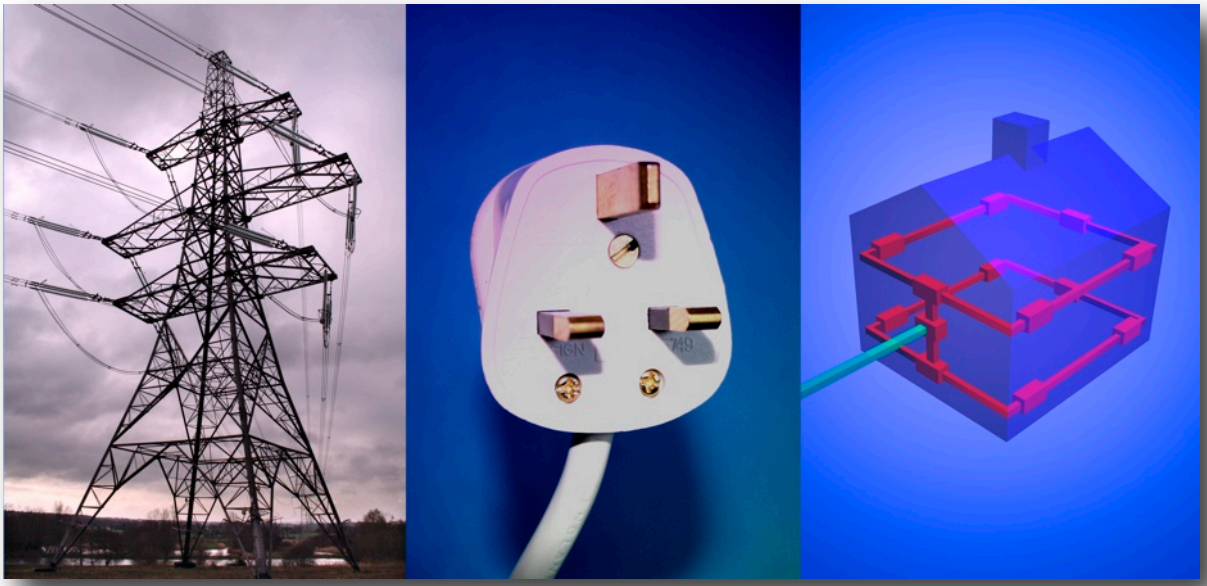
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Stakeholder Advisory Group on ELF EMFs (SAGE)
Precautionary approaches to ELF EMFs



First Interim Assessment:
Power Lines and Property, Wiring in Homes, and Electrical Equipment in Homes

Date of issue: 27/04/2007

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The SAGE process was initiated by National Grid but is now under the lead of the Department of Health. It is funded equally by the Department of Health, the Electricity Industry (National Grid and the Energy Networks Association) and the charity CHILDREN with LEUKAEMIA.

The process was designed and facilitated by Rob Angell of RK Partnership Ltd and by Brendan Hickling of TW Welch & Partners. The facilitators hold no formal position on any of the substantive issues that have been, or might be, considered. It is for the participants to decide what issues are raised, how they might be addressed and how any observations, conclusions and recommendations might be recorded and communicated.

The R K Partnership website www.rkpartnership.co.uk has a full description of the process, as well as papers considered by the participants and assessments produced from the process.

PLEASE NOTE

The remit of SAGE is to provide advice to Government. It is for Government to take decisions on policy relating to EMFs and health, based on this advice and whatever other inputs it deems necessary.

This Assessment represents a record and a distillation of the discussions that have taken place within SAGE. It is not a single definitive set of universally agreed conclusions and recommendations, but rather captures the point our evolving discussions have reached. We are aware of places where particular issues need further consideration, and intend to progress our work. Merely by having participated in the process, no stakeholder is thereby bound to agree with every statement in the Assessment, or deemed to agree with every recommendation.

Government officials are a part of the process, informing the debate and supplying factual input to the Assessment. The Government supports the production of the Assessment and welcomes the material and the contribution it makes to consideration of the EMF issue. However, this does not necessarily imply that Government is aligned with the views expressed or the conclusions stated in this Assessment and Government representatives will not be formally supporting any particular conclusions and options outlined in the Assessment, as that is a matter for Government as a whole to consider once it has received the Assessment.

Recognising that this Assessment reflects some degree of agreement but not total agreement, each stakeholder has been given the opportunity to make a statement of their view of the point the SAGE discussions have reached. These are contained in the appendix on page 57.

Stakeholders (individuals and organisations) are not bound by this Assessment in their future activities or commercial decisions.

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Contents

Overview 6

Abbreviations and Acronyms 7

1 Introduction 9

1.1 Context 9

The Project 9

Aim 9

1.2 Background to the science of EMFs 12

Electric and magnetic fields 12

Views of external bodies on the science of EMFs 13

Views within SAGE on the science of EMFs 16

Comparison of EMFs to other issues 16

1.3 Background to protection from EMFs 17

1.4 Ways of working and stakeholders 19

1.5 What happens next 22

2 Generic issues 24

2.1 Decisions about the science 24

Childhood leukaemia 24

Other adverse health effects 25

Issues common to both 25

2.2 Assumptions about risk 26

2.3 Criteria for assessing consequences and implications of options 27

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2.4 Cost-benefit analysis 27

Costs *28*

Benefits *28*

2.5 Public Opinion 30

2.6 Other countries 33

2.7 The WHO "Precautionary Framework" 34

3 Wiring in homes 36

3.1 Introduction 36

3.2 Options for reducing fields from wiring in the home 37

3.3 Best available options 38

3.4 Conclusions 39

4 Electrical equipment in homes 41

4.1 Introduction 41

4.2 Options for reducing fields 41

4.3 Conclusions 42

5 Power lines and property 43

5.1 Introduction 43

5.2 Options for reducing exposures from power lines 44

5.3 Recommended options 45

5.4 The best-available option for obtaining significant exposure reduction 46

Implementation of this option *49*

Consequences of this option *50*

5.5 Conclusion 51

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Participants in SAGE 54

Appendix: Stakeholder Commentaries on the Report 57

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Overview

The remit of SAGE is to provide advice to Government. It is for Government to take decisions on policy relating to EMFs and health, based on this advice and whatever other inputs it deems necessary.

This first SAGE Assessment represents a record and a distillation of the discussions that have taken place within SAGE. It is not a single definitive set of universally agreed conclusions and recommendations, but rather captures the point our evolving discussions have reached. We are aware of places where particular issues need further consideration, and intend to progress our work. Merely by having participated in the process, no stakeholder is thereby bound to agree with every statement in the Assessment, or deemed to agree with every recommendation, or constrained by the contents of the Assessment in their future activities.

This Assessment considers EMFs from two groups of sources: high-voltage overhead power lines; and sources inside the home (home wiring, and domestic equipment and appliances). SAGE intends to go on to consider other sources such as low-voltage distribution wiring, railways, etc.

This Assessment opens with an introductory Section 1. This summarises the state of the science on EMFs, the history of protection from EMFs and the events which led to the creation of SAGE, and describes how we have gone about our work.

Section 2 details the decisions we have made that are generic to all our work. This is where we set out the assumptions we have made about how big the possible risk is, and how we assess the different precautionary options, including how we consider costs and benefits, and public opinion.

The next three sections consider EMFs from particular sources: Section 3 for home wiring, Section 4 for equipment in the home, and Section 5 for power lines. In each case, we describe very briefly the source of the fields; we list the various options for reducing exposures and discuss how we narrowed these options down; then we discuss which options we recommend or not.

Recognising that this Assessment reflects some degree of agreement but not total agreement, each stakeholder has been given the opportunity to make a statement of their view of the point the SAGE discussions have reached. These are contained in ??.

Much of the factual material which informs our discussion is contained in Supporting Papers which are available from the SAGE web site. As with the main Assessment, these reflect the discussions that have taken place among stakeholders, without all stakeholders necessarily agreeing with all the content. Within the SAGE process, however, there has been more emphasis on the main Assessment, and the Supporting Papers should be seen as more provisional and interim. Also on the SAGE web site is a section of douments submitted as contributions to the wider debate by SAGE participants.

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Abbreviations and Acronyms

AC	Alternating Current
ALL	Acute Lymphocytic Leukaemia
ALS	Amyotrophic Lateral Sclerosis, the most common form of Motor Neurone Disease
AM	Arithmetic Mean
AMDEA	Association of Manufacturers of Domestic Appliances
BS	British Standard
BSI	British Standards Institution
CLA	Country Land and Business Association
CML	Council of Mortgage Lenders
CPC	Circuit Protective Conductor
CPO	Compulsory Purchase Order
DC	Direct Current
DCLG	Department for Communities and Local Government (formerly part of ODPM)
Defra	Department of Food and Rural Affairs
DfES	Department for Education and Skills
DH	Department of Health
DNO	Distribution Network Operator
DTI	Department of Trade and Industry
EDM	Early Day Motion
ELF	Extremely Low Frequency
EF	Electric Field
EIE	Electrical Installations and Equipment (SAGE Working Group)
EMFs	Electric and Magnetic Fields
ENA	Energy Networks Association
EPA	Environmental Protection Act 1990
EPA	Environment Protection Agency (US body)
ESQCR	Electricity Safety, Quality, and Continuity Regulations 2002
FUW	Farmers' Union of Wales
GM	Geometric Mean
HPA	Health Protection Agency (part of which was formerly NRPB)
HPA-RPD	HPA Radiation Protection Division
HSE	Health and Safety Executive
Hz	Hertz (unit of frequency)
IARC	International Agency for Research on Cancer
ICNIRP	International Commission for Non-Ionizing Radiation Protection
IEE	Institution of Electrical Engineers, now part of IET
IET	Institution of Engineering and Technology, successor body to IEE
kV	Kilovolt

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MF MND MOA	Magnetic Field Motor Neurone Disease Mobile Operators' Association
NCRP NFU NGT NI NICE NIEHS NRPB	National Council on Radiation Protection and Measurements (US body) National Farmers' Union National Grid Transco (former name of National Grid) Northern Ireland National Institute for Health and Clinical Excellence National Institute of Environmental and Health Sciences (USA body) National Radiological Protection Board (now part of HPA)
ODPM Ofgem	Office of the Deputy Prime Minister, now DCLG Office for Gas and Electricity Markets
PLP PME	Power Lines and Property (SAGE Working Group) Protective Multiple Earthing
QALY	Quality Adjusted Life Years
RCBO RCD RCM RCMS RF RIA RICS RPD	Residual Current Circuit Breaker with Overload Protection Residual Current Device Rate of Change Metric Rate of Change Metric Standardised Radio Frequency Regulatory Impact Assessment Royal Institute of Chartered Surveyors Radiation Protection Division (of HPA)
SAGE	Stakeholder Advisory Group on ELF EMFs
T THD TWA	Tesla (unit of magnetic field) Total Harmonic Distortion Time Weighted Average
UKCCS	United Kingdom Childhood Cancer Study
V/m or V m^{-1}	Volts per metre (unit of electric field)
WHO	World Health Organization
μT	Microtesla

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1 Introduction



1.1 Context

Over the course of the last 30 years there has been a growing understanding of the effects of electric fields (EF) and magnetic fields (MF) on people. Together EFs and MFs are known as electromagnetic fields EMFs.

In 2004 the UK adopted new guidelines which set magnetic field levels (a reference level of 100 μT) above which members of the public should not usually be exposed. However this left open the question of what effects the fields have (if any) on people below these levels. This question is highly controversial partly because it includes levels which can be found in homes, from their wiring circuits, and in homes that are near to power lines.

The Stakeholder Advisory Group on ELF EMFs was set up in November 2004 to involve all key stakeholders to address this question. This group process deliberately set out to change the dynamic and type of relationships that had existed between stakeholders over the preceding 20 or so years, which had been characterised by constant conflict and "standing on opposing sides at inquiries".

The state of relations between stakeholders at the start of this process was therefore not good. Significant progress has been made on this front since then.

The Project

Aim

The aim of the process was agreed by stakeholders in November 2004 as:
"To bring together the range of stakeholders to identify and explore the implications for a precautionary approach to ELF EMF (electric and magnetic fields) and make practical recommendations for precautionary measures".

The Process

This stakeholder group is not a formally constituted body nor are the participants formally appointed by government. Rather the dialogue process has been constructed to involve all the key stakeholders as defined by their knowledge, experience, professional responsibility, and the impact on them of any future government decisions. This has included a mix of industry, national government departments, regulators & advisory bodies, academics, individuals, local & national campaign groups and professional bodies. It is recognised that the make up of the group may not have completely reached the ideal intended but it is believed that it is close enough to validate the work.

One of the ways of working that was agreed from the start was not to have "a high profile chair" and follow a conventional path. Instead, stakeholders agreed to keep the structure more informal and work with a professional facilitator. R K Partnership Ltd were engaged in this role and are acting as process consultants and managers, with Rob Angell leading the facilitation for SAGE.

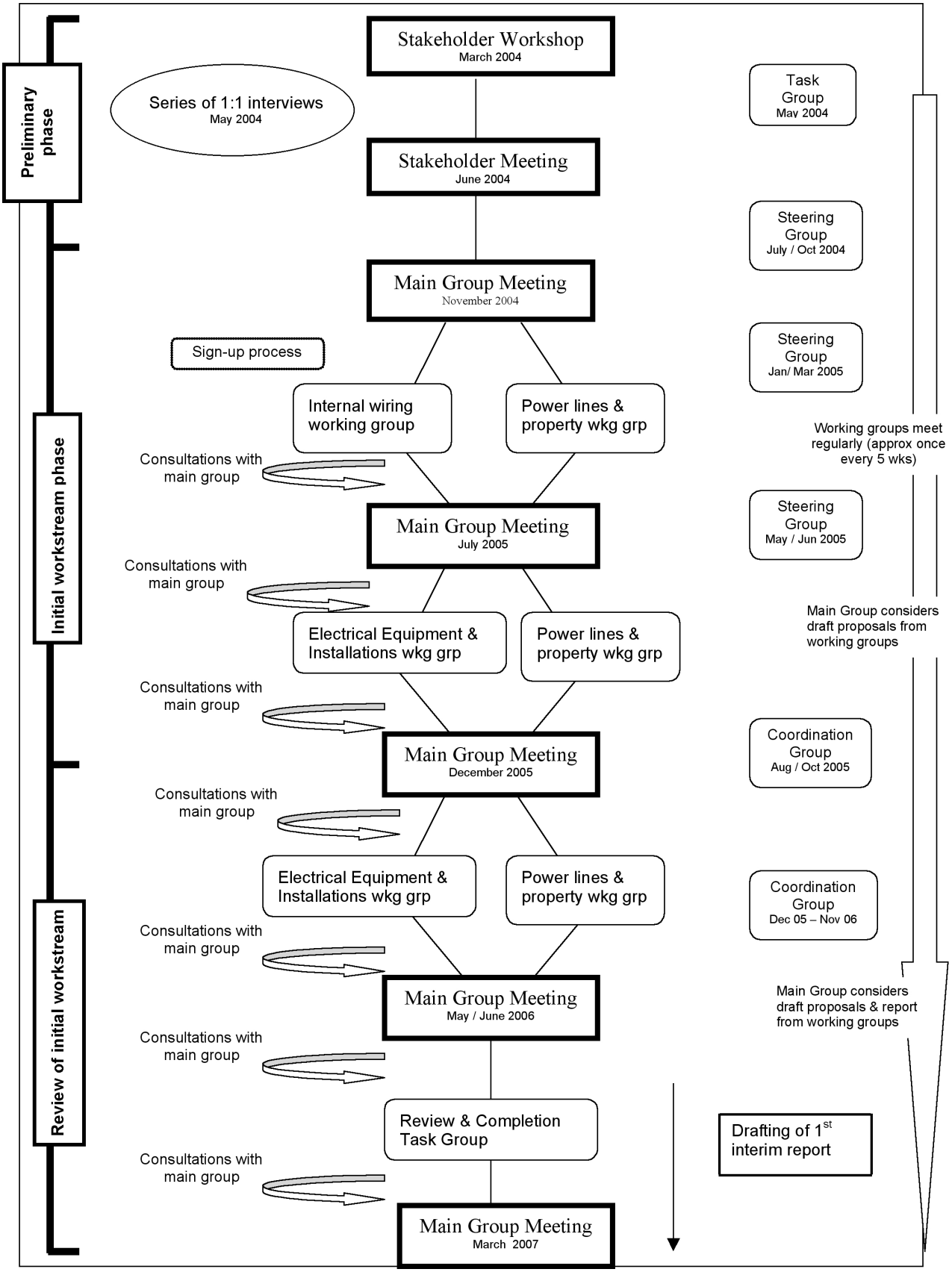
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There are about 40 Stakeholders directly involved in the process (see the list of participants at the end of this Assessment). Together, they are referred to as the Main Group . This "main group" is the overall decision making body within the process . However this group is too large to undertake detailed work so it was agreed to set up working groups to consider the issues in depth and a coordination group to help guide the process. Two groups have been active so far with two still to come, as described in Section 1.4. The structure of how the process "hangs" together is shown in the process diagram on P10.

It has been one of the core principles of the process that decisions be taken by consensus. However, it was recognised that this was not always going to be possible so it was also agreed that, as well as identifying where consensus exists, the areas where consensus does not exist should also be identified and the reasons set out. This principle is carried through the work into this SAGE Assessment.

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The Stakeholder Dialogue Process



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1.2 Background to the science of EMFs

Electric and magnetic fields

Electric and magnetic fields (EMFs) are produced wherever electricity is generated, transmitted or used. In the UK, the power system is an alternating current system, operating at 50 cycles per second (50 Hertz or Hz) so the EMFs also alternate at 50 Hz. This is known, scientifically, as "extremely low frequency" (ELF). It is distinct from the much higher frequency radiofrequency (RF) EMFs, produced by broadcast and cellular communication systems, which interact with the body in different ways, and also from static fields such as the earth's geomagnetic field. Unlike static fields, ELF EMFs are almost entirely of human origin. All further references in this Assessment to fields are basically to ELF fields, but where appropriate we include other frequencies up to a few kilohertz.

At 50 Hz, the electric and magnetic fields are effectively separate entities. Electric fields are produced by voltage, magnetic fields by current, and their magnitudes vary depending on the source producing them. Both fields fall with distance from the source.

Magnetic fields (MFs) are measured in teslas, or, for practical purposes, more often in microteslas (μT, one millionth of a tesla). Electric fields (EFs) are measured in volts per metre (V/m) or kilovolts per metre (kV/m, one thousand volts per metre).

The average ELF magnetic field in UK homes is around 0.05 μT. Typically, in homes, this comes mainly from the low-voltage distribution wiring supplying electricity to the home. About 0.4% of homes have a field in the home of 0.4 μT or more, and in these higher-field homes, the balance of sources is different. In about half of these homes, the field comes from a nearby high-voltage overhead power line. In the other half, the source is a mixture of distribution wiring and wiring within the home. Electrical equipment in the home can produce high localized fields, but people are not generally exposed to these fields for long periods of time. The average ELF electric field in homes is in the range 5-25 V/m, but with localized regions of higher fields. More information on fields and their sources can be found at www.emfs.info .

There is no doubt that ELF EMFs can have effects on the body if the fields are high enough. Specifically, external EMFs induce internal electric fields in the body tissue, which can interfere with the action of nerves. There is uncertainty as to the exact level of field required to produce these effects, but the threshold for observable induced-field effects on nerves from ELF EMFs is, according to most advisory bodies, above 1000 μT and 50 kV/m. Electric fields below this level can also produce indirect effects such as microshocks and contact currents due to surface charge effects.

We are aware of a body of literature concerning how birds and other animals use the geomagnetic field and the variations in it, of order 0.2 μT, for navigation, and how some fish detect low electric fields, but we have not considered these further in this Assessment. Similarly, we are aware that there is a body of literature on geomagnetic activity and human health. The exposures and diseases involved have similarities but also differences to those we are considering. We have not taken this literature into account in our work and have not made any judgment as to how relevant it is.

There are demonstrable physical effects from EMFs at the levels produced by electricity supply systems in some equipment whose design may render it sensitive to EMFs, such as interference with computer screens

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(above about 0.1-1 μT) and with some heart pacemakers (above about 100 μT). Hand-held fluorescent tubes glow in the electric fields under power lines.

At levels below about one microtesla, well below those required to interfere with nerves through induced fields, there are numerous suggestions of other effects on people. Historically, early suggestions concerned childhood cancer, and childhood leukaemia in particular. Other health outcomes for which, with varying degrees of certainty, there have been suggested links to ELF EMFs include (in alphabetical order): adult leukaemia, adult brain cancer, Alzheimer's disease, amyotrophic lateral sclerosis (ALS, the most common form of motor neurone disease), breast cancer, other childhood cancers, depression, electrical sensitivity symptoms, certain types of heart disease, miscarriage, and suicide.

The evidence for these possible health effects has been variously considered by a number of national and international review bodies. Not all bodies reviewed all the outcomes, and the bodies have come to a variety of conclusions. However, for the purposes of this Assessment, we have found it helpful to describe the range of views by reference to just two positions, recognising that this is a simplification.

Views of external bodies on the science of EMFs

We will identify two broad viewpoints on the science, and we will label these by reference to representative bodies which have adopted them. We stress, however, that these viewpoints are not limited to the precise formalism or conclusions reached by HPA, WHO or California (see below) or anyone else; these are simply convenient labels to describe broad viewpoints that exist in the scientific community.

One view is, with minor differences, adopted, among other bodies, in the UK by the Health Protection Agency (HPA, formerly the National Radiological Protection Board, NRPB), and internationally by the International Agency for Research on Cancer (IARC), the World Health Organization (WHO) (though their latest detailed Report is not yet published and may change from what is currently reporteded), and the EU's Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR). We refer to this view in shorthand as "WHO/HPA".

The other view, again with variants, has been set out in a number of places, for instance in draft Reports for the US National Council on Radiation Protection and Measurements (NCRP) and the US Environment Protection Agency (EPA) (though neither of these were adopted by those institutions or published). The National Institute for Environmental and Health Sciences (NIEHS), in a 1999 Report which informed both IARC and California in their reviews, supported this view in part. However, this view has perhaps been most clearly expounded in the Report from the California Department of Health Services[1], and for convenience, we refer to this view in shorthand as "California".

Around the world, most review bodies with an official status seem to have adopted the "WHO/HPA" view, and in particular, in the UK the HPA itself has a statutory role in providing advice. However, on other issues, views which depart from the current orthodoxy, as "California" does, have at times proven to be correct. These considerations do not, of course, prove that either view is necessarily correct.

[1] http://www.dhs.ca.gov/ps/deodc/ehib/emf/RiskEvaluation/riskeval.html

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Both the "WHO/HPA" and "California" views agree that a consistent statistical association (which may or may not reflect causation) exists in epidemiological studies between unusually high background magnetic fields found in homes and a raised risk for childhood leukaemia. This scientific evidence on childhood leukaemia has led:

- IARC to classify magnetic fields as "possibly carcinogenic" (a category used for agents *"for which there is limited evidence of carcinogenicity in humans and less than sufficient evidence of carcinogenicity in experimental animals"*).

- NRPB (now HPA-RPD) *"The government should consider the need for further precautionary measures in respect of exposure of people to EMFs. In doing so, it should note that the overall evidence for adverse effects of EMFs on health at levels of exposure normally experienced by the general public is weak. The least weak evidence is for the exposure of children to power frequency magnetic fields and childhood leukaemia."*

- SCENIHR to state *"The previous conclusion that ELF fields are possibly carcinogenic, chiefly based on childhood leukaemia results, is still valid. There is no known mechanism to explain how electromagnetic field exposure may induce leukaemia. The effects have not been replicated in animal studies."*

- California to state: *"Using the Guidelines developed especially for the California EMF program, one of the reviewers "strongly believes" that high residential EMFs cause some degree of increased risk of childhood leukaemia, another was "prone to believe" that they do, and another was "close to the dividing line between believing or not believing."*

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The WHO/HPA view is that it is only for childhood leukaemia that the evidence is as strong as this. For each other adverse health effect considered, though to varying extents, the evidence is significantly less. Thus:

- IARC classified the evidence from humans for all cancers other than childhood leukaemia as "inadequate", a category one below the "limited" used for childhood leukaemia.
- WHO state *"A recent comprehensive health risk assessment by the WHO ELF Task Group … found, for example, that the evidence "does not support an association between ELF exposure and cardiovascular disease" (WHO, in press). The evidence for breast cancer was also considered to be effectively negative, while for other diseases it was judged to be inadequate."*
- NRPB (now HPA-RPD) *"There is no clear evidence of a carcinogenic effect of ELF EMFs in adults…Studies of occupational exposure to ELF EMFs do not provide strong evidence of associations with neurodegenerative diseases. … Studies of suicide and depressive illness have given inconsistent results … evidence for a link with cardiovascular disease is weak …."*
- SCENIHR state *"For breast cancer and cardiovascular disease, recent research has indicated that an association is unlikely. For neurodegenerative diseases and brain tumours, the link to ELF fields remains uncertain. A relation between ELF fields and symptoms (sometimes referred to as electrical hypersensitivity) has not been demonstrated."*

The "California" view does not see the same difference in the strength of evidence between childhood leukaemia and some other health effects. Thus:

- The NIEHS concluded that ELF EMF exposure should be regarded as a *"possible human carcinogen"* in the IARC classification, saying that the decision was largely based on *"limited evidence of an increased risk for childhood leukemias with residential exposure and an increased occurrence of CLL (chronic lymphocytic leukemia) associated with occupational exposure"*. In this sense NIEHS implicated two health outcomes: both child and adult leukaemia, which is a significant addition insofar as adult leukaemia is much more prevalent, although the evidence cited relates to occupational rather than residential exposure.
- The California Report placed five health effects in the same *"possibly carcinogenic"* category (or equivalent for non-cancers) that IARC used for childhood leukaemia: childhood leukaemia, adult leukaemia, adult brain tumours, miscarriage, and ALS.
- The California Report used another assessment method leading to a Degree of Certainty (between 0 and 100%) for each of 11 specific health outcomes in respect of which there was published scientific evidence. The Degree of Certainty was for the proposition that ELF exposure *"increases [the specific] disease risk to some degree"*. The resulting figures, averaged for the three reviewers, ranged from 25% for childhood brain cancer and 26% for Alzheimer's disease to 57% for adult leukaemia, 64% for adult brain cancer and 72% for childhood leukaemia. In that sense, all 11 health outcomes are given a possibility of risk from ELF, even though only 5 of them would, in the California reviewers' assessment, meet the IARC classification requirements for a *"possible human carcinogen"*.

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Although, for convenience, we describe the "California" view mainly by reference to the California Report, the essence of this view lies in the fact of there being a list of more health effects than just childhood leukaemia, rather than in exactly which health effects they are or how many (five or eleven or any other number) there are in the list.

Within SAGE, we considered why the different review bodies reached their differing conclusions. However, we decided this was not sufficiently material to the policy issues we are considering and so do not include it here.

Views within SAGE on the science of EMFs

Within SAGE, some stakeholders align themselves with the "California" view of the science and some with the "WHO/HPA" view of the science.

This then affects views on precaution. In general, the stakeholders who align themselves with the "California" view of the science also see precautionary measures as being informed by, and based on, the evidence for a number of health outcomes. In general, the stakeholders who align themselves instead with the "WHO/HPA" view reject the idea that the evidence for this range of health effects is a strong enough basis for precautionary measures, and instead see childhood leukaemia as the primary health outcome warranting the consideration of precautionary measures.

This leads us to offer alternative advice to Government. We consider that in detail in Section 5. Here, we confine ourselves to describing the different viewpoints, recognising that some stakeholders agree and some disagree with each view described.

We wish to stress that our task has been to consider possible precautionary measures. By discussing what to do if EMFs caused certain health effects, we are not making any comment on how likely or unlikely it is that EMFs actually do cause those effects, and this Assessment should not be interpreted in that way.

Comparison of EMFs to other issues

Childhood leukaemia (and other diseases and health effects) does not have a single cause, and even in one individual case, more than one causal factor can be operating. Therefore, EMFs are far from the whole picture. Indeed, on some estimates (discussed in more detail later) as few as 2 cases a year out of the over 400 occurring each year in the UK are attributable to EMFs even if EMFs are indeed a cause. However, in this work we are concerned only with EMFs. Note that if EMFs caused some other adverse health effects, about which there is less agreement, then the cases attributable to exposure to EMFs would be much larger.

There are many environmental factors to which most or all people are exposed that are hypothesised to cause harm. These include electric and magnetic fields. In considering the potential hazards posed by electric and magnetic fields, and the effort that should be made to mitigate those risks, it is useful to compare with risks from other hazards. The importance of a hazard can be expressed in two ways: the relative risk of the adverse outcome occurring because of exposure (at a certain level) compared to unexposed persons and the absolute risk in terms of the number of people who may be affected. The number of attributable cases depends on both the size of the relative risk and the number of people exposed to the hazard. For some

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hazards, such as climbing Mount Everest above base camp, the "risk" is very high (about 10% of people die), but because very few people undertake this feat, the attributable numbers of deaths are small.

Public health measures are often directed at hazards that cause a large number of attributable deaths or serious illnesses (for example smoking, lack of exercise, obesity and common childhood illnesses). However, in some circumstances, health protection measures are taken to avert risks that affect fewer people (for example screening of all infants for the rare metabolic disease phenylketonuria).

Supporting Paper S5 shows the UK annual attributable deaths and relative risk of disease incidence for a number of environmental and lifestyle hazards. (For consistency of comparison we show numbers of deaths, but we recognise non-fatal outcomes can also be very serious.) Exposure to electric and magnetic fields at levels below current exposure guidelines has not been recognised by review bodies as an established cause of ill health. However, the existing epidemiological literature has allowed SAGE to estimate the relative risk and possible number of cases and deaths from childhood leukaemia attributable to electric and magnetic fields in the UK, if a causal link were established. These have been used by SAGE to develop its advice (the Ahlbom and Draper scenarios for childhood leukaemia as defined in Section 2). Other medical conditions have been linked to electric and magnetic fields in some published studies, but there is less agreement on these. If a causal link were established for these, the number of cases and deaths attributable to magnetic fields would be considerably greater and the relative risks would apply to a larger selection of diseases.

Within the environmental hazards listed in Supporting Paper S5, childhood leukaemia attributable to electric and magnetic fields or residential proximity to power lines may cause only a few of the deaths. However the relative risk of high exposure to electric and magnetic fields or residential proximity to power lines may be more substantial when compared with relative risks from other environmental hazards.



1.3 Background to protection from EMFs

In radiation protection organisations, both internationally (eg the International Commission on Non-Ionizing Radiation Protection, ICNIRP) and in the UK (eg HPA), there is a paradigm, not always accepted elsewhere, that quantitative exposure limits should be set to protect only against established effects. Thus, the exposure limits in force in the UK, which are numerically the same as those of ICNIRP and the 1999 European Union Recommendation on public exposure, are designed to protect against these induced-field effects on nerves and are not designed to protect against the possibility that much lower EMFs cause cancer or other adverse health effects such as those listed above.

For many years there has been growing recognition in the broader scientific and political community that there are situations where it is sensible to take action (usually described as "precautionary" action) where the evidence is not strong enough to be classified as "established". This has given rise to a body of experience in applying precautionary measures, which can include communication and research.

The pressure to take, or at least to consider, precautionary measures concerning ELF EMFs at levels below present exposure guidelines has been growing in the UK. Public concern on EMFs arises particularly when there are proposals to build new power lines near existing homes, but also sometimes when there are proposals to build new homes near power lines, when individuals contemplate buying a home near a power line or substation, and when existing residents in homes with high fields become particularly aware of health issues. EMFs have often been marked by controversy, polarisation of views, sterile argument, and poor communication, particularly when they have become part of larger disputes which involve the imposition of a detriment (a power line or a new development) on unwilling residents. Further, Government policy

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relating to EMFs has been perceived in some circles as not always clearly expressed or justified, or indeed adequate.

Against this climate of some dissatisfaction with present arrangements and desire to consider precautionary measures for EMFs, two developments in particular led to the formation of SAGE:

- In 2003, National Grid instituted an ad hoc forum to bring stakeholders together, using The Environment Council to organise two workshops in early 2004.

- In March 2004, NRPB (now HPA-RPD) recommended:

  "The government should consider the need for further precautionary measures in respect of exposure of people to EMFs. In doing so, it should note that the overall evidence for adverse effects of EMFs on health at levels of exposure normally experienced by the general public is weak. The least weak evidence is for the exposure of children to power frequency magnetic fields and childhood leukaemia."

The participants of the first two workshops felt that the process should have a more formal, ongoing status, and the Department of Health (DH) adopted this process as the initial vehicle for fulfilling the HPA recommendation to consider the need for precautionary measures. Accordingly, in Autumn 2004 the process became the Stakeholder Advisory Group on ELF EMFs (SAGE) under the lead of the DH. Formal statements of the role of SAGE in Government's eyes are contained in the response of the Minister for Public Health to the HPA:

"The Government will be exploring further the practical applications of precautionary measures within a stakeholder engagement process. This will be the subject of wide consultation and will explore any risks and benefits arising in the same manner as a Regulatory Impact Assessment."

And in similar answers to several Parliamentary Questions, eg:

"The stakeholder advisory group on electromagnetic ELF fields (SAGE) set up last year has already enabled Government officials to engage in detailed discussions with industry, regulators, professional bodies and interest groups about how to respond to this complex issue. The intention of the process is to offer carefully considered practical recommendations in the interests of society as a whole. Information about this process can be found at: www.rkpartnership.co.uk/sage"

In SAGE, our own definition of our objective has been:

"To bring together the range of stakeholders to identify and explore the implications for a precautionary approach to ELF EMF (electric and magnetic fields) and make practical recommendations for precautionary measures"

SAGE has a remit for the whole of the UK, and the devolved administrations are part of the process, but we recognise that the details of how our recommendations are implemented may be different in the different countries.

SAGE is funded equally by DH, the charity CHILDREN with LEUKAEMIA, and the electricity industry, principally through National Grid. No funder has any special status within the process by virtue of their funding.

Independently of SAGE, WHO has been developing precautionary policies on EMFs. SAGE has noted that in many respects their approach and conclusions are similar to ours, but we have not felt bound by their conclusions, or indeed those of any other body.

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Also in parallel with SAGE, the Department of Trade and Industry (DTI) have been leading a working group over the implementation of the 2004 HPA recommendations on exposure guidelines for EMFs. This has involved some of the same stakeholders as SAGE but is distinct from it. The DTI group is concerned with exposure limits at the levels of hundreds of microteslas and tens of kilovolts per metre as a response to established effects; SAGE is concerned with precautionary measures below this level, related to uncertain effects.



1.4 Ways of working and stakeholders

It has been widely acknowledged that public trust and confidence in official information has been an issue in the UK for some years, not least in scientific advice. There is increasing recognition of the issues concerning biases, conflicts of interest, and independence. For example the House of Commons Committee on Science and Technology[1] notes the *"backdrop of widespread concern over a perceived loss of public confidence in the system of scientific advice supporting Government policy making"* in the wake of the BSE affair and the ensuing Phillips Report, and describes subsequent government changes in structure, guidance and review of its systems. In this period of change the relevant UK advisory body on EMFs, the NRPB, has been subsumed in the HPA.

This widespread lack of trust in scientific advice and allegations of conflict of interest are reflected in the history of EMFs and health. There have been (and continue to be) specific published and unpublished allegations, from both sides of the debate, concerning the validity or integrity of the processes used by review bodies and other bodies making statements about EMFs. SAGE does not make a judgement about these reports or about the EMF advice, but is aware of the underlying issue for some stakeholders.

It is in the light of these concerns about the way in which EMFs have been managed before that, within SAGE, we have tried to find a better way of working.

The intent of SAGE is that all relevant stakeholders should be represented. This includes all of the following:

- Government departments with relevant responsibilities: DH; DTI (because of responsibility for overhead lines and underground cables including consent, use of compulsory powers, and, during most of the SAGE process, safety); Department for Communities and Local Government (DCLG, formerly ODPM) (because of responsibility for the planning system); the devolved administrations. The particular role of Government officials is explained in the box on p2.
- Ofgem
- HPA-RPD
- Academics and research organisations working on EMFs
- Professional bodies with relevant expertise either on EMFs and their health effects (eg the Institution of Engineering and Technology, IET), or on relevant issues (eg the Royal Institution of Chartered Surveyors, RICS, the Council of Mortgage Lenders, CML, and the Wiring Regulations part of IET/BSI)
- Environmental groups, citizen groups and activists
- Industry (the electricity industry and equipment manufacturers, and the mobile phone industry because of the similarity of some of the issues)

[1] Seventh Assessment of 2005/6, Scientific Advice, Risk and Evidence Based Policy Making

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We explored with the Department for Education and Skills (DfES) and the Health and Safety Executive (HSE) whether they should participate and agreed that, whilst desirable, it was not strictly necessary. The stakeholders that we invited, and would have liked to have been involved but were not, are:

- Housebuilders and developers
- Cancer Research UK
- The part of DCLG (formerly ODPM) who deal with Building Regulations (who did, however, provide some input)

The inputs needed, and therefore the relevant stakeholders, have to be relevant to the issues we are considering, and is open to review. If you feel you should be a stakeholder in the process you should contact RK Partnership.

A complete list of participants is in Supporting Paper S1 and also at the end of this Assessment. There is no counting of votes or anything comparable within the SAGE way of working so there is no significance in numbers of representatives; the emphasis has been on ensuring that all relevant constituencies are represented

SAGE does not have a Chair. Instead, a professional facilitator, Rob Angell, of RK Partnership Ltd, assisted by Brendan Hickling of TW Welch and Partners Ltd, is employed. We have followed a style of working which:

- encourages the complete range of viewpoints to be expressed and heard
- encourages all issues to be aired and explored before any move towards decision making occurs
- gathers relevant information and encourages a shared ownership of such information
- uses a structured approach to identifying issues and evaluating them
- makes strenuous efforts to reach consensus
- if consensus is not possible, enables stakeholders to explain why they cannot agree, thereby avoiding minority reports
- proceeds by clearly recognising assumptions where necessary
- does not involve voting, or any one viewpoint or sectional interest being allowed to dominate others

In the course of our work, we became aware of numerous papers related to EMFs, some published and some not, some by people outside SAGE and some by SAGE members. It has been important to us to share and to consider all such papers, whether or not we agree with them. These papers are all available via our web site.

This Assessment represents a record and a distillation of the discussions that have taken place to date within SAGE.

Much of what we have discussed we have in fact reached agreement over. However, given the complexity of the issues and the wide range of viewpoints and needs that are represented in SAGE, it has not been realistic to produce a single definitive set of universally agreed conclusions and recommendations. We have come closer in some areas than others, and if we carried on discussing the issues for longer, we might well reach closer agreement on other areas as well. However, rather than continue discussions indefinitely, we have chosen to issue this Assessment now, and therefore it captures the point our evolving discussions have reached.

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Our work so far has in fact seen considerable convergence and shared understanding of the facts and the issues. To some extent, therefore, perhaps to quite a large extent, the contents of this Assessment are agreed by all stakeholders. However, there is probably no stakeholder who is happy with every single statement in this Assessment. Merely by having participated in the process, no stakeholder is thereby bound to agree with every statement in the Assessment, or deemed to agree with every recommendation, or constrained by the contents of the Assessment in their future activities.

Recognising that this Assessment reflects some degree of agreement but not total agreement, each stakeholder has been given the opportunity to make a statement of their view of the point the SAGE discussions have reached. These are contained in ??.

We realise that an Assessment with a status like this one – reflecting some measure of common agreement but without the participants in the process necessarily having agreed with all of it – is unusual as an output of a process designed to provide advice to Government. However, we think this different way of presenting our work has an integrity about it that is in keeping more generally with our way of working in SAGE and with the way understanding of EMFs evolves over time. It would be dishonest to claim we had reached complete agreement among all stakeholders on an Assessment, and it would lead to problems in the future as it would become apparent that not all stakeholders were in agreement with whatever single line was presented in the Assessment. Equally, however, to present two or more completely separate Assessments reflecting different strands of thought and different conclusions would not do justice to the considerable measure of common understanding we have reached and would fail to acknowledge the commitment that has gone in to the SAGE process from many individuals and organisations.

The remit of SAGE has been (and is) to formulate advice for Government and in doing so to identify where consensus exists and, where it does not, why. It is recognised that it is for Government to take decisions, on policy on EMFs and health, based on this advice and other inputs as they deem necessary.

SAGE has deliberated on the issues in this Assessment for two years and the Stakeholders who have participated are listed in Supporting Paper S1. Participation (by organisation or individuals) in either the overall dialogue or the working groups must not be taken as in indication of support or disagreement with the dialogue itself or its outputs.

We consider that the membership of SAGE and our ways of working, whilst not unique, is a leading example of new, more collaborative and inclusive ways of working in science and public affairs.

The Main Group of SAGE members, now over 40 people, has met 7 times so far. We decided to divide the work into (in the first instance) four areas on the basis of different sources of exposure, which would also largely correspond to different expertise needed to address them:

- Electrical installations and equipment, dealing with sources of EMFs inside the home
- Power lines and property
- Distribution, dealing with low-voltage distribution wiring outside the home
- Railways and other sources of EMFs

This choice of working groups reflects a recognition that we are concerned mainly with precaution for the general public, rather than occupational exposure.

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We have prioritised the work, and so far, we have had two Working Groups running in parallel, considering the first two areas. Each has held approximately 12 one-day meetings, followed by a further six days of meetings of a smaller Review and Completion group to finish off the work. A smaller group held two meetings to consider public opinion.

This Assessment covers those first two areas. Following completion of this stage of the work, we intend to consider the other two areas. We have also learnt that the work in the areas we have covered is likely to be ongoing.

There has also been a Coordination Group and a Funders' Group, with membership shown in Supporting Paper S1.



1.5 What happens next

We have put considerable effort into ensuring that as many relevant stakeholders as possible have been part of the SAGE process. Therefore we believe this Assessment should reflect all the main relevant facts and viewpoints, within the constraints of its length; we will be disappointed if it emerges that there is any significant perspective which is missing from our considerations, or that there is a need to consult significant new stakeholders.

However, most of the decisions that have to be made fall to Government, and Government have the responsibility to make their own decisions, both about the principles of precaution involved and about any action to be taken. We reach conclusions, and because we believe those conclusions are soundly based we have an expectation that Government will take them seriously. But where changes to regulation or policy are involved, we recognise that Government will need to perform a Regulatory Impact Assessment (RIA) and go through a formal process of public consultation.

This could take many months, but we urge Government to complete this process as swiftly as possible and to make a clear decision at the end of it. We believe our analysis of costs and benefits provides Government with much of the material needed for an RIA.

In SAGE we now propose to consider the remaining areas we have identified (distribution, and railways and other sources), and we will also be prepared to revisit this Assessment should there be a need to do so. In particular, within the areas we have covered so far, we are aware further work may be useful on (in no particular order):

- Understanding why different scientific review bodies have reached the different conclusions that they have (see Section 1.2), which will include considering the scientific evidence for a variety of health outcomes, and considering different ways of assessing scientific evidence.
- The costs of undergrounding, if new data emerge which suggest the costs may be less than we have assumed (see Supporting Paper S18 Section 5.2)
- The treatment of land which is not currently allocated for development in local plans and whether an option based round this land only might be more attractive (see Supporting Paper S19 Section 1.3)

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- The treatment of land, if the "corridor" option (as defined in Section 5) were introduced, where no development is currently planned and a new power line is built (see Section 5.4 under "implementation of this option")
- Existing homes near existing power lines
- New or alternative approaches to our cost-benefit assessments

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2 Generic issues



2.1 Decisions about the science

We have adopted a principle of seeking ways to make people's exposure to electric and magnetic fields *"as low as reasonably achievable."* We use this phrase in its plain English sense rather than as a legally defined principle. Much of our work has been in determining what is "reasonable."

As discussed in the Introduction we have noted the range of views about the science of EMFs, typified by the two views we have described as "WHO/HPA" and "California". We have therefore considered both. The first leads us to consider the appropriate precautionary response to the possibility that there is a risk from magnetic fields for childhood leukaemia (the "WHO/HPA" view). The second leads us to consider the appropriate precautionary response to the possibility that EMFs also cause other adverse health effects (the "California" view). In Section 5 we describe how some stakeholders align themselves with one view or the other, but in this section we simply describe factually the consequences of each view.

Childhood leukaemia

Consideration of childhood leukaemia is common to both the "WHO/HPA" view and to the "California" view.

The association between magnetic fields and an increased risk of childhood leukaemia is often expressed as occurring at long-term average fields greater than 0.4 μT. For magnetic fields, therefore, we recognise that, within the overall concept of "as low as reasonably achievable", there is a greater imperative to reduce fields that are above 0.4 μT, and a lesser imperative to reduce fields that are below 0.4 μT, and what is "reasonable" will be different in these situations. We also recognise that 0.4 μT is not a precise threshold, does not represent a boundary between "safe" and "unsafe", and should not be used as such. It is simply not possible to be dogmatic about where and at what rate the risk, if any, increases.

The epidemiological evidence on childhood leukaemia, as summarised by the Ahlbom pooled analysis, suggests a relative risk of two (a doubling of the normal risk, see Supporting Paper S4) for children in homes where the field over the general area of the house, averaged over 24 hours or longer, fell in the category "greater than 0.4 μT", when compared to a reference category of "less than 0.1 μT". Even if this is a causal effect there are still uncertainties in interpreting this evidence:

- it could reflect a raised risk only in some high-exposure category, or it could reflect a gradually increasing risk with exposure, of which one example is the "linear no-threshold" model as assumed for ionising radiation
- it could mean the risk is doubled at 0.4 μT or it could mean that the risk averaged over the whole category is doubled and it is less at 0.4 μT but more at even higher fields
- the estimate of the raised risk could be in error if there were errors in measuring the exposure of some of the children in the studies, or if the risk in the reference category is itself raised.

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We have no basis for distinguishing these possibilities, so we have made what we stress is only a working assumption, recognising that it is almost certainly not correct, but believing it to be a suitable basis for considering and comparing precautionary options.

This working assumption, for the purposes of assessing options, is that for all time-average fields greater than 0.4 μT the risk is doubled, and for all time-average fields less than 0.4 μT there is no increase in risk.

Other adverse health effects

Consideration of other adverse health effects is specific to the "California" view.

The other adverse effects that have been linked with EMFs are, principally, (in alphabetical order) adult leukaemia, adult brain cancer, Alzheimer's disease, amyotrophic lateral sclerosis, breast cancer, other childhood cancers, depression, electrical sensitivity symptoms, certain types of heart disease, miscarriage, and suicide. For some of these the potential public-health impact if EMFs did cause the suggested increased incidence would be much greater than it would be for childhood leukaemia, because they are more common. We list the number of cases of some of these health effects occurring nationally in Supporting Paper S4.

0.4 μT, measured as the 24 hour or longer average, is a value from the literature on childhood leukaemia. Even there it has uncertainties, which we discuss elsewhere, and evidence involving peak exposure has been suggested in relation to miscarriage.

While it may not be the best value to use for all other possible adverse health effects, we use the same long-term average value as a benchmark for exposure reduction across all the possible health effects we consider.

Issues common to both

We considered in detail various alternative measures of the field (see Supporting Paper S2) but concluded that the long-term average field in the home was the best measure to use as our benchmark. Exposure reduction actions are in any case likely to reduce fields in most measures. This conclusion could change if, for instance, evidence involving peak exposure (as has been suggested with reference to miscarriage) or night-time exposure (with reference to the "melatonin hypothesis") became stronger.

Existing scientific data, certainly for childhood leukaemia, largely relate to homes only and the data say little about schools. We have considered alternative approaches to schools and other places where people spend time outside the home, as laid out in Supporting Paper S20.

Overall, we consider it reasonable, if taking measures for homes, to take equivalent measures for schools, whilst recognising that this is an extrapolation from the scientific data. [1]

1 Ofgem did not agree with this extrapolation from homes to schools

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As well as the main body of evidence on magnetic fields we considered the "Draper study", which suggests raised risks for childhood leukaemia from power lines but at greater distances than would be accounted for by magnetic fields; and the "corona-ion hypothesis", which likewise suggests effects at larger distances from power lines. In both of these cases the evidence is weaker than that for magnetic fields, and we did not formulate recommendations specific to either. However, we have investigated whether consideration of either case would modify our conclusions and this is incorporated in our recommendations on power lines.

We consider that the options available for reducing fields and the technical and cost implications are unlikely to change greatly over, say, the next decade, and therefore we suggest there is little point in revisiting our conclusions unless: new evidence comes to light; factors relevant to our cost-benefit analysis change significantly (for example the incidence or survival from childhood leukaemia); if our working assumptions become seen as no longer appropriate; or the science changes substantially.

A "substantial" change in the science would be one, for example, justifying a change in the classification of EMFs on the IARC scheme (described in Section 1.1; note that, although IARC itself is concerned only with cancer, other bodies have used its scheme to classify effects on non-cancers), specifically:

- for childhood leukaemia, the classification changing from the present 2B either upwards or downwards
- for any other adverse health effect with a significantly larger public-health impact than childhood leukaemia, a classification from a major review body significantly stronger than at present.



2.2 Assumptions about risk

For childhood leukaemia, where we have made a numerical assumption (no increased risk below 0.4 μT and a doubled risk above 0.4 μT) for the purposes of assessing options, we have found it helpful to set out some of the basic figures on risks and exposed populations, and these can be found in Supporting Paper S4. That paper deals with two scenarios: that there is a risk from magnetic fields at 0.4 μT, referred to in shorthand as the "Ahlbom" scenario, and that there is a risk with distance from power lines, based on the paper by Draper et al (2005) and referred to as such.

The key figures for the Ahlbom scenario are that, if magnetic fields do cause childhood leukaemia: the base risk for childhood leukaemia of 1 in 24,000 per year would be increased to 1 in 12,000 per year for homes above 0.4 μT; and the number of excess cases attributable to magnetic fields would be 2 per year in the UK from all sources, of which 1 is from power lines. These are the figures we use in some of our cost-benefit calculations. The figures for the "Draper" scenario, as can be seen in Supporting Paper S4, are larger.

As already discussed, we do not present equivalent calculations for the scenario where magnetic fields cause other adverse health effects, but we note that the potential public health impact would be greater, and we estimate how much greater in Section 2.4. Nor have we performed calculations for electric fields.

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2.3 Criteria for assessing consequences and implications of options

We recognise that any measure we might propose would have numerous consequences, some directly related to EMFs and some much wider. To judge the acceptability of possible measures and to choose between them, we need to assess these consequences. We have therefore identified certain criteria. These are listed in more detail in the specific sections on power lines and on home wiring. However, we have deliberately not treated these criteria as a definitive list, nor attempted to use them quantitatively to produce a mechanistic formula for decision-making. The objective has been to use the criteria to ensure we have understood the consequences and implications of each option, then to make an overall assessment of that option.

One criterion is the cost of an option, and one way of addressing this is to perform a cost-benefit analysis. We have constructed a form of cost-benefit analysis and present the results in Supporting Paper S6. We also summarise our approach in the following Section 2.4.

Another issue that we recognise as a valid factor for Government to take account of is public opinion, and we discuss this in the following Section 2.5 and in Supporting Paper S7.

We are aware of the recommendations from the Better Regulation Commission[1], who emphasise the importance of shifting management of risk, where possible, away from regulation by state to informed decision-making by the people affected. However, we recognise that members of the public may often have limited control over exposure from some sources, eg power lines.

When Governments come to decide whether or not to implement our recommendations they will be influenced by a number of factors. Many of these, such as financial costs, health benefits, and public opinion, we have already included in our considerations.



2.4 Cost-benefit analysis

We recognise that cost-benefit analysis is an important tool for society in determining the most effective use of resources, and in ensuring that society does not devote so much resource to one issue that it results in more harm in other areas than the benefit it creates. It is a way of assessing the proportionality of any response to a health or safety issue. We also recognise that cost-benefit analysis is just one tool; other social or political factors, which do not lend themselves to inclusion in a cost-benefit analysis, are relevant.

Within the SAGE process we have regarded cost-benefit analysis as important but not providing a definitive answer on its own. However, although Governments always retain the right to make their own decisions

[1] "Risk, Responsibility and Regulation – Whose risk is it anyway?", http://www.brc.gov.uk/publications/risk_Assessment.asp

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whatever the cost-benefit analysis shows, we recognise that cost-benefit considerations are highly important for Government, and that is why we give them considerable prominence in this Assessment.

We have performed a quantitative analysis of costs and benefits of the main options we have considered. The benefits of an option depend on whether we are considering the possibility that magnetic fields cause childhood leukaemia or in addition the possibility of other adverse health effects, whereas the costs of an option are the same in both cases. The details are set out in Supporting Paper S6; here we give a summary. We are concerned only with health benefits; some of the options we consider have other benefits (such as reducing the visual impact of a power line) which are clearly relevant and which could add to the health benefits, but those lie outside the scope of this analysis.

Costs

We identified the costs of each option by considering the whole of society; that is, we have not restricted ourselves to costs to specific sections of society, but have aimed to identify all costs regardless of where they fall. We have been mindful of the Cabinet Office guidance[1] to quantify in general "first-round" effects only; where this is ambiguous, we give alternative figures for different definitions of this.

Our estimates of costs for options relating to wiring in homes are contained in Supporting Paper S10, and range from nothing to £30 per home built this way. Our estimates of costs for options relating to power lines and property are contained in Supporting Paper S19, for example costs of £10M per km to place high-voltage power lines underground, or a possible cost of £1bn or more for restricting any further development near power lines.

To reach all these figures we have made many assumptions, as set out in Supporting Paper S6. The details of these assumptions could undoubtedly be challenged, and we recognise the many imprecisions in our work. Nonetheless we believe the results we obtain, whilst not intended to be precise, provide a realistic estimate of the order of magnitude of the relevant quantities.

Benefits

Our estimates of costs tell us how much it could cost to reduce exposure by a given amount. The next stage is to estimate, as best we can given the many uncertainties, how big a reduction in adverse health effects this reduction in exposure could produce. We do this for our two views of the science, "WHO/HPA" and "California".

[1] http://www.cabinetoffice.gov.uk/regulation/ria/ria_guidance/index.asp

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Benefits for childhood leukaemia

Consideration of childhood leukaemia is common to both "WHO/HPA" and "California".

For the purposes of this analysis only, we made an explicit assumption that magnetic fields do cause childhood leukaemia; there is no allowance in our analyses for the uncertainty in whether this is true.

Similarly in some places our valuation of benefits errs on the high side compared to current Government practice. On the other hand, some considerations, listed in Section 5 of Supporting Paper S6, would err the other way. We discuss alternative assumptions we could have made, and the effect this would have on the result, in Supporting Paper S6. Here we present just our agreed values.

We take the value to society of preventing a fatal case of childhood leukaemia as £4M, and for a non-fatal case, £0.5M. This gives an aggregate value of preventing a single case of £1.6M, To obtain the value of preventing one case per year going forward in time, we used the HSE and Treasury Green Book procedures on discounting future benefits to obtain a value of preventing one case per year going forward of £50M. We recognise that alternative approaches are possible, described in Supporting Paper S6, but all these variations are fortuitously likely to result in similar answers to the Treasury approach, at least to within a factor of two or so, and we proceed on this basis.

To relate this benefit to the options for precautionary measures, we assume that removing a home from a field of greater than 0.4 μT to a field of less than 0.4 μT removes any child living there from a relative risk of two for childhood leukaemia. Nationally, therefore, on the basis of the figures in Supporting Paper S4, removing all homes from fields of >0.4 μT from all power lines has a value to society of £50M (one case prevented per year); removing them just for National Grid power lines, a value of £25M (one case prevented per two years). For each single home that is moved from above to below 0.4 μT (regardless of the source of the field) the value is £1k (see Supporting Paper S6 for the derivation of this figure).

Benefits for other adverse health effects

We now consider the health benefits that would occur from removing exposure to magnetic fields if these were a cause of health endpoints other than childhood leukaemia. This consideration of other adverse health effects is specific to the "California" view. Whilst not all stakeholders agree on this view, as discussed in Section 1.1, we all recognise the need to work through what the consequences of this view would be.

The health benefit depends, of course, on which health endpoints are considered. It also depends on how likely we think magnetic fields are to cause those endpoints, the level of increased risk, and at what field this occurs. Just as with childhood leukaemia, but often to a greater extent, there is uncertainty in all these factors and in any calculation of health benefits.

Despite the uncertainties, some sample calculations have been performed, following a similar approach to that with childhood leukaemia, but using, in part, numerical values and assumptions from the California Assessment. These calculations suggest the health benefit of removing a home from magnetic fields could be a hundred or so times larger if a range of endpoints is considered than if just childhood leukaemia is considered. As with childhood leukaemia, the choice of data and assumptions used to derive this figure can undoubtedly be challenged. In particular, some of the calculations assumed, as we did for childhood leukaemia, that magnetic fields actually do cause all the adverse health effects considered, but others included factors expressing the uncertainty of whether magnetic fields cause each health endpoint. This quantification of the uncertainty has a moderating effect on the estimate of benefit in this "California" approach. These sample calculations would not necessarily be agreed by all stakeholders. However, the purpose of them is to get a sense of the order of magnitude of the answer under various assumptions, rather than to imply that any of the specific assumptions and the answers that follow are valid or correct.

An alternative perspective, albeit less rigorous, is that, when moving from considering childhood leukaemia alone to a wider range of adverse health outcomes, we are doing two things: one, increasing the number of health outcomes considered, and two, including some outcomes which are much more common. It therefore seems plausible that the impact could be something around two orders of magnitude (ie two factors of ten, giving a hundred overall) larger. Given the uncertainties involved, it does not seem appropriate to seek to achieve any greater precision than this.

Note that, as for childhood leukaemia, EMFs are hypothesised to cause only a proportion of the cases of each disease, all of which have multiple or complex causes.

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2.5 Public Opinion

Another issue we considered is public opinion. We recognise that Government will always wish to consider public opinion when making decisions on public policy. In addition, public concern, separately from the actual health issue, is accepted as a material consideration in the planning system in England and Wales, albeit one usually carrying only limited weight. Some argue therefore that there is a legal basis for considering public concern alongside scientific evidence and cost-benefit analysis in determining what precaution, if any, to take. Others disagree with this legal interpretation. But we all accept that in practice, public opinion is a relevant factor for Government.

Measuring public opinion is an imprecise art. There are two principal techniques; qualitative and quantitative. Each is limited in what information it can reveal. The biggest problem in interpreting results is that they depend on the stimulus to which the respondent is exposed. No single study is capable of getting the all-round view. For example, a person will respond differently depending on whether they are told that childhood leukaemia is mercifully rare or whether they are told that despite huge advances in treatment, it is still on the increase and even in the last five years has claimed the lives of more children than any other disease.

We have considered several UK surveys and studies on or directly relevant to EMFs of which we are aware (Table 2.1). We believe these represent a cross section of methodology, stimulus material, and commissioning organisations. Full details of these studies and web links are given in Supporting Paper S7.

Alan Preece, University of Bristol, for Department of Health	A quantitative study looking at the effect of different stimulus materials on levels of concern.
Nick Pidgeon, University of East Anglia, for Department of Health	A detailed study using a mix of quantitative and qualitative techniques.
MORI for National Grid	A quantitative study repeated every two years since 1997 looking at public opinion with prompted and spontaneous awareness.
Opinion Leader for CHILDREN with LEUKAEMIA	Deliberative work exploring opinions in a group setting, with and without stimulus material.
TNS for CHILDREN with LEUKAEMIA	Quantitative studies (one in GB and one in Scotland) using stimulus material.
Scottish Executive	A study of 24 environmental issues, including power lines, with a prompted qualitative comparison.

Table 2.1

We have also considered various sources of anecdotal evidence (eg usage of web sites and telephone helplines; reports of concern expressed in Netherlands following introduction of precautionary measures) which were never intended as measures of public opinion but which afford some insight, which we have regarded as useful.

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These studies build up to a reasonably consistent picture:

- The risk of adverse health impacts from EMFs is not a "top of the mind" issue at present; low percentages of people mention it spontaneously or pick it out from lists that cover a range of environmental, health or local issues.

  Example: with no specific prompt, 1% of public mention EMF/power lines etc; when prompted, but still with no explanatory stimulus material, 9% of people say it is of concern.

- If the public are given stimulus material, describing the possible health risks of EMFs, surveys can return much higher levels of public concern. Generally, the more the stimulus material characterises the risk as established and the more serious it makes it sound, the greater the concern expressed, up to 80% in one study.

- There is some evidence that the effect of stimulus material in raising concern may be temporary, and public concern may revert to normal lower levels in the absence of continued or further stimulus.

  Examples: several months after being sent "high risk" material the response was the same as people sent "low risk". After both the publication of Draper et al in 2005 and leaks of the SAGE draft Assessment in the media in 2006, calls to the electricity industry helpline and hits to its web site doubled or trebled, but reduced to only slightly higher than normal levels after one or two months.

- Whenever presented with a number of alternative environmental or health issues, EMFs are rarely of greatest concern. The wider the range of issues, the smaller the proportion of respondents selecting EMFs. However, EMFs are ranked higher than some other issues, and one notable example is the low level of concern surrounding the established health risks from radon.

  Examples: Power lines ranked 15th out of 16 environmental incivilities; EMFs/power lines 9% concern compared to Bird Flu 39%, Passive smoking 39%, GM crops 19%, Mobile phones masts/telephones 16%.

- If presented with appropriate stimulus material, and if invited to concentrate on EMFs alone rather than comparing it with other issues, many people will express a desire to see preventative action taken and a willingness to contribute to the cost themselves.

  Example: following stimulus material, 58% of people said they are willing to pay extra on their electricity bills to fund action.

We have concentrated here on describing rather than explaining public opinion. However, much of what we have described is understandable in terms of what is known generally about public fear of risks and which types of risk are of more concern.

There is evidence (anecdotally from Netherlands, and in a series of published studies on precautionary measures for mobile phones from Switzerland) that taking precautionary action can itself be a stimulus that increases public concern. However, we do not know how long such an effect would last, and it may be that, logically, the introduction of precautionary measures could decrease concern.

In a rather different context, the willingness of MPs to sign Early Day Motions (EDMs) is, in part, an indication of their concern about the issues involved, although it no doubt reflects political and other factors as well. An EDM in support of action to protect children's health attracted many more signatures than one on fuel poverty. The EDM on EMFs (EDM403) ranked within the fifty most supported EDMs in the 2005-6 parliament, with the support of well over 200 MPs.

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Some of the options we consider for power lines, for example corridors along lines where development is not permitted, are likely to have an effect on property values (which we discuss in Section 5 and Supporting Paper S17). For many people, fear of a loss of their money through devaluation of their house, or fear of not being able to sell their house, may be just as great or greater than fear of health effects (there is anecdotal evidence of this from calls to the electricity industry helpline). This extra factor is generally not addressed in the work on public opinion we have considered here. Similarly, by focussing on public opinion on the health issue, opinion regarding the visual impact of power lines and the desirability of taking action for that reason has not been addressed in this work.

We recognise that an expressed willingness, when answering questions in an opinion poll, to spend money may not always translate into an actual willingness to do so when the time came, but we do not have evidence on the size of this effect. Neither have we considered the effect on public opinion of a Government failure to introduce precautionary measures in a context of growing public awareness, or indeed the form that such growth in public awareness might take, e.g. the possibility of sporadic waves of public alarm following media stories.

We conclude that public concern can be argued either way.

- If the focus is on how "top of the mind" the issue is – what the current level of concern is – this is a sound basis for ranking precaution as a low priority. Action on EMFs could be ranked as an even lower priority if it is compared to other energy issues such the nuclear-power debate.

- If the focus is on what is revealed after people are supplied information about EMFs, and if that is seen as a representing a genuine underlying concern, there is evidence of a public willingness to see precaution taken, and this effect is most marked when compared only with other children's or health issues rather than to wider energy issues. For some stakeholders this could then become a basis for Government to implement the "best available option" despite an unfavourable cost-benefit analysis.

HPA do not have a view on whether public opinion alone should be the basis for precaution, but they state that where science is uncertain, public concern can sometimes be a legitimate factor to consider, and they imply this is the case for EMFs.

We agree that it is right and proper for a government to give consideration to public concern when determining what action to take.

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2.6 Other countries

Many countries have adopted the ICNIRP exposure guidelines. We are aware of a number of countries that have taken precautionary measures on EMFs, though such countries are a minority. These are detailed in Supporting Paper S8.

These precautionary measures have been of a variety of types:

- Reduction of the international exposure guidelines (which are based on interference with nerves, not on long-term effects at lower levels, and are accordingly at much higher levels) by various factors: eg China, Poland
- Requirement to spend a certain proportion of the cost of a project on reducing fields from new power lines: eg Australia, California
- General, non-quantitative encouragement to reduce fields: eg Sweden, Denmark
- Exposure limits in the range 0.4 – 10 μT, almost always applying to fields from power lines in particular rather than fields in general, almost always applying to new lines or new homes near lines rather than existing situations, and almost always applying to a specified list of locations such as homes, schools etc rather than land in general: eg Italy, Switzerland, Israel, Netherlands, Slovenia

For most of these countries, our knowledge of what lies behind the measure is limited. For example, we rarely know:

- what cost-benefit analysis was performed before introducing the measures
- how effectively the measure is enforced in practice and how often exemptions are granted
- an assessment of costs and other consequences since introducing the measure.

We also note that costs depend critically on arrangements for land ownership and compensation around power lines, and on the economic structure and regulation of the electricity industry, which differ from country to country.

We are not aware that these measures have had unsustainable consequences in any of the countries involved. However, because of the limitations in our knowledge, we are unable to read too much into this.

We are not aware of any evidence that links different rates of childhood leukaemia (or any other adverse health effect) in different countries to whether that country has adopted precautionary policies or not, or to whether it has, eg, ring mains or radial circuits (see Section 3), or indeed simply to whether it has higher or lower exposures. However, given that on our assumptions magnetic fields are estimated to cause only a few percent at most of cases of childhood leukaemia, if indeed they cause any, a reduction in any cases caused by magnetic fields would be effectively undetectable in epidemiological studies.

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2.7 The WHO "Precautionary Framework"

There are several international treatments of the precautionary principle. There is one, however, that has particular relevance to our work, because it relates specifically to EMFs. This is WHO's "Framework guiding public health policy options in areas of scientific uncertainty with particular reference to EMFs". This has evolved over several years and some SAGE participants were also involved at various stages in the formation of this Framework.

Within SAGE, we do not feel compelled to follow automatically whatever WHO may recommend. Nevertheless, WHO is an influential and, to some extent for the UK, authoritative body. If there are significant differences, we want to be aware of them and to understand why we differ from WHO.

WHO have not yet formally issued a final version of the Framework. We have used the most recent version to have been made publicly available by WHO (in May 2006), recognising that this is still a draft version.

In fact, in most respects, the WHO Framework and our Assessment do indeed reflect similar approaches. The WHO discussion of how to apply precautionary thinking stresses, among other things, recognising the social and political context; identifying all relevant uncertainties; considering a full range of options; analysing benefits and costs, both financial and other; recognising when society may wish to err on the side of caution; selecting options that are proportionate to the strength of scientific evidence and the consequences; and performing a quantitative health-economics analysis where the data permit. All of these are consistent with our approach. The list of precautionary options considered and the general discussion of them is also similar.

Their main conclusions (including some relevant to the lower distribution voltages, which SAGE has not yet considered) under the heading "Option Selection" are:

"Even after fully allowing for the legitimate desire by society to err on the safe side, it seems likely that only very low-cost measures will be justified.

Specifically:

- *exposure limits set at 0.3 - 0.4 μT or similar levels are not scientifically justifiable. WHO considers that for EMFs, exposure limits should continue to be based on effects scientifically regarded as "established" and recommends against setting exposure limits as a precautionary measure.*
- *any measures involving changes to engineering practice seem unlikely to be justifiable, unless they bring other benefits as well, such as greater safety, or unless local circumstances mean they are of particularly low cost.*
- *it seems unlikely that a precautionary approach to EMFs alone could justify a change to distribution grounding practices, but EMFs should be considered alongside safety, reliability and economics when changes are contemplated*
- *appliance manufacturers should investigate whether magnetic fields could be reduced at low cost, and whether offering consumer choice of low-field appliances could be an advantageous marketing strategy*
- *enforcing existing wiring codes so as to reduce unintentional ground currents must be sensible, but high costs in proactively seeking out and identifying existing errors are unlikely to be justifiable*
- *planning and land-use regimes for high-voltage power lines can incorporate genuinely low-cost options, but the costs and consequences of changes to existing regimes is so dependent on national circumstances that no generalisation is possible*

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- *continuing and enhanced research programmes are desirable to remove uncertainty in the future*
- *communication to the public allowing informed decision making seems eminently sensible and justifiable"*

One of the main differences between our work and WHO's is in the area of adverse health outcomes other than childhood leukaemia. WHO, in this policy recommendation (which is a separate document from their review of the scientific evidence) conclude:

- *"Power-frequency magnetic fields are classified as "possibly carcinogenic" (IARC 2B carcinogen) on the basis of the evidence on childhood leukaemia. The evidence linking power-frequency magnetic fields to other health outcomes, and the evidence on power-frequency electric fields, is weaker than the IARC 2B classification.*

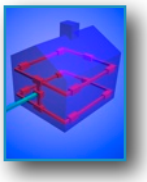
- *Therefore, under this Framework, magnetic fields and childhood leukaemia warrants a full cost-benefit analysis, but for other health outcomes, there is a presumption that only no-cost or very low-cost options would be justifiable, and the assessment is less detailed. Cost-benefit or cost-effectiveness analysis should therefore primarily be based on childhood leukaemia."*

Thus, in this draft WHO align themselves with the view we have described as "WHO/HPA" rather than the view we have described as "California".

As already discussed, not all stakeholders within SAGE agree with this view; some stakeholders strongly disagree with the WHO approach.

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3 Wiring in homes



3.1 Introduction

In all homes, the internal wiring makes some contribution to the electric and magnetic fields inside the home. For magnetic fields, however, normal, correctly installed home wiring is rarely a significant source of fields, because "go" and "return" currents are usually balanced and close together, resulting in a large degree of cancellation. Home wiring becomes a significant source of magnetic fields only if one of a number of specific features is present (described in more detail in Supporting Paper S9):

- A ring-main power circuit where, because of an interrupted conductor or a high-impedance joint, the phase and neutral currents split in different proportions round the two arms of the ring, resulting in unbalanced currents.
- A circuit, usually a two-way switched lighting circuit, where the phase and neutral currents flow different ways round a loop
- An accidental connection between neutral and earth within the wiring which allows some of the neutral current to return via earth and creates an unbalanced current
- Loops of current in the vicinity of the electricity meter and the consumer unit
- The electricity meter itself; traditional rotating disc meters produce relatively high magnetic fields, which fall off over a metre or so but which can be a significant source of exposure eg if a child sleeps with their head close to the meter, including on the other side of a wall.

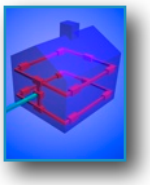
The best data available in the UK[1] suggest that, of the 0.4% of homes (80,000 homes) where fields are greater than 0.4 μT, perhaps a quarter or 0.1% (20,000 homes) are due to house wiring.

For electric fields, external sources of field are less significant inside the home because they are screened by the building structure. Wiring in the home is therefore a more significant source of field than for magnetic fields. In addition, the cancellation between phase and neutral is not as effective. Electric fields are produced by all wiring containing a live conductor, unless the wiring is contained in a metal conduit or has a screen in the sheath, and are present all the time.

For blocks of flats and apartments, we believe our analysis and conclusions about internal wiring still apply. In addition, however, fields can arise from the way electricity is distributed to the flats within a building. These issues will be considered by the next SAGE Working Group, on Distribution, discussed in Section 1.3.

[1] http://www.hpa.org.uk/radiation/publications/hpa_rpd_reports/2005/hpa_rpd_005.htm

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3.2 Options for reducing fields from wiring in the home

We looked at a long list of possible options for reducing exposures, so as to be sure of covering everything relevant, including:

Primarily to reduce magnetic fields

- Changing ring power circuits to radial circuits
- Inserting plastic sections in metal services such as gas and water pipes
- Keep "go" and "return" currents together at all times
- Protect whole installation with a residual current device (RCD, see Supporting Paper S9)

Primarily to reduce electric fields

- Placing all wiring in metal conduits
- Use all-metal accessories and mounting boxes
- Use cables with a screen
- String-pull or remote control light switches
- Locate sockets away from the bed
- Apply earthed metal screening tape over cables in walls and ceilings
- Use demand switches to disconnect voltage when circuit not in use

For both electric and magnetic fields

- Site the meter and consumer unit appropriately
- Use extra-low-voltage circuits in homes
- Use DC circuits in homes

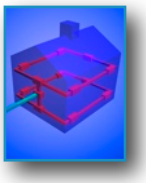
To allow people to know about and reduce their exposures by their own actions

- Labelling of meter and installed equipment
- Requiring a document in each home recording the fields

We assessed these options against the following criteria:

- Safety
- Effectiveness at reducing fields
- Level of technical difficulty
- Complexity to introduce
- Cost

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3.3 Best available options

For wiring in homes, there is no single "best" option, and instead we have identified the following as the best available package of options:

To reduce magnetic fields:

- Wire power circuits as radial circuits instead of ring circuits
- Ensure that "go" and "return" currents are kept physically close together at all time, particularly in relation to two-way switching of lights and to the layout of underfloor heating cables
- Protect the whole electrical installation with a residual current device (RCD)
- Use electronic electricity meters rather than rotating-disc meters
- Keep meter tails physically close together
- Position consumer units (and rotating-disc meters) away from high-occupancy areas

To reduce electric fields:

- Wire homes using cable which has a screen within the overall sheath

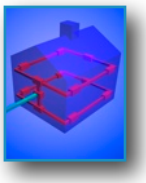
We have examined these options for their consequences, including safety. None have any serious problems, and specifically, we do not believe that any are less safe than at present, and some bring safety advantages.

These options could be applied to varying degrees, which we summarise in Table 3.1 below.

	Precautionary Action	Implementation	Characteristics
Range of options with increasing precaution	Do nothing; no change to existing situation	No legislation, regulation or voluntary codes needed	• No cost • Likely continuing dispute • Potential political fallout and continuing criticism • No reduction in exposure levels
	Provide information	No legislation or regulation needed	• Demonstrates acceptance of desirability of reducing exposures • Empowers people to make a choice • Could either allay or aggravate public concern • Low cost • Does nothing directly to reduce exposures
	Voluntary testing of homes for high fields. Remedial action paid for by householder.	No legislation or regulation needed. Agreed procedures and training for tests.	• Empowers people to make a choice • Take up may be low (based on radon experience)
	New wiring practices for all new homes	IET guidance to electricians	• Reduces exposures in new homes and when homes rewired • Additional cost
		Changes to Wiring Regulations or Building Regulations	
	Mandatory testing of existing homes and remediation	Building Regulations or other regulation or secondary legislation	• More effective at reducing high fields now • Considerable extra cost • Training for electricians

Table 3.1 (shaded areas show SAGE's preferred options)

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3.4 Conclusions

As discussed in Section 2.1, our primary focus is to reduce magnetic fields, because it is these which are most strongly associated with childhood leukaemia. For electric fields, we consider more research would be desirable. To apply our package of options to reduce magnetic fields to a new home or when completely rewiring an existing home would, we estimate, cost an additional £20. The benefit in terms of reduced cases of childhood leukaemia ("WHO/HPA"), even assuming that magnetic fields are causal, we estimate as £1 per new home (the details of how we derived these figures are in Supporting Paper S10). Considering other adverse health effects as well as childhood leukaemia ("California", as discussed in Section 1.1) would strengthen the case for these options, but amongst the stakeholders within SAGE we do not have agreement on whether this is appropriate. Therefore, we do not have a clear justification for this package of options in health cost-benefit terms. However, in view of the small absolute cost per home, particularly when seen in the context of the total cost of building a new home, and the fact that there is a trend for some of these options to happen anyway for other reasons, we nonetheless recommend that this package of options should be implemented.

Therefore we recommend that:

- **The IET should issue guidance to electricians (contained either in the On Site Guide or as a separate Guidance Note) recommending the change to radial power circuits, keeping "go" and "return" currents together, and keeping meter tails together. The IET Wiring Regulations Policy Committee should consider this, and the Government representatives on this committee should take responsibility for monitoring acceptance and implementation of this recommendation. We considered the alternative of recommending a change to BS7671 (the "wiring regulations"), but felt that guidance to electricians would be just as effective and easier to achieve.**
- **BS7671 should be changed to require RCDs for the whole installation. We understand this is likely to happen with the next revision in January 2008 anyway, but if it does not, then the IET should implement it as guidance for electricians as for the previous options.**
- **Use of rotating-disc electricity meters should be phased out. There is already a strong trend to this and 95% of meters currently being installed in new properties, and to meet re-certification requirement, are electronic. However, it is not clear how this can be made mandatory.**
- **Alternatively, depending on how effectively a move to electronic meters can occur, DCLG (formerly ODPM) should modify the Building Regulations to specify that electricity meters and consumer units for new homes should not be located close to high-occupancy areas.**
- **HPA should produce information for householders on sources of field and steps that can be taken to reduce them.**

These measures would result in the package of options being applied to new homes and when rewiring is taking place anyway. We do not believe it is justifiable to require these options to be applied retrospectively in all homes. However, if a test shows that high magnetic fields are present in a home due to some feature of the wiring, we believe it is sensible to take actions to reduce the field, using whichever of these options is appropriate to the source of field that has been identified. Taking such action would also be justified in cost-benefit terms as shown in Supporting Paper S10.

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We therefore recommend:

- **That where high magnetic fields as a result of house wiring are identified in an existing home, the source of those fields should be removed or remediated.**
- **To identify high fields in existing homes, it should be an option that a simple measurement of magnetic fields be performed when either a Periodic Inspection of the house wiring or a Building Survey in connection with the sale of the home is being performed.**

This would require at least some electricians and surveyors to be suitably trained and equipped. If this test identified high fields, identification of the source might require a separate visit by a more highly trained person. We describe the tests we envisage in Supporting Paper S11. In due course, in the light of experience, a separate decision could be made as to whether to make this test mandatory, perhaps as part of the new home buyer's Assessment.

Occasionally, high fields in one home arise from a source in the neighbouring home. We recognise that the options available to the person affected may be limited in this situation.

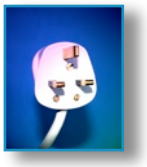
In line with Supporting Paper S3, we consider that the measures we propose for homes should also be applied to schools, similarly applying to new wiring and available as an option for existing wiring, though we recognise this places an extra burden on school budgets.

For electric fields, there is a less strong case for reduction, and we do not recommend that our option should be implemented routinely. Rather, it should be available to those householders or developers who wish to use it.

Our option for reducing electric fields requires a type of cable (conventional twin-and-earth but with a screen inside the sheath) that is available at present only at a considerably higher price than normal cable; we recommend that a cheaper version should be developed. In the interim, we give other methods of reducing electric fields which householders or developers can use if they wish, in Supporting Paper S12.

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4 Electrical equipment in homes



4.1 Introduction

We use "equipment" to include all items of equipment or appliances that use mains electricity in the home: "brown goods" such as radios, TVs, etc; "grey goods" such as computers; "white goods" such as washing machines and cookers; mains adaptors and power supplies; etc.

These all produce magnetic fields. This is partly produced by the wiring within the equipment, but the largest source is usually either a motor or a transformer. It is often the smaller, lighter and cheaper motors or transformers which produce the highest fields.

Equipment also produces electric fields. This depends on several factors, but the biggest determinant of the electric field is whether the equipment has an earthed metal case or chassis, or not. Another significant factor is the position of any switch, which can determine whether the wiring remains live and producing electric fields when the appliance is not operating.

Some equipment is fixed in the home (eg burglar alarms, bell transformers, heating pumps), but whether the equipment is fixed or portable makes little differences to the EMF issues. Electricity meters could be seen as an item of fixed equipment, but because they are an essential part of domestic installations, and represent involuntary exposure to the residents, they are treated under house wiring rather than here.



4.2 Options for reducing fields

It is relatively easy to see in principle how fields from equipment can be reduced:

Choices made by manufacturers:

- To reduce magnetic fields, use better quality (and hence heavier and more expensive) transformers and motors
- To reduce electric fields, use earthed metal rather than plastic cases (again, heavier and more expensive, and with safety issues as well)
- For a few specific items of equipment, for example CRT VDUs and televisions and electric blankets, there are other design measures, specific to those items.

Choices made by users:

- Exposure can be reduced by changing patterns of use of equipment, for example sitting further away from cathode-ray TVs and computer screens, and moving equipment further away from the bedside.

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4.3 Conclusions

Equipment contributes to the general EMF environment in a home and therefore, on our principle of "as low as reasonably achievable", we would like to see the fields from equipment reduced where this is reasonable. However, the implication of the scientific evidence on childhood leukaemia is that it is long-term exposure in the general volume of the home that is associated with a possible risk. Fields from equipment, being localised to the equipment and usually experienced for short periods (see Supporting Paper S13), are less clearly implicated.

Equipment design is governed by international and European standards and manufacturers usually manufacture in volume for an international market. We have not identified any realistic mechanism for requiring changes to the design of equipment to reduce the fields, and conclude that Government could do no more than encourage voluntary measures by manufacturers even if they wished. Further, we have not attempted to weigh the advantages of reducing fields against the disadvantages of extra weight and cost and environmental detriment on disposal that would usually follow.

Therefore, our recommendations are that:

- **Equipment manufacturers should investigate whether fields could be reduced at low cost, and whether offering consumer choice of low-field appliances could be an advantageous marketing strategy**
- **HPA should provide information for householders on actions they can take to reduce fields from equipment in the home**

Government should ensure that the issue of possible reductions to EMFs is considered when relevant international guidelines, technical standards and recommendations are reviewed.

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5 Power lines and property



5.1 Introduction

Overhead power lines produce electric and magnetic fields. These fields are highest close to the line and fall with distance. Magnetic fields vary as the load on the line changes whereas electric fields stay roughly constant.

Fields are higher for higher-voltage lines. For the highest voltages in use in the UK, 275 kV and 400 kV, the "transmission" system carried on large lattice steel pylons, the magnetic field falls below the value of 0.4 μT implicated in the epidemiology of childhood leukaemia on average at 60 m from the line (though in extreme cases where the load is high or the line unbalanced, 150 m from the line). The distance is smaller for lower-voltage lines, and small wood-pole distribution lines do not produce 0.4 μT at ground level at all (but see the discussion in Supporting Paper S20).

The costs of new underground cables can be broadly comparable to overhead lines at the lowest voltages, depending on what reinstatement of the land above is required, and are increasingly preferred, but they become progressively more and more expensive as the voltage increases. At transmission voltages, underground cables cost an average of £10M/km in the UK (compared to £0.5-1M/km for overhead lines) and they are used at present only where there is no realistic alternative. Underground cables eliminate the electric field and reduce the width over which the magnetic field is elevated. More detail on overhead lines, underground cables, and the fields they produce are in Supporting Paper S14.

In the UK, there are no rules preventing house building right up to and indeed underneath overhead lines, provided the electrical safety clearance distances, set out in the ESQCR, are not infringed. In every country, the lower-voltage lines must come close to homes to provide electricity to them, but in some other countries, the higher-voltage lines are often in corridors where no development is permitted. In the UK, where there is no such restriction, there are, for example, roughly 25,000 homes in the UK within 60 m of the centreline of transmission lines, and more being built all the time. More detail on the numbers of homes near lines is in Supporting Paper S15 and on international comparisons is in Supporting Paper S8.

Electricity companies do not usually own the land the lines pass over. Lines are present by a contractual arrangement between the landowner and the electricity company called a "wayleave" or an "easement". If a landowner loses value because of the presence of a line over it, they can claim compensation from the electricity company, but owners of adjacent land have no rights to compensation. More detail on contractual and legal issues is in Supporting Paper S16.

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5.2 Options for reducing exposures from power lines

We looked at a long list of possible options for reducing exposures, so as to be sure of covering everything relevant, including:

- Restrictions on building of lines and homes in proximity to each other
- Restrictions on use of buildings near power lines (eg restrictive covenants)
- Changing the routing of power lines
- Placing the line underground
- Building the line higher
- Building a compact line which produces lower fields
- Changing the phasing of a line
- Improving the balance between loads on a two-circuit line
- Screening the field where it is produced by the line
- Screening the field at the home
- Radical changes to the nature of the electricity system such as local generation or direct-current transmission

More detail on these options is in Supporting Paper S18.

In looking at these options, we considered:

- Effectiveness at reducing fields or exposure
- Safety
- Cost including impact on land and property values
- Visual impact
- Environmental impact
- Ease of implementation

We used a systematic option-analysis and decision-making process called dominance analysis to identify the best options from the long-list of options, informed by the criteria that we had defined as important to distinguish options. This was initially done without quantitative assessment of costs or benefits, but we did consider effectiveness at reducing electric and magnetic fields as separate criteria. We considered two main situations, new lines near existing buildings and new buildings near existing lines. Options were judged against criteria using a qualitative ranking. We then examined the rankings to see if there were options that "beat" others on all, or most, of the ranking criteria in each of the situations considered, but did not "rule in" or "rule out" any options at this stage.

As a result of the dominance analysis, we concluded that some options were unlikely ever to be chosen, because another option would be preferable in almost all situations. An example of something that we ruled out through the dominance analysis is undergrounding as an option in its own right (though we recognise that if our data on costs of undergrounding changed, this conclusion could change; see Supporting Paper S18

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Section 5.2). Other options such as increased physical separation between new lines and existing buildings (and vice versa) have the same beneficial effects on reducing exposures to magnetic and electric fields, but undergrounding scores less favourably on cost, safety and reliability of electricity supply. Another example we ruled out is "protecting by trees". This was a poor performer on effectiveness at reducing magnetic and electric fields compared with other options. Details of all the options are included in Supporting Paper S18, so if, despite our conclusion that these are less favourable, Government wish to consider them, the information is available.

We assessed these options in four situations:

- Existing homes and new lines
- Existing lines and new homes
- New homes and new lines
- Existing homes and existing lines



5.3 Recommended options

As a result of our analysis, we have identified two options which we believe should be implemented anyway, which we describe here. However, these two options will not make a dramatic difference to exposures, and therefore we also identify and give some detail on the best available option for obtaining significant reduction in exposures, described in Section 5.4.

Firstly, we recommend that more information be provided to members of the public about exposures and the actions they could take themselves to reduce exposures if they wished. We consider that HPA would be a suitable body to issue such guidance, but whoever compiles it should consult at least the same range of stakeholders as are represented on SAGE, and should ensure the information they provide reflects the spirit of this Assessment.

A recommendation for more public information to allow people to manage any risk for themselves is very much in keeping with the recommendations of the Better Regulation Commission. However, we recognize that members of the public may often have limited control over exposures from power lines.

Secondly, we have identified that choosing the optimal relative phasing for the two circuits of an overhead line can reduce the distance for the magnetic field to fall to a given level. This is often described as "transposed phasing" (or sometimes "rotated phasing") and is discussed further in Supporting Paper S14. This can be applied to new lines, but also, existing lines can, in principle, be converted. Sometimes, with existing lines, the required phasing can be achieved simply by making minor changes to the ends of the circuits. Where this is the case, the cost is comparatively minor, and our analysis suggests may often be justified by cost-benefit considerations on the basis of childhood leukaemia alone ("WHO/HPA").

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On this basis, we recommend that electricity companies be encouraged to choose the optimal phasing (usually transposed phasing) for all new lines, and also be encouraged to convert existing lines where possible and justifiable.

The National Grid (the 275 kV and 400 kV lines) has always been constructed with a policy of transposed phasing where possible; over 90% has transposed phasing already, and there is little scope for increasing this at reasonable cost. We do not expect our recommendation to result in any change for the National Grid. The 132 kV system, however, has more scope for change. We estimate that perhaps 12% of 132 kV lines are not currently transposed but could reasonably be so. It is this 12% that we are recommending be converted when possible and justifiable; but because it is only 12%, and only of the 132 kV system, and because it only reduces rather than eliminates the fields, we are realistic that this option, whilst nonetheless desirable, will not make a dramatic difference to exposures.

Although we believe there are 132 kV overhead lines where the cost of conversion is low enough and the number of people affected is high enough for this option to be justified, there would always be scope for dispute about the cost-benefit calculation, and exactly how many people had to be affected or exactly how low the cost should be before a line was converted. For this reason, we do not advocate a rigorous definition of what should be done, nor do we believe it should be enshrined in regulation or should have a specific timescale attached. Instead, we consider this will be most effective if expressed as a general encouragement to electricity companies to take the desired action where possible.



5.4 The best-available option for obtaining significant exposure reduction

To reduce exposures significantly, beyond what the two options described in Section 5.3 would achieve, we have identified a range of variants of an option regarding physical separation of buildings from power lines.

Beyond our two recommendations, we urge Government to make a clear decision either to implement or not to implement one of the variants of this option. We have not identified any realistic alternative choices.

This range of options is shown in Table 5.1 (below).

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	Precautionary Action	Implementation	Characteristics
Range of options with increasing precaution	Do nothing; no change to existing situation	No legislation, regulation or voluntary codes needed	• No cost • Likely continuing dispute • Potential political fallout and unrest • No reduction in exposure levels
	Provide information	No legislation or regulation needed	• Demonstrates acceptance of desirability of reducing exposures • Enables people to make a choice • Could either allay or increase public concern • Low cost • Does nothing directly to reduce exposures
	No new overhead lines built close to existing buildings (eg within 60 m)	Voluntary code by industry	• Demonstrates acceptance of precautionary principle by industry • Starts to reduce new exposures (but not by much in practice as voluntary action likely to be limited) • Significant cost • Not enforceable • Development still happens close to lines
		DTI policy	• Demonstrates acceptance of precautionary principle by Government • Largely enforceable but with some flexibility
		DTI regulation or legislation	• Enforceable with no flexibility
	No new land allocated for residential development in local plans	DCLG (formerly ODPM) Planning Guidance	• Costs lower than next option because less land affected. • Benefits lower than next option because less land affected.
	No new residential build close to existing lines (eg within 60 m)	DCLG (formerly ODPM) Planning Guidance	• Starts to reduce new exposures • Takes land out of residential use • Significant compensation costs • Largely enforceable with some flexibility • Likely legal challenges by developers
	Combination of no new lines and no new residential build close to each other (eg within 60 m)	DTI policy plus DCLG (formerly ODPM) planning guidance	• Takes land out of residential use • Significant compensation costs • Largely enforceable with some flexibility • Likely legal challenges by developers • Reduces both sorts of new exposure but does not address existing situations
	Combination of no new lines and no new residential build close to each other (eg within 60 m), but extended to some non-residential buildings, eg schools	DTI policy plus DCLG (formerly ODPM) planning guidance	• Takes land out of residential use • Significant compensation costs • Largely enforceable with some flexibility • Likely legal challenges by developers • Extends precaution beyond the home • Raised concern about existing schools close to lines • Reduces both sorts of new exposure but does not address existing situations
	As previous row plus taking action on existing homes close to lines as well	Legislation	• Compulsory eviction and/or demolition of properties • Very large costs and public disturbance • Reduction in present exposure
	Any of above extended to larger distances, eg 200 m or 600 m	As above	As above but • To greater extent • Larger fraction of the situations producing exposure addressed

Table 5.1

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We have identified from this range the following option (the "corridors for new build" option) as the best available precautionary intervention for obtaining significant reduction in exposures from power lines. This is the shaded option in the table.

We describe this option here, then in the next section we discuss whether or not it is sufficiently attractive to be implemented. Please note that the description of how the option could be implemented and its consequences must not be taken to carry any implication either way as to whether it should be implemented; our conclusion on that is in Section 5.5.

In summary, the option is to stop building any new buildings for residential use (and some other uses including schools) within specified distances of overhead power lines, and to stop building new overhead power lines within the same specified distances of existing such buildings.

It avoids future exposure that would otherwise occur, but does not reduce present exposures. It therefore makes a difference to the situations we identified as "new lines, existing homes" and "existing lines, new homes", but does not make a difference to "existing homes, existing lines".

We considered the alternative of expressing the restriction in terms of the magnetic field rather than the distance from the power line (see Supporting Paper S20). This would relate more directly to the health evidence, but would cause immense problems to implement in practice. We recognise views either way, but overall, for practical reasons, we consider any restriction is best expressed in terms of a distance derived from the field.

Derived from the magnetic-field level of 0.4 μT, we consider the distances concerned should be:

Voltage of line	Horizontal distance at ground level from centreline to nearest part of building
275 kV and 400 kV	60 m
66 kV, 110 kV and 132 kV	30 m
6.6 kV, 11 kV, 22 kV and 33 kV*	Provisionally, no restriction (see Supporting Paper S20 for an explanation of this)
400 V	No restriction

* these will be considered further by the SAGE distribution group

It would be possible to choose larger distances, providing greater protection against any possible health effect but at increasing cost, or smaller distances, providing lesser protection but at less cost. (Even a distance which would remove all homes from a level of 0.4 μT would not necessarily remove all possible risk, as this is not a precise threshold.) We consider that, if this option were to be implemented, the distances we have given are the optimum, but in Supporting Paper S20 we provide information to allow alternatives to be assessed.

A variant of the option would be simply to prevent any new land (within the same distances) being allocated in Local Plans for residential development; we discuss this in Supporting Paper S19 Section 1.3.

If underground cables were used instead, there would need to be an equivalent distance, smaller than for overhead lines, but this would need to be calculated on a case-by-case basis. For cables sufficiently deep, no restriction would be needed.

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The buildings affected would be, in essence: residential dwellings; schools (for children up to age 15), other childcare facilities where children spend a substantial fraction of the week; hotels and the like; and holiday facilities. In formal terms, these would be defined in terms of the Town & Country Planning (Use Classes) Order 1987 as Classes C1, C2, C3, and D1 (ideally parts b and c only)[1], plus any "sui generis uses" (a defined term in the Order) that meet the broad objective.

The justification for this selection of buildings, given in detail in Supporting Paper S3, relates to the epidemiological evidence. The aim is to include buildings where people spend long periods of time, using overnight stays as an indicator of this. For children, where there is the greatest priority for protection, the net is cast wider, and hence schools etc are included. For adults, the restrictions are more relaxed, hence workplaces are not included. The Use Classes used in planning law do not correspond exactly to the uses we would ideally define (see Supporting Paper S3), but we consider that using these existing definitions is nonetheless the best approach.

Implementation of this option

If desired, this option could probably be implemented entirely within the existing legislative and regulatory framework; no new legislation or regulation would be required. However:

- An existing provision, the powers for compulsory purchase within Schedule 3 to the Electricity Act, would have to be used in a very different way to the way it is used at present. Because this would be a new departure, and would probably be tested in the courts, we cannot be certain this would in fact prove possible.
- It has been suggested that taking these measures would give endorsement to the idea that EMFs are a health hazard and would therefore create a pressure to modify other legislation, to ensure that EMFs were treated consistently with other health hazards.

We discuss these legal issues and implications in more detail in Supporting Paper S16.

Specifically, if, following Regulatory Impact Assessment and consultation, the Government and Devolved Administrations decided to implement this measure:

- In England and Wales, the DTI would create a formal policy stating that in future the Secretary of State will give Section 37 Consent under the Electricity Act only for lines where the applicant can demonstrate that the above criteria are met. The DTI would also indicate, as part of that policy, that the Secretary of State will, where necessary, grant Compulsory Purchase Orders under Schedule 3 of the Electricity Act to applicants to enable them to acquire such rights over land. In Scotland these actions would fall to the Scottish Executive and in Northern Ireland to the Department of Enterprise, Trade and Investment.

- In practice, the electricity company seeking to build a new line would seek a route that kept the required distance from existing relevant properties. If this were not possible, they would probably seek to purchase (and, subject to planning permission, either demolish or convert to non-residential use) any such properties. If voluntary agreement to purchase was not possible, they could choose either to place the line underground or to use compulsory powers to purchase the property, depending on which alternative they, and ultimately the Secretary of State, judged most expedient. Affected landowners would receive compensation as for any other compulsory purchase.

- To ensure the new line, once built, continues not to have homes within the specified distance, either we could rely on the other part of this option (preventing new homes being built near existing lines) or the applicant for a new line could also be required to demonstrate that they have acquired sufficient rights over land to ensure that the above criteria will continue to be met in the future. We have not, at this

1 see http://www.opsi.gov.uk/si/si1987/Uksi_19870764_en_2.htm

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stage, decided between these alternative methods of achieving the same objective, but we recognise this makes a large difference to costs and needs to be addressed.

- DCLG (formerly ODPM) would issue a Planning Circular stating that planning permission should not be granted for new developments in the above classes within the specified distance of existing overhead lines. This would lead to Local Authorities building such provisions into their Local Plans, and then to determining applications for Planning Permission on this basis. Planning Inspectors, and ultimately the Secretary of State, would then uphold this guidance in adjudicating appeals against decisions by local authorities. Where routes for proposed new lines are identified in Local Plans, these provisions could apply to those proposed routes also, but we have not decided on this. In practice, developers or land owners would either abandon the development or would negotiate with the electricity company to remove the power line.

This option, if taken up, would therefore probably be implemented as policy guidance rather than regulation. We believe that if the justification for the policy were clear, it would be generally applied; in the nature of policy rather than regulation, exceptions would be possible, but we would expect these to be few. We explored the alternative of implementation by voluntary agreement, but this would be very unlikely to be effective in practice (neither property developers nor the electricity industry are likely to incur large costs voluntarily), and we consider Government should take a clear policy lead, deciding either that the option is implemented or it is not, in the best interests of society as a whole.

Consequences of this option

The main benefit of this option is clear: new instances of people being exposed in their homes above 0.4 μT from power lines would be largely prevented. Because we have chosen to express the restriction in terms of an average distance, there would be some exceptions, where people living outside the distance concerned (eg 60 m for 275 kV and 400 kV lines) would still be exposed to fields greater than 0.4 μT, but we estimate this would apply to just 15% of people (see Supporting Paper S20), and we regard this as acceptable given that 0.4 μT is not a precise threshold.

If magnetic fields are a cause of childhood leukaemia (and on the basis of our other assumptions including our estimate of likely future building that would be prevented) this would, in the fullness of time, prevent perhaps from one-half to one extra case per year of childhood leukaemia in the UK. If EMFs are a cause of other adverse health effects the benefit could be a hundred or so times higher. In both cases, because the option is concerned with preventing new exposures, it would make no difference to existing exposures and hence to any existing health effects. Any benefit would occur progressively over future decades rather than all occurring at once, reflecting the timescales of the future building programme that would be prevented.

We have also analysed the consequences of this option in detail, and present just the main issues here. Several of these consequences relate to the effect on land and property values, and we discuss this in Supporting Paper S17.

- A strip of land around power lines is removed from the pool of available land for residential development (though still available for other uses). In some areas where alternative land is readily available this would have little immediate consequence for home building but in some areas (eg Thames Gateway) it would probably prevent present plans for homebuilding (or would require expensive undergrounding of the line to allow the development to proceed, though we recognise that other commercial factors would then come into play).
- Land within the specified distance, where currently there is an expectation of being able to develop, would lose value. Where the power line crosses part of that land, the landowner would receive compensation from the electricity company for the whole loss of value, and this cost would probably

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ultimately be paid by electricity consumers. Where the land was within the specified distance but not crossed by the line, the landowner would not receive any compensation. We recognise that this difference in the treatment of landowners at similar distances from lines is unfair but we note that this unfairness already exists and we consider there is no easy way of rectifying this. We estimate that the total loss of land value nationally could be in the region of £1-2bn. Good design practice (flexible use of space in large developments) could reduce but not eliminate this figure and there may be other changes in values of land not near power lines which reduce the net cost to society, though not the burden on individuals. These compensation costs would be payable as soon as the policy were implemented, unlike the benefits which would accrue only gradually.

- The desirability of existing homes close to power lines (within the corridor and perhaps slightly further) could probably be reduced, resulting in some homes losing value. We find it impossible to predict how much devaluation would occur in practice. Estimates of the possible loss of value nationally range from almost nothing up to £2bn or more. As with undeveloped land, some homeowners would receive compensation and some not. Some landowners would probably seek to have existing lines removed, arguing that a precedent had been set, and Government and electricity companies would probably need to manage a considerable increase in Wayleave Terminations and Consent Reviews. There might be strong parental pressure to take action over some existing schools close to power lines. All this would probably also cause considerable distress and anxiety for some people living in these homes.
- It would become more expensive and would probably take longer to build new power lines when they are required, with greater recourse to compulsory powers being necessary.

Our formal cost-benefit conclusion on this option can be found in Supporting Paper S19, and is:

- Cost per home removed from a field of 0.4 μT: £20k-160k
- Health benefit per home removed from a field of 0.4 μT on the "WHO/HPA" view of the science and assuming magnetic fields above 0.4 μT do cause childhood leukaemia: £1k
- Health benefit per home removed from a field of 0.4 μT on the "California" view of the science: perhaps a hundred or so times larger (as discussed in Section 2.4).



5.5 Conclusion

We have identified two precautionary measures (better information for members of the public, and optimal phasing of 132 kV overhead lines not already thus phased) that we recommend. These options, however, will not have a dramatic effect on exposures. We have therefore identified the best-available option for obtaining significant exposure reduction (in fact, it avoids new future exposures that would otherwise occur). This is a restriction on new homes and schools close to existing lines, and on new lines close to existing homes and schools (the "corridors for new build" option, which can in fact be seen as a suite of options used to achieve a single objective). The main costs of this option arise from the effects on land and property values. We urge Government to make a clear decision on whether to implement this option or not.

Decisions about siting a power line or placing it underground often involve balancing a number of factors, including visual amenity. Many of the options we considered, including the "corridors for new build" option, affect visual amenity, generally improving it. Our analysis of costs and benefits quantifies health

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benefits only; we recognise that there may be specific situations where health considerations could make an additional contribution to other factors, such as visual amenity, as a justification for, eg, placing power lines underground[1].

The stakeholders in SAGE, regardless of their views on the science, are broadly in agreement on the facts as they relate to this option:

- that the choice facing Government resolves down to whether or not to implement this option
- that there are no other agreed and realistic options that are more cost-effective at reducing exposures
- what the financial cost and other consequences of implementing it would be, whilst noting the uncertainties
- that this option does not reduce exposures for people currently living near high-voltage power lines

Further, we largely agree on the answers to the "what if..?" questions: what would be the benefit of implementing the option under the "WHO/HPA" view of EMFs, and what would be the benefit of implementing it under the "California" view. Although we disagree over which view to adopt, we are able to recognise each as a legitimate viewpoint and we respect each other's right to come to different conclusions based on interpretations of the science and we all support more research to clarify these issues. This ability to recognise and understand each other's viewpoint, to have clarity over exactly where the differences lie, and to recognise how much common ground there is between us, has been a significant gain from the SAGE process.

However, as described in Section 1, stakeholders take different views on the "WHO/HPA" and "California" views of the science and have consequently not been able to reach a consensus on the advice that stems from these views. Therefore SAGE needs to set out alternative advice to Government, depending on which of these views is followed through, recognising that not all stakeholders are comfortable with each piece of advice.

1 Some discussion of this is found in an EU Background Paper of 2004

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The "WHO/HPA" view identifies childhood leukaemia as the only adverse health effect where the evidence is strong enough to be the basis for considering precautionary measures. In this view, the evidence for other adverse health effects is seen as too weak to use to justify precautionary measures with significant costs. In addition, this view of the science is seen by some stakeholders as having a particular status by virtue of being held by HPA, the body charged by Act of Parliament with advising the UK Government, and by WHO, which has a similar status internationally. On this basis, the costs of the option outweigh the benefits by a factor of at least 20, and this is likely to remain the case even allowing for the uncertainties in the calculation. It is recognised that cost-benefit considerations are not the only relevant factor but they are seen as key to optimising the use of resources in public health, and the margin of the disparity is large. The advice to Government from following this "WHO/HPA" view would therefore be to tend not to favour implementing the "corridors for new build" option.

The "California" view identifies, not just childhood leukaemia, but a range of other adverse health effects as the basis for considering precautionary measures. It is acknowledged that there is less agreement about whether these health effects might be caused by power lines, but the public-health consequences if they are would be considerably greater. On this basis, the costs and benefits of this option are considered to be at least comparable. Further, it is recognised that cost-benefit considerations are not the sole factor and there are other arguments for taking action. The advice to government from following this "California" view would therefore be to tend to favour implementing the "corridors for new build" option.

Other stakeholders do not wish to identify with either view in particular, but believe Government should be aware of both.

If electric fields are considered as well as magnetic fields, this option would still be the best, but if electric fields were the only consideration, screening of the fields would probably be a better option. If action were considered on the basis of the Draper result or of corona ions, where the distance from the line of the suggested risks is ten or so times larger, this option would be less effective; but if this option were extended to larger distances, so as to make it more effective in health terms, the increasing costs would outweigh the benefits by even more.

We all recognise that the costs are not the only factor that Government will wish to consider, and if Government decide to implement precautionary measures that would result in a significant reduction of exposure (ie that go beyond our two recommendations) despite the costs, our conclusion is that this "corridors for new build" option would be the best option available to implement.

In our work, we considered options applicable both to new construction and to existing homes near lines. Our analysis clearly showed that the starting point for any action should be with new construction.

Taking action on existing situations (with the exception of limited rephasing of 132 kV overhead lines as already discussed) would be more complex and more expensive and we suggest that the initial decision Government should make is whether or not to take action in relation to new construction.

However, if action were taken to prevent new instances of lines and homes in proximity whilst allowing the existing instances to continue, this is likely to create some concern among the people affected. We propose to do more work on existing homes near existing lines.

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Participants in SAGE

The following stakeholders have been involved in the SAGE process (this same information is also presented in Supporting Paper S1).

Everyone has been a member of the Main Group. Participation in other groups is indicated as follows:

Power Lines and Property	PLP
Electrical Installations and Equipment	EIE
Review and Completion	RC
Public Opinion	PO
Coordination group	C
Funders' group	F

Person	Organisational Affiliation	Participation in groups (additional to Main Group)
Academics		
Roger Coghill	Coghill Research Laboratories	EIE
Denis Henshaw	University of Bristol	PLP, C, RC
Alan Preece	University of Bristol	EIE
Electricity Industry		
Tony Glover	Energy Networks Association	
Ross Hayman	National Grid	
Gareth Llewellyn	National Grid	
Keith Maclean	Scottish and Southern Energy (December 2005 until March 2007)	PO
Hector Pearson	National Grid	PLP
David Renew	National Grid	
John Swanson	National Grid & Energy Networks Association	PLP, EIE, C, F, RC, PO
Individuals		
Ingrid Dickinson	MastSanity until November 2005, thereafter Individual	PLP
Mike O'Carroll	University of Sunderland & Revolt	PLP, C, RC

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Person	Organisational Affiliation	Participation in groups (additional to Main Group)
Geoffrey Stokes	Institution of Engineering and Technology (IET) Wiring Regulations Policy Committee	EIE
Local campaign groups		
Maureen Asbury	Trentham Environmental Action Group	
Caroline Paterson	Scotland Before Pylons (since December 2006)	
National campaign groups		
Edward Copisarow	CHILDREN with LEUKAEMIA	F, PO
Katie Martin	CHILDREN with LEUKAEMIA (until March 2007)	
Alasdair Philips	Powerwatch	EIE
Chantelle Roberts	CHILDREN with LEUKAEMIA (since March 2007)	
Brenda Short	Powerwatch	
National government departments		
Katy Collins	Office of the Deputy Prime Minister (up to July 2006)	PLP
Alison Edwards	DCLG (since September 2006)	
David Gray	DTI	PLP
George Hooker	Department of Health	PLP, EIE, C, F, RC, PO
Arthur Johnston	Scottish Executive Health Department	
Nigel McMahon	Department of Health, Social Services & Public Safety (NI)	
Richard Mellish	DTI	
Rod Robson	Energy Division of the Department of Enterprise, Trade and Investment, Northern Ireland	
John Steed	DTI (up July 2006, subsequently HSE)	EIE
Hilary Walker	Department of Health	C, F
Stephen Wall	Welsh Assembly Government	
Other Industry		
Mike Dolan	Mobile Operators' Association	PLP
David Dossett	BEAMA (British Electrotechnical & Allied Manufacturers Association) (since November 2006)	
Richard Hughes	AMDEA (Association of Manufacturers of Domestic Appliances)	EIE

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Person	Organisational Affiliation	Participation in groups (additional to Main Group)
Professional bodies.		
Tony Barker	Institution of Engineering and Technology (IET) (formerly Institution of Electrical Engineers (IEE))	PLP, RC
John Ware	Institution of Engineering and Technology (IET) (formerly Institution of Electrical Engineers (IEE))	EIE
Property		
Barry Hall	Council of Mortgage Lenders	PLP
Michael Jayne	Nottingham Trent University & Royal Institution of Chartered Surveyors	PLP, RC
Sally Sims	Oxford Brookes University	PLP
Regulators		
John Benson	Office for Gas and Electricity Markets (Ofgem) (until February 2007)	PLP, EIE, C, RC
Statutory Advisory Bodies		
Jill Meara	Health Protection Agency (formerly NRPB)	PLP, EIE, RC

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Appendix: Stakeholder Commentaries on the Report

Recognising that this Assessment reflects some degree of agreement but not total agreement, each stakeholder has been given the opportunity to make a statement of their view of the point the SAGE discussions have reached.

Academics

Roger Coghill Research Laboratories

Whilst this first interim assessment is a welcome step, it contains three important omissions:

a) Only childhood cancer is considered, when much peer-review published evidence points to implication of EMF exposure in other cancers, disorders, and neurodegenerative diseases such as Parkinsons and Alzheimers..

Emerging experimentally-confirmed mechanisms of interaction between non-thermal EMF exposures and biological fluids show a build-up of reactive nitrite species (RNS, e.g. peroxynitrite) in biofluids, thereby causing widespread damage to DNA, immune system cells, and mitochondrial processes. RNS are linked to all the disorders also associated epidemiologically with EMF exposure, particularly the electric component.

b) The role of the ELF electric component in causing ill health is not given anything like proper emphasis.

Were this done the percentage of homes at risk would increase dramatically. Most homes somewhere contain ELF electric fields in excess of 20 V/m. That level of chronic exposure has now been linked with increased cancer incidence in three epidemiological studies and one occupational study. Most plausible interaction mechanisms implicate the electric not the magnetic component.

c) The powerfully electro-protective effect of exogenous melatonin supplementation, particularly among the UK's 20 million elderly population, and the adverse effects of EMFs on melatonin synthesis within the body have not been addressed.

Fifteen studies now report suppression of melatonin by EMFs, especially electric fields. External melatonin administration is a proven radio-protective agent with powerful antioxidant, oncostatic, immuno-enhancing, and cardiovascular benefits, and should form part of precautionary stratagems.

More information available at www.cogreslab.co.uk .

Denis Henshaw University of Bristol

This Report is deeply flawed and unrepresentative of what was agreed in meetings. The now extensive epidemiological evidence of a range of adverse health effects, especially childhood leukaemia, associated with EMF exposure from the electricity supply, backed up by recent advances in mechanistic understanding, receives no proper mention, and the Report does little to advance precaution against exposure.

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The California Report considered over 200 epidemiological studies. It considered the aggregate findings and linked five health outcomes to magnetic field, MF exposure. Similar aggregate findings for adult leukaemia and brain cancer are evident in the IARC report, but that report shows no evidence of considering the aggregation of results other than subjectively. It considered individual studies but this led to a tendency to fragment and dismiss evidence which is intrinsically highly significant. (see:: http://www.electric-fields.bris.ac.uk/OcarrollHenshaw01.03.07.pdf)
There is compelling evidence from laboratory studies that MFs enhance the effects of known carcinogens on cells. The evidence supports the established mechanism by which MFs can increase the lifetime of free radicals and hence their ability to damage DNA.

There is similar evidence that populations exposed to the neighbourhood EMFs suffer associated disruption of nocturnal production of melatonin, providing a common link with reported adverse health effects.

Linear-no-threshold models, usual for cancer risk assessment, suggest some 60 cases of childhood leukaemia annually linked to EMFs. Overall, the weight of scientific evidence supports a favourable cost-benefit analysis for a powerline corridor and other precautionary measures.

Further information is available at: http://www.electric-fields.bris.ac.uk/

Alan Preece University of Bristol

The statement "Electromagnetic fields are a possible human carcinogen" has been made by three bodies with wide scientific representation, and accepted as possibly true by others. This conclusion is unusual in science because it makes a statement about possible causation which is based on only ***one*** of the ***ten Bradford Hill criteria***. However the evidence so consistently points in the same direction that it can become an article of faith for the unbiased scientist.

The SAGE report in my view rightly summarises this scientific faith. It very succinctly outlines the procedures that can give society the opportunity to mitigate the effects of electricity distribution and use, and allow the benefits of electrical power to be used and enjoyed while reducing the possible harm. Although the cancer association is a strongly held belief this should not be imposed on the agnostic or atheist and it is right that the conclusions of the report are suggestions and guidelines rather than recommendations for legislation.

Thus, the right to choice in the light of "a possible association" is preserved and leads to precaution, pending clarification in the future. Such clarification is needed and presupposes that more research needs to be done to find out just how electromagnetic fields might be associated with childhood leukaemia and whether this might extend to adult cancer or other non-cancer conditions. These other possibilities have been studied by the scientific community, and conclusions drawn but not widely accepted. The main omission is to fail to take note of these.

Electricity Industry

Energy Networks Association

ENA (the industry body funded by UK gas and electricity transmission and distribution license holders) has supported the SAGE process throughout. ENA values this document as a summary of discussions by SAGE stakeholders to date but does not agree with all the statements contained in it.

ENA's most significant disagreement is that we feel the document does not properly convey the relative status within the scientific community of the "WHO/HPA" and "California" views of the science. "WHO/

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HPA" is the view of virtually every authoritative national or international review body in the world, whereas "California" has been adopted by hardly anyone, not even by California's state legislators. ENA's own view of the science agrees with "WHO/HPA", but in addition, in the UK, the HPA view is legally authoritative and the industry is bound to take its lead from it. In terms of responding to the science, ENA would support the Government's Principles of Good Regulation, in particular that proposals should be proportionate to the risk. Accordingly, as the document explains, "corridors" round power lines are not a proportionate or responsible option. If anything, the document underplays the adverse consequences of corridors for existing homeowners. ENA understands that the industry would be prepared to examine the costs and benefits of rephasing of power lines. The other recommendations in the document, which are low-cost, we support as appropriate and proportionate to the scientific evidence.

Whatever Government decides, we will continue supporting high-quality research, and open and honest communication.

National Grid

As a responsible company, National Grid is committed to open dialogue on EMFs, and therefore has supported the SAGE process throughout. We welcome the fact that this Assessment sets out the full range of views from the members of SAGE. National Grid agrees with some, but by no means all, of these views.

We take our lead on the science of EMFs from the positions adopted by authoritative independent bodies such as WHO and HPA, who review scientific developments from around the world. We accept the analysis of costs and benefits that stems from these positions.

We support the *Recommendations* on power lines (public information, and consideration of limited rephasing of 132 kV lines) and those on home wiring and equipment as appropriate in the light of the evidence and the limited burden on society.

We do not support the *Option* considered in the Assessment of implementing "corridors". We already have a policy of routing our new power lines away from existing homes where possible, and we encourage developers to avoid building new homes directly under lines. We are clear, however, from the analysis presented in the SAGE Assessment that any benefits of applying "corridors" to building new homes near existing lines are greatly outweighed by the costs to society. Whilst it is clearly Government's responsibility to make the final decision on the way forward, we believe Government should not implement this option which is not in the interests of electricity consumers or of society as a whole.

Individuals

Ingrid Dickinson MastSanity until November 2005, thereafter Individual

In my view the SAGE process has been deeply flawed due to the decision not to consider all the latest scientific research regarding the health effects of electromagnetic fields and the imbalance of stakeholder representation between government, industry and representatives of public interest groups, which deems this report far too limited to be of real value to those affected by EMFs.

Unfortunately, due to SAGE's narrow remit, the effects of EMFs on Nature have not even been considered. My comments, urging the group to look at the synergistic effect of `all' EMFs in the `present day' environment have been shelved away for discussion at a`later date'. This delaying tactic will prove extremely irresponsible. In my view SAGE has been far behind the times from the moment it was set up. A

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valuable opportunity has been missed! The latest scientific evidence regarding the effects of EMFs on Nature and human health can be viewed on www.hese-project.org/hese-uk.

Mike O'Carroll University of Sunderland & Revolt

The Assessment goes part way to recognising scientific evidence supporting precaution. In presenting polarised positions and alternative advice, it perpetuates material flaws.

One such flaw is the "threshold" assumption: that risk of childhood leukaemia suddenly doubles for fields above a threshold of 0.4μT. Because few people are exposed above 0.4μT, that leads to the extreme minimal estimate of only 2 cases per year attributable to EMF in the UK. The estimate could alternatively be about 60 cases per year using a "linear-no-threshold" assumption. Available scientific data neither support nor reject these assumptions, but suggest something in between. A fair picture would show a range from 2 to 60, but any departure from the exclusive "official" estimate has been vigorously resisted.

Likewise, instead of assessing the range of potential adverse effects associated with EMFs, with their strengths and weaknesses, the Assessment presents alternative advice based on polarised views. The non-aligned view has been suppressed. It would advise that, within the high levels of scientific uncertainty and imprecision, the powerline corridor option could defensibly be either adopted or rejected, depending on political factors.

Our powerlines work concentrated on 275/400kV lines, sometimes forgetting 132/110/66kV lines. Conclusions dismissing undergrounding are wrongly presented as applying to all lines. We omitted to consider cost-limited phased removal of the worst existing exposures. We have acknowledged that further (basic) work is needed. In that respect the Assessment is also unsatisfactory.

My further concerns and analyses are indexed at http://www.revolt.co.uk/sage/.

Local campaign groups

Trentham Environmental Action Group

This report succeeds in a comprehensive analysis of a wide range of ELF's and EMF's the public are now subjected to. It does however spectacularly fail in that a dominance of proceedings by SAGE's Industry representatives produced a veto on consideration of current research and thinking of the perceived and acknowledged effects on public health. It is therefore simply a reference document highlighting areas for serious investigation.

This failure to grasp the opportunity to get to grips with all of the up to date science, has not only set back progress two years but also offers no real advice to Government due to the failure to focus on the science.

No report in the public interest will ever be achieved until such time as the dominance of costs on recommendations for precaution or action is removed from the equation.

One has to ask the question as to how relevant is a report that rejects most of the evidence without investigation and consideration and whose conclusions are essentially based on the balance of acceptable risk versus cost.

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The Government is recommended by us to be guided instead by the Swiss Agency for the Environment Forests and Landscapes 'Electrosmog in the Environment' www.electric-fields.brisc.ac.uk

Trentham Campaign conducted / supported the collection of controlled information from residents from 3 different areas in the vicinity of 132 kV powerlines, requesting illness details. Significant increases in headaches, depression, miscarriages found in these surveyed areas.

See survey results, www.powerwatch.org.uk www.electric-fields.brisc.ac.uk www.revolt.co.uk/trentham

Scotland Before Pylons (since December 2006)

Although SAGE was established to investigate precautionary measures in response to studies showing a high increased risk of childhood leukaemia in proximity to power lines, its recommendations will do little to protect vulnerable lives. Cost benefit analysis rather than public health protection has dominated the proceedings. The only substantive precautionary recommendation in the report, namely the "corridors for new build" option quantifies distances substantially less than those currently attempted by industry. Ironically, the public may find themselves less protected in the future than presently.

There has been much "talk" within SAGE, but almost no practical precautionary measures have resulted. The uncompromising anti-precautionary stance of certain industry representatives (some of whom have now left the process) has resulted in a report studded with factual errors and inaccurate interpretations of the science. SAGE's basic working assumption that there is no risk below the 0.4 microtesla threshold is highly questionable. Ironically, as this equates to where most people live in relation to power lines, this is the area of greatest risk. Tens of thousands of homes, now and in the future, will continue to be unnecessarily exposed if these recommendations are adopted.

This report does not address the concerns of the 14,000 members of the Scottish public who objected to the Beauly to Denny 400kV proposals on health grounds. I represent those concerns and have actively participated in the process since Dec 2006, but have been unable to influence the report.

National campaign groups

Children with Leukaemia

We welcome the publication of this report. Not because it is perfect, but because it removes the final obstacle to government action on this life-threatening issue. Leukaemia is Britain's most common childhood cancer and it is on the increase. Fields from power lines have been implicated in this increase and government must now act to protect young lives. Not because it is cost-effective but because it is the right thing to do.

We are not satisfied with this report: it does not convey accurately the relative weight of agreements and disagreements reached in our meetings. Most notably, the principal finding of this process has been downplayed, namely that government must now consider public concern on this issue and take a public decision as to whether we should have a substantive reduction in exposure to ELF EMF.

We are not satisfied with the quality of the work contained in this report: the cost benefit analysis ignores the public's willingness to pay (a treasury green book requirement) and there is a consistent failure to state assumptions. We repudiate the unstated assumption that cost benefit analysis should be treated as the principal basis for government action rather than political or public will.

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We feel that the SAGE process has been of limited value in what it can achieve simply because of the inevitable conflict between the regulator and the electricity companies. This resulted in us being unable to address the overarching problem of who is to pay for precautionary measures.

Powerwatch

Powerwatch believes that SAGE plenary discussions reached agreement that implementation of a 60 metre "no new build" corridor should be firmly recommended to Government. We believe that sleight-of-hand actions by certain participants influenced this being significantly weakened to an information booklet and re-phasing of some lines, which is a wholly inadequate course of action from our perspective.

Some participants seemed to fail to understand that a precautionary approach can only be taken before scientific certainty is reached. Other adverse health effects (CL+) were left out of the SAGE conclusions despite being adopted by two plenary meetings and having significant scientific support.

Powerwatch appreciated the co-operative way that the members of the workgroup on house-wiring and equipment functioned and agree with its final recommendations.

Our Contributing Paper [1] by Brenda Short on legal liability outlines the duties of the Secretary of State and GEMA (corporate body to OFGEM) under Electricity Act 1989 to protect the public from dangers arising from electricity generation, transmission, distribution and supply. It examines how UK & EU law, existing planning, EIA and pollution control legislation (e.g. statutory nuisance, waste, contaminated land, Pollution Prevention Control) might apply to EMFs and corona ions from powerlines. It suggests other offences that might arise (e.g. public nuisance). Civil liability (e.g. nuisance, negligence, trespass), citizen's redress including judicial review and the Human Rights Act 1998. Most of this important information is missing from the SAGE Report.

Powerwatch comments on the SAGE process are available [2].

[1] www.powerwatch.org.uk/sage/legalcomments.asp
[2] www.powerwatch.org.uk/sage/comments.asp

Other Industry

Mobile Operators' Association

SAGE's remit is to bring together the range of stakeholders to identify and explore the implications for a precautionary approach to ELF EMF (electric and magnetic fields) and to make practical recommendations for precautionary measures. The MOA's remit is to represent the collective interests of the UK's five mobile network operators on issues relating to radiofrequency (RF) EMF and planning. The MOA was invited to take part in the SAGE process even though the MOA is in no way involved in the ELF EMF issue. It is important to emphasize that the MOA's participation in the SAGE process should not be taken as an acceptance (implied or otherwise) by the MOA or its members that the SAGE conclusions or recommendations are in any way applicable to them or to the issue of RF EMF and planning.

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BEAMA (British Electrotechnical & Allied Manufacturers Association) (since November 2006)

BEAMA Installation cannot support the conclusions and proposals in this report which in our view have not been based on a reasonable interpretation of the conflicting scientific evidence nor on a sensible cost benefit analysis. The IET position statement of May 2006 is much more objective.

The basic objectives of SAGE have not been followed: -

> "constructed to involve all the key stakeholders"
> - BEAMA Installation should have been identified as a stakeholder before late 2006 as at that stage previously taken decisions could not be revisited.

> "one of its core principles is that decisions should be taken by consensus".
> - There is clear lack of consensus on many issues and several major participants have withdrawn.

BEAMA Installation is critical of the approach and is offended both by the lack of consultation and consensus in the process. It is simply not sensible to use a nonconsensus based approach with such an important issue.

The desire to produce recommendations aimed at reducing ELF fields is understandable but not at any cost. The use of an untested assumption that many ring circuits have open circuit faults has led to a recommendation which we find unacceptable.

Ring circuits have been the basis of the majority of domestic installations in the UK since 1949 and have delivered what is by common consensus the safest and most reliable system in the world. For this to be abandoned in the face of such flimsy evidence and with no clear benefit would be irresponsible.

AMDEA (the Association of Manufacturers of Domestic Appliances)

The SAGE process was instigated by the National Grid to address long-standing concerns regarding the proximity of homes and overhead power transmission lines. AMDEA makes no comment on this aspect, but notes that it is an area where UK-specific guidelines or legislation could be created.

This report discusses various aspects of the science associated with EMFs and it is clear that there continues to be disagreement regarding what is the 'state of the art' beyond that contained in Council Recommendation 1999/519/EC. When considering this report, the Government is urged to consider the validity of the underlining science and, if they believe that the 1999/519/EC needs amending, AMDEA urge the UK to reach a common understanding with other Member States. This is particularly important for the domestic appliance industry since our products are designed to comply with the requirements of the EU or world-wide markets.

EMFs emanating from domestic appliances are typically only 1% of the reference level given in 1999/519/EC. Although this level is slightly above the 0.4 μT mentioned in the SAGE report, exposure to such fields – especially by children - is for a very limited period of time and not throughout the day, as would be the case from overhead powerlines.

The report suggests that EMFs could be reduced by using more expensive components: not only would this increase product-cost it is also likely to conflict with obligations imposed by other Community provisions, such as the Waste Electrical & Electronic Equipment (WEEE) Regulations.

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Professional bodies

Institution of Engineering and Technology (IET) (formerly Institution of Electrical Engineers (IEE))

The IET, Europe's largest body of professional engineers, has a paramount responsibility for safety, both to its members and to society as a whole. The IET has supported the SAGE process throughout and in particular the assessment of the benefits and costs of the various possible options.

The IET Policy Advisory Group of scientific experts (http://www.theiet.org/publicaffairs/bepag/) has spent over fourteen years evaluating the ongoing evidence for biological effects of low-level EMFs. Its current assessment is that there is credible scientific evidence of a possible risk from ELF EMFs only for childhood leukaemia. The "WHO/HPA" and "California" views of the science identified by SAGE are not equal; "California" has much lower international credibility and scientific support. The IET is of the opinion that government decisions must be based on sound science and hence should be consistent with the "WHO/HPA" view.

If a causal link with childhood leukaemia exists (which is far from certain), ELF EMFs from all sources may account for about two out of 450 cases a year in the UK. Where low-cost measures to reduce exposures exist, it is sensible to take them, and SAGE has helpfully identified some. However, the careful analysis by SAGE shows that for high-voltage power lines there are no low-cost options that significantly decrease exposure. Measures costing billions of pounds for the uncertain benefit of perhaps avoiding two cases a year would be a disproportionate use of society's resources; vastly greater health benefits could be obtained by using these resources elsewhere.

Property

Council of Mortgage Lenders

The Council of Mortgage Lenders is the trade association for the residential mortgage industry. We represent around 98% of the UK's mortgage lenders. We welcomed the opportunity to be part of the SAGE process and will ensure that members are made aware of the recommendations of the report. There is no central policy on how lenders should treat properties near power lines or how their valuation should be approached. It has always been, and will remain the case, that it will be for individual lenders to determine whether they will impose any restriction on lending to properties near power lines, and how to treat valuation of those properties, in the light of the recommendations of the report.

Royal Institution of Chartered Surveyors

The role of RICS has been to consider and advise on the property aspects of the SAGE process. RICS is not a scientific body and it does not believe it is appropriate for it to make a judgement on the validity of the scientific evidence. In this respect, RICS has been informed by the nature of the debate and the appropriate experts engaged in SAGE. It is the nature of scientific uncertainty which has driven the need for the development of a precautionary approach. RICS is of the opinion that the SAGE process should be seen as part of a societal evolution towards developing and instituting the precautionary principle. The policy which has resulted from the SAGE process is inevitably based on a judgement balancing the current state of scientific knowledge against the needs of society. It is important that the risks arising from high voltage transmission apparatus and electric and magnetic fields should be viewed in the wider context of other risks which are also encountered by occupiers of property, such as those arising from Radon.

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RICS believes the report's recommendations and any resulting guidance should be reviewed every five/ten years and updated as required to reflect the results of any further research findings.

Statutory Advisory Bodies

Health Protection Agency (formerly NRPB)

HPA is an independent statutory body whose role includes the provision of advice to Government and others on electromagnetic fields and health. The HPA Board wishes to consider the SAGE first interim assessment and make an appropriate response after it has been published.