How as a transmission system operator (TSO) to respond to the growing public concern on the potential health effects of ELF exposure? Internal actions and scientific cooperation agreement with the BBEMG

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SUMMARY

Elia, as TSO in a densely populated country (Belgium), has to deal with a growing public concern about ELF in his daily operations. In order to provide an adequate answer to this concern Elia has worked out, step by step, a policy to inform and communicate with the public, authorities and other stakeholders. Potential health effects, exposure and the technical aspects were identified as the mean topics to address.

In connection with the health issues, a cooperation agreement was concluded in 1997 with eight research centres, which have joined forces within the Belgian BioElectroMagnetic Group (BBEMG). Their mission is double: first to carry out research designed for a better understanding of the interactions between electromagnetic fields and biological activity and secondly to create expertise and information centres accessible to the public, scientists and authorities. The experts accepted this mission provided that they would be totally independent in carrying out their work and presenting their opinion. An indispensable part of this cooperation is the diffusion of their scientific knowledge and expertise. Besides the classic academic papers and conferences, a more get-at-able way of informing the general public is accommodated by organising public workshops and the development of a comprehensive website. The website presents the research activities of the BBEMG but tries also to support a better understanding of the electromagnetic fields and their possible effects on health in general. Hence a quality educational and documentation tool is proposed. Contacts and exchanges are encouraged by the way of forms inserted in various pages.

Another aspect addressed is the public exposure to ELF, both from overhead lines and underground cables. Different studies were conducted to assess the levels of exposure, including field measurements, analytic models and personal monitoring. An internal study of 1996 concluded that about 1% of the Belgian population lives in a corridor along the grid with average magnetic field levels above 0.4μT. Later on these results were confirmed by other, independent, studies. Beside these large scale assessments, case by case measurements are performed at demand or within the framework of permitting procedures for new infrastructure. Since 2000 individuals can request for

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field measurements in the proximity of our installation. These requests, already more then 200 this year are mainly related to property transactions or the anxiety (after statements in the press) of (young) families living in the proximity of power lines. Although there are no ELF limits into force in Belgium, only for the electric field, authorities sometimes restrict real-estate development projects nearby power lines. In these cases a simulation study to predict exposure levels can help to find a compromise between the authorities and the project developer.

A final aspect is the use of certain technical solutions to reduce ELF corridors for the construction of new or the modification of existing grid infrastructure.

The construction of new power lines and cables, despite the use of mitigating techniques and a well-considered routing, still faces significant opposition. The above described initiatives in combination with an open and honest dialogue with the population and the authorities are important to gain public acceptance.

KEYWORDS

High-voltage grid, Popularization, Web-based communication, Exposure assessment, Cables, Lines, Corridors of influence, Public perception.

INTRODUCTION

The Elia grid (Belgium) consists of 70, 150, 220 and 380kV overhead lines and 36, 70 and 150kV underground cables. The older lines, especially 70kV, and most cables traverse often residential areas or villages. To date, houses are still constructed underneath the lines. The only restrictions are the electric security distances to comply with. The lack of an efficient special planning but above all the absence of any right of way promotes this situation. This practice and the growing public concern, reflected in a common opposition against new lines and even cables, demonstrate the need of an adequate policy. This paper describes the actions undertaken by Elia to tackle the ELF issue, in particular an exposure assessment along the Belgian grid, a technical/ economical evaluation of mitigation techniques, and the free service of field measurements at the people's home [1]. The health aspects are addressed by the Belgian BioElectroMagnetic Group (BBEMG).

1. POTENTIAL HEALTH EFFECTS : RESEARCH AND COMMUNICATION

In connection with health issues, a cooperation agreement was concluded in 1997 with eight research centres, which have joined forces within the Belgian BioElectroMagnetic Group (BBEMG). The BBEMG has established a contract with a private partner, Elia. The terms of the contract, which establish the relations between the partner and BBEMG scientists, guarantee the latter a complete independence of communication, publication and working conditions.

In the present contract, the BBEMG is composed of five teams from various research areas: (1) Biological investigations on neurodegenerative conditions, (2) EMF effects on cell differentiation, (3) ELF EMF & Contact current hypothesis evaluation, (4) Electrosensitivity, (5) Epidemiology follow-up & Risk assessment of the ELF EMF health effects in workers.

The BBEMG's multidisciplinary program aims to fulfill a double mission:

- Contribution to a better comprehension of the interactions between electromagnetic fields and biological organisms;
- Diffusion of scientific knowledge and expertise to scientists, authorities and the public.

Here we will describe actions undertaken regarding the diffusion of knowledge. It is divided into direct communication and web-based communication.

1.1. Direct communication

As scientific researchers, each member of the Group disseminates the results of their studies through scientific publications and attendance to conferences. Some of them are also involved in governmental working groups.

Besides these actions towards a more specialised public, the BBEMG tries to keep in touch with the general public through the organisation of public workshops, *in situ* measurements of ELF exposure and contacts currents and privileged contacts with electrosensitive persons.

1.2. Web-based communication

The BBEMG website (www.bbemg.ulg.ac.be) has been launched on the internet in 2001. It is developed in three languages: French, Dutch and English.

It aims to present the results of the BBEMG research teams, to inform about electric and magnetic fields and their potential effects on health and to become a centre of documentation and education able to provide information regarding 50 Hz electromagnetic fields to the general public, scientists, physicians, public officials...

The website, containing around 100 pages in each language, is divided in five headings: **(1) Presentation of the BBEMG**; **(2) Basic concepts**: Information developed in Flash format on EMF concepts and 50 Hz EMF in our environment; **(3) EMF and Health**: The heart of the website. What are the results of scientific research related to ELF health effects? A synthesis developed in Flash format is proposed, followed by another one on electrosensitivity. Information on guidelines and standards is also available. Overviews of epidemiologic studies and a FAQ complete this heading; **(4) Scientific information**: Listing of relevant reports, booklets and fact sheets, Agenda; **(5) Contacts and exchanges**.

Communication within the website is developed through various actions:

- **Popularization**

Contents have been popularized through modules developed in Flash format. We chose Flash in order to organise contents in a friendly manner, with sequential presentations and summaries. Practically, as pointed out by Bader and Strickman-Stein ([2]), even if they do not learn more with it, people prefer Flash format. However, we also propose more documents and publications for visitors ready to make more efforts to understand.

Two modules present an overview of potential health effects: a first one on the whole EMF and Health problematic, with information on guidelines and standards, methods of research and exposure analysis, and a second one on electrosensitivity. Another module invites people to explore our everyday exposure at home, at work and in the vicinity of power lines or transformers. Other modules are currently under development: popularization of BBEMG researches (lipoatrophia semi-circularis, EMF effects on bones and cell differentiation) and advantages versus drawbacks of the methods of research (*in vitro* studies, *in vivo* studies, epidemiology, human studies, modelling).

- **Contacts**

Contacts are encouraged through forms inserted in various pages. Direct contact of the BBEMG members is also facilitated: email addresses and phone numbers are placed on team pages and other useful places (F.A.Q. page, modules…).

Online forms received in 2010 were issued from 150 visitors. They mainly belonged to the general public (80%). Among the others, a large majority contacted us in relation with their occupational profile, e.g. general practitioners, people from public institutions. They were seeking for advices or expertise. Others were interested in further information on the BBEMG research programme, e.g. scientists, students, journalists. A little bit more women asked questions than men. A large majority of questions came from Belgium (59%) and countries bordering Belgium (of whom 23% from France).

Concerning the sources, a large majority of requests were oriented to ELF. The questions were mainly related to power lines but we also noticed an increasing number of questions related to transformers and electrical apparatuses. Around 10% of questions concerned electromagnetic fields in general without any frequency specification and 15 % of questions were related to radiofrequencies, sometimes also in combination with ELF. Despite the frequency range being outside BBEMG expertise, we answered these inquiries at least to orient people towards another contact or institution. We also took into account some of these questions because they arose from people who claim being electrosensitive.

Here are the topics of the questions (table 1):

- 47.3% of questions referred to potential health effects of electromagnetic field exposure, of which 14.3% related to electrosensitivity.
- Many questions concerned EMF measurements and exposure values or 'safety distance' for dwellings. Other questions were oriented to technical aspects or shielding.

- BBEMG collaboration are related to requests about BBEMG functioning, copyright (pictures or contents of the website), invitation to conference, questions on study methods, direct collaboration in the electrosensitivity study ...

Table 1 – Topics of the questions according to the gender

	Women	*Men*	*Undetermined*	*Total*	
Health	41	31	4	76	33,0%
Electrosensitivity	19	12	2	33	14,3%
Measurement	14	14	2	30	13,0%
Level of exposure, distance	7	18	1	26	11,3%
Technical questions	7	9	1	17	7,4%
Standards	3	8	1	12	5,2%
Shielding	4	3	1	8	3,5%
BBEMG collaboration, expertise	5	4	0	9	3,9%
Others	11	6	2	19	8,3%

Here are the main concerns, or why did people ask questions? (table 2):

- Major concerns are health in general, without any other. People were often informed of the 0,4μT epidemiological threshold and were seeking for safety solutions. However, they were often not really aware of real exposure values.
- More and more people were also seeking for information on the safety of a house or a land according to the vicinity of powerlines or transformers. It is interesting to note that more than 80% of the requests were treated within a week. Reactivity is important for the credibility.

Table 2 – Concerns according to the gender

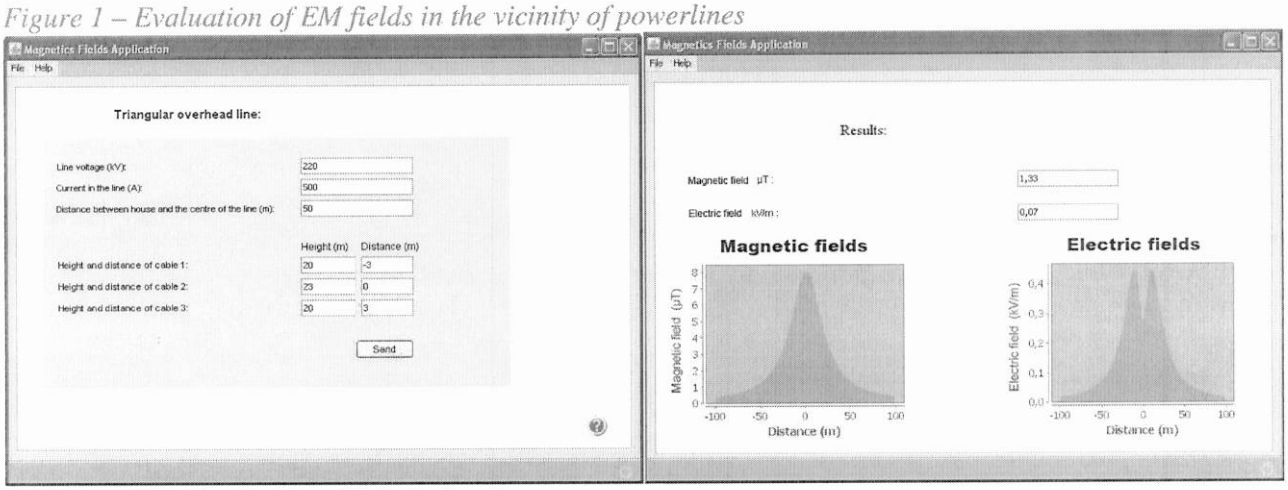
	Women	*Men*	*Undetermined*	*Total*	
House or land safety	14	21	2	37	23,3%
Health in general	21	14	1	36	22,6%
Health of children	12	7	0	19	11,9%
Advices, expertise	7	11	1	19	11,9%
Homework, PhD	9	5	3	17	10,7%
Health at work	2	4	0	6	3,8%
Interview	3	1	0	4	2,5%
Unspecified	11	7	3	21	13,2%

- **'In brief' pages**

From the feedback received from the visitors and the analysis of their questioning, it appears without surprise that too much information kills information. An extensive analysis of the scientific results does not allow people to decide how to interpret what they are reading. In brief pages, we intend to introduce the contents of each header, even if it proves to be difficult for example in the EMF and Health header. People are encouraged to go further by the way of links directing to detailed contents.

All other headers also contain these 'In Brief' pages: for example in 'General information' header, people have a direct access to a programme developed by the engineers of our group (figure 1). It allows them to roughly evaluate their exposure to fields according to the vicinity of a powerline. Links to contact forms and explanations allow people to get contact and go further if needed.

Figure 1 – Evaluation of EM fields in the vicinity of powerlines



(Developed by PP. Barbier, PhD Student)

- **Update follow-up**

It is crucial for a website to provide the very last pieces of information. Web surfers need to find up-to-date contents. The follow-up of changes is eased by the insertion of RSS feeds in each part of the website. Moreover, each page is separately dated. Both actions have proven to be really helpful to keep an eye open-wide on updates.

Next to these actions of communication, efforts have also been made to improve the visibility of the website on the internet: a web-based communication means nothing if the website is poorly visited. Web ranking has been developed through search engine optimisation strategy, as for example friendly html and css codes or other usual tips. Content updates are also important for search engines as Google: a website poorly updated will be considered as inactive and by consequence quickly lowered in its search result pages.

We closely follow the traffic on the website through usage statistics provided by dedicated tools or services. This analysis, combined with the questions asked by our visitors, orients the development of the website. This process of continuing evaluation was initiated in 2001 and renewed in 2004 ([3], [4]) through two major qualitative analyses of the website usability and utility.

2. EXPOSURE ASSESSMENT

It was recognized that in order to rationale a policy on ELF, an exposure assessment along the Elia grid had to be performed first. The objective of this assessment was to estimate the percentage of the population exposed to a certain level of magnetic field generated by the Belgian high voltage network (36 - 380 kV). The assessment was performed in two steps. First the corridors of influence were determined, i.e. the strip centred on the axis of the line or cable extending both sides in which a certain field strength is exceeded. Thereupon the number of people within these exposure corridors was approximated. The results and methodologies applied are detailed below.

2.1. Overhead Lines

First a systematic measurement campaign was conducted in the vicinity of HV lines (70-150-220-380 kV). The campaign was based on a sampling of the lines and the spans, for each tension level. In order to evaluate the decay law and the width of the corridors of influence, at the spans sampled, field measurements were carried out by the tower, mid-range and at four other points distant of the axis of the line. Along with these field measurements, current measurements were conducted simultaneously to correlate the field values with the charge state of the line. Further this charge state was followed for one year to obtain valid statistics over a long period. As a result the measurement campaign allow to follow both the statistical behaviour of fields in space (between one span and line to another) and over time, and giving overview of the field profiles in the longitudinal(tower / mid range) and transverse. With the resulting data the statistical behaviour of the fields could be followed, both in space (between one span/ line and another) and time, giving overview of the field profiles in the longitudinal (tower/ mid range span) and transverse way.

The width of the corridors in which a field specific level (exposure level) is exceeded depends of the evaluation criterion (yearly mean, 95%, max. rated...) and the limit field value selected. As the average field levels under a line are generally low and the maximum levels never exceed the 100 μT, the value of 0.4μT was selected to calculate the yearly mean corridors of influence. This "cut of point" originating from epidemiological studies regarding long term exposure is often applied in permitting procedures and environmental impact assessments, although it is no legal binding limit in Belgium. Accordingly, the width of the mean 0.4μT corridors widths ranged from 60 m for 70 kV up to 294 m for 280 kV lines (see table 3). However, these are average values calculated for the entire network. At 380 kV the theoretical maximum 0.4 μT corridor width is 430 m and important individual differences may exist between the different lines.

To estimate the percentage of population exposed to average field levels of 0,4 μT, the number of people living within these corridors has been defined using a cartographic approach. With the previously calculated corridors, the proportions of dwellings affected were estimated: the surfaces of land considered "settled areas" were identified and the lengths of the lines through these settlements were calculated using GIS maps of the network. Witch resulted in large series of small sections of line (sometimes less than 100 m), whose sum by tension level is shown in Table 3. After that the "settled areas" affected were calculated by multiplying the lengths of the intersections with the corresponding corridor widths. Finally the number people living in these corridors were calculated taking into account the average population density in habited areas. Adjusted to the total network length and total Belgian population (10^6) the number of people exposed to an average magnetic field of 0.4 μT is estimated at 0.8%. This is in line with the 0.7% concluded in a similar study of the Flemish environmental administration in 2003, for the Flemish territory only at a 50% load [5].

Table 3 – results exposure assessment lines

Tension (kV)	Length (km)	Average width for 0,4 μT (m)	Length intersections (km)	Surface intersections (ha)	Number of habitants in corridors	Population exposed (%)
380	863	166	15,1	251	11.295	0,11
220	267	111	14,5	161	7.243	0,07
150	1841	74	106,3	787	35.415	0,35
70	2660	28	190,7	534	24.030	0,24
Total				**1746**	**77.983**	**0.8**

2.2. Underground Cables

Because for cables there are less different configurations and models are less complicated then for lines. The exposure assessment of the cable grid (36, 70 and 150KV) was based on data calculated with an analytical model and not from a measurement campaign. The corridors of influence were obtained by defining the profiles of field types (per configuration and kA) and a statistical analysis of the currents. More specific:

- an inventory of all existing cable configurations (plane or cloverleaf, depth, cross-section conductor, diameter cable, distances between conductors ...) was made and all cable links were mapped;
- for the selected configurations the fields were calculated with a current of 1 kA;
- a sample was selected for each tension level to evaluate the load evolution over time, consisting of all routes for which count data were available;
- the currents (nominal, annual max., annual mean,..) were determined for each route sampled and the mean currents were calculated per tension level;
- finally the mean field profiles were defined using the currents calculated in the previous step.

Similar as for the lines, the average fields produced by cables is lower then the limit of 100 μT. The highest field levels close to 100 μT are encountered at ground level around certain junctions and occasionally in the vicinity of 150 kV in plane configuration. Such levels are exceptional, the most common values remaining below 20 μT. Therefore the mean corridor of influence has been defined for a field of 0,4 μT. The resulting corridors for the cables and junctions with a mean and annual maximal current are listed in table 4.

Table 4 – the average 0,4 μT corridors (m) of the sampled cables and junctions

	150 kV	**150 kV**		**70 kV**		**36 kV**		**36 kV**	
	Plan	clover	junction	clover	junction	clover	junction	twisted	junction
Annual max.	22	11,4	26	9	24	7,4	25	2,5	16
Mean	12	5,6	14	3,4	11	3	11	1,3	8

These corridors, as fare as there is an estimate of the average number of dwellings located along each type of link, could be used to analyse the overall public exposure level. However, such approach is more difficult to apply in the case of underground connections than for lines. Primarily because of their particular tracking in the roads in combination with corridors which are much narrower. It appeared that, except for 36 kV cables in urban areas, most cables are placed lateral to the streets or in the paved roads and rarely in the sidewalk or path. Therefore a more realistic approach is to analyse several types of connections and then extrapolate them to the national level. This has been done for 22 individual connections. Consequently for each of these 22 connections the number of dwellings situated in the 0,4 μT corridor were counted using their situation maps.

To make an estimate of the total exposure, the data obtained from the 22 connections were extrapolate to the whole network and the relative percentages of urban and rural network were determined. The total exposure (N) is approximate by performing, for each tension level *(Ui)* and network type *(urban, rural or build)*, the product of the percentage connection length *(%urban)* by the number of houses/ km *(hous_u/km)*, and the percentage of homes affected *(%hous_u)*. And in the end making the sum of each term *(ΣNui)* multiplied by the average number of inhabitants per house (estimated to be equal to 3).

$$N = \Sigma\, Nui = \Sigma\ Ltot\_Ui\ \times \{[\%\ urban] \times [hous\_u / km] \times [\%\ hous\_u] + [\%\ build] \times$$

[hous_b / km] x [% hous_b] + [% rural] x [hous_r / km] x [% hous_r]} x (3)

The resulting parameters per tension level and network type are show in table 5. The total exposure (N) was estimated at a maximum of 9000, or less than 0.1% of the Belgian population who is residing in the 0,4 μT (mean) corridor of the cable grid. According to a study of the Flemish environmental administration in 2007 [6], about 0,2 % of the Flemish youth (0 - 14 y) would be exposed to an average field of 0,4 μT for a 50 % load of the cable grid.

Table 5 – the resulting exposure parameters

Ui	150	70	36	N
Ltot_Ui	331	189	594	
Nui_u	506	198	1533	2237
Nui_b	1275	583	2744	4602
Nui_r	480	126	1157	1763
Nui	**2262**	**907**	**5433**	**8602**

Contrary to the corridor widths (table 4) it are the single pole 36 kV cables that represent the largest source in terms of population exposure. This stems primarily from the greater length of the 36 kV network and the fact that the cables are often laid in the sidewalk or narrow roads. The 70 and 150 kV are laid in the roads and wherever possible on the side of the road where there is less housing, therefore there are less homes in the corridor of influence.

3. TECHNICAL ASPECTS

There are different ways to reduce/ prevent exposure at the houses implicated. For **lines**, methods like the transposition of conductors can reduce the width of the corridor of influence (i.e. the proportion of population exposed) without reducing the maximum field inside the corridor. Such means do normally not solve the problems arising from the setting of absolute limits. They are rather suitable in the context of a proactive approach. Other techniques can only solve a local problem - this is the case of compensation loops or the splitting of the phases. But there are only two possibilities which guarantee to remain below the levels encountered in practice today: moving of lines and underground development. But they are, by far, the most expensive and difficult to implement.

For **cable**s there are essentially three ways to reduce the magnetic fields generated by power cables:

- action on the position of conductors and / or the sequence of phases (configurations, transposition);
- placement of compensation loops in which circulate induced currents (passive loop);
- placing a shield in the vicinity of the cables (shielded metal).

Among these, only the shielding of the open type, i.e. in good conducting material, can be applied for existing routes. This is similar for passive loops. The closed shielding with ferromagnetic materials however requires the movement of cables.

The practical implication and the economical impact of these techniques vary according it concerns existing or new connections, lines or cables. For new projects, besides optimal routing, techniques like transposition and configuration are integrated automatically. If these kind of proactive measures are insufficient, other more costly and difficult to apply solutions have to be worked out. In terms of population exposure, as determined in the exposure assessment, the corridors of influence of lines are significantly larger than those of underground connections. If for existing connections an

exposure limit would be imposed below the average field levels encountered today the economical impact, next to the practical implications, would be huge.

4. THE PUBLIC AND OTHER STAKEHOLDERS

With regard to informing the public, Elia offers, if is in the proximity of our installations, every citizen the service for field measurements at their home. The objective hereby is to provide objective information. Specific question on health, witch are the not the competence of a TSO, are always referred to more competent bodies; i.e. the BBMEG. Since 2000 more then 600 demands were handled and last year alone about 200 requests were received after statements in the media.
The demands are mainly inspired by property transactions or concern of (young) families living along a power line. It is our experience that most people are satisfied with the information they receive; the fact that they are offered measurements easy accessible, mostly meet to someone's needs. Of course people are not always satisfied, especially for new connections where the issue of property depreciation is raised more.
Because these are single, short time measurements and in house other sources can not be excluded, there are difficult to interpret. Nevertheless, these data show that field values in the range of theoretical maximum rated were registered; moreover the majority of the results were below 1μT.

Besides these brief interventions more complete studies are performed. In these studies the actual situation is mapped and the future situation (corridor of influence) is simulated in function of possible interaction with sensitive objects like houses, schools and nurseries. This kind of study is performed for all our grid development projects, even if is not mandatory. These simulations allow to introduce mitigating techniques proactively in the project and helps optimising the routing. In the context of an environmental impact assessment (EIA) a field survey is also included. For major projects meetings with the different stakeholders (local authorities, politicians, press) and public hearings are organised often with support of independent experts.
Such studies are also carried out for not Elia projects, if requested. When a project, e.g. real-estate development, hospital... is planed in the neighbourhood of our installations the promoter often request for a study. or it is mandatory in the context of an EIA. Although there are no ELF limits into force in Belgium, only for the electric field, authorities often restrict projects nearby power lines. Simulation the corridors of influence can help to find a compromise between the authorities and the project developer. And sometimes mitigating measures like raising a tower are negotiated.

CONCLUSIONS

For many years now research on the potential health effects of 50Hz electric and magnetic field is done, also at exposure levels encountered in everyday life. This ongoing debate enhances the perception of risk and the need for risk communication, especially when people are confronted with the perceptible power lines. To operate and develop an electricity transmission network it has become indispensable to establish a policy on ELF addressing health risks, public exposure, information and communication. Since several years Elia has tried to tackle these different aspects.

Already in 1997 a collaboration was concluded with the BBEMG. The multidisciplinary research teams of the BBEMG conduct research, in total scientific freedom, for a better understanding of the interactions between electromagnetic fields and biological activity. Their research has already resulted in several peer-reviewed international publications and the recognition as a centre of expertise. The BBEMG website, launched in 2001, contributes significantly to the

diffusion of this knowledge and expertise among the general public and other stakeholders, even outside Belgium.

With regard to ELF exposure an assessment was realised along the Elia grid. Hence, corridors of influence were defined for lines and cables based on data from field measurements and analytic models, respectively. According these corridors it was estimated that about 0.8% of the Belgian population is exposed to average magnetic field level of 0.4 μT generated by overhead lines, whereas only 0.1% of the population is exposed to equivalent levels from the underground network. Considering these findings, an evaluation of mitigating techniques showed that moving of lines or undergrounding are the only solutions in case a limit would be imposed lower then the values encountered in practice today.

Complementary to the communication on health topics by the BBEMG the more technical issues are addressed by Elia. The success of the field measurements at the people's homes demonstrates the need of the general public to this kind of service. Moreover the elaboration of comprehensive studies, e.g. in case of a grid-development project or a real-estate development, has become indispensable to move on in the permitting procedures.

Elia, as TSO in a densely populated country, has to deal with a growing public concern about ELF in his daily operations. With the actions described in this paper Elia tries to bridge diverse values and change the perception of stakeholders in favour of high voltage grid development.

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