

Effects of 5G wireless communication on human health

SUMMARY

The fifth generation of telecommunications technologies, 5G, is fundamental to achieving a European gigabit society by 2025.

The aim to cover all urban areas, railways and major roads with uninterrupted fifth generation wireless communication can only be achieved by creating a very dense network of antennas and transmitters. In other words, the number of higher frequency base stations and other devices will increase significantly.

This raises the question as to whether there is a negative impact on human health and environment from higher frequencies and billions of additional connections, which, according to research, will mean constant exposure for the whole population, including children. Whereas researchers generally consider such radio waves not to constitute a threat to the population, **research to date has not addressed the constant exposure that 5G would introduce.** Accordingly, a section of the scientific community considers that more research on the potential negative biological effects of electromagnetic fields (EMF) and 5G is needed, notably on the incidence of some serious human diseases. A further consideration is the need to bring together researchers from different disciplines, in particular medicine and physics or engineering, to conduct further research into the effects of 5G.

The EU's current provisions on exposure to wireless signals, the Council Recommendation on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz), is now **20 years old, and thus does not take the specific technical characteristics of 5G into account.**



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Background

Under the EU [digital single market strategy](#), the European Commission presented new policy measures in its 2016 communication on [Connectivity for a Competitive Digital Single Market – Towards a European Gigabit Society](#). The Commission's aim is to advance the digitalisation of the EU and to increase its competitiveness by launching networks with much higher capacities, with 5G as a building block to achieve a 'gigabit society' by 2025. Its main characteristics would enable the [internet of things](#), which means that billions of connections between devices share information.¹ The Commission has established the following connectivity targets for 2025:

- schools, universities, research centres, hospitals, main providers of public services and digitally intensive enterprises should have access to internet download/upload speeds of one gigabit of data per second;
- urban and rural households should have access to connectivity of download speed of at least 100 megabits per second;
- urban areas, major roads and railways should have uninterrupted 5G coverage.

The '[5G for Europe: An action plan](#)' presents measures for timely and coordinated deployment of 5G networks in Europe through a partnership between the Commission, Member States, and industry. This initiative concerns all private and public stakeholders, in all EU Member States.

The connectivity objective has been regulated by the adoption of the [European Electronic Communication Code \(EECC\) at the end of 2018](#), under which EU Member States have to authorise the use of the new 5G frequency bands at [700 MHz, 3.5 GHz and 26 GHz](#)² and reorganise them by the [end of 2020](#),³ in line with the EECC. This decision enables the take-up of 5G services in the Union.

According to the [European 5G observatory](#), supported by the European Commission, at the end of September 2019, 165 trials had been carried out in the European Union and 11 Member States had already published their [national 5G action plans](#).

Challenges and opportunities of 5G

Advantages

Allowing much larger volumes of data to be transported more quickly, and reducing response time, 5G will enable instantaneous connectivity to billions of devices, the internet of things and a truly connected EU population. Furthermore, [millions of jobs and billions of euros](#) could be expected to be gained from the digital economy.

The possibilities that the fifth generation of wireless communication offers, such as downloading or uploading one gigabit of data per second, may provide advantages, for instance, for the military and medical research, which could benefit from having access to such extremely high gigabit connectivity. However, the military, hospitals, the police and banks continue to use wired connections, at least for their most essential communications, mainly for security reasons. Wired networks generally offer a faster internet speed and are considered to be more secure. This is due to the fact that a wired network is only accessible through a physical cable connection, whereas with wireless networks, the signal may be broadcast outside the physical premises. Wired connection offers more control than radio or wifi, because such organisations already provide protection for servers and internal IT facilities within their physical locations, taking advantage of almost 100 % of the bandwidth, which also reduces response times. That also contributes to increased security.

Disadvantages

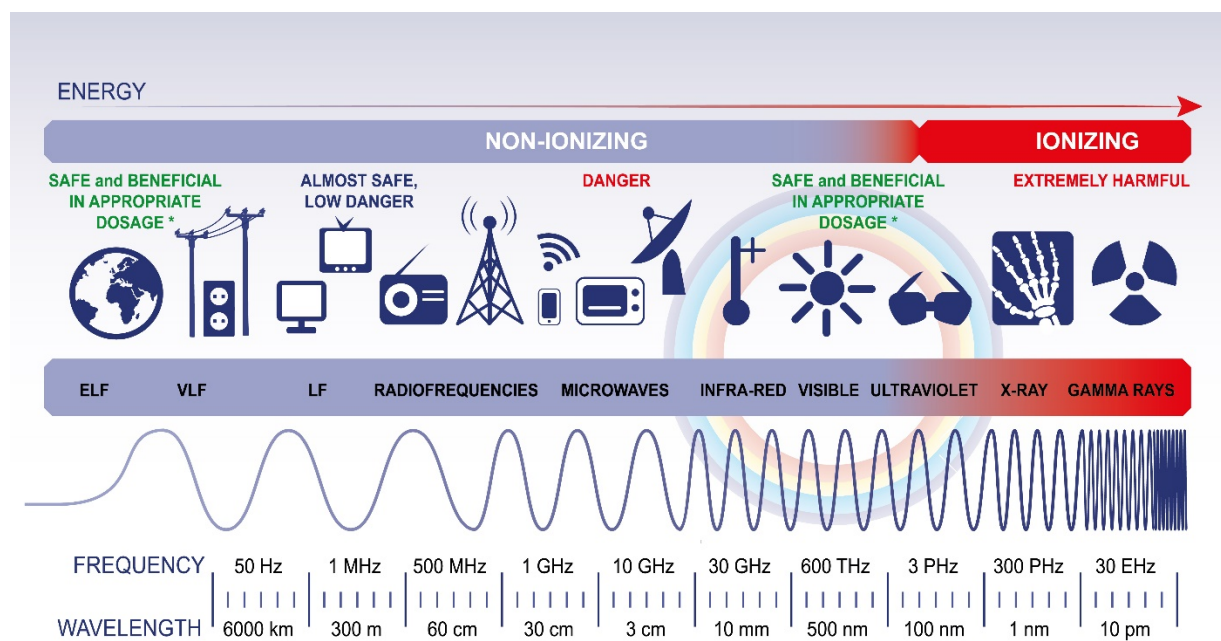
Because it is more complex and requires a denser coverage of base stations⁴ to provide the expected capacity, 5G will [cost much more to deploy](#) than previous mobile technologies. According to [European Commission](#) estimates, to reach the target, including 5G coverage in all urban areas, this cost is estimated at around €500 billion by 2025.

Questions remain unanswered as to what 5G actually is, what it is for, whether it has impacts on human health and environment, whether it is secure, whether it offers good value for money or whether anyone will be prepared to pay for it.⁵ As an alternative, according to some experts,⁶ fibre optics would be more secure, safe and offer higher speed than 5G. However, fibre optics are not wireless.

Difference between 5G and current technology

Employing millimetre waves and higher frequencies than previous technologies, 5G needs a much more extensive network of antennas and other transmitting devices. Electromagnetic fields (EMF) are invisible areas of energy,⁷ measured in hertz (Hz). Longer wavelengths with lower frequency are less powerful in terms of energy, while shorter wavelengths at higher frequencies are more powerful. Depending on the frequency, there are two categories of EMF: ionising and non-ionising radiation (see Figure 1).

Figure 1 – Electromagnetic spectrum



Source: Polina Kudelkina / Shutterstock.com.

Ionising radiation (mid to high-frequency) includes ultraviolet rays, x-rays and gamma rays. The energy from ionising radiation can [damage human cells and cause cancer](#). Non-ionising radiation has lower frequencies and bigger wavelengths. Many experts are of the opinion that non-ionising radiation produces only thermal effects, or [tissue heating](#), and that at high exposure levels, temperature-sensitive biological structures, including humans, and processes can become damaged.

Microwave and millimetre wavelength radiation is non-ionising. Millimetre wave ranges from around 10 to 1 millimetre. This is a very effective spectrum with large bandwidth, but it is also very sensitive to external variables and can be subject to interference from walls, trees or even rain.

For the first time, 5G will use millimetre waves in addition to the microwaves that have been used to date in 2G, 3G and 4G technology. Due to the limited coverage, to implement 5G, cell antennas will have to be installed very close to one another, [which will result in constant exposure of the population to millimetre wave radiation](#). Use of 5G will also require new technologies to be employed, such as active antennas capable of [beam-forming](#), massive inputs and outputs.⁸ With higher frequencies and shortened ranges, base stations will be more closely packed into an area, to

provide complete coverage and avoid 'not-spots'. This could mean possible ranges of 20-150 metres with smaller coverage areas per 'small cell'.⁹ A cell radius of 20 metres would imply about 800 base stations per square kilometre (or 'small area wireless access points' (SAWAPs), the term used in the EECC). This contrasts with 3G and 4G technologies, which use large or 'macro' cells, offering ranges of 2-15 kilometres or more, and therefore covering a larger area but allowing fewer simultaneous users since they have fewer individual channels.¹⁰

Furthermore, 5G will employ higher frequencies¹¹ than previous 'G' networks and greater bandwidth which will enable users to transfer wireless data faster.

Regulation of electromagnetic fields and 5G exposure

European Union

Primary responsibility for protecting the population from the potential harmful effects of EMF falls to the governments of EU Member States under [Article 168 of the Treaty on the Functioning of the European Union](#). In 1996, the World Health Organization (WHO) established [the International EMF Project](#) to evaluate the scientific evidence of possible health effects of EMF in the frequency range from 0 to 300 GHz. It has elaborated 'model legislation' to offer a legal framework for implementing protection programmes against non-ionising radiation.

The International Commission on Non-Ionising Radiation Protection ([ICNIRP](#)), a non-governmental organisation formally recognised by WHO, issues [guidelines](#) for limiting exposure to electric, magnetic and electromagnetic fields (EMF), which are revised periodically. In the EU, **Council Recommendation 1999/519/EC**, of 12 July 1999, on the limitation of exposure of the general public to EMF (0 Hz to 300 GHz), follows these guidelines.

As the Council Recommendation is the common protective framework guiding EU Member States and setting basic restrictions and reference levels, depending on frequency, the following physical quantities specify basic restrictions on electromagnetic fields:

- between 0 and 1 Hz, basic restrictions are provided for magnetic flux density for static magnetic fields (0 Hz) and current density for time-varying fields¹² up to 1 Hz, to prevent effects on the cardiovascular and central nervous system;
- between 1 Hz and 10 MHz, basic restrictions are provided for current density¹³ to prevent effects on nervous system functions;
- between 100 kHz and 10 GHz, basic restrictions on the specific absorption rate (SAR) are provided to prevent whole-body heat stress and excessive localised tissue heating. In the 100 kHz to 10 MHz range, restrictions on both current density and SAR are provided;
- between 10 GHz and 300 GHz, basic restrictions on power density are provided to prevent tissue heating on or near the surface of the human body.

While these exposure limits are non-binding on EU Member States, some Member States have nevertheless adopted stricter limits than those recommended above.

The recommendation encourages Member States to establish a common protective framework and inform the public of the health impact of electromagnetic fields, as well as to harmonise national approaches for measurement. The Council suggests that the European Commission keep possible health effects under review.

The **European Environment Agency** (EEA) has long advocated [precaution](#) concerning EMF exposure, pointing out that there were cases of failure to use the precautionary principle in the past, which have resulted in often irreversible damage to human health and environments. Appropriate, precautionary and proportionate actions taken now to avoid plausible and potentially serious threats to health from EMF are likely to be seen as prudent and wise from future perspectives. **The EEA requests that EU Member States do more to inform citizens about the risks of EMF exposure, especially to children.**

In its [2 April 2009 resolution](#), the European Parliament urged the Commission to review the scientific basis and adequacy of the EMF limits in Recommendation 1999/519/EC and to report back. Parliament also requested that the Scientific Committee on Emerging and Newly Identified Health Risks carry out a review of the EMF limits. Parliament requested consideration of the biological effects, acknowledging the results of studies that reveal harmful effects at lowest levels of electromagnetic radiation, as well as calling for active further research and consequently development of solutions to negate or reduce pulsations used for transmission. It suggested that the Commission elaborate a guide to available technology options for reducing exposure to EMF in coordination with experts from Member States and the industries concerned.

The European Commission **Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR)** has a mandate to evaluate the [risks of electromagnetic fields](#) and periodically reviews the scientific evidence available to assess whether it still supports the exposure limits proposed in Council Recommendation 1999/519/EC. In its latest [opinion](#) of January 2015, SCENIHR suggested that there is a lack of evidence that EMF radiation affects cognitive functions in humans or contributes to an increase of the cases of cancer in adults and children. However, [the International EMF Alliance \(IEMFA\)](#) suggested that many members of SCENIHR could have a conflict of interests, as they had professional relationships with or received funding from various [telecom companies](#).

Consequently, the Scientific Committee on Health, Environmental and Emerging Risks ([SCHEER](#)), replacing the former Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR), [indicated a preliminary estimate of the importance of 5G as high, in a statement in December 2018](#). Furthermore, it evaluates the scale, urgency and interactions (with ecosystems and species) of possible hazard as high. It suggested that there could be biological consequences from a 5G environment, due to the fact that there is a lack of 'evidence to inform the development of exposure guidelines to 5G technology'.

Council of Europe

Council of Europe [Resolution 1815 \(2011\)](#) points to the [potential health effects](#) of the very low frequency of electromagnetic fields surrounding power lines and electrical devices, [which are the subject of ongoing research and public debate](#). It also states that some non-ionising frequencies appear to have more or less potentially harmful, non-thermal, biological effects on humans, other animals and plants, even when exposed to levels that are below the official threshold values. [The resolution identifies young people and children as particularly vulnerable groups and suggests that there could be extremely high human and economic costs if early warnings are neglected](#). The issue of possible environmental and health effects of electromagnetic fields is considered to have clear parallels with other current issues: the licensing of medication, chemicals, pesticides, heavy metals or genetically modified organisms. The resolution highlights that the independence and credibility of the scientific expertise employed is crucial for a transparent and balanced assessment of possible negative effects on human health and environment. The resolution recommends:

- taking all reasonable measures to reduce exposure to EMF (especially from mobile phones) and particularly to protect children and young people who seem to be most at risk of developing head tumours;
- reconsidering the scientific basis for the present standards on exposure to electromagnetic fields set by the International Commission on Non-Ionising Radiation Protection, which have serious limitations;
- distributing information and awareness-raising campaigns on the risks of potentially harmful long-term biological effects on the environment and on human health, especially targeting children, teenagers and young people of reproductive age;
- giving preference to wired internet connections (for children in general and particularly in schools), and strictly regulating the use of mobile phones by schoolchildren on school premises;
- increasing public funding of independent research to evaluate health risks.

European Parliament

A [resolution](#) of 2 April 2009 on health concerns associated with electromagnetic fields urged the European Commission to review the scientific basis and adequacy of the EMF limits in Recommendation 1999/519/EC and to report back. It also requested that the Scientific Committee on Emerging and Newly Identified Health Risks carries out a review of the EMF limits.

Research on EMF and 5G effects on human health

The academic literature on EMF exposure effects and 5G in particular is growing rapidly. Some research papers support possible health risks, while others do not.

The WHO¹⁴/International Agency for Research on Cancer (IARC) classified radiofrequency EMF as [possibly carcinogenic to humans](#) in 2011. The IARC has recently prioritised EMF radiation for review in the next five years (2020-2024).

A section of the scientific community – mainly doctors and researchers in medical sciences – argues that there are negative impacts from EMF exposure and that these will increase with the implementation of 5G. A **5G appeal** was presented to the [United Nations](#) in 2015, and to the

Ethics in research

The [European Code of Conduct for Research Integrity](#) (last revised in 2017) sets out principles of research integrity, criteria for good research practice, and describes how to prevent violations of research integrity.

The principles it states are the following:

- **Reliability** in ensuring the quality of research, reflected in the design, the methodology, the analysis and the use of resources.
- **Honesty** in developing, undertaking, reviewing, reporting and communicating research in a transparent, fair, full and unbiased way.
- **Respect** for colleagues, research participants, society, ecosystems, cultural heritage and the environment.
- **Accountability** for the research from idea to publication, for its management and organisation, for training, supervision and mentoring, and for its wider impacts.

[European Union](#) from 2017, with an increasing number of scientists' signing (268 scientists and medical doctors as of 18 December 2019). The signatories state that with the increasingly extensive use of wireless technology, especially when 5G is deployed, nobody could avoid exposure to constant EMF radiation because of the huge number of 5G transmitters with an estimated 10 to 20 billion connections (to self-driving cars, buses, surveillance cameras, domestic appliances, etc.). In addition, the appeal states that a large number of scientific publications illustrate EMF exposure effects such as an elevated risk of cancer, genetic damage, learning and memory deficits, neurological disorders, etc. The appeal points out not only harm to humans, but also to the environment.

The appeal recommends a moratorium on the deployment of 5G for telecommunications until potential hazards for human health and the environment have been fully investigated by scientists independent of industry. They urge the EU to follow Resolution 1815 of the Council

of Europe, and demand that a new assessment is carried out by an independent task force.

In this regard, some scientists consider it necessary to establish new exposure limits that take account of the new characteristics of exposure. [Such limits should be based on the biological effects of EMF radiation, rather than on the energy-based specific absorption rate.](#)

Non-ionising radiation, which includes radiation from mobile phones and 5G, is perceived as harmless in general, due to its lack of potency. However, [some of the above-mentioned scientists point out that, in the particular case of 5G, the issue is not the potency, but the pulse,](#)¹⁵ the frequency to which the whole population will be exposed due to the dense network of antennas and the estimated billions of simultaneous connections. [As 5G employs a very high level of pulsations,](#) the idea behind 5G is to use higher frequencies, which allows such high levels of pulsation, in order to

carry very large amounts of information per second. Studies show that pulsed EMF are in most cases more biologically active and therefore more dangerous than non-pulsed EMF. Every single wireless communication device communicates at least partially via pulsations, and the smarter the device, the more pulsations. Consequently, even though 5G can be weak in terms of power, its constant abnormal pulse radiation can have an effect. Along with the mode and duration of exposures, characteristics of the 5G signal such as pulsing seem to **increase the biologic and health impacts of exposure**, including DNA damage, which is considered to be a cause of cancer. DNA damage is also **linked to reproductive decline and neurodegenerative diseases.**

A 2018 [review](#) of more recently published peer-reviewed articles on the biological and health effects of radio frequency EMF, including 5G, also verifies the available evidence on the effects of millimetre waves. The review concludes that evidence of the biological properties of radiofrequency EMF are accumulating progressively and even though they are, in some cases, still preliminary or controversial, **point to the existence of multi-level interactions between high-frequency EMF and biological systems**, and to the possibility of oncological and non-oncological (mainly reproductive, metabolic, neurological, microbiological) effects. Moreover, it points out that the **wide and increasing density of wireless devices and antennas raises particular concerns.** Taking this into account, '...although the biological effects of 5G communication systems are very scarcely investigated, an international action plan for the development of 5G networks has started, with a forthcoming increase in devices and density of small cells, and with the future use of millimetre waves'. However, there are indications that millimetre waves can increase skin temperature, promote cellular proliferation, and inflammatory and metabolic processes. According to the review, further studies are necessary to improve independent exploration of the health effects of radio frequency EMF in general and of millimetre waves in particular.¹⁶

Far less research exists to determine the effects of 5G technologies on humans and the environment, according to another [review of studies](#) published in 2018. Considering the already existing complex mix of lower frequencies, it argues that in addition to those, the expected higher frequency 5G radiation would cause negative impacts on physical and mental public health. Concretely in the case of millimetre waves, it analyses the results of studies which find **effects on the skin, eyes, and immune system, and bacterial antibiotic resistance.** The review suggests that the effects of radiofrequency EMF will be problematic to sort out epidemiologically, as no unexposed control group will remain. The study consequently calls for precaution in the deployment of this new technology. The author argues that while physicists and engineers give assurances that the only measure to harm health is heat, medical scientists indicate that there are other mechanisms whereby cellular functioning can be disrupted by non-thermal exposures to radiofrequency.

A 2016 [review of scientific articles](#), covering experimental data on the oxidative effects of low-intensity radiofrequency radiation in living cells, finds that, among 100 currently available peer-reviewed studies (18 *in vitro* studies, 73 studies in animals, 3 studies in plants and 6 studies in humans), '... dealing with oxidative effects of low-intensity radiofrequency radiation, in general, **93 confirmed that radiofrequency radiation induces oxidative effects in biological systems**'. More precisely, in 58 studies of laboratory rats, 54 show positive results, and 4 of 6 studies in humans were positive. In addition, 17 of the 18 of the *in vitro* studies were positive, including two on human spermatozoa and two on human blood cells. According to the authors, 'The analysis of modern data on biological effects of low-intensity radiofrequency radiation (RFR) leads to a firm conclusion that this physical agent is a powerful oxidative stressor for living cells'.

A 2018 [study](#) carried out on animals, showed that electromagnetic radiation emitted by wifi networks can lead to hyperglycaemia, increased oxidative stress and impaired insulin secretion in rat pancreatic islets. **A method of creating diabetes (which can lead to kidney deficiency in the long term) in laboratory rats is to expose them, even briefly, to 2.4 Ghz.**

A 2019 report of the [Swedish Radiation Safety Authority's Scientific Council on Electromagnetic Fields](#) considers two large animal studies: [the US National Toxicology Program \(NTP\) study](#) and the

Italian [Falcioni et al.](#) study, which analyse the relationship between radio wave exposure and [schwannoma](#) of the heart in male rats.¹⁷ The report concludes that there is some inconsistency in the results between the two studies and that **no new causal relationship between EMF exposure and health risks was established.** It recommends that further research is important, particularly regarding long-term effects and especially since the entire population will be exposed. It points out that a possible relationship between radio wave exposure and oxidative stress should be a subject of further research, as well as the **association between weak low-frequency magnetic fields and childhood leukaemia,** as observed in epidemiological studies.

The scientific community reaction in response to this report, is illustrated in the recent '[Commentary](#) on the utility of the National Toxicology Program study on cell phone radiofrequency radiation data for assessing human health risks despite unfounded criticisms aimed at minimizing the findings of adverse health effects.' The author states that the NTP study was designed to test the hypothesis that, at non-thermal exposure intensities, mobile phone radiation could not lead to adverse health effects, and to provide data for assessment of health risks caused by any detected toxic or carcinogenic effects, as little was known about long-term exposure to mobile phone radiation health effects. Regarding the NTP study results, among others, the author defends the use of animal studies that can eliminate the need to wait until enough human cancer data are available before implementing strategies to protect public health. **According to the author, the intensity of exposure in the brains of rats in the NTP study were similar to potential human mobile phone exposures.**

In turn, a 2019 [review](#) of 94 articles, funded by Deutsche Telekom, states that the '... available studies do not provide adequate and sufficient information for a meaningful safety assessment, or for the question about non-thermal effects. There is a need for research regarding local heat developments on small surfaces, e.g., skin or the eye, and on any environmental impact. There was no consistent relationship between power density, exposure duration, or frequency, and exposure effects'.

There is no noticeable increase in everyday EMF exposure since 2012, despite the increasing use of wireless communication devices, according to another [review of studies from 2019](#). Nevertheless, it remains unclear how well these studies of everyday exposure represent the population's absorbed radiofrequency EMF dose. This study maintains the urgent need for better quantification of the population's absorbed radiofrequency EMF dose from their own communication devices.

Stakeholders' views

Considering the huge estimated investment, the **mobile telecommunications industry needs to convince governments of 5G's economic and social benefits** and perform widespread marketing campaigns. 'It suits the industry if policy-makers believe that there is a race between nations to be the first to launch 5G services'.¹⁸

The EU telecommunications industry continues to state that the weight of evidence regarding harm from EMF exposures is inconclusive. The 5G Infrastructure Public Private Partnership ([5G PPP](#)), a joint initiative between the European Commission and European information and telecommunications (ICT) industry (ICT manufacturers, telecommunications operators, service providers, SMEs and research institutions), supports research and innovation to develop 5G networks that comply with international standards and regulations and develops systems designed to operate below the safe health limits of electromagnetic emissions.¹⁹ However, **it does not refer to the biological impacts of 5G radiation.**

Nevertheless, according to the [IEMFA](#), a need to measure real potential exposure to 5G and update the safety limits of such exposure does exist. The **alliance calls for more research and scientific consent** along these lines. It maintains that scientists with experience of long research into EMF health effects should be included in the SCENIHR, following the demands of the 2015 [IEMFA complaint](#).²⁰

The road ahead for 5G

There is an urgent need for economic recovery and leadership in implementing digital technologies; and for long-lasting economic growth in Europe. However, it is necessary to consider any possible collateral negative impacts. Taking the economic aspects of 5G into account, there are many challenges ahead on the path to achieving a 'gigabit society', such as for instance industry concerns whether the plans for commercial launch of 5G in 2020 will be fulfilled, considering the technical complexity and the necessary investment.

Other concerns relate to the creation of sufficient demand for 5G, security and health, safety and environmental issues.²¹ These need wider public awareness and consent, however this is doubly salient regarding the possible negative health impacts due to the inescapability of constant exposure of citizens in a 5G environment. The recent academic literature illustrates that continuous wireless radiation seems to have biological effects especially considering the particular characteristics of 5G: the combination of millimetre waves, a higher frequency, the quantity of transmitters and the quantity of connections. Various studies suggest that 5G would affect the health of humans, plants, animals, insects, and microbes – and as 5G is an untested technology, a cautious approach would be prudent. The [UN Universal Declaration of Human Rights](#), the [Helsinki Accords](#) and other international treaties recognise that informed consent prior to interventions that might affect human health is an essential, fundamental human right, which becomes even more controversial when considering children's and young people's exposure.

A certain divergence exists among scientists on the potential negative effects of EMF exposure and 5G. Experts rarely possess complementary backgrounds in both physics or engineering and medicine, therefore more complete scientific expertise could be achieved by combining research teams experienced in all relevant disciplines. Optical fibre technology has been suggested by some experts as a secure alternative to 5G, because the signal is confined within the fibre. Its potential is much higher than that of 5G and there is no comparison between optical fibre and wireless. Investment in optical fibre can be upgraded to superior speeds in the future, whereas it is necessary to change the whole system for wireless technologies.

According to the 2019 [study](#) '5G deployment: State of Play in Europe, USA and Asia' prepared for the European Parliament, long-term technology research is essential. 'One key problem is the unusual propagation phenomena, especially controlling and measuring radio frequency EMF exposure with Multiple Input Multiple Output (MIMO) at millimetre wave frequencies for the handset and the base station. The technology presents challenges to the current level of expertise (based on previous generations of mobile cellular radio engineering) both for suppliers and standards organisations who must incorporate the specifications in future 5G standards'. The study states that the main problem seems to be that it is not currently possible to accurately simulate or measure 5G emissions in the real world.

To understand potential mechanisms underlying possible health effects of EMF better and to characterise population levels of exposure, the [Generalised EMF Research using Novel Methods](#) (GERoNiMO) project was launched in 2014, funded under the EU's Seventh Framework Programme for Research and Technological Development to address pertinent questions on EMF and health. It proposes an integrated approach using epidemiological studies, exposure assessment techniques, mechanistic and animal models, and expert networks applying novel methods when possible. The project ended in 2018.

The European Commission has not yet conducted studies on the potential health risks of the 5G technology.²²

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ENDNOTES

- ¹ Industry estimates that 5G capacity will be 40 times that offered by current 4G technology. See M. Negreiro, [Towards a European gigabit society Connectivity targets and 5G](#), EPRS, June 2017.
- ² A Megahertz (MHz) is a million cycles per second and a Gigahertz (GHz) pulses at a billion cycles per second. In order to carry data at faster speeds, each new generation of telecommunications uses higher frequency radio waves.
- ³ See [5G deployment agenda](#).
- ⁴ In addition to spectrum licensing costs, a large share of the cost will be due to the much denser network needed, rolling out the [small cells](#) necessary to transmit signals in much higher frequency bands.
- ⁵ See '[5G Deployment: State of Play in Europe, USA and Asia](#)', European Parliament, June 2019.
- ⁶ '[Fiber is safer, faster, more reliable, and far more cyber secure and energy efficient than wireless](#).' R. M. Powell. See also similar opinions from experts such as [T. Schoechele](#) and [P. Héroux](#).
- ⁷ Also known as waves or radiation.
- ⁸ Which would make measuring radiation exposures even more difficult.
- ⁹ Usually, the longer the wavelength the further it travels. The higher frequency millimetre wavelengths of 5G travel only a few hundred metres.
- ¹⁰ See '[5G Deployment: State of Play in Europe, USA and Asia](#)', European Parliament, June 2019.
- ¹¹ Radio frequency includes a continuum of the electromagnetic spectrum wavelengths from around 3 kHz to 300 GHz. The wavelengths in the radio frequency vary from hundreds of metres to fractions of a centimetre. The frequencies used in current digital communications have shorter wavelengths and faster data transfer. This enables the transfer of more data simultaneously.
- ¹² Time-varying means that as time (t) increases, the magnetic field changes.
- ¹³ The amount of charge per unit of time that flows through a unit area of a chosen cross section.
- ¹⁴ According to the WHO, EMFs of all frequencies represent one of the most common and fastest growing environmental influences. Exposure of the whole population to EMFs will continue to increase along with technological advance.
- ¹⁵ An electromagnetic pulse is a short blowout of electromagnetic energy. Its origin can be manmade and can occur as a radiated, electric, or magnetic field or a conducted electric current.
- ¹⁶ Millimetre waves, which will be employed by 5G, are mostly absorbed within a few millimetres of human skin and in the surface layers of the cornea. Short-term exposure [can have adverse physiological effects in the peripheral nervous system](#), the immune system and the cardiovascular system.
- ¹⁷ For more information on the two studies, see also the EPRS briefing on [Mobile phones and health](#), March 2019.
- ¹⁸ See '[5G Deployment: State of Play in Europe, USA and Asia](#)', European Parliament, June 2019
- ¹⁹ According to the limits established by Council Recommendation 1999/519/EC.
- ²⁰ In an [open letter](#) from 2011 to the Health and Consumer Policy Commissioner, public interest stakeholders expressed their concerns over the lack of transparency and pluralism [in the evaluation of evidence by SCENIHR](#), and other EU risk assessment committees, of the health risks of non-ionising EMF radiation (see [EPRS Briefing](#), March 2019).
- ²¹ See EPRS briefing '[Towards a European gigabit society: Connectivity targets and 5G](#)', June 2017.
- ²² See answer given by the European Commission to parliamentary question [E-005128/2018\(ASW\)](#). See also '[MEP: Commission 'irresponsible' on 5G health risks](#)', Euractiv, 12 December 2019.

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