Health effects of Extremely Low Frequency (ELF) Electric and Magnetic Fields (EMF)

Overview of international regulation and recommendations for regulation in Oman

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EXECUTIVE SUMMARY

Public concern about the possible health effects of exposure to magnetic fields from overhead power lines and related equipment has intensified over recent years. This was prompted by the publication of epidemiological studies identifying correlations between long-term exposure to magnetic fields from overhead power lines and childhood leukemia. Other areas of scientific research have been less conclusive, for example scientific research aimed at establishing causal relationships between exposure to electric magnetic fields and health effects has not yet established or confirmed any such relationships. There is evidence that extremely low frequency electric and magnetic fields with high intensity can be harmful to health by causing undesired nerve stimulation. However, citizens do not typically encounter such strong fields in their everyday environment.

The World Health Organization (WHO) provides help and support to governments and stakeholders concerned about the health risks of EMF exposure. Internationally, the leading authority on exposure limits is the International Commission on Non-Ionizing Radiation Protection (ICNIRP). The ICNIRP has recommended exposure limits based on the results of scientific research into the possible health effects of exposure to electric and magnetic fields. ICNIRP exposure limits have been set to prevent nerve stimulation associated with very strong electric and magnetic fields. The ICNIRP considered epidemiological risk indicators, but concluded such risk indicators did not justify further reductions in exposure limits given that no causal relationship between exposure to electric and magnetic fields and health effects had been established.

International advisory committees have issued guidelines to safeguard the health effects of exposure to strong electric and magnetic fields. However, the risk indicators identified in epidemiological studies (that identify correlations between exposure to magnetic fields and childhood leukemia) were generally lower than the limits issued in guidelines. For this and other reasons, national authorities in some countries have implemented precautionary measures in the form of regulation or advice to alert the general public of the health risks of exposure to magnetic fields.

Most European countries (21 of 27) have acted on the Council of the European Union's advice to implement exposure limits recommended by ICNIRP. Four countries have implemented the ICNIRP’s recommendations in the form of formal advice supplemented by precautionary measures that reflect epidemiological risk indicators. More EU countries are expected to implement precautionary measures based on the epidemiological risk indicators.
Outside Europe, only nine countries have implemented (or advised) exposure limits for ELF-EMF in their regulation. In six of these countries the exposure limits correspond with the ICNIRP exposure limits. Only in one country supplementary precautionary measures have been introduced. None of the six member states of the Gulf Cooperation Council have implemented legislation or regulation to limit exposure to ELF-EMF.

The Authority for Electricity Regulation, Oman (the Authority) has a statutory duty to safeguard the health and safety of the public. The Authority, in accordance with this duty, wishes to introduce ELF Electric and Magnetic Field regulation (ELF-EMF Regulation) and precautionary measures to safeguard the health and safety of the public. The Authority retained KEMA to provide expert guidance on the preparation of ELF-EMF Regulation and the implementation of precautionary measures based on best international practice.

KEMA’s recommendations to the Authority are as follows:

1. The introduction of new ELF-EMF regulation for Oman based on ICNIRP exposure limit guidelines

2. The Authority may consider supplementary precautionary measures, based on an evaluation of all risks, costs and benefits involved. A precautionary measure would be the enforcement of minimum clearance zones around newly constructed overhead power lines (based on distance or magnetic field strength), as well as around existing power lines with regard to the construction of new residences and schools

3. KEMA recommends Oman not to enforce supplementary precautionary measures for other sources (e.g. electricity distribution cables, transformers, (household) appliances. Scientific evidence to support such measures is insufficient

4. In some countries there is public concern that governments are not doing enough to mitigate the health effects of exposure to ELF-EMF. To provide the public with reassurance in this regard, KEMA recommends Oman implement arrangements to monitor ongoing developments and scientific research into the health effects of ELF-EMF exposure and, if necessary, implement further safeguards.
INTRODUCTION AND OUTLINE OF THE REPORT

The concern about potential health effects from exposure to extremely low frequency (ELF) electric and magnetic fields (EMF) is increasing worldwide. The main reason for this concern is the publication of epidemiological studies that show an association between magnetic fields from overhead power lines and childhood leukaemia (Ahlbom et al., 2000; Greenland et al., 2000).

International advisory committees have set up guidelines to limit health effects among people who are exposed to relatively strong electric and magnetic fields. However, the above mentioned epidemiological association with childhood leukemia has been found for magnetic fields that are much weaker than the guideline limits. Mainly for this reason, national authorities of some countries have implemented precautionary measures in their regulation or advice on exposure of the general population to magnetic fields.

The Authority retained KEMA to provide expert guidance on the preparation of ELF-EMF Regulation and the implementation of precautionary measures based on best international practice.

The assignment terms of reference require KEMA to:

1. Undertake a desk based study and review of guidelines and measures implemented in other countries to limit exposure to ELF-EMFs
2. Make recommendations to the Authority for new ELF-EMF Regulation and precautionary measures for implementation in Oman
3. Conduct a seminar for the Authority and senior decisions makers in Oman to present the results of the review of guidelines and measures implemented in other countries and explain the basis of the recommendations made in this report for implementation in Oman.

In a complimentary exercise, KEMA performed field based EMF measurements at selected sites and locations in Oman. The results of these field measurements are presented in a separate report (KEMA, 2009).

This report presents the results of items 1 and 2: an overview of guidelines/advises in other countries and recommendations for EMF regulation in Oman. The report is outlined as follows:
- Chapter 2: a short description on possible health effects of ELF electric and magnetic fields, scientific state of the art

- Chapter 3: an overview of ELF-EMF exposure related guidelines by international advisory committees

- Chapter 4: inventarisation of ELF-EMF exposure related guidelines or advice imposed or recommended by national or international authorities (more elaborate information in Appendix I)

- Chapter 5: recommendations for ELF-EMF exposure regulation in Oman

- Chapter 6: conclusions and recommendations.
2 HEALTH EFFECTS OF ELF MAGNETIC AND ELECTRIC FIELDS

2.1 Introduction

Electric and magnetic fields are generated in the vicinity of all electric installations and appliances. In most countries, these fields have a frequency of 50 Hz and are designated as extremely low frequency (ELF) fields. Due to the widespread use of electrical systems and appliances, human beings are continuously exposed to these fields generated by numerous sources in numerous places. Over the last thirty years concern has grown among people living in the vicinity of overhead power lines. They fear that the magnetic fields from these overhead lines may be dangerous to their own health or their children’s health.

An important question is whether exposure to ELF fields from overhead power lines can have negative effects on human health? A considerable number of scientific publications report the results of research in this area. In this chapter a short overview will be presented of the different types of research and the main conclusions.

More detailed information can be found in a report by the World Health Organization (WHO) published in 2007 (WHO, 2007).

2.2 Types of research

Scientific research into biological and health effects of ELF electric and magnetic fields can be divided in two categories:

- **Epidemiological research** (discussed further in paragraph 2.3) is statistical research that compares populations to investigate the possibility of statistical relationships between exposure to ELF fields from or presence near overhead lines and certain diseases or health disorders. This type of research can show statistical differences in occurrence of a disease or disorder between population subgroups, but can not show a causal relation nor give any information about mechanisms leading to these differences. Put in another way, epidemiological research cannot identify mechanisms to explain how exposure to ELF can cause ill health.

- **Mechanism related research** (discussed further in paragraph 2.4) is research performed under carefully designed and controlled conditions to investigate the possibility of causal relationships between exposure to ELF fields and certain diseases or health disorders.
This type of research aims to find and identify mechanisms that explain how EMF exposure can influence and cause diseases and disorders.

2.3 Epidemiological research

The first scientific results of epidemiological research on health effects of power lines were published in 1979 (Wertheimer and Leeper, 1979). In this publication an increased incidence of childhood leukaemia was linked to the presence of overhead power lines. Since then, more than 100 epidemiological studies have been carried out, focusing on several diseases (ICNIRP, 2001). More than 20 publications were devoted to childhood leukaemia (IARC, 2002).

Most epidemiological studies were case-control studies. In a case-control study a group of patients (cases) is compared to a group of persons without the disease (controls). The selection of the control group is an important parameter. Patients and controls have to be matched closely to prevent the influence of interfering factors (e.g. age, sex, social economic status, housing conditions, and education). The statistical difference in disease risk between these groups is expressed as an odds ratio.

At this moment, the conclusions from epidemiological research on effects of exposure to ELF fields are (WHO, 2007):

- no epidemiological relations have been found between exposure to electric fields of any source and any disease or disorder

- no epidemiological relations have been found between exposure to magnetic fields of different sources and any disease or disorder, with the exception of an increase in the incidence of childhood leukemia among children living close to overhead power lines.

The epidemiological indications of correlations between residential proximity to power lines and childhood leukemia stem from two pooled epidemiological analyses, both published in 2000. The authors of these pooled analyses combined the results of already published epidemiological research on childhood leukemia. In each pooled analysis an increased incidence of childhood leukemia was found in the group of children that had been exposed to magnetic fields higher than a certain "long term mean field strength" (as specified in the following examples):
Ahlbom found that leukemia was 2 times more likely to occur among children exposed to mean field strengths higher than 0.4 microTesla (μT), generated by overhead power lines (Ahlbom et al, 2000)

Greenland found that leukemia was 1.7 times more likely to occur among children exposed to mean field strengths higher than 0.3 μT, generated by overhead power lines (Greenland et al, 2000).

Some remarks can be made regarding the statistical relations from the pooled analyses:

- in both pooled analyses, measured exposures and calculated exposures have been combined, which may lead to a bias in the results (see below)
- epidemiological research from different countries have been combined, while there are large differences in electricity supply between these countries
- the basic epidemiological results were corrected for possible confounders. On the other hand, the knowledge about the onset and the development of childhood leukaemia is still limited. It is possible that there is a confounder that is responsible for the statistical relation but has not yet been recognised.

One of the most important issues of epidemiological research on effects of exposure to ELF electric or magnetic fields is the determination of the exposure itself. This determination is very difficult, especially since the exposure has to be assessed in a subsequent manner. Human beings are mobile, and are always exposed to ELF electric and magnetic fields caused by several different sources. Exposure can be measured, but this is only an indication at a given moment in time that does not give any information about exposures in the past (which is crucial in the aetiology of diseases like cancer). Exposure can also be calculated, but the contribution of a wide range of sources and the mobility of people are crucial in those cases.

Based on the epidemiological indications, the International Agency for Research on Cancer (IARC) has classified ELF magnetic fields as a category 2B agent, "possibly carcinogenic to humans". Some examples of other agents classified as such are petrol vapour, exhaust fumes, pickles and coffee (IARC, 2002).
2.4 Mechanism related research

ELF electric and magnetic fields induce electrical currents inside the human body. As long as these currents are small, they do not disturb the "naturally present electrical currents", like, for example, the information transfer through the central and peripheral nervous system between senses, brains and muscles. At very high field strengths, nerves can be stimulated by the induced currents, as has been shown by animal tests. This may lead to uncontrolled movement of muscles, which is not directly a negative health effect but may lead to shock reactions. These very strong fields do not occur in our environment. Extremely strong fields can even induce fibrillation of the heart muscle, which may be life threatening.

The effects mentioned above have been described in the scientific literature (WHO, 2007). Nerve stimulation is the only broadly accepted mechanism for the effects of electric and magnetic fields on human beings. Internationally advised exposure limits (see chapter 3) aim to prevent these effects under all circumstances. The recommended exposure limits include safety margins.

Besides research dedicated to these well known effects, many research studies have been performed in laboratories to investigate other presumed effects or mechanisms. Research based on experiments with human volunteers, animal models and human or animal cell cultures has never shown a reproducible health effect, other than nerve stimulation. More than 20 hypotheses have been defined in the past; presumed mechanisms that might explain a biological or health effect caused by exposure to electric and magnetic fields. Not one of these mechanisms has been shown to be likely (WHO, 2007).

The correlations between (magnetic fields of) overhead power lines and childhood leukemia identified in epidemiological research prompted many causal or mechanism related research attempts to explain the correlations. None of the research identified a plausible explanation: a causal relation between magnetic fields and childhood leukaemia has not been found.

Besides the nerve stimulation effects of very strong fields, no causal relation has been found between exposure to ELF electric or magnetic fields and any disease or disorder.

2.5 Conclusions on the health effects

The most important conclusions from this chapter are summarized as follows:
very strong ELF electric and magnetic fields can cause nerve stimulation. These very strong fields do not occur in our everyday environment. Nevertheless, the application of exposure limits has been advised by e.g. ICNIRP, aiming to prevent these effects under all circumstances (see chapter 3).

there is no evidence that ELF electric fields below the exposure limits cause any health effect.

there are epidemiological indications of a statistical correlation between (magnetic fields of) overhead power lines and increased incidence of childhood leukemia.

these epidemiological indications are not supported by mechanism related research. In other words, no causal relation between magnetic fields and childhood leukemia has been found, nor is there any likely mechanism available that may explain the epidemiological correlations.

there are no other epidemiological correlations relating magnetic fields to other diseases or disorders.

based on the epidemiological correlations between the magnetic fields of overhead power lines and childhood leukemia, the International Agency for Research on Cancer has classified ELF magnetic fields as a category 2B agent, "possibly carcinogenic to humans". Other agents classified as such are petrol vapour, exhaust fumes, pickles and coffee.
3 INTERNATIONAL EXPOSURE LIMITS

3.1 Introduction

In the previous chapter, an overview has been given of the scientific state of the art regarding biological and health effects of ELF electric and magnetic fields. To protect people against the effects of these fields, international commissions formulated recommendations for exposure limits. From an international point of view, ICNIRP is the most widely referenced commission.

3.2 ICNIRP

The International Commission on Non-Ionizing Radiation Protection (ICNIRP) is an international commission of scientific experts in the area of biological and health effects of electric and magnetic fields. ICNIRP advises the United Nations and the World Health Organization (WHO) about these effects.

The most recent ICNIRP guidelines on the exposure of people to electric and magnetic fields with frequencies up to 300 GHz were published in 1998 (ICNIRP, 1998). These guidelines have been added to this report in Appendix II.

ICNIRP has based its guidelines on the current state of the science regarding biological and health effects of electric and magnetic fields. The main objective of the guidelines is to protect against the known adverse health effects, which have been described in paragraph 2.4 of this report. ICNIRP has defined two types of guidelines:

- **basic restrictions**: these have been based directly on established health effects of ELF electric and magnetic fields. ICNIRP states that these basic restrictions should not be exceeded. For the electricity supply (50 Hz) this basic restriction has been defined as current density (unit: mA/m²)

- **reference levels**: the current density inside a human body can not be measured. Because of this, ICNIRP translated the basic restrictions into a more practical exposure metric, namely the electric field strength (unit: V/m), the magnetic field strength (A/m) and the magnetic induction (μT). The translation has been performed in a rather conservative way. This means that if a field strength is higher than the reference level, this does not directly mean that the basic restriction has been exceeded.
In table 1 the relevant ICNIRP guidelines for the frequency of 50 Hz have been summarized.

Table 1  ICNIRP guidelines (1998) for 50 Hz

<table>
<thead>
<tr>
<th>ICNIRP guidelines Frequency: 50 Hz</th>
<th>Basic restriction (mA/m²)</th>
<th>Reference levels</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Electric field strength (V/m)</td>
</tr>
<tr>
<td>General public</td>
<td>10</td>
<td>5,000</td>
</tr>
<tr>
<td>Occupational exposure</td>
<td>2</td>
<td>10,000</td>
</tr>
</tbody>
</table>

* The unit of the magnetic field strength is the Ampere per meter (A/m). The unit microTesla (μT) is the unit of magnetic flux density. In practice, however, it is a general custom to use the unit of microTesla (μT) to measure the “strength” of the magnetic field. To avoid confusion, this general practice has also been applied in this report.

ICNIRP has based these exposure limits on the prevention of the nerve stimulation effects of strong ELF electric and magnetic fields. ICNIRP has investigated the epidemiological indications for a correlation between magnetic fields of power lines and childhood leukemia as well, but judged these indications to be not sufficiently strong enough to warrant a reduction of the exposure limits. The absence of a causal relation and the absence of an explanatory mechanism were decisive factors in the decision not to reduce the exposure limits.

3.3 IEEE

The Institute of Electrical and Electronics Engineers (IEEE) is a global organisation of electrical engineers. IEEE published a standard containing recommendations to prevent harmful effects in human beings exposed to electromagnetic fields in the frequency range of 0-3kHz in 2002 (IEEE, 2002). The recommendations were reaffirmed in 2007.

Like ICNIRP, IEEE has based its recommendations on known adverse health effects that have been described in the scientific literature. Two types of guidelines have been set up for the general public: basic restrictions (induced electric fields inside the body, which cannot be measured easily) and maximum permissible exposure. The maximum permissible exposures have been defined as measurable field strengths. For 50 Hz the maximum permissible exposures are as follows:
– electric field: 5,000 V/m (in right-of-way of power line under normal load conditions
  10,000 V/m is permissible)

– magnetic field: 904 μT (head and torso), 75,800 μT (arms and legs).

It is obvious that IEEE’s maximum permissible magnetic field levels are much higher than
ICNIRP’s reference level.

In practice, the IEEE standard has not been implemented in the legislation or advice of any
country. In Australia, a draft standard has some similarities with the IEEE standard, but extra
safety margins are included.
4 ELF-EMF REGULATION WORLDWIDE

4.1 Regulation in Europe

In July 1999, the Council of the European Union published a Council recommendation on the limitation of exposure of the general public to electromagnetic fields (European Union, 1999). The EU recommends its member states to provide for a high level of health protection against exposure to electromagnetic fields. In this recommendation basic restrictions and reference levels have been proposed that are identical to the ICNIRP basic restrictions and exposure levels (see chapter 3).

Many European member state governments have followed the recommendation of the Council of the European Union. In this chapter, this recommendation is referred to as “EU recommendation”. The term “exposure limits” that is used in this chapter, refers to both the reference levels of the EU recommendation and the reference levels of the ICNIRP (since they are identical).

The European Parliament issued a directive regarding occupational exposure to electric and magnetic fields in 2004 (European Union, 2004). This directive is based on the exposure limits as formulated by the ICNIRP. Occupational exposure is beyond the scope of the present report.

4.1.1 Overview of European regulation and advice

Most European countries have adopted regulation or advice related to health effects of exposure of the general public to ELF electric and magnetic fields. An elaborate overview with more information on specific national regulation can be found in Appendix I to this report. A short summary of this appendix is presented in table 2.
Table 2  Overview of ELF-EMF regulation/advice on exposure of the general public in European countries

<table>
<thead>
<tr>
<th>Law/advice based on ICNIRP values</th>
<th>Austria</th>
<th>France</th>
<th>Malta</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICNIRP values</td>
<td>Bulgaria</td>
<td>Greece</td>
<td>Norway</td>
</tr>
<tr>
<td></td>
<td>Croatia</td>
<td>Hungary</td>
<td>Portugal</td>
</tr>
<tr>
<td></td>
<td>Czech Republic</td>
<td>(Ireland)</td>
<td>Spain</td>
</tr>
<tr>
<td></td>
<td>Estonia</td>
<td>Latvia</td>
<td>United Kingdom</td>
</tr>
<tr>
<td>Short term higher peaks allowed</td>
<td>Finland</td>
<td>Germany</td>
<td></td>
</tr>
<tr>
<td>Supplemented with precautionary values</td>
<td>Italy</td>
<td>Netherlands</td>
<td>Slovenia</td>
</tr>
<tr>
<td></td>
<td>Switzerland</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Law/advice based on other values</td>
<td>Poland</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No law/advice based on exposure limits</td>
<td>Denmark</td>
<td>Luxembourg</td>
<td>Sweden</td>
</tr>
<tr>
<td>Precautionary advice only</td>
<td>Belgium</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No standard</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Regulation or advice in most European countries (21) are based on the EU recommendation, and thus have adopted the ICNIRP exposure limits. 15 of these countries use only these exposure limits, without supplementary conditions. In two countries (Finland and Germany), short-term exposures exceeding the ICNIRP limits are permitted under certain conditions. In four countries, the ICNIRP exposure limits are the basis of the regulation or advice, but these are supplemented by more stringent measures that are based upon precaution.

There is only one country in Europe (Poland) that has regulation based on exposure limits that differs from the ICNIRP values (electric field maximum: 10 kV/m, magnetic field maximum 48 μT). The Polish government has no plans to comply to the EU recommendation.

Denmark, Sweden and Luxembourg have no regulation or advice based on exposure limits. Nevertheless, it has been general practice in these countries to apply the precautionary principle in order to discourage building activities near power lines. Belgium has no regulation or advice based on health effects of exposure to ELF electromagnetic fields.
4.1.2 Practical experience and trends

4.1.2.1 Actions related to ELF-EMF regulation or advice

The magnetic field strength underneath overhead power lines in Europe is practically always lower than the ICNIRP exposure limit of 100 μT. The same holds for the electric field strength underneath most European overhead power lines in inhabited areas: the field strengths comply with the ICNIRP exposure limit of 5 kV/m. Therefore, since most European countries have adopted the ICNIRP exposure limits, actions and measures in these countries are limited in practice.

The actions that have been necessary in countries that have supplemented precautionary measures to the ICNIRP exposure limits depend strongly on the nature of these precautionary measures. Since there are some differences between these measures, the actions necessary in each country will be discussed separately below.

**Switzerland:**

the EMF protection law in Switzerland was introduced by the Bundesrat (Upper House) in 2000. This law prescribes an exposure limit of 1 μT for sensitive use (for more detailed information see Appendix I). Actions that were necessary for existing overhead lines and underground cables were limited to phase sequence optimisation. New power connections have been constructed in compliance with the 1 μT limit. In cases where this turned out to be hardly feasible, the law offers some relaxation by stating that “exemptions are possible if all reasonable measures have been taken”. Such relaxation applies to new and existing electric installations other than power lines or cables as well.

**Italy:**

the only actions necessary in Italy in relation to the EMF exposure decree (2003) follow from the compliance to the magnetic field quality target of 3 μT. This quality target is applicable to new power lines and new premises. In practice, this means that in Italy new houses are not built directly underneath overhead power lines.

**Netherlands:**

in the Netherlands, the magnetic field level that has been advised for new situations (2005) is very low: 0.4 μT. Several towns and villages had to adapt their plans for the realisation of new residential districts. As a consequence, several overhead power lines have been adjusted or replaced by a compact underground cable in order to make room for new residential districts. The Dutch transmission system operator is
constructing a new 380 kV power line through the most densely populated area. For this purpose, a new pylon concept has been designed to narrow the zones in which the magnetic field exceeds 0.4 μT.

**Slovenia:** the magnetic field limit for new facilities (10 μT) in Slovenia hardly poses any problems. The electric field limit (0.5 kV/m) can only be met by increasing the physical distance to the power line.

**Poland:** realisation of the Polish 48 μT limit does not give rise to problems since the magnetic fields near power lines are lower than this limit. There is no information available about the actions based on the compliance to the Polish electric field limit of 1 kV/m in residential areas.

There are three countries that have no regulation or advice on exposure limits, but apply precautionary measures (Denmark, Sweden and Luxembourg). No information is available that gives an overview of the resulting actions on a national scale.

Belgium has no regulation or advice that relates to health effects of ELF-EMF.

### 4.1.2.2 Trends in regulation/advice in Europe

Most European countries attach importance to the ICNIRP recommendations (through the EU recommendation), which is clearly visible in table 1. On the other hand, many governments feel uneasy about the epidemiological indications of a correlation between overhead power lines and childhood leukemia. The constant pressure that is exerted by environmentalist groups, media reports and anxious citizens feeds this uneasiness.

At the moment, four European countries have included precautionary measures in their regulation or advice as a supplement to the ICNIRP exposure limits. It is quite conceivable that during the upcoming years more countries will introduce precautionary measures. It is KEMA's opinion that countries most likely to take such measures are Austria, Germany, Portugal, Spain and the United Kingdom. Pressure put on these government to take measures is relatively large.
4.1.2.3 Public concern

The epidemiological findings relating power lines to childhood leukemia has led to an enormous increase in public concern. This was further strengthened by the development of the Internet, which made all sorts of information widely available to the general public.

In all European countries, the planning of new power connections has given rise to a strong increase in public concern. This has been the case in, for example, Austria, Ireland, the Netherlands and Portugal.

Contrary to what one would probably expect the introduction of precautionary measures does not lead to a decrease in public concern. The opposite is true; in countries like Switzerland, Italy and the Netherlands public concern has increased during the last few years. Obviously, once the attention has been drawn, it will not get weaker.

The WHO has recognized the importance of dealing with public concern and supports governments in their communication about the health effects of electric and magnetic fields. Some examples of this support can be found on their website (WHO, 2009).

4.2 Regulation outside Europe

4.2.1 Overview of regulation and advice in other countries

In countries outside Europe, the situation concerning ELF-EMF-regulation is much more diverse. Many countries have no regulation at all, including the Gulf Cooperation Council member states (see 4.3).

At least eight countries only have regulation for electromagnetic fields at higher frequencies that the power frequencies. Examples of such countries are: Brazil (≥ 9 kHz), Canada (≥ 3 kHz), China (≥ 100 kHz), Jordan (telecommunication frequencies), Peru (≥ 9 kHz), Philippines (≥ 3 kHz), Turkey (≥ 10 kHz), and United States of America (≥ 3 kHz).

Some examples of countries that have implemented the ICNIRP exposure limits in their regulation or advice are: Israel, New Zealand, Republic of Korea, Singapore, South Africa, and Taiwan. Only two of these countries have implemented or advised supplementary precautionary measures (Israel and New Zealand).
Israel: for new facilities in the ELF frequencies, a maximum magnetic field of 1 μT is allowed. This has been implemented in a national law since 2006.

New Zealand: the National Policy Statement on Electricity Transmission in New Zealand contains a suggestion to consider precautionary measures for new power lines near sensitive activities, but these measures have not been specified.

In three countries, the regulation concerning ELF-EMF are based on other exposure limits that differ from ICNIRP exposure limits. The basis for the regulation in each country is summarized below.

Australia: the ARPANSA (Australian Radiation Protection And Nuclear Safety) has initiated a draft standard that shows some similarities with the IEEE exposure limits (see Chapter 3), but included extra safety margins. No further precautionary measures have been included.

Japan: Japan has a law that prescribes an electric field exposure limit of 3 kV/m. However, this limit is not intended to protect human health from the direct effects of strong fields, but to avoid electric shocks. Since 2007, application on the ICNIRP exposure limits is advised by a working group from the Ministry of Economy, Trade and Industry.

Russia: Russia has a safety standard for magnetic fields, that is mandatory since 2007. A maximum magnetic field of 5 μT is allowed for long-term exposure, while 10 μT is allowed for short-term exposure.

4.2.2 Practical experience and trends

Similar to Europe, in most countries actions and measures are limited in practice. However, there are two exceptions.

In Japan, the electric field exposure limit has led to adjustments on new as well as existing overhead high voltage towers by means of an increase in height of these towers.

In Israel, the maximum magnetic field level of 1 μT has induced many actions to shield the magnetic field of overhead distribution lines near apartment buildings.
As can be seen from the overview above, there is a trend that an increasing number of countries implement the ICNIRP exposure limits. The greater part of these countries do not implement supplementary precautionary measures.

Public concern outside European countries seems not to be as widespread as in Europe. However, in some countries the construction of new power lines has led to some increase in public concern and opposition (e.g. Canada, New Zealand)

4.3 Gulf Cooperation Council Member States

None of the six member states of the Gulf Cooperation Council (Bahrain, Qatar, Kuwait, Oman, Saudi Arabia and the United Arab Emirates) have implemented legislation or regulation to limit exposure to ELF-EMF.

The issue was discussed at the second CIGRE International conference, GCC Power 2005 on 27-29 November 2005 in Doha, Qatar. The conference approved the following Conference Recommendation (source: GCC CIGRE website):

Although field experiments and testing show no clear evidence of the effects of ELF-EMF on health, electric utilities are encouraged to participate in research into the effects of ELF-EMF exposure on health and to follow measures and practices stipulated in available international standards on exposure limits of ELF-EMF to ensure the safety of their workers against associated health risks.
5 RECOMMENDATIONS FOR REGULATION IN OMAN

5.1 Introduction

The Authority is considering introducing EMF regulation in Oman based on the scientific evidence of the health effects of ELF-EMF exposure (Chapters 2 and 3) taking account of policies and regulation in other countries (Chapter 4).

We have identified four possible approaches:

1. No ELF-EMF regulation or advice
2. ELF-EMF advice precaution with no formal obligations
3. ELF-EMF regulation implementing ICNIRP recommendations, with or without additional precautionary measures and advice
4. ELF-EMF regulation based on arbitrarily chosen exposure limits

These basic options will be further elaborated in this chapter. Advantages and disadvantages of each option have been summarized according to several criteria. In principle, it is possible to select a regulation option for Oman, based on the advantages and disadvantages for each option. However, a distinction has to be made between general criteria and culturally based criteria. The general criteria are valid for each country. The culturally based criteria are relevant for those countries where (a part of) the population lacks trust in the actions by the government or stakeholders. Public concern may be a crucial factor in these countries.

The criteria have been chosen in such a way that a positive rating corresponds with a positive or stimulating effect for the Authority and Oman.

General criteria

A short clarification of the general criteria:

- easy option; a positive rating implies that minor or no actions from the Authority are required
- stakeholder involvement; a positive rating implies that stakeholders (grid operators, lobby groups) are being involved
visible actions: a positive rating implies that the Authority will be recognized for taking clear actions.

international support: a positive rating implies that the Authority will be recognized by the international community as being right up to date.

scientific basis: a positive rating implies that the Authority can refer to a sound scientific basis.

knowledge development: a positive rating implies that scientific knowledge and/or communication skills will be stimulated in Oman.

culturally based criteria

In some countries, the lack of trust in the government and stakeholders by (a part of) the population seems to be increasing. This lack of trust is mainly culturally based. In this case, three extra criteria can be defined:

public image: a positive rating implies that the Authority will be recognized by the public as being sympathetic towards public health.

public concern: a positive rating implies that there is less chance that concern escalates.

grip on situation: a positive rating implies that the Authority has grip on the situation.

The Authority has to investigate whether these culturally based criteria may be relevant for the people of Oman.

5.2 Option 1: no ELF-EMF regulation or advice

The Authority may consider implementing no advice or regulation regarding ELF-EMF. For ELF-EMF, this option has been pursued in Belgium, Brazil, Canada, China, Jordan, Peru, Philippines, Turkey and United States of America.
Consequences for public concern

Public concern will remain and may even escalate drastically since there is an increasing amount of alarming information available on the Internet. People may have serious doubts about whether the Authority is sympathetic to the health risks of ELF-EMF and may even fear health effects are being ignored.

Support for this option

From a scientific point of view, there is no basis for this option. Extensive scientific evidence about health effects at high field strengths support the introduction of exposure limits to safeguard the health of citizens.

Actions and measures

No spatial planning actions or technical measures have to be taken.

Ratings for option 1: no ELF-EMF regulation or advice

<table>
<thead>
<tr>
<th>General criteria</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Easy option</td>
<td>++</td>
</tr>
<tr>
<td>Stakeholder involvement</td>
<td>-</td>
</tr>
<tr>
<td>Visible actions</td>
<td>- -</td>
</tr>
<tr>
<td>International support</td>
<td>- -</td>
</tr>
<tr>
<td>Scientific basis</td>
<td>- -</td>
</tr>
<tr>
<td>Knowledge development</td>
<td>- -</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Culturally based criteria</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public image</td>
<td>- -</td>
</tr>
<tr>
<td>Public concern</td>
<td>- -</td>
</tr>
<tr>
<td>Grip on situation</td>
<td>- -</td>
</tr>
</tbody>
</table>
5.3 **Option 2: ELF-EMF advice precaution without obligations**

The Authority may consider not implementing EMF-regulation, and rely on advice and precautionary measures without obligations. This option has been pursued in Sweden, Denmark and Luxembourg.

**Consequences for public concern**

Public concern will remain since there is an increasing amount of alarming information available on the Internet. It is well conceivable that concerned people exert pressure on stakeholders (transmission system operators, local authorities, property developers) to take precautionary measures. In fact, the responsibility will be completely passed on to the stakeholders.

**Support for this option**

From a scientific point of view, there is no basis for this option. Extensive scientific evidence about health effects at high field strengths support the introduction of exposure limits to safeguard the health of citizens.

**Actions and measures**

Following this option, actions and measures are completely dependent on the opinion of the stakeholders. These opinions may differ to a large extent, which in turn will lead to differences in the stakeholders' approaches. Therefore, it is advisable for the Authority to establish an effective and open communication programme with the stakeholders to assist them in this area.
Ratings for option 2: ELF-EMF advice precaution with no formal obligations

<table>
<thead>
<tr>
<th>General criteria</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Easy option</td>
<td>+</td>
</tr>
<tr>
<td>Stakeholder involvement</td>
<td>+</td>
</tr>
<tr>
<td>Visible actions</td>
<td>- -</td>
</tr>
<tr>
<td>International support</td>
<td>- -</td>
</tr>
<tr>
<td>Scientific basis</td>
<td>- -</td>
</tr>
<tr>
<td>Knowledge development</td>
<td>- -</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Culturally based criteria</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public image</td>
<td>- -</td>
</tr>
<tr>
<td>Public concern</td>
<td>- -</td>
</tr>
<tr>
<td>Grip on situation</td>
<td>- -</td>
</tr>
</tbody>
</table>

5.4 **Option 3: ELF-EMF regulation based on ICNIRP recommendation, with or without precautionary measures**

The Authority may consider implementing the ICNIRP recommendations in their EMF-regulation. If desired, this may be supplemented by precautionary measures.

Implementation of this option has been recommended by the European Union to its member states in 1999. Most European countries (21 of 27) have adopted this EU/ICNIRP recommendation. Other countries that have adopted the ICNIRP guidelines are Israel, New Zealand, Republic of Korea, Singapore, South Africa, and Taiwan.

Consequences for public concern

Public concern will remain since there is an increasing amount of alarming information available on the Internet. For many (European) citizens, it is reassuring to know that the majority of European countries have adopted the EU/ICNIRP recommendation. Nevertheless, there will always be a demand for implementing more stringent protection
measures. This demand is mainly based on the indistinctness of the epidemiological indications for a correlation between power lines and childhood leukemia. In some countries, the demand is even stronger due to the population's mistrust in the government.

According to the WHO, monitoring relevant scientific development combined with an adequate communication strategy is one of the most elementary forms of precaution. In fact, the WHO itself has been following this strategy. The WHO is often looked upon by the general public as a leading authority, which means that its opinion is considered to be important. If the Authority is able to answer the questions raised by concerned citizens in a fast and adequate way (based on the WHO opinion), then the chance that these concerns escalate will probably decrease. Therefore, KEMA recommends Oman implement arrangements to monitor ongoing developments and scientific research into the health effects of ELF-EMF exposure.

**Support for this option**

There is a strong scientific basis for this option since it complies with the current ICNIRP recommendations. ICNIRP bases its recommendations on a profound scientific basis. ICNIRP states that the epidemiological indications for a correlation between power lines and childhood leukemia are not strong enough to justify lowering their exposure limits.

**Actions and measures**

Ratification of the ICNIRP recommendations in Oman in practice means that no actions have to be taken to lower the exposure of the general public to ELF-EMF. As expected, all measured electric and magnetic field strengths are well below the ICNIRP reference values.

**Precautionary measures: basic assumptions**

The Authority may consider supplementing the ELF-EMF-regulation (based on ICNIRP exposure limits) by precautionary measures. In that case, the epidemiological indications for a correlation between childhood leukemia and proximity to overhead power lines are considered to be important enough to justify precautionary measures. According to the WHO, implementing precautionary procedures is reasonable and warranted as long as the costs of such measures are low (WHO, 2007). For the situation in Oman, this probably means that precautionary measures only apply for new houses or schools or new overhead power lines. The removal of existing houses, schools or power lines will have a large social and financial
impact. In practice, precautionary measures can be based on two different basic assumptions:

1. The **presence of the overhead power line** itself is regarded as the cause for the correlation. This assumption emphasizes the fact that a causal relationship between magnetic fields and childhood leukemia has not been found. The cause for the epidemiological correlation is considered to be an unknown factor that is related to the presence of the power line. Distance to the overhead power line is chosen to be the main parameter. Precautionary actions are based upon increasing the physical distance between overhead power lines and places where children may be present for a long period of time (e.g. residences, schools).

2. The **exposure to the magnetic field of the power line** is regarded as the cause for the correlation. This assumption emphasizes the significance of the epidemiological findings. Precautionary actions are based upon reduction of the exposure of children to the magnetic fields of power lines at places where they may be present for a long period of time (e.g. residences, schools).

**Precautionary measures: actions**

If the **presence of the overhead power line (assumption 1)** is regarded as the cause for the correlation, the Authority may consider to define precautionary zones along these power lines based on distance from the power line. Within these zones, the construction of new residences and schools is discouraged or prohibited. At the same time, the precautionary zones for new power lines will have to be situated well outside urbanized regions.

The choice of the width of the precautionary zones can only be done on an arbitrary basis since the epidemiological studies do not provide enough information on distance. In the United Kingdom for example, a working group has advised the government to consider the introduction of precautionary zones of 60 meters on either side of a power line. This distance has been chosen upon the statement that the magnetic field strength is lower than 0.4 μT at a distance of 60 meters from any British power line.

If the **exposure to the magnetic field of the power line (assumption 2)** is regarded as the cause for the correlation, the Authority may consider to define precautionary zones along power lines based on magnetic fields from the power line. Within these zones, the construction of new residences and schools is discouraged or prohibited. At the same time,
the precautionary zones for new power lines will have to be situated well outside urbanized regions.

The choice of the width of the precautionary zones may be based on information from the epidemiological studies. In the two pooled analyses cut-off points of 0.4 μT (Ahlbom) and 0.3 μT (Greenland) were applied for long-term mean exposure. However, one has to keep in mind that these cut-off points were arbitrarily chosen, based on statistical grounds and have no health-related scientific meaning. Furthermore, the magnetic field of power lines is subject to variation in time and only expert people are able to measure and interpret the fields in a correct way.

**Precautionary measures: recommendations**

The implementation of precautionary measures can be an expensive and complex process. Some measures can have an influence on other risks as well. As an example, the construction of a new school at an alternative location (away from an overhead power line) may lead to a decrease in children's traffic safety if the alternative location is situated near busy streets. Therefore, the decision whether or not to take supplementary precautionary measures should be based on a balanced evaluation of all risks involved, as well as the costs and the benefits of precautionary measures. This evaluation is beyond the scope of this report, since this report focuses on magnetic fields only.

If the Authority considers to supplement the regulation based on ICNIRP exposure values with precautionary measures, KEMA recommends to define clearance zones based on fixed distances from the overhead power line. For all stakeholders as well as the general public distance is a clear, verifiable and unambiguous measure, in contrast to the "intangible" magnetic field levels. The distances may be arbitrarily chosen, or (partially) based on estimated magnetic field levels.

At this moment, it is difficult to set up recommendations for clearance zones in Oman. During the measurements that were performed by KEMA in November and December 2008, the current loads of the power connections were relatively low, which leads to an underestimation of the mean magnetic field strength during the whole year. KEMA recommends the AER to repeat the measurements during the summer season, when the current loads are expected to be higher. The combined measurements will provide a more reliable estimation of the clearance zones.
Ratings for option 3: ELF-EMF regulation based on ICNIRP recommendation

<table>
<thead>
<tr>
<th>General criteria</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Easy option</td>
<td>- to -</td>
</tr>
<tr>
<td>ELF-EMF regulation has to be developed. Regulation based on ICNIRP exposure limits is rather straightforward (rating: -). Definition of supplementary precautionary actions and measures is an elaborate task, especially if precautionary measures are based directly on magnetic field levels (rating: - -)</td>
<td></td>
</tr>
<tr>
<td>Stakeholder involvement</td>
<td>++</td>
</tr>
<tr>
<td>Active involvement of stakeholders in actions and communication</td>
<td></td>
</tr>
<tr>
<td>Visible actions</td>
<td>++</td>
</tr>
<tr>
<td>The Authority takes clear action</td>
<td></td>
</tr>
<tr>
<td>International support</td>
<td>++</td>
</tr>
<tr>
<td>ICNIRP is internationally respected as a scientific authority</td>
<td></td>
</tr>
<tr>
<td>Scientific basis</td>
<td>++</td>
</tr>
<tr>
<td>There is a strong scientific basis for this option</td>
<td></td>
</tr>
<tr>
<td>Knowledge development</td>
<td>+</td>
</tr>
<tr>
<td>Oman builds up relevant knowledge and communication possibilities</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Culturally based criteria</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public image</td>
<td>++</td>
</tr>
<tr>
<td>The Authority will improve its public image by showing its care for public health</td>
<td></td>
</tr>
<tr>
<td>Public concern</td>
<td>+</td>
</tr>
<tr>
<td>Public concern will probably not escalate drastically, but there will be doubts whether the chosen measures are safe enough. Concern may increase in already existing situations</td>
<td></td>
</tr>
<tr>
<td>Grip on situation</td>
<td>++</td>
</tr>
<tr>
<td>The Authority has a strong grip on the situation, provided that the actions and measures are specified in a clear manner</td>
<td></td>
</tr>
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</table>

5.5 Option 4: ELF-EMF regulation based on arbitrarily chosen exposure limits

The Authority may consider choosing their own exposure limits, which deviate from the ICNIRP recommendations, and implement them as advice or legislation.
In Europe, only Poland has adopted a law in which exposure limits lower than the ICNIRP values have been defined. Until a few years ago, some European countries advised their own exposure limits based on the recommendations of their own national scientific committees (e.g. the United Kingdom and the Netherlands). At present, the recommendations of these national scientific committees comply with the ICNIRP values. Outside Europe, only Australia, Japan and Russia have regulation that are based on other exposure limit values than the ICNIRP values.

Consequences for public concern

Public concern will remain since there is an increasing amount of alarming information available on the internet. People will probably still question whether the chosen exposure limits are sufficiently low to prevent alleged health effects.

Support for this option

From a scientific point of view, there is no basis for this option. The WHO even states that it is not recommended to reduce the limit values in exposure guidelines to some arbitrary level in the name of precaution. This would undermine the scientific foundation of the limits and is likely to be an expensive and not necessarily effective way of providing protection.

Actions and measures

The actions and measures that have to be taken completely depend on the selection of the exposure limits. The measures will probably be based upon reduction of the exposure of children to the magnetic fields of power lines. In practice, this means that precautionary zones along power lines have to be defined in which the construction or presence of houses or schools is discouraged or prohibited. According to the WHO, this is only warranted in low-cost situations (with low financial and social impact), and therefore only applies to new buildings or power lines.
Ratings for option 4: ELF-EMF regulation based on arbitrarily chosen exposure limits

<table>
<thead>
<tr>
<th>General criteria</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Easy option</td>
<td>- -</td>
</tr>
<tr>
<td>Stakeholder involvement</td>
<td>++</td>
</tr>
<tr>
<td>Visible actions</td>
<td>++</td>
</tr>
<tr>
<td>International support</td>
<td>- -</td>
</tr>
<tr>
<td>Scientific basis</td>
<td>- -</td>
</tr>
<tr>
<td>Knowledge development</td>
<td>+</td>
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<table>
<thead>
<tr>
<th>Culturally based criteria</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public image</td>
<td>++</td>
</tr>
<tr>
<td>Public concern</td>
<td>+</td>
</tr>
<tr>
<td>Grip on situation</td>
<td>++</td>
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</table>

5.6 Summary of options

A summary of the general advantages and disadvantages in terms of the general criteria and culturally based criteria for the four defined ELF-EMF regulation options is presented in Table 3.

The options are:
1. No ELF-EMF regulation or advice
2. ELF-EMF advice: precaution without obligations
3. ELF-EMF regulation based on ICNIRP recommendation, with or without precautionary measures
4. ELF-EMF regulation based on arbitrarily chosen exposure limits.
Table 3  Summary of general and culturally based advantages and disadvantages of the defined policy options for Oman. Note: the ratings cannot be used in a quantitative way

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Explanation of criteria rating</th>
<th>Options</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td><strong>General criteria</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Easy option</td>
<td>Minor or no actions required from the Authority</td>
<td>++</td>
</tr>
<tr>
<td>Stakeholder involvement</td>
<td>Stakeholders actively involved</td>
<td>-</td>
</tr>
<tr>
<td>Visible actions</td>
<td>Authority recognized for taking clear actions</td>
<td>-</td>
</tr>
<tr>
<td>International support</td>
<td>Authority considered right up to date</td>
<td>-</td>
</tr>
<tr>
<td>Scientific basis</td>
<td>Regulation based on scientific findings</td>
<td>-</td>
</tr>
<tr>
<td>Knowledge development</td>
<td>Knowledge development in Oman</td>
<td>-</td>
</tr>
<tr>
<td><strong>Culturally based criteria</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Public image</td>
<td>Authority recognized as being sympathetic to public health</td>
<td>-</td>
</tr>
<tr>
<td>Public concern</td>
<td>Concern will not escalate drastically</td>
<td>-</td>
</tr>
<tr>
<td>Grip on situation</td>
<td>Authority has a grip on the situation</td>
<td>-</td>
</tr>
</tbody>
</table>

5.7  **Recommendations for Oman**

Based on the advantages and disadvantages of the options as mentioned above, KEMA recommends the Authority to follow the approach of option 3: the introduction of ELF-EMF regulation based on the exposure limits of the ICNIRP. If desirable, this approach can be supported by precautionary measures to prevent new cases where children's residences or other long-term accommodations are situated in the proximity of overhead power lines. A
A precautionary measure would be the enforcement of minimum clearance zones around newly constructed overhead power lines (based on distance or magnetic field strength), as well as around existing overhead power lines with regard to the construction of new residences and schools.

KEMA also recommends Oman to implement national initiatives to monitor and follow scientific research and development into the health effects of ELF-EMF's. Knowledge gained from such initiatives would allow the government to keep stakeholders and citizens informed of the status of known or presumed health effects of exposure to ELF-EMF's. These initiatives would generate confidence amongst citizens and stakeholders that the government was taking positive measures to remain alert to relevant risks.

The WHO developed a model legislation that provides the legal framework for implementing protection programmes against health effects of electric and magnetic fields (WHO, 2006). This model legislation follows the widely accepted practice among lawmakers of having an enabling Act that permits the responsible official to subsequently issue Regulations, Statutory Orders or Ordinances, as appropriate, to deal with specific areas of concern. It comprises a Model Act, a Model Regulation and an Explanatory Memorandum describing the approach to the Act and its Regulation. KEMA understands that the Authority has powers to introduce new regulation. The WHO program may assist the government implement other national initiatives and programs.

The epidemiological indications are limited to exposure to magnetic fields caused by overhead power lines. Since there are still many uncertainties attached to these indications (see chapters 2 and 3), it may be expedient to expand precautionary measures to other sources of magnetic fields e.g. cables, transformers and (household) electrical appliances. There is no positive proof that the magnetic field itself is the cause of the epidemiological indications. Furthermore, there is no information available on which exposure metric is indicative for a health effect; this implies that translation of an effect to other sources is not possible. Therefore, in case the Authority is planning to apply precautionary measures, KEMA recommends to apply such measures for overhead power lines only.
CONCLUSIONS AND RECOMMENDATIONS

Extremely low frequency (ELF) electric and magnetic fields (EMF) of very high intensity may cause biological effects by means of undesired nerve stimulation. These very strong fields do not occur in the everyday environment. A large amount of research has been carried out dedicated to possible health effects of much weaker electric and magnetic fields, which are present in the everyday environment. This research has not demonstrated or confirmed any other health effects, with the exception of epidemiological indications of positive correlation between incidences of leukaemia among children living in the vicinity of overhead power lines. However, these correlations are not supported by mechanism related research: no causal relation or mechanism has been found between childhood leukemia and other diseases and exposure to ELF-EMF.

From an international point of view, the leading authority in recommending exposure limit values is the International Commission on Non-Ionizing Radiation Protection (ICNIRP). The ICNIRP has based its recommended exposure limit values upon the scientific knowledge of health effects. The exposure limits have been set to prevent the nerve stimulation effects of very strong fields. The ICNIRP has investigated the epidemiological indications as well, but judged these indications to be not sufficiently strong enough to warrant a further reduction of the exposure limits. The absence of a confirmed causal relation and the absence of a plausible mechanism were decisive factors in ICNIRP's conclusions.

Most European countries (21 of 27) have acted on the Council of the European Union's recommendation to implement the exposure limits by ICNIRP. Four countries have implemented or advised the ICNIRP exposure limits, supplemented with precautionary measures based on the epidemiological indications. It is expected that in the upcoming years more European countries will implement such supplementary measures, since the public concern for health effects as well as the public opposition towards the government and stakeholders increases strongly in those countries.

Public concern about health effects has increased sharply during the last decade and will definitely increase further, especially in countries where the government is taking actions to assuage the concerns of citizens and stakeholders about the exposure risks of ELF-EMF. The WHO supports governments and other stakeholders in dealing with public concern about ELF-EMF.
Outside Europe, only nine countries have implemented (or advised) exposure limits for ELF-EMF in their regulation. In six of these countries the exposure limits correspond with the ICNIRP exposure limits. Only in one country supplementary precautionary measures have been introduced. None of the six member states of the Gulf Cooperation Council have implemented legislation or regulation to limit exposure to ELF-EMF.

In this report, having considered several options, KEMA recommends the Authority implement regulation based on ICNIRP exposure limits. If desirable (e.g. as identified by means of a balanced evaluation of all risks, costs and benefits of measures), these regulation may be supplemented with precautionary measures for overhead power lines. There is insufficient scientific evidence to support supplementary precautionary measures for other sources of magnetic fields (e.g. electricity distribution cables, transformers, (household) appliances). KEMA also recommends Oman take national initiatives to follow ongoing scientific research and developments in the area of ELF-EMF's and consider further action as and when necessary.
REFERENCES


IEEE, 2002. IEEE Standard for safety levels with respect to human exposure to electromagnetic fields, 0 to 3 kHz. International Committee on Electromagnetic Safety (ICES), Institute of Electrical and Electronics Engineers (IEEE). Standard no. C95.6-2002


WHO, 2006. Model legislation for electromagnetic fields protection. World Health Organization,


APPENDIX I  EMF REGULATION/ADVICE IN OTHER COUNTRIES

In this appendix, an overview of the regulation or advice regarding exposure of the general public to ELF electric and magnetic fields in other countries is presented. Relevant information has been collected by means of an internet search, information from the WHO, as well as information from international contact persons of KEMA.

For each country the relevant regulation or advice has been outlined, with details on status and basic values (when available). Typical information on public concern on a national scale has also been recorded.

Australia

Standard: "Limits & precautionary measures for reducing exposure to electric and magnetic fields – 0 to 3 kHz", by ARPANSA (Australian Radiation Protection And Nuclear Safety Agency).
Status: draft standard to replace ICNIRP advice.
Basis: some similarities with IEEE exposure limits, but including extra safety margins:
- Electric field maximum 5 kV/m (higher values only under controlled circumstances
- Magnetic field maximum 30 μT for exposure of the human head (exposure of limbs only: maximum 300 μT).

Austria

Status: pre-standard (since 2006). An ÖNORM is not legally binding, but defines the state of the art. Experts use ÖNORMs in administrative proceedings. ÖNORMs can be imposed by official notifications.
Basis: EU recommendation.
Public concern exists regarding the construction of new power lines; major new power line projects have been initiated recently.

Belgium

No standard or advice based on health protection
In Belgium, there are only technical guidelines for the electric fields of overhead power lines:
- Electric field maximum 10 kV/m
Electric field maximum 7 kV/m (at road crossings)
Electric field maximum 5 kV/m (for accessible or inhabited areas)

**Brazil**

Standards only for higher frequencies (≥ 9 kHz).
Public concern on ELF-EMF’s seems to be decreasing in Brazil. The proposed construction of two new substations and associated transmission lines did not evoke widespread opposition. The fact sheets of the WHO seemed to be accepted by the population on these two cases.

**Bulgaria**

**Standard**: the EU recommendation will be implemented into Bulgarian law by the Ministry of Health.

**Status**: the implementation is in its final stage. According to the proposal, different exposure limits have been defined for various regions and places where the population may stay, depending on exposure time. The source documents are only available in the Bulgarian language.

**Basis**: EU recommendation.
Public concern is mainly focused on mobile telephone base stations; power lines are not an issue of concern at the moment.

**Canada**

Standards only for higher frequencies (≥ 3 kHz).
Public concern in Canada results in widespread public opposition to the proposed construction of power lines and mobile telephone base stations. Opposition is often influenced by factors other than health issues (i.e. aesthetics and property devaluation). Concern focuses mainly on mobile telephone base stations.

**China**

Standards and regulation only for higher frequencies (≥100 kHz).

**Croatia**

**Standard**: Law, by Croatian Parliament, Ministry of Health.

Basis: ICNIRP values.

Public concern in Croatia is mainly focused on mobile telephone base stations.

**Czech Republic**

**Standard:** Governmental Decree No 480/2000, introduced in 2001.

**Status:** this decree is legally binding.

**Basis:** ICNIRP values.

Public concern: self-claimed electro-sensitive citizens often argue that Italy and Switzerland offer their citizens better protection. Nevertheless, compared with the situation in most European countries, the public concern regarding electromagnetic fields is negligible in the Czech Republic.

**Denmark**

**No EMF standard, no known plans for legislation**

Since 1993 a precautionary approach has been applied in Denmark. The basis of this approach: do not build new high voltage installations close to existing dwellings, or new homes close to existing high voltage installations. “Close to” has not been defined in terms of distance or exposure metrics.

**Estonia**

**Standard:** Regulation by the Ministry of Social Affairs.

**Status:** draft, but compulsory when passed.

**Basis:** EU recommendation.

**Finland**

**Standard:** Law (since 2002), by the Ministry of Social Affairs and Health.


**Basis:** ICNIRP values, supplemented with short-term exposure limits:

- Electric field maximum: 5 kV/m (continuous exposure), 15 kV/m (short-term exposure)
- Magnetic field maximum: 100 μT (continuous exposure), 500 μT (short-term exposure).

The EU recommendation has been regarded in Finland as implemented through a new law.
France

No plans for implementation of EU recommendation; ICNIRP values are already applied in practice.
All new electrical installations are required to meet a set of technical specifications set down by an interministerial ruling (Reference: Order of May 2001, Journal Officiel June 2001).
For power systems:
- Electric field maximum 5 kV/m for new or modified installations at normal operating conditions
- Magnetic field maximum 100 μT for new or modified installations at normal operating conditions

Germany

Standard: 26th Ordinance implementing the Federal Immission Control Act (26 BimSchV, December 1996). Law, regarded as fulfilling the requirements of the EU recommendation.
This law applies to power lines, transformers and switchgear.
Basis: continuous exposure values equal the ICNIRP exposure limits, supplemented with short-term exposure limits:
- In general: electric field maximum 5 kV/m. At places where there is no long-term presence of children: electric field maximum 10 kV/m, allowed during 5% of the day or in small areas outside buildings
- In general: magnetic field maximum 100 μT. At places where there is no long-term presence of children: magnetic field maximum 200 μT, allowed during 5% of the day or in small areas outside buildings.

Greece

Basis: EU recommendation.
Public concern in Greece focuses on mobile telephone base stations.

Hungary
Standard: Decree in 2004: Decree 63/2004 EszCsM on the limitation of exposure of the general public to electromagnetic fields (0Hz to 300 GHz); by the Ministry of Health, Social and Family Affairs.

Basis: EU recommendation.
Since implementation in 2004: no problems with public concern.
Public concern in Hungary focuses on electric power transformers. Typically, 10/0.4 kV transformer stations in Hungary have been installed in the basement or ground floor of apartment buildings. This results in magnetic field strengths of several tens of μTs in apartments or offices close to the transformers. Residents are concerned about the possible health effects.

Ireland

No EMF standard yet.
Status: in 2007, the responsibility for potential health effects of EMF shifted towards the Department of the Environment, Heritage & Local Government. As a consequence, the Radiological Protection Institute of Ireland (RPII) will probably expand its ionising radiation activities with non-ionising radiation, including health effects of EMF.
The government plans to incorporate the EU recommendation into law, but the timescale is unknown. The state-owned electricity supply board, ESB, voluntarily complies with the ICNIRP values, as requested by the government.
Public concern over power fields has increased in some Irish areas due to the expansion of the high voltage transmission network.

Israel

National law, by Ministry of the Environment.
Status: since 2006.
Basis: ICNIRP exposure limits, supplemented with precautionary measures: Magnetic field maximum 1 μT for new facilities in the ELF frequencies.

Italy

Standard: Decree of Prime Minister, July 2003.
Document: Establishing the exposure limits, attention values and quality targets for the protection of the population from exposure to electric and magnetic fields at the network
frequency (50 Hz) generated by power lines (Gazzetta Ufficiale della Repubblica Italiana no. 200, 29/8/2003).

**Basis:** EU recommendation, supplemented with precautionary "attention values" and "quality targets" for power lines.
- Exposure limits: comply with the EU recommendation
- Attention values for magnetic field: 10 μT (maximum 24 hours median value; limit for daily exposure duration 4 hours)
- Quality target for magnetic field, applicable to new power lines and new premises: 3 μT (maximum 24 hours median value).

For all other applications: comply with EU recommendation.

Three Italian regions Veneto, Emilia-Romagna and Toscana, have set exposure limits for power lines at 0.2 μT for new installations near schools, nurseries, hospitals, houses and places where people spend more than four hours per day. Veneto also has a similar limit of 0.5 kV/m. These remain in force but the National Decree prevents further Regions doing likewise.

The Regional Agencies for Environmental Protection in Italy (ARPA) are responsible for the verification of the compliance of power lines to the exposure limits. This verification is carried out by means of theoretical calculations or experimental measurements. In the year 2003, 1600 controls were performed on power lines.

**Japan**

**Standard:** Ordinance, by Ministry of Economy, Trade and Industry.
**Status:** mandatory since 1976. In 2007, a working group from the Ministry recommended the Ministry to adopt the ICNIRP exposure limits.
**Basis:** Not (yet) based on ICNIRP exposure limits. Electric field exposure limit is not intended to protect human health, but to avoid electric shocks caused by electric fields.
- Electric field maximum 3 kV/m
- Magnetic field: no reference levels.

**Jordan**

Standards only for higher frequencies (telecommunication).

**Latvia**
Basis: values comply with EU recommendation.

Lithuania

Standard: two legally binding Hygiene Norms, one for the general public (overhead power lines only, 2000), and one for occupational exposure (2001).
Basis: details not known.

Luxembourg

No standard or advice on exposure limits.
In Luxembourg, there is a precautionary advice to local authorities by means of Circular 1644 (ref 26/94, March 1994): land in immediate proximity of high voltage power lines should not be approved as building land.

Malta

Advice: Recommendation by the Ministry of Health, Transport and Communications, and Social Policy.
Reference: report on recommendations for limiting human exposure to time-varying electric, magnetic and electromagnetic fields in the frequency range from 0 Hz to 300 GHz, August 2000.
Basis: ICNIRP values.

Netherlands

No plans for legislation.
Advice: from the Ministry of Housing, Spatial Planning and the Environment (2005) to local and regional authorities and power companies. Apply the EU recommendation, with the addition of a precautionary advice: avoid new situations where children will be subject to long-term exposure to magnetic fields from overhead power lines with mean field strength > 0.4 μT. The field strength is based on an average annual field calculated for each power line, resulting in a precautionary clearance zone for each power line. New situations: new dwellings, schools or crèches, or new power lines.
Basis: EU recommendation, plus results from pooled epidemiological analysis (Ahlbom et al, 2000).
Public concern: a new power line has to be constructed in the western part of the country, which is heavily urbanized. This has led to many objections by the public. People who are already living close to power lines, as well as people who are living close to other electrical systems (like transformers), complain that the government does not care about their health.

**New Zealand**


Basis: ICNIRP exposure limits, suggestion to consider precautionary measures for new power lines near sensitive activities (schools, residences, hospitals). Guidelines for local authorities on how to implement the National Policy Statement are being prepared. Precautionary measures are not specified.

Public concern focuses on the construction of a proposed 400 kV transmission line in New Zealand.

**Norway**

Standard: Law regarding use of radiation, since 2003.

Regulations on Radiation Protection and Use of Radiation, by Ministry of Health.

This law contains a section on exposure levels, which points out that

“All exposure (ionising radiation?) shall be kept as low as practically possible. Relevant guidelines from ICNIRP shall as a rule be followed provided no national or European standard exists”.

In Norway, there is some public concern regarding residences close to power lines. Like in the other Scandinavian countries, EMF hypersensitivity receives a lot of attention.

**Peru**

Standards only for higher frequencies (≥ 9 kHz).

**Poland**

Standard: Law by the Ministry of Environment.


Basis: the exposure limits deviate from the ICNIRP values:

- Electric field maximum 10 kV/m, in residential areas maximum 1 kV/m
Magnetic field maximum 48 μT.

In Poland, there is an ongoing discussion about the results of the pooled epidemiological analyses, which ultimately may lead to the setting of different permissible levels of public magnetic field exposure.

**Portugal**

**Standard:** National law by the Portuguese government since 2004 (Portaria no. 1421/2004).

**Basis:** EU recommendation.

Public concern about power lines is increasing in Portugal. In 2007, a Portuguese judge decided that a power line near Lisbon had to be put out of operation because no guarantee could be given that the magnetic fields were “safe”. The media paid much attention to this verdict. The transmission system operator REN was only allowed to utilize the line after six months.

**Philippines**

Standards and regulation only for higher frequencies (≥ 3 kHz).

**Republic of Korea**

**Ordinance,** by Ministry of Information and Communication.

**Status:** since 2001, compliance is voluntary.

**Basis:** ICNIRP exposure limits.

Public concern in the Republic of Korea focuses mainly on mobile telephone base stations. To prepare for possible adoption of the precautionary principle, a research project for cost-benefit analysis as well as for other related issues has been started for all non-ionising radiation frequencies, including ELF-EMF.

**Russia**

**Standard:** Safety standard "Maximum permissible levels of magnetic fields of power frequency (50 Hz) in residential and public buildings and in residential areas".

**Status:** mandatory, since 2007.

**Basis:** Not based on ICNIRP exposure limits.

Magnetic field maximum 5 μT inside continuously inhabited residences (long-term exposure), maximum 10 μT in other residential areas (short-term exposure).
Singapore

National guidelines, by Health Sciences Authority.
Status: since 2001, compliance is voluntary.
Basis: ICNIRP exposure limits.

Slovak Republic

Standard: Decree by the Ministry of Health No. 123/1993 on the protection of health from the harmful effects of electromagnetic fields.
Details are not known.

Slovenia

Standard: Decree by the Ministry of Environment, valid for electric power facilities > 1 kV.
Basis: part of the EU recommendation, supplemented with precautionary measures:
- Limit for public exposure: Electric field maximum 10 kV/m, magnetic field maximum 100 μT
- Limit for new facilities and protected areas: Electric field maximum 500 V/m, magnetic field maximum 10 μT
Protected areas are hospitals, health resorts, residential areas, tourism buildings, nurseries, schools, playground, public parks and recreational areas, public centres with services or restaurants.
Public concern in Slovenia focuses mainly on mobile telephone base stations.

South Africa

Status: since 1973, revision is pending. Department of Health recommends voluntary compliance with ICNIRP.
Basis: recommendation for ICNIRP exposure limits, revision will be based on ICNIRP exposure limits.

Spain

Advice by the Ministry of Health and Consumer Protection in 2001: use EU recommendation.
Additional advice by the Ministry of Health and Consumer Protection in 2003: current Spanish regulation is satisfactory.
Since 1997, there is an initial draft from the Spanish Ministry of Industry for a standard, wherein a corridor free from residential area close to power lines is envisaged. This draft has incurred many practical problems, especially since there are already existing power lines in urban areas. Some regions, like Madrid, have already published regulation that is in line with this draft. In other regions, like Extremadura, Asturias, Castilla-León and Castilla-La-Mancha, there are local initiatives to move existing lines. Regions like Murcia and Valencia have rejected the draft.

**Sweden**

No law enforcement plans, application of precautionary principle.


**Document:** Low frequency electrical and magnetic fields: the precautionary principle for national authorities. Guidance for decision makers, September 1996.

**Statement:**

“If measures to reduce exposure can be taken at reasonable expense and with reasonable consequences in all other aspects, an effort should be made to reduce fields radically deviating from what could be deemed normal in the environment. Where new electrical installations and buildings are concerned, efforts should be made already at the planning stage to design and position them in such way that exposure will be limited”

According to this report, a “normal magnetic fields level” in Sweden is 0.1 μT (median value), with 10% of homes having at least one room with a field > 0.2 μT.

**Switzerland**

**Standard:** Law by the Bundesrat (Upper House) since 2000.

**Document title:** Ordinance concerning protection from non-ionising radiation (NISV).

Existing constructions had three years to meet the requirements.

Exposure from fixed facilities only, not valid for facility operational staff.

**Basis:** EU recommendation, supplemented with precautionary measures:

- Exposure limit: Electric field 5 kV/m, magnetic field 100 μT (excl. in-house sources)
- Limit for sensitive use:
- Overhead line or underground cable (> 1 kV) 1 μT. New installations: exemptions possible if all reasonable measures have been taken. Old installations: does not apply, provided the phases are optimised
- Transformer station, substation, switching station: 1 μT. New and old installations: exemptions possible if all reasonable measures have been taken
- Interior electrical installations: new installations in accordance with best available technology to reduce field.

Sensitive use: rooms in buildings regularly occupied for significant periods of time, children’s playgrounds designated as such under planning law (not private gardens) and undeveloped land where the above forms of utilisation are permitted.

Taiwan

**Standard:** National decree.
**Status:** since 2001, compliance is voluntary.
**Basis:** for ELF, reference levels correspond with ICNIRP exposure limits.

Turkey

Standards only for higher frequencies (≥ 10 kHz).

United Kingdom

**Advice** by the Health Protection Agency (complies with ICNIRP values).
**Document:** Advice on limiting exposure to electromagnetic fields (0 – 300 GHz).
**Basis:** ICNIRP values.

Public concern regarding power lines is increasing in the UK. The main subject of this concern is the electric field of the power line (the University of Bristol is very active in emphasizing possible corona ion effects). The government installed a working group (SAGE), consisting of about 40 stakeholders, to set up an advice to the government on how to deal with the health issue. In 2007, the SAGE group advised the government to consider implementation of precautionary zones of 60 meters at each side of power lines. The Government has not yet replied to this advice.

United States of America

Standards only for higher frequencies (≥ 3 kHz).