamp to cause photosensitisation in the skin, was less than half that of the incandescent. It should be noted that this study was on a single lamp, in contrast to more thorough studies on up to 73 lamps (Khazova and O'Hagan, 2008).

The negative effect of UV on Lupus sufferers has been confirmed by experts (e.g. European Lamp Companies Federation, 2007; Hawk, 2008; Sarkaney, 2008; Australian Department for the Environment, Water, Heritage and the Arts, 2008), press (e.g. Freeman, 2008; Connor, 2008; Rosenfeld, 2008; *BBC News*, 2008; Anon. *'Rays of rash'*, 2009) and anecdotal sources ('Jenny', 2009). Photosensitive health sufferers' organisations *Right to Light* and Spectrum Alliance (2008) reinforce the gravity of conditions like Lupus which they say can lead to fatalities.

Fewer sources link the light spectrum emitted by different lamp types to Lupus (European Lamp Companies Federation 2007; Sarkaney, 2008) but all indicate the likelihood of either the 'spikiness' of the spectrum of light emitted or the dominance of blue light having a negative effect on Lupus sufferers.

(i)J Migraine

Linked to lamp property/properties: flicker and light spectrum, (EMF)
Linked to lamp type(s): CFL
Prevalence: 6-8% in men and 15-18% in women[13], approximately 10% in UK[14]

Studies have causally linked migraine attacks to both the flicker of CFLs and the spectrum of light emitted.

Kowacs *et al* (2004) refer to abnormal flicker fusion thresholds that have been described in migraineurs and Shepherd (2000) describes abnormal cortical processing in migraine sufferers which indicates a difference in the way migraineurs respond to visual stimuli compared to the general population. The link between flicker and migraine has been established but less information is available on the flicker produced by CFLs. Sufferers' organisations are in

[13] Based on European and American studies WHO http://www.who.int/mediacentre/factsheets/fs277/en/)
[14] http://www.migraine.org.uk/index.php?sectionid=11

disagreement over the risk posed by CFLs. The Migraine Trust (2008) states that new CFLs will not cause a problem as they flicker at a higher frequency. In contrast, the Migraine Action Association (no date) claims that new low energy lamps can trigger migraines in sufferers and reports a great deal of concern from its members. These concerns are also reinforced by light sensitive group *Right to Light* and SPECTRUM Alliance (2008), as well as by a number of political, press and anecdotal sources (*EurActiv*, 2008 and 2009; *BBC News,* 2008; Reid, 2009; 'Junction26', 2009).

Abnormal sensitivity to parts of the light spectrum in migraine sufferers has been identified in a study by Main *et al* (2002). Compared to a control group, migraine sufferers had significantly lower discomfort thresholds when exposed to short (blue) and long (red) visible wavelengths (though not significantly different when exposed to green). *Right to Light* and SPECTRUM Alliance (2008), collectives of light sensitive groups, confirm this finding with anecdotal evidence, as does the Migraine Trust (2008), which indicates that blue light is the most problematic for light sensitive people.

One media source has also been found that makes the link between migraine and the electromagnetic fields emitted by lamps (Anon. *'Dirty electricity'*, 2009).

(i)K Photokeratitis

(also known as Arc Eye)
Linked to lamp property/properties: UV
Linked to lamp type(s): metal halide
Prevalence: N/A

Photokeratitis can be experienced by anyone who is acutely exposed to UV radiation – it results in keratitis, a painful inflammation of the eye's cornea (Parrish *et al*, 2003). The condition has been observed in those exposed to a damaged metal halide lamp for several hours, where the lamp shell is broken but the lamp continues to function, emitting UV. The condition in relation to UV exposure from metal halides has been reported academically (Kirschke *et al*, 2004, and references therein) and in several anecdotal accounts (*News Review Today*, 2005; Silverman, 2007).

(i)L Retina damage

Linked to lamp property/properties: light spectrum, (flicker)
Linked to lamp type(s): CFL and LED
Prevalence: variable depending on cause

Three papers by Rózanowska (1995, 1998, and with Sarna *et al*, 2003) describe a scheme of work in which exposure to intense light, particularly blue light, and damage to the retina are examined. This work has found that blue light excites lipofuscin granules in the eye that in turn give off oxygen. This oxygen is taken up by retinal pigment cells exposed to light. They have found that this is strongly wavelength-specific, being greatest at the shortest wavelength

studied (290nm). The Rózanowska studies found that this photo-oxidisation in the eye may contribute to retinal aging.

However, Okuno *et al* (2002) conclude the hazard is mainly posed by light sources of considerable intensity (e.g. the arc of welding and plasma cutting devices), and that the CFLs and white or blue LED lamps tested may be considered as posing a negligible risk for short exposure times. Over longer exposure periods Sayre *et al* (2004) caution against chronic exposure to indoor lighting which may deliver cumulative UV exposure to the eyes.

The SCENIHR (2008) reviews the literature and confirms that blue light may be harmful to those with existing retinal diseases but goes on to conclude that blue light may reduce the colour sensitivity of the intact retina (non-pre-existing condition). Roberts (2005) advises that those with pre-existing retinal damage in particular (for example sufferers of macular degeneration) should not take unnecessary risks such as blue light treatment, though concludes that task lighting should be risk-free.

Finally, Plummer *et al* (1998) make reference to HIV/Aids sufferers who are susceptible to retinal damage and experience an increased sensitivity to the flicker of lamps.

(i)M Skin damage or reactions

Linked to lamp property/properties: UV
Linked to lamp type(s): CFL, metal halide
Prevalence: N/A

The connection between UV exposure from lamps and skin reactions or skin damage has been variously made by informed sources (ICNIRP, 2004; Sayre *et al*, 2004; Khazova and O'Hagan, 2008) and by less formal sources (Stretton, 2009; Freeman, 2008; Connor, 2008).

Technical tests carried out by the Health Protection Agency (Khazova and O'Hagan, 2008) found that 20% of 73 CFLs tested exceeded the ICNIRP exposure guidelines at close proximity (2cm) in ten minutes, whilst half exceeded guidelines at the same distance in 30 minutes. At a larger distance of 20cm eight per cent of lamps tested exceeded exposure guidelines after eight hours. The ICNIRP indicate that the immediate risk to skin if the guidelines are exceeded is of a reddening similar to sunburn (ICNIRP, 2004). Other sources describe the impact on pre-existing photosensitive diseases, eczema (see sections on photosensitive skin diseases and eczema), skin allergies (Stretton, 2009), rashes (*Layman.org.uk*, no date) and skin sensitivity (Havas, 2008).

Acute exposure to UV from damaged metal halide lamps has resulted in burns documented academically (Kirschke *et al*, 2004) and anecdotally (*News Review Today*, 2005; Silverman 2007).

(i)N Xeroderma Pigmentosum (XP)

Linked to lamp property/properties: UV
Linked to lamp type(s): CFL

Prevalence: estimates vary from 0.000004 in Europe (SCENIHR, 2008) to 0.0001% in USA and 0.0025% in Japan[15]

XP is an inherited photosensitive skin disease, or genophotodermatosis. Fluorescent light has been identified as a risk to all photodermatoses (Rihner and McGrath, 1992; Sayre *et al*, 2004).

The SCENIHR (2008) review recognises that there is a marked sensitivity to UV-B wavelengths in the disease. Wavelengths in the UV-B range have been shown by a recent Health Protection Agency report (2008) to be emitted by both single and double-skinned CFLs on the market currently.

Due to the risk of skin cancer in XP sufferers, the SCENIHR report recognises that protection against UV-B wavelengths is a priority. It recommends avoiding unfiltered CFL illumination. Photosensitive condition sufferers' organisations *Right to Light* and SPECTRUM Alliance (2008) have reinforced the gravity of conditions like XP and Lupus which they say can lead to fatalities.

(ii) *Group 2: Less commonly referenced*

This group contains conditions that are referenced by one expert source, with or without less formal sources.

(ii)A Cutaneous Porphyria

Porphyrias are a group of photosensitive skin conditions, both inherited and environmentally induced, that result as an accumulation of photosensitive porphyrin in the skin (SCENIHR, 2008). Prevalence estimates vary between 0.002% and 0.00006%[16]. The SCENIHR (2008) report confirms that cutaneous prophyria are particularly sensitive to the blue light region. One particularly prevalent porphyria (cutanea tarda) which is induced by, amongst other factors, excessive alcohol intake and chronic hepatitis infection, is mainly produced by visible wavelengths other than UV-A (SCENIHR, 2008) (UV-B and UV-C are not in the visible range).

(ii)B Diabetes, MS, Asthma, behavioural changes

The above conditions have all been referred to by the work of one author, Magda Havas, (various 2004-2008) in her work surveying building users for perceived health impacts of electromagnetic fields or 'dirty electricity'.

(ii)C Headache/eye strain/visual performance

The above effects have also been referenced in relation to the flicker of low energy lights. Wilkins *et al* (1991) found that the rapid modulation of fluorescent lamps is responsible for

[15] http://www.xps.org/student_tips.htm

[16] The prevalence of congenital erythropoietic porphyria (Günther's disease) in the UK is approximately 2 per 3,000,000 live births, although Marco *et al*, 2007 estimates 1 in 130,000, Erythropoietic protoporphyria prevalence has been reported at around 1 to 2 per 100,000 inhabitants (Burns, 2004 referenced in SCENIHR, 2008). The prevalence of porphyria cutanea tarda is estimated to be 1:5,000 (SCENIHR, 2008).

eye-strain and headaches, a finding that is backed up by anecdotal evidence ('Judith Wilde', 2007, 'Vivian', 2008 and 'Andrew P', 2007). Veitch and McColl (1995) tested students' visual performance when exposed to low frequency flicker (120 Hz) and high frequency flicker (20-60kHz). Both of these frequencies are emitted by CFLs currently available (Khazova and O'Hagan, 2008). Visual performance scores of 18 to 24-year-old male and female university students were significantly better under the high-frequency flicker conditions than the low-frequency flicker conditions.

(ii)D Miscarriage

Miscarriage has been causally linked to the extremely low frequency electromagnetic fields, emitted by CFLs (SCENIHR, 2008), by one study (Lindbohm *et al*, 1992) and also by one unpublished medical expert source (Goldsworthy, 2008). Anecdotally, reference is also made to a connection with fluorescent lights ('DC', 2007).

(ii)E Conditions affecting balance (Vestibular disorder and Ménière's Disease)

The SCENIHR report (2008) and the Australian Department for the Environment, Water, Heritage and the Arts (DEWHA) (2008) confirm that Ménière's disease sufferers may be affected by flicker, although the DEWHA source states that the condition is only likely to be affected by frequencies up to 30Hz, which is below the range detected in modern CFLs (Khazova and O'Hagan, 2008). Less formal sources make more specific links between fluorescent lights, flicker (Vestibular Disorder Association, 2008) and CFLs ('Jerry S', 2007). Anecdotally, a survey undertaken by the Ménière's Society (2007) on the effects of the built environment on sufferers recorded that 31% (10 out of 32) of respondents reported to be affected by lighting though there is no indication of which properties of light or sources of light cause reactions.

(iii) *Group 3: Anecdotal*

Health issues in this group have only been referenced by non-expert sources. Conditions referred to by health sufferers' organisations have been included here if no expert information is used to reference the claims.

(iii)A Headaches, eye strain, fatigue and confusion, nausea, dizziness and ringing in the ears, joint pain and sleep problems

The above symptoms are all noted in quotes from Magda Havas (a Canadian academic interested in EMF) in two informal sources (EMF Solutions, 2007; Anon. *'Dirty Electricity'*, 2009). Havas reports all of these symptoms have resulted from exposure to electromagnetic fields from CFLs.

(iii)B Hyperactivity, irritability, accidents and misjudgements

The above have all been referred to in a blog on the subject of fluorescent lighting ('DC', 2007; 'Janet Love', 2008; 'Pete', 2008). Although the press article the blog is linked to is specifically about CFLs, it is not clear from the blog entries if these or old fluorescent tubes are being referred to.

3.c) Potential health benefits

The main focus of this study has been on the potential health risks associated with low energy lighting. The study has also considered (in lesser details) the potential health benefits that can result from specific lamp types, or specific technical properties of a lamp.

There is a vast body of work on the general benefits of light and good lighting design but, as this is not specific to any particular source of light, lamp type or technical property, it has not been included in this study. A number of guides or guidelines for designing light for specific health sufferers have been identified by this review. They provide some useful information on the preferred properties of light and lamps for different health sufferers; on Chronic Fatigue Syndrome (CFS)/ME (*Action for ME*, 2007), lighting for older eyes (Lighting Research Centre, 2009), Dementia (Stirling University, 2008) and Alzheimers' Disease (Brawley, 1997).

There is also a large body of work on full spectrum light and the benefits to general health and specific conditions (see for example McColl and Veitch, 2001; Ott, 2000) but similarly, as this is not directly specific to any one lamp type it has not been included.

This study did not find any evidence that any of the lamp types considered (CFLs, metal halides, LEDs) offer health benefits in their current forms. There are, however, some lamp properties related to the use of LEDs which could lead to health benefits in future.

(i) Blue light and light therapy

High temperature, blue light is used in 'bright light therapy' (see references in Sloane *et al*, 2008) indicating that blue light might offer some potential health benefits. Blue light is deemed to be effective in suppressing melatonin secretion, the hormone that regulates the human circadian system (numerous references in Sloane *et al*, 2008) and thus may be effective in regulating sleep/wake patterns.

Many studies and trials have attempted to investigate the impact and efficacy of light therapy in treating seasonal affective disorder (for example Thalén *et al*, 1995) and other forms of depression (Tuunainen *et al*, 2004), improve the sleep quality and efficiency of dementia patients (including Alzheimer's sufferers) (Figueiro *et al*, 2003; Wallace, 2003), and treat sleep disorders in broader segments of the population. Sloane *et al* (2008) have carried out a comprehensive review of the literature in this area but found few studies focused on older adults. Similarly, Montgomery and Dennis (2002) in their review of bright light treatments state that "in view of promising results [...] in other populations [...], further research into their effectiveness with older adults would seem justifiable".

One pilot study of regulated exposure to blue light (LEDs, 470nm maximum) of Alzheimer's patients in a nursing home found sufficient signs of improved sleep efficiency to recommend bigger trials (Figueiro, 2008). For sleep management in dementia sufferers more broadly, a review by Forbes *et al* (2004) concludes that "there is insufficient evidence to determine whether bright light therapy is effective".

(ii) Red light and infra-red therapy

For near-infrared red light, at the other end of the visible light spectrum, other effects on the human physiology have been asserted and/or observed (Schmidt *et al*, 1999; Whelan *et al*, 2001). Most of the assertions are based on laboratory observations that near-infrared light gives a brief boost to cellular mitochondrial activity, an as yet poorly understood process (Eells *et al*, 2004; Wong-Riley *et al*, 2005). The inference is that this supports cellular regeneration, with numerous subsequent assertions made (see below).

Perhaps fairly well established in practice is the non-invasive and cosmetic treatment of non-malignant skin melanomas through controlled exposure to near infra-red LEDs, which has given rise to a trial of 'wearable' Organic LEDs[17] as an alternative to sessions in clinics (Attili *et al*, 2009).

Barolet and Boucher (2008) in their research testing controlled exposure to near-infrared LEDs prior to sunlight UV exposure are fairly confident of a reduced risk of skin erythema as a result. This appears to have some scientific salience, being built on the same underlying assumptions as those informing the treatment of non melanoma skin cancer (Braathen *et al*, 2007).

There appears to be much unchallenged evidence of the use of near-infrared LED exposure to reduce the appearance of skin wrinkles and skin ageing (e.g. Sommer and Zhu, 2008; University of Sunderland, 2005).

More tenuously, researchers at the University of Sunderland (2008) have been reported in the national and science media numerous times in connection with the use of near-infrared LED 'helmet' slowing or even reversing the effects of dementia and Alzheimer's (for example *Channel 4*, 2008; Derbyshire, 2008; Stephens, 2009; *Science Daily*, 2008). Evidence from expert sources is currently limited to reports (original paper cannot be found) on a trial with laboratory mice (e.g. *Encouraging Health*, 2008) and sources referring to human benefit are currently purely anecdotal. Nevertheless, this 'discovery' has managed to garner a lot of attention, with famous Alzheimer's sufferer Terry Pratchett trying out the helmet. The 'Lay Science' blog ('Martin', 2009) provides a good deconstruction of both these premature assertions and the repeatedly delayed promise of proper human trials. Whilst certainly not yet established, the potential link between near-infrared light and boosts to cells' regenerative abilities appears to have been picked up by the entrepreneurial community. Evidence has been found of obscure manufacturers supplying red LED hairbrushes to stimulate hair re-growth[18] and toothbrushes to improve the health of gums and whiten teeth[19].

[17] OLEDs may have different technical properties than domestically used LEDs
[18] http://www.amazon.com/Viatek-Hair-Pro-Laser-Brush/dp/B000ENQQTW
[19] www.alibaba.com/product-tp/103234257/LED_toothbrush.html

4) Conclusions

As previously stated, it is not in the remit of this study to draw conclusions on whether or which lamp properties or types pose any risk to health. It is possible however, to draw together some general points of note that are not directly related to a technical property (which have been summarised in the relevant sections). These concluding points have been grouped by the three lamp types included in the study.

4.a) CFLs

The first point to draw from the review of sources on CFLs is the diversity of different lamps currently available. The wide variety of available lamps feature different technical properties (spectrum of light emitted, UV range and intensity, EMF, modulation) which carry potential levels of risk to health. In this market of limited standardisation, it is difficult to attribute certainty and rule out risk. Although the academic and technical references do make a distinction in some cases between lamps of the same type that have different technical properties, anecdotal sources generally do not. Therefore, public opinion could easily be damaged by the presence of the worst-performing lamps on the market.

Second, questions have been raised in the reviewed sources about the risk assessment methodology used in association with some of the less well understood technical properties (particularly EMF) and health issues (e.g. EHS). The evidence required to show causality and level of precaution used when analysing risk to health has come under question. The most prominent example of this is the lobby for revised international guidelines on non-ionising radiation protection (see section on EMF and the BioInitiative report[20]). Health sufferers' organisations have also questioned the level of proof required by the SCENIHR in its review of the risk to health from CFLs. *Right to Light* and SPECTRUM Alliance (2008) acknowledge that the SCENIHR are unable to draw a conclusion when the research is inadequate but criticises the fact that where there is a lack of consensus in the scientific community, these issues are not treated with more precaution. Overall, it appears that more precaution is being called for. Some European countries have already responded to these calls by, for example, introducing stricter guidelines on EMF.

Third, the sources on CFLs and health impacts are contemporary, and are continually being updated; the knowledge is incomplete but expanding. The phase-out of incandescent bulbs, begun voluntarily in 2008 and continuing incrementally until 2011, has provoked much of this interest. The SCENIHR (2008) report and the HPA report (Khazova and O'Hagan, 2008), which are the two most central sources of information in this review, were both published within the last eight months (at the time of writing). These studies will be updated with further sources that should be monitored. This review has identified two reports on the horizon that will add to the current and relevant body of information of CFLs: an Impact Assessment, to be published by Defra in the summer of 2009, will include an Equality Impact Assessment prepared by the Department of Health on health issues associated with CFLs and halogen

[20] http://www.bioinitiative.org/

lamps; and Health Canada is due to publish a study into the UV emissions from CFLs (similar to the HPA study) in the autumn of 2009. To supplement the point in time review of the sources provided in this report, the study also provides a list of interested and active organisations (Appendix 2) that will help ongoing monitoring.

Of particular note in this list of organisations are those that appear to be most prominent and outspoken: light sensitive health issue coalitions *Right to Light* and SPECTRUM Alliance are supporting a petition directed at No 10 to keep incandescent bulbs; Migraine Action through their Director, Lee Tomkins, has received a lot of press coverage on the issue of CFLs and migraine; Magda Havas (Canadian academic based at Trent University, Canada) is the leading academic in the EMF area and receives media attention.

4.b) Metal halides

There are far fewer references that relate metal halide lamps to health issues, in either the academic literature or anecdotal sources, than there are for CFLs despite the two lamps sharing several technical properties. Explanations for this may be found in the lamp application: metal halide lamps have limited use domestically and are generally to be found in commercial or industrial properties. Furthermore, they are not proposed as a major alternative to incandescent light. As a result, there is far less media attention placed on their use, and arguably, a less pressing need for academic institutions to test the risks associated with them.

Issues that have been reported relate to episodic events (such as acute UV exposure through shell damage, or end of life rupture) rather than those resulting from long-term exposure. Again, this is may be a function of the typical settings in which metal halides are used – commonly at distances above floor level that are greater than in domestic settings – negating the proximity risk that has been linked to some technical properties (e.g. UV and EMF) and lamp types (CFLs).

4.c) LEDs

Discussions in popular press and blogs on the purported negative effects of CFLs on health reveal a perception that concerns over CFLs are temporary provided that LEDs ultimately supplant CFLs as the main future lamp type (for example ‘Mark’, 2009; ‘mittfh’, 2009). It appears therefore that, current cost and efficacy issues aside, LEDs are well-perceived with as yet no purported negative health effects reported or alleged.

Virtually all purported health effects of LEDs identified by this review relate to healthcare and cosmetic applications, rather than general lighting. As such, all asserted effects are positive, with varying degrees of significance in terms of the frequency and source of references. It should be noted that a number of the health benefits have received wide popular coverage but have yet to produce solid scientific foundations. There is a small risk that, if not substantiated, these niche applications could prove detrimental to the reputation of the lamp type for more general uses.

All of the health effects relate to the two extreme ends of the visible light spectrum: near-UV (blue) and near-infrared light. Broadly speaking, the former purportedly impacts upon the circadian system and as a result affects sleep patterns, whilst it is suggested the latter supports cellular regenerative capacity. The science of these links is by no means established and some assertions of the positive effects border on the fanciful. It is important to note that these light properties are not LED-specific, but LEDs are able to deliver precise colour ranges at low colour temperatures, making 'treatment' more convenient than (say) bright light therapy.

Whilst enjoying a relatively 'clean bill of health' at the moment, this may be in part due to the focus and attention brought to bear on CFLs as the 'successor' to incandescent lamps. As the market for widespread application and use of LED lamps matures, it is reasonable to expect that the level of research activity and attention focusing on potential negative impacts of LED lighting on health will increase, altering the balance of a debate which at present may appear to be one-sided.

5) Appendices

5.a) Appendix 1: Health issue prevalence

(i) Asthma – 4.5% worldwide

Some 300 million people currently suffer from asthma. It is the most common chronic disease among children.
http://www.who.int/mediacentre/factsheets/fs307/en/index.html

(ii) Autism and Asperger's Disease (autism spectrum disorders) – autism 0.2%, autism spectrum diseases 0.6%

Recent epidemiological data show that autism is a frequent disorder, observed in one child in 500. The cumulated prevalence of diseases belonging to the spectrum of autism (autism, Asperger's syndrome) and pervasive developmental disorders not otherwise specified, has been estimated at 1/167 (Orphanet, 2008).

(iii) Skin cancer

The incidence of both non-melanoma and melanoma skin cancers has been increasing over the past decades. Currently, between two and three million non-melanoma skin cancers and 132,000 melanoma skin cancers occur globally each year. One in every three cancers diagnosed is a skin cancer. (http://www.who.int/uv/faq/skincancer/en/index1.html)

(iv) CFS/ME - 0.2 – 2% (UK 0.41%)

It has a prevalence that varies from 0.2% to above 2% (Wyller, 2007). According to self-reporting, about 52,500 people in the UK (21% of myalgic encephalomyelitis) have increased sensitivity to light (Action for M. E., 2008).

250,000 in UK current suffer (0.41%)
(http://www.meassociation.org.uk/content/blogcategory/38/83/)

(v) Diabetes – UK 4.3%

The overall prevalence of diabetes increased from 2.8 per cent of the population in 1996 to 4.3 per cent in 2005 (http://www.diabetes.org.uk/About_us/News_Landing_Page/Rise-in-new-cases-of-diabetes/)

(vi) Eczema – UK 8% of adults and 20% of children

In the UK one in five children and one in twelve adults have eczema while eczema and contact dermatitis account for 84-90% of occupational skin disease. (http://www.eczema.org/eczema.html)

(vii) Electromagnetic hypersensitivity (EHS) – variable 1.5% to 5% (based on European studies)

There is a very wide range of estimates of the prevalence of EHS in the general population. A survey of occupational medical centres estimated the prevalence of EHS to be a few individuals per million in the population. However, a survey of self-help groups yielded much higher estimates. Approximately 10% of reported cases of EHS were considered severe. There is also considerable geographical variability in prevalence of EHS and in the reported symptoms. The reported incidence of EHS has been higher in Sweden, Germany, and Denmark, than in the United Kingdom, Austria, and France. VDU-related symptoms were more prevalent in Scandinavian countries, and they were more commonly related to skin disorders than elsewhere in Europe. Symptoms similar to those reported by EHS individuals are common in the general population. (http://www.who.int/mediacentre/factsheets/fs296/en/index.html)

Swedish study found prevalence of 5%
(http://www.springerlink.com/content/q5n731u88v6m1642/)

Stockholm population-based study found prevalence of 1.5% and more prevalent in women
(http://cat.inist.fr/?aModele=afficheN&cpsidt=13478173)

An Austrian telephone study of a cross-section of 526 people showed that an increasing number of people suffer from non-specific health symptoms such as headaches, sleep disturbances, difficulties in concentrating etc and attribute their ill-health to electromagnetic hypersensitivity (EHS) and electromagnetic pollution. It showed an EHS prevalence of 3.5%. In 2007, a UK survey aimed at a randomly selected group of 20,000 people found a prevalence of 4% for symptoms attributed to electromagnetic exposure.
(http://www.radiationresearch.org/pdfs/20090224_eileen_eu_presentation_text.pdf)

(viii) Epilepsy – 0.74% of world pop (5% epileptics are light sensitive)

Around 50 million people worldwide have epilepsy (WHO, http://www.who.int/mediacentre/factsheets/fs999/en/index.html)

Five percent of the total world population has single seizures, and the annual incidence is 50 in 100,000 (WHO, 2001). About five in 100 epileptic people have photosensitive epilepsy (Epilepsy Action, 2007).

(ix) Idiopathic Photodermatoses

One study shows photodermatoses are three times more common in females than males
(http://www.nature.com/jid/journal/v125/n4/full/5603571a.html)

Polymorphic light eruption – increases with distance from the equator 10-20% in Europe, higher in women

The prevalence increases with the distance from the Equator (5% in Australia; 21% in Sweden; 15% in England) and also with altitude. The overall European estimate is 10-20%. The disorder

usually starts during the second and third decades of life and affects females two to three times more often than males (SCENIHR, 2008).

Chronic Actinic Dermatitis – mainly in males over 50 years old (prevalence in Scotland 0.017%)

Occurs mainly in males over the age of 50 years with a prevalence in Scotland of 16.5:100,000 population (Dawe, 2008).

Solar Uticaria – approximately 0.0031%

The prevalence has been estimated to be 3.1 per 100,000 (Beattie, 2003).

Actinic Prurigo

Well known in the US among Native Americans but rarely seen in Europe or Asia.

(x) Irlen syndrome/Irlen Meares syndrome – 12-15% of UK population

Irlen Syndrome is a condition that affects the quality of life for 12-15% of the population (http://www.irlenuk.com). This percentage rises to 46% of those with dyslexia, attention deficit disorders and learning difficulties (Helen Irlen quoted in Nandakumar and Leat, 2008).

(xi) Lupus – 0.028%, although UK approximation is 0.08%

Its prevalence is estimated at 27.7 per 100,000 of the general population with a much higher prevalence reported for females of Afro-Caribbean ethnicity (Hopkinson *et al*, 1993, Johnson *et al*, 1995 referenced in SCENIHR, 2008).

Lupus UK estimate 50,000 in UK (0.08%) and predict 90% of sufferers are females, mainly between the ages of 15 and 55. (http://www.lupusuk.org.uk/soitslupus.asp)

(xii) Migraine – 6-8% men and 15-18% women (approximately 9.8% in UK)

European and American studies have shown that 6-8% of men and 15-18% of women experience migraine each year (WHO http://www.who.int/mediacentre/factsheets/fs277/en/)

It is estimated that 14% of adults in Europe have migraine (Stovner *et al*, 2006).

It affects over 6 million people in the UK (9.8%)
(http://www.migraine.org.uk/index.php?sectionid=11)

(xiii) Meniere's disease – approx 0.1%

Approximately one in 1,000 people develop Ménière's disease.
(http://www.nhs.uk/Conditions/Menieres-disease/Pages/Introduction.aspx?url=Pages/What-is-it.aspx)

(xiv) Multiple Sclerosis – 0.14% UK

Around 85,000 people in the UK have MS.

(http://www.mssociety.org.uk/about_ms/index.html)

(xv) Porphyrias - estimates vary between 0.00006% and 0.002%

The prevalence of congenital erythropoietic porphyria (Günther's disease) in the UK is approximately two per 3,000,000 live births [although Marco, 2007 estimates one in 130,000]. Erythropoietic protoporphyria prevalence has been reported at around one to two per 100,000 inhabitants (Burns *et al*, 2004 referenced in SCENIHR, 2008; Marco *et al*, 2007). The prevalence of porphyria cutanea tarda is estimated to be one in 5,000. It is caused by excessive alcohol intake, chronic hepatitis infection and other factors (SCENIHR, 2008).

(xvi) Vestibular Disorder

No definitive statistics exist about vertigo/dizziness/imbalance. In part, this is because symptoms are difficult to describe and differences exist in the qualifying criteria within and across studies. http://www.vestibular.org/vestibular-disorders/statistics.php

(xvii) XP – from 0.0001% USA to 0.0025% Japan

Prevalence is estimated at one in 1,000,000 in the United States. Certain populations have a higher prevalence. For example, in Japan, the prevalence is estimated as one in 40,000 http://www.xps.org/student_tips.htm

5.b) Appendix 2: List of contacts and organisations

Those in **bold** have been found to be particularly active.

UK Government Contacts

- Domestic Lighting Lead at the Department for Agriculture Food and Rural Affairs (Defra), Steven Mills steven.mills@defra.gsi.gov.uk; phone 0207 238 4820
- Scientific Policy Officer (Radiation) lead on lighting, Department of Health, Dr Patricia Keep patricia.keep@dh.gsi.gov.uk; phone 0207972 4542

Online groups and ongoing BLOGS

- Healthy light network http://healthylightnetwork.verilux.com/
- Facebook group on Fluorescent light sensitivity http://www.facebook.com/group.php?sid=4f0d2b17362244812f095ad9a22398d3&gid=55819957111

Alzheimer's Disease and Dementia

- Alzheimer's research trust http://www.alzheimers-research.org.uk/
- Stirling University Dementia Services Development Centre http://stirling.jellycommunications.com/

Autism and Asperger's

- Asperger's Foundation (UK) http://www.aspergerfoundation.org.uk/
- Autism Research Centre (University of Cambridge) http://www.autismresearchcentre.com/arc/default.asp
- National Autistic Society http://www.nas.org.uk/
- **Research Autism http://www.researchautism.net/pages/welcome/home.ikml**

CFS/ME

- Action for ME http://www.afme.org.uk/
- ME Association http://www.meassociation.org.uk/component/option,com_frontpage/Itemid,130/

EHS

- Electro-sensitivity UK http://www.es-uk.info/
- Essex University studying EHS and phone masts (mainly) http://www.essex.ac.uk/psychology/EHS/
- Powerwatch http://www.powerwatch.org.uk/
- List of associations for the electrosensitive http://www.feb.se/FEB/Addresses.html

Epilepsy

- **Epilepsy Action http://www.epilepsy.org.uk/**
- National Society for Epilepsy http://www.epilepsynse.org.uk/Homepage

Irlen Syndrome and dyslexia

- Irlen UK http://www.irlenuk.com/
- British Dyslexia Association http://www.bdadyslexia.org.uk/
- Dyslexia action http://www.dyslexiaaction.org.uk/

Light sensitivity groups

- Eclipse http://eclipse.lupusuk.org.uk/
- Right to Light
- **Spectrum Alliance http://www.spectrumalliance.org.uk/index.php?id=1**

Lupus

- Lupus patients' understanding and support http://www.lupus-support.org.uk/
- Lupus UK http://www.lupusuk.com/
- The Lupus Site http://www.uklupus.co.uk/

Ménière's Disease and Vestibular Disorder

- Ménière's Info Centre http://www.menieresinfo.com/
- Ménière's Society http://www.menieres.org.uk/
- Vestibular Disorders Association http://www.vestibular.org/vestibular-disorders/specific-disorders/meniere92s-disease.php

Migraine

- **Migraine Action http://www.migraine.org.uk/**
- Migraine Trust http://www.migrainetrust.org/

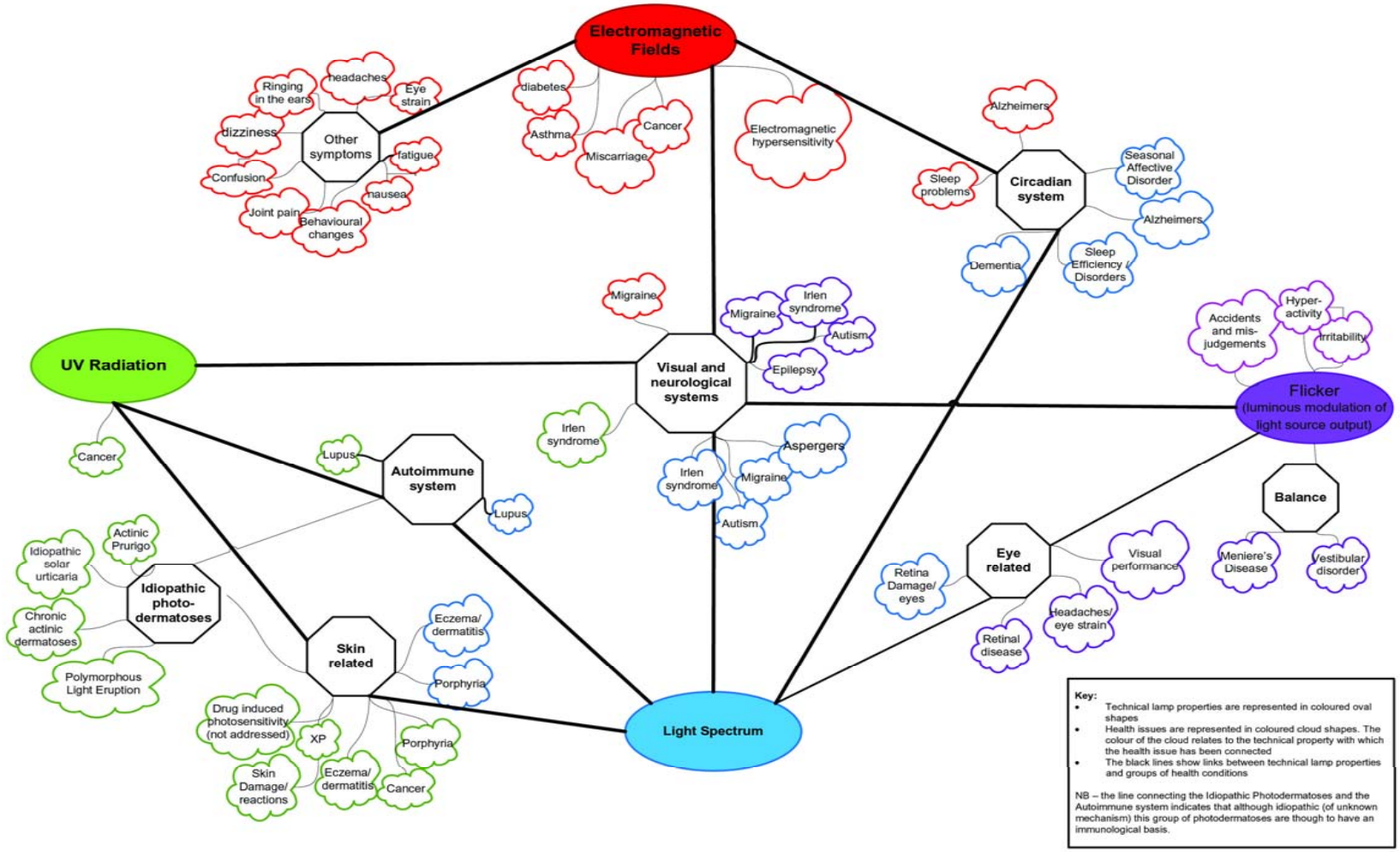
Porphyria

- British Porphyria Association http://www.porphyria.org.uk/

Xeroderma Pigmentosum XP

- Xeroderma Pigmentosum Support Group http://joomla.xpsupportgroup.org.uk/

5.c) Appendix 3: Technical property and health issue summary map



5.d) Appendix 4: Tables of references

See attached database