International Center for Law & Economics

Comments of the International Center for Law & Economics

Re: Request for Information on Electromagnetic Field Exposure and Human Health

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I. Introduction and Overview

The International Center for Law & Economics (ICLE) submits these comments in response to the Department of Health and Human Services' (HHS) Request for Information on Electromagnetic Fields (EMFs), Radiofrequency (RF) Radiation, and Wireless Radiation Exposure.[1] ICLE is a nonprofit, nonpartisan research center that applies law & economics to public policy. Its work promotes sound economic analysis and consumer welfare, particularly in dynamic, technology-driven markets such as telecommunications.

These comments focus on Question 12, which asks what scientific evidence supports potential adverse health effects from radiofrequency (RF) exposure below current federal limits. The evidence does not establish significant adverse health effects at exposure levels permitted under Federal Communications Commission (FCC) rules.

Large studies that follow participants over time and systematic reviews commissioned by the World Health Organization (WHO) find no increased cancer risk. Controlled studies show no impairment of cognition or sleep, and reviews of human studies find no adverse effects on fertility or pregnancy. Blinded experiments, in which participants do not know whether exposure occurs, consistently find that RF exposure does not cause the symptoms attributed to electromagnetic hypersensitivity.

Studies reporting harm rely predominantly on older case-control designs vulnerable to errors in participants' recollections, animal experiments involving whole-body exposures far above public limits whose findings other studies have not replicated, and compilations that count positive findings without weighing study quality.

Uncertainty remains, particularly for higher-frequency bands, prenatal exposure, and very long-term use. That uncertainty reflects research gaps rather than evidence of harm. HHS should base its assessment on the systematic evidence and direct new federal research toward those gaps.

II. The Evidence on RF Exposure Below Federal Limits

The RFI asks what scientific evidence exists on potential health effects from RF exposure below current federal limits.[2] It also asks commenters to "clearly distinguish established evidence from emerging findings and areas of uncertainty."[3] HHS should assess the full body of evidence, weighing study design, exposure measurement, and replication.

These comments draw principally on peer-reviewed systematic reviews, large studies that follow participants over time, and expert agency assessments. Subsection A reviews the major assessments,

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[1] *Request for Information on Electromagnetic Fields (EMFs), Radiofrequency (RF) Radiation, and Wireless Radiation Exposure*, 91 FED. REG. 59,792 (Sept. 21, 2026), https://www.federalregister.gov/documents/2026/09/21/2026-19252/request-for-information-on-electromagnetic-fields-emfs-radiofrequency-rf-radiation-and-wireless [hereinafter RFI].

[2] *Id.* at 59,793.

[3] *Id.*

including 12 WHO-commissioned systematic reviews. Subsections B through F examine cancer, cognition and sleep, fertility and development, oxidative stress, and symptoms attributed to RF exposure.

Several themes connect these findings. A measurable biological change does not necessarily indicate harm. Laboratory results require careful assessment before they can establish human risk at everyday exposures. Personal accounts deserve attention, but attributing symptoms to RF exposure requires evidence of causation.

Taken together, the evidence establishes no adverse health effects below current federal limits. Confidence varies across outcomes, and important research gaps remain. Those gaps warrant targeted research and continued monitoring, but do not themselves establish a basis for changing exposure standards.

A. Assess Study Quality and the Weight of the Evidence

Systematic reviews and expert assessments offer the most reliable guide to the extensive RF safety literature because they weigh study quality. Taken together, they establish no adverse health effects in humans at exposures below current limits. They also identify important uncertainties, including low confidence in some findings, unresolved animal results, and limited research on higher-frequency bands. HHS should ground its assessment in this evidence and direct new research toward those gaps.

The most comprehensive recent effort comprises 12 systematic reviews commissioned by the World Health Organization (WHO) and published in *Environment International* between 2023 and 2025.[4] The reviews of human studies found no clear evidence of adverse effects, although confidence in the findings varied:

- **Cancer.** Mobile phone use showed no association with glioma, meningioma, acoustic neuroma, pituitary or salivary tumors, or childhood brain tumors, including among long-term users. The review rated the evidence as moderately certain.[5]
- **Headaches.** Blinded experiments found that exposure does not cause headaches or other symptoms, with moderate to high certainty.[6]

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[4] *See* Jos Verbeek *et al.*, *Systematic Reviews and Meta-Analyses for the WHO Assessment of Health Effects of Exposure to Radiofrequency Electromagnetic Fields, An Introduction*, 203 ENV'T INT'L 109751 (2025), https://www.sciencedirect.com/science/article/pii/S0160412025005021?via%3Dihub.

[5] Ken Karipidis *et al.*, *The Effect of Exposure to Radiofrequency Fields on Cancer Risk in the General and Working Population: A Systematic Review of Human Observational Studies–Part I: Most Researched Outcomes*, 191 ENV'T INT'L 108983 (2024), https://www.sciencedirect.com/science/article/pii/S0160412024005695?via%3Dihub#s0400.

[6] Xavier Bosch-Capblanch *et al.*, *The Effects of Radiofrequency Electromagnetic Fields Exposure on Human Self-Reported Symptoms: A Systematic Review of Human Experimental Studies*, 187 ENV'T INT'L 108612 (2024), https://www.sciencedirect.com/science/article/pii/S0160412024001983?via%3Dihub#s0130.

- **Cognition.** Across 76 experimental studies, exposure did not reduce cognitive performance. Most findings carried high or moderate certainty.[7]
- **Reproduction.** Human studies showed no clear adverse effects on male fertility or pregnancy and birth outcomes, although the evidence carried very low to low certainty.[8]

Switzerland's expert group on non-ionizing radiation reviewed all 12 WHO-commissioned reviews. It found that human observational studies offer little indication of substantial health effects in healthy people at everyday exposure levels. It also cautioned that the overall evidence remains too uncertain and mixed to support firm conclusions.[9]

Major regulatory and scientific bodies likewise have found no established harm below applicable exposure limits. The U.S. Food and Drug Administration (FDA) reviewed animal and human population studies published between 2008 and 2018 and found insufficient evidence that RF exposure causes tumors.[10] The European Commission's Scientific Committee on Health, Environmental and Emerging Risks found no moderate or strong evidence of adverse effects from short- or long-term exposure below European Union limits.[11] The International Commission on Non-Ionizing Radiation Protection found neither evidence of adverse health effects below its previous exposure restrictions nor evidence of a mechanism that would predict such effects.[12] These assessments provide no basis to conclude that current FCC guidelines inadequately protect public health.

HHS will receive submissions citing individual studies that report biological effects and compilations that tally those findings. Such submissions can distort the overall picture when they overlook study quality. In RF research, stronger study designs and more accurate exposure measurements tend to

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[7] Blanka Pophof *et al.*, *The Effect of Exposure to Radiofrequency Electromagnetic Fields on Cognitive Performance in Human Experimental Studies: Systematic Review and Meta-Analyses*, 191 ENV'T INT'L 108899 (2024), https://www.sciencedirect.com/science/article/pii/S0160412024004859?via%3Dihub.

[8] Ryan P.W. Kenny *et al.*, *The Effects of Radiofrequency Exposure on Male Fertility: A Systematic Review of Human Observational Studies with Dose–Response Meta-Analysis*, 190 ENV'T INT'L 108817 (2024), https://doi.org/10.1016/j.envint.2024.108817; Emma E. Johnson *et al.*, *The Effects of Radiofrequency Exposure on Adverse Female Reproductive Outcomes: A Systematic Review of Human Observational Studies with Dose-Response Meta-Analysis*, 190 ENV'T INT'L 108816 (2024), https://www.sciencedirect.com/science/article/pii/S0160412024004021?via%3Dihub.

[9] Swiss Expert Grp. on Electromagnetic Fields & Non-Ionising Radiation (BERENIS), Newsletter Special Issue: Assessment of WHO-Commissioned Systematic Reviews on Health Effects of RF-EMF 2 (Dec. 2025), https://www.bafu.admin.ch/dam/en/sd-web/eJ9UQK3V4VeM/Newsletter%20BERENIS%20Special%20Issue%20-%20December%202025.pdf [hereinafter BERENIS Newsletter].

[10] U.S. Food & Drug Admin., Review of Published Literature Between 2008 and 2018 of Relevance to Radiofrequency Radiation and Cancer (Feb. 2020), https://www.fda.gov/media/135043/download.

[11] Sci. Comm. on Health, Env't & Emerging Risks (SCHEER), Opinion on the Need of a Revision of the Annexes in the Council Recommendation 1999/519/EC and Directive 2013/35/EU (Apr. 18, 2023), https://health.ec.europa.eu/system/files/2023-06/scheer_o_044.pdf.

[12] Int'l Comm'n on Non-Ionizing Radiation Prot., *Guidelines for Limiting Exposure to Electromagnetic Fields (100 kHz to 300 GHz)*, 118 HEALTH PHYSICS 483 (2020), https://www.ovid.com/jnls/health-physics/fulltext/10.1097/hp.0000000000001210~guidelines-for-limiting-exposure-to-electromagnetic-fields.

produce fewer reported effects. One systematic review of base-station studies found that "the more sophisticated the exposure assessment, the less likely it was that an effect would be reported."[13] A meta-analysis of millimeter-wave studies similarly found smaller reported effects as study quality improved.[14]

Compilations such as the BioInitiative Report therefore offer poor guides to the evidence when they count positive findings without adequately assessing study design, radiation-dose measurements, or temperature controls.[15] HHS should give greater weight to systematic reviews that assess these features and use established methods to rate confidence in their conclusions.

B. Cancer Risk Below Federal Limits

Cancer is the most extensively studied potential health effect of RF exposure. The strongest human evidence comes from prospective cohort studies, which record phone use before diagnosis and follow participants over time. This design avoids asking patients to reconstruct their exposure after learning they have cancer—a central source of recall bias in case-control studies.

The international COSMOS study followed 264,574 adults in five European countries and calibrated self-reported phone use against operator records. Participants in the highest tenth of cumulative call time had no greater risk of glioma, meningioma, or acoustic neuroma than light users. The study also found no association between glioma and 15 or more years of use.[16]

The UK Million Women Study followed 776,156 women for 14 years, during which 3,268 developed brain tumors. It found no increased risk overall, by tumor type, or in the temporal and parietal lobes nearest the phone. Right- and left-sided tumors occurred at similar rates, although people more often hold phones on the right side.[17] A nationwide Danish cohort of approximately 420,000 early subscribers likewise found no increased risk.[18]

Research involving younger people points in the same direction. MOBI-Kids, the largest study of brain tumors in young people, compared 899 patients ages 10 to 24 with 1,910 controls across 14

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[13] Martin Röösli *et al.*, *Systematic Review on the Health Effects of Exposure to Radiofrequency Electromagnetic Fields from Mobile Phone Base Stations*, 88 BULL. WORLD HEALTH ORG. 887, 887 (2010), https://pubmed.ncbi.nlm.nih.gov/21124713.

[14] Andrew W. Wood *et al.*, *Meta-Analysis of In Vitro and In Vivo Studies of the Biological Effects of Low-Level Millimetre Waves*, 31 J. EXPOSURE SCI. & ENV'T EPIDEMIOLOGY 606, 611 (2021), https://pmc.ncbi.nlm.nih.gov/articles/PMC7962924.

[15] *See* Health Council of the Neth., BioInitiative Report, No. 2008/17E, at 4–5 (Sept. 2, 2008), https://www.healthcouncil.nl/documents/2008/09/02/bioinitiative (concluding that selective use of scientific data and other shortcomings prevent the BioInitiative report from providing "an objective and balanced reflection of the current state of scientific knowledge").

[16] Maria Feychting *et al.*, *Mobile Phone Use and Brain Tumour Risk–COSMOS, a Prospective Cohort Study*, 185 ENV'T INT'L 108552 (2024), https://pubmed.ncbi.nlm.nih.gov/38458118.

[17] Joachim Schüz *et al.*, *Cellular Telephone Use and the Risk of Brain Tumors: Update of the UK Million Women Study*, 114 J. NAT'L CANCER INST. 704 (2022), https://pubmed.ncbi.nlm.nih.gov/35350069.

[18] Patrizia Frei *et al.*, *Use of Mobile Phones and Risk of Brain Tumours: Update of Danish Cohort Study*, 343 BMJ d6387 (2011), https://pmc.ncbi.nlm.nih.gov/articles/PMC3197791.

countries and found no evidence of a causal association.[19] A national UK study also found no association between estimated prenatal exposure to base stations and early childhood cancer.[20]

Systematic reviews reinforce these findings. The WHO-commissioned review of 63 human studies from 22 countries found no association between mobile phone use and glioma, meningioma, acoustic neuroma, pituitary or salivary gland tumors, or childhood brain tumors, including after 10 or more years of use. It rated that conclusion as moderately certain.[21] A companion review found no association with leukemia, lymphoma, or thyroid cancer and also examined base-station and occupational exposure.[22]

Population trends provide a further check. If mobile phone use caused a substantial share of brain tumors, widespread adoption should eventually produce a detectable increase in incidence. The FDA's 2020 review instead noted that public cancer registries showed a slight decline in brain tumors despite a large increase in mobile phone use over two decades.[23]

Positive human findings come principally from INTERPHONE and Swedish case-control studies by Lennart Hardell and colleagues.[24] These studies asked people who already had brain tumors to recall years of phone use. Patients' recollections can introduce bias, including overestimates of past exposure.[25] The larger risks reported by Hardell's studies have not appeared in prospective cohorts and conflict with flat national incidence trends.[26] These case-control studies supplied the principal human evidence for the International Agency for Research on Cancer's (IARC) 2011 classification

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[19] Gemma Castaño-Vinyals *et al.*, *Wireless Phone Use in Childhood and Adolescence and Neuroepithelial Brain Tumours: Results from the International MOBI-Kids Study*, 160 ENV'T INT'L 107069 (2022), https://pubmed.ncbi.nlm.nih.gov/34974237.

[20] Paul Elliott *et al.*, *Mobile Phone Base Stations and Early Childhood Cancers: Case-Control Study*, 340 BMJ c3077 (2010), https://pubmed.ncbi.nlm.nih.gov/20570865.

[21] Karipidis *et al.*, *supra* note 5.

[22] Ken Karipidis *et al.*, *The Effect of Exposure to Radiofrequency Fields on Cancer Risk in the General and Working Population: A Systematic Review of Human Observational Studies–Part II: Less Researched Outcomes*, 196 ENV'T INT'L 109274 (2025), https://www.sciencedirect.com/science/article/pii/S016041202500025X?via%3Dihub#s0315.

[23] U.S. Food & Drug Admin., *supra* note 10, at 4.

[24] *See* INTERPHONE Study Grp., *Brain Tumour Risk in Relation to Mobile Telephone Use: Results of the INTERPHONE International Case–Control Study*, 39 INT'L J. EPIDEMIOLOGY 675 (2010), https://academic.oup.com/ije/article-abstract/39/3/675/631387; Lennart Hardell & Michael Carlberg, *Mobile Phone and Cordless Phone Use and the Risk for Glioma–Analysis of Pooled Case-Control Studies in Sweden, 1997–2003 and 2007–2009*, 22 PATHOPHYSIOLOGY 1 (2015), https://pubmed.ncbi.nlm.nih.gov/25466607.

[25] *See* Hardell & Carlberg, *supra* note 24, at 5 (attributing results to "participation bias or other methodological limitations" and noting "implausible values of reported use").

[26] *See* Hardell & Carlberg, *supra* note 24, at 1 (reporting threefold odds of glioma among those who first used a mobile phone more than 25 years earlier, with a 95% confidence interval of 1.7–5.2); Mark P. Little *et al.*, *Mobile Phone Use and Glioma Risk: Comparison of Epidemiological Study Results with Incidence Trends in the United States*, 344 BMJ e1147 (2012), https://pmc.ncbi.nlm.nih.gov/articles/PMC3297541 (concluding that the elevated risks reported by the Swedish study "are not consistent with observed incidence trends in US population data").

of RF radiation as possibly carcinogenic. That assessment preceded COSMOS, the Million Women Study update, MOBI-Kids, and the WHO-commissioned reviews.

Animal findings also require careful interpretation. The National Toxicology Program (NTP) reported "clear evidence" of malignant heart schwannomas—tumors of nerve-supporting cells—in male rats and some evidence of gliomas.[27] Several features limit what those findings establish about human risk.

The rats received whole-body exposure for nine hours a day over two years at 1.5, 3, or 6 watts per kilogram (W/kg), roughly 19 to 75 times the public whole-body limit of 0.08 W/kg. The tumor findings appeared in male rats, but not female rats or mice of either sex. The FDA also noted no clear relationship between exposure dose and heart tumors.[28]

Exposed male rats lived longer than unexposed controls, whose unusually short survival could have reduced the number of tumors observed in the comparison group. The FDA, which nominated the study, concluded that its findings "should not be applied to human cell phone usage."[29]

The Ramazzini Institute likewise reported more heart schwannomas in male rats only at the highest of three exposures to a signal resembling base-station emissions.[30] Its exposure levels were roughly 1,000 times lower than the NTP's, yet it reported a similar effect. That discrepancy complicates a causal interpretation based on dose. After reviewing both studies, the International Commission on Non-Ionizing Radiation Protection concluded that their findings "do[] not provide evidence that radiofrequency EMF is carcinogenic."[31]

Subsequent studies have not reproduced the rat findings. In a coordinated partial replication, Japanese and Korean teams used the same rat strain, signal type, and whole-body exposure of 4 W/kg. Both teams reported no reproducible carcinogenic effects or damage to genetic material.[32]

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[27] Nat'l Toxicology Program, NTP TR 595 (2018), https://ntp.niehs.nih.gov/sites/default/files/ntp/htdocs/lt_rpts/tr595_508.pdf.

[28] *See* Press Release, Nat'l Insts. of Health, *High Exposure to Radio Frequency Radiation Associated with Cancer in Male Rats* (Nov. 1, 2018), https://www.nih.gov/news-events/news-releases/high-exposure-radio-frequency-radiation-associated-cancer-male-rats; *see also* Statement from Jeffrey Shuren, Dir., Ctr. for Devices & Radiological Health, U.S. Food & Drug Admin., on the National Toxicology Program's Report on Radiofrequency Energy Exposure (Nov. 1, 2018), https://www.fda.gov/news-events/press-announcements/statement-jeffrey-shuren-md-jd-director-fdas-center-devices-and-radiological-health-recent-national.

[29] Statement from Jeffrey Shuren, *supra* note 28.

[30] L. Falcioni *et al.*, *Report of Final Results Regarding Brain and Heart Tumors in Sprague-Dawley Rats Exposed from Prenatal Life Until Natural Death to Mobile Phone Radiofrequency Field Representative of a 1.8 GHz GSM Base Station Environmental Emission*, 165 ENV'T RSCH. 496 (2018), https://pubmed.ncbi.nlm.nih.gov/29530389.

[31] Int'l Comm'n on Non-Ionizing Radiation Prot., ICNIRP Note on Recent Animal Carcinogenesis Studies 6 (2018), https://www.icnirp.org/cms/upload/publications/ICNIRPnote2018.pdf.

[32] Katsumi Imaida *et al.*, *The International Collaborative Animal Study of Mobile Phone Radiofrequency Radiation Carcinogenicity and Genotoxicity: The Japanese Study*, 209 TOXICOLOGICAL SCIS. 1 (2026), https://pmc.ncbi.nlm.nih.gov/articles/PMC13078595/pdf/kfag002.pdf; Hye Sun Kim *et al.*, *The International Collaborative*

Australia's radiation protection agency also noted that a separate systematic review rated the animal evidence as low or inadequate. It further explained that RF energy at these frequencies reaches a rat's heart but does not penetrate to a human's heart.[33]

The weight of the evidence does not establish that RF exposure below federal limits causes cancer. HHS should give greatest weight to prospective cohort studies and systematic reviews, incorporate IARC's re-evaluation when available, and support continued monitoring of long-term cohorts as patterns of use evolve.

C. Cognition and Sleep

RF exposure at levels typical of mobile phone use can produce small, measurable changes in brain electrical activity. The evidence does not, however, establish that those changes impair thinking, memory, or sleep.

The WHO-commissioned review of 76 human experimental studies found that short-term RF exposure did not reduce performance across seven areas of cognition. Most findings carried high or moderate certainty.[34] A companion review of observational studies, mostly involving children, found little to no association with learning, memory, executive function (the ability to plan and manage tasks), or attention.[35]

A Swiss adolescent cohort often cited as contrary evidence linked estimated brain exposure to poorer figural memory, which involves recalling visual patterns. It found no effect on verbal memory, and studies in other countries have not replicated the finding. The Swiss study's authors cautioned that it did not provide "conclusive evidence of causal effects."[36]

The largest field study of sleep near base stations followed 397 residents at 10 German sites without prior mobile service.[37] Researchers installed an experimental base station and monitored sleep at home on nights when it was on or off. Neither participants nor the researchers assessing sleep knew the exposure status.

Animal Study of the Carcinogenicity and Genotoxicity of Mobile Phone Radiofrequency Radiation: The Korean Study, 209 TOXICOLOGICAL SCIS. kfag001 (2026), https://pmc.ncbi.nlm.nih.gov/articles/PMC13017829/pdf/kfag001.pdf.

[33] Austl. Radiation Prot. & Nuclear Safety Agency, *Study of Experimental Animals and Cancer Provides No Reason to Change ARPANSA's Assessment of Safety of Wireless Technology* (May 2025), https://www.arpansa.gov.au/study-experimental-animals-and-cancer-provides-no-reason-change-arpansas-assessment-safety-wireless-technology.

[34] Pophof *et al.*, *supra* note 7.

[35] Geza Benke *et al.*, *The Effects of Radiofrequency Exposure on Cognition: A Systematic Review and Meta-Analysis of Human Observational Studies*, 188 ENV'T INT'L 108779 (2024), https://pubmed.ncbi.nlm.nih.gov/38821015.

[36] Milena Foerster *et al.*, *A Prospective Cohort Study of Adolescents' Memory Performance and Individual Brain Dose of Microwave Radiation from Wireless Communication*, 126 ENV'T HEALTH PERSPS. 077007 (2018), https://pubmed.ncbi.nlm.nih.gov/30044230.

[37] Heidi Danker-Hopfe *et al.*, *Do Mobile Phone Base Stations Affect Sleep of Residents? Results from an Experimental Double-Blind Sham-Controlled Field Study*, 22 AM. J. HUM. BIOLOGY 613 (2010), https://pubmed.ncbi.nlm.nih.gov/20737608.

The study found no effect on measured or self-reported sleep quality. Residents concerned about base stations slept worse even on nights without exposure, linking poorer sleep to concern rather than the RF signal. These findings align with the WHO-commissioned review of blinded experiments, which found with moderate to high certainty that RF exposure does not cause symptoms.[38]

Some recent studies report poorer sleep during RF exposure. One small experiment using 2.45-gigahertz exposure during sleep found reduced self-reported sleep quality.[39] Such findings warrant follow-up, but unreplicated individual studies carry less weight than larger blinded studies. Observational studies linking devices in children's bedrooms to poorer sleep also struggle to separate RF exposure from screen use, nighttime light, and notifications, each of which can disrupt sleep.

The evidence does not establish that RF exposure below federal limits impairs cognition or sleep. HHS should prioritize studies that follow children over time and blinded sleep experiments that measure exposure directly.

D. Fertility, Pregnancy, and Child Development

Human studies have not established adverse effects of RF exposure on fertility, pregnancy, or child development. Reviewers have nevertheless expressed particular caution about this evidence, and HHS should acknowledge its limits.

The WHO-commissioned review of human observational studies found no clear adverse effect on male fertility or sperm quality, although it rated the evidence as very low to low certainty.[40] A 2014 meta-analysis often cited as evidence of harm reported approximately 8% to 9% reductions in sperm motility and viability—the ability to move and survive. Most included studies, however, exposed sperm samples in laboratory dishes rather than studying exposure in men. None of the studies involving men measured actual RF dose, and the authors lacked data on smoking and age.[41] The WHO-commissioned review of laboratory studies likewise found inconsistent, low-certainty evidence of effects on human sperm.[42]

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[38] Bosch-Capblanch *et al.*, *supra* note 6.

[39] Nicole Bijlsma *et al.*, *Does Radiofrequency Radiation Impact Sleep?*, 12 FRONTIERS IN PUB. HEALTH 1481537 (2024), https://pubmed.ncbi.nlm.nih.gov/39534742.

[40] Kenny *et al.*, *supra* note 8.

[41] Jessica A. Adams *et al.*, *Effect of Mobile Telephones on Sperm Quality: A Systematic Review and Meta-Analysis*, 70 ENV'T INT'L 106, 110 (2014), https://pubmed.ncbi.nlm.nih.gov/24927498.

[42] Eugenia Cordelli *et al.*, *Effects of Radiofrequency Electromagnetic Field (RF-EMF) Exposure on Male Fertility: A Systematic Review of Experimental Studies on Non-Human Mammals and Human Sperm In Vitro*, 185 ENV'T INT'L 108509 (2024), https://www.sciencedirect.com/science/article/pii/S0160412024000953?via%3Dihub.

For pregnancy outcomes, the WHO-commissioned review found no consistent effect on birth weight, preterm birth, miscarriage, or congenital anomalies. The evidence remained very uncertain because few rigorous studies exist.[43]

Studies using the Danish National Birth Cohort linked maternal phone use during pregnancy to behavioral problems in children at age 7.[44] Several limitations weaken a causal interpretation. Mothers recalled their phone use approximately seven years after pregnancy, when they already knew about their children's behavior. That timing creates a risk that knowledge of the outcome influenced their recollections.

Comparisons between siblings largely eliminated the association, suggesting that shared family characteristics, potentially including parenting practices, could explain it.[45] During calls, a phone held at the mother's head also exposes the fetus to only a small fraction of the mother's exposure. Other cohort research has not consistently reproduced the association.[46]

The largest pooled analysis, covering 83,884 mother-child pairs in five countries, found no significant association with overall behavioral problems and only a small association with hyperactivity and inattention. Its authors cautioned that "uncontrolled confounding"—other factors associated with both maternal phone use and child behavior—could explain the findings.[47]

These uncertainties warrant further research. Switzerland's expert group concluded that the evidence cannot rule out an effect on the fetus and recommended treating pregnant women and their unborn children as a potentially vulnerable group.[48] That recommendation reflects the limits of available evidence and does not establish harm.

HHS should prioritize prospective studies that measure exposure during pregnancy and early childhood, along with well-controlled animal studies using exposures relevant to people. These studies would provide a stronger basis for assessment than the existing animal findings and observational studies that cannot adequately separate RF exposure from other influences.

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[43] Johnson *et al.*, *supra* note 8.

[44] Hozefa A. Divan *et al.*, *Cell Phone Use and Behavioral Problems in Young Children*, 66 J. EPIDEMIOLOGY & CMTY. HEALTH 524 (2012), https://jech.bmj.com/content/66/6/524.long.

[45] Madhuri Sudan *et al.*, *Complexities of Sibling Analysis When Exposures and Outcomes Change with Time and Birth Order*, 24 J. EXPOSURE SCI. & ENV'T EPIDEMIOLOGY 482 (2014), https://pubmed.ncbi.nlm.nih.gov/24064530.

[46] Mònica Guxens *et al.*, *Maternal Cell Phone and Cordless Phone Use During Pregnancy and Behaviour Problems in 5-Year-Old Children*, 67 J. EPIDEMIOLOGY & CMTY. HEALTH 432 (2013), https://pubmed.ncbi.nlm.nih.gov/23386674.

[47] Laura Birks *et al.*, *Maternal Cell Phone Use During Pregnancy and Child Behavioral Problems in Five Birth Cohorts*, 104 ENV'T INT'L 122 (2017), https://pmc.ncbi.nlm.nih.gov/articles/PMC5506372/pdf/nihms866566.pdf.

[48] BERENIS Newsletter, *supra* note 9, at 5.

E. Oxidative Stress and DNA Damage

Oxidative stress—an imbalance between reactive oxygen molecules and the body's antioxidant defenses—is a proposed mechanism through which low-level RF exposure might cause disease. A frequently cited review reported that 93 of 100 peer-reviewed studies found oxidative effects from low-intensity RF exposure.[49] But it counted positive findings without assessing study design, exposure measurement, or temperature controls.

The review also defined "low-intensity" by reference to the International Commission on Non-Ionizing Radiation Protection's limit of 2 W/kg, rather than the lower U.S. limits. As Judge Karen LeCraft Henderson observed in her partial dissent in *Environmental Health Trust v. FCC*, "it is uncertain how many, if any," of those studies examined exposures below federal limits.[50]

The WHO-commissioned systematic review, which assessed study quality, reached a more qualified conclusion. It found some indications of oxidative stress in a few rodent tissues—including blood, testes, and the thymus—but no consistent changes elsewhere. It rated nearly all the evidence as low or very low certainty.[51] Exercise, heat, diet, and other ordinary stimuli also affect oxidative stress markers. A temporary change in a marker alone does not establish harm.

Reviews likewise have not confirmed RF-induced DNA damage, one proposed consequence of oxidative stress. A systematic review of cell studies found, with moderate confidence, no genotoxic effect (damage to genetic material) from RF exposure.[52] The 2026 Japanese and Korean partial replications of the NTP study also found no DNA damage or chromosomal abnormalities in exposed rats.[53]

The evidence does not establish oxidative stress as a pathway from RF exposure below federal limits to disease. HHS should support carefully controlled research to test that hypothesis and determine whether reported biological changes have consequences for health.

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[49] Igor Yakymenko *et al.*, *Oxidative Mechanisms of Biological Activity of Low-Intensity Radiofrequency Radiation*, 35 ELECTROMAGNETIC BIOLOGY & MED. 186 (2016), https://pubmed.ncbi.nlm.nih.gov/26151230.

[50] *Env't Health Tr. v. FCC*, 9 F.4th 893, 915–16 (D.C. Cir. 2021) (Henderson, J., dissenting in part).

[51] Felix Meyer *et al.*, *The Effects of Radiofrequency Electromagnetic Field Exposure on Biomarkers of Oxidative Stress In Vivo and In Vitro: A Systematic Review of Experimental Studies*, 194 ENV'T INT'L 108940 (2024), https://pubmed.ncbi.nlm.nih.gov/39566441.

[52] Stefania Romeo *et al.*, *Genotoxicity of Radiofrequency Electromagnetic Fields on Mammalian Cells In Vitro: A Systematic Review with Narrative Synthesis*, 193 ENV'T INT'L 109104 (2024), https://www.sciencedirect.com/science/article/pii/S0160412024006901?via%3Dihub.

[53] *See* Imaida *et al.*, *supra* note 32; *see also* Kim *et al.*, *supra* note 32.

F. Symptoms Attributed to RF Exposure

HHS has invited individuals and families to describe health experiences they associate with RF exposure.[54] Many submissions will likely describe headaches, fatigue, sleep disruption, and difficulty concentrating—symptoms often attributed to "electromagnetic hypersensitivity," also known as idiopathic environmental intolerance attributed to electromagnetic fields. These symptoms deserve serious attention. The evidence does not establish RF exposure as their cause.

Blinded provocation studies directly test that proposed link by exposing people who report sensitivity to real or sham fields without telling them which. A systematic review of 46 such studies involving 1,175 participants found no robust evidence that exposure triggered symptoms. It did find support for a nocebo effect, in which the expectation of harm produces symptoms.[55] People who report sensitivity also perform no better than others at identifying when a field is on.[56] The WHO-commissioned review of experimental studies likewise found, with moderate to high certainty, that RF exposure does not cause headaches or other self-reported symptoms.[57]

Field studies reinforce these findings. In the German blinded experiment discussed above, residents concerned about base stations slept worse even on nights when the experimental station was off.[58] A systematic review of base-station studies found fewer reported effects as exposure assessment improved. It concluded that strong evidence weighs against acute symptoms at exposures up to 10 volts per meter, a measure of electric field strength.[59] Population studies likewise show no association between measured RF exposure and tinnitus, migraine, or nonspecific symptoms.[60]

Critics argue that provocation studies use exposures that are too brief, test the wrong signals, or overlook delayed reactions. Reviewers have also identified methodological limitations in individual experiments.[61] Those concerns warrant attention, but the studies span many frequencies, signal

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[54] RFI, *supra* note 1, at 59,793.

[55] G. James Rubin *et al.*, *Idiopathic Environmental Intolerance Attributed to Electromagnetic Fields (Formerly "Electromagnetic Hypersensitivity"): An Updated Systematic Review of Provocation Studies*, 31 BIOELECTROMAGNETICS 1, 1 (2010), https://pubmed.ncbi.nlm.nih.gov/19681059.

[56] Martin Röösli, *Radiofrequency Electromagnetic Field Exposure and Non-Specific Symptoms of Ill Health: A Systematic Review*, 107 ENV'T RSCH. 277, 277 (2008), https://www.sciencedirect.com/science/article/abs/pii/S0013935108000601?via%3Dihub (pooling seven studies involving 182 participants who identified as sensitive to electromagnetic fields and 332 controls).

[57] Bosch-Capblanch *et al.*, *supra* note 6.

[58] Danker-Hopfe *et al.*, *supra* note 37.

[59] Röösli *et al.*, *supra* note 13, at 893–94.

[60] Martin Röösli *et al.*, *The Effects of Radiofrequency Electromagnetic Fields Exposure on Tinnitus, Migraine and Non-Specific Symptoms in the General and Working Population: A Systematic Review and Meta-Analysis on Human Observational Studies*, 183 ENV'T INT'L 108338 (2024), https://sfrp.asso.fr/wp-content/uploads/2024/04/Roosli-2024.pdf.

[61] *See* Kristina Schmiedchen *et al.*, *Methodological Limitations in Experimental Studies on Symptom Development in Individuals with Idiopathic Environmental Intolerance Attributed to Electromagnetic Fields (IEI-EMF)–A Systematic Review*, 18 ENV'T HEALTH 88 (2019), https://pubmed.ncbi.nlm.nih.gov/31640707.

types, exposure durations, and research groups. No single design limitation readily explains their consistent failure to detect an effect.

Personal accounts can document suffering and guide research questions, but they cannot establish that RF exposure caused the symptoms. HHS should assess those accounts alongside controlled studies and the broader evidence. Because concern about exposure can itself produce symptoms, public communications that overstate RF risks may worsen the problems they seek to address.

HHS should support clinical approaches that address symptoms directly and research into their causes. The evidence provides no sound basis to expect exposure-avoidance measures to relieve these symptoms.

III. Assess Exposure Across Technologies

Question 13 asks how 5G, 6G, Wi-Fi, satellite communications, smart meters, and other technologies affect cumulative exposure. HHS should focus on the RF energy that reaches the body across sources. Exposure depends on transmitter power, distance, transmission time, and frequency, which affects how deeply energy penetrates tissue. A service's name reveals little about those factors.

Federal limits already take this approach. FCC rules restrict the rate at which the body absorbs RF energy, as well as field strength or power density at a given frequency, regardless of the service producing it.[62] A smart meter and a 5G base station operating at similar frequencies and producing the same field at a person's location create comparable exposure conditions.

Measurements illustrate why technology labels offer a poor proxy for exposure. Smart meters transmit at roughly the power of a mobile phone but generally in brief bursts. Vermont field measurements found a maximum time-averaged exposure of 0.068% of the FCC limit at 1 foot from a meter, falling to approximately 0.0013% at 10 feet.[63] Typical Wi-Fi exposure in Australian classrooms measured 0.0002% of the applicable limit, below exposure from broadcast radio.[64] Measurements at 100 locations near 5G base stations using large antenna arrays to direct signals toward users found actual exposures of 0.04% to 1.1% of international reference levels, well below theoretical worst-case estimates.[65]

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[62] 47 C.F.R. § 1.1310(c), (e)(1) tbl. 1.

[63] Vt. Dep't of Pub. Serv., Vermont Smart Meter Health Report (Feb. 24, 2014), https://publicservice.vermont.gov/sites/dps/files/documents/2014%20Scientific%20and%20Public%20Health%20Agency%20Perspectives%20on%20Radio%20Frequency%20Fields%20Related%20to%20Smart%20Meters.pdf.

[64] Ken Karipidis *et al.*, *Exposure to Radiofrequency Electromagnetic Fields from Wi-Fi in Australian Schools*, 175 RADIATION PROT. DOSIMETRY 432 (2017), https://pmc.ncbi.nlm.nih.gov/articles/PMC5927334.

[65] Christian Bornkessel *et al.*, *Measurement and Analysis of RF EMF Exposure to 5G Mobile Communication Base Stations with Beamforming*, BIOEM 2023 (June 3, 2025), http://db-thueringen.de/servlets/MCRFileNodeServlet/dbt_derivate_00067067/ilm1-202520015.pdf.

Device placement and use patterns affect absorbed energy, but established exposure-related hazards do not depend on the service label. The evidence does not establish different health risks among technologies that comply with applicable limits. HHS should assess combined exposure using measured levels and realistic operating conditions.

Less-studied frequency bands, including millimeter waves, warrant targeted research. Gaps in that research do not establish danger. Treating each new service as a distinct health hazard without evidence risks delaying technologies that meet existing safety standards and deliver substantial public benefits.

IV. Conclusion

The extensive scientific record does not establish adverse health effects from RF exposure below current federal limits. Large prospective cohorts, WHO-commissioned systematic reviews, and expert agency assessments support that conclusion across cancer, cognition, sleep, reproduction, and self-reported symptoms, although confidence varies by outcome.

HHS should weigh study quality, exposure measurement, and replication. Measurable biological changes alone do not establish harm, and personal accounts cannot establish causation. Assessments of new technologies should likewise focus on actual exposure across sources.

Important uncertainties remain, particularly for prenatal exposure, very long-term use, and less-studied frequency bands. These gaps warrant targeted research and continued monitoring. They do not establish that current standards inadequately protect public health. Clear communication should acknowledge uncertainty while avoiding unsupported warnings that may themselves worsen symptoms.

ICLE appreciates the opportunity to comment and urges HHS to ground its assessment in the weight of the evidence.