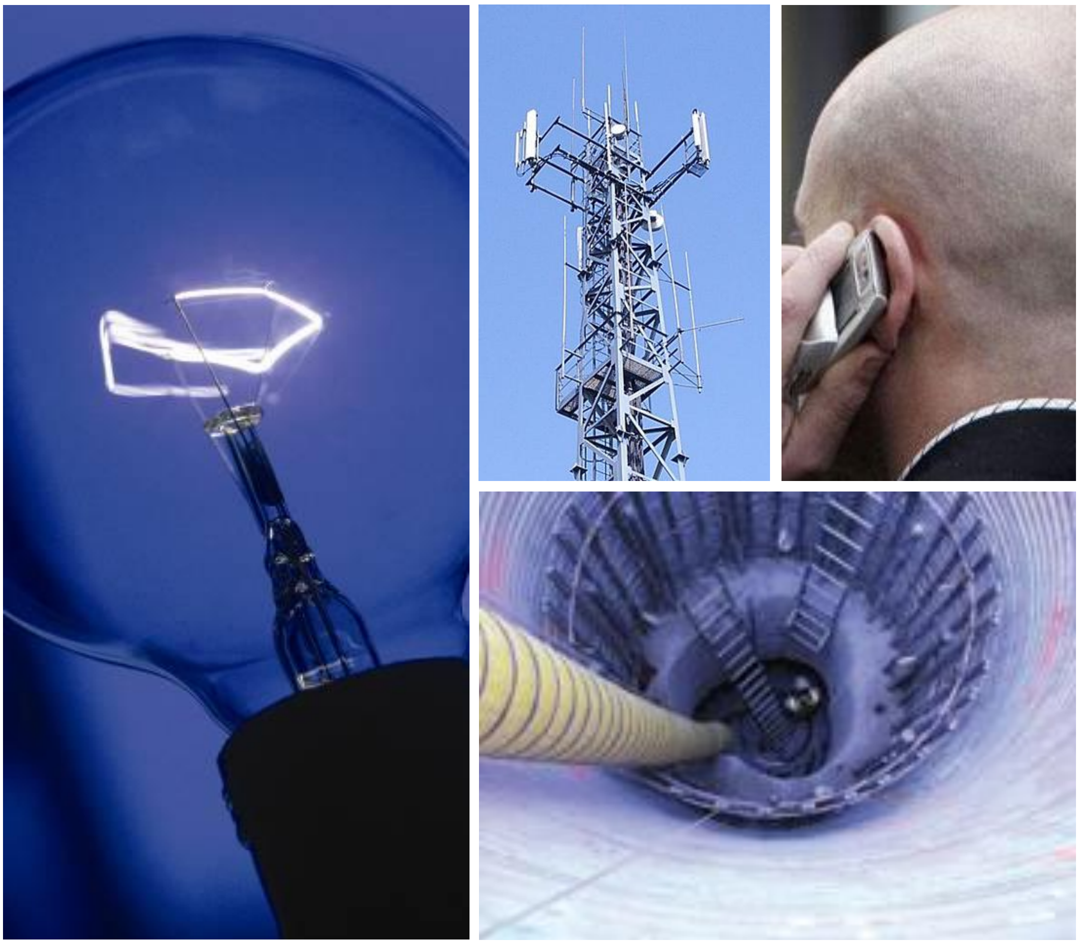
Energy Impact of Lower RF-EMF Exposure Limit

Brussels Capital Region



Prepared for:

GSMA Europe
4th Floor - Park View
Chaussée d'Etterbeek 180
B-1040 Brussels
Belgium

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Prepared by:

AMEC Earth & Environmental GmbH

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57841000NL

EXECUTIVE SUMMARY

Due to ongoing scientific uncertainties, public exposure to radio frequency electromagnetic field has been a concern for many years. Various exposure limits were proposed by scientific bodies on national and international level. Some governments accepted these proposals and gave them statutory status. However, there are also institutions and governments which set much lower exposure limits. In 2007, the Brussels Capital Region parliament passed an ordinance which forces mobile network operators to comply with much lower exposure limits for locations accessible to the general public.

Based on several interviews with mobile network operators in the Brussels Capital Region, the impact of the new legislation was investigated. Network planning and modification is an iterative process and initial adaptive measures were recently taken, initially focusing on the macrocell base stations. The smaller base stations have not yet been tackled (June 2011). Consequently, experience regarding the impacts of the new legislation is still preliminary and limited.

There are various practical measures which can be taken to reduce public exposure to electromagnetic fields transmitted by mobile network base stations. These include changing the physical set-up of the sites, especially the antennas (antenna height above ground, horizontal and vertical direction), network sharing, and reducing transmission power. The last option will almost inevitably lead to the installation of new base stations and cause additional electricity consumption and associated greenhouse gas (GHG) emissions. The installation of new base stations involves substantial planning and permitting efforts as well as additional investments and is obviously the operator’s least preferred alternative.

In summary, the three operators anticipate that approximately 400 new base stations will need to be added to the already existing 1,000 sites in the Brussels Capital Region. Approximately 10 % of the macrocell sites will require technical modifications and upgrade. This will cause an increase in the associated electricity consumption of roughly 40 % or 4,100 MWh per year and an additional thousand tons of CO_2 released to the atmosphere annually.

While these numbers do not appear to be too large, scaling up to European Union (EU) conditions demonstrate that this would equate to the annual CO_2 emissions of a 250 MW gas-fired power plant. Furthermore, they only take into account the CO_2 emissions from directly induced additional electricity consumption. Aspects of life cycle assessments would include the production and installation of the necessary equipment as well as its maintenance and recycling or disposal at the end of its lifetime. Respective studies are sparse but suggest that indirect GHG emissions in the same order of magnitude as the GHG emissions from increasing power consumption may result.

CONTENTS

Page No

ANNEXES

1. INTRODUCTION

Although the number of mobile phone subscriptions has been stagnant in many industrialized countries during recent years, better access to mobile networks and their growing ability to transfer increasing volumes of data continue to fuel society's need for information. Business and private life increasingly involve communication and information exchange using mobile phones, smart phones, mobile internet connections with notebooks and similar devices. The high demand for information has resulted in, and continues to stimulate, the further development of mobile network technology and infrastructure. Antenna sites with a higher density in towns, but also widespread in rural areas, are a visible sign of this development.

While the benefits of improved mobile communication capabilities are obvious, there is also concern about negative impacts, especially with regard to human exposure to radiofrequency electromagnetic fields (RF-EMF). This issue has been investigated for the past 50 years or more, covering a large range of frequencies, modulations and power levels to determine whether RF-EMF can have adverse health effects. The International Commission on Non-Ionizing Radiation Protection (ICNIRP), an independent scientific body, continually reviews the scientific research performed around the world on health effects associated with exposure to RF-EMF. In its 2009 review, ICNIRP concluded among others that[i]:

- "The mechanisms by which RF exposure heats biological tissue are well understood and the most marked and consistent effect of RF exposure is that of heating … (biological tissue)";
- "Recent concern has been more with exposure to the lower level RF radiation characteristic of mobile phone use. Whilst it is in principle impossible to disprove the possible existence of non-thermal interactions, the plausibility of various non-thermal mechanisms that have been proposed is very low";
- "Concerning cancer-related effects, the recent in vitro and animal genotoxicity and carcinogenicity studies are rather consistent overall and indicate that such effects are unlikely at Specific Absorption Rate (SAR) levels up to 4 W/kg";
- "Here is some evidence of small changes in brain physiology, notably on spontaneous electroencephalography (EEG), and somewhat more variable evidence of changes in sleep EEG and regional cerebral blood flow but these may be of limited functional consequence";
- "Results of epidemiological studies to date give no consistent or convincing evidence of a causal relation between RF exposure and any adverse health effect. On the other hand, these studies have too many deficiencies to rule out an association"; and
- Overall the studies published to date do not demonstrate a raised risk within approximately ten years of use for any tumor of the brain or any other head tumor". "….Despite these methodologic shortcomings (…..) the available data do not suggest a causal association between mobile phone use and fast-growing tumors". "For slow-

growing tumors (….) the current observation period is still too short."

The World Health Organization (WHO) presents similar information in its Fact Sheet No. 304 on mobile and wireless networks. In June 2011, the International Agency for Research on Cancer (IARC), a sub-body to the WHO, classified radio frequency electromagnetic fields as possibly carcinogenic (class 2B), a category used when a causal association is considered credible, but when chance, bias or confounding cannot be ruled out with reasonable confidence. [ii,iii,iv]

Based on the evaluation of available biological, medical and epidemiological studies, ICNIRP established basic restriction on EMF exposure. These are laid down in the "Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic, and Electromagnetic Fields"[v]. Protection against adverse health effects requires that these basic restrictions are not exceeded. For the frequency range relevant to mobile networks, the physical quantity used to specify the basic restrictions on exposure to EMF is the specific absorption rate (SAR). The SAR is a dosimetric value and cannot be directly measured in field applications.

For comparison with measured values of physical quantities, ICNIRP converted the SAR levels to reference levels using conservative assumptions, computational and measurement techniques. Compliance with all reference levels given in the ICNIRP guidelines will ensure compliance with basic restrictions. If measured values are higher than reference levels, it does not necessarily follow that the basic restrictions have been exceeded. The reference levels are expressed in electric field strength, magnetic field strength, magnetic flux density or power density, depending on which physical quantity is considered to cause biologic impacts. However, these physical quantities can easily be converted into each other.

The ICNRIP's reference levels for general public exposure for the frequency ranges relevant to mobile networks are displayed in the following table[1].

Frequency range	**Electric field [V/m]**	***Equivalent plane wave power density [W/m²]***
10 – 400 MHz	28	2
400 – 2000 MHz	$1.375 \cdot f^{1/2}$	$f / 200$
2 – 300 GHz	61	10

where *f* is the frequency as indicated in the frequency range column

[1] For better comparison with the Brussels Capital's Ordinance values for lower frequency ranges are also given. For the same reason, the reference is only expressed as electric field strength and equivalent planar power density.

The WHO recommends adoption of the ICNIRP limits and the European Council also recommends ICNIRP for public exposure levels[vi].

Recent surveys have shown that the RF exposures from base transceiver stations (BTS)[2] range from 0.002% to 2% of the levels of international exposure guidelines, depending on a variety of factors such as the proximity to the antenna and the surrounding environment. Limits for individuals who are exposed to EMF as a consequence of their profession (occupational exposure) are generally higher.

In the EU, 18 member states adopted the European Council's recommendations and the ICNIRP's reference levels. [vii,3] Six countries decided to implement lower RF-EMF exposure limits on the whole frequency range covered by the ICNRIP guidelines, and three countries implemented lower RF-EMF exposure limits for a part of the frequency range. However, the picture looks different for the basic restrictions. A more comprehensive overview is provided in the annex to this report.

In 2007, the Government of the Brussels Capital Region passed an ordinance[viii] defining RF-EMF exposure limits between 0.01 and 0.05 W/m^2 for the frequencies between 400 MHz and 2 GHz and also limiting the exposure to fields composed of various frequencies. These limits are significantly lower than those in other countries and lie below the limits proposed by WHO and ICNIRP by a factor of 200.

Concerns regarding potential health impairment are understandable. However, eventual impacts must not be viewed in isolation and potential solutions need to be balanced against their consequences and impacts in other areas. This applies even more due to the scientific uncertainties surrounding the effects of RF-EMF on human health. There are numerous societal and environmental topics currently on the agenda and climate change is one of the most obvious and important. It is the scientific community's common understanding that there is little doubt regarding the science of climate change. It is also largely accepted that climate change will have the potential to drastically change the environment and thus impact individuals and societies around the globe. The ultimate measure to combat climate change is to reduce greenhouse gas (GHG) emission. The most prominent GHG is carbon dioxide (CO_2) and the most important means to achieve emission reductions are energy saving and increasing energy efficiency.

Lowering RF-EMF limits will require more base stations to be installed if current coverage and quality of service is to be maintained or even improved. This will be accompanied by an increase in the electricity consumption of the network as a whole. Mobile network operators

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[2] Base Transceiver Station (BTS) - for the purpose of better readability the remainder of this study will refer to the term "base station" or – where referring to specific types of base stations, to the terms "macrocell site", "microcell site", "picocell site" or "femtocell site".

[3] Denmark also follows the ICNIRP recommendations, but has not implemented any legally binding measures to protect the public against exposure to electromagnetic fields.

are aware that the lowering of RF-EMF exposure limits will require more base stations and may change electricity use. Most EU countries have several operators with varying network size and coverage. The principle means of competition other than price has been ‘network quality’ meaning that the exact size and distribution of an operator’s network capacity has been a closely guarded commercial secret. In addition, the impacts of technical development also make it difficult to produce a detailed characterization of the environmental impact of a mobile network.

This study aims to provide an initial assessment of the change in energy use and GHG emissions (especially carbon dioxide) resulting from the new legislation to assist in balancing the various aspects associated with reducing the RF-EMF exposure limits.

1.1. Approach

The background information to this study was established by collecting and evaluating information from various sources, including the internet and some publications in specialized journals. In November 2010, an initial round of face-to-face interviews with three mobile network operators was held to identify the characteristics of their network installations in the Brussels Capital Region at the time, before adaptive measures were taken. A second and a third round of interviews were held in January and March 2011 to investigate the revised network planning and to quantify the necessary changes which would need to be realized in order to achieve compliance with the new RF-EMF limits. A last round of telephone interviews was conducted in June 2011 to retrieve information about the experiences gathered so far during the implementation of the modifications. The information obtained during these discussions was used to calculate the changes in electricity consumption caused by the operation of the networks and associated GHG emissions.

1.2. Report structure

The remainder of this report is organized as follows:

- Section 2 gives a brief introduction to the Ordinance 2007-1164;
- Section 3 presents an overview on how mobile networks are organized and operate. It should help the reader to gain a basic understanding of the technical background of mobile networks.
- Section 4 provides an overview on the interviews held with network operators;
- Section 5 briefly describes how the retrieved information was evaluated and electricity consumption and CO_2 emissions calculated;
- Section 6 provides the estimates for the changes in energy consumption and CO_2 emissions, and
- Section 7 addresses aspects which could not be discussed in detail and will need further investigation.

2. INTRODUCTION TO THE NEW EMF LEGISLATION

On 1 March 2007, the Ministry of the Brussels Capital Region issued the “Ordinance regarding the protection of the environment against the long-term noxious effects of non-ionizing radiation”. The ordinance sets RF-EMF exposure limits expressed in power densities for any location accessible to the public. The limits are set in different ways for three different frequency ranges. For the upper and the lower part of the regulated frequency band, fixed limit values were set. For the range in the middle of the regulated frequency band, a limit value was defined which depends of the frequency of the electromagnetic field. When only single frequencies are transmitted the detailed limit values are:

- 0.01 W/m^2 for frequencies between 100 kHz and 400 MHz
- The ratio of the frequency in MHz and the constant number 40,000 expressed in W/m^2 for frequencies ranging from 400 MHz to 2 GHz, and
- 0.05 W/m^2 for frequencies between 2 GHz and 300 GHz.

Thus, the limit for 400 MHz, 900 MHz and 1.8 GHz electromagnetic fields are 0.01 W/m^2, 0.0225 W/m^2 and 0.045 W/m^2, respectively.

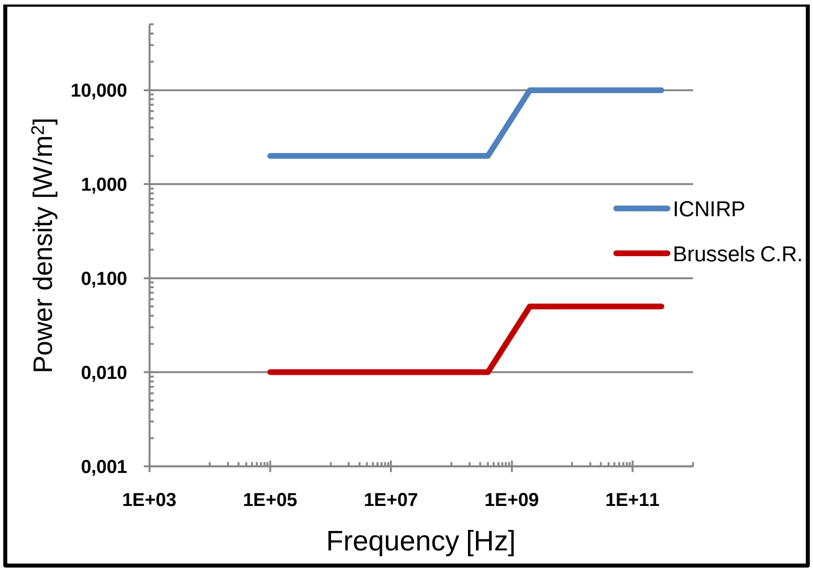
Where several fields of varying frequency exist, the extent to which the thresholds are utilized by each of the frequencies is calculated as the ratio between actual power density and applicable limit value. The sum of these ratios across all frequency ranges must then not exceed 1. This is expressed by the following formula:

$$\sum_{100kHz}^{300GHz} \frac{Si}{Sri} \leq 1$$

where
S is the power density of an electromagnetic field at a certain frequency i in the range from 100 KHz to 300 GHz, and
Sr is the EMF limit value for the respective frequency i as identified in the bullets above.

Figure 1 gives a comparison of the Brussels Capital Region RF EMF exposure limits and the reference levels of the ICNIRP guidelines.

Figure 1 Comparison of Brussels Capital Region RF EMF Exposure Limits with ICNIRP reference levels (400 MHz – 300 GHz)



Note: The Brussels exposure limits are lower than the ICNIRP reference levels by a factor of 200

The ordinance explicitly excludes from its applicability RF-EMF from mobile devices and wireless Local Area Network (LAN) devices operated by private individuals as well as Digital enhanced cordless telecommunications (DECT) based telephone systems as well as non-pulsed RF-EMF fields related to radio and television broadcasting. Hence the focus is mainly on mobile networks, radio relay and radar installations.

Further, according to the decree of the Brussels government of 30 October 2009, each operator is granted 25 % of the above-mentioned standard. Besides this, the decree requires operators to apply for an environmental license for each antenna installation, showing that the 25 % standard is complied with. The environmental license files are handled by the Institut bruxellois pour la gestion de l'environnement (IBGE)[ix].

3. BASIC INTRODUCTION TO MOBILE COMMUNICATION NETWORKS

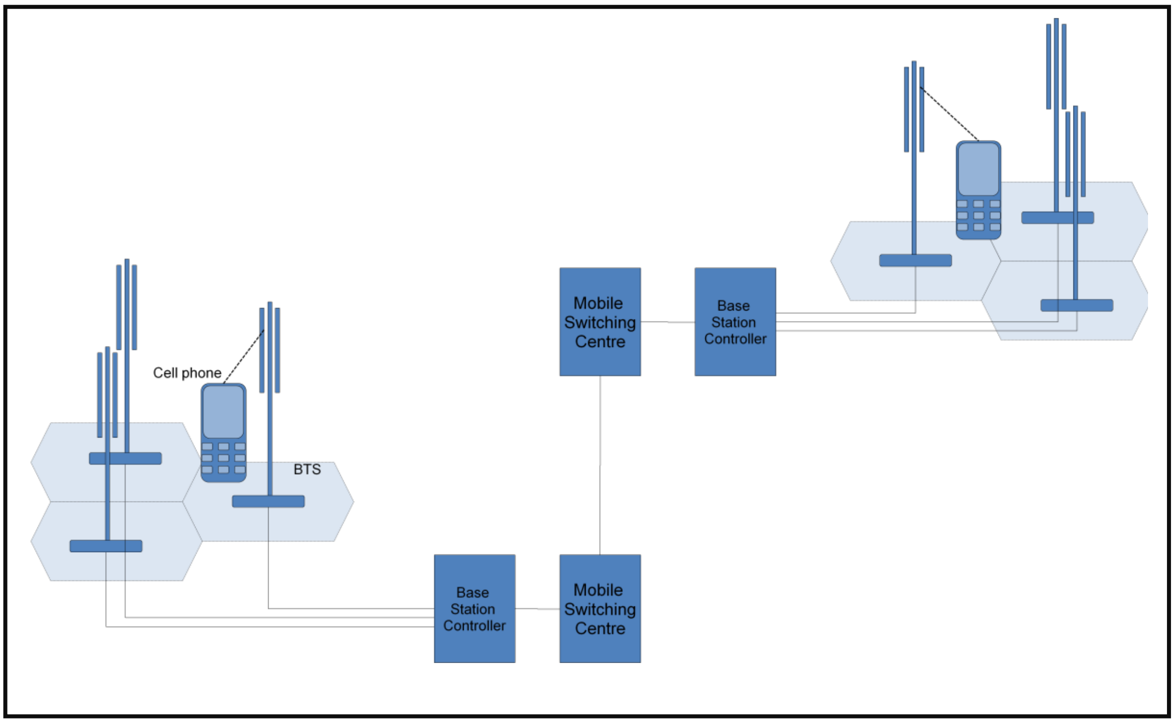
3.1. Simplified structure of mobile communications networks

Whenever a mobile phone is used, this device will exchange data with a base station which is the final interface with the individual mobile phone. The base station forwards the phone calls to the so-called Base Station Controller (BSC), which itself bundles signals from several base stations and sends them to Mobile Services Switching Centres (MSCs). MSCs provide the entire administration of any outgoing and incoming phone call. From the MSC, a call to another mobile phone is forwarded down the same route (MSC – BSC – base station) to the recipient of the call. MSCs also provide the interface with the fixed network. This scheme similarly applies to mobile internet connections and other data transfers in public mobile networks.

In contrast with communication between mobile phones and base stations, information and data transfer between base stations, BSCs and MSCs is based on radio relay technology or landlines. Hence, these modules are not relevant with regard to the RF-EMF exposure of the general public.

Figure 2 illustrates the principal structure of mobile networks.

Figure 2 Simplified structure of a mobile network[x]



3.2. Types of base stations and typical usage

A mobile network is geographically structured into cells with a base station in the heart of each of the cells. Base stations with a relatively high transmission power, macrocell sites, are used to establish the main network coverage. Gaps, also caused by topographic features and built infrastructure, are then closed using base stations with lower transmission power, so called microcell and picocell sites. These are also used to cover hotspots of mobile phone usage such as public buildings, railway stations, commercial quarters, etc. However, macrocell sites can be considered the backbone of the networks and most operators have installed far more macrocell sites than microcell or picocell sites.

Femtocell sites and repeaters are finally used to ensure network coverage on the smallest scale, e.g. inside buildings. They are not linked to the mobile networks through BSCs but connect through the internet. Femtocell sites have not yet been commercialized in Belgium.

Repeaters do not communicate with BSCs directly but receive signals from base stations and mobile phones and retransmit them at a higher power level.

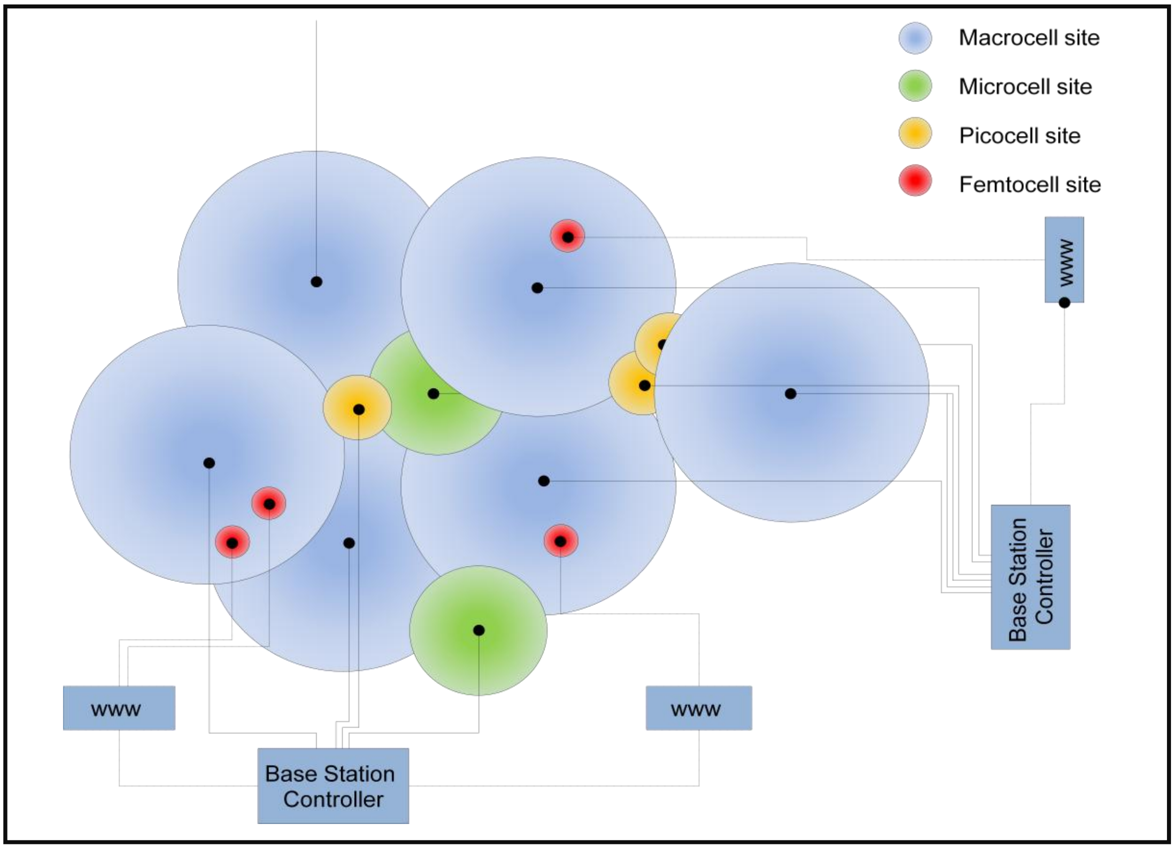
Table 1 provides a short characterization of the various types of base stations while Figure 3 illustrates how area-wide coverage is achieved through the combination of macrocell, microcell, picocell and femtocell sites.

Table 1 Characterization of the various types of base stations[xi]

BTS type	Transmission power	Range	Typical use
Macrocell site	60 to 80 W	< 8 km	• provide main coverage • installed on masts or on top of buildings
Microcell site	1 to 10 W	few hundred meters to 2 km	• fill major gaps • built urban areas
Picocell site	< 1 W	< 200 m	• overcome built barriers such as walls, etc. • inside buildings, parking lots, etc.
Femtocell site	0.02 to 0.1 W	30 to 50 m	• inside buildings to overcome concrete walls and floors
Repeaters	variable	variable	• slight range extension where possibility to install base station equipment is restricted • coverage of shadowed areas

It is worth mentioning that in the past many mobile network operators tried to accomplish network coverage mainly or purely based on the use of macrocell sites.

Figure 3 Schematic interaction between macrocell, microcell, picocell and femtocell sites



3.3. Typical configuration of a base station (macrocell site) and electricity consumption

A typical base station consists of several individual modules. These can be categorized into three groups:

- Transmission equipment, including the antenna and power amplifier for signals to and from the antenna;
- Data and signal processing equipment including transceiver, duplexer, baseband receiver and eventually a combiner; and
- Control and system management equipment including alarm extension systems and control function.

The electricity consumption of the transmission equipment strongly depends on transmission power whereas the electricity consumption of the signal processing and the control and system management equipment rather depends on data traffic and usage profile of the base station. Other factors influencing electricity consumption are

- Equipment design;

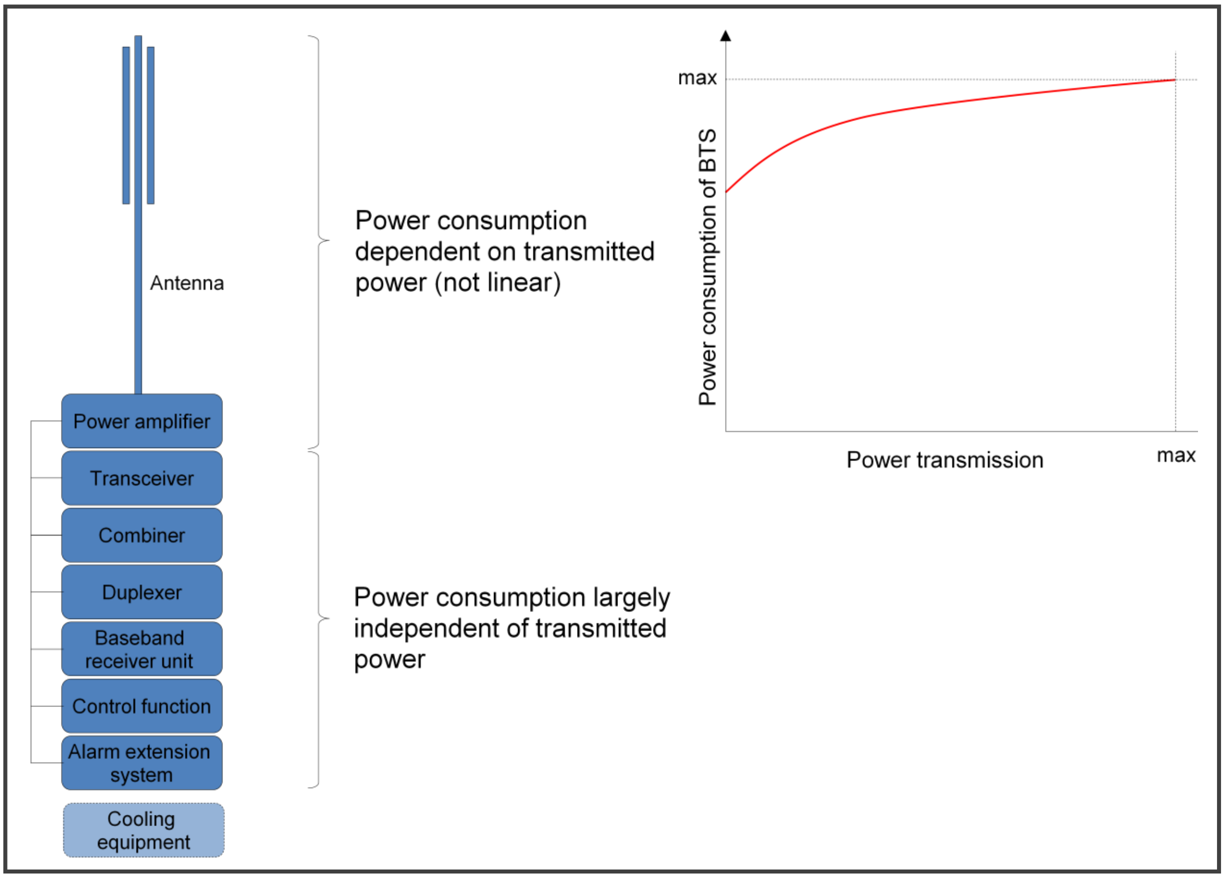
- Frequency used (lower frequencies propagate further);
- Climate (affects cooling load required);
- Population and customer density (affects cell usage and signal traffic).

As a result the electricity consumption of the entire base station can be characterized by a base load, which is practically independent of the transmission power, and a relatively subordinate portion that depends on the chosen transmission power. It is important that the system is never shut-off and consumes electricity 24 hours per day regardless of whether data traffic takes place or not. The need for cooling strongly influences the absolute power input of a base station which may, in the case of macrocell site, reach or even exceed 3 kW. Current developments, especially the use of more heat-tolerant components, reduce and even obviate the need for cooling. Some mobile network operators have made it part of their environmental policy that newly purchased base station equipment, either for replacement of old equipment or for first time installation, must be able to run without cooling and no new cooling equipment is installed. By doing this they contribute to the reduction of GHG emissions beyond the economically attractive options.

Typical set-up and electricity consumption profile of a base station are illustrated in Figure 4.

In the near future, further technological progress may enable additional reductions in equipment electricity use. Nevertheless, with the demand for customer mobile data use rising all the time it is at least possible that efficiency gains will be masked by traffic growth unless it becomes possible to send data at higher levels of signal efficiency.

Figure 4 Typical configuration of a base station



3.4. Frequency bands

The term "radio spectrum" refers to a range of electromagnetic frequencies, which are used for radio transmission purposes. Frequencies below 30 kHz are used for very specialized purposes such as communication with submarines. Frequencies between 30 kHz and 300 MHz are, for example, used for long-, medium- and shortwave broadcasting, frequency modulation (FM) broadcasting and television. The frequencies between 300 MHz and 3 GHz are used for mobile communication (i.e. mobile phones) but also for Bluetooth technology, wireless LAN, global positioning, television and microwave ovens. Higher frequencies up to 30 GHz are used for more wireless LAN applications, modern radar systems and satellite communication. All these frequencies are still well below the frequencies of infrared radiation (300GHz to 400 THz) and visible light (400 to 790 THz). X-ray radiation and cosmic radiation have even higher frequencies.

As can be seen from the relatively large variety of applications above, there is a keen interest in using the radio spectrum for civil, governmental, military and commercial purposes. Moreover, the frequencies used for different applications by the various users need to be strictly separated to avoid mutual interference. Consequently, the usage of radio frequencies is strictly governed and intensively regulated, especially in industrialized countries.

In Europe, frequency ranges between 870.4 and 960.0 MHz (the 900 MHz frequency band), between 1710 and 1880 MHz (the 1800 MHz frequency band) and between 2110 and 2200 Hz (the 2.1 GHz frequency band) are reserved for mobile phone communication. These are divided into frequency channels which were allocated to individual mobile network operators by national regulators. The use of these channels is usually restricted by the network administrating authority (Belgisch Instituut voor postdiensten en telecommunicatie – BIPT) to specific technologies (please refer to Section 3.5).

It is obvious that with the use of these frequency bands for existing technologies in mobile phone communication and current information and data traffic, emerging new technologies and the growing demand for rapid mobile data transfer will trigger the need for additional frequency bands. The BIPT has thus announced that it will auction licenses for the use of frequencies in the 2.6 GHz band (2500 to 2690 MHz) and 3.5 GHz (range to be determined) band in the near future.

The principle that diffraction of waves with high frequencies is smaller than diffraction of waves with lower frequencies is applicable throughout the entire radio spectrum (and beyond). With regard to mobile networks this means that operation in higher frequency bands requires more line-of-sight to achieve network coverage. Thus the 900 MHz band is generally the preferred band of operation for in-building coverage and in areas of lower population density.

3.5. Mobile communication technologies

3.5.1. 2G

“2G” denotes second generation wireless telephone technology and marks the transition from analogue to digital mobile telephone networks. It was commercially launched in 1991 and the standard Global System for Mobile Communication (GSM) provided the technical specifications. In Europe, 2G networks are operated in the 900 MHz and 1800 MHz bands. The GSM standard works on two different frequencies within the various channels: One frequency for up-link communication (from mobile phone to base station) and a second frequency for down-link communication (from base station to mobile phone). The data transfer resources for both up-link and down-link communication are equal and reflect the amount of information exchanged in both directions during a typical phone call. The GSM standard allows for data transfer rates up to 14.4 kbit/s and is thus almost exclusively used for telephone application; internet and multimedia applications, require significantly higher data transfer rates.

Amendments to the 2G standard such as High-Speed Circuit-Switched Data (HSCSD), General Packet Radio Service (GPRS) and Enhanced Data Rates for GSM Evolution (EDGE) marked the transition to the more powerful 3G technology and increased the maximum data transfer rate up by a factor of 26 (EDGE: 384 kbit/s).

3.5.2. 3G

"3G" means third generation mobile telecommunications and is a family of standards allowing much higher data transfer rates than 2G. Besides mobile phone communication, 3G facilitates additional mobile services such as mobile television, video on demand, video conferencing, location-based services and others. Smart phones generally use 3G technology. The standard used in Europe is the Universal Mobile Telecommunications System (UMTS) based on the Wideband Code Division Multiple Access (WCDMA) technology. The UMTS includes two different modes of communication. The Frequency Division Duplex (FDD) mode realizes up- and down-link communication on different frequencies, as the GSM standard does, and allows for data transfer rates up to 384 kbit/s. Allocation of data transfer capacities is similar to that for 2G, i.e. identical for up- and down-link communication. In Europe, UMTS-FDD uses the 900 MHz, the 1800 MHz and 2.1 GHz frequency bands and will also use the 3.6 GHz frequency band in the future.

In the Time Division Duplex (TDD) mode, up- and down-link communication use the same frequency band, but at different times. This allows the network operator to allocate his data transfer resources more flexibly between up-stream and down-stream communication, which takes into account that, during the usage of the mobile services above, the mobile device typically sends relatively small quantities of data (such as phone calls and internet information requests) while video sequences, music and internet files received easily exceed transmitted data volume by an order of magnitude. TDD allows for data transfer rates up to 2Mbit/s. UMTS-TDD is not currently operational in Europe.

3.5.3. NGMN or 4G

"NGMN" denotes Next Generation Mobile Networks, which are defined by the fourth generation mobile telecommunication standard. This standard requires down-link data transfer rates of up to 100 Mbit/s for fast-moving applications (such as mobile devices used in trains or cars) and up to 1 Gbit/s for slow-moving or stationary applications.

A main characteristic of NGMN is that the frequency used will be adaptively allocated. This means that user will not receive a fixed data transfer capacity but only that capacity which he needs at a certain time. The Long Term Evolution (LTE) standard is the basis for 4G services deployed in Sweden and planned for several European countries. LTE provides high data rates (up to 326 Mb/s downlink and 86 Mb/s uplink), low-latency (10 ms) and improved spectrum efficiency.

4. OVERVIEW ON INTERVIEWS WITH NETWORK OPERATORS AND DATA OBTAINED

4.1. Data collection

Interviews with all three current network operators in Brussels were held between November 2010 and June 2011. The current network operators in Brussels are:

- Proximus/Belgacom;
- Mobistar;
- KPN/Base.

People interviewed included representatives of the Public Relations functions, contact people to the GSMA, as well as network, radio and site/facility engineers. The focus of the interviews was to obtain data that permitted calculation of (ballpark) energy consumption changes incurred due to the ordinance.

The obtained data consists in all cases of:

- An estimate of network/base station changes to be made (modification of existing, addition of new);
- An estimate of current electricity consumption per base station and the respective total throughout all base stations in the Brussels Capital Region;
- An estimate of changed electricity consumption per base station and the respective total throughout all base stations in the Brussels Capital Region

Between three and four interviews were held per operator.

4.2. Data quality obtained

Due to the nature of the problem, the operators are all quite unsure about the exact measures to take in order to:

- Comply with the ordinance;
- Maintain the services delivered to their customers (both coverage and capacity).

As it is impossible to measure each and every single location for compliance with the norms, the Brussels government checks the sites using simulation software that calculates, based on a theoretical model of the situation, what the RF EMF exposure will be for a specific antenna setup. As the final requirement is the reality and not the simulation, and that no simulation can have sufficient precision to predict actual exposure levels, operators are aware that they will need to adapt their antenna setup iteratively.

The quality of the data that was obtained is therefore limited to first-order estimates and presents views at the time before actual deployment of any change in the antenna network.

The operators were reluctant to confirm that their data accurately depicted what will be the final situation.

As the obtained data for all three operators do not differ too strongly, this suggests that either the data represents the actual changes to be expected from the introduction of the ordinance or that all three operators are making the same systematic mistake.

4.3. Generic methodology of change planning

Although the specific approaches of the operators varied, some common ground was identified. All approaches make use of several complementary elements.

4.3.1. Prospective Planning

Using both, in-situ measurements and the results of the simulation software, points of non-compliant RF EMF exposure can be identified (this is also used to validate the correctness of the simulation software). Adaptive measures can be proposed and effects simulated to determine their impact (see Section 4.4 for a portfolio of possible adaptive measures). Planning can be set up to implement all or some of the adaptive measures. The measures tend to cater for ordinance compliance as well as for unchanged customer service levels.

4.3.2. Retrospective tuning

Again, points of non-compliance or lowered service levels are identified by taking measurements after execution of the prospective adaptive measures. Ad hoc changes can be tried (trial and error), either aimed at a specific problem area, or more thoroughly and holistically for a more complex area.

4.3.3. Practical approach

All three operators showed various levels of plans to apply to the problem. However, each operator had a different level of reliance on the prospective planning. Whereas one operator calculated the whole Brussels region coverage extensively and made detailed plans on that basis, being careful to not miss a single coverage point, another operator planned in a minimalistic way to reduce power where needed and then take adaptive measures based on customer complaints to recover service levels only where needed.

4.4. Portfolio of measures

Reducing the RF EMF exposure can obviously be achieved by reducing the transmitted power at the antenna but this is not the only option. The ordinance refers only to the power densities in locations accessible to public. No limits are set for other locations, such as above people’s heads, between buildings (as opposed to inside the buildings or on the balconies), etc.

Operators can therefore opt, wherever possible, to redirect the main beam to non-regulated space. Other options include sharing facilities with other operators as well as reducing transmission power and then installing additional sites to cover the gaps which will originate due the reduction in transmission power.

4.4.1. Optimization of physical setup

Changing physical setup changes the locations to which electromagnetic field is sent. There are three parameters that can be adjusted:

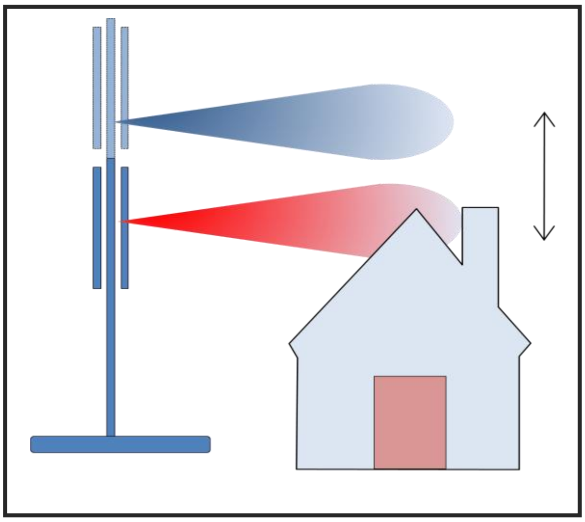
- Height of antenna above ground
- Horizontal change of direction (azimuth)
- Vertical change of direction (tilt)

4.4.1.1. Change of height above ground

It is important to know that the coverage is not just inside the main beam, but extends far beyond this kernel range. It is preferable that the main beam extends into free space such that the coverage range is maximized. As an example, if a beam is orientated directly at a building, the energy is scattered and attenuated by the building and most of it is wasted. If the beam is pointed alongside the building, the coverage inside is more uniform and goes farther, and causes less RF EMF exposure to people inside the building.

Figures 5 to 7 illustrate the three physically significant changes.

Figure 5 Change of height above ground.



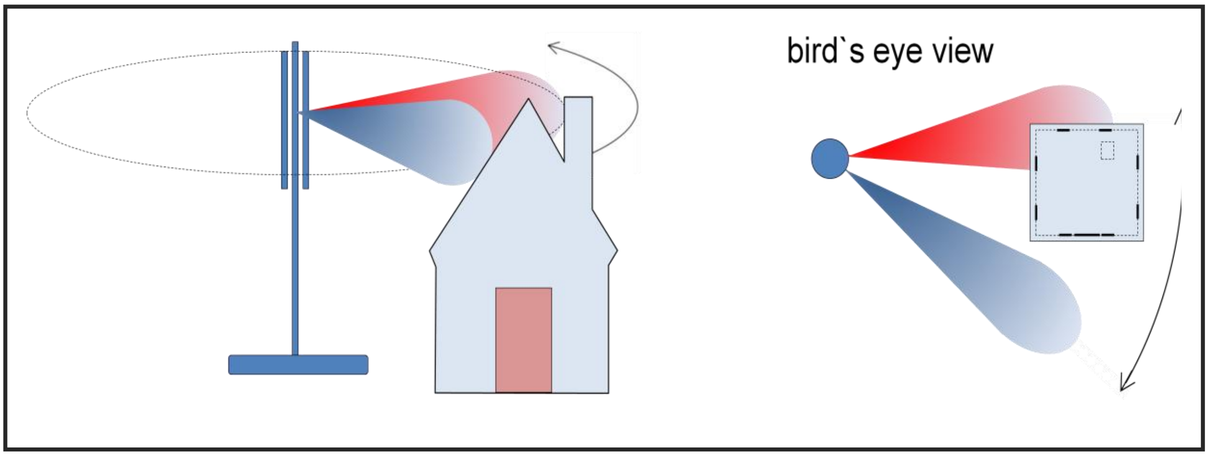
Changing height not only allows electromagnetic field to be moved away from specific populated locations, but also enables a better range for the concerned antennas. This is actually one of the best options for the operators provided that interference with nearby cells can be managed. The reason that in many places this was not executed earlier is that building regulations and limitations generally do not permit it.

One would now think that, as the Brussels government installed the RF EMF exposure limits, it would be facilitate such measures, but unfortunately, the building permits are determined by a separate administration and are, in many places, unlikely to cooperate.

4.4.1.2. Variation of azimuth

As well as the variation in height, a variation in azimuth is useful where trying to relocate the main beam away from populated locations. There are no physical or legal limitations to azimuth changes.

Figure 6 Effects of the variation in azimuth

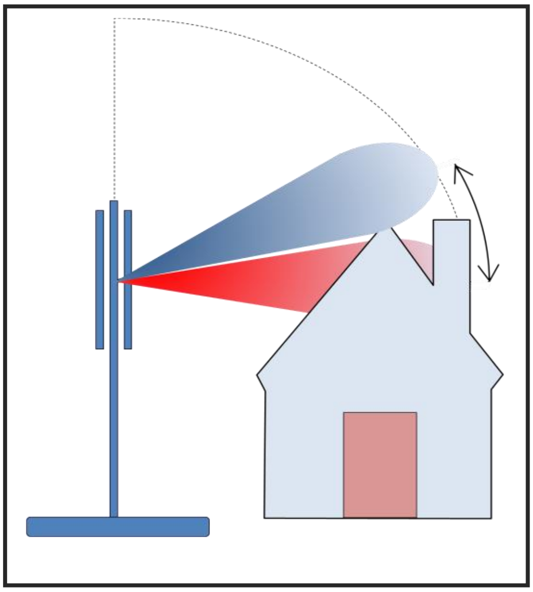


This can be applied in cases where a beam can be directed straight down a street instead of towards buildings.

4.4.1.3. Variation of tilt

Again, this variation is useful when adjusting the line of the beam to avoid populated locations. Preventing the beam from hitting the building across the street from the antenna position is a good option for lowering power density while conserving most of the coverage or even improving it.

Figure 7 Effects of the variation in tilt



However, for all three potential physical setup modifications, antennas are usually already tuned to an optimal position, so the benefits are rather limited.

4.4.2. Network sharing

At first sight, sharing resources such as locations, buildings, electricity supplies, and other equipment would sound like a way to reduce the power density of transmissions or electricity consumption as a whole.

In some places, the operators already share facilities such as antenna sites. This is favourable from an esthetical viewpoint as it reduces the number of antenna sites. The reduction in electricity consumption and GHG emissions, however, is almost negligible, as EMF is sent out per frequency channel, each of which is assigned individually to the operators. It is therefore impossible, even in off-peak hours, to share radio equipment and frequencies.

Network sharing is therefore not possible and is not a viable measure to reduce power transmission for any operator.

4.4.3. Reduction in transmission power

When all physical measures have been exhausted and still the RF EMF exposure is too high in certain locations, the only remaining reduction available is to reduce the transmitted antenna power. In some marginal cases it is possible that this will have no impact on coverage and capacity, but in the vast majority of the cases, the range of the cell is reduced and the capacity lowered (the range generally for 2G, the capacity for 3G). This reduction is, however, necessary in order to comply with the ordinance.

The ordinance does not force network operators to compensate for this reduction, but obviously the operators will want to counteract these effects to avoid customer loss and service reduction. The operators in all cases will add antenna sites to fill the coverage gaps. Figure 8 schematically illustrates the ordinance's impact on mobile network coverage and consequent addition of new base stations.

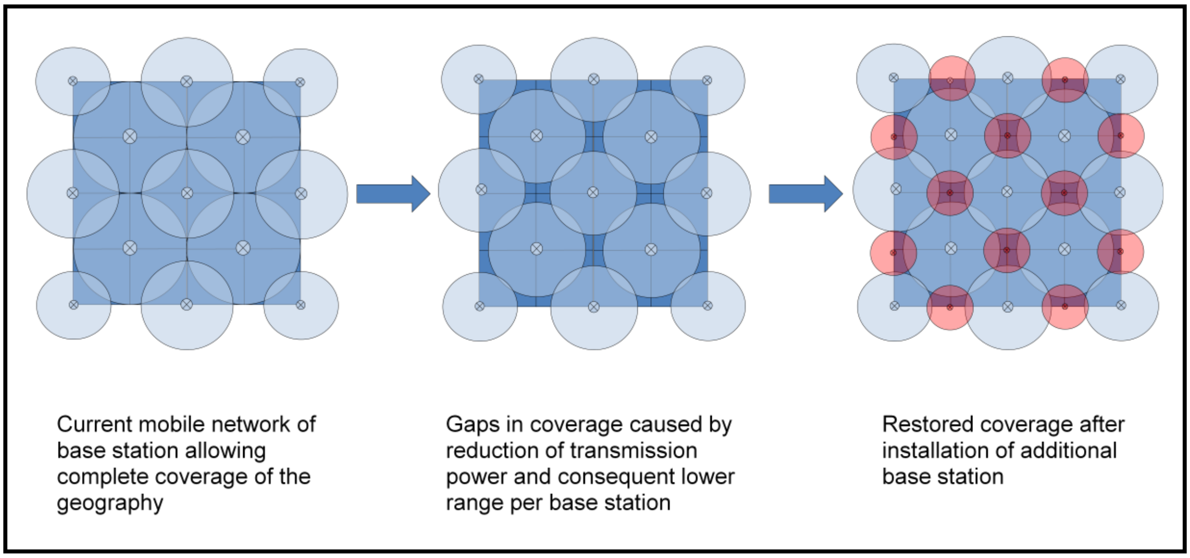
The operators will determine which type of sites to add, and where it would be ideal to place these sites. They will apply for building permits deploy the new sites and then check compliance with the ordinance, as well as testing for remaining coverage gaps and capacity shortcomings. Further delays may be caused when building permits are refused and need to be re-applied for until a suitable location is found and permitted.

The original (macrocell) sites that made up the Brussels networks of the three operators did not cater for the new ordinance, and were optimized for the types of equipment used by each of the operators. The ordinance disturbs this optimization and will likely generate gaps in coverage and capacity that are not well catered for by the types of sites normally deployed by the operators.

The importance of deploying smaller sites, including microcell and picocell sites will increase, filling the gaps in a more efficient way than macrocell sites in many cases (e.g. in buildings).

The effect of these technology shifts will become clearer in the second iteration of the operators, as they will start filling smaller gaps.

Figure 8 Schematic presentation of the effects reductions in transmission power



Femtocell sites have not been considered as they were not being used by the Belgian operators at the time of preparing this assessment.

4.4.4. Reshuffle technologies and frequencies on sites

Some sites are single technology (e.g. 2G), some are dual (e.g. 2G and 3G, or 900 MHz and 1800 MHz 2G). As the RF EMF exposure limits are defined as a composition of all used frequencies, in some cases it is advantageous to limit a certain site to a single technology / frequency band, and in others it might be advantageous to do the reverse and combine them. As the original deployments did not take the new limits into account, the recalculation of power density can indicate a different mapping of technologies and frequency bands to sites.

This reshuffling and the metrics delivered by the operators determined the "number of technologies per site" parameter in Section 5.2.

5. METHODOLOGY FOR DATA EVALUATION, ASSUMPTIONS AND LIMITATIONS

5.1. Calculation

The calculation of the GHG emissions from electricity consumption is based on the World Business Council for Sustainable Development's (WBCSD) and the World Resource Institute's Greenhouse Gas Protocol (GHG protocol). GHG emissions caused by electricity consumption are considered to be indirect emissions because they do not occur at an operator's installations themselves and are thus categorized as Scope 2 emissions. However, the reporting boundaries in this study differ from those of the GHG protocol. The latter generally addresses GHG emissions within an organization and its entire operations. The restriction of this study on the macrocell sites within the Brussels Capital region means that only a part of the operations of three different organizations has been considered.

The interviews with the network operators resulted in first-estimate numbers of the new macrocell sites to be added and in some estimates for the numbers of sites which need to be upgraded with additional antennas as a consequence of the ordinance. The data are operator-specific and cannot be published as such for reasons of confidentiality. The interviews also obtained average power consumption information for existing BTS and those anticipated to be upgraded.

Furthermore, the interviews gave average power input data. It turned out that operators tend to use the same kind of base station, including technical setup, throughout their networks to increase compatibility and facilitate maintenance work.

The calculation of related electricity consumption is straightforward - the number of stations was multiplied by the average power input and the average operating hours per year.

Calculation of associated GHG emissions was limited to CO_2 as the most important GHG, in general as well as with regard to power generation. This was again accomplished by multiplying the annual power consumption with CO_2 intensity for Belgian power generation, the so-called CO_2 grid factor. The CO_2 grid factor is the ratio of CO_2 emissions caused by Belgium power generation in metric tons and the amount of electricity produced in Belgium in megawatt hours (MWh). Other GHG emissions, which may play a larger role during the production of electronic equipment, were not taken into account.[4]

Both, the calculation of electricity consumption as well as the calculations of GHG emissions, were conducted (i) for the approximate number of macrocell sites as of the end of 2010 and (ii) for the numbers projected by the operators for the situation where final compliance with the Ordinance will have been achieved. Where possible, changes in electricity consumption due to the upgrade of existing base stations were considered.

5.2. Assumptions

Key assumptions made for the calculations are:

- The CO_2 grid factor for Belgium is 249 g CO_2/kWh[xii]
- Average power input for a macrocell BTS ranges between 900 W and 1,500 W, depending on the equipment that a network operator prefers.
- There are 8,760 operating hours per year for each piece of equipment
- The reduction in energy demand for individual base stations due to reduced power consumption is negligible
- The assumed number of technologies per site is 1.5 (please refer to Section 3.5)
- Smaller base stations (microcell and picocell sites) can be neglected since
    - the existing networks are mainly based on macrocell sites
    - the transmission power of microcell and picocell sites is lower and they thus will require fewer modifications
    - most microcell and picocell sites are put in place at customer request (e.g. shadow corners, in-building coverage) and have less direct relation to the ordinance.

5.3. Limitations

The scope of this study is limited to the electricity consumption of the additional base station, which will be installed as a consequence of the lower EMF limit values. Other GHG emissions caused by the production and maintenance of the equipment are not included (life cycle emissions [for some qualitative aspects, please refer to section 7.1]).

At the time when the operator interviews were held, the process to modify microcell and picocell sites had not started. Since the operators based their networks mainly on macrocell sites, the contribution of microcell and picocell sites is estimated to be relatively small. Additionally, the planning and modification of the networks is an iterative process and the installation of new macrocell sites may make some smaller sites superfluous. These impacts could not be investigated.

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4 such as methane, nitrous oxide, hydrofluorocarbons, sulphur hexafluoride or nitrogen trifluoride

Also not included are the additional power consumption and potentially additional equipment that will be required, other than the base stations. Taking into account the fact that BSCs and MSCs will need to process data streams from a larger number of base stations in the future, it is likely that their power consumption will also somewhat rise; at the same time it cannot be excluded that the capacity of certain BSCs or MSCs will be exhausted and additional equipment will need to be installed. This again would cause additional emissions of GHGs.

6. RESULTS AND DISCUSSION: IMPACTS ON ENERGY DEMAND AND GREENHOUSE GASE EMISSIONS

At the end of 2010, the Brussels network for the three existing commercial operators consists of close to one thousand macrocell sites. Some site sharing is conducted but this is limited to the physical space and facilities such as power supply.

Transmission networks are very different for each operator, which is to be expected considering that the incumbent operators have an existing useable transmission network ready. Newcomers will needed to start establishing their network from the scratch, favouring microwave wireless techniques and leasing fixed connections from other telecommunications providers.

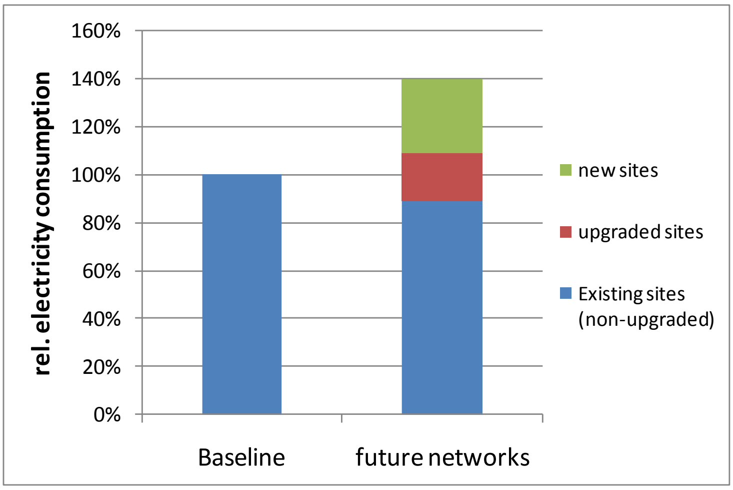
The overall electricity consumption associated with the operation of the macrocell sites totals approximately 10,100 MWh per year for all three operators.

Operators are facing the need to increase the number of macrocell sites by 30 to 55 %. However, these estimates are uncertain and one operator's worst case estimate even ranged up to 80%. About 10 % of the existing sites are planned to be modified and upgraded with additional equipment, which will increase their average power input by about 1 kW. In addition, microcell and picocell sites will become increasingly necessary to fill in specific coverage gaps, mostly within buildings, shopping centres, railway stations, etc.

There are no specific data available or identified that show dependencies of these numbers on geographic regions (terrain profile, land use), building characteristics (high-rise, low-rise buildings) or any other macro feature.

The correlation between change in electricity consumption and number of added sites is almost linear as the operators mentioned the same types of equipment as they are already using will be installed. The electricity consumption for the modified networks will likely rise to some 14,200 MWh per year, which is equivalent to a 40 % increase. This results in additional costs for electricity of 400,000 to 500,000 EUR[xiii] for all three operators, which the operators will partly need to absorb but will also try to pass to the subscribers. Figure 9 compares the power consumption of the base stations at the end of 2010 and the forecast for the network of base stations when it will be in compliance with the lower RF EMF exposure limits.

Figure 9: Comparison of base stations' electricity consumption end 2010 and after implementation of the Ordinance 2007-1164



Compared to the number of subscriptions, the numbers above mean that the base station consumed 7.8 kWh of electricity per subscription and year prior to the implementation of the new ordinance. The corresponding value after the implementation of the ordinance is 11.0 kWh per subscription and year.[xiv] These numbers may be applicable to other major cities as a first approximation assuming that other factors like density of population, physical geography, development structure are comparable to the Brussels conditions.

All three operators are using green electricity. Thus, they report zero GHG emissions for this part of their business, currently and in the future. But green electricity can still be considered a scarce good with limited generation potential. An increase in demand does not necessarily result in an increase in electricity generation but may be covered by re-allocating green electricity from a consumer who has not subscribed to green electricity but to the conventional power mix, thus indirectly making his electricity consumption more carbon intensive.

In this case one can convert the increase in electricity consumption (some 4,100 MWh) to GHG emissions using the average Belgium CO_2 grid factor. The GHG emissions in the Brussels capital region will then rise by slightly more than 1,000 tons CO_2 due to the modification of the mobile networks of the three operators. This is equivalent to the annual CO_2 emissions of approximately 135 EU citizens[xv].

It is noteworthy to say that the Belgium power sector's dependency on nuclear power is relatively strong resulting in a low CO_2 grid factor. Comparing to other countries where fossil fuels play a more important role in electricity generation shows that additional CO_2 emissions could be significantly higher. As an example, for Poland and Greece the CO_2 grid factor is 0,653 and 0,731 tons CO_2/MWh, respectively, compared to 0,249 tons CO_2/MWh in Belgium[xii]. Thus the additional CO_2 emissions in Poland or Greece would be 2.6 and 3 times higher, respectively, under otherwise similar conditions.

If a similar regulation was implemented across the EU and the conditions encountered in the Brussels Capital Region were applicable throughout the Member States, the associated additional power consumption would scale up to the annual power generation of an 800 MW power plant.[xvi]

7. FURTHER CONSIDERATIONS

7.1. Qualitative discussion of lifecycle aspects

So far, only the Ordinance's impact on electricity consumption and associated GHG emissions during the operation of the equipment has been discussed. Further energy is consumed and GHGs emitted during the equipment's production, maintenance and further treatment and processing at the equipment's end of life.

Hydrofluorocarbons (HFC), nitrogen trifluoride (NF_3) and sulphur hexafluoride (SF_6) are common substances in the production of semiconductors and electronic components. These are highly potent GHGs and exceed CO_2's ability to capture infrared radiation by a factor of up to 23,000. Consequently, the production of any electronic equipment can cause relatively high GHG emissions and the energy inputs to the production and processing of raw materials are not even considered in this argument. The production of antenna poles, their concrete foundations and shelters for the equipment also require energy inputs and cause GHG emissions, as well as the machines and vehicles which are needed to mount and maintain the installations.

In order to assess these indirect impacts, a life cycle approach will need to be adopted looking at the specific equipment to be installed and at the sites where it is to be installed. Life cycle assessments (LCA) are always case-sensitive and start from the material requirements and energy inputs for the production of each single component. But available information on the energy inputs to, and the GHG emissions of, the production of information and communication technology equipment in general, as well as in mobile networks equipment in particular, such as base stations, is limited. A LCA study published in 2008 evaluates an entire mobile service system ranging from cell phone production and base station operation to operator's office, maintenance and sales and marketing activities. The peer-reviewed study calculates the annual emissions required to provide the mobile services as ranging between 24 and 29 kg per subscription, depending on the technology used. But the data, as far as published, do not allow the results to be broken down for individual pieces of equipment. Nevertheless, very rough estimations based on this LCA study and a number of assumptions [xvii] may suggest that the production and installation of the additional macrocell sites have the potential to cause further energy consumption and GHG emissions, which are in the same order of magnitude as the electricity consumption and associated GHG emissions during the operation phase of the equipment. This rough estimate is supported, for some parts of the life cycle, by additional information retrieved during the interviews with the network operators.

7.2. Potential energy consumption impacts of a fourth network operator

Recently, an auction for GSM frequencies for a fourth operator was held. The consortium between Telnet and VOO was the only candidate bidding for these frequencies. The impact of the addition of this operator is strongly dependent on its strategy for deployment and service offering.

Looking at the auction procedure, there are some channels in both 900 MHz and 1800 MHz range, and most likely the obligation to use these. The extent, services, coverage, and other technologies to be used by the operator are unknown and guessing about the licensee's intentions would be pure speculation. Representatives of this consortium were not interviewed, as they were not known at the start of the study. Furthermore, Telnet does not hold a radio license and is not a full member of the GSMA, although it is a full mobile virtual network operator (MVNO) using the Mobistar radio network.

Although it would be theoretically possible for the fourth operator to collaborate with one or more existing operators and share some infrastructure, it is unlikely that this would extend very far, as they will be a direct competitor. In the event that a fourth operator needs to install its own networks, the average number of base stations used by current operators is a useful first estimate of the number that would be required by the new operator. However, as a new entrant, the operator would be able to better optimize coverage and location of the base stations, assuming that obtaining building permits does not constitute a limiting factor. Calculating the energy change due to the legislation change is difficult due to the number of variables such as the strategy of the new entrant, desired coverage and type of equipment used. The overall consequences of the legislation in terms of energy consumption change for a fourth entrant is not considered to significantly vary from that of the existing operators but may be slightly lower. The assumption made for the current operators will also apply for the new operator, meaning that the new operator will need to install about 400 macrocell sites instead of only 300 in absence of the Ordinance. The associated increase in electricity consumption and GHG emissions will similarly be around 30 % or, in absolute terms, about 1,000 MWh and 250 tons CO_2 annually.

8. CONCLUSIONS

The mobile industry has acknowledged that reducing energy consumption and related GHG emissions are a common task for the whole society. It has accepted its responsibility and agreed to contribute to this task by reducing energy consumption of its own operations on the one side, and by enabling energy efficient solutions for other industries and private consumers on the other side. This commitment is backed by the recommendations of the European Commission "Mobilising Information and Communications Technologies to

Facilitate the Transition to an Energy-efficient, Low-carbon Economy"[xviii]. The mobile industry forecasts that it will reduce its total global greenhouse gas emissions per connection by 40% by 2020 compared to 2009. This forecast covers all emissions from energy sources under the control of the mobile operators, including energy consumption from the radio network, buildings, energy consumption and emissions from transport.[xix]

The operation of base stations is largely responsible for the electric power consumption of MNOs. The Brussels Capital Region's Ordinance 2007-1164 forces the local MNOs to install about 30 to 55% more macro base stations and upgrade about 10 % of the existing base stations compared to end 2010 levels if they are to maintain the same level of service. These changes will be accompanied by a proportional increase in energy consumption for this part of the operations. The ordinance thus entirely compensates the MNOs most important potential to reduce energy consumption and may even cause an increase in emissions (per connection as well as in absolute terms). Affected MNOs are likely to be unable to contribute their share to the mobile industries commitment which should be taken into account when the mobile industry's commitment to reduce energy consumption is broken down to individual members of the industry sector.

Should policy and society decide in future that further exposure to RF EMF is a high priority and similar regulations are to be implemented across larger regions, this will certainly reduce the MNOs ability to reduce the energy consumption of their operations and limit their contribution to fight climate change to enabling energy efficient solutions to others.

ENDNOTES

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[i] ICNIRP - International Commission on Non-Ionizing Radiation Protection (2009): Exposure to high frequency electromagnetic fields, biological effects and health consequences (100 kHz-300 GHz), http://www.icnirp.org/documents/RFReview.pdf, (last accessed: 19 June 2011)

ii WHO – World Helath Organization (2011): Electromagnetic fields and public health: mobile phones; Fact sheet N°193; June 2011, http://www.who.int/mediacentre/factsheets/fs193/en/index.html (accessed 11 August 2011) .

[iii] IARC - International Agency for Research on Cancer (2011): IARC classifies radiofrequency electromagnetic fields as possibly carcinogenic to humans; Press release N^{o} 208, 31 May 2011, http://www.iarc.fr/en/media-centre/pr/2011/pdfs/pr208_E.pdf, (last accessed: 19 June 2011)

[iv] Robert Baan a, Yann Grosse a, Béatrice Lauby-Secretan et all (2011): Carcinogenity of electromagnetical fields, The Lancet Oncology, Volume 12, Issue 7, Pages 624 – 626, http://www.thelancet.com/journals/lanonc/article/PIIS1470-2045(11)70147-4/fulltext ((last accessed: 5 July 2011).

[v] ICNIRP (1998): Guidelines for Limiting Exposure to Time-Varying, Electric, Magnetic, and Electromagnetic Fields, (up to 300 Ghz), Health Physics April 1998, Volume 74, Number 4, also available at http://www.icnirp.de/documents/emfgdl.pdf (last accessed 7 July 2011)

[vi] European Council (1999): Council Recommendation (1999/519/EC) of 12 July 1999 on the limitation of the exposure of the general public to electromagnetic fields (0 Hz- 300 GHz, http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:1999:199:0059:0070:EN:PDF (last accessed: 8 July 2011)

[vii] Adopted from: European Commission (2008): Report from the Commission on the Application of Council Recommendation of 12 July 1999 (1999/519/ec) on the Limitation of the Exposure of the General Public to Electromagnetic Fields (0 Hz to 300 GHz), COM (2008)532 final

[viii] Parliament of the Brussels Capital Region: Ordonnance 2007-1164: Ordonnance relative à la protection de l'environnement contre les éventuels effets nocifs et nuisances provoqués par les radiations non ionisantes, 1 March 2007, Moniteur Belge / Belgisch Staatsblad No. 13693; http://www.ejustice.just.fgov.be/cgi/article_body.pl?language=fr&caller=summary&pub_date=2007-03-14&numac=2007031104 (accessed 17 June 2011).

[ix] Institut bruxellois pour la gestion de l'environnement)/Brussels Instituut voor Milieubeheer (BIM) http://www.ibgebim.be/

[x] Adopted from http://en.wikipedia.org/wiki/File:GSM_ArchitecturePL.svg (last accessed. 22 June 2011)

[xi] Adopted from ICNIRP (2009), modified using e.g. http://en.wikipedia.org/wiki/Pico_cell; http://en.wikipedia.org/wiki/femto_cell (last accessed 10 June 2011)

[xii] IEA – International Energy Agency (2010): CO_2 emissions from fuel combustion – highlights, 2010 editions, http://www.iea.org/co2highlights/CO2highlights.pdf, page 107 (last accessed 23 May 2011)

xiii Energy prices were taken from Europe`s Energy Portal - Industrial Electricity Rates (web content), http://www.energy.eu/#Industrial (last accessed 20 June 2011)

xiv Assuming that 1.3 million subscribers are served in the Brussels Capital Region due to the relatively large number of individuals commuting to the city.

xv CO_2 emissions of EU were taken from the National Communication of the EU to the United Nations Convention on Climate Change, available at: http://www.eea.europa.eu/data-and-maps/data/national-emissions-reported-to-the-unfccc-and-to-the-eu-greenhouse-gas-monitoring-mechanism-5 (last accessed: 21 June 2011); the number of EU-citizen was taken from Wikipedia, http://en.wikipedia.org/wiki/EU (last accessed 21 June 2011)

xvi Assuming that additional power consumption and GHG emissions can be extrapolated based on the number of inhabitants (Brussels Capital region = 1.1 Mill. Inhabitants, EU-27 = 501 Mio inhabitans) the extrapolated additional electricity consumption is 1.8 TWh, which is approximately the power generation of a power plant with a rated thermal input of 800 MW during one year (assuming an efficiency of 40% and roughly 5,500 full load hours per year).

xvii Assumptions are, among others: the number of citizens in the Brussels capital region, estimated lifetime of built infrastructure and electronic infrastructure

xviii European Commission (C(2009) 7604 final): Commission Recommendation of 9.10.2009 on Mobilising Information and Communications Technologies to facilitate the transition to an energy-efficient, low-carbon economy, http://ec.europa.eu/information_society/activities/sustainable_growth/docs/recommendation_d_vista.pdf (last accessed: 8 July 2011).

xix GSM Association (GSMA; 2009): Mobile`s Green Manifesto, http://www.gsmworld.com/our-work/mobile_planet/mobile_environment/green_manifesto.htm (last accessed: 8 July 2011)

Abbreviations

2G	Second-generation wireless telephone technology
3G	Third-generation wireless telephone technology
4G	Fourth-generation wireless telephone technology, synonym with NGMN
BIM	Brussels Instituut voor Milieubeheer, synonym with IBGE
BIPT	Belgisch Instituut voor postdiensten en telecommunicatie
BSC	Base station controller
BTS	Base transceiver station
CO_2	Carbon dioxide (a greenhouse gas)
DECT	Digital enhanced cordless telecommunications
EDGE	Enhanced data rates for GSM evolution
EEG	Electroencephalography
EMF	Electromagnetic field
EU	European Union
EUR	Euro (currency)
FDD	Frequency division duplex
FM	Frequency modulation
g CO_2/kWh	Gram carbon dioxide per kilowatt hour (emission factor)
GHG	Greenhouse gas
GHz	Gigahertz = one billion (10^9) Hertz (frequency)
GPRS	General packet radio service
GSM	Global System for Mobile Communications, originally Groupe Spécial Mobile
GSMA	GSM Association
HFC	Hydrofluorocarbon
HSCSD	High-Speed Circuit-Switched Data
Hz	Hertz, 1 Hz = 1 oscillation per second (frequency)
IARC	International Agency for Research on Cancer
IBGE	Institut bruxellois pour la gestion de l'environnement, synonym of BIM
ICNIRP	International Commission on Non-Ionizing Radiation Protection
kbit/s	Kilobit per second = one thousand (10^3) bit per second (speed of data transfer or processing)
kg	Kilogram = one thousand (10^3) grams
kHz	Kilohertz = one thousand (10^3) hertz' (frequency)
kW	Kilowatt = one thousand (10^3) watts (capacity)
LAN	Local area network
LCA	Life cycle assessment
m	Meter
Mbit/s	Megabit per second = one million (10^6) bit per second (speed of data transfer or processing)
MHz	Megahertz = one million (10^6) hertz' (frequency)
MSC	Mobile network switching centre
MW	Megawatt = one million (10^6) watts (capacity)
MWh	Megawatt hour = one million (10^6) watt hours (energy)

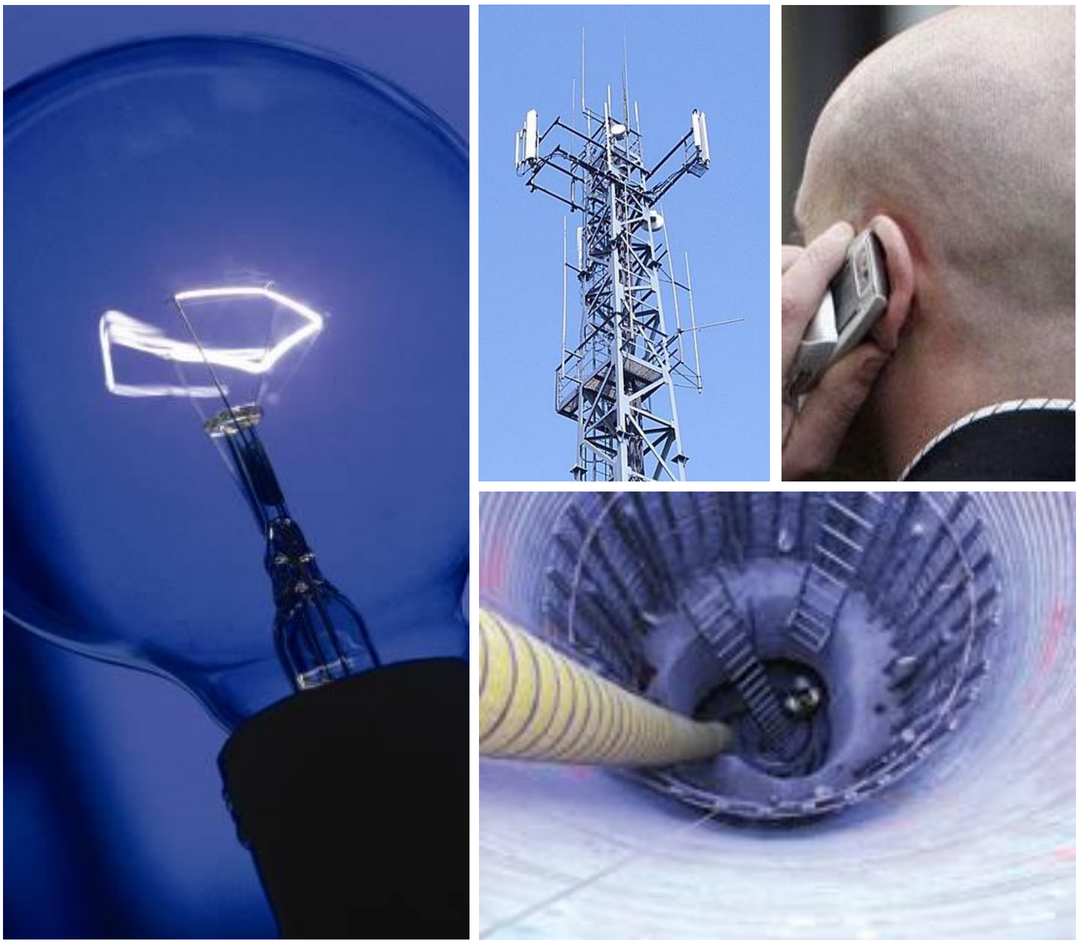
NF_3	Nitrogen trifluoride
NGMN	Next generation mobile network, synonym with 4G
RF	Radio frequency
RF EMF	Radio frequency electromagnetic field
SAR	Specific absorption rate
SF_6	Sulphur hexafluoride
TDD	Time division Duplex
THz	Terahertz = one trillion (10^{12}) hertz' (frequency)
UMTS	Universal mobile telecommunication system
V	Volt (electric tension)
V/m	Volt per meter (electric field strength)
W	Watt (capacity)
W/kg	Watt per kilogram (specific absorption rate)
W/m^2	Watt per square meter (power density)
WBCSD	World Business Council for Sustainable Development
WHO	World Health Organization

Summary overview of the way implemented measures in Member States relate to the Reference Levels of Council Recommendation 1999/519/EC

Country	Implemented reference levels		
	stricter than in the recommendation	the same as in the recommendation	less strict than in the recommendation
Austria		x	
Belgium	x[a]		
Bulgaria	x		
Cyprus		x	
Czech Republic		x	
Denmark		x[b)]	
Estonia		x	
Finland		x	
France		x	
Germany		x	
Greece	x[a]		
Hungary		x	
Ireland		x	
Italy	x		
Latvia		x	
Lithuania	x		
Luxembourg	x		
Malta		x	
Netherlands	x[a]		
Poland	x		
Portugal		x	
Romania		x	
Slovakia		x	
Slovenia	x		
Spain		x	
Sweden		x	
United Kingdom		x	

a) Not for the whole frequency range
b) Denmark applies the ICNIRP limits to base stations as a voluntary requirement. As the requirement is voluntary it is regarded as less strict than the Council recommendation.

AMEC Earth & Environmental GmbH
Kalfjeslaan 56
2623 AJ Delft
Netherlands



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