Report
Mobile Radio and Radiation

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Management Summary

In Switzerland the introduction of 5th generation mobile radio technology (5G) has begun. This report describes technical facts about 5G, addresses the operation of the Swiss mobile radio networks and their regulation, estimates the exposure of the population to non-ionising radiation (NIR) and summarises the scientific findings on possible health consequences. The report was prepared by an interdisciplinary working group acting on behalf the Federal Department of the Environment, Transport, Energy and Communications (DETEC).

Starting point

The Federal Council wants Switzerland to exploit the opportunities of digitalisation and launched the "Digital Switzerland" strategy in 2016. An important element of this strategy is the creation of high-performance and open transmission networks for a competitive information society.

The objective of the Telecommunications Act is to provide the population and the economy with a wide range of affordable, high-quality, nationally and internationally competitive telecommunications services. Competition and a market-based approach mean that high-quality telecommunications services are being provided in Switzerland.

The Environmental Protection Act is intended to protect people, animals and plants, their biological communities and habitats against harmful effects or nuisances and to preserve the natural foundations of life sustainably. As a precautionary measure, the act specifies that early preventive measures should be taken to limit effects which could become harmful or a nuisance. To this end, emissions have to be limited, as much as technology and operating conditions allow, provided that this is economically acceptable.

To protect the population from non-ionising radiation from mobile communications antennas, the Federal Council has specified two types of limits in the Ordinance on Protection from Non-ionising Radiation (ONIR): immission limit values and installation limit values. The immission limit values protect against the scientifically proven health effects (heating of body tissues) and must be complied with wherever persons may be present - even for a short time. They are the same limit values which are applied in the majority of neighbouring countries, and are between 36 and 61 volts per metre (V/m) in the frequency range used for mobile communication.

Because there are different well supported observations from research according to which there could also be other effects, on the precautionary principle of the Environmental Protection Act the ONIR additionally specifies installation limit values. The precautionary installation limit values are distinctly lower than the immission limits for mobile communication radiation and are from 4 to 6 V/m. According to the ONIR, each individual mobile radio installation may be subject to a maximum of approximately one tenth of the immission limit, with reference to the electrical field strength, at locations where persons regularly stay for some time. These so-called places with sensitive use (PSUs) include dwellings, schools, hospitals, permanent workplaces or children's playgrounds as defined by the planning authorities. As a result of the installation limit values, non-ionising radiation from mobile communications antennas is more strictly restricted in Switzerland than in most European countries.

With reference to the future expansion of the mobile radio networks, a broad and intensive discussion around the needs, benefits and possible risks of future mobile coverage has arisen in the sphere of politics, among the population and in the media. A relaxation of the precautionary regulations was narrowly rejected twice by the federal parliament in 2016 and 2018.

In the spring of 2019, the Confederation awarded new frequencies to the three existing mobile operators within the framework of an auction. These frequencies constitute the precondition for the introduction of the new 5G mobile communication technology and also serve the expansion of the existing networks. The subsequent announcements of operators to the effect that they would quickly construct a 5G network in Switzerland have also

intensified the current discussions on the configuration of future mobile provision and on the health-related concerns about mobile radio radiation.

The task

On the one hand DETEC wants to promote the digitalisation of society and the economy and considers high-performance mobile radio networks based on the 5G standard as indispensable to this end. On the other hand, DETEC continues to adhere to the precautionary principle of the EPA. For this reason, the former head of DETEC, Federal Councillor Doris Leuthard, set up the "Mobile Radio and Radiation" working group in September 2018, with the task of drawing up a report on how to proceed with reference to the immediate and more distant future of mobile radio, taking into account the aspects of utility and protection. 5G was the focus of the analysis. The working group also had to address the issue of whether the installation limit values in force for mobile antennas still meet the criteria of the precautionary principle or whether amendments are necessary with reference to the future development of mobile communications. The working group was not tasked with deciding on the introduction of 5G or with carrying out studies on the health-related effects of mobile radio radiation.

Technology and applications of 5G

By means of 5G, faster transmission rates and shorter response times become possible; in addition, substantially more terminals can be operated via 5G than previously, and the energy efficiency per unit of transmitted data also increases. This opens up perspectives for new applications: for example, it will be possible to control machines in industrial production and autonomous vehicles in real time and with virtually no delay. Also, a 5G network can be split into virtual subnetworks of different quality, so that, for example, emergency services such as the police, the fire brigade, the ambulance service and disaster protection services can be provided with extremely high-performance subnetworks with a high degree of availability.

The 5G radio technology permits much more flexible and more efficient networks than 4G. The frequencies currently available for 5G are comparable with those for 4G and WLAN, but enable considerably higher bandwidths. The maximum data transmission rates of 5G are currently between 2 and 3 gigabits per second; in future, using millimetre waves, over 20 gigabits per second may be possible. In addition, the computing capacities of 5G base stations and terminals permit much more efficient data communication than previously.5G also uses a more streamlined and flexible signal structure than 4G. This means that the large bandwidths and various frequency bands can be used more efficiently. Furthermore, 5G sends 5 times fewer control signals than 4G; this reduces exposure times in periods with little data traffic.

In order to transmit signals in a more targeted and flexible manner, 5G also uses new antenna technologies. With adaptive antennas, which consist of a multiplicity of individually controlled elements, the signal can be sent in a more targeted way in the direction of the user or their mobile device than with conventional antennas. On the one hand this so-called beamforming reduces interference in the radio cells and on the other hand (for the same quantity of transferred data) it also reduces average exposure in the radio cells. However, anyone who is located in the portions of the beam close to the antenna will experience greater exposure for a short time.

For the launch of 5G in Switzerland, the initial phase will use the 3.5 GHz band. These frequencies make it possible to transfer greater volumes of data; but they have worse propagation characteristics than the lower frequency ranges currently used. Compared with the latter, they cannot penetrate obstacles such as trees, buildings, windows or vehicles as well and are also attenuated more by the air as they propagate. These worse propagation characteristics can be partially offset by the use of adaptive antennas.

In addition to the 3.5 GHz frequency band, in the next few years 5G will also be used on the mobile frequencies from 700 MHz to 2.6 GHz currently in use. As a result of the use of frequencies above 24 GHz (so-called millimetre waves) 5G's maximum data rates could be increased to over 20 gigabits per second. The use of millimetre waves for mobile radio is not currently approved in Switzerland. Furthermore, for physical reasons these frequencies are

not suitable for comprehensive nation-wide coverage by mobile radio and would therefore probably be used with small cells.

Data traffic and mobile radio networks

Since the widespread introduction of smartphones in 2007, the volume of data carried on mobile radio networks in Switzerland has doubled every 12 to 18 months. According to forecasts, this trend will continue. The majority of mobile data traffic is attributable to video applications for private and business purposes (68%); in this sector too, continued strong growth is forecast.

The volume of mobile data transferred in Western Europe and hence also in Switzerland is estimated to increase by more than 500 percent by 2024. It is assumed that in this case a quarter of the entire mobile radio data volume will be transmitted by 5G; this alone corresponds to about one and a half times the total volume of data currently being transferred. For the Internet of Things – i.e. networked devices – growth of approximately 400 per cent in the number of data links is expected over the next five years.

Because of these constantly increasing volumes of data, the mobile radio networks must be constantly expanded. The mobile radio networks consist of a multitude of contiguous and partially overlapping radio cells. Macrocells with powerful antennas, which are mostly installed on free-standing masts or rooftops, serve to provide comprehensive coverage in an area. They typically have a coverage radius of between 200 metres and 2 kilometres. The power of an antenna is determined in such a way that the emitted radio signals still reach terminals in buildings, vehicles and also at the periphery of the cell without interfering with the signals in other cells. In areas with very high data traffic, macrocells are complemented by small cells (known as microcells) in order to increase capacity. Outdoors, microcells with less powerful antennas typically provide coverage of a few metres to a maximum of 200 metres. In addition, in special situations (e.g. hospitals, shopping centres, concert halls and stadiums) solutions inside buildings are applied. This network structure consisting of macrocells and microcells together with solutions inside buildings is also termed a "hybrid network" and has become generally accepted internationally as a standard in mobile networks.

Today in Switzerland there are approximately 12,300 mobile radio installations (70% macrocells and 30% small cells).In order to construct extensive 5G networks within the available frequencies and with only the existing radio cells, the transmitting power of the existing approximately 8500 macrocell installations would have to be increased by a factor of 12.4. While there is still a margin for expansion of existing transmitting installations in rural areas, the NIR power budget has to a large extent been exhausted in densely populated areas, since the installation limit value laid down in the ONIR, which as a precaution limits the maximum transmitting power of a mobile radio installation, has to a large extent already been reached. In cities and conglomerations, only approximately 2% of the existing installations can be expanded with the capacities needed for 5G. The reserves are somewhat larger in rural areas, where a good quarter of the installations can be upgraded to 5G.

Exposure to non-ionising radiation

The human body is exposed to various close and distant sources non-ionising radiation. Sources distant from the body include base stations for mobile radio, radio and television transmitters, WLAN routers and other people's mobile telephones. Sources close to the body include, for example, one's own mobile and other people's mobiles, as well as cordless telephones, tablets, Bluetooth devices and laptops. The non-ionising radiation in use varies and is distinguished by its frequency, intensity, signal form and temporal pattern.

Not all parts of the body are uniformly exposed to devices which are close to the body: when telephoning using a mobile phone near one's ear, the head is exposed to the highest radiated power. The technology also affects exposure. Thus the newer mobile radio standards are distinctly more efficient than the older ones: telephoning using 3G or 4G instead of 2G results in distinctly less exposure. Good connection quality also has a positive effect: the better the connection, i.e. the closer the base station and mobile phone are to each other and the fewer

obstacles there are on the transmission path, the lower the transmitting power which a mobile has to use, and consequently the lower the radiated power absorbed by the head or by other parts of the body.

To date only a few surveys relating to personal exposure to NIR exist in Switzerland. According to these, the exposure due to NIR sources distant from the body averaged across all habitations and over time is typically approximately 0.2 volts per metre (V/m) and remained constant from 2008 to 2015. During this period, only the exposure due to mobile radio base stations increased slightly from a low level. Average exposure due to mobile base stations tends to increase with increasing urbanity, but the differences between town and country are small. In urban areas the short-term maximum exposure which occurs due to surrounding users' mobiles is approximately four times higher than that caused by base stations. Average exposure is highest in modes of public transport where many people are using their mobiles (0.55 V/m).

The absorbed radiation dose due to one's own terminal may be several orders of magnitude greater that that from base stations, in particular in the case of poor connections to the base station. This means that by far the greatest part of non-ionising radiation to which the average user is exposed originates from terminals which are close to the body (approximately 90%).

State of knowledge concerning health-related consequences

A starting point for indicating the current state of research on the health effects of mobile radio radiation was the report by Hug et al. (2014)[i], which was drawn up for the Federal Council's "Zukunftstaugliche Mobilfunknetze"[ii] (future-oriented mobile radio networks) report in fulfilment of two postulates. It has since been supplemented by recently evaluated studies which were mainly selected from the newsletter of the NIR Experts Group (BERENIS) of the Federal Office for the Environment (FOEN). International evaluation reports published since 2014 were also taken into account. Finally, the connection between mobile radio radiation and cancer risk, as well as other health-related effects, were evaluated according to a conventional scale (adequate, limited, inadequate or non-existent validity).

In relation to possible health effects of 5G radio technology, there are as yet few studies on cells and animals relating to acute effects. The working group's risk assessment therefore relied on studies conducted in the past on 2G, 3G and 4G technology and which work with frequencies which lie in the same range as those frequencies currently being used for 5G.

The working group determined that to date, for the mobile radio frequencies currently in use, no health effects below the guideline values of the international radiation protection commission ICNIRP, on which the immission limit values of the ONIR are based, have been consistently scientifically proven. The ICNIRP confirmed its guideline values of 1998 in the 2018 revision and essentially left them unchanged.

However, the question for the working group is whether, with reference to the precautionary principle, there are indications or proven findings for effects below the ICNIRP limit values (and the ONIR immission limit values respectively).

The working group assesses the evidence of effects as follows:

- In 2011 the International Agency for Research on Cancer (IARC) classified high-frequency radiation as possibly carcinogenic for humans, on the basis of the results of studies on mobile telephone use, with indications of increased risks for gliomas and tumours of the auditory nerve. Since 2014 two important large animal studies have appeared which give indications of carcinogenic effect for mobile radio radiation. The results of new population-based studies on the connection between mobile telephone use and tumour development have so far been inconsistent. Most investigations carried out to date in several cancer registers indicate no increases in disease rates. Overall, the evidence for a carcinogenic effect is assessed as limited, as it was in 2014.
- On the question of tumours in connection with mobile communication base stations, television and radio transmitters there are still very few studies. A study published in 2014 found no connection between TV and radio transmitter exposure for all cases of child cancer diagnosed in Switzerland between 1985 and 2008. In

the case of lower exposure due to transmitter installations, the evidence is judged to be insufficient, as in 2014.

- A study on mice published in 2015 was able to confirm earlier results according to which simultaneous exposure to high-frequency NIR and exposure to a proven carcinogenic substance causes faster tumour growth than with the carcinogenic substance alone. Replication of this tumour promotion could be used as an argument for upgrading the evidence from limited to sufficient. However, the absence of an exposure-response relationship and methodical limitations in the study, as well as the absence of confirmation for a tumour-promoting effect from an epidemiological study, are arguments against upgrading the evidence of co-carcinogenesis. Overall, therefore, the evidence for co-carcinogenesis continues to be assessed as limited.
- There is sufficient evidence of physiological effects on humans in the event of exposure of the brain to radiation intensities within the range of the ICNIRP guidelines for local exposure. Thus a series of experimental studies with test subjects came to the conclusion that exposure within the intensity range of the ICNIRP guideline value for exposure due to a mobile telephone against the head affects brain waves in the at-rest waking state as well as during sleep. However, since the quality of sleep was not impaired as a result, the significance of this effect for health is unclear. Some of these experimental studies also found different effects as a function of modulation, which indicates that in addition to signal strength the signal form of the exposure could play a part. The extent to which the signal characteristic (e.g. modulation) plays a part has still not been adequately systematically evaluated.
- There are hardly any studies on humans in which the entire body is exposed within the range of the ICNIRP whole-body guideline value, corresponding to the immission limit value for mobile radio base stations. In everyday life such exposures practically do not occur, although they are permissible in principle up to the limit value, making observational studies difficult. In epidemiological studies the persons most exposed are exposed to levels significantly lower (approx. 0.2-1 V/m) than the whole-body limit value. A series of new studies from Holland and Switzerland found no link between the occurrence of symptoms and NIR exposure at the place of residence. This indicates that that there is no such link (evidence for absence). In these studies (as also in reality) the proportion of persons who are subject to higher exposure compared to the average is very small. The studies are therefore not sufficiently conclusive to assess effects of exposures in the range of the installation limit value and above (evidence insufficient).
- In medical practice there are cases in which patients plausibly attribute their complaints to high NIR exposures in their everyday life. However, proof of such an effect cannot be provided in individual cases. In double-blind, randomised studies no proof of such electromagnetic hypersensitivity could be provided, though predominantly the perception of short-term exposure was investigated. It cannot, however, be excluded that the effects manifest themselves only under certain conditions or exposure situations which are not yet understood. Owing to methodical difficulties with investigation of electromagnetic hypersensitivity, additional research activities are therefore urgently required.
- Many cell studies and animal studies have been carried out. These frequently find biological effects, but the results are not uniform. Thus, for example, there is no consistent pattern with regard to exposure/effect relations or to the question of which cells are particularly sensitive. Since these studies include a multitude of biological systems and the corresponding expertise was not represented in the working group, they were not assessed in depth. Accordingly, there is also no evaluation of evidence.
- There are already a few cell studies and animal studies on exposures within the 30 to 65 GHz range (millimetre waves).However, the results are not sufficiently robust for an evaluation of the evidence.

Health effects can never be scientifically excluded with absolute certainty. The working group therefore also described the potential effects for which further research is indicated. On the basis of the scientific uncertainties, the working group suggests maintaining the precautionary principle in accordance with the EPA, although there is no consensus about its specific form.

Options

Stakeholders represented in the working group drew up various options as to how, from their respective viewpoints, the Swiss mobile radio network could be further developed. It is the intention of the mobile operators to be able to offer 5G based on the ITU IMT-2000 standard on a nationwide basis, outdoors and indoors, including basements. The precautionary principle of the EPA is taken into consideration differently in the different options. Consequently, the precautionary margins differ with regard to possible long-term health effects.

The proposals put forward (see figure below) can be split into three groups:

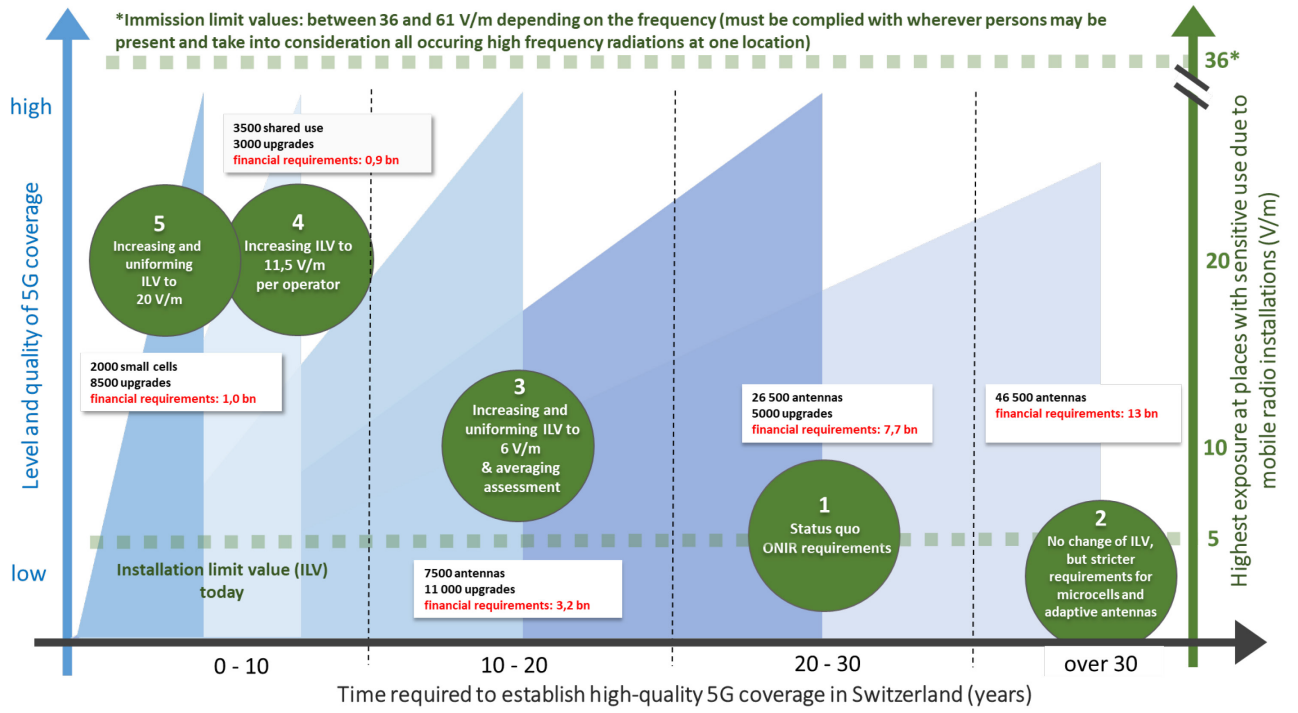
For the status quo (option 1), the installation limit value in the ONIR will be left at the current level. In order to ensure a high-performance 5G network, this option would require new construction of approximately 26,000 additional antenna sites in Switzerland and the upgrading of approximately 5000 existing installations. According to industry calculations, the financial resources needed for this amount to approximately CHF 7.9 billion for the investments and approximately CHF 2.1 billion for operation over five years. According to this scenario, the time required to establish high-quality nation-wide 5G coverage in Switzerland was estimated as 20 to 30 years. The maximum exposure at PSUs due to mobile radio installations would remain the same as at present; the number of PSUs located close to mobile radio installations would increase due to the higher number of mobile radio installations. Exposure when using mobile telephones would be reduced for all users as a result of the denser network accompanying this option (the denser the network the lower the exposure when a mobile is used, because the distance between the antenna and the terminal will generally become shorter and both will dynamically reduce their power).

In a second group there are options which increase the performance of existing installations by increasing the installation limit values and partially supplementing this by further amendments to the ONIR. Consequently, a high-performance 5G network could be constructed within a few years (options 4 and 5) or within 10 to 20 years (option 3) respectively. Depending on the variant, no additional macro sites would be necessary (options 4 and 5) or up to 7500 new installations would be needed (option 3). In addition, almost all existing sites would be upgraded. Option 4 additionally provides a possibility of shared use of 3000 sites by several operators. And with option 5, density would be increased, with approximately 2000 additional small cells. According to industry estimates, the financial requirements of these options would amount to approximately CHF 1 billion for the investments and CHF 300 million for operation over five years (options 4 and 5) or CHF 3.2 billion for the investments and CHF 0.8 billion for operation over five years (option 3). The maximum exposure at PSUs due to mobile radio installations would double from the current level with option 3 and would increase by a factor of 4 to 5 with options 4 and 5.Exposure due to terminals would remain about the same as it is today.

Option 2 does not envisage any change in the installation limit value, but does envisage stricter requirements in the ONIR for small cell installations and adaptive antennas. This is intended to ensure that the protection level with reference to NIR is at least maintained in the future and also that no higher exposures at PSUs in the short term could occur. The construction and operation of small cell antennas should be as strictly regulated as macro antennas, in order to also guarantee the appropriate protection level for these. In this option, approximately 46,500 additional sites (macrocells without adaptive antennas) would be required for the nation-wide introduction of 5G. Indoors, the requirements of 5G could not be met in full because under these conditions the necessary coverage and performance could not be achieved. According to OFCOM estimates, the financial resources for this option would amount to approximately CHF 13 billion for the investments and to approximately CHF 3.5 billion for operation over five years.

For the enforcement authorities, considerable additional expenditure would be involved for all options compared to the current situation, as a large number of new installations and numerous upgrades would have to be monitored.

The working group was not able to agree on a single option because of the weighting of the factors to be taken into account depending upon the point of view, so it cannot give any recommendation in this matter.



Possible concepts with a view to future developments

The options described indicate how the expansion of the mobile radio networks could proceed in the next few years under existing general conditions or through amendments to the ONIR in order to rapidly provide Switzerland with nation-wide 5G coverage. With reference to future development, the question is also posed of how quickly, for example, the increased capacity achieved by building macrocells or as a result of a possible increase in installation limit values will be exhausted because of the continuing surge in the volume of data carried on mobile networks and further action will again become necessary.

In order to ensure that operators and the regulator do not face the same issues in a few years as they do today, the Swiss association of cities (Schweizerische Städteverband SSV) and the Swiss association of doctors for the environment (Ärztinnen und Ärzte für Umweltschutz AefU) submitted suggestions to the working group which aim to develop mobile communications in the medium term by starting to take the necessary steps today.

The main strategic thrusts are the promotion of small cells plus separation of indoor and outdoor coverage based on sufficient availability of fibre networks. In the SSV's proposal, such mobile coverage should be achieved through increased cooperation between cities/municipalities and mobile operators, conceived as a public-private partnership (PPP). In the AefU's concept, separation of indoor and outdoor coverage should be achieved by reducing the installation limit value to 0.6 V/m. Buildings would basically be made accessible via fixed-network connections and optionally by complementary microcell installations; the owners and tenants of properties would decide independently whether mobile coverage is necessary or desirable within their premises. If necessary, a low-radiation infrastructure with the lowest possible transmission power would be used which does not significantly affect adjacent rooms.

Whether and how these network structures are compatible with the international development of mobile radio standards cannot be gauged at present. In the case of the AefU's variant with an installation limit value of 0.6 V/m, the mobile operators consider that high-performance mobile communication would no longer be possible in Switzerland.

Accompanying measures

The working group proposes the following accompanying measures:

- Simplification and harmonisation during implementation:
  In order to simplify and harmonise the approval and inspection of mobile radio installations, to implement the ONIR the fundamentals and processes on which the approvals are based should be amended and updated to the latest state of the art.
- Monitoring of exposure and effects on health:
  Monitoring which includes both exposure to NIR and possible health effects on the population must be carried out. Such monitoring has already been commissioned by the Federal Council and is currently being set up.
- Informing and raising the awareness of the population:
  Information is important in order to promote objectivity in the debate. However, in this context it is essential to communicate this information for the population in an understandable manner. It is assumed that publicly available information on individual mobile radio installations can increase acceptance of the technology among the population. This could usefully compliment the information obtained from monitoring.
- Promotion of research in relation to mobile radio and health:
  In view of the scientific uncertainties the working group recommends that further research be conducted. Support for research has positive results in many respects: it closes gaps in scientific knowledge in a politically sensitive area, it acts as an early warning system for health-related risks, as a broadly accepted accompanying and precautionary measure it supports the expansion of the network and communication by the Confederation and cantons and it secures Swiss research skills in a technology sector which is developing at very great speed.
- Environmental medical NIR advice centre:
  The establishment of an independent environmental medical NIR advice centre is also recommended. This will carry out, under medical control, interdisciplinary environmental and related medical investigations of persons who attribute their complaints to NIR or other environmental factors.
- "Mobile radio of the future" exchange platform:
  The introduction of an exchange platform with federal and cantonal authorities, the telecoms industry, organisations from medicine, protection associations and user associations is suggested. The objective is mutual exchange and information about emerging technologies or developments with all stakeholders. The dialogue with stakeholders, as initiated in the working group, should be continued in a timely fashion with reference to imminent new developments in the mobile radio sector.

Recommendations

The working group makes the following recommendations to DETEC:

- The decisions concerning the future development of mobile radio in Switzerland should be based on the facts and forecasts outlined in Chapters 1 to 7.
- Note should be taken of the proposals made in Chapter 8 (Options).
- Note should be taken of the proposals made in Chapter 9 (Possible concepts with reference to future developments).
- The accompanying measures (Chapter 10) should be implemented.
- The task assigned on 28 September 2018 should be concluded and the Mobile Radio and Radiation working group should be dissolved.

[i] Hug K., Achermann P., Dürrenberger G. et al. (2014): Beurteilung der Evidenz für biologische Effekte schwacher Hochfrequenzstrahlung, Bern, Report on behalf of the Federal Office for the Environment (FOEN). https://www.bafu.admin.ch/dam/bafu/de/dokumente/elektrosmog/externe-studien-berichte/beurteilung_der_evidenzfuerbiologischeeffekteschwacherhochfreque.pdf

[i] Zukunftstaugliche Mobilfunknetze – Report of the Federal Council in fulfilment of the Noser (12.3580) and FDP-Liberal Fraction (14.3149) postulates, February 2015: https://www.bakom.admin.ch/bakom/de/home/das-bakom/organisation/rechtliche-grundlagen/bundesratsgeschaefte/zukunftstaugliche-mobilfunknetze.html