GSMA

The 14th EMF Forum

The evolution of EMF science, technology and communication

Tuesday, 30 September 2025

#EMFFORUM

Dr Jack Rowley
Senior Director,
EMF & Deployment Policy
GSMA

Introduction

Welcome

Mike Wood
Telstra
Chair GSMA EMF and Health

GSMA™

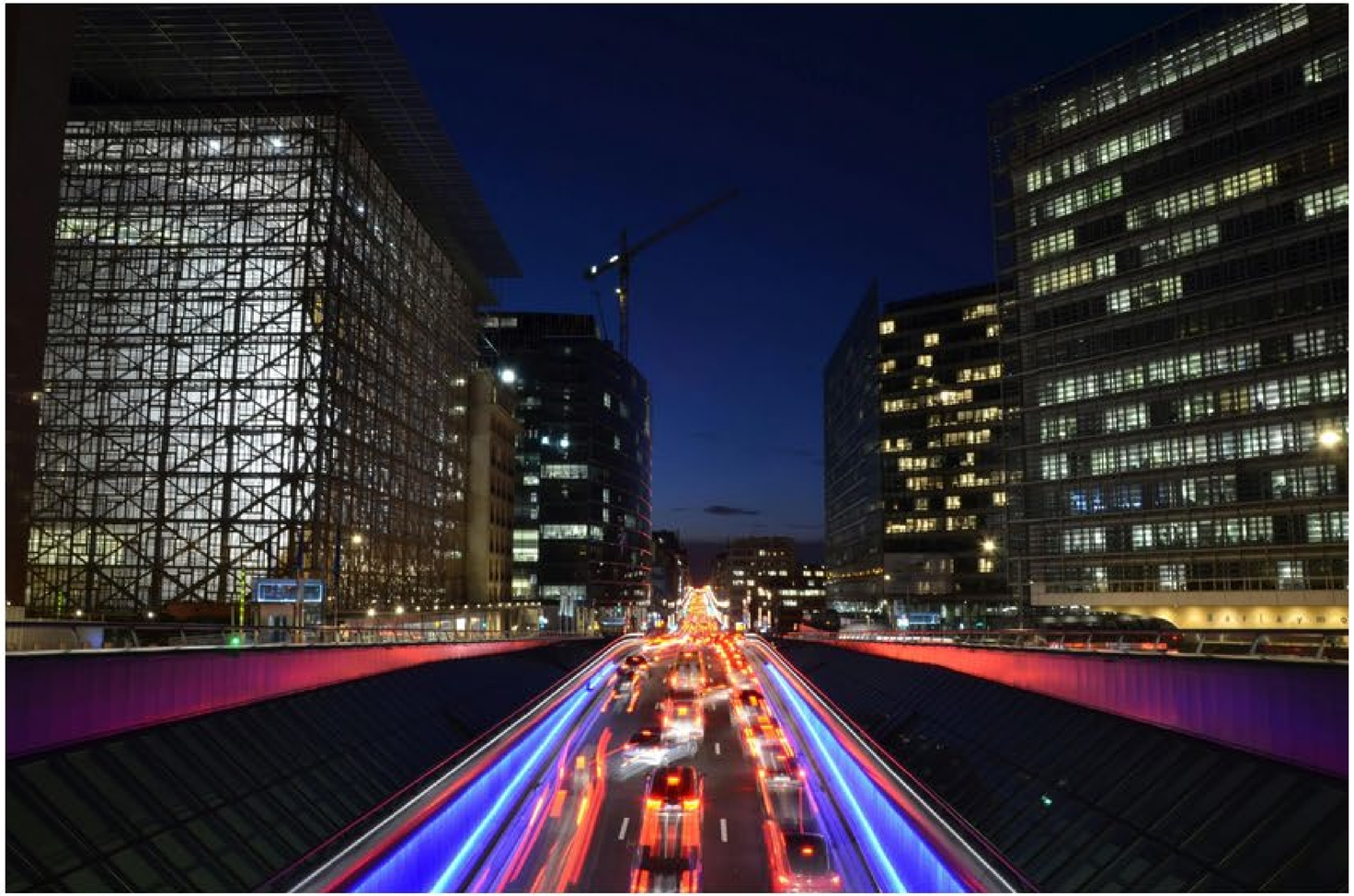
Laszlo Toth
Head of Europe & CIS
GSMA

Opening remarks

Setting the scene

Dr Jack Rowley
Senior Director,
EMF & Deployment Policy
GSMA

Event Recording | The GSMA 13th EMF Forum 2024: Learnings From Five Years of 5G EMF



Start: Tuesday 1 October 2024 09:00

End: Tuesday 1 October 2024 16:30

Venue: Le Louise Hotel Brussels - MGallery

Location: Brussels, Belgium

+ google map

https://www.gsma.com/solutions-and-impact/connectivity-for-good/public-policy/gsma_events/the-gsma-13th-emf-forum-2024/

ICNIRP (2020) adoption – mobile networks (public)

7

2020 Ireland, *Mongolia*, Norway Uganda

2021 Australia, Benin, Malaysia, Malta, Mauritius, Netherlands, Saudi Arabia, Senegal, United Arab Emirates, United Kingdom

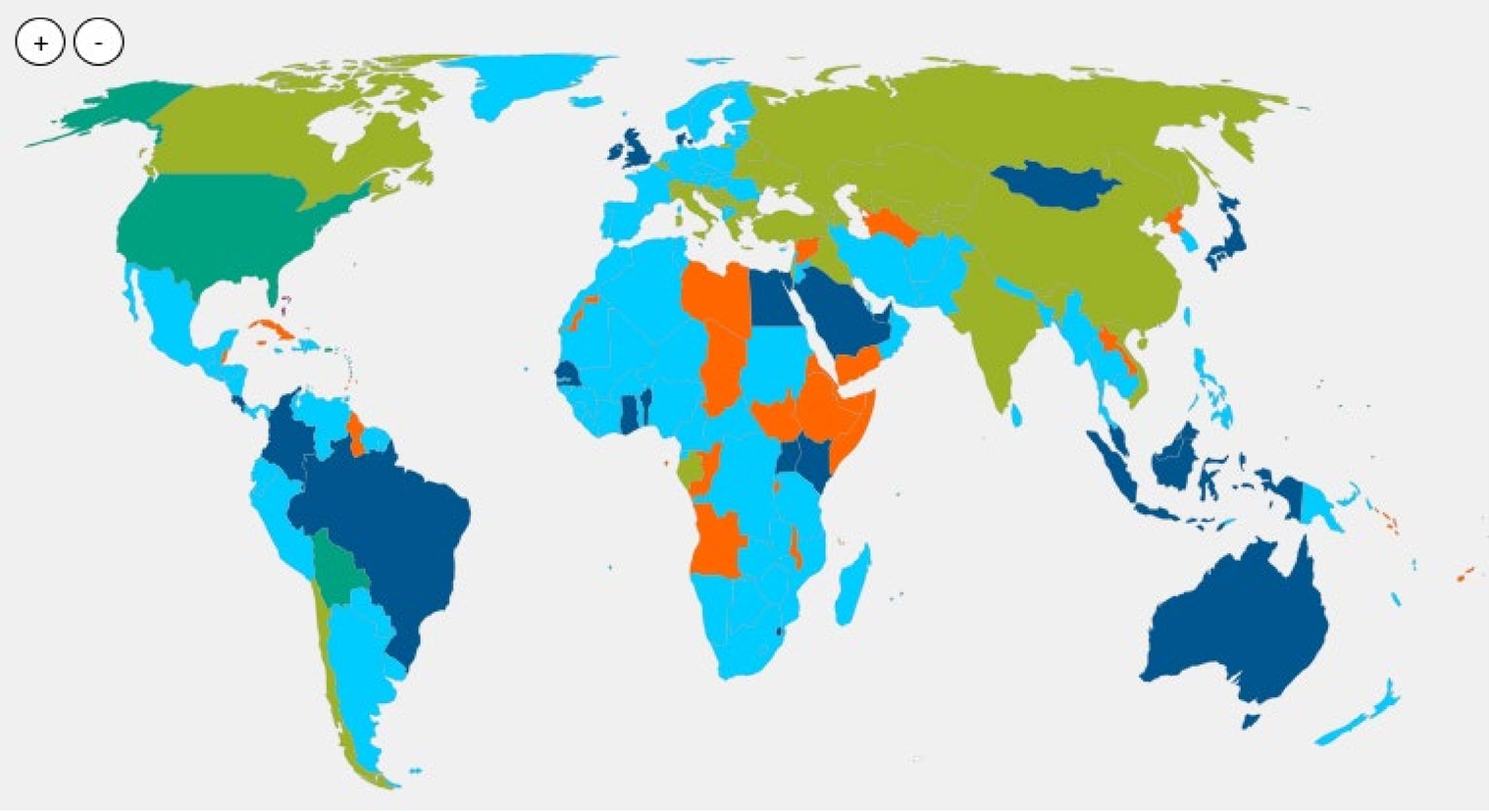
2022 Denmark, Egypt, Indonesia, Kenya

2023 Burkina Faso, Colombia, Eswatini, Ghana, Mauritania

2024 Brazil, Costa Rica

2025 Tanzania?

2026 Bahamas, Trinidad and Tobago? Europe?



https://www.gsma.com/solutions-and-impact/connectivity-for-good/public-policy/regulatory-environment/emf-and-health/emf-policy

ICNIRP 2020 equivalent

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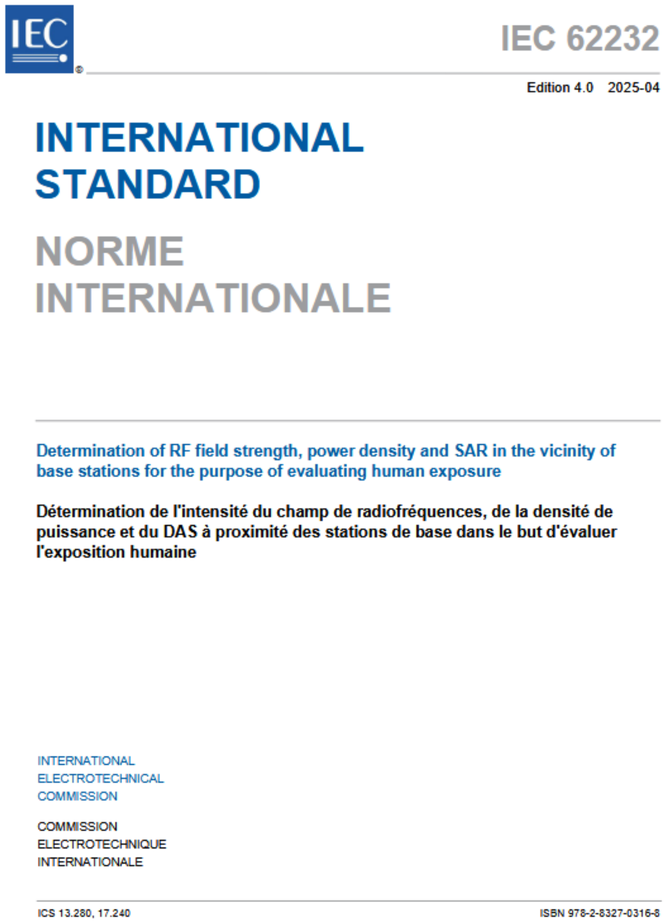
Necessity of actual maximum approach



IEC 62232

Edition 4.0 2025-04

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Determination of RF field strength, power density and SAR in the vicinity of base stations for the purpose of evaluating human exposure

Détermination de l'intensité du champ de radiofréquences, de la densité de puissance et du DAS à proximité des stations de base dans le but d'évaluer l'exposition humaine

INTERNATIONAL ELECTROTECHNICAL COMMISSION

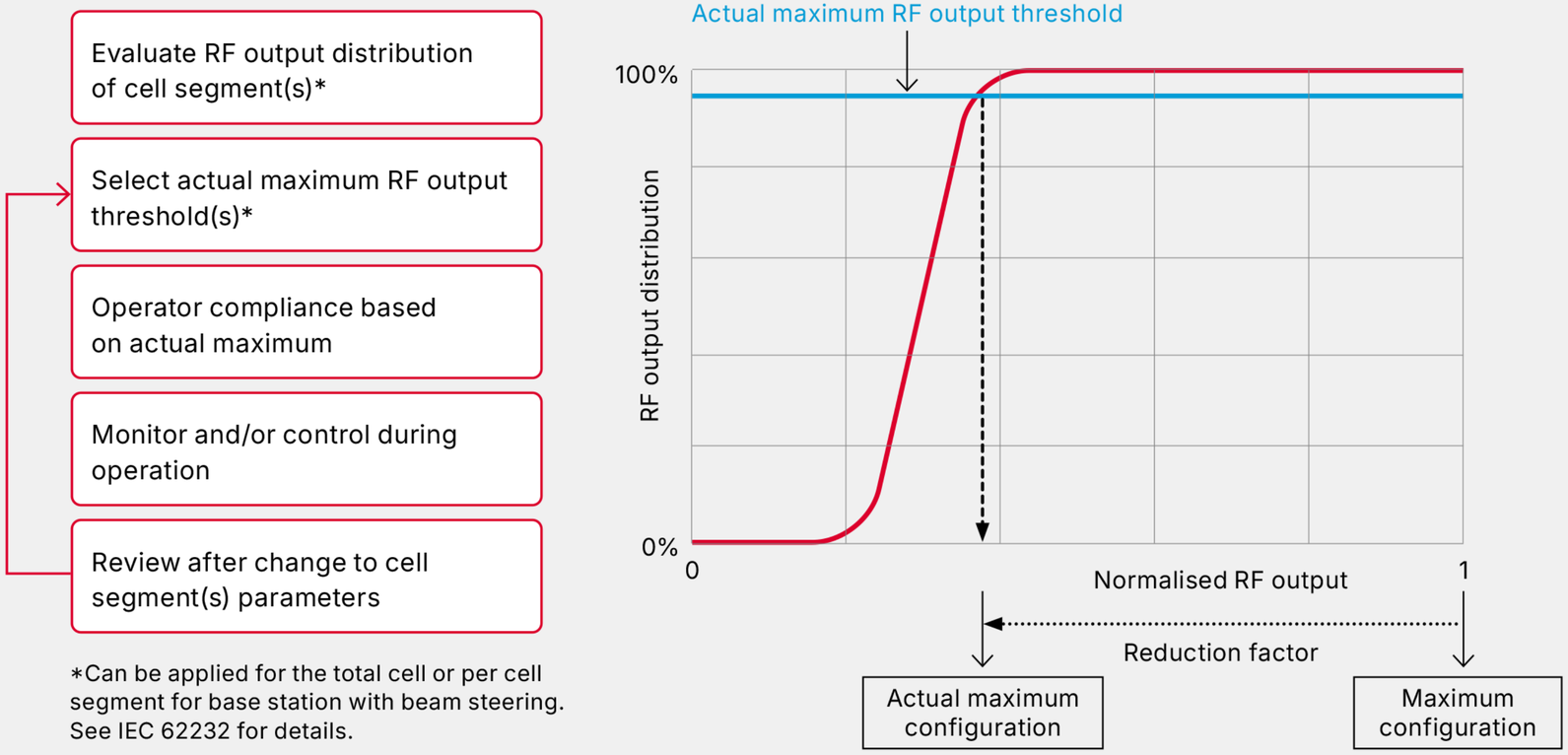
COMMISSION ELECTROTECHNIQUE INTERNATIONALE

ICS 13.280, 17.240

ISBN 978-2-8327-0316-8

Figure 12

Representation of the actual maximum approach



*Can be applied for the total cell or per cell segment for base station with beam steering. See IEC 62232 for details.

Application of IEC 62232/TR 62669

https://www.gsma.com/solutions-and-impact/connectivity-for-good/public-policy/gsma_events/the-gsma-13th-emf-forum-2024

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5G RF-EMF Surveys

Global results demonstrate low 5G levels

5G maximum EMF levels typically less than 1% of international public limit

37 countries, including

- Australia
- Austria
- Belgium
- China
- Colombia
- Croatia
- Denmark
- France
- Germany
- Greece
- Hungary
- Ireland
- Italy
- Japan
- Luxembourg
- Malaysia
- Malta
- Netherlands
- New Zealand
- Nigeria
- Norway
- Poland
- Portugal
- Romania
- Saudi Arabia
- South Korea
- Spain
- Sweden
- Switzerland
- Taiwan
- UK
- USA

Sources

18 Academia surveys

9 Operator surveys

34 Government & regulator surveys

Survey types

Measurements conducted on commercial and trial networks using normal and high data rate traffic

65 surveys

Low-band (<1 GHz)	Mid-band (1-8.4 GHz)	High-band (>8.4 GHz)
6	42	11
Indoor small cell	Smart apartment	Rooftop
3	1	2

5G EMF levels across all surveys **0.0000005% to 8.5%** of public limit

https://www.gsma.com/solutions-and-impact/connectivity-for-good/public-policy/regulatory-environment/emf-and-health/safety-of-5g-networks/5g-emf-surveys/

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Continuous RF-EMF risk assessment

Figure 14
Large body of research on EMF and health

Over

28,500

studies published since 1995 on electromagnetic fields and health with more than

5,300

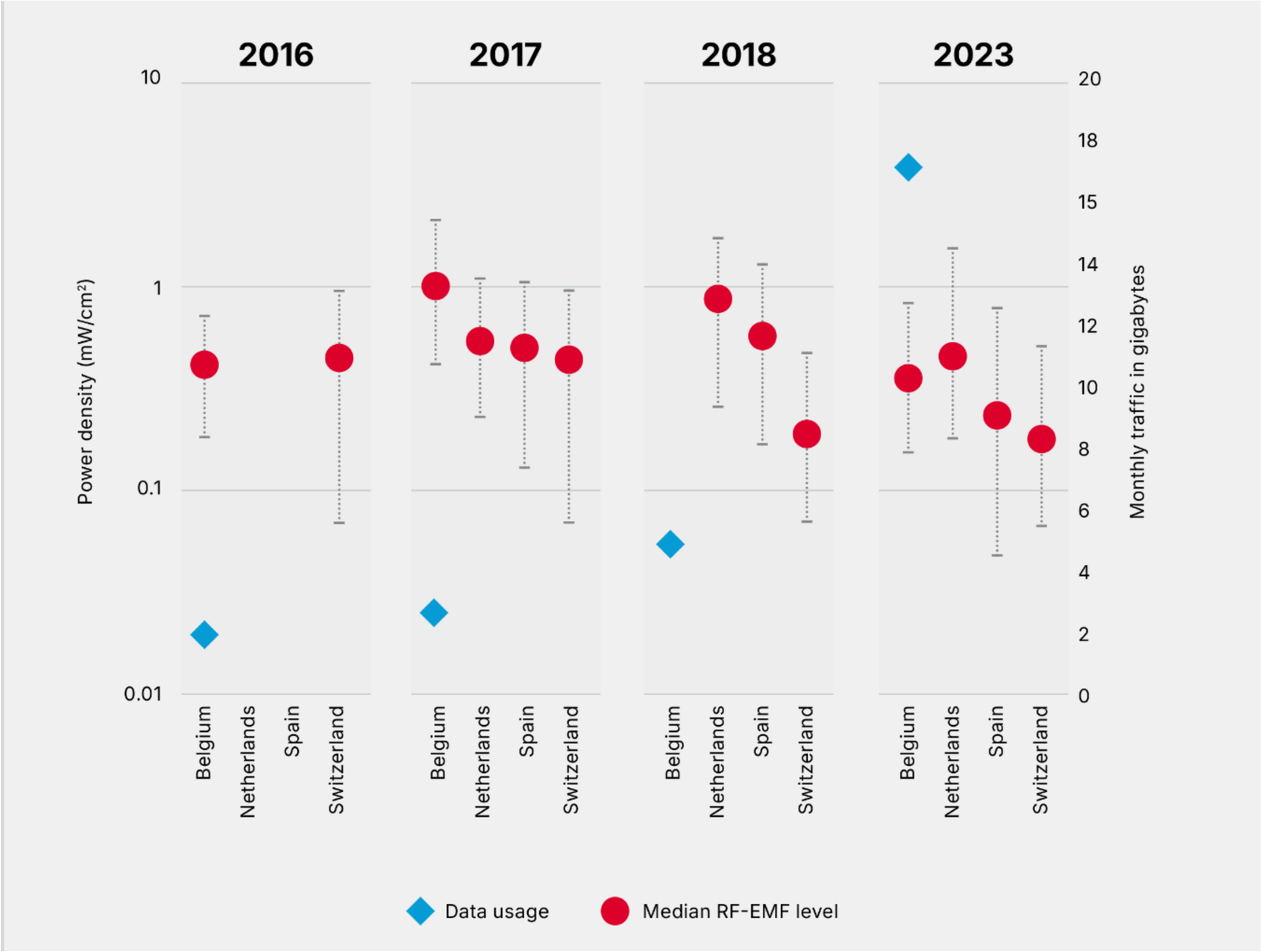
related to mobile communication

Data from EMF Portal, https://www.emf-portal.org/

WBF-Expertenforum 2024: Nach Prüfung der aktuellen Studienlage: Keine Gesundheitsgefährdung für den Menschen durch Mobilfunk

2025:04 Recent Research on electromagnetic fields and Health Risk, nineteenth report from SSM's Scientific Council on Electromagnetic Fields, 2024

BERENIS



Typical average radio wave levels largely unchanged

8-fold increase in data traffic per smartphone

Similar to previous mobile technology transitions

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Science is necessary but not sufficient

Science, Technology, & Human Values
OnlineFirst

https://doi.org/10.1177/01622439251333090

Sage Journals

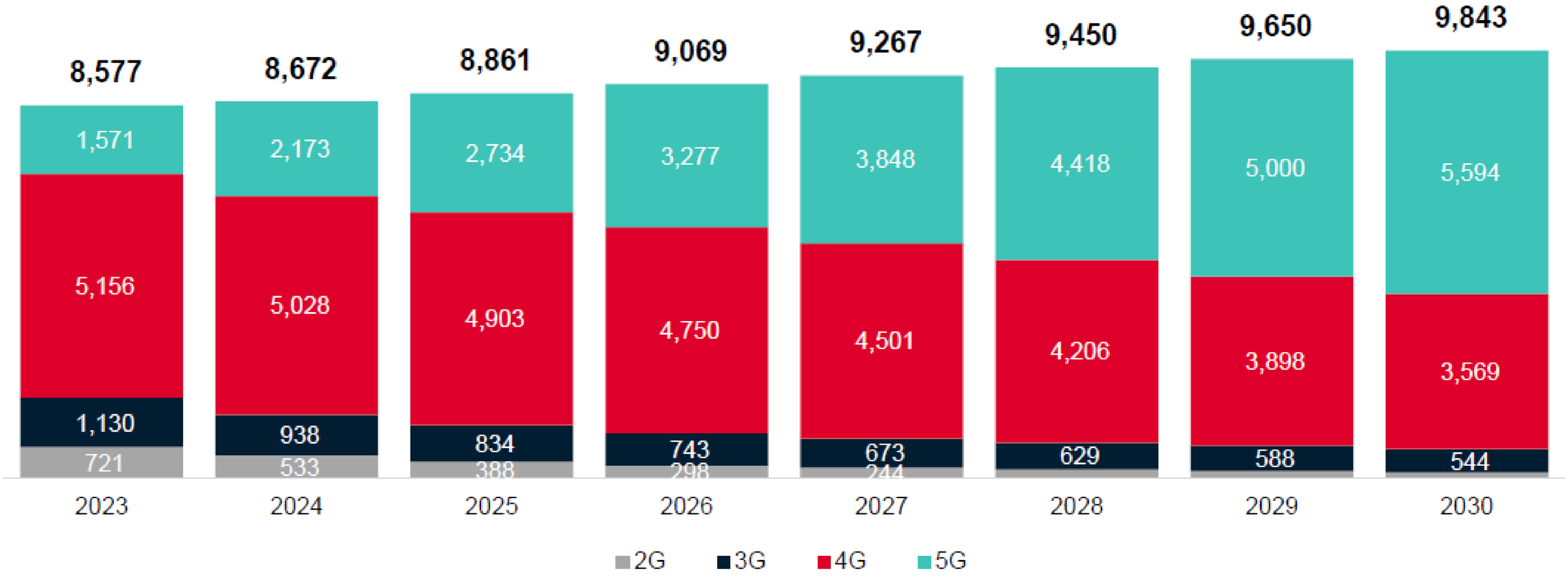
Original Article

"Bogeymen," "Murderers," and "Loonies": Emotions in Dutch Debates on 5G and Health

Floortje Moes [1], **Christian Bröer** [2], **and Klasien Horstman** [1]

'… to gain a voice in the public debate, citizens, and policymakers are expected to present scientific evidence. Yet accumulating scientific data and technical insights did not settle the debate. Instead, polarized views grew more vehemently apart.'

Total mobile connections by generation (million)
Global



Data as of July 2025
Source: GSMA Intelligence

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Mobile technology evolution: RF-EMF

Figure 6

Representation of the mix of mobile network cell types

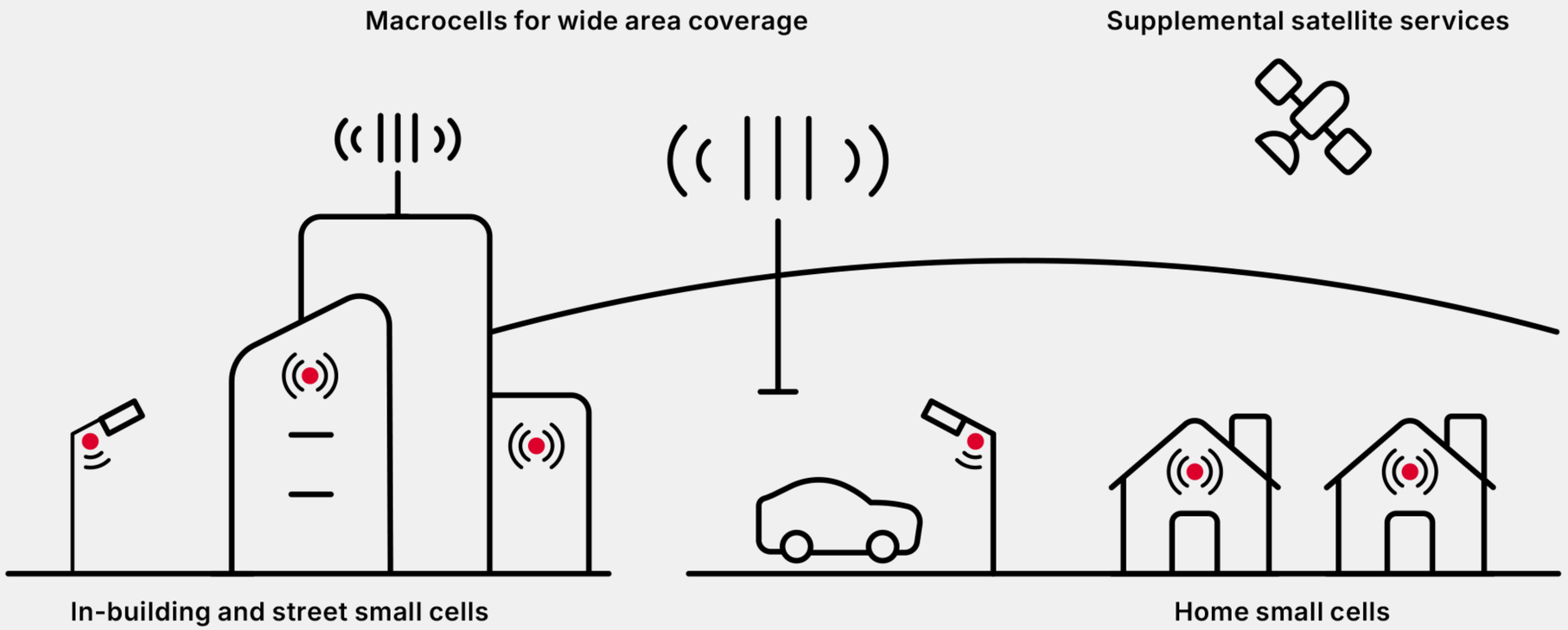


Figure 4

5G can be deployed in three key frequency ranges

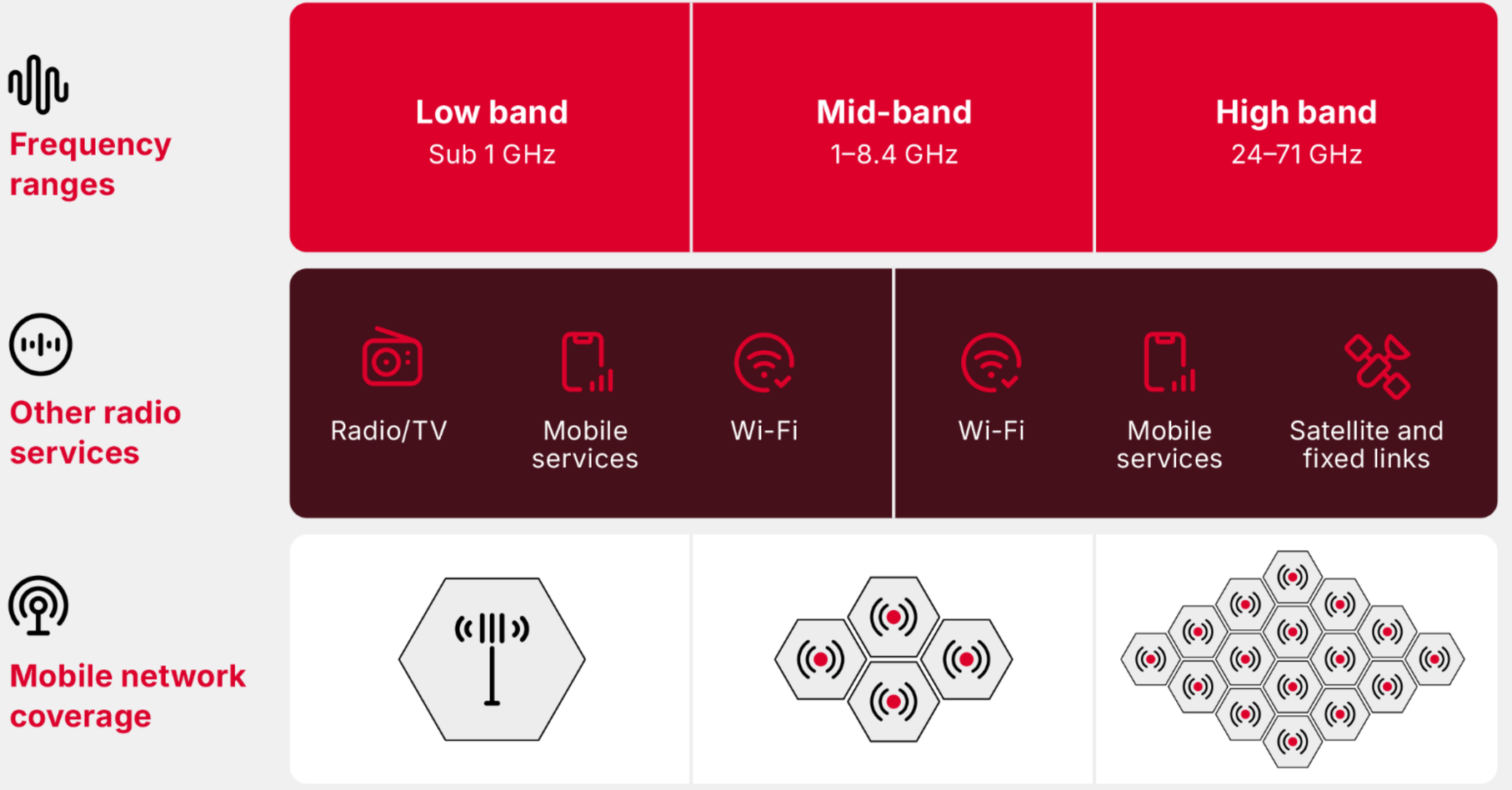


Figure 2

Mobile technology evolution

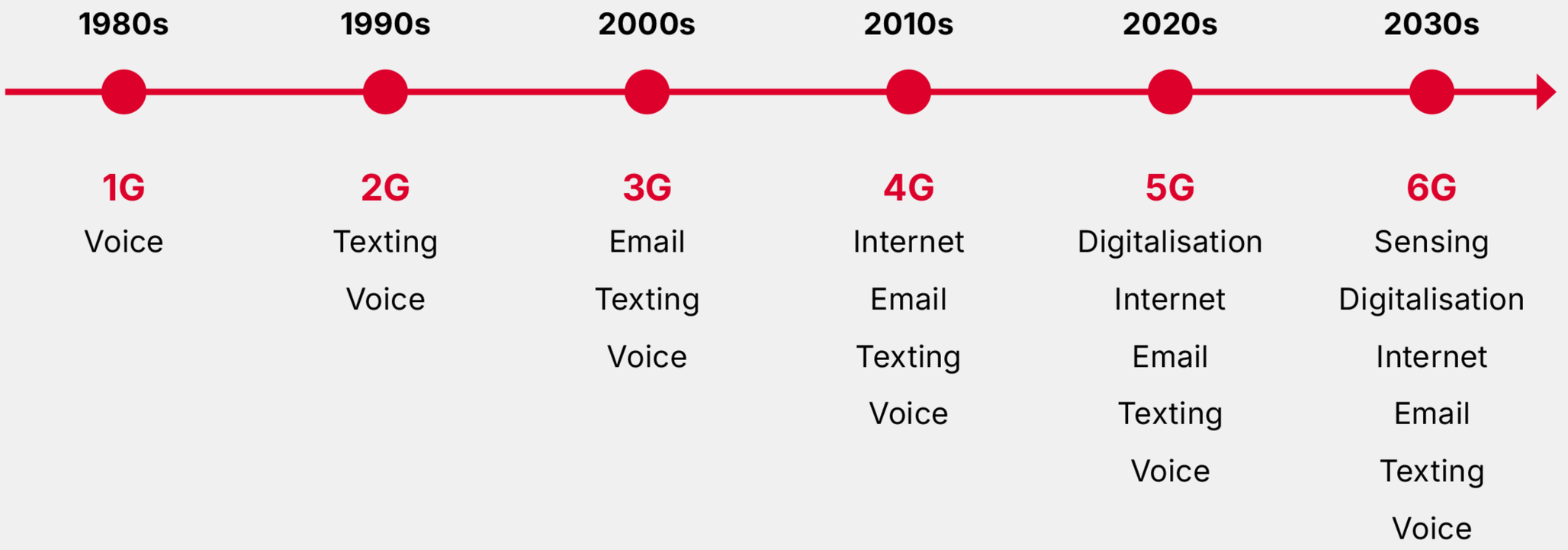
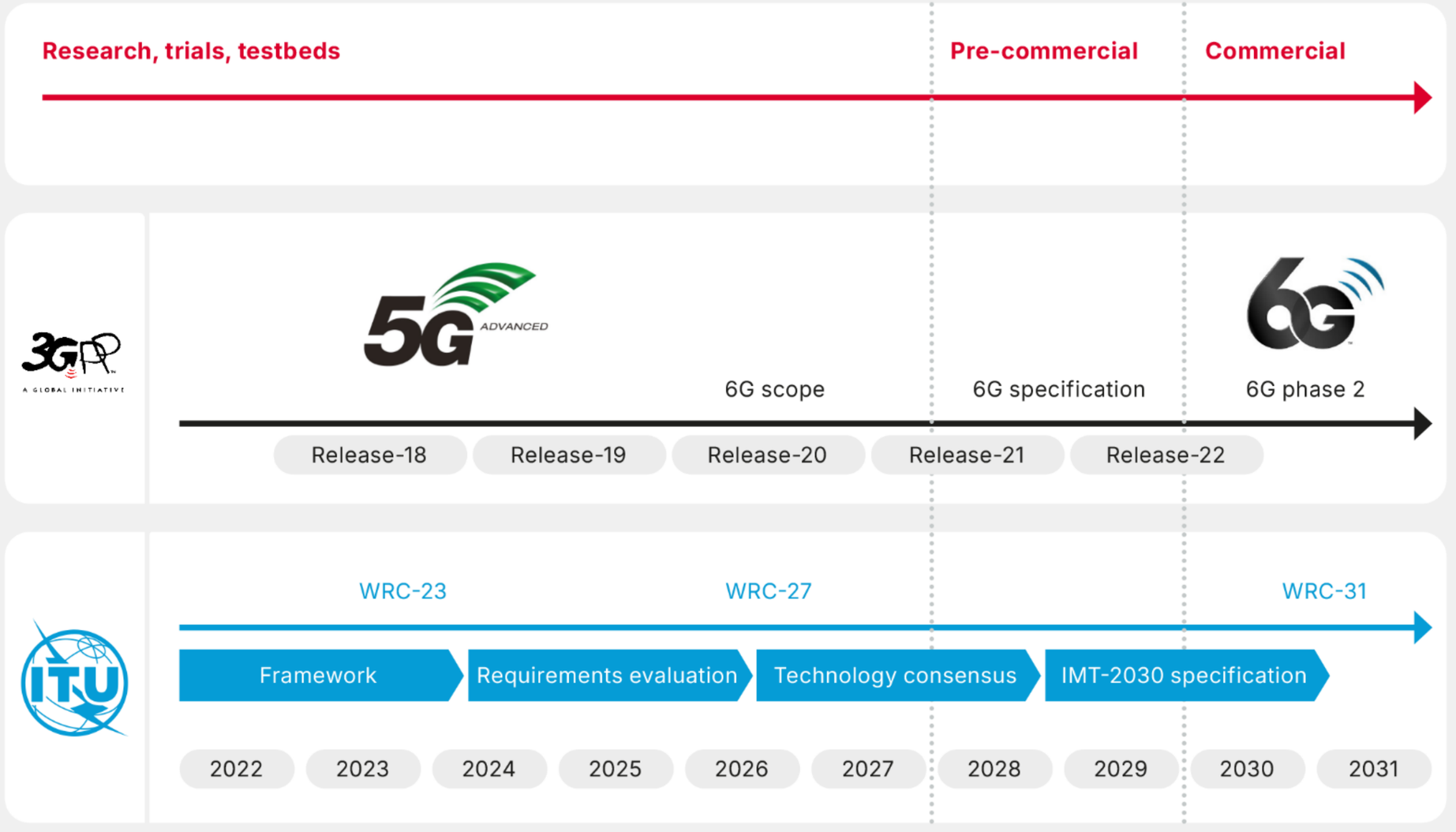


Figure 3

5G and beyond 6G timeline forecast



DI Manfred Ruttner
A1 Telekom Austria
GSMA EMF and Health
Deputy Chair

Introduction to session 1: WHO assessment of health effects of exposure to RF-EMF

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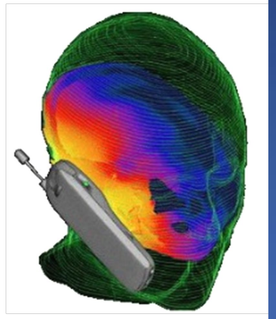
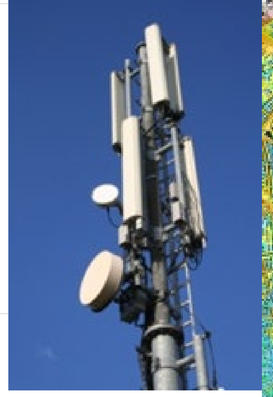
WHO commissioned systematic reviews of RF-EMF effects on cancer and symptoms: epidemiological and human experimental evidence

Professor Martin Röösli
Swiss Tropical and
Public Health Institute,
Switzerland


Swiss TPH

EMF Forum 2025, Brussels 30. 09. 2025

WHO commissioned systematic reviews of RF-EMF effects on cancer and symptoms: epidemiological and human experimental evidence

Martin Röösli on behalf of **Ken Karipidis,** Xavier Bosch-Capblanch, Dan Baaken, Tom Loney, Maria Blettner, Chris Brzozek, Mark Elwood, Clement Narh, Nicola Orsini, Marilia Silva Paulo, Susanna Lagorio, Stefan Dongus, Hamed Jalilian, John Eyers, Ekpereonne Esu, Chioma Moses Oringanje, Martin Meremikwu

Schedule

draft 1. update 2. update 3. update 4. update

RF-EMF monograph (Environmental Health Criteria)

2B cancer classification

Mission (almost) completed → Task group

2011 2013 2015 2017 2019 2021 2023 2025

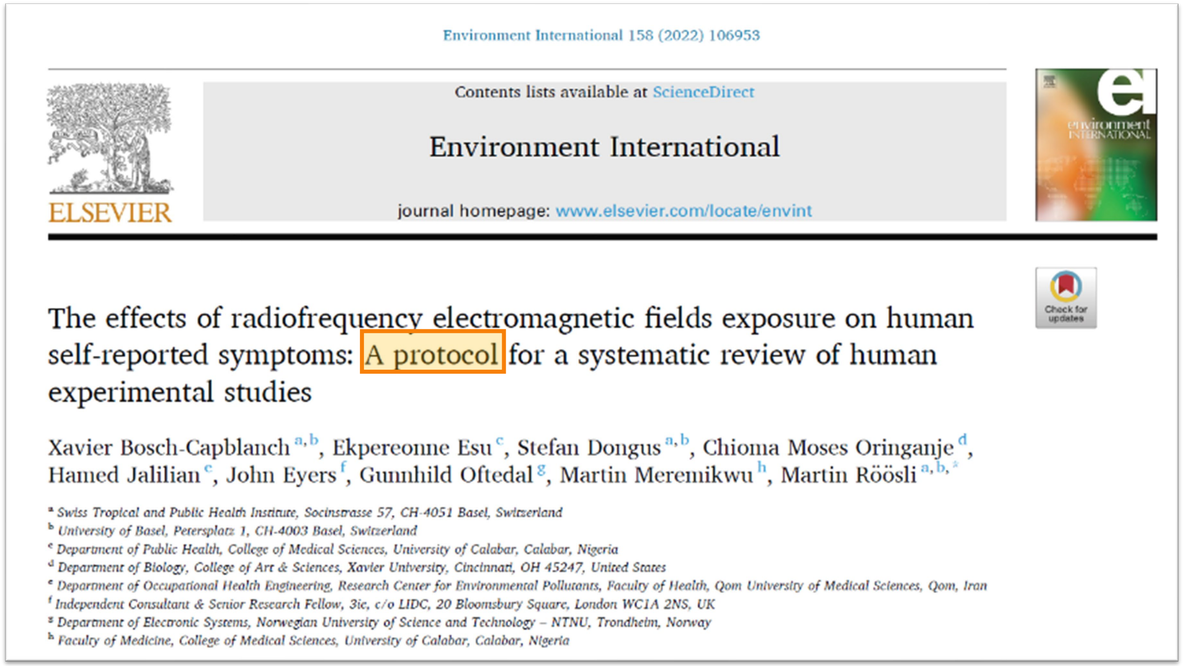
Priority setting

- WHO survey with all health endpoints reported in the literature
- 300 RF EMF experts and researchers asked to prioritize
- 164 (54%) responded

*IEI-EMF: Idiopathic environmental intolerance attributed to EMF

Verbeek, Env Int, 2021

SR8: Self-reported symptoms - human experimental studies



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Contents lists available at ScienceDirect

Environment International

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Xavier Bosch-Capblanch [a,b], Ekpereonne Esu [c], Stefan Dongus [a,b], Chioma Moses Oringanje [d], Hamed Jalilian [e], John Eyers [f], Gunnhild Oftedal [g], Martin Meremikwu [h], Martin Röösli [a,b,*]

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[b] University of Basel, Petersplatz 1, CH-4003 Basel, Switzerland
[c] Department of Public Health, College of Medical Sciences, University of Calabar, Calabar, Nigeria
[d] Department of Biology, College of Art & Sciences, Xavier University, Cincinnati, OH 45247, United States
[e] Department of Occupational Health Engineering, Research Center for Environmental Pollutants, Faculty of Health, Qom University of Medical Sciences, Qom, Iran
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[g] Department of Electronic Systems, Norwegian University of Science and Technology – NTNU, Trondheim, Norway
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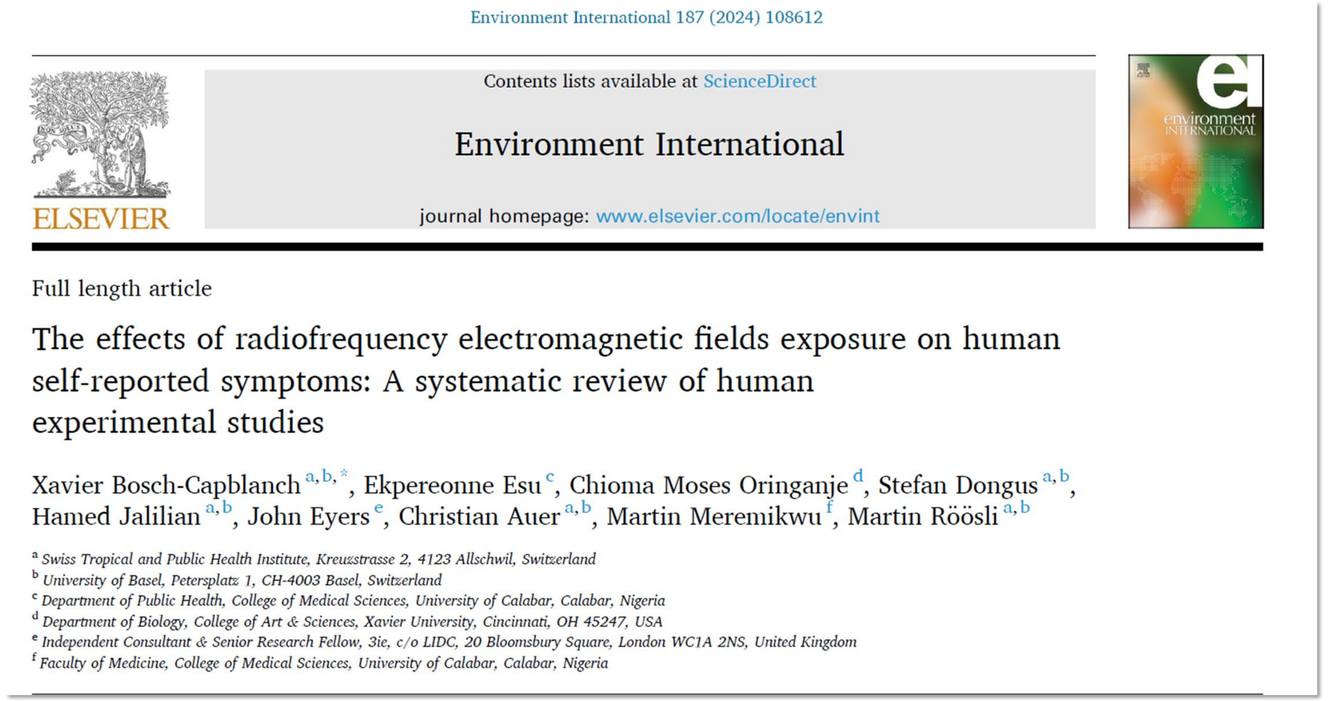

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Full length article

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Xavier Bosch-Capblanch [a,b,*], Ekpereonne Esu [c], Chioma Moses Oringanje [d], Stefan Dongus [a,b], Hamed Jalilian [a,b], John Eyers [e], Christian Auer [a,b], Martin Meremikwu [f], Martin Röösli [a,b]

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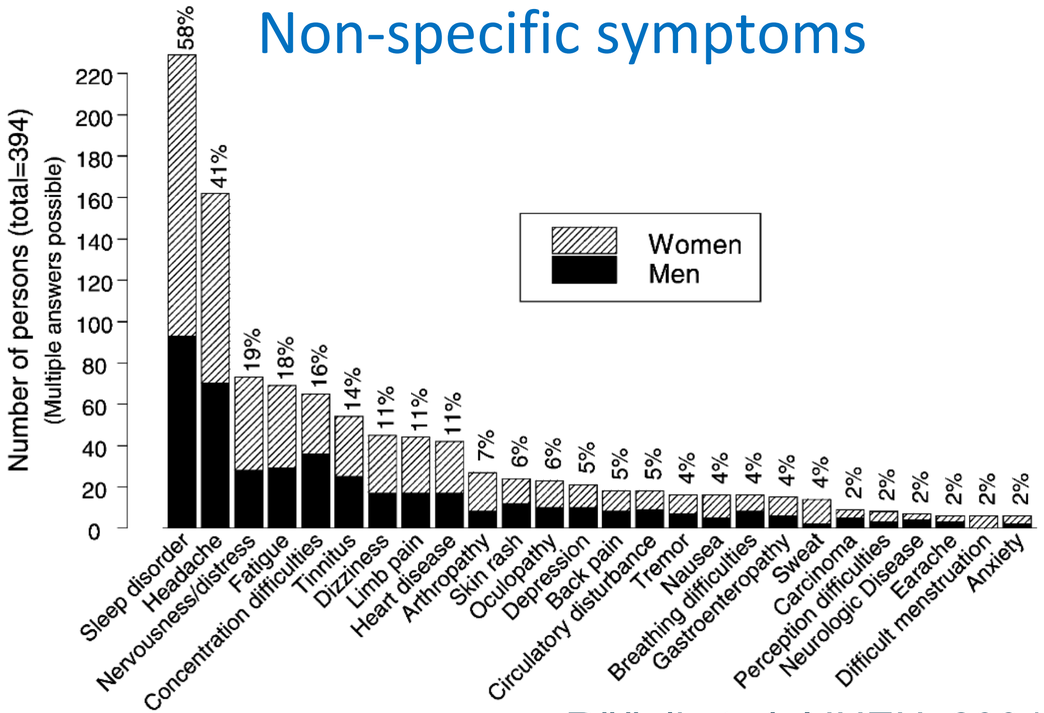
[b] University of Basel, Petersplatz 1, CH-4003 Basel, Switzerland
[c] Department of Public Health, College of Medical Sciences, University of Calabar, Calabar, Nigeria
[d] Department of Biology, College of Art & Sciences, Xavier University, Cincinnati, OH 45247, USA
[e] Independent Consultant & Senior Research Fellow, 3ie, c/o LIDC, 20 Bloomsbury Square, London WC1A 2NS, United Kingdom
[f] Faculty of Medicine, College of Medical Sciences, University of Calabar, Calabar, Nigeria

Special issue in Env. Int. With all protocol and result papers

Background: my first EMF study

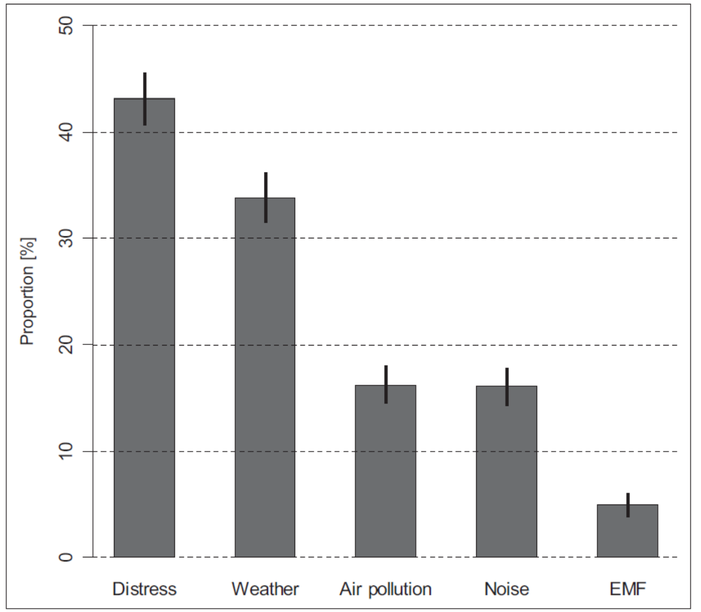
Survey of 394 Swiss individuals ascribing symptoms to EMF

Non-specific symptoms



Röösli et al, IJHEH, 2004

Attribution of health effects to…



Schreier et al. SPM, 2006

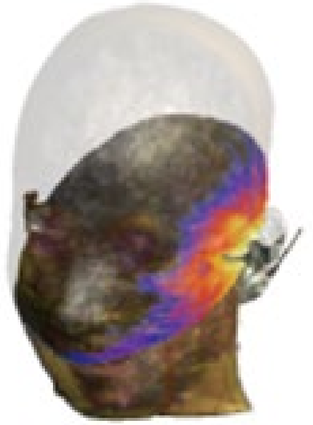
- No distinct symptoms related to a specific field source could be identified
- A substantial part of EHS individuals claimed to immediately perceive low level EMF when they are exposed (56%) and to develop symptoms within a few minutes (53%).

PECO

Population	Volunteers with IEI-EMF and without IEI-EMF
Exposure	RF-EMF, near and far field

Bosch-Capblanch et al. 2024, Environ Int

RF-EMF: Two types of exposure



close to body
(near field)

BAFU, 2019

Regel, 2006

environmental
(far field)

mobile phone
cordless phone

W-LAN

broadcast transmitter
mobile phone base station
mobile and cordless phones

Specific Absorption Rate
SAR (W/kg)

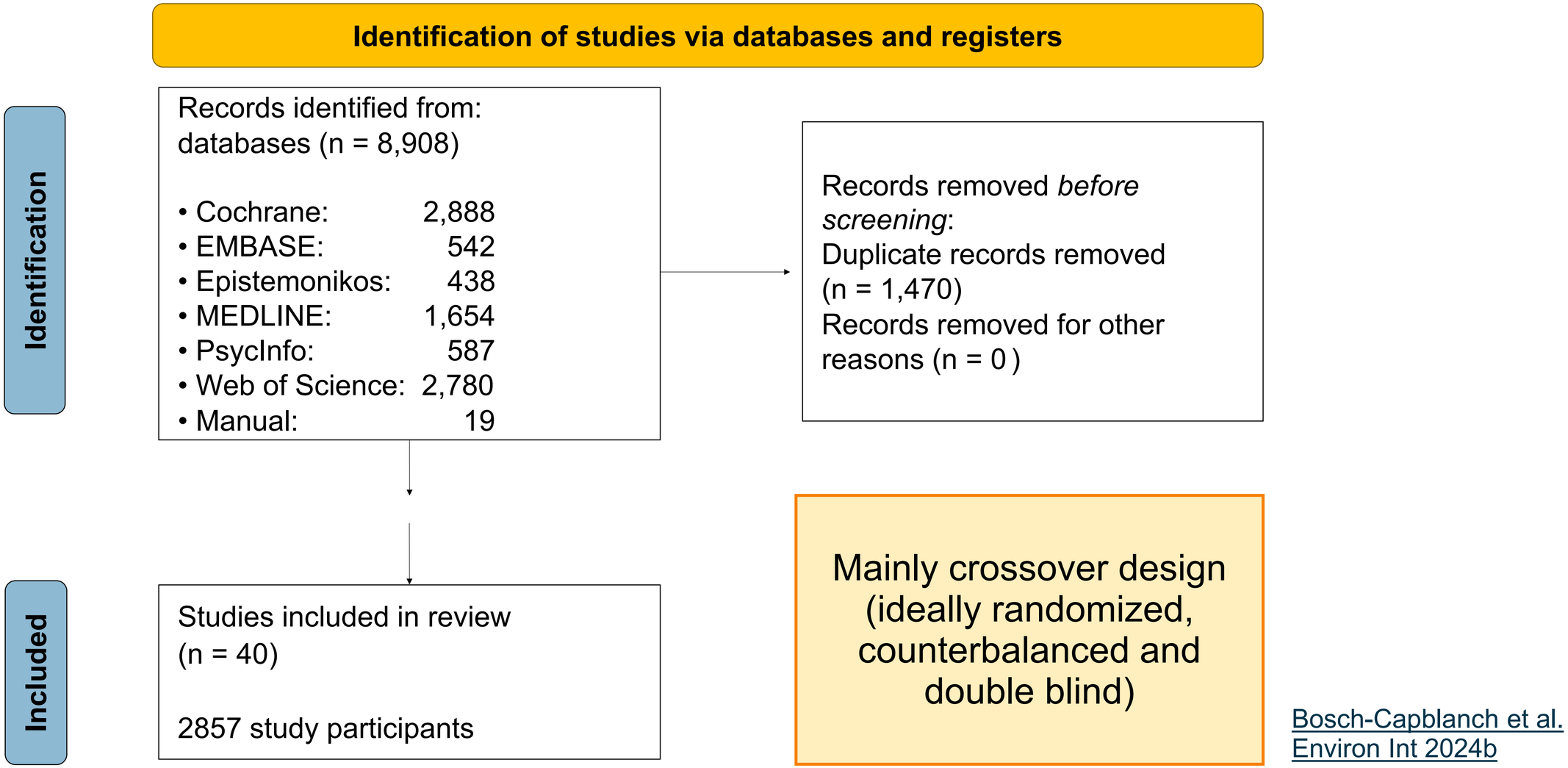
Electric Field (V/m)

PECO

Population	Volunteers with IEI-EMF and without IEI-EMF
Exposure	RF-EMF, near or far field
Comparator	at least one active and one control (sham) condition
Outcome	**Non-specific symptoms** • Headache • Sleep disturbances • Composite scores • … **Ability to perceive EMF**

Bosch-Capblanch et al. 2024, Environ Int

Literature search



Bosch-Capblanch et al. Environ Int 2024b

Risk of Bias (adapted from OHAT)

Example:

A - Randomisation of exposures	-	Information not available
B - Allocation concealment	-	Information not available
C - Blindness to exopsure condition	++	Blindness was described
D - Attrition	++	No drop out.
E - Characterisation of exposure	++	[0.405 W/kg] Signal generator | Sham
F - Outcomes assessments	--	Participants were asked but without any particular tool to collect or standard mechanisms to collect outcomes
G - Outcomes reporting	-	Ad hoc reporting in the manucript (further information obtained by email)
I - Funding source	See narrative	Exclusively public funded
J - Other biases	See narrative	No remark

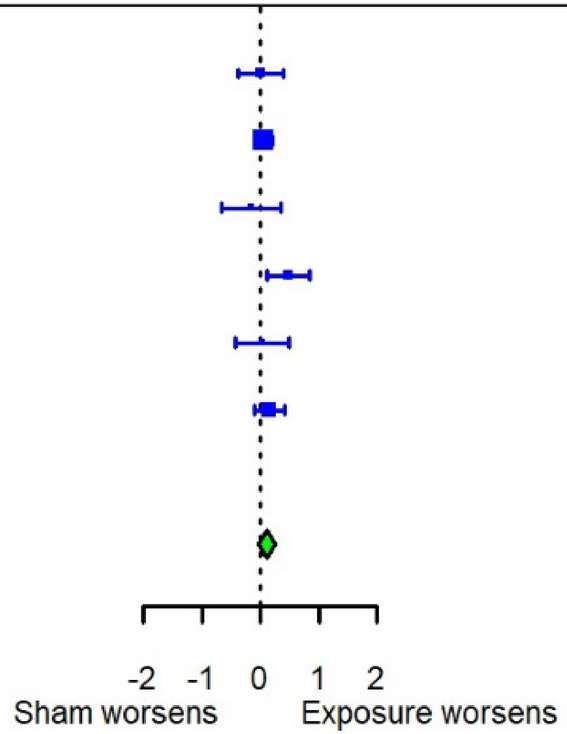
Meta-Analysis: Head exposure and headache in the general population

Headache in the general population - head exposure (r = 0.5) | Exposure = 0.5 to 1.6 W/kg

Study or Subgroup	Exposed Value	Exposed Events	Sham Value	Sham Events	Weight	SMD Effect size [95% CI]	Risk of Bias A	B	C	D	E	F	G
Choi-2014	1.30	26	1.30	26	11.0%	0.00 [-0.38, 0.38]	-	++	+	++	++	+	++
Cinel-2008	1.58	167	1.54	167	40.8%	0.05 [-0.10, 0.20]	+	+	++	++	-	-	++
Curcio-2009	39.27	15	43.18	15	6.6%	-0.17 [-0.68, 0.34]	++	+	+	--	++	+	++
Hillert-2008	0.45	33	0.26	31	12.2%	0.48 [0.12, 0.84]	+	+	+	++	++	+	++
Lowden-2019	1.53	18	1.45	18	7.9%	0.03 [-0.43, 0.49]	-	+	+	+	++	+	++
Nieto-Hernandez-2011	0.52	60	0.38	60	21.4%	0.15 [-0.10, 0.40]	-	+	+	++	++	+	++
Overall effect (95% CI)		**319**		**317**	**100.0%**	0.10 [-0.03, 0.24]							

Heterogeneity: $Tau^2 = 0.01$; $Chi^2 = 6.25$, df = 5 (P = 0.28); $I^2 = 20\%$

Test for overall effect: Z = 1.47 (P = 0.14)



Bosch-Capblanch et al. Environ Int 2024b

Certainty of evidence rating

Initial certainty

High Certainty

Experimental studies

Moderate Certainty

Observational studies

- Large magnitude of effect
- Dose-response relationship
- Residual confounding

Factors that determine the certainty of evidence

- Risk of bias
- Inconsistency
- Indirectness
- Imprecision
- Publication bias

Final certainty

High certainty

Moderate certainty

Low certainty

Very low certainty

Slide: Ken Karipidis

Human studies: overview of evidence

	Certainty assessment							Summary of findings			
	N of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Publication bias	Number of events Exposure	Number of events Comparison	SMD (95% CI)	Certainty
	General population										
1	**Outcome**	Headache - head exposure | Exposure = 0.5 to 1.6 W/kg									
	6	Trial	Some concerns	No concerns	No concerns	No concerns	No concerns	319	317	0.08 (-0.07 to 0.24)	**Moderate**
2	**Outcome**	Headache - whole body exposure | Exposure = 1.0 and 19.4 V/m									
	2	Trial	No concerns	No concerns	No concerns	No concerns	No concerns	132	132	0.09 (-0.35 to 0.54)	**High**
3	**Outcome**	Sleeping disturbances - head exposure | Exposure = 1.0 to 6.0 W/Kg									
	8	Trial	Some concerns	No concerns	No concerns	No concerns	No concerns	196	196	-0.01 (-0.22 to 0.20)	**Moderate**
4	**Outcome**	Sleeping disturbances - whole body exposure | Exposure = NA									
	1	Trial	Some concerns	Some concerns	No concerns	No concerns	No concerns	363	363	0.00 (-0.15 to 0.15)	**Low**
5	**Outcome**	Composite symptoms - head exposure | Exposure = 0.4 to 1.6 W/kg									
	3	Trial	Some concerns	Some concerns	Some concerns	No concerns	No concerns	54	56	0.13 (-0.51 to 0.76)	**Very low**
6	**Outcome**	Composite symptoms - whole body exposure | Exposure = 1.9 to 19.4 V/m									
	4	Trial	No concerns	No concerns	No concerns	No concerns	No concerns	572	572	-0.05 (-0.17 to 0.07)	**High**
	IEI-EMF individuals										
7	**Outcome**	Headache - head exposure | Exposure = 0.8 to 1.4 W/kg									
	3	Trial	Some concerns	No concerns	No concerns	No concerns	No concerns	161	163	-0.16 (-0.38 to 0.06)	**Moderate**
8	**Outcome**	Headache - whole body exposure | Exposure = 19.4 V/m (all)									
	1	Trial	No concerns	Some concerns	No concerns	No concerns	No concerns	58	58	0.11 (-0.29 to 0.52)	**Moderate**
9	**Outcome**	Composite symptoms - head exposure | Exposure = 0.8 W/kg (all)									
	2	Trial	Some concerns	Serious concerns	No concerns	No concerns	No concerns	84	85	0.05 (-0.58 to 0.68)	**Very low**
10	**Outcome**	Composite symptoms - whole body exposure | Exposure = 1.9 to 19.4 V/m									
	3	Trial	No concerns	No concerns	No concerns	No concerns	No concerns	139	139	-0.19 (-0.46 to 0.07)	**High**

Bosch-Capblanch Environ Int 2024b

EMF perception

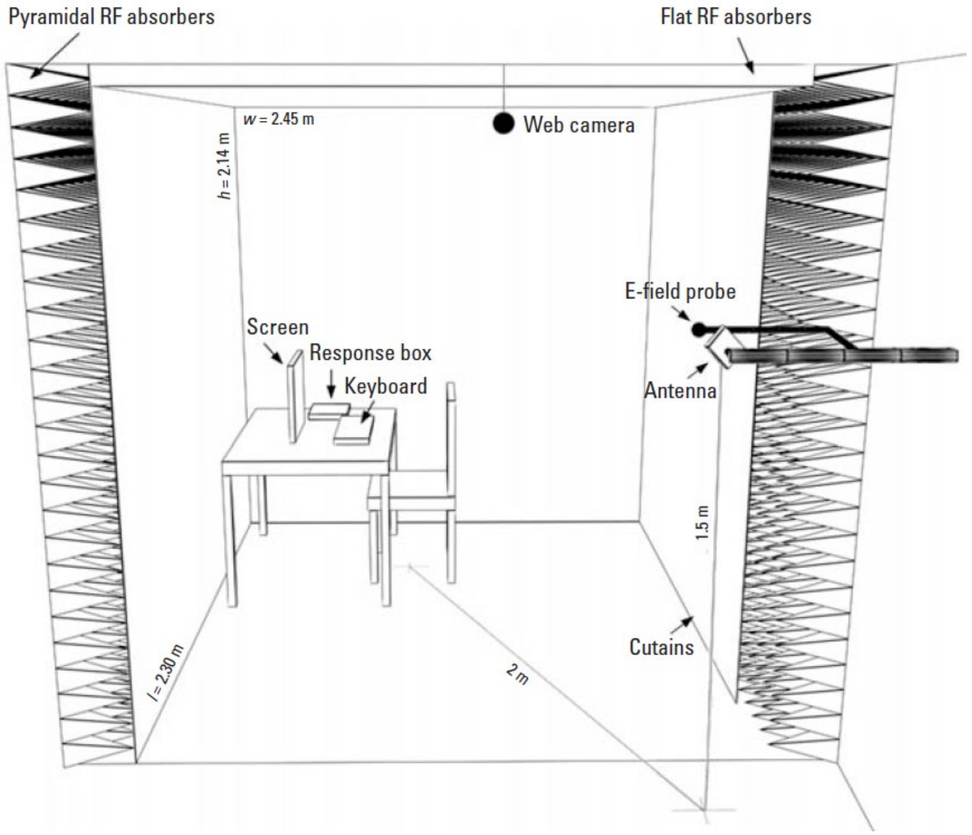
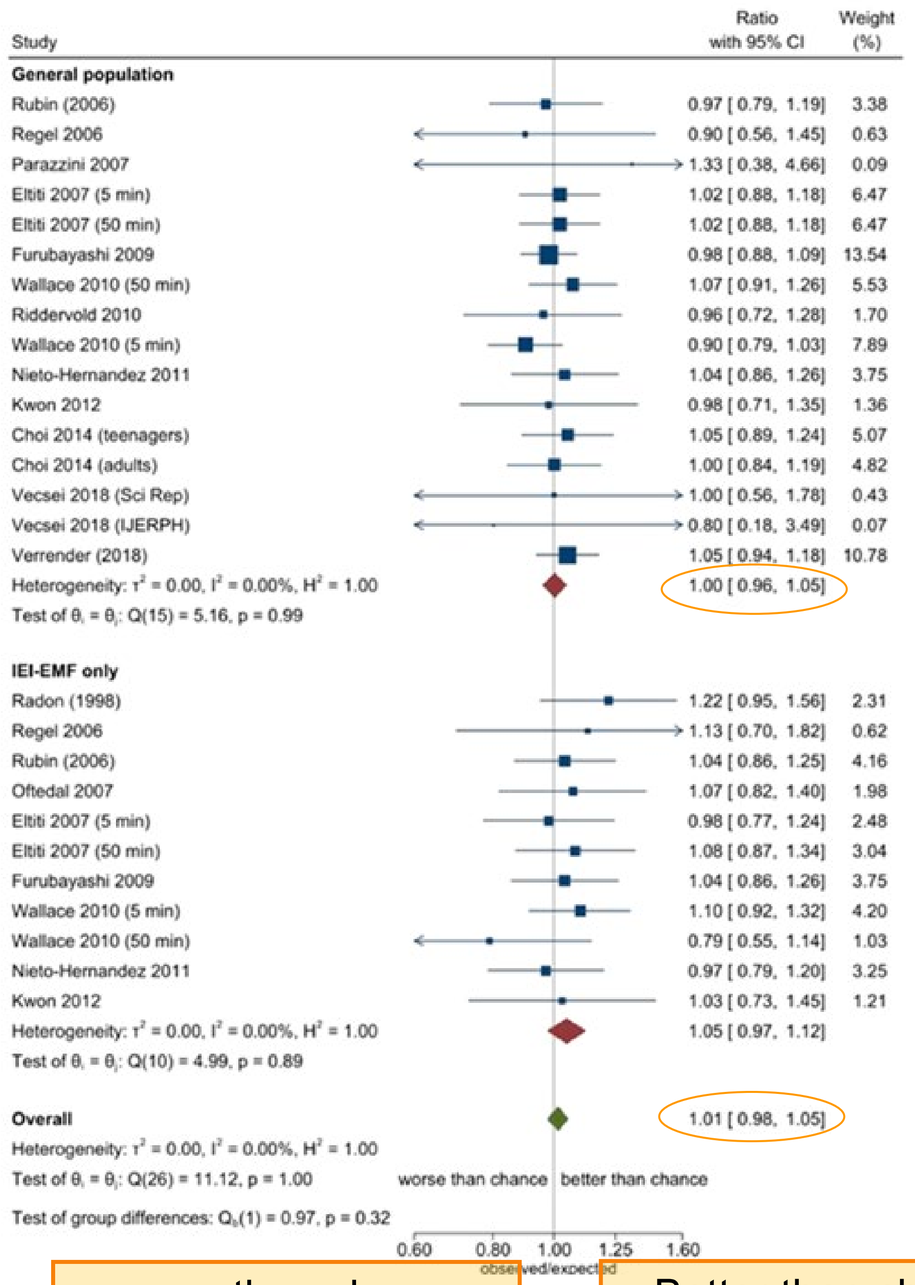


Figure from Regel et al, 2006



General population

IEI-EMF

Bosch-Capblanch et al. 2024, Environ Int

worse than chance

Better than chance

Conclusion SR 8

- 40 studies with a total of 2,857 participants.
- No or small non-significant effects of exposure on symptoms with
  - high (three comparisons),
  - moderate (four comparisons),
  - low (one comparison) and very low (two comparisons) certainty of evidence.
- No indications that volunteers or IEI-EMF individuals could perceive exposure.
- Limitations of evidence:
  - experimental conditions are substantially different from real-life situations in the duration, frequency, distance and position of the exposure.
  - Most studies were conducted in young, healthy volunteers, who might be more resilient to RF-EMF than the general population.
- Interpretation: available evidence suggests that acute RF-EMF below regulatory limits does not cause symptoms and corresponding claims in the everyday life are related to perceived and not to real EMF exposure status.

SR7: Self-reported symptoms - human observational studies

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[c] Department of Occupational Health Engineering, Research Center for Environmental Pollutants, Faculty of Health, Qom University of Medical Sciences, Qom, Iran
[d] Unit of Epidemiology, Institute of Environmental Medicine, Karolinska Institutet, Stockholm, Sweden
[e] International Initiative for Impact Evaluation, 3ie, c/o LIDC, 20 Bloomsbury Square, London WC1A 2NS, United Kingdom
[f] Department of Public Health, College of Medical Sciences, University of Calabar, Calabar, Nigeria
[g] Department of Biology, College of Art & Sciences, Xavier University, Cincinnati, OH, USA
[h] Faculty of Medicine, College of Medical Sciences, University of Calabar, Calabar, Nigeria

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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

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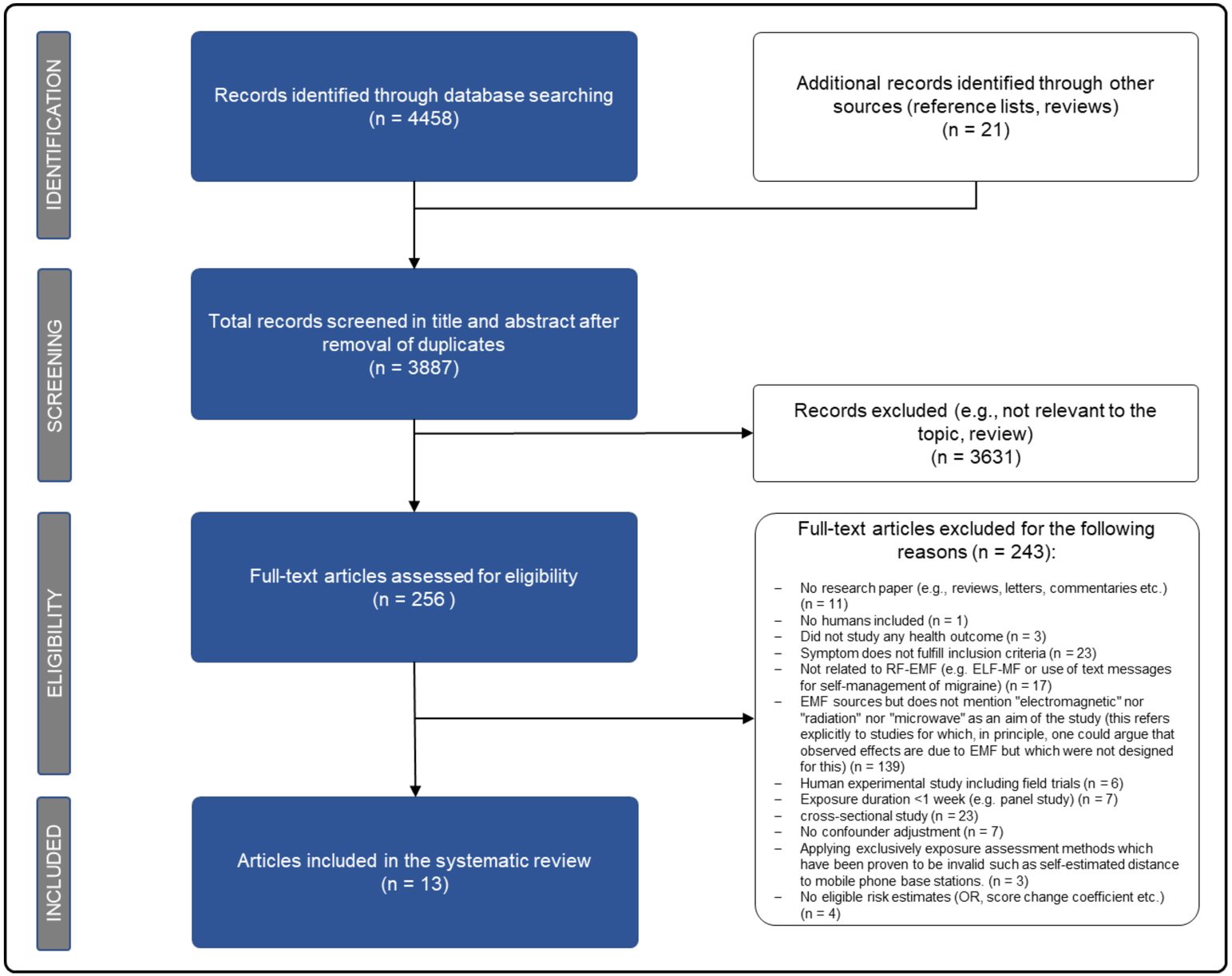
Special issue in Env. Int. With all protocol and result papers

PECO

Population	General population or workers
Exposure	Continuous or repeated local and whole human body RF-EMF exposure of one week or longer
Comparator	per-unit increase
Outcome	**tinnitus, migraine and nonspecific symptoms** 5 primary hypotheses: 1. Tinnitus 2. Migraine 3. Headaches } brain exposure  4. Sleep disturbances 5. Composite symptom scores } whole body exposure 

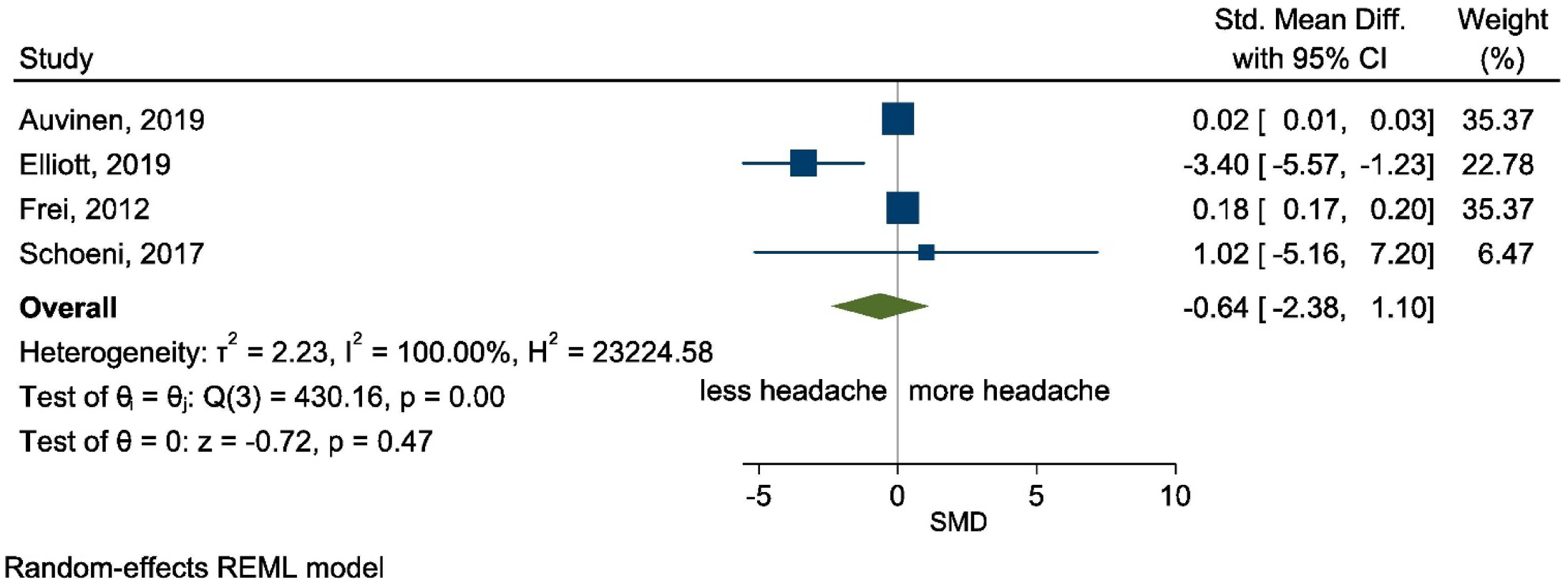
Röösli et al. 2024, Environ Int

Literature search



Röösli et al. 2024, Environ Int

Headache in relation to exposure sources close to the brain



SMD per 100 min wireless phone usage per week.
SMD: standardized mean difference

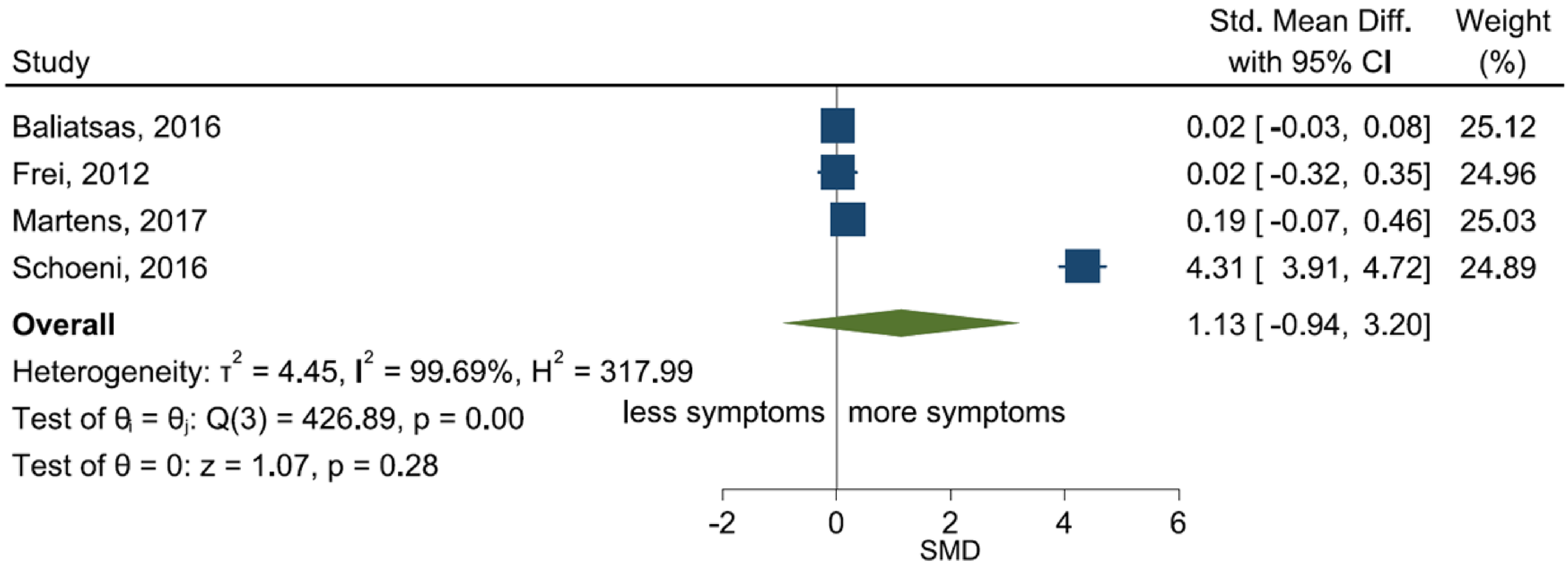
Röösli, Env Int, 2024

Risk of Bias (adapted from OHAT)

Example:

Selection/participation bias	+ +	Nationwide study
Confounding	–	No adjustment for socioeconomic status and a measure of distress
Attrition/exclusion bias	+	Linkage with national data bases: no indication for attrition
Exposure assessment errors	–	Only mobile phone subscription status available. Exposure misclassification from non-private subscriptions
Outcome assessment errors	+ +	Use of hospital discharge register
Selective reporting	+	No indication for selective reporting
Appropriate statistical methods	+	Use of standard analysis methods
Reverse causality	–	No information whether patients have suffered from disease before exposure period. Disease may thus have affected the decision to get a mobile phone subscription

Composite symptom scores in relation to whole-body RF-EMF exposure



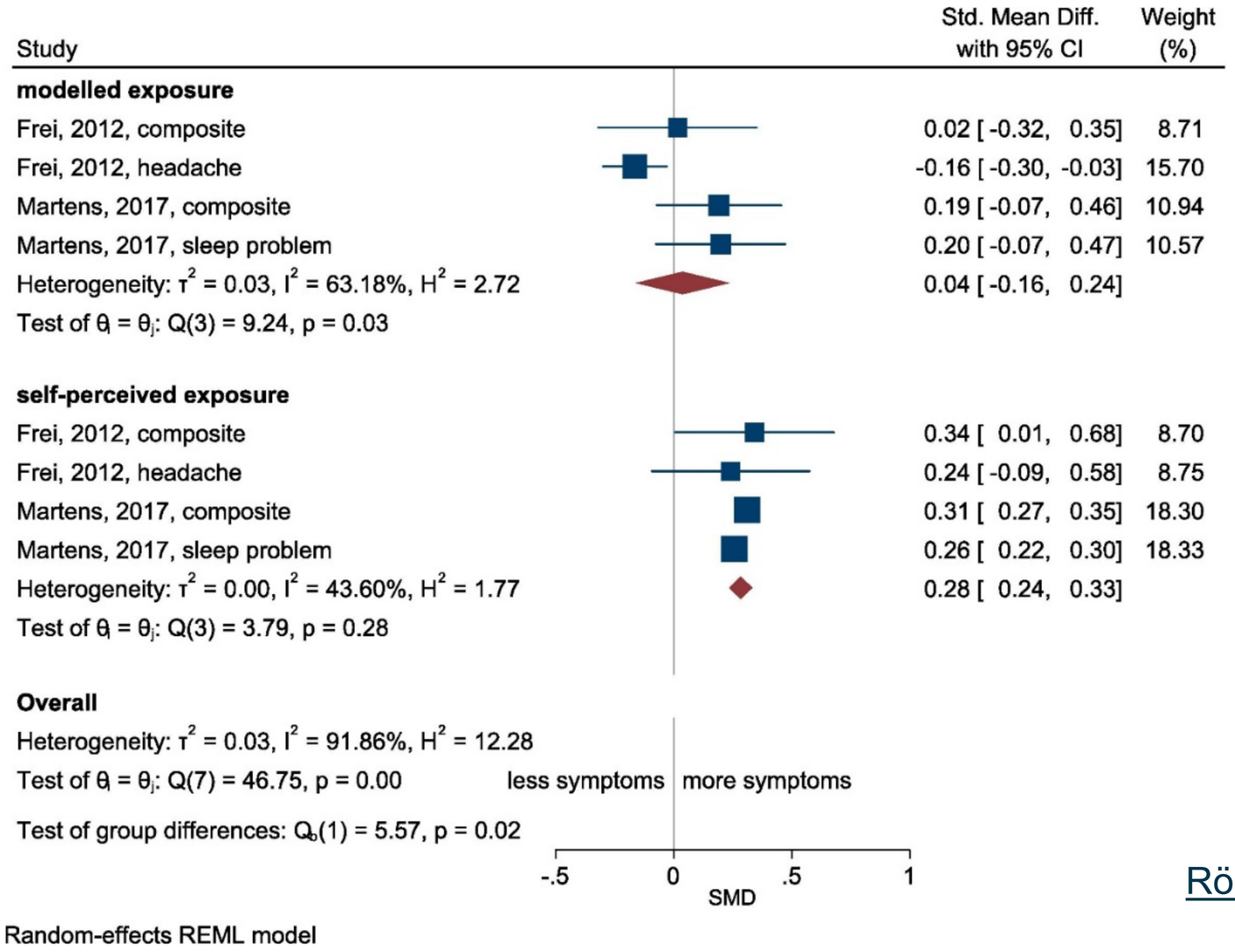
SMD per 1 V/m
SMD: standardized mean difference

Röösli, Env Int, 2024

Modelled vs. perceived exposure

modelled

Self-perceived



Röösli, Env Int, 2024

Evidence rating for no association

Outcome	Type of exposure	Start rating	Factors decreasing confidence					Factors increasing confidence			Overall certainty of evidence
			Risk of bias	Inconsistency	Indirectness	Imprecision	Publication bias	Strength of association	Exposure-response gradient	Residual confounding	
Tinnitus	Brain	3	-2	-1	-1	-1	0	0	0	0	**<0 (very low)**
Migraine	Brain	3	-2	-1	-1	0	0	0	0	0	**<0 (very low)**
Headache	Brain	3	0	-1	-1	-1	0	0	0	0	**0 (very low)**
Sleep disturbances	Whole-body	3	-1	-1	0	-1	0	0	0	0	**0 (very low)**
Composite symptoms	Whole-body	3	-1	-1	0	-1	0	0	0	0	**0 (very low)**

Röösli, Env Int, 2024

Conclusion SR 7

- 8 cohort and 1 case-control studies with 486,558 participants (13 papers).
- Available research suggest that RF-EMF exposure below guideline values does not cause symptoms, but the evidence is very uncertain.
- No indications that volunteers or IEI-EMF individuals could perceive exposure.
- Limitations of evidence:
  - Long term exposure assessment is challenging.
  - Near field (mobile phone) use is related to lifestyle (-> confounding, reverse causality).
- Interpretation: no indication that RF-EMF below guideline values causes symptoms. However, inherent limitations of the research results in substantial uncertainty.

SR1: Cancer - human observational studies

Environment International 157 (2021) 106828

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Environment International

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The effect of exposure to radiofrequency fields on cancer risk in the general and working population: A protocol for a systematic review of human observational studies

Susanna Lagorio [a,*], Maria Blettner [b], Dan Baaken [b], Maria Feychting [c], Ken Karipidis [d], Tom Loney [e], Nicola Orsini [f], Martin Röösli [g], Marilia Silva Paulo [h], Mark Elwood [i]

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[i] University of Auckland, New Zealand

Special issue in Env. Int. with all protocol and result papers

Environment International 191 (2024) 108983

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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

Ken Karipidis [a,*], Dan Baaken [b,d], Tom Loney [c], Maria Blettner [d], Chris Brzozek [a], Mark Elwood [e], Clement Narh [f], Nicola Orsini [g], Martin Röösli [h,i], Marilia Silva Paulo [j], Susanna Lagorio [k]

Environment International 196 (2025) 109274

Contents lists available at ScienceDirect

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journal homepage: www.elsevier.com/locate/envint

Full length article

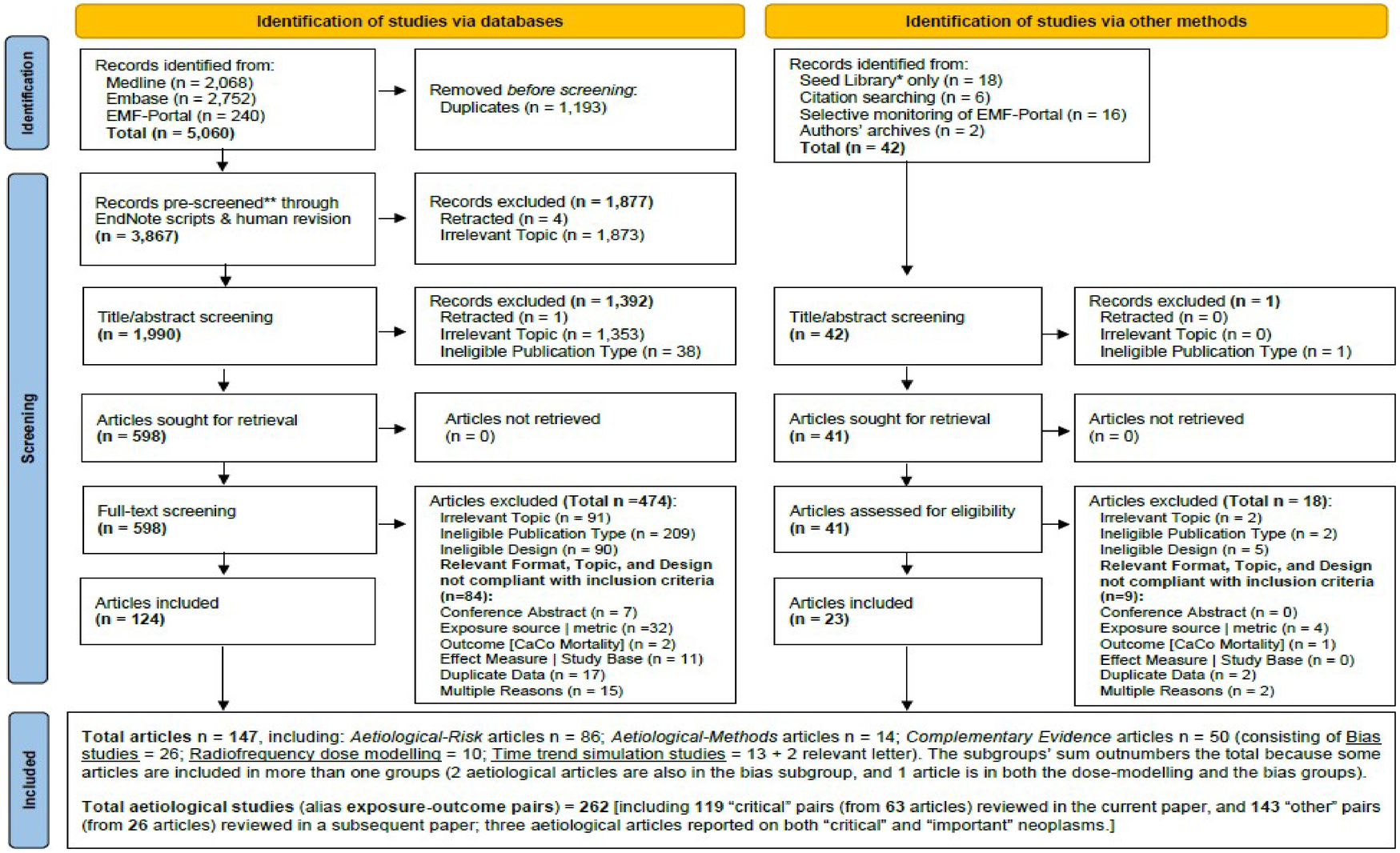
The effect of exposure to radiofrequency fields on cancer risk in the general and working population: A systematic review of human observational studies – Part II: Less researched outcomes

Ken Karipidis [a,*], Dan Baaken [b,d,1], Tom Loney [c], Maria Blettner [d,1], Rohan Mate [a], Chris Brzozek [a], Mark Elwood [e], Clement Narh [f], Nicola Orsini [g], Martin Röösli [h], Marilia Silva Paulo [i], Susanna Lagorio [j,2]

PECO	SR-A	SR-B	SR-C
Population	General population		Workers
Exposure	Near field (phone)	Far field (transmitters)	Near & far field
Comparator	Never/non-regular use	No or low-level exposure	
Outcome	**Critical:** Glioma/brain cancer in adults; paediatric brain tumours; meningioma; acoustic neuroma; pituitary gland tumours; salivary gland tumours **Important:** Any other neoplasm	**Critical:** Childhood leukaemia, paediatric brain tumours, glioma/ brain cancer in adults, and leukaemia in adults **Important:** Any other neoplasm	**Critical:** Glioma/brain cancer, leukaemia **Important:** Any other neoplasm

Lagoria et al. 2021, Environ Int

Literature search



Karipidis et al. 2024, Environ Int

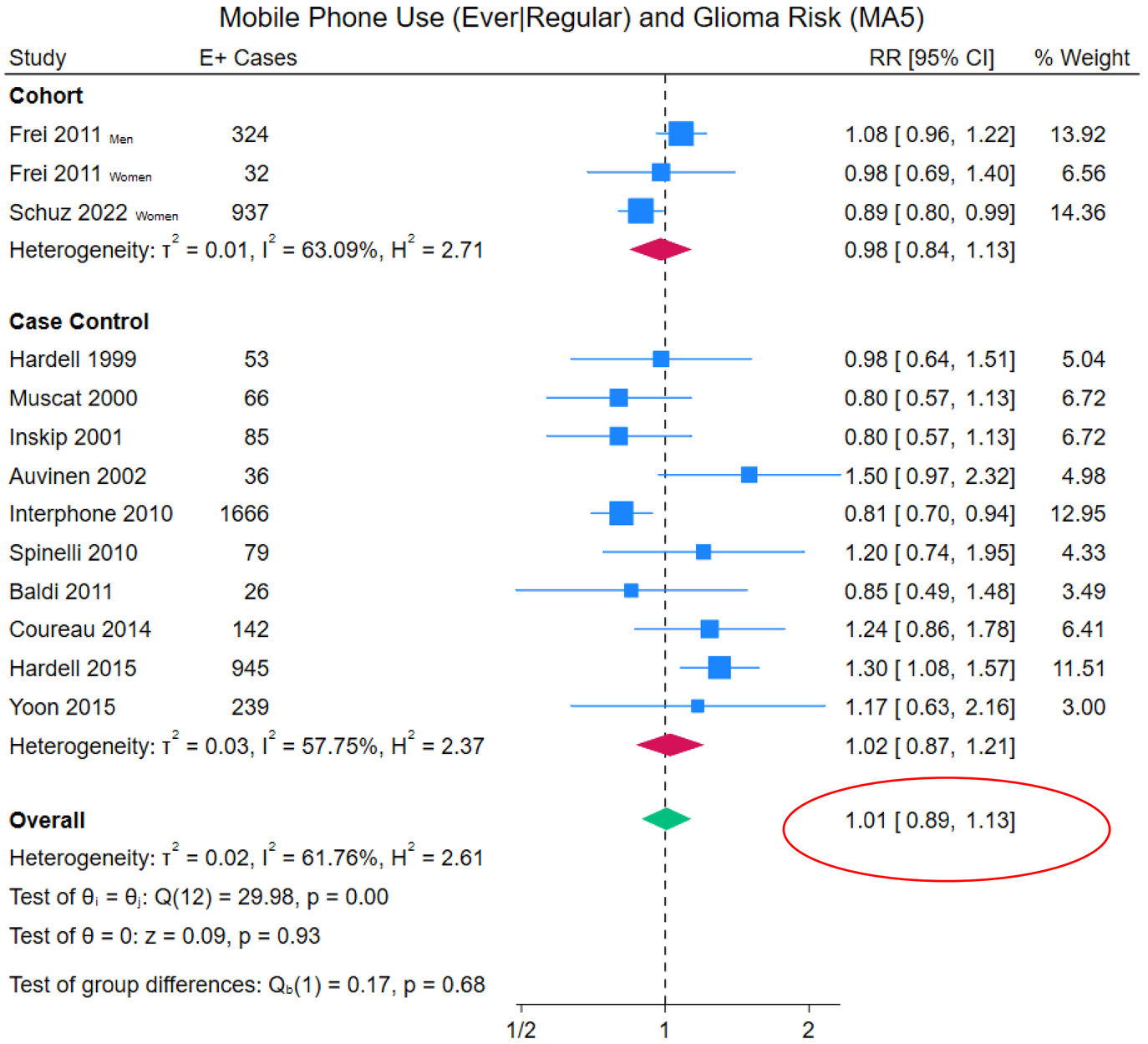
Risk of bias (adapted from OHAT)

Table 7
Heat map illustrating the risk of bias assessment results.

SR-A Mobile phones	Selection	Attrition	Exposure	Outcome	Confounding	Selective reporting	Statistical methods	Summary bias tier
Paediatric Brain Tumours								
Aydin et al. 2011b	(+)	(++)	(+)	(++)	(+)	(++)	(++)	1
Feltbower et al. 2014	(+)	(NR)	(+)	(++)	(+)	(++)	(++)	2
Castano-Vinyals et al. 2022	(+)	(++)	(+)	(++)	(+)	(++)	(++)	1
Glioma								
Hardell et al. 1999	(NR)	(--)	(NR)	(++)	(NR)	(++)	(++)	2
Muscat et al. 2000	(+)	(+)	(NR)	(++)	(+)	(+)	(++)	1
Inskip et al. 2001	(+)	(+)	(+)	(++)	(+)	(++)	(++)	1
Auvinen et al. 2002	(+)	(++)	(+)	(++)	(+)	(++)	(++)	1
Hardell et al. 2002b	(NR)	(--)	(--)	(++)	(NR)	(++)	(++)	2
Christensen et al. 2005	(++)	(+)	(+)	(++)	(+)	(++)	(++)	1
Lonn et al. 2005	(+)	(+)	(+)	(++)	(+)	(++)	(++)	1
Hardell et al. 2006	(--)	(--)	(--)	(++)	(+)	(++)	(++)	2
Hepworth et al. 2006	(+)	(+)	(+)	(++)	(+)	(++)	(++)	1
Schuz et al. 2006a	(+)	(+)	(+)	(++)	(+)	(+)	(++)	1
Hours et al. 2007	(+)	(NR)	(+)	(++)	(+)	(++)	(++)	2

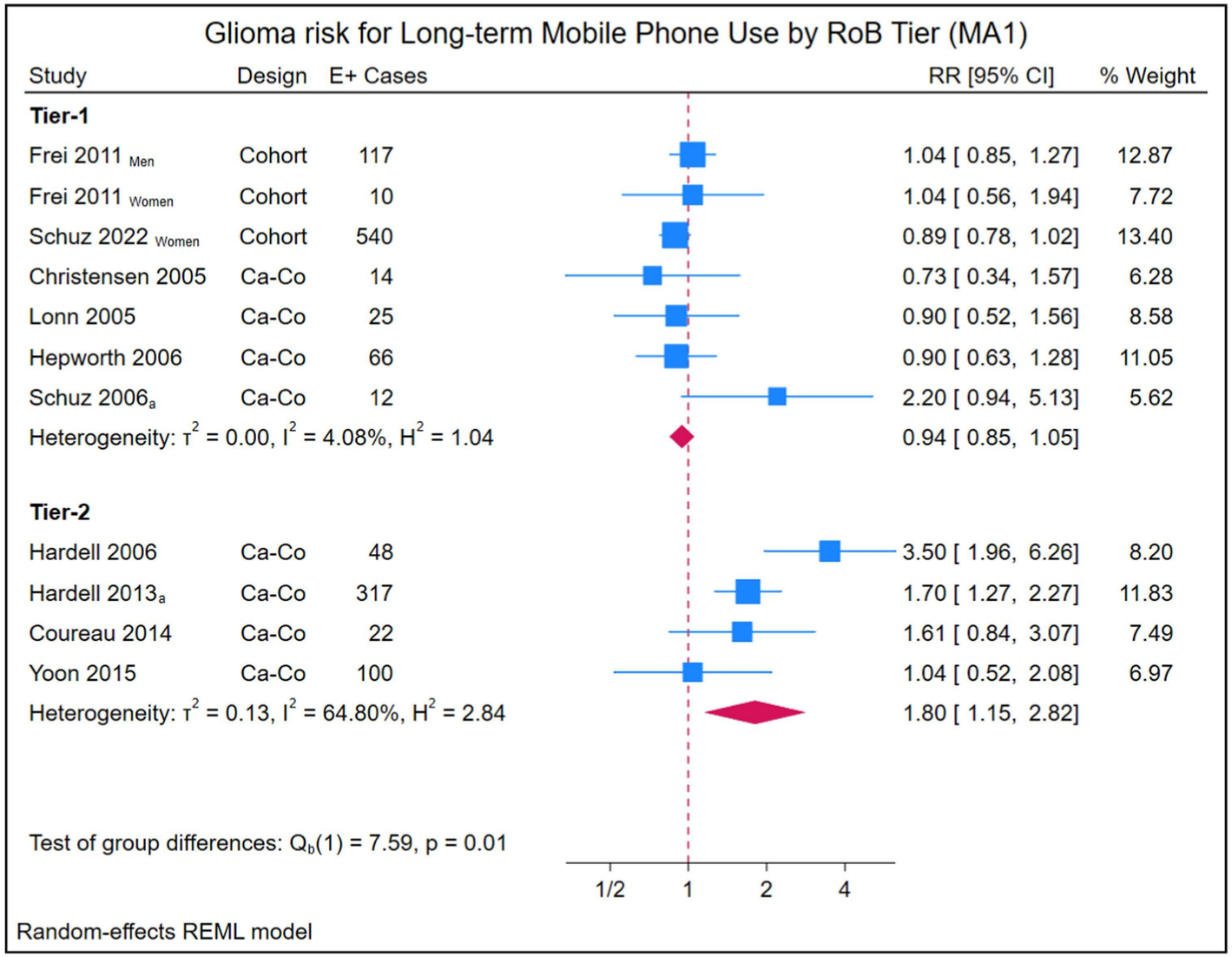
Karipidis et al. 2024, Environ Int

Main Results



Karipidis et al. 2024, Environ Int

Long-term use, stratified by study quality



Karipidis et al. 2024, Environ Int

Brain cancer results

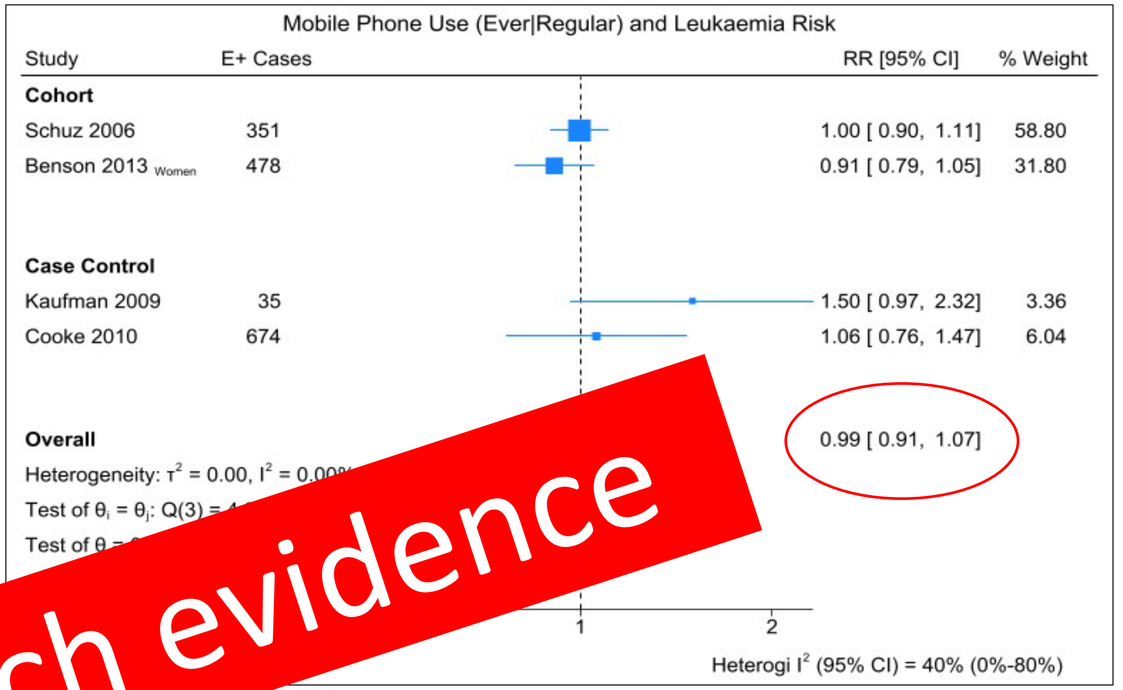
Moderate certainty evidence that RF exposure from mobile phones is not associated with brain cancer in adults or children

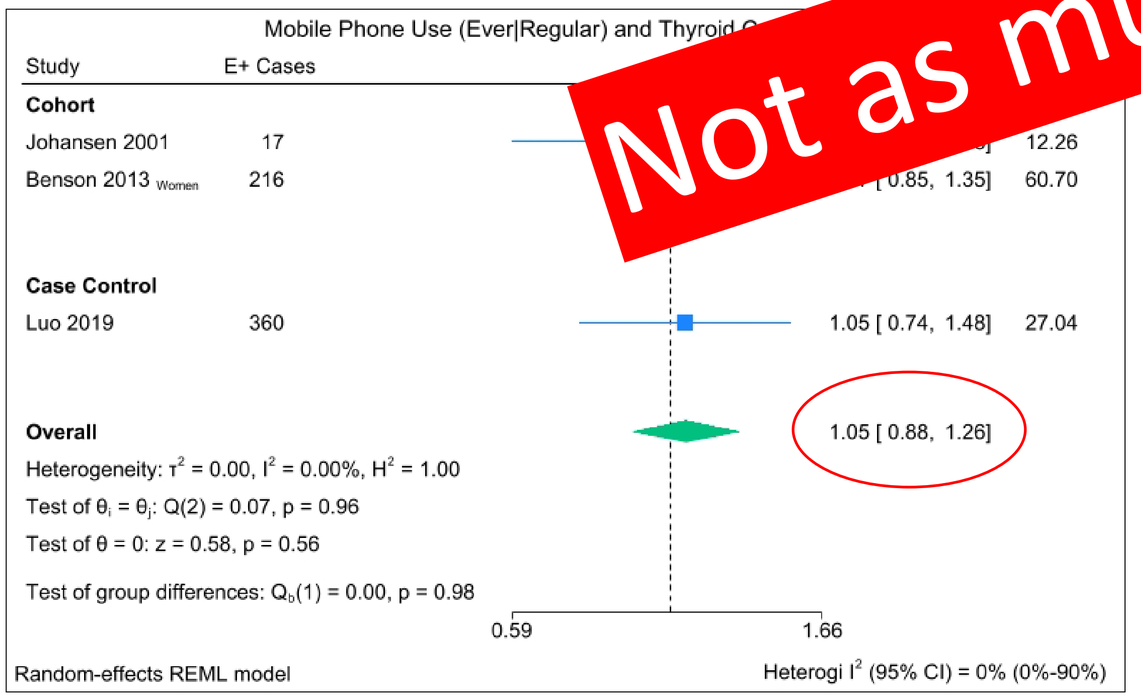
Low certainty evidence that RF exposure from base stations or broadcast antennas is not associated with brain cancer in children

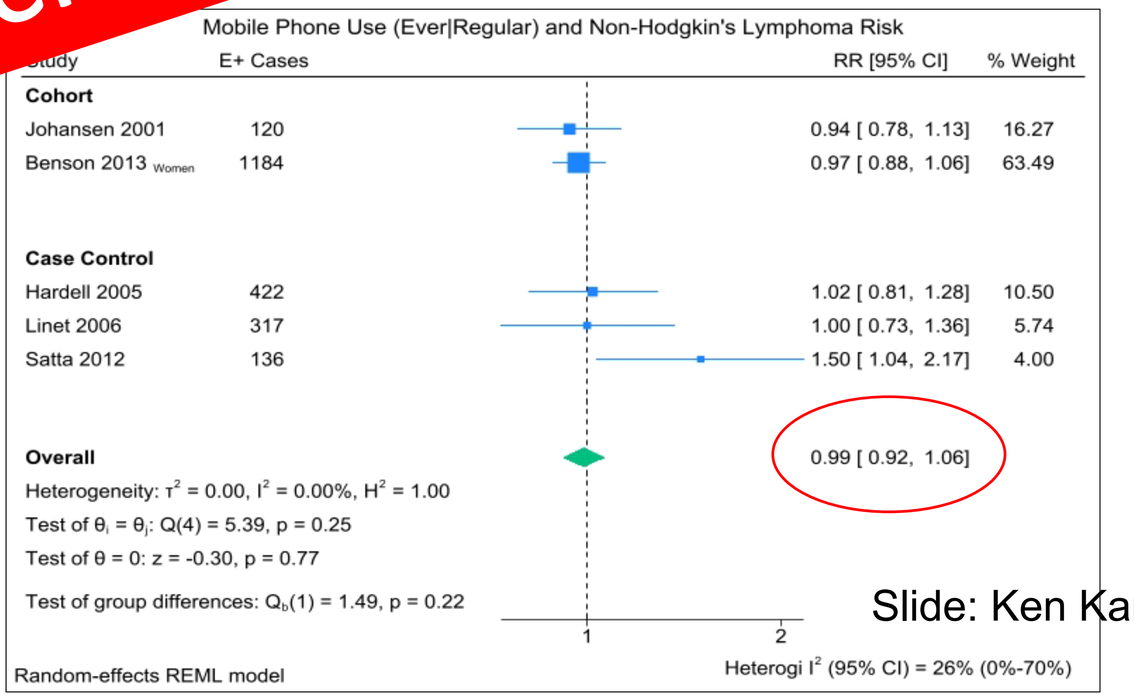
Low certainty evidence that occupational RF exposure is not associated with brain cancer

Slide: Ken Karipidis

Mobile phone use and other cancers





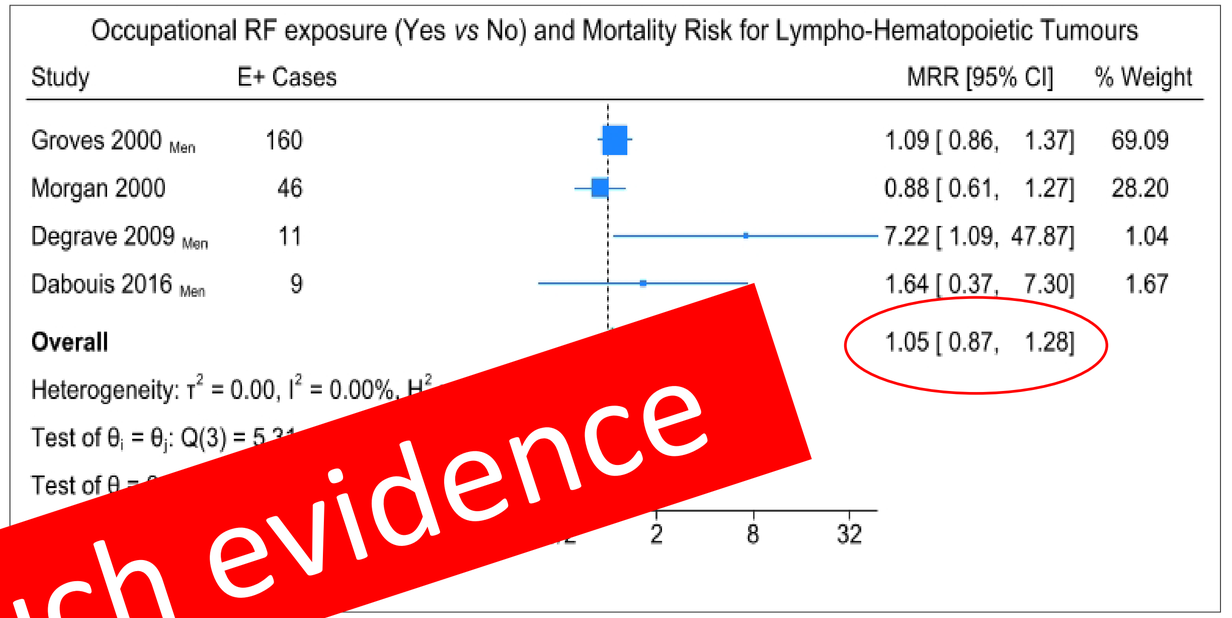


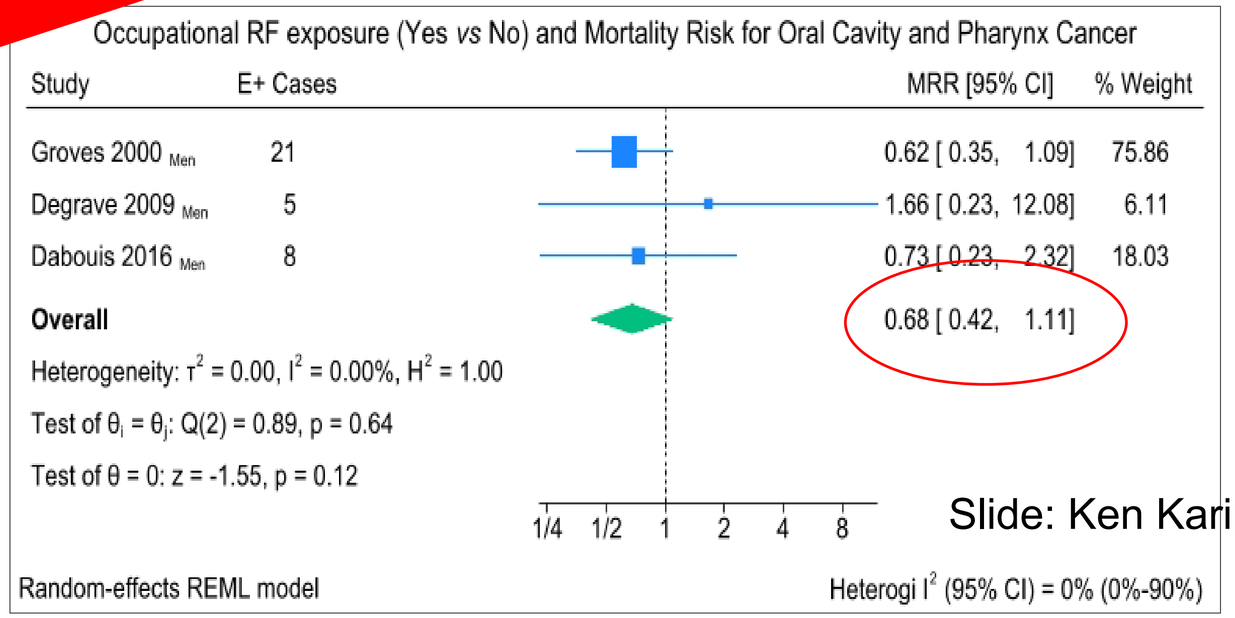
Not as much evidence

Slide: Ken Karipidis

Occupational exposure and other cancers

Not as much evidence





Slide: Ken Karipidis

Conclusion for other cancers

Low certainty evidence that RF exposure from mobile phones is not associated with leukaemia, non-Hodgkin’s lymphoma or thyroid cancer.

Not enough evidence on base stations or broadcast antennas

Low certainty evidence that occupational RF exposure is not associated with blood cancers or mouth cancer

Slide: Ken Karipidis

Conclusion SR 1

- Critical outcomes: 63 aetiological articles on 119 different E-O pairs
  Important outcomes: 26 articles on 143 different E-O pairs (65 types of neoplasms
- Available research does not indicate increased cancer risk with varying degree of certainty
- Complementary evidence from time-trend studies indicate that the increased risks observed in some case-control studies are incompatible with the actual incidence rates in several countries.

All reviews

My talks

Outcome	Human Studies	Animal Studies
Non-specific symptoms and general effects	**Experimental**: General symptoms – whole body (all) & headaches (general population) with whole-body exposure, perception [Bosch-Capblanch 2024] [---]	Oxidative stress in rodents (blood serum, thymus, testes) [Meyer 2024] [+]
	Experimental: headaches -head exposure (all) – whole body (EHS) sleep – head exposure (general population) [Bosch-Capblanch 2024] [--]	
	Experimental: sleep – whole body (general population), general symptoms – head exposure (all) [Bosch-Capblanch 2024] [--] **Observational**: tinnitus, migraine, headache – head exposure, sleep, general symptoms – whole body [Röösli 2024] [-]	Oxidative stress (inconsistent brain, liver, blood in animals & cell cultures) [Meyer 2024] [-]
Tumors	**Observational**: glioma, meningioma, acoustic neuroma, pituitary & salivary gland tumors (near field)[Karipidis 2024] [--]	Glioma, heart schwannoma [Mevissen 2025] [+++]
		Lymphomas, kidney, liver, lung cancers [Mevissen 2025] [++]
	Observational: Leukemia, lymphoma, thyroid cancer (near-field) [Karipidis 2025]; brain tumors in children (far-field); glioma (occupational) [Karipidis 2024] [-]	gastrointestinal/digestive, kidney, mammary gland, urinary, endocrine, musculoskeletal, reproductive, auditory , immune , pituitary, skin, urinary [Mevissen 2025] [-/+]
Reproduction & fertility	**Observational**: Reproduction – Women; general population and occupational exposure (birth weight, preterm birth, stillbirths, fetal development) [Johnson 2024] [-]	Female fertility (litter size/offspring number) [Cordelli 2023] [---]
	Observational: Reproduction – Men; general population (sperm count, concentration, motility, morphology) [Kenny 2024] [-]	Male fertility (litter size/offspring number) [Cordelli et al. 2024] [--]
		Female reproduction (offspring infertility, sex ratio) [Cordelli 2023] [-]
	Ex vivo: Male semen quality [Cordelli 2023] [+]	Male fertility (frequency of non-pregnancy) [Cordelli et al. 2024] [++]
	Ex vivo: Male semen quality DNA [Cordelli et al. 2024] [-]	Infertile animals, sperm & DNA quality, testis health, sperm production, testosterone [Cordelli 2024] [+]
Cognition & development disturbances	**Experimental**: short-term memory, attention, reaction time [Pophof 2024] [---]	Female reproduction in animals (brain development of offspring [Cordelli 2023] [--]
	Experimental: Perception, motor skills, conceptualization, processing [Pophof 2024] [--]	Female reproduction in animals (reduced fetal weight) [Cordelli 2023] [++]
	Experimental: Speed of motor Functions [Pophof 2024] [+]	Female reproduction in animals (fetal abortions, malformations; offspring learning, memory, motor/sensory functions [Cordelli 2023] [+]

egend of Evidence Reliability

- [---] High certainty of no effects
- [--] Moderate certainty of no effects
- [-] (Very) low certainty of no
- [+++] High certainty of effects
- [++] Moderate certainty of effects
- [+] (Very) low certainty of effects

Swiss TPH

Questions?

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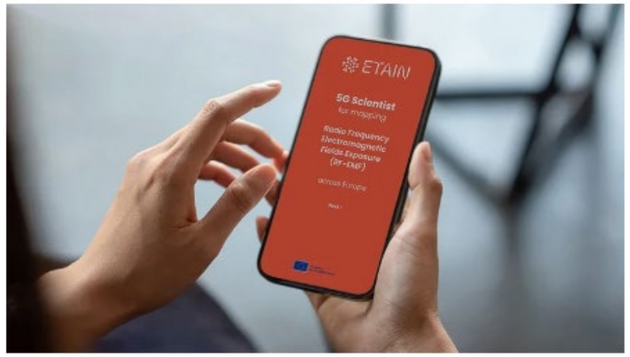
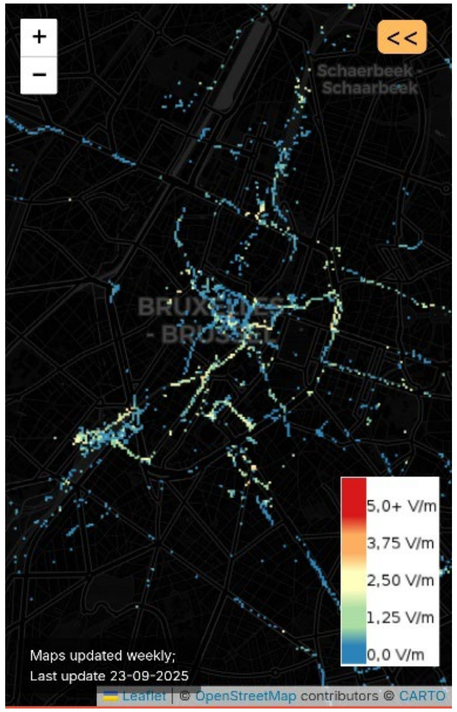
Improved exposure assessment:



ETAIN 5G Scientist App



https://www.etainproject.eu/etain-5g-scientist

WHO assessment of health effects of exposure to RF-EMF

Dr Jos Verbeek
WHO Task Group on Radiofrequency Fields and Health Risks, 2023

Assessing health risks from exposure to Radiofrequency Electromagnetic Fields (RF-EMF): The systematic reviews

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Guideline methodologist, WHO consultant
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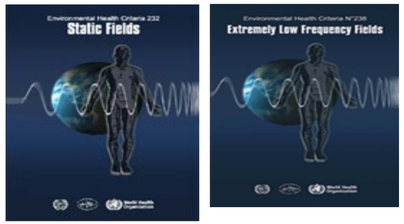
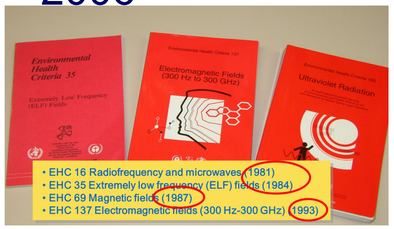
30 September, 2025

WHO RF EMF project

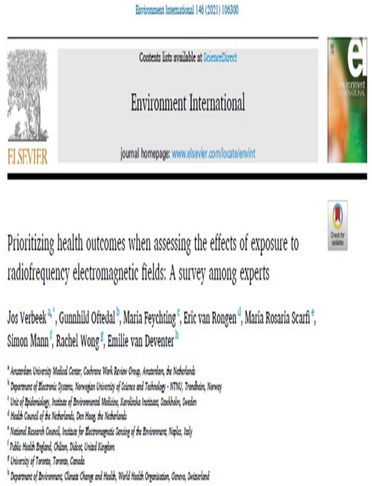


2006

2007



2002 2013



2021

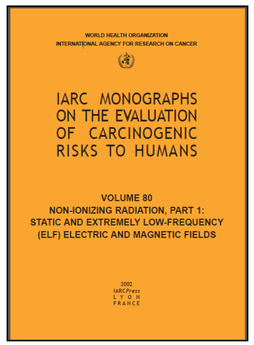
2022

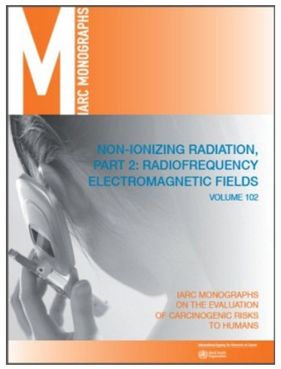
2025

2025

EHC
Monograph
Taskgroup
Report

2026





Systematic reviews

Human Observational studies	Human Experimental studies	Animal Experimental studies	In-vitro studies
SR1 - Cancer		SR2 - Cancer	
SR3 - Adverse reproductive outcomes		SR4 - Adverse reproductive outcomes	SR4 - Adverse reproductive outcomes
SR5 - Cognitive impairment	SR6 - Cognitive impairment		
SR7 - Symptoms	SR8 – Symptoms		
		SR9 - Oxidative stress	SR9 - Oxidative stress
SR10 – Heat and pain, burns, cataract, etc.	SR10 – Heat and pain, burns, cataract, etc.		

Systematic Review (SR) results

- Each SR includes a Summary of Findings table that presents:
  - All evaluated outcomes relevant to the topic
  - For each outcome, the table provides:
    - A **numerical result**, e.g., Risk Ratio , Relative Risk (RR) or Standardized Mean Difference (SMD)
    - A **95% Confidence Interval (CI)** indicating the range of likely values
    - An **assessment of certainty** attached to the result

- Example: The RR of glioma associated with mobile phone exposure compared to no exposure is **1.01**, with a **95% CI of 0.90 to 1.14**, assessed with **moderate certainty**

How to judge a result?

1. Effect: Direction and Magnitude
   - RR > 1 → Suggests a harmful effect
   - RR < 1 → Suggests a beneficial effect
   - RR = 1 → Indicates no effect
2. Statistical certainty/confidence
   - Reflects the range of values that are plausible given statistical uncertainty
   - If the 95% CI includes 1, the RR is not statistically significantly different from 1 (similar to $p < 0.05$)
3. Certainty of the evidence
   - Indicates how confident we are that the observed result reflects the **true effect**

How to judge a Relative Risk (RR)?

- **Example**: Glioma RR=1.01
  - Indicates a 1% increase in risk
  - From individual perspective
    - This increase is negligible
    - The small risk disappears against other risks
  - From population perspective
    - Widespread exposure means even small risks can affect many people
    - Cumulative impact can be significant
- **Comparison**: Air pollution and mortality
  - RR for mortality with 10 µg/m^3 increase in $PM_{2.5}$ = 1.08
  - Global burden of disease: 7 to 8 million premature deaths per year

How to judge a 95% Confidence Interval (CI)?

- Wider CI – indicates greater statistical uncertainty

Example 1: Small study

  - Study A: 10 RF EMF-exposed and control participants and risk for cancer
  - RR = 5 (95% CI: 0.1 to 105) statistically non-significant

- Example 2: Large study
  - Study B: 10,000 RF EMF-exposed and control participants and risk for cancer
  - RR = 1.2 (95% CI: 0.9 to 1.4) statistically non-significant

- What narrows the 95% CI?
  - More events, larger study populations, more studies

How to judge a 95% CI

- **Example**: Glioma RR = 1.01, **95% CI: 0.9 to 1.14**
  - If the study were repeated, the **true effect** would likely fall within this range
  - The CI still includes possibilities of **meaningful benefit or harm**
    → Especially relevant from a **population health perspective**

- **Comparison**: Air Pollution and Mortality
  - WHO systematic review:
    → **RR = 1.08**, 95% CI: **1.06 to 1.09**
    → Based on ~**9.5 million participants** across **17 cohort studies**

How to judge certainty of evidence?

- GRADE approach - Downgrade when:
  - Risk of bias: Limitations in study design or conduct
  - Inconsistency: Results vary across studies
  - Indirectness: Evidence does not directly apply to the research question
  - Imprecision: Wide confidence intervals or limited data
  - Publication bias: Selective publications of positive results
- Certainty levels: High, Moderate, Low, Very low
  - Evidence typically starts at High or Moderate, depending on study type.
- Example: Glioma
  - Certainty level: Moderate
  - No downgrading applied → Starts and remains at Moderate

How to better state ‘no effect’?

- RR = 1→ Indicates similar risk in exposed and control groups
- However, always statistical uncertainty, reflected in the confidence interval (CI)
- A statement of ‘no effect’ is only possible if
  - A prespecified threshold defines what counts as “no effect”
  - The 95% CI excludes that threshold

Example: WHO Drinking Water Quality Guideline

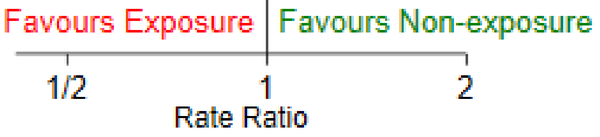
- Defines **tolerable risk** as **less than 1 in a million** lifetime cancer risk from chemical exposure in drinking water

Systematic review on cancer in humans
‘No effect’ for glioma

- Glioma RR = 1.01 (95% CI: 0.9 to 1.14)
  - Suggests no statistically significant effect
  - But: the confidence interval still includes potential for harm or benefit
- What is a reasonable ‘no effect’ threshold or tolerable risk?
  - Water Quality Guidelines: Tolerable risk = less than 1 in a million lifetime cancer risk
  - Air Quality Guidelines: RR =1.08 for mortality, or RR =1.12 for lung cancer
- Conclusion:
  - More studies would be needed to narrow the 95% CI
  - More discussion is needed to define tolerable risk thresholds
  - Current evidence: No statistically significant effect observed

Risk of various cancers from RF EMF in meta-analysis of human observational studies

Study	E+ Cases	Datasets	RR with 95% CI	Grade
Glioma MP Ever/Never	4200	13	1.01 [0.90, 1.14]	Moderate
Glioma CP Ever/Never	>1022	3	1.04 [0.74, 1.46]	Low
Glioma Occ Expo/No Expo	313	3	1.06 [0.72, 1.55]	Low
Meningeoma MP Ever/Never	2990	10	0.92 [0.82, 1.03]	Moderate
Meningeoma CP Ever/Never	>1089	3	0.91 [0.70, 1.18]	Moderate
Acoustic Neuroma MP Ever/Never	1614	11	1.03 [0.85, 1.24]	Moderate
Acoustic Neuroma CP Ever/Never	>716	4	1.16 [0.83, 1.62]	Low
Pituitary Tumours MP Ever/Never	>466	5	0.81 [0.62, 1.05]	Moderate
Salivary Gland Tumours MP Ever/Never	611	10	0.91 [0.78, 1.06]	Moderate
Pediatric brain Tumours MP Ever/Never	733	3	1.06 [0.74, 1.51]	Moderate
Pediatric brain Tumours FF Expo/No Expo	1056	4	0.97 [0.73, 1.29]	Low
Childhood Leukemia FF Expo/ No Expo	2219	5	0.93 [0.84, 1.02]	Moderate
Leukemia MP Ever/Never	1538	4	0.99 [0.91, 1.07]	Low
Leukemia MP 10+ years	260	3	1.03 [0.85, 1.24]	Low
Non-Hodgkin Lymphoma MP Ever/Never	2179	5	0.99 [0.92, 1.06]	Low
Non-Hodgkin Lymphoma MP 10+ years	295	4	0.99 [0.86, 1.14]	Low
All Lymphoma Occ Expo/No Expo	215	4	1.05 [0.87, 1.27]	Very low
Thyroid cancer MP Ever/Never	1040	3	1.05 [0.88, 1.26]	Low
Oral cavity Pharynx Occ Expo/ NO Expo	34	3	0.68 [0.42, 1.11]	Very low



World Health Organization

https://doi.org/10.1016/j.envint.2025.109751

Verbeek et al Env Int 2025

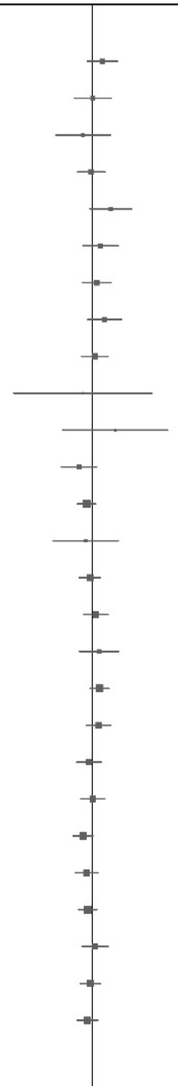
Systematic review on cancer in animals

- Methodological differences
  - No meta-analysis conducted
  - No numerical summary of results provided
- Definition of Effect
  - A statistically significant increase in cancer incidence in at least one study
  - Studies showing no effect are not considered in the conclusion
- Certainty of Evidence
  - Based solely on the ‘positive’ studies
  - Rated as high certainty if the study is large and has low risk of bias
- Key Concern
  - Different methodological approaches can lead to different conclusions
  - This was not addressed in the review

RF EMF and Cognition

Effects of RF EMF on Cognitive Performance in Human Observational and Experimental studies

Study	Participants	Studies/Datasets	Standardized Mean Difference with 95% CI	Grade
Orientation and Attention				
Exp Attention-Concentration; focussed attention-accuracy	379	4	0.10 [-0.05, 0.24]	Moderate
Exp Attention-Concentration; focussed attention-speed	264	3	0.00 [-0.17, 0.18]	High
Exp Attention-Divided attention-accuracy	267	4	-0.09 [-0.35, 0.18]	Low
Exp Attention-Divided attention-speed	527	6	-0.01 [-0.14, 0.12]	High
Exp Attention-Selective attention-accuracy	865	10	0.18 [-0.02, 0.38]	Low
Exp Attention-Selective attention-speed	904	13	0.08 [-0.09, 0.25]	Moderate
Exp Attention-Vigilance-accuracy	398	6	0.04 [-0.09, 0.18]	High
Exp Attention-Vigilance-speed	494	7	0.12 [-0.04, 0.28]	Moderate
Exp Attentional capacity; attention-accuracy	871	5	0.02 [-0.10, 0.15]	High
Obs Complex attention Env Expo Children	79	1	-0.09 [-0.75, 0.57]	Low
Obs Complex attention MP Adults	159	1	0.22 [-0.29, 0.73]	Very low
Exp Processing speed- > 2 choice reaction time task-accuracy	262	3	-0.13 [-0.30, 0.04]	Moderate
Exp Processing speed- > 2 choice reaction time task-speed	1033	7	-0.05 [-0.14, 0.03]	High
Exp Processing speed-2 Choice reaction time task-accuracy	234	3	-0.06 [-0.38, 0.25]	Low
Exp Processing speed-2 Choice reaction time task-speed	747	9	-0.02 [-0.13, 0.08]	High
Exp Processing speed-Other tasks-accuracy	608	5	0.04 [-0.08, 0.15]	High
Exp Processing speed-Other tasks-speed	478	6	0.07 [-0.12, 0.26]	Moderate
Exp Processing speed-Simple reaction time task-speed	1585	14	0.07 [-0.02, 0.16]	High
Exp Working Memory- 0-back task-accuracy	534	8	0.06 [-0.06, 0.18]	High
Exp Working Memory- 0-back task-speed	534	8	-0.03 [-0.15, 0.09]	high
Exp Working Memory- 1-back task-accuracy	566	9	0.00 [-0.11, 0.12]	High
Exp Working Memory- 1-back task-apeed	840	11	-0.09 [-0.18, 0.00]	High
Exp Working Memory- 2 back task-accuracy	626	10	-0.05 [-0.16, 0.05]	High
Exp Working Memory- 2 back task-speed	948	13	-0.04 [-0.13, 0.04]	High
Exp Working Memory- 3 back task-accuracy	474	7	0.03 [-0.10, 0.15]	High
Exp Working Memory- 3 back task-speed	796	10	-0.02 [-0.11, 0.08]	High
Exp Working Memory- Mental tracking-accuracy	801	7	-0.05 [-0.15, 0.05]	High



Systematic review on cognition in humans

- How to judge the results
  - Interpretation challenges
    - Many different tests used
    - No result is statistically significant
- Individual perspective
  - Patients often score 1–2 standard deviations (SDs) below average on similar tests
  - Review findings show very small effects (fractions of an SD) with narrow 95% Cis
- Population perspective
  - More study would be needed
- Certainty of the evidence
  - Rated as high
  - Results are likely to reflect the true effect, despite being small

Results for other health outcomes

- Fertility Female and Fertility Male
  - Observational studies: no clear pattern, very low certainty
  - animal studies consistently positive, low certainty
- Symptoms
  - consistently negative, moderate to low certainty
- Oxidative stress
  - very inconsistent results, very low certainty

What's next?

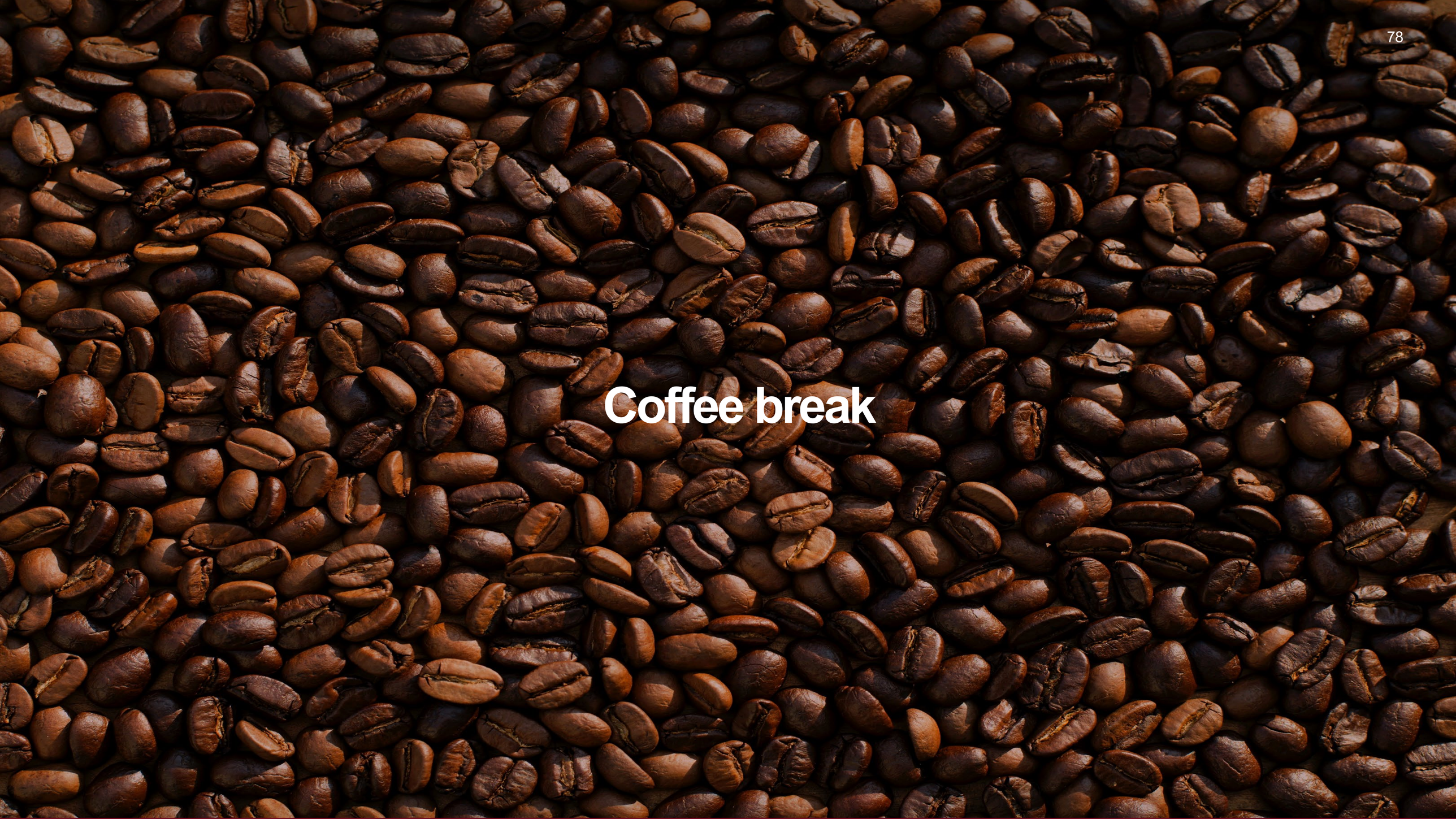
- Task group
  - Will integrate evidence streams into a conclusion on broader health topics (e.g. cancer)
  - Has already formulated conclusions for all topics except cancer
  - Will complete its report by the end of the year
- External review group
  - Will review and comment on the Task Group's report
- WHO Guideline Review Committee
  - Will evaluate the report according to WHO guideline handbook
- Publication of the report as an EHC Monograph in 2026

Q&A: WHO assessment of health effects of exposure to RF-EMF

Professor Martin Röösli
Swiss Tropical and Public Health Institute
Switzerland

Dr Jos Verbeek
WHO Task Group on Radiofrequency Fields and Health Risks, 2023

DI Manfred Ruttner
A1 Telekom Austria,
Deputy Chair GSMA EMF and Health


Coffee break

Stefano D'Elia
Vodafone Group,
GSMA EMF and Health Delegate

Introduction to session 2: GOLIAT project and the perspective of EMF expert groups

GOLIAT (5G expOsure, causaL effects, and rIsk perception through citizen engAgemenT): project overview and current status

Dr Gemma Castaño
Epidemiologist
ISGlobal (Spain)

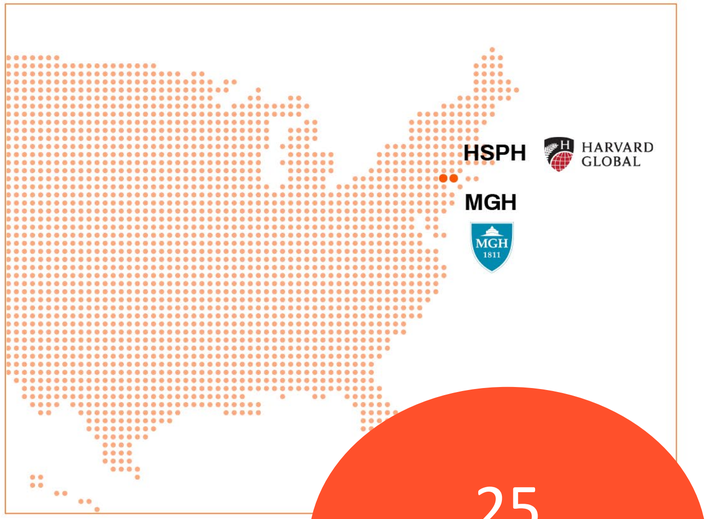
5G exposure, causal effects, and risk perception through citizen engagement

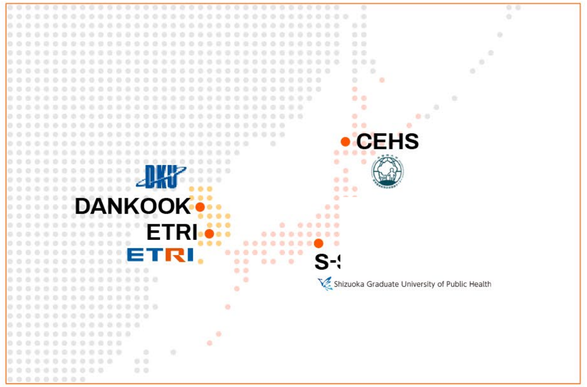
Gemma Castaño-Vinyals, PhD
Scientific Coordinator
ISGlobal

This project has received funding from the European Union's Horizon Europe research and innovation programme under Grant Agreement No 101057262

GOLIAT

Fact sheet





25 partners

5 years

>10 million €

7.0 million € (EU)

1,348 PM

Overarching aim

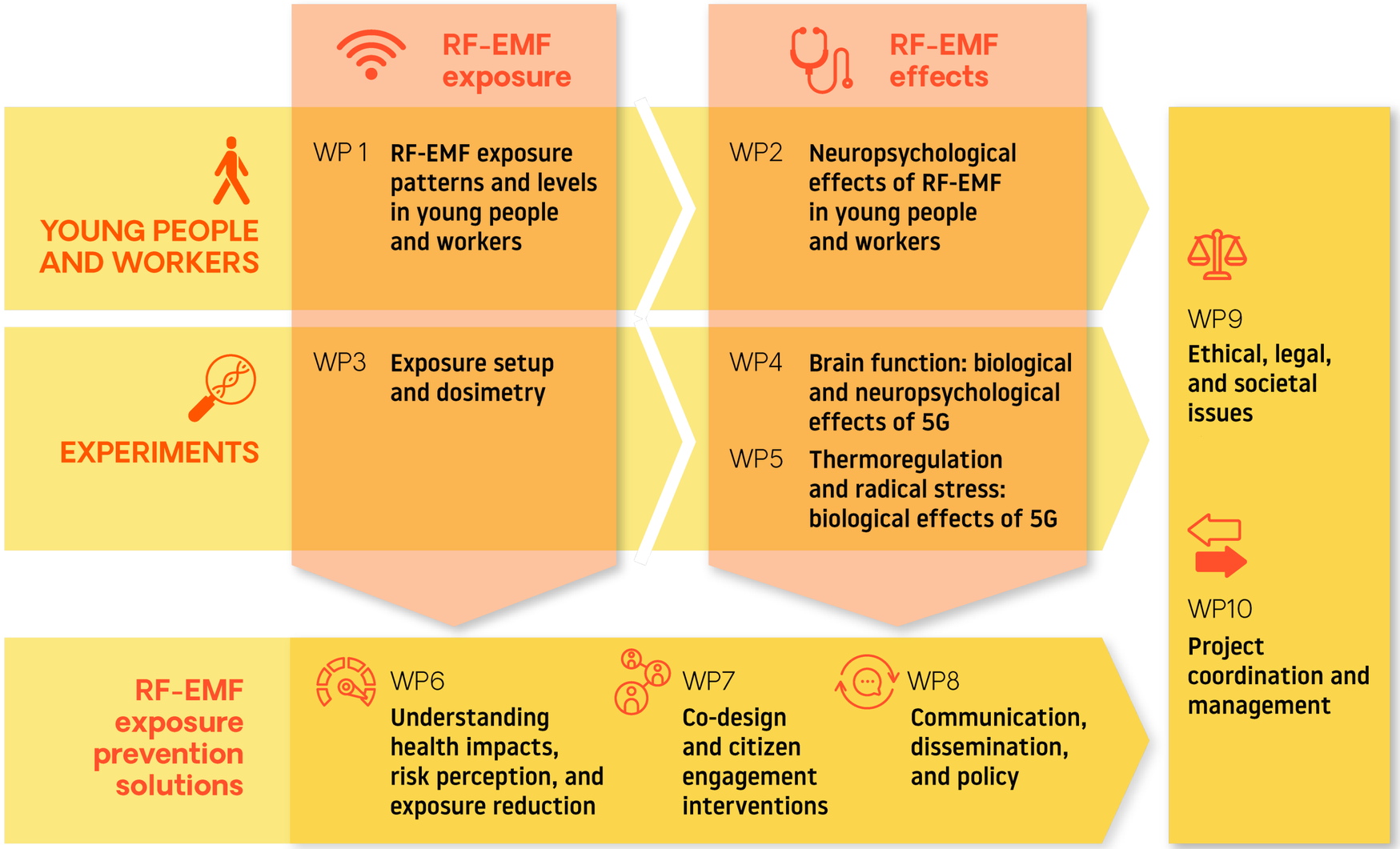
To characterize and monitor RF-EMF exposure, in particular 5G

To provide novel insights into potential causal neuropsychological and biological effects

To understand risk perception and communication through citizen engagement

To use an integrative and transdisciplinary pan-European approach

PERT diagram



WP1

Monitoring the current and evolving use of communication/connected devices and technologies and expected widespread use of IoT in young people and workers is essential for understanding how new generation radio-communication networks, in particular 5G, will influence their exposure to RF-EMF

Young people

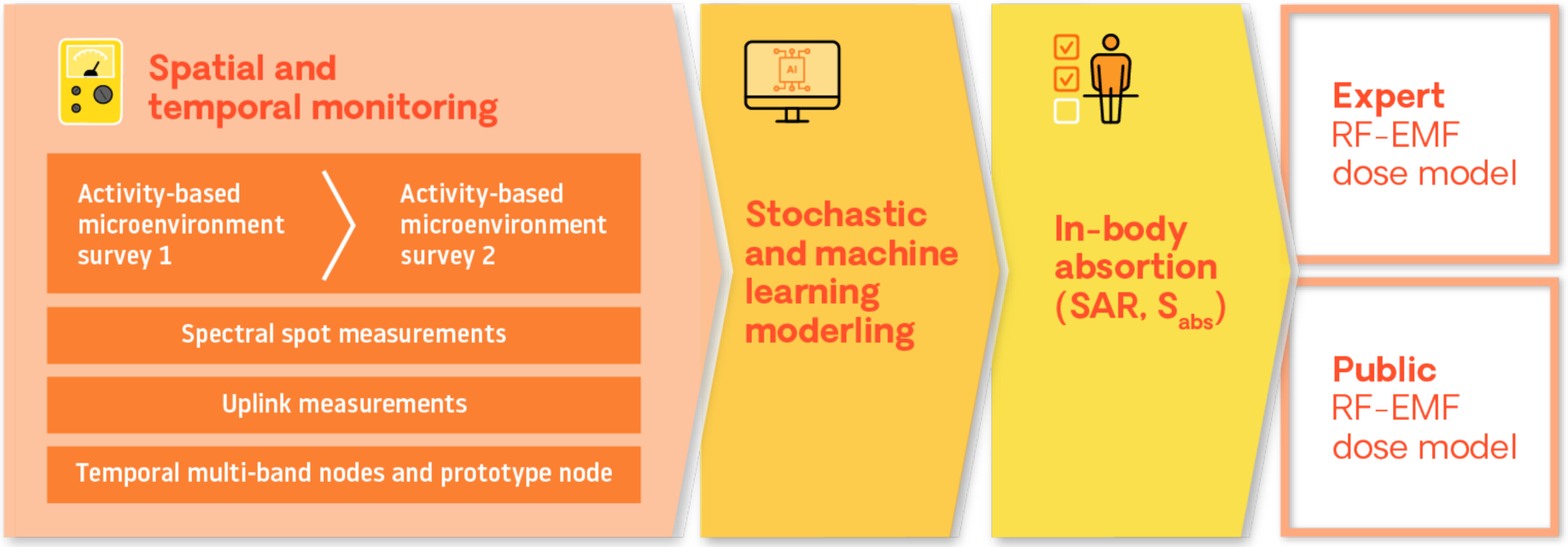
- Questionnaire to identify devices and type of applications used, activities performed, and technologies used
- Position of the devices in relation to the body and microenvironments in which they are used, including wirelessly connected (peripheral) devices

Workers

- Identification of new and emerging occupational RF-EMF sources and scenarios
- Monitoring the current and evolving RF-EMF exposures related to these sources, including personal measurements and spectral spot measurements
- Compare exposure levels in occupational settings with non-occupational RF-EMF sources (including own device) to which the workers are exposed

WP1

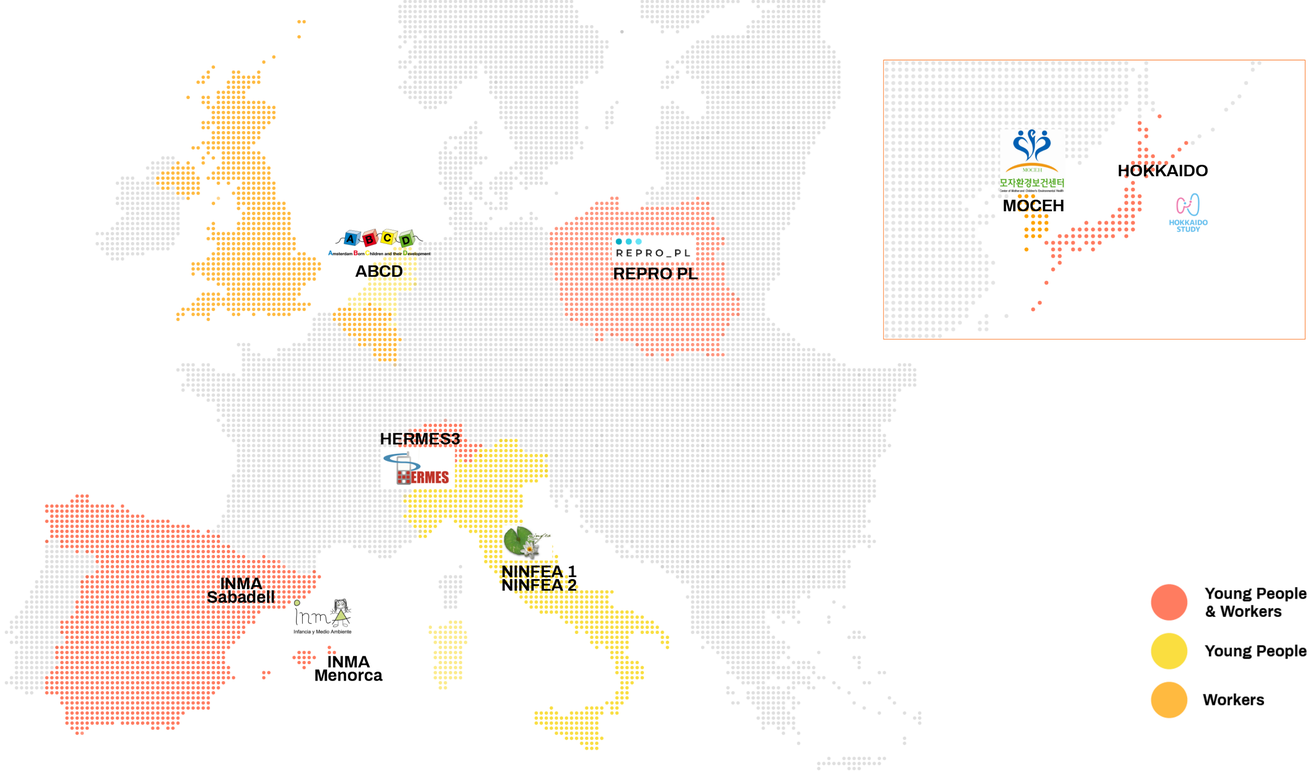
Characterizing RF-EMF exposure patterns and levels from new generation radio-communication networks, in particular 5G, in young people requires the development of next-generation exposure assessment methods



Next generation exposure assessment methods for young people

WP2

State-of-the-art causal inference methods are needed to estimate valid causal effects in RF-EMF epidemiological research



Young people

- Longitudinal data on both exposure and neuropsychological outcomes in 8 cohorts (N=4,000)
- Approaches that control for unknown or unmeasured confounding
- Approaches that balance observed background covariates
- Triangulation of results

Workers

- Controlled cross-over quasi-experimental design
- Recruit companies where 5G technology will be installed
- Repeated measures of both exposure and neuropsychological outcomes before and after 5G implementation + control group
- Difference-in-differences analysis

WP3, WP4, WP5

Using an integrative approach including *in vitro, in vivo,* humans, and *in silicon* experiments will help estimate valid causal effects in RF-EMF biological research

Table 1. Mapping of experimental studies – GOLIAT

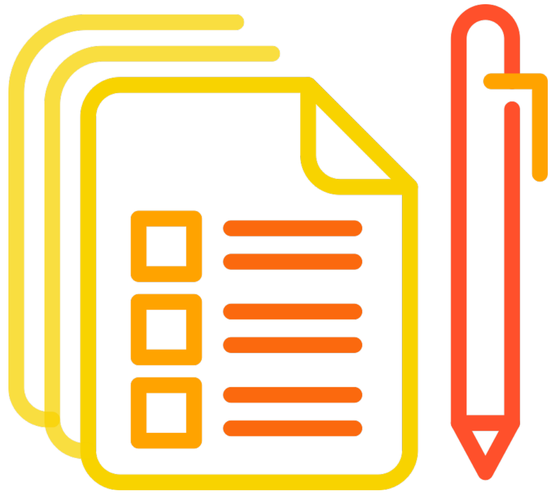
Outcome	Type of experiment	Frequency (GHz)	SAR / S_{abs}	Type of field
Brain function				
	In vitro	0.7, 3.5	0.08, 0.4, 4W/kg	Far-field
	In vivo	3.5 26	0.08, 0.4, 4W/kg 10, 50, 100W/m^2	Far-field
	Humans	3.5 26	1 W/kg 1 W/m^2	Far- / near-field
Thermoregulation				
	In vitro	0.7, 3.5 26	0.08, 0.4, 4, 35 W/kg 10, 50, 100W/m^2	Far-field
	In vivo	3.5 26	0.08, 0.4, 4W/kg 10, 50, 100W/m^2	Far-field
	Humans	3.5 26	up to 0.8 W/kg up to 10 W/m^2	Near-Field
	In silico	0.7, 3.5 26	0.08, 0.4, 4W/kg 10, 50, 100W/m^2	---
Radical stress				
	In vitro	3.5 26	0.08, 0.4, 4W/kg 10, 50, 100W/m^2	Far-field
	In vivo (M)	3.5	0.08, 0.4, 4W/kg	Far-field
	In silico	0.7, 3.5 26	0.08, 0.4, 4W/kg 10, 50, 100W/m^2	---

SAR=specific energy absorption rate; S_{abs}=absorbed power density

WP6

Understanding mental models of RF-EMF exposure in key far efficiently communicating risks

- A lack of clarity around the nature, magnitude, and likelihood of potential health risks continues to rise concerns, misapprehensions, and even outright rejection of novel technologies such as 5G by some groups
- Mental models to address poor communication of potential risks associated with RF-EMF
  - Identify misconceptions by comparing how experts and citizens think about RF-EMF technologies work and their potential health effects
  - European survey on misconceptions to ascertain prevalence of certain ideas
  - Guide risk communication messages and improve citizens understanding



WP6

Evaluating exposure reduction scenarios will contribute to a better understanding and acceptance of novel RF-EMF technologies

- Select exposure reduction scenarios that are likely to have a large impact on exposure, as well as scenarios, which seem counterintuitive for lay people
- Both for young people and in occupational settings
- Web-based interactive public RF-EMF dose model to allow the public to quantify their dose
- Better acceptance of communication infrastructure by the public and empower citizens to take actions to minimize exposures in an effective manner

WP7

Engaging young people and workers is essential for properly addressing doubts, concerns, and misconceptions about RF-EMF

- Deploy a state-of-the-art citizen engagement plan based on a highly inclusive engagement "leave no one behind" model, engaging different audiences and social realities
- Young people and workers: self-assessment RF-EMF exposure levels, with subsequent activities to raise awareness and engage them in exposure/risk-reduction actions
- Co-design and test the public RF-EMF dose model, to ensure the tool is useful, understandable, inclusive, and helps citizens avoid misinterpretations of the RF-EMF exposure data
- Co-design and test communication formats and messages to properly address the doubts, concerns, misconceptions, and risk perceptions detected in GOLIAT

WP9

Engaging in two-way dialogue with stakeholders on the broader implication of RF-EMF exposure to go beyond physical harm and include psychological, societal, and ethical factors

- Different perceptions of risk are influenced by ethically relevant factors such as control and consent, and potential for discrimination, while the societal impacts of misinformation and fake news about 5G may have consequences that go far beyond the health of individuals
- Privacy, security, and transparency are all important

CLUE-H

EMF and Health Cluster

4 projects funded

SEAWave

Theo Samaras, Aristotle University of Thessaloniki

ETAIN

Anke Huss, Institute for Risk Assessment Sciences, Utrecht University

NextGEM

Nikolaos Petroulakis, Institute of Computer Science of Foundation for Research and Technology - Hellas

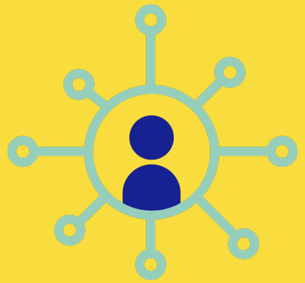
GOLiAT

Mònica Guxens, Barcelona Institute for Global Health

CLUE – H

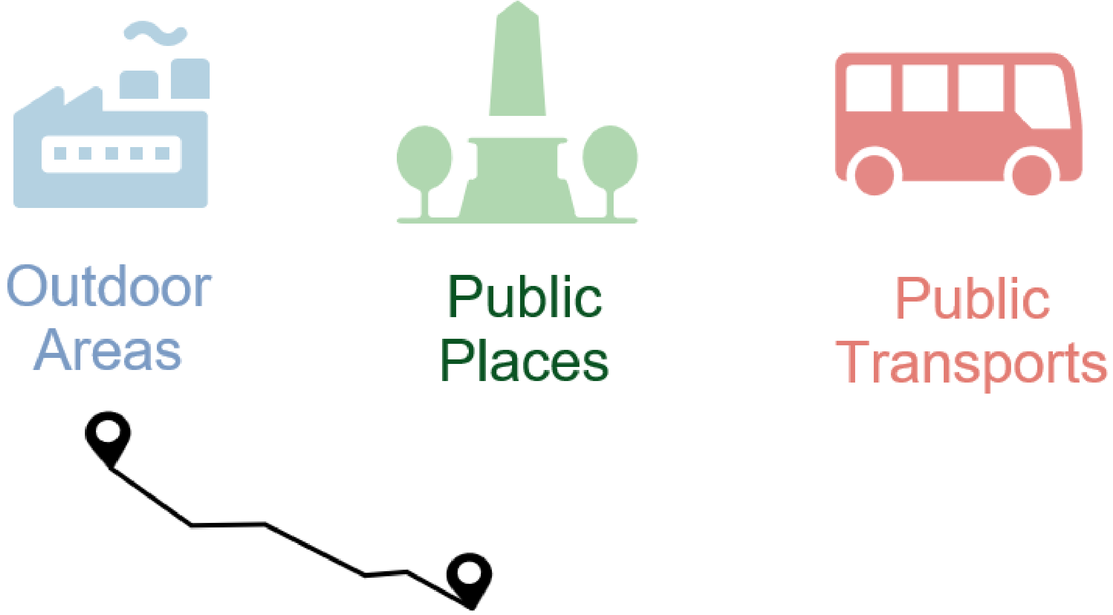
Join activities:

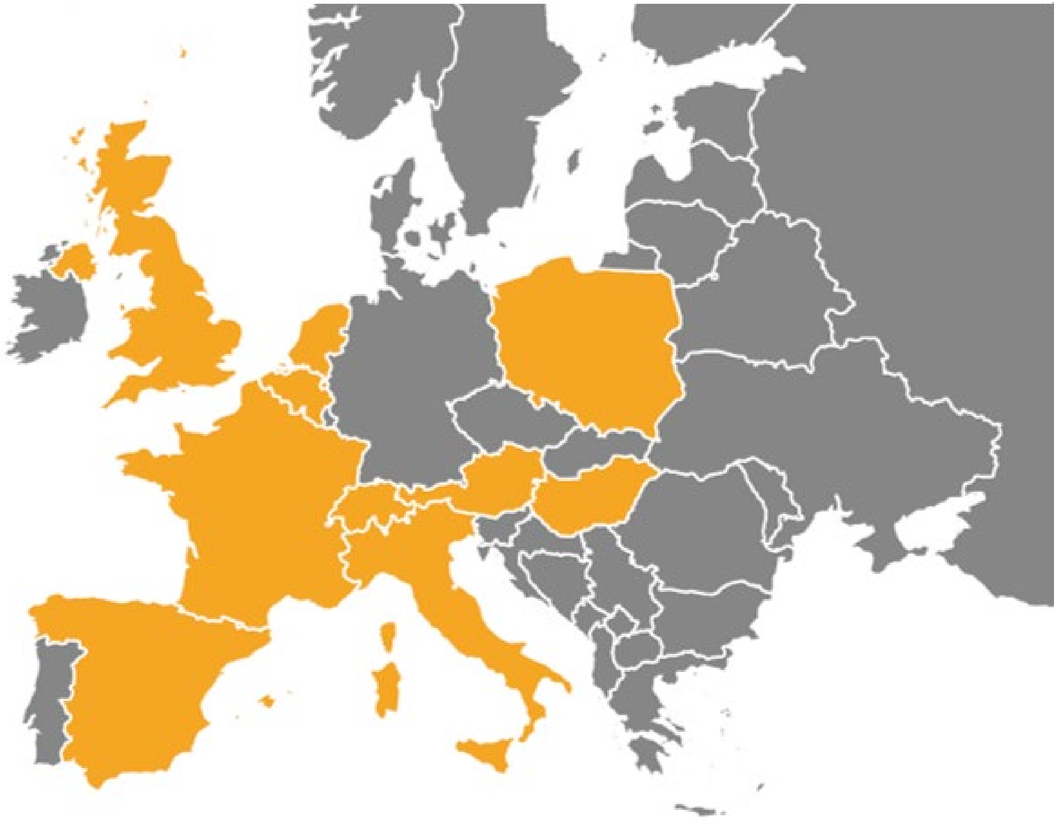
- Working groups: Scientific strategy, Data management/analysis, Communication, Policy
- Joint webpage and social media
- Annual meetings
- Yearly newsletters, brochures, policy briefs
- Joint stakeholders list
- Joint trainings and workshop



Activity based micro-environmental surveys

- Aim: To assess RF-EMF exposure in multiple micro-environments in 10 countries

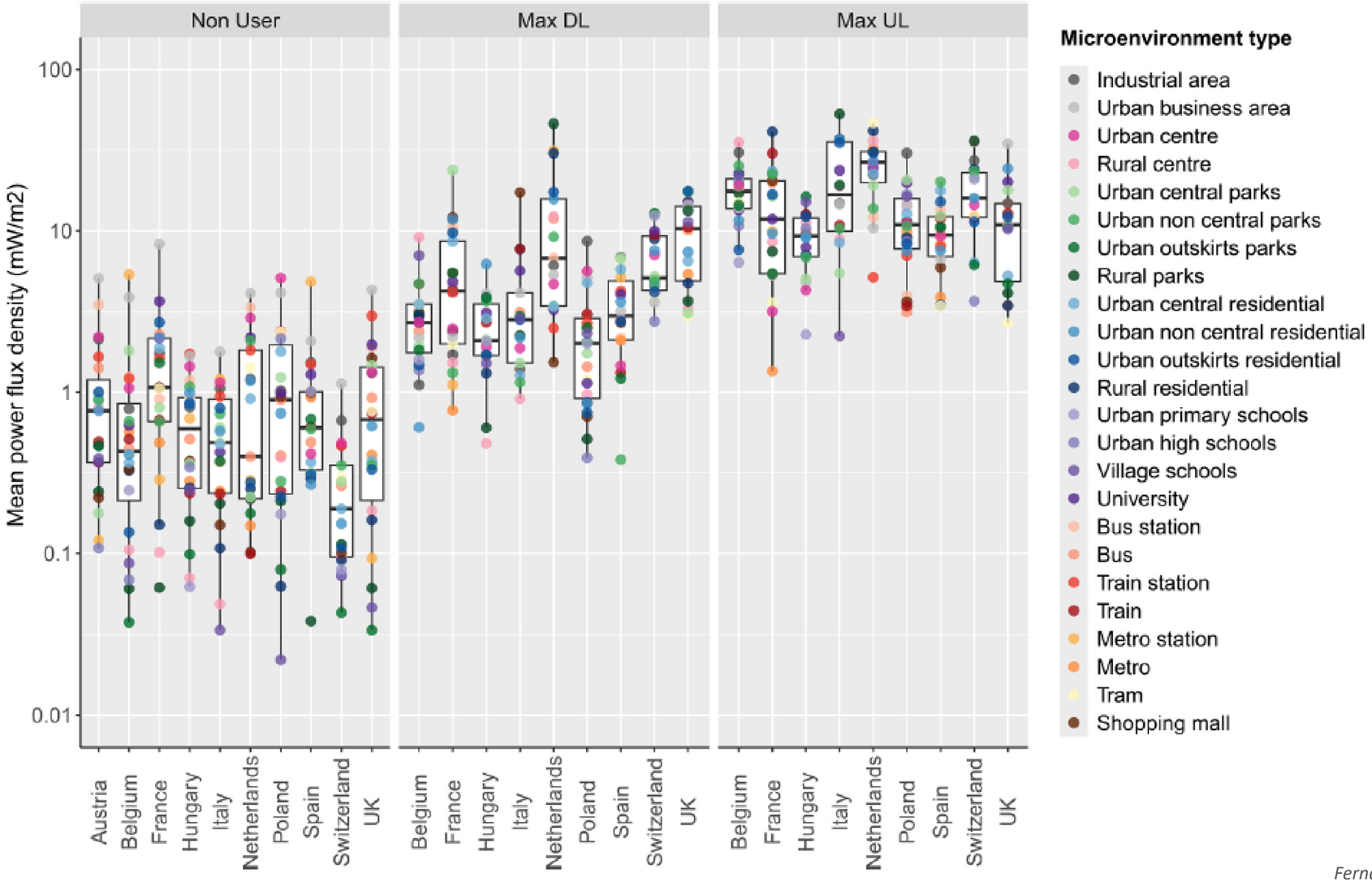




Activity based micro-environmental surveys

Measurement devices

Activity based micro-environmental surveys



Fernandes Veludo et al. Environ Int 2025;200:109540

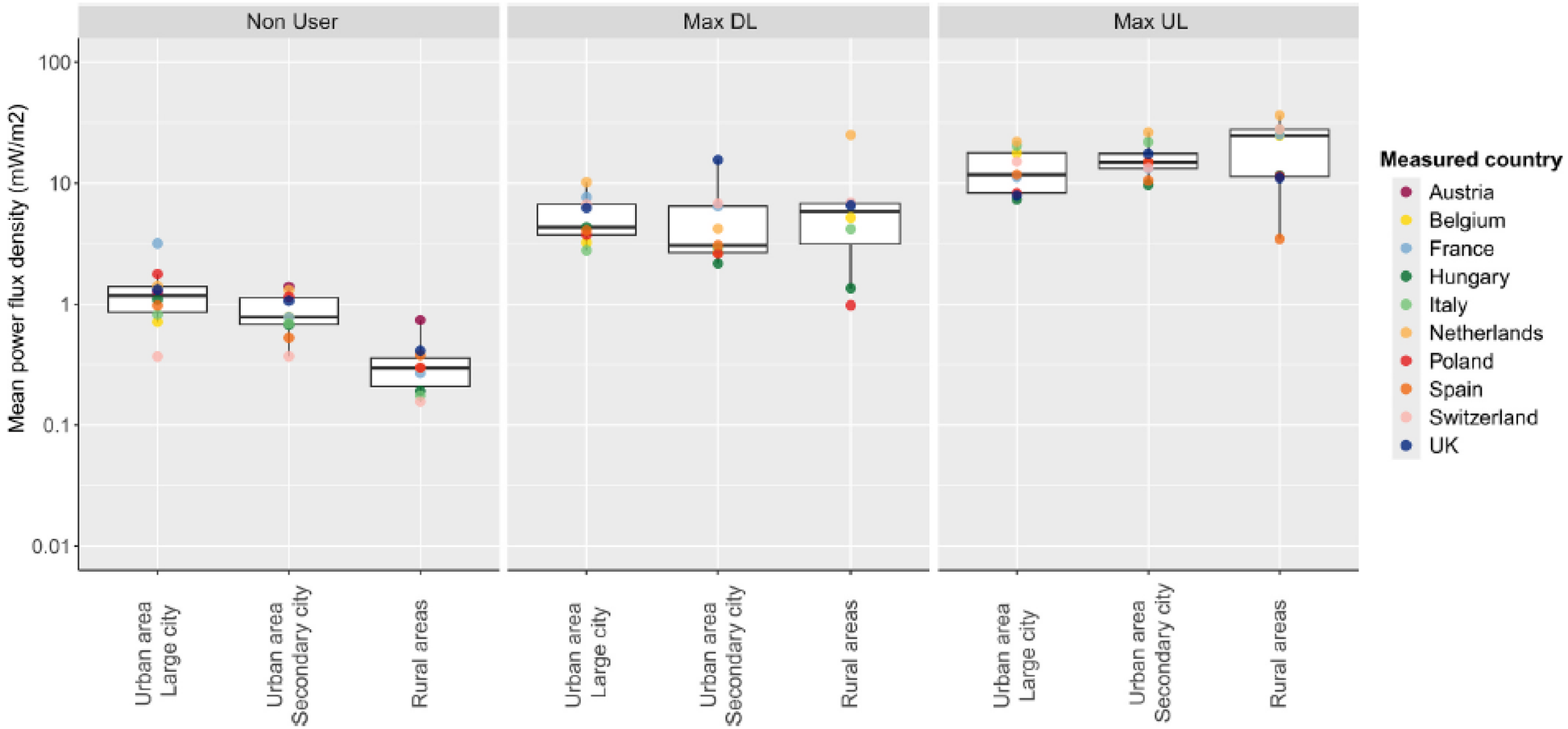
Activity based micro-environmental surveys

Urban business areas

80% lower levels in villages

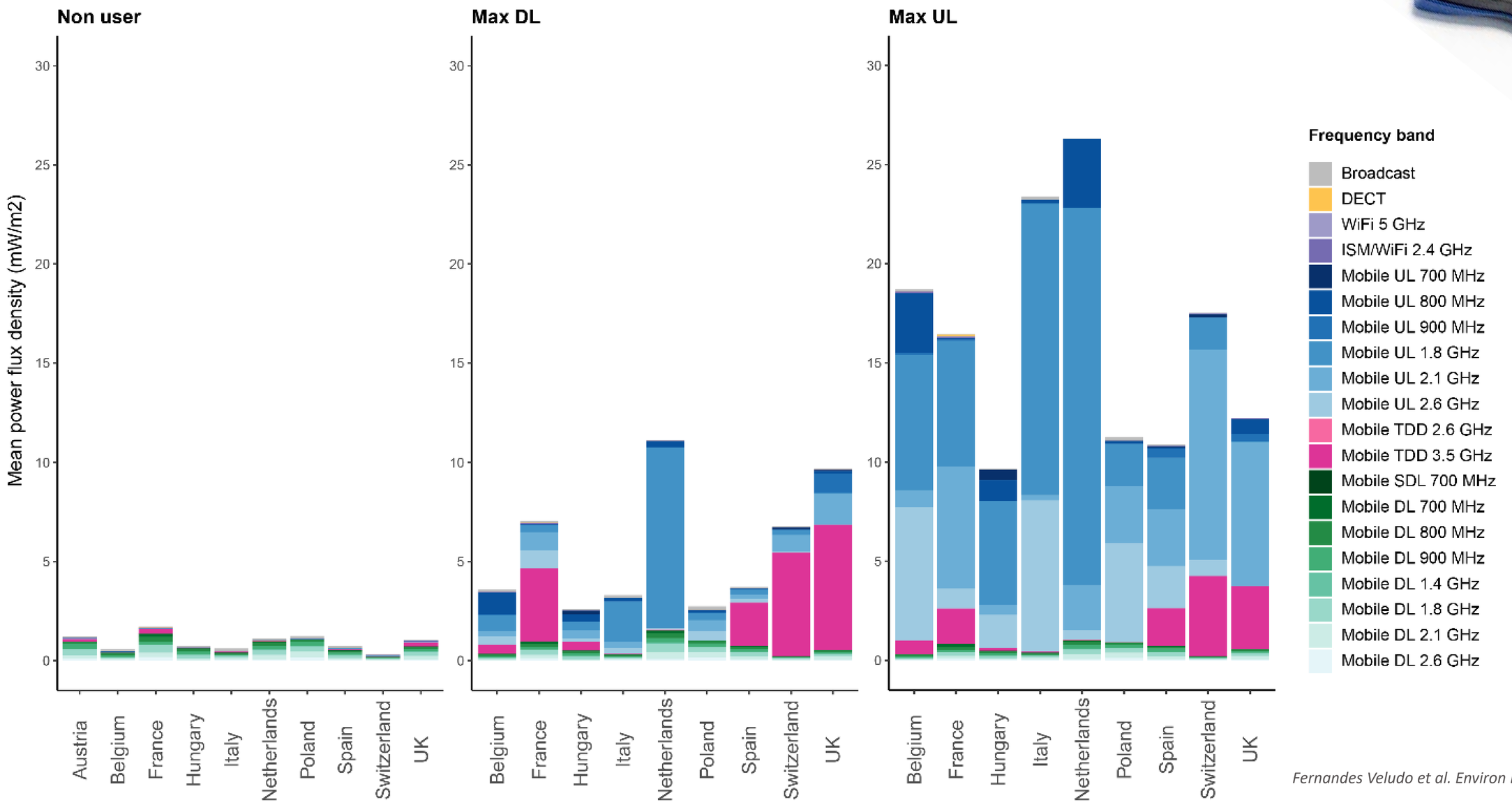
Less differences by urbanization

30% higher levels in villages



Fernandes Veludo et al. Environ Int 2025;200:109540

Activity based micro-environmental surveys

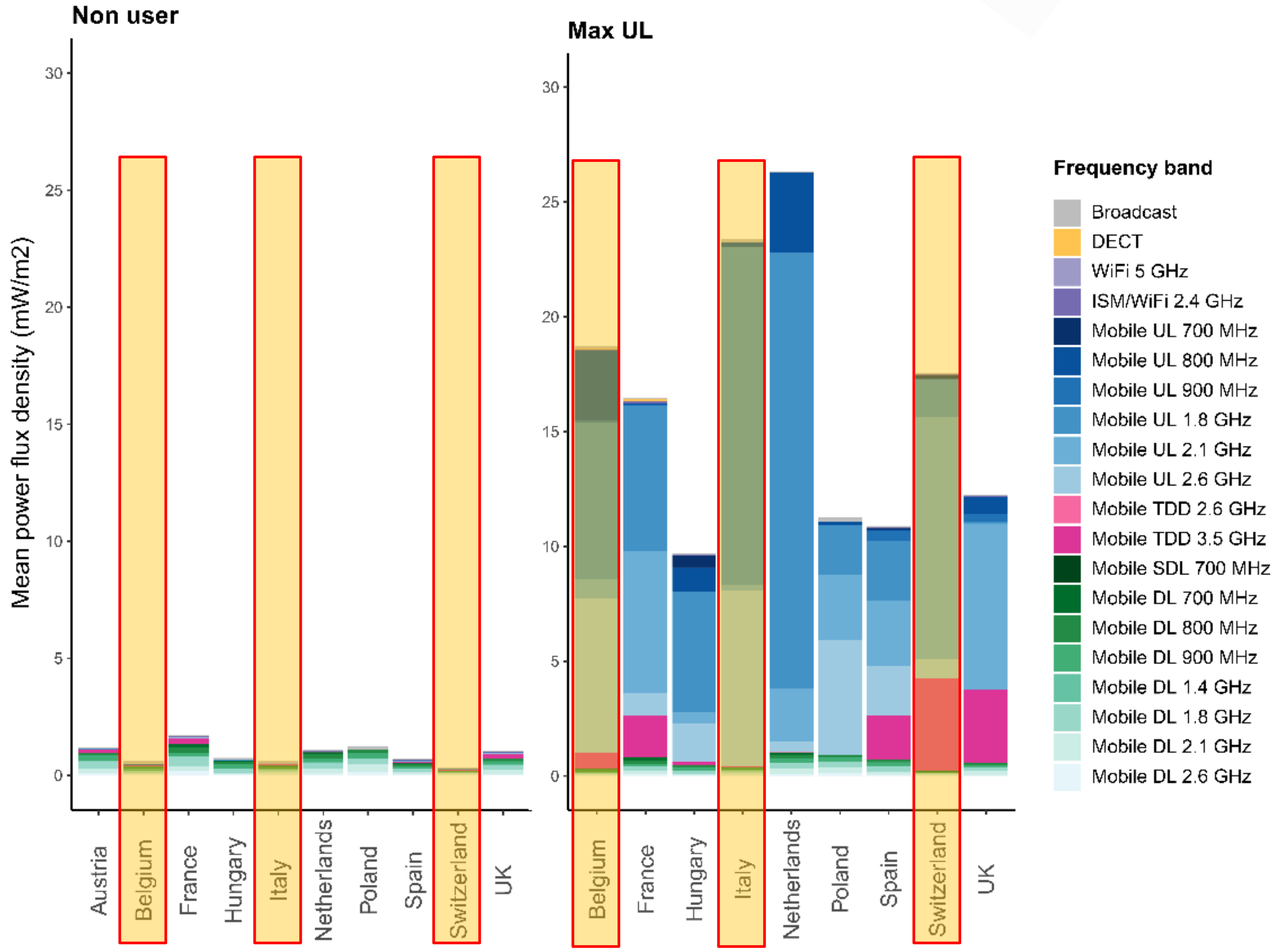


Fernandes Veludo et al. Environ Int 2025;200:109540

Activity based micro-environmental surveys

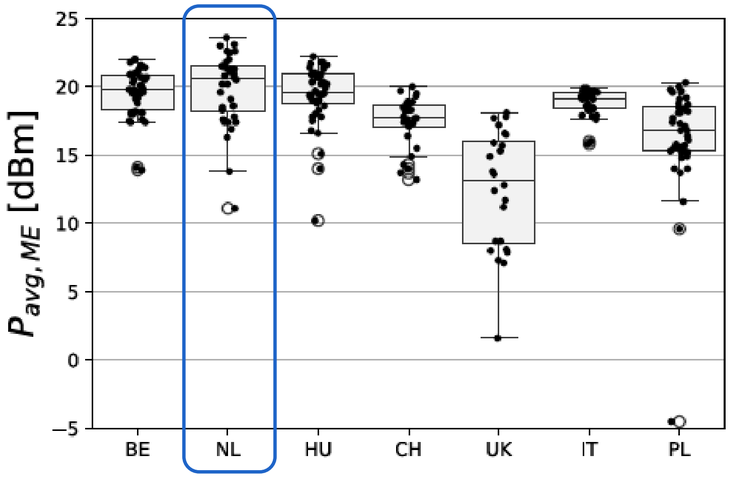
Do precautionary limits do more harm than good?

- The precautionary approach may trigger concern ("where there's smoke, there's fire“) *[e.g. Wiedemann, 2005; Wiedemann, 2013]*
- The precautionary approach may increase trust and accountability of the government
- Trust in our research may decrease if we are critical about the precautionary approach

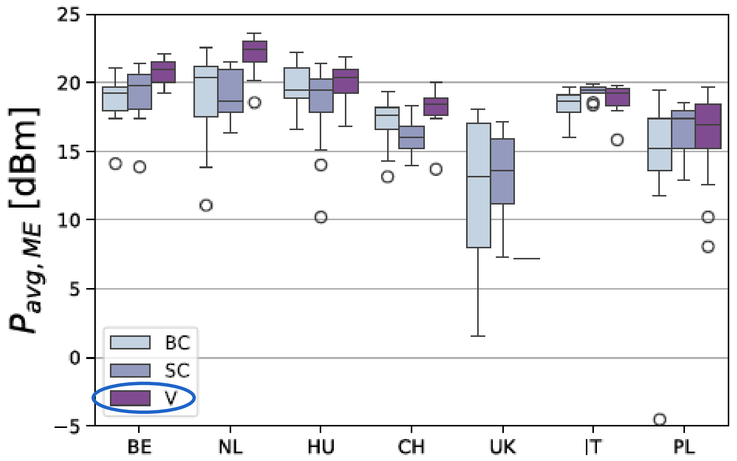


Fernandes Veludo et al. Environ Int 2025;200:109540

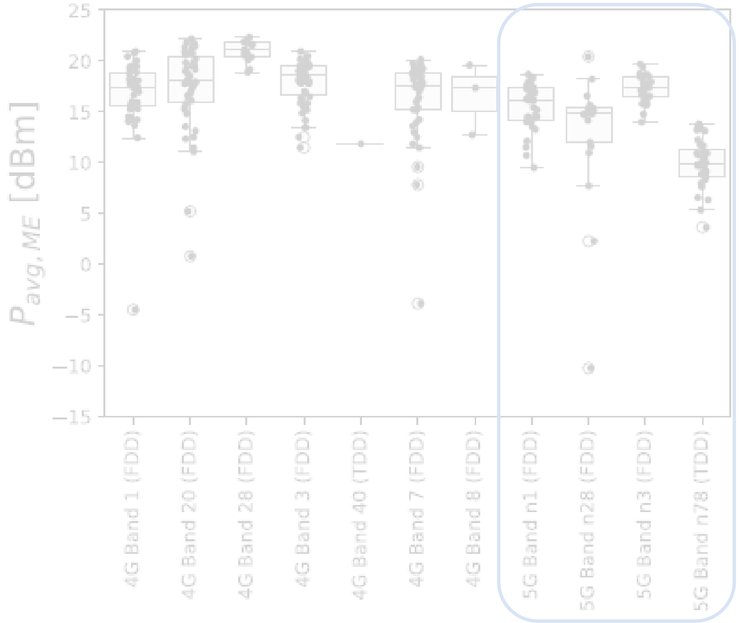
Activity based micro-environmental surveys



- Highest average uplink transmit powers (median 20.6 dBm) in the NL



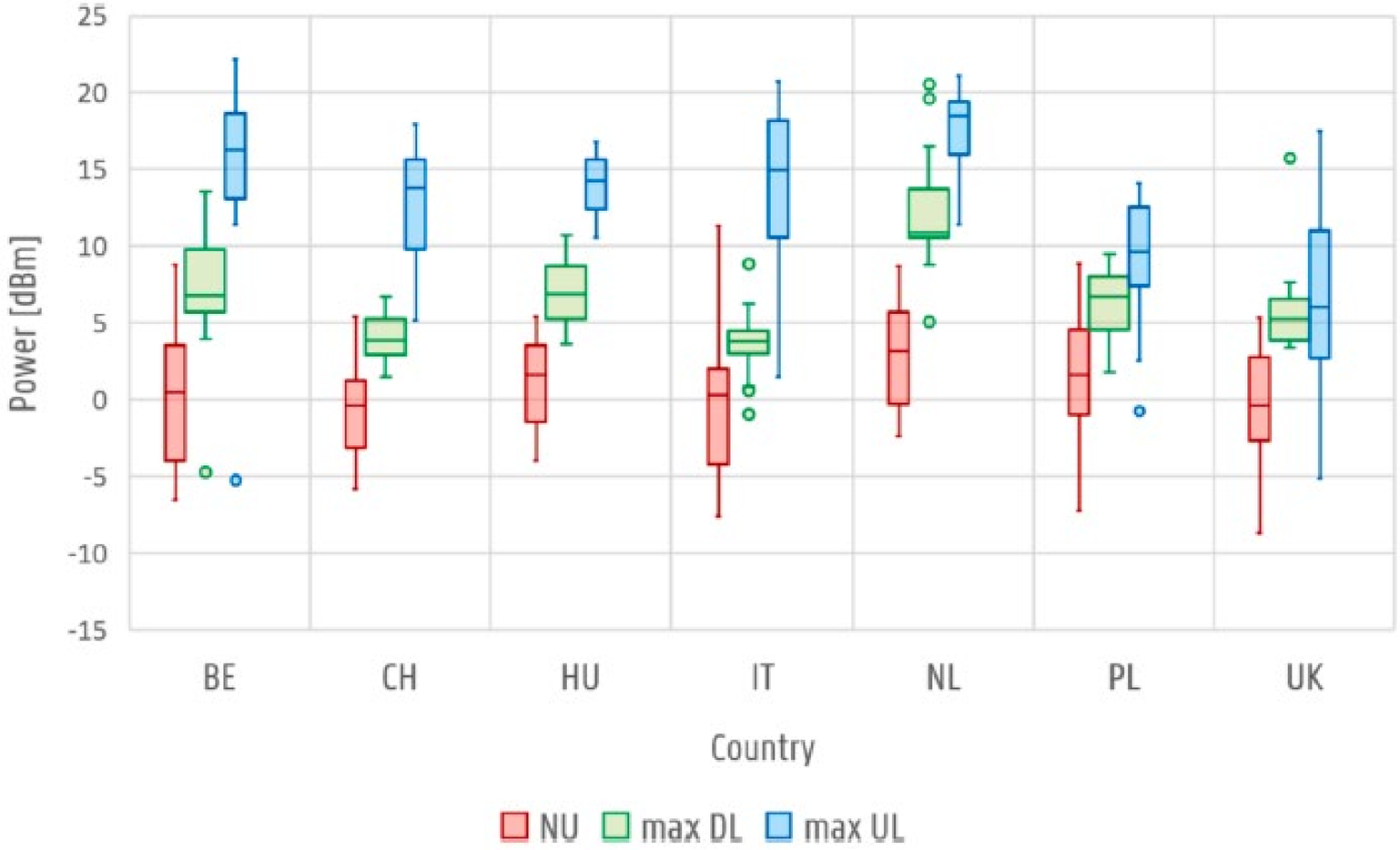
- Villages (V) > Big cities (BC) by 0.6-2.1 dB
- Base station density as key predictor of a-UL exposure



- 4G about 3.3 dB > 5G

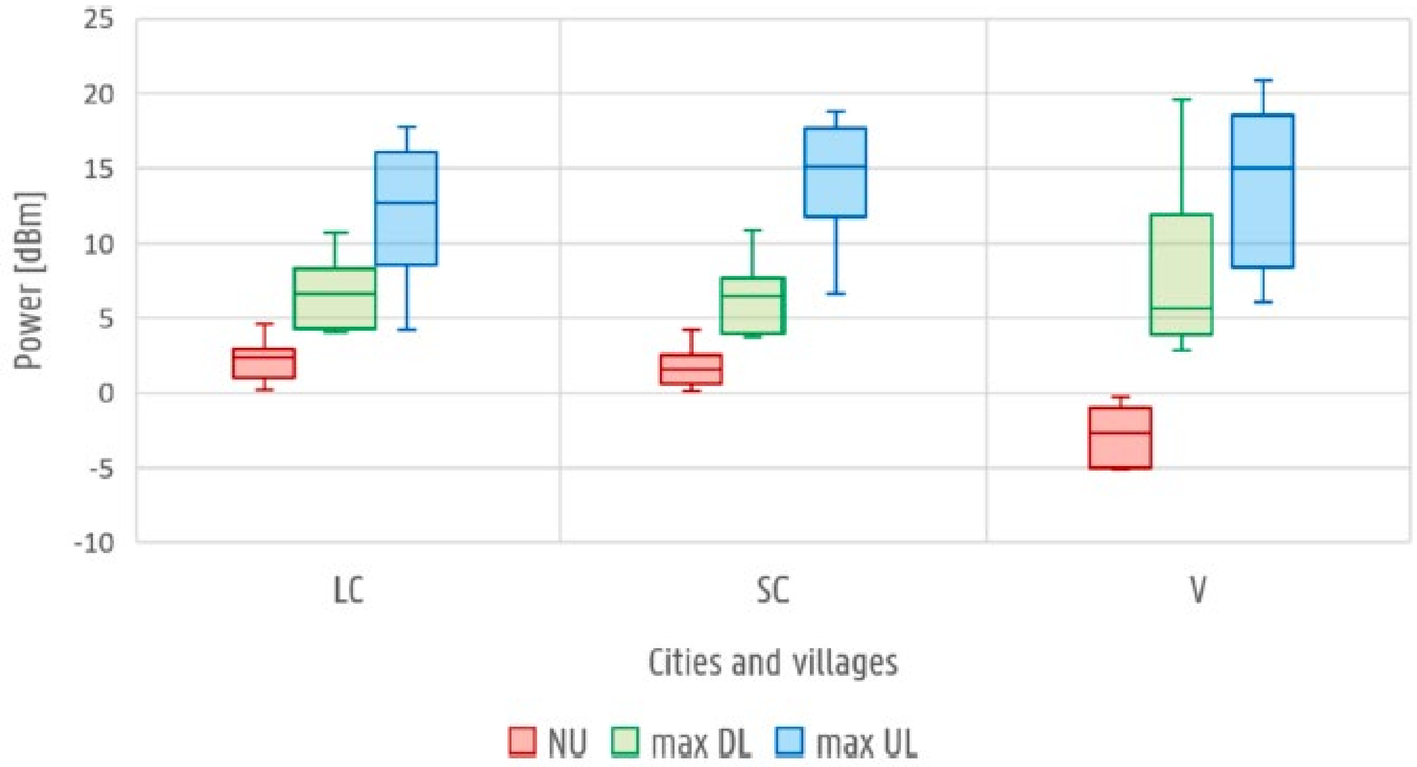
Stroobandt et al. Environ Res 2025;270:121029

Activity based micro-environmental surveys



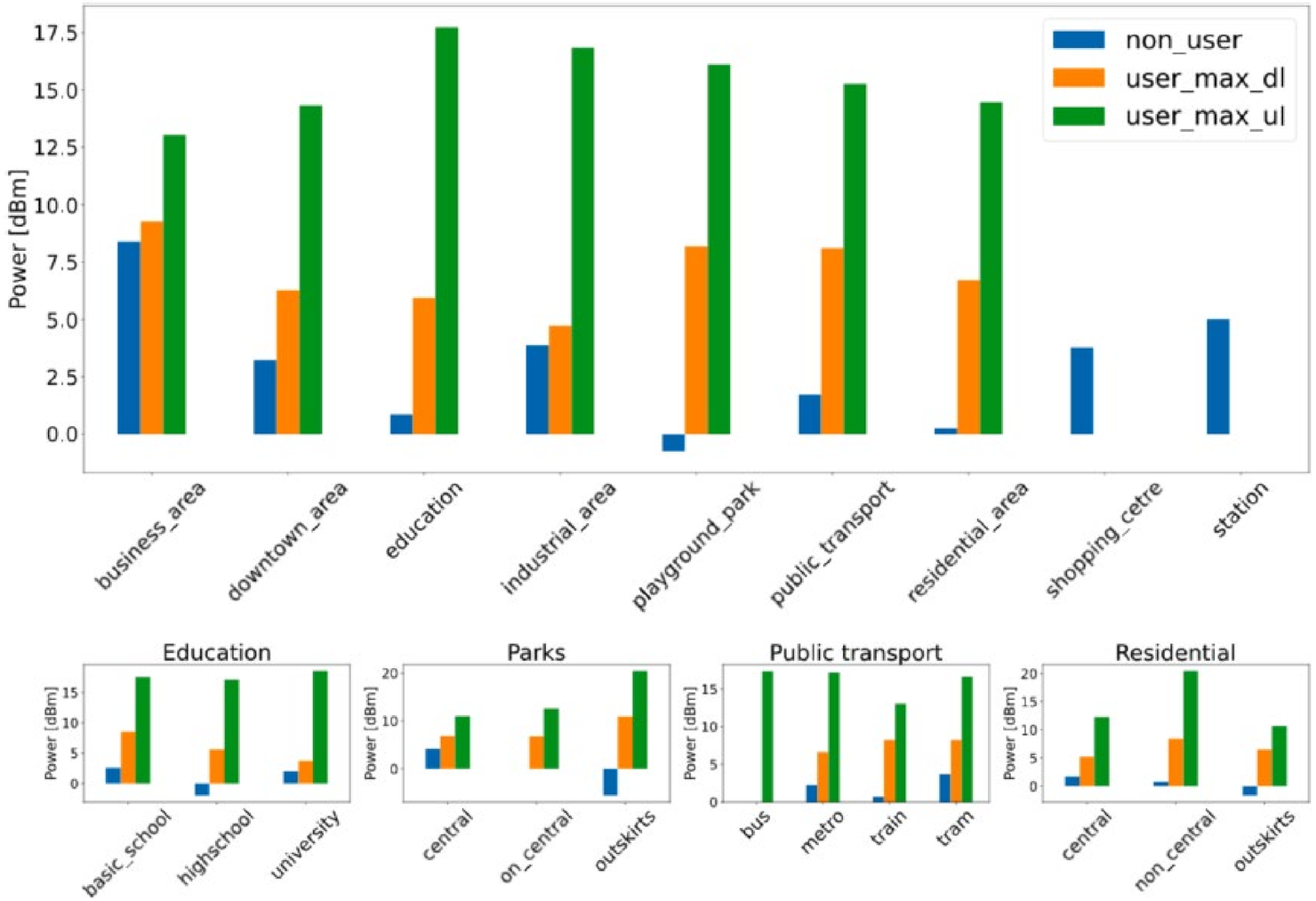
Van Badel et al. Environ Int 2025;197:109368

Activity based micro-environmental surveys



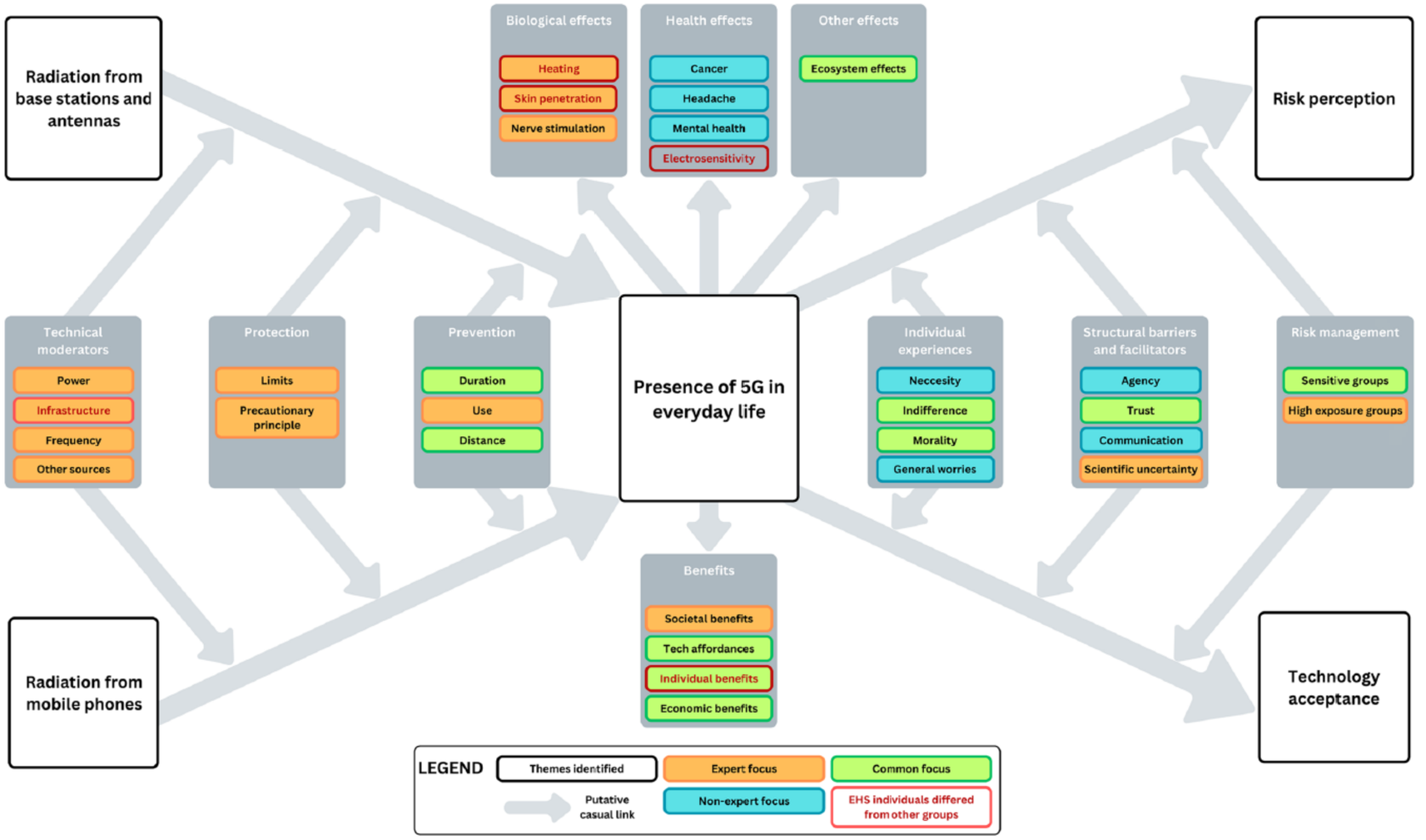
Van Badel et al. Environ Int 2025;197:109368

Activity based micro-environmental surveys



Van Badel et al. Environ Int 2025;197:109368

Mental model of RF-EMF exposures and potential risks to health



Vaupotič et al. J Risk Res 2025;28(5):446-470

ISGlobal Institute for Global Health Barcelona

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Thank you!

GOLiAT

projectgoliat.eu

What do we know, what is uncertain? The perspective of EMF expert groups

Dr Mònica Guxens
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ISGlobal, Spain

Dr Gemma Castaño
Epidemiologist
ISGlobal, Spain

Dr Georg Neubauer
Radio Scientific Advisory
Board (WBF), Austria

Dr Alberto Nájera López
Scientific Advisory
Committee on
Radiofrequencies and
Health (CCARS), Spain

Stefano D'Elia
Vodafone Group,
GSMA EMF and Health
Delegate

Lunch break

Introduction to session 3: National experiences in addressing public concern

Isabel María Álvaro Alonso
Telefónica,
GSMA EMF and Health Delegate

GSMA™

International questionnaire survey on risk perception of EMF among the general public in Japan, Poland, and Germany

Professor Urszula Soler
Warsaw University of
Life Sciences, Poland

GSMA™

INTERNATIONAL QUESTIONNAIRE SURVEY ON RISK PERCEPTION OF EMF AMONG THE GENERAL PUBLIC IN JAPAN, POLAND, AND GERMANY

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INTRODUCTION

While natural EMF sources exist, anthropogenic EMF exposure has increased significantly due to developments in electricity, telecommunications, and medical technologies. Common sources include power lines, household devices, mobile phones, and wireless networks, leading to public concern about potential health effects.

The European Commission conducted surveys on EMF risk perception in 2006 and 2010. With recent advancements like 5G and wireless power transfer, updated surveys are needed to assess current public perceptions and improve risk communication strategies.

In 2023, organizations from Japan, Germany, and Poland signed a Memorandum of Understanding (MoU) to enhance international cooperation on EMF risk communication, and national surveys were conducted in 2024 under this framework.

METHODS

- **Japan: Has conducted an internet survey using Computer-Assisted Web Interviewing (CAWI). The respondents were male and female in 10s to 70s and pregnant women in 20s and 30s (more than 100 in each category/gender), and the total number was 6000.**
- **Poland: Poland did 1015 computer-assisted personal interviews (CAPI) conducted as part of a nationwide OMNIBUS survey.**
- **Germany: Germany conducted its part (2000 respondents) of the survey using Computer-Assisted Telephone Interviewing (CATI).**

MoU countries general: The questions are divided into a General Part (common to all three countries) and a Country-Specific Part; here, the questions in the General Part are outlined.

METHODS

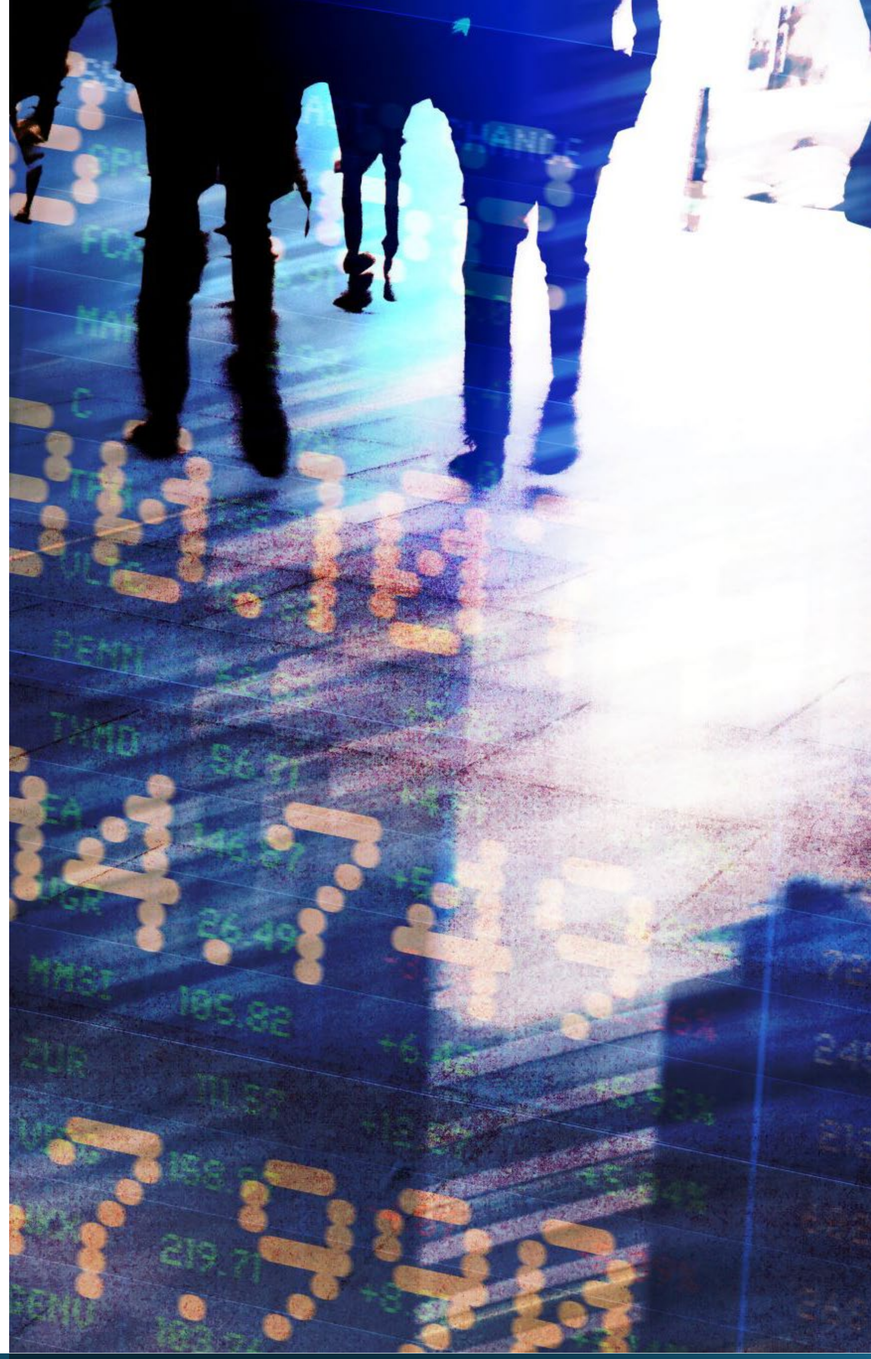
Survey category

1. **Risk perception related to EMF**
2. **Levels of scientific understanding on EMF**
3. **Levels of trustworthiness of EMF risk information**
4. **Expectations towards the sources/organizations/persons of EMF risk information**
5. **Risk perception other than EMF**
6. **Other characteristics**

Respondents were asked to rate their perceived level of risk for each survey item using a 1–5 numerical scale based on a visual analogue scale (VAS) , where:1 = "I am not concerned at all", 2–4 = Increasing levels of concern, 5 = "I am very concerned".

Additionally, two extra response options were provided: 6 = "Cannot determine the degree of risk" and 7 = "Do not understand the question."

The present analysis of risk perception relies on the results of the web-based survey (CAWI) in Japan and compares perceived risk levels using only the VAS responses, with options 6 and 7 excluded.

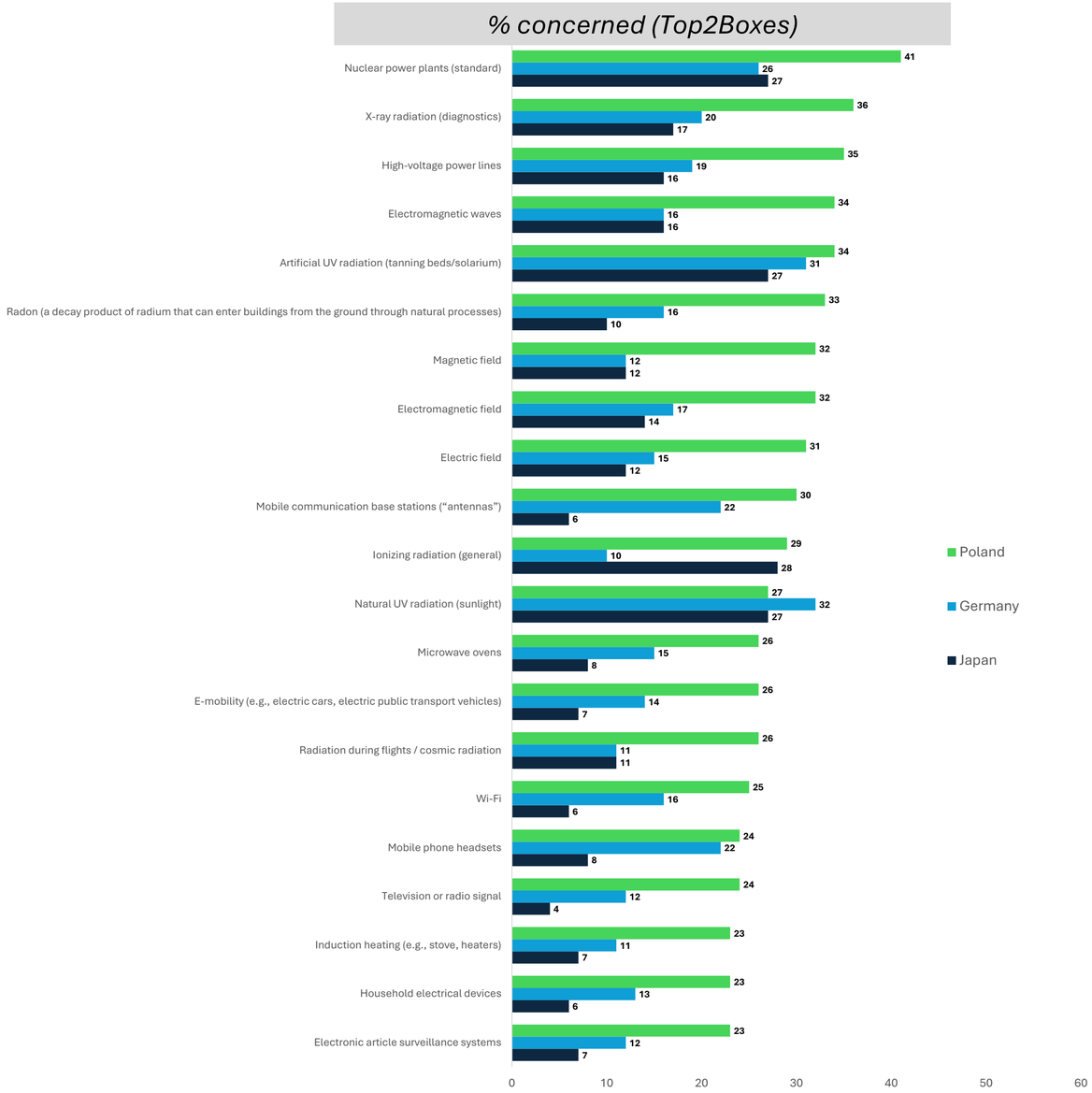


Sources of concern

Q1A. To what extent are you currently concerned about the following issues?
When answering, please use a scale from 1 to 5, where **“1” means you are not concerned about this issue at all**, and **“5” means you are very concerned about this issue**.
Base: Respondents aged 15+, N=1015/2000/6000 (PL/GER/JPN), in %

Concern Index:
Poland = 58.3
Germany = 47.2
Japan = 51.5
The **concern index** is a synthetic measure of perceived anxiety about technologies.
It is calculated as the sum of average concern ratings
for all studied phenomena/devices.
The higher the score, the stronger the concerns.
The maximum possible score is 105, and the minimum is 21.

TOP 5 Technological Sources of Concern:			
	Poland	***Germany***	***Japan***
Nuclear power plants	X	X	X
X-ray radiation (RTG)	X		X
High-voltage power lines	X		
Artificial UV radiation	X	X	X
Electromagnetic waves	X		
Natural UV radiation		X	X
Mobile phone headsets		X	
Mobile communication base stations		X	
Ionizing radiation			X

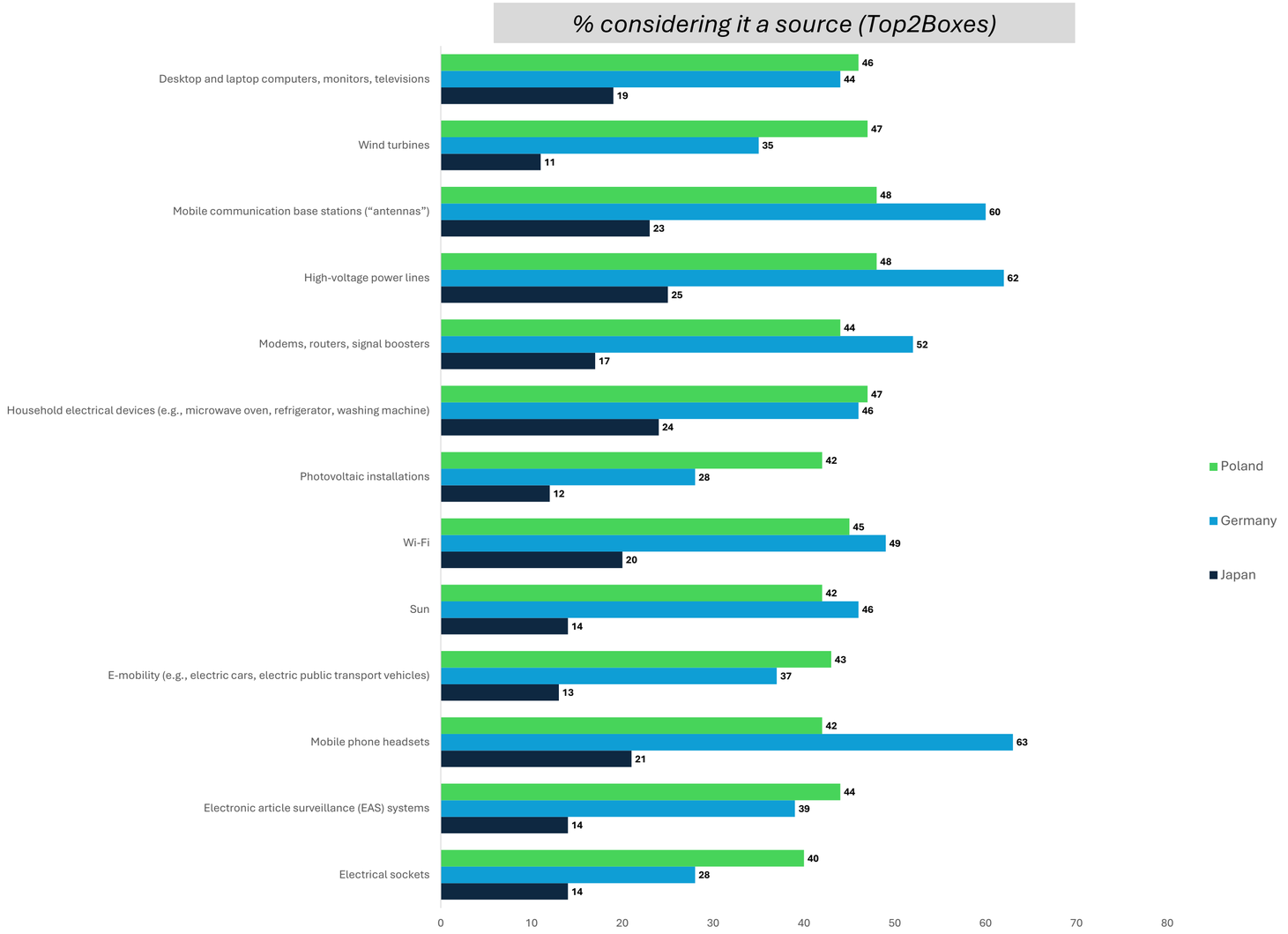


Knowledge about sources of EMF

Q2A. Which of the following devices or phenomena do you think are sources of electromagnetic fields?
When answering, please use a scale from 1 to 5, where **"1" means this device or phenomenon is definitely not a source of electromagnetic fields**, and **"5" means this device or phenomenon is definitely a source of electromagnetic fields**. *Base: Respondents aged 15+, N=1015/2000/6000 (PL/GER/JPN), in %*

Knowledge Index:
Poland = 42.2
Germany = 42.7
Japan = 38.5
The **knowledge index** is a synthetic measure of perceiving phenomena/devices as sources of EMF.
It is calculated as the sum of average ratings across all studied phenomena/devices.
The higher the score, the more frequently the phenomena/devices are perceived as EMF sources.
The maximum possible score is 65, and the minimum is 13.

TOP 3 Sources of EMF:			
	Poland	***Germany***	***Japan***
Desktop and laptop computers, monitors, televisions	X		
High-voltage power lines	X	X	X
Mobile communication base stations	X	X	X
Mobile phone headsets		X	
Household electrical devices	X		X
Windmills generating electricity	X		



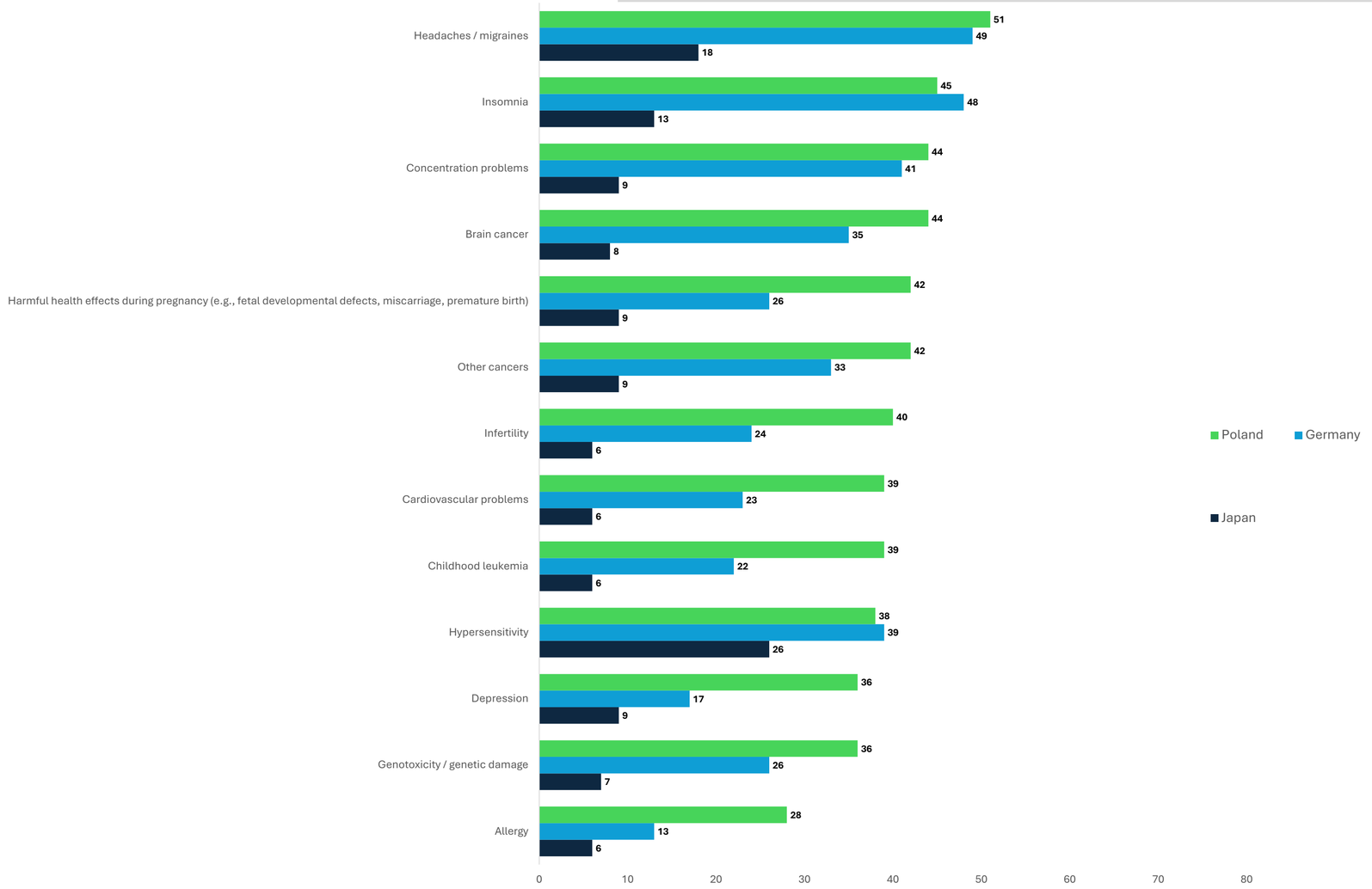
Health effects caused by EMF

Q2B. What adverse health effects, if any, do you think electromagnetic fields may cause?
When answering, please again use a scale from 1 to 5, where **“1” means electromagnetic fields definitely do not cause such health effects**, and **“5” means electromagnetic fields definitely may cause such health effects**. *Base: Respondents aged 15+, N=1015/2000/6000 (PL/GER/JPN), in %*

Knowledge Index on Health Effects:
Poland = 42.9
Germany = 36.6
Japan = 35.2
The **knowledge index** is a synthetic measure of perceiving EMF as a cause of health conditions.
It is calculated as the sum of average ratings assigned to individual health conditions.
The higher the score, the more frequently EMF is attributed as responsible for health problems.
The maximum possible score is 65, and the minimum is 13.

TOP 3 Health Effects Caused by EMF:			
	Poland	***Germany***	***Japan***
Headaches / migraines	X	X	X
Insomnia	X	X	X
Brain cancer	X		
Hypersensitivity		X	X
Concentration problems	X		

% considering it a cause of health problems (Low2Boxes)



Trust in media sources of information

Q3A. Overall, to what extent do you trust information about electromagnetic fields and health from the following sources?
When answering, please use a scale from 1 to 5, where **“1” means you do not trust information about electromagnetic fields and health from this source at all**, and **“5” means you trust information from this source completely**. *Base: Respondents aged 15+, N=1015/2000/6000 (PL/GER/JPN), in %*

Media Trust Index:

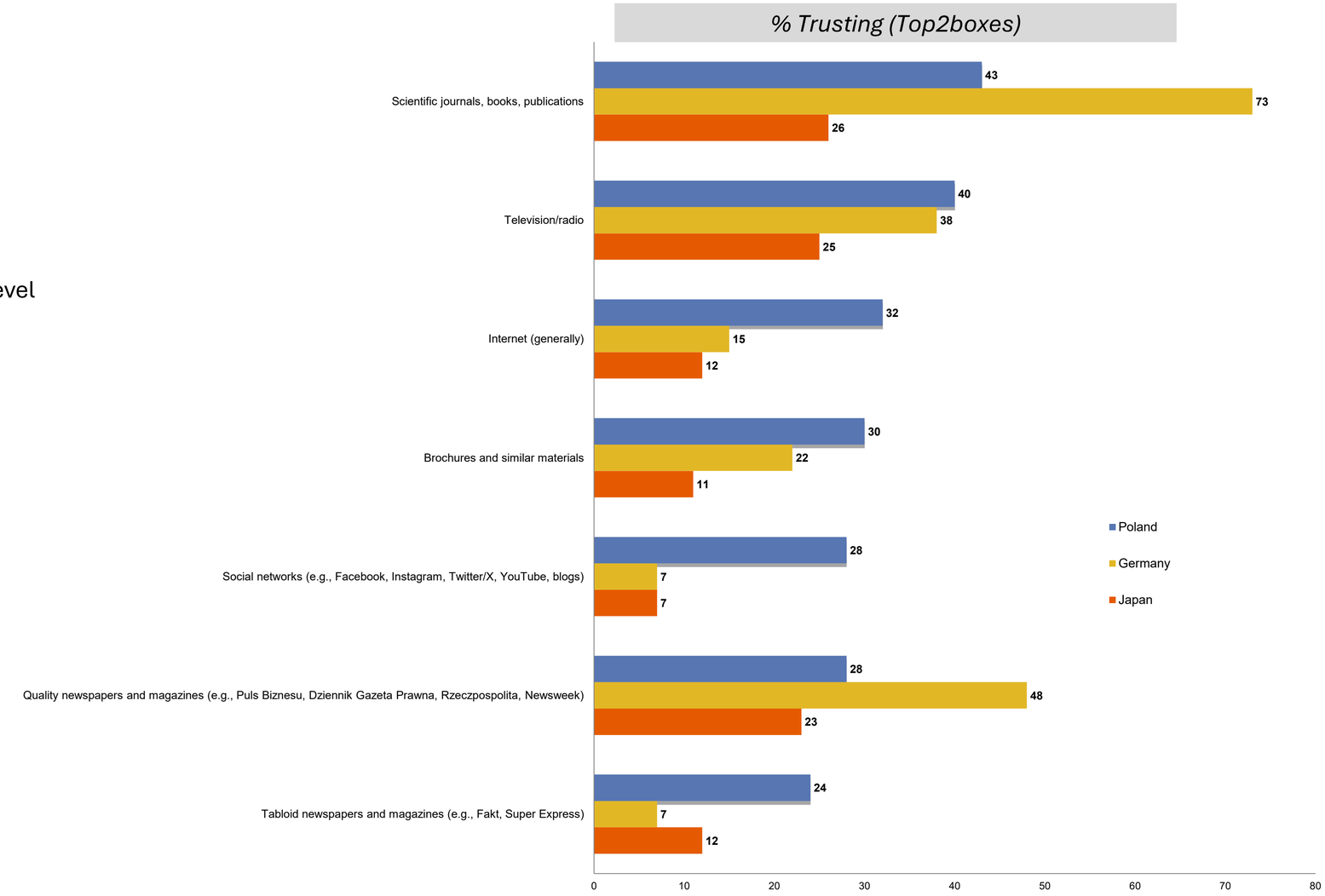
Poland = 21,6

Germany = 19,5

Japan = 20,2

Trust Index
The trust index is a synthetic measure of perceived trust, in this case toward different types of media.
It is calculated as the sum of average trust ratings assigned to individual types of media. The higher the score, the greater the level of trust. The maximum possible score is 35, and the minimum is 7.

TOP 2 Trusted Media Sources:			
	Poland	***Germany***	***Japan***
Scientific journals, books, publications	X	X	X
Television / radio	X		X
Quality newspapers and magazines		X	



Trust in institutional sources of information

Q3B. And to what extent do you trust information about electromagnetic fields and health coming from ...?
Base: Respondents aged 15+, N=1015/2000/6000 (PL/GER/JPN), in %

Media Trust Index:

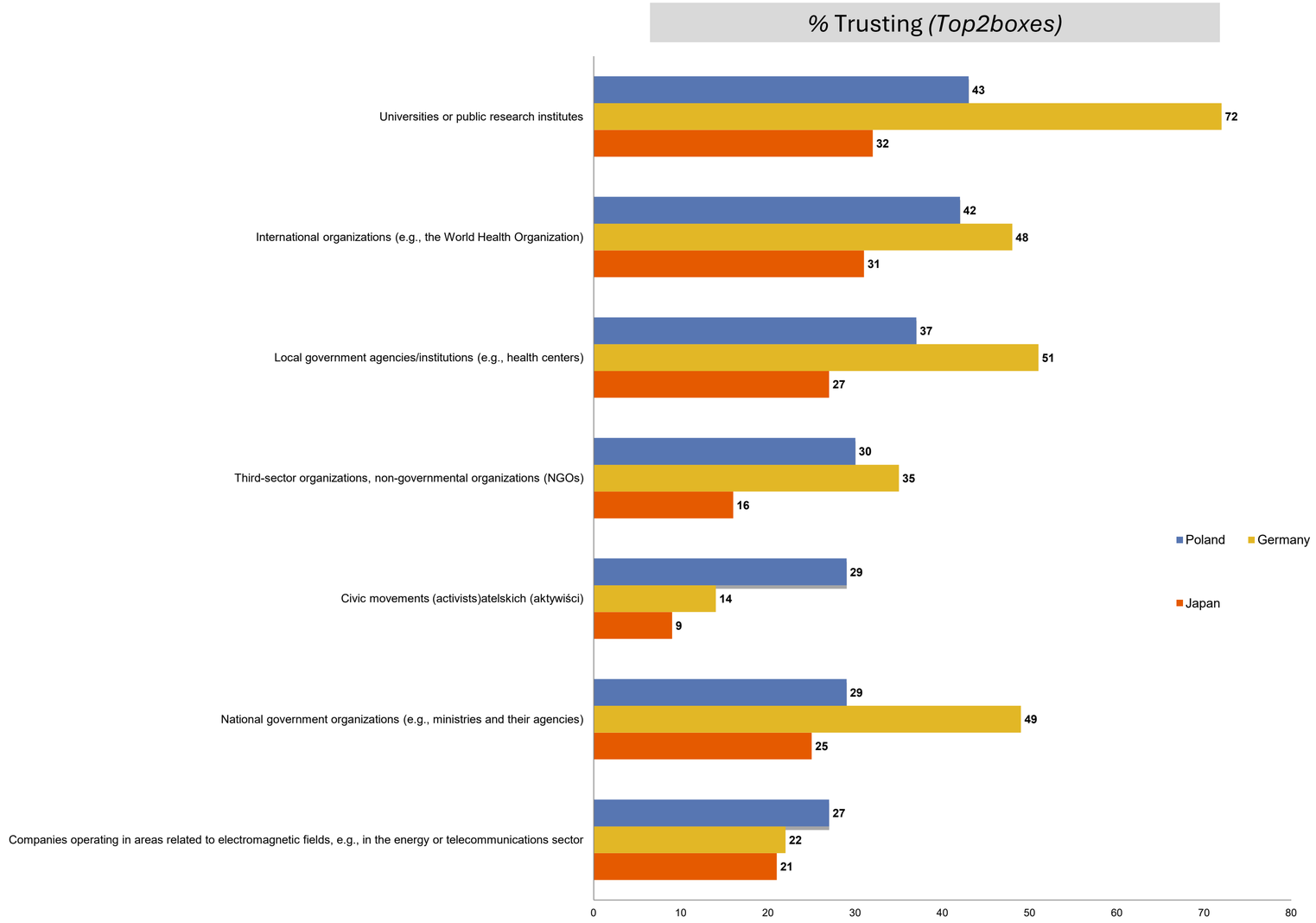
Poland = 22,1

Germany = 22,3

Japan = 21,4

The trust index is a synthetic measure of perceived trust, in this case toward different types of institutions.
It is calculated as the sum of average trust ratings assigned to individual types of institutions.
The higher the score, the greater the level of trust.
The maximum possible score is 35, and the minimum is 7.

TOP 2 Trusted Institutional Sources:			
	Poland	***Germany***	***Japan***
Universities, public research institutes	**X**	**X**	**X**
International organizations	**X**		
Local government agencies/institutions		**X**	

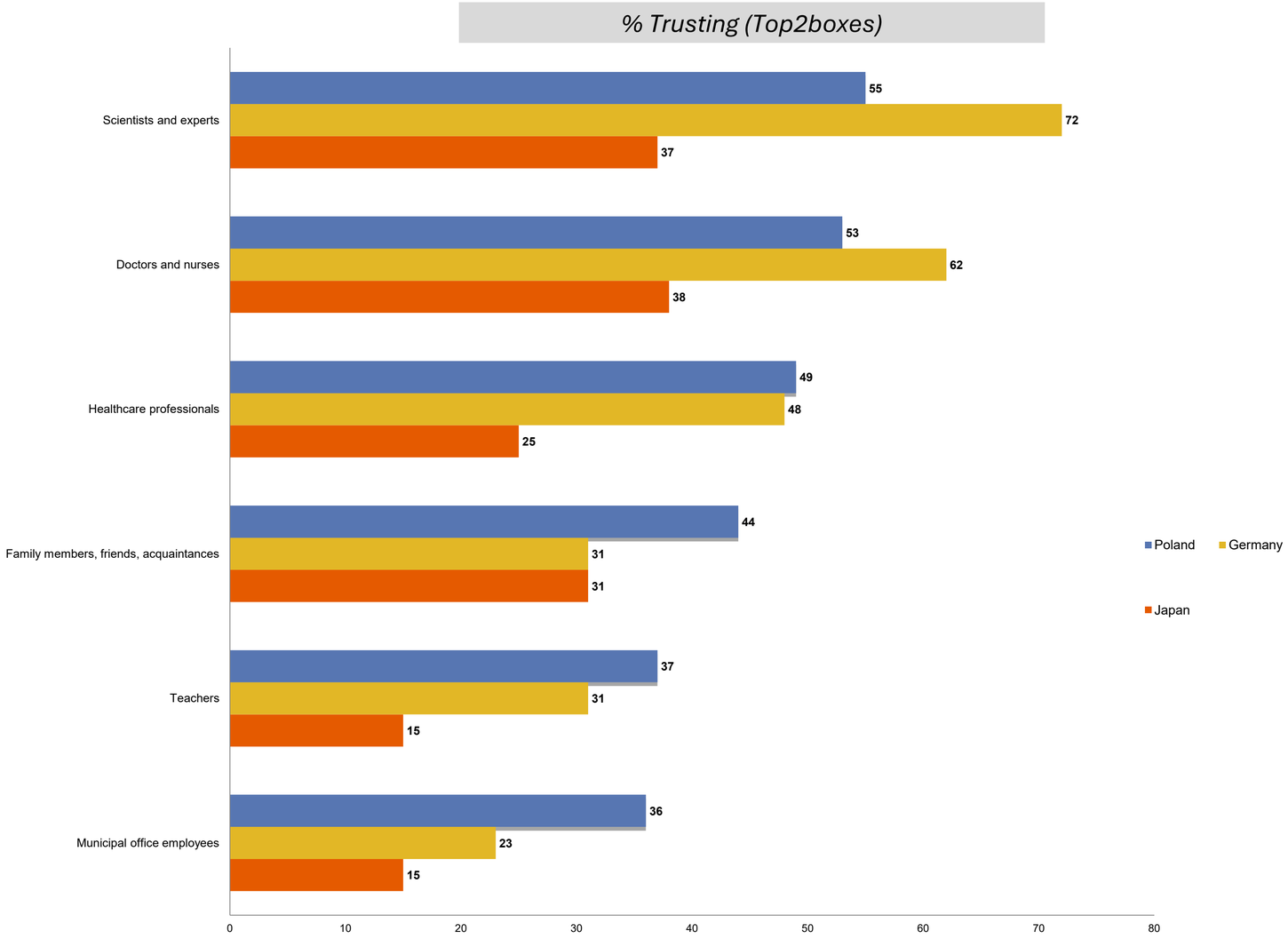


Trust in personal sources of information

Q3C. And to what extent do you trust information about electromagnetic fields and health coming from ...?
Base: Respondents aged 15+, N=1015/2000/6000 (PL/GER/JPN), in %

Personal Trust Index:
Poland = 20.2
Germany = 20.0
Japan = 18.8
The **trust index** is a synthetic measure of perceived trust, in this case toward different types of individuals.
It is calculated as the sum of average trust ratings assigned to each type of person.
The higher the score, the greater the level of trust.
The maximum possible score is 30, and the minimum is 6.

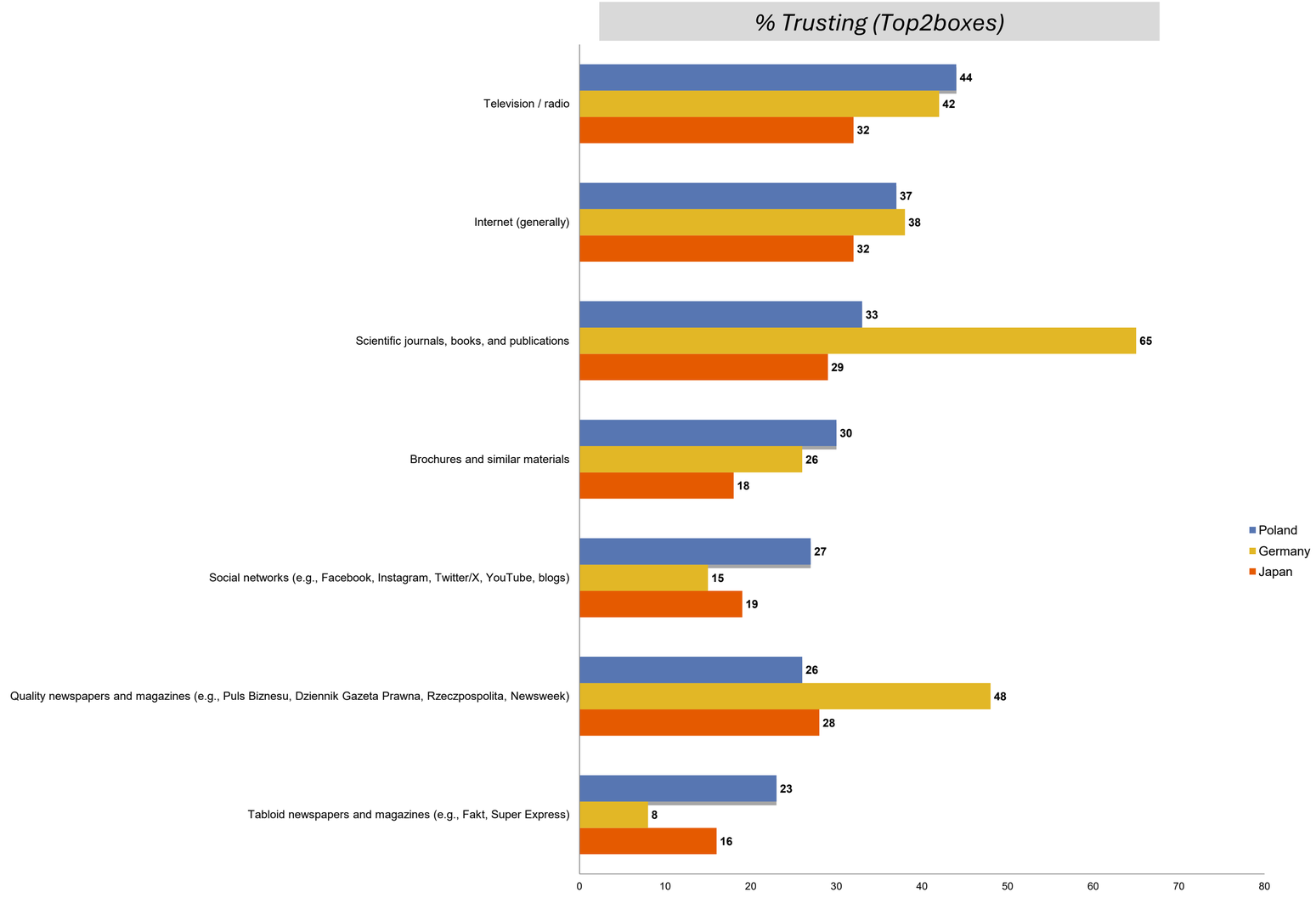
TOP 2 Trusted Personal Sources:			
	Poland	***Germany***	***Japan***
Scientists and experts	**X**	**X**	**X**
Doctors and nurses	**X**	**X**	**X**



Preferred media sources of information

Q4A. Would you like to receive more information about electromagnetic fields and health from the following sources?
Base: Respondents aged 15+, N=1015/2000/6000 (PL/GER/JPN), in %

Media Preference Index:
Poland = 12.4
Germany = 12.0
Japan = 13.8
The **index** is a synthetic measure of preferences,
in this case regarding different types of media.
It is calculated as the sum of average preference
ratings assigned to individual types of media.
The higher the score, the stronger the level of preference.
The maximum possible score is 21,
and the minimum is 7 (3 points for each preferred medium,
2 points for lack of decisiveness – “not sure” or
“don’t know,” and 1 point for no preference).



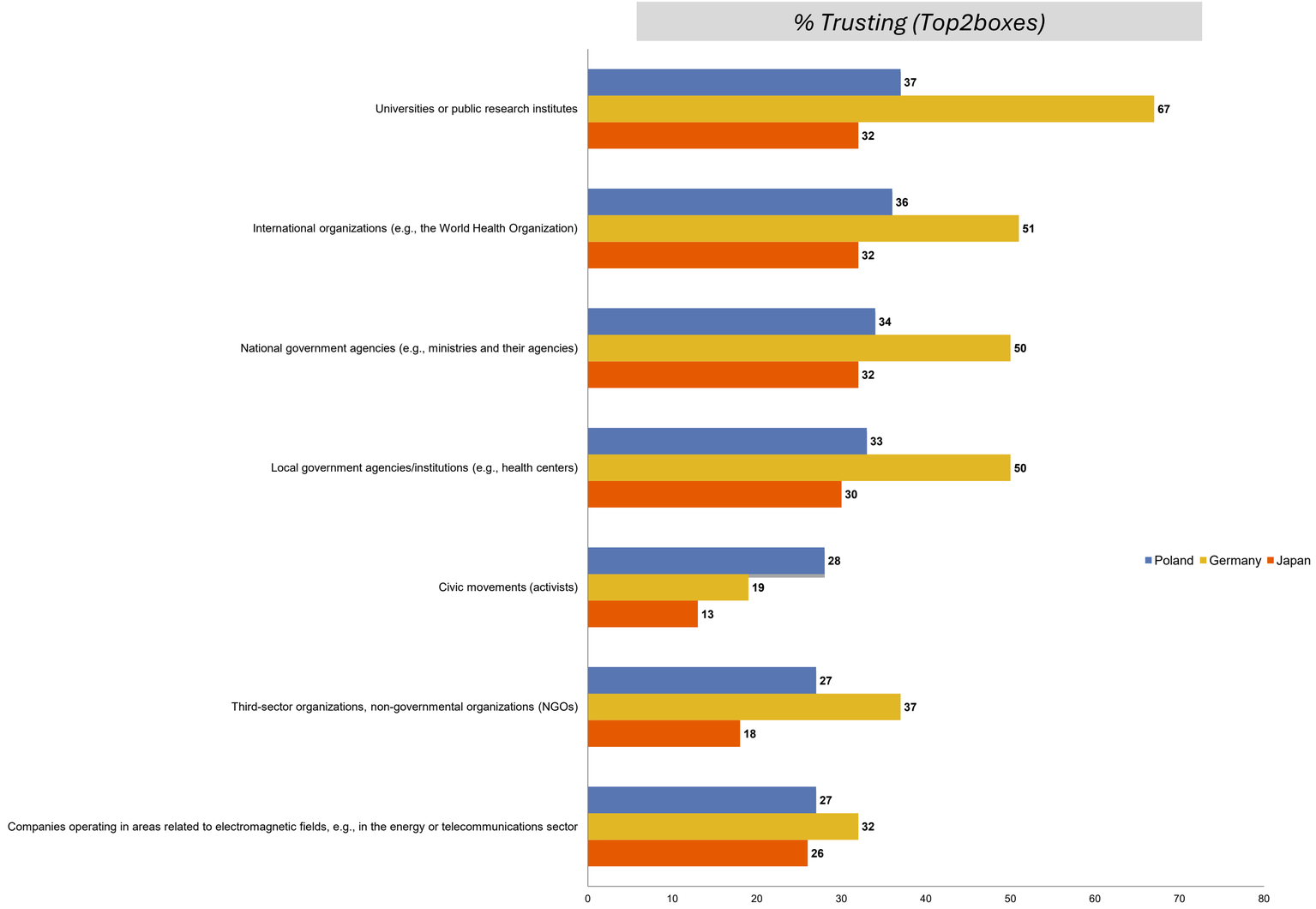
TOP 2 Preferred Media Sources:			
	Poland	***Germany***	***Japan***
Television / radio	**X**		**X**
Internet (generally)	**X**		**X**
Scientific journals, books, and publications		**X**	
Quality newspapers and magazines		**X**	

Preferred institutional sources of information

Q4B. Would you like to receive more information about electromagnetic fields and health from the following sources?
Base: Respondents aged 15+, N=1015/2000/6000 (PL/GER/JPN), in %

Institutional Preference Index:
Poland = 12.5
Germany = 13.2
Japan = 14.2
The **index** is a synthetic measure of preferences, in this case regarding different types of institutions. It is calculated as the sum of average preference ratings assigned to individual types of institutions. The higher the score, the stronger the level of preference. The maximum possible score is 21, and the minimum is 7 (3 points for each preferred institution, 2 points for lack of decisiveness – “not sure” or “don’t know,” and 1 point for no preference).

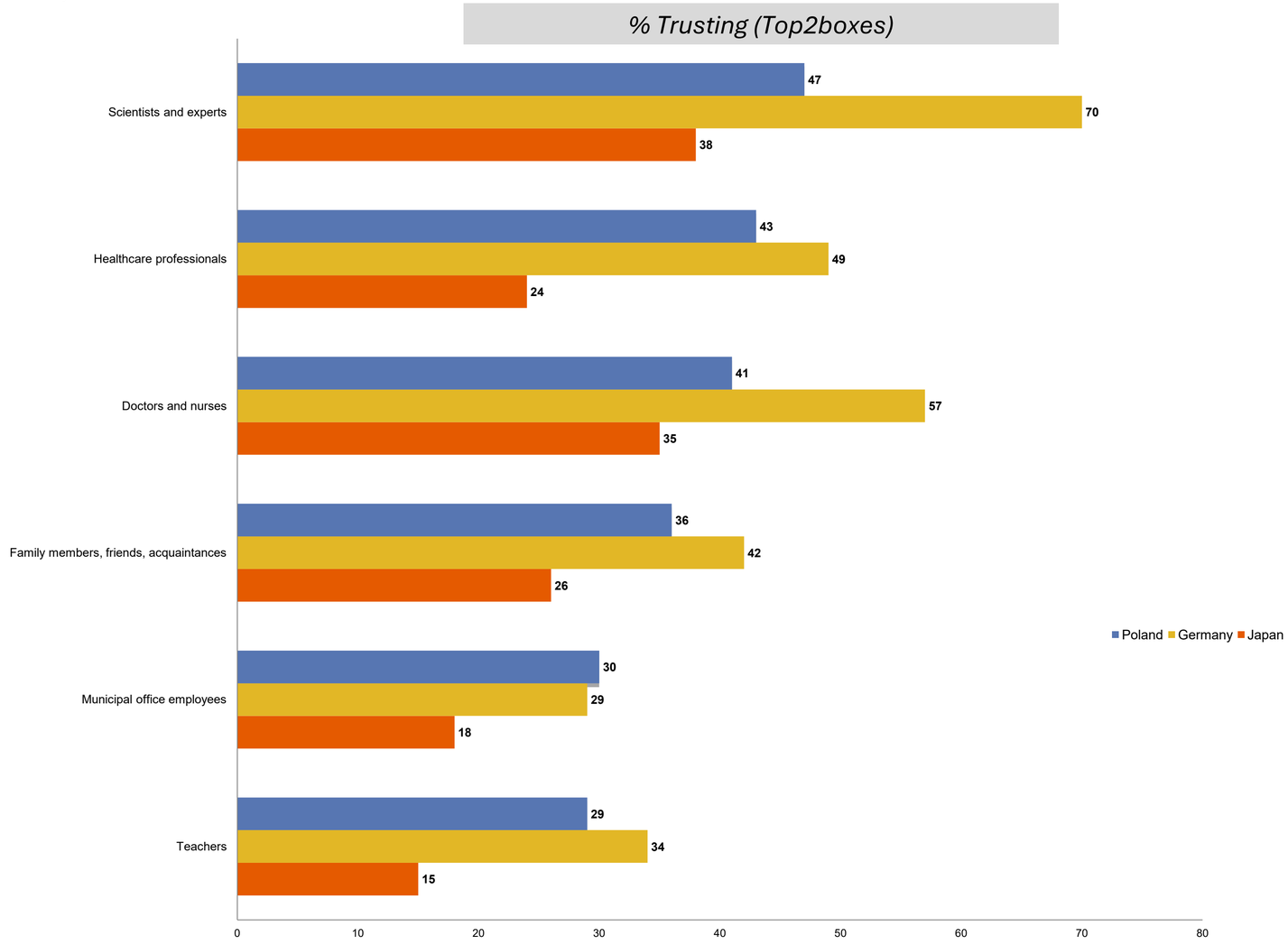
TOP 2 Preferred Institutional Sources:			
	Poland	***Germany***	***Japan***
Universities, public research institutes	**X**	**X**	**X**
International organizations	**X**	**X**	**X**



Preferred personal sources of information

Q4C. Would you like to receive more information about electromagnetic fields and health from the following sources?
Base: Respondents aged 15+, N=1015/2000/6000 (PL/GER/JPN), in %

Personal Preference Index:
Poland = 11.4
Germany = 11.7
Japan = 12.2
The **index** is a synthetic measure of preferences, in this case regarding different types of individuals. It is calculated as the sum of average preference ratings assigned to each type of person. The higher the score, the stronger the level of preference. The maximum possible score is 18, and the minimum is 6 (3 points for each preferred type of person, 2 points for lack of decisiveness – “not sure” or “don’t know,” and 1 point for no preference).



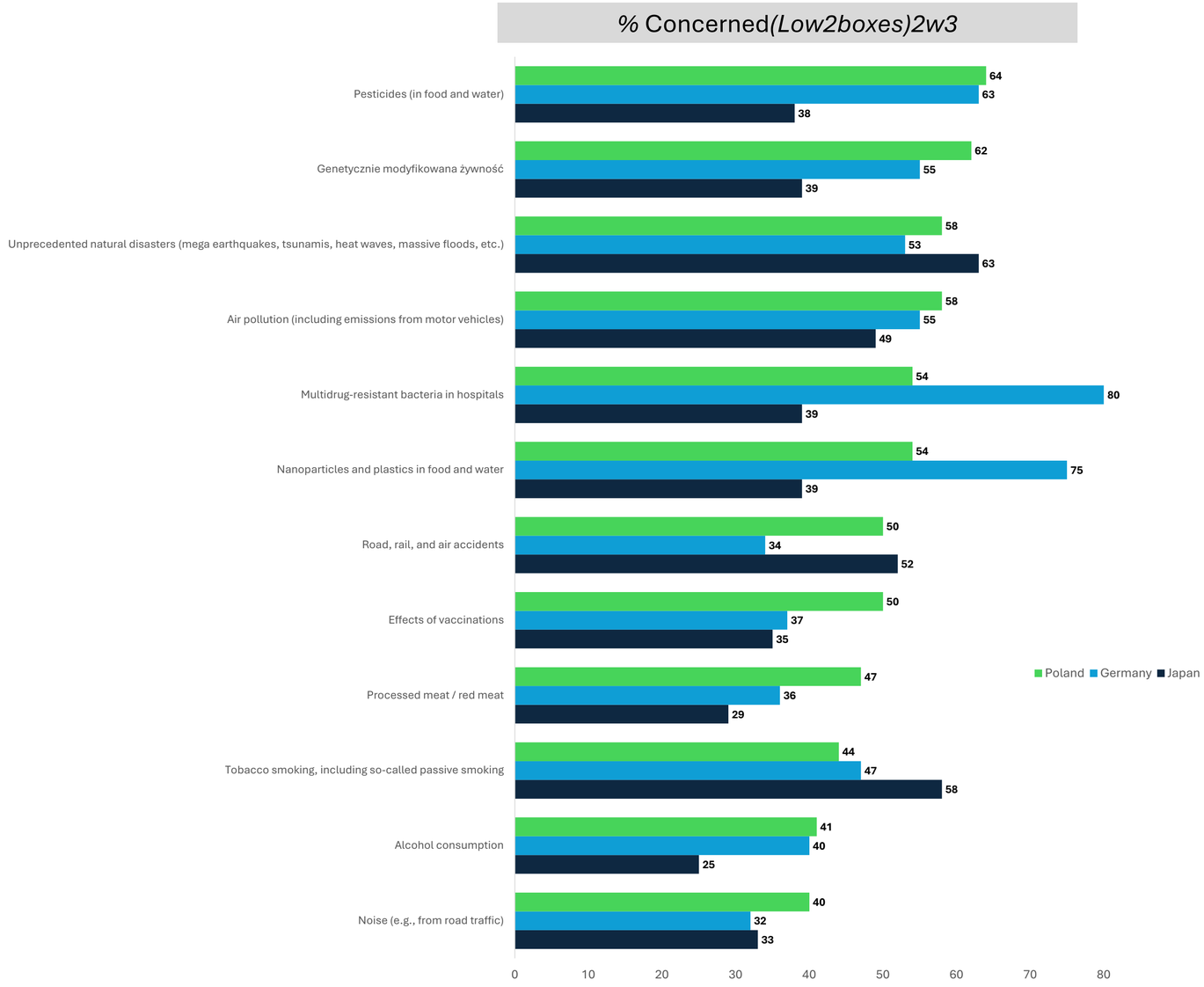
TOP 2 Preferred Personal Sources:			
	Poland	***Germany***	***Japan***
Scientists, experts	**X**	**X**	**X**
Healthcare professionals	**X**		
Doctors and nurses		**X**	**X**

Sources of concern

Q5A. How concerned are you at present about the following issues?
When answering, please use a scale from 1 to 5, where **“1” means you are not concerned at all** and **“5” means you are very concerned**.
Base: Respondents aged 15+, N=1015/2000/6000 (PL/GER/JPN), in %

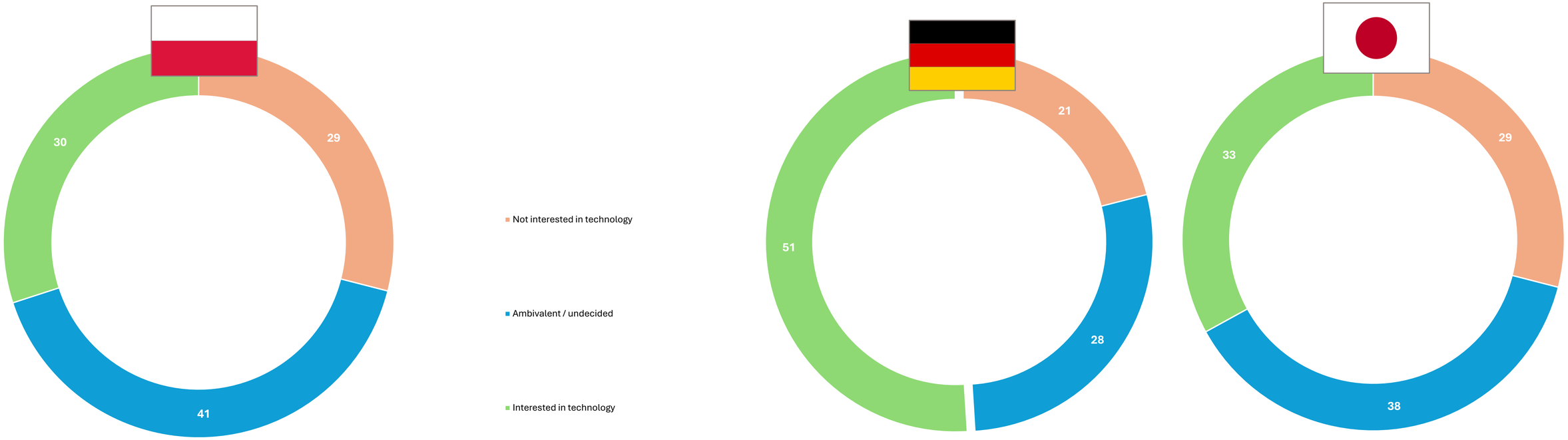
Concern Index:
Poland = 41.3
Germany = 40.7
Japan = 40.6
The **concern index** is a synthetic measure of perceived anxiety regarding various phenomena. It is calculated as the sum of average concern ratings across all studied phenomena. The higher the score, the stronger the concerns. The maximum possible score is 60, and the minimum is 12.

TOP 5 Sources of Concern:			
	Poland	***Germany***	***Japan***
Pesticides	X	X	
Genetically modified food	X	X	X
Air pollution	X	X	X
Unprecedented natural disasters	X		X
Nanoparticles and plastics in food and water	X	X	X
Multidrug-resistant bacteria in hospitals		X	
Road, rail, and air accidents			X
Tobacco smoking, including passive smoking			X



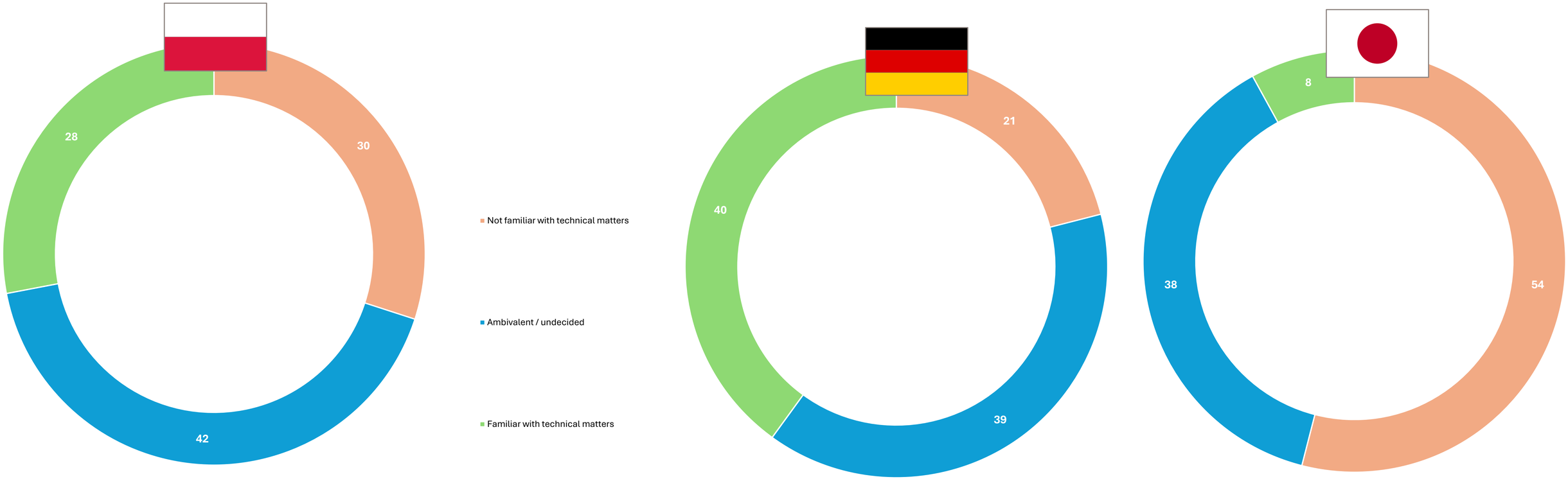
Interest in technology

Q5D1. To what extent are you interested in technology?
When answering, please use a scale from 1 to 5, where **“1” means you are not interested in technology at all**, and **“5” means you are very interested in technology**.
Base: Respondents aged 15+, N=1015/2000/6000 (PL/GER/JPN), in %



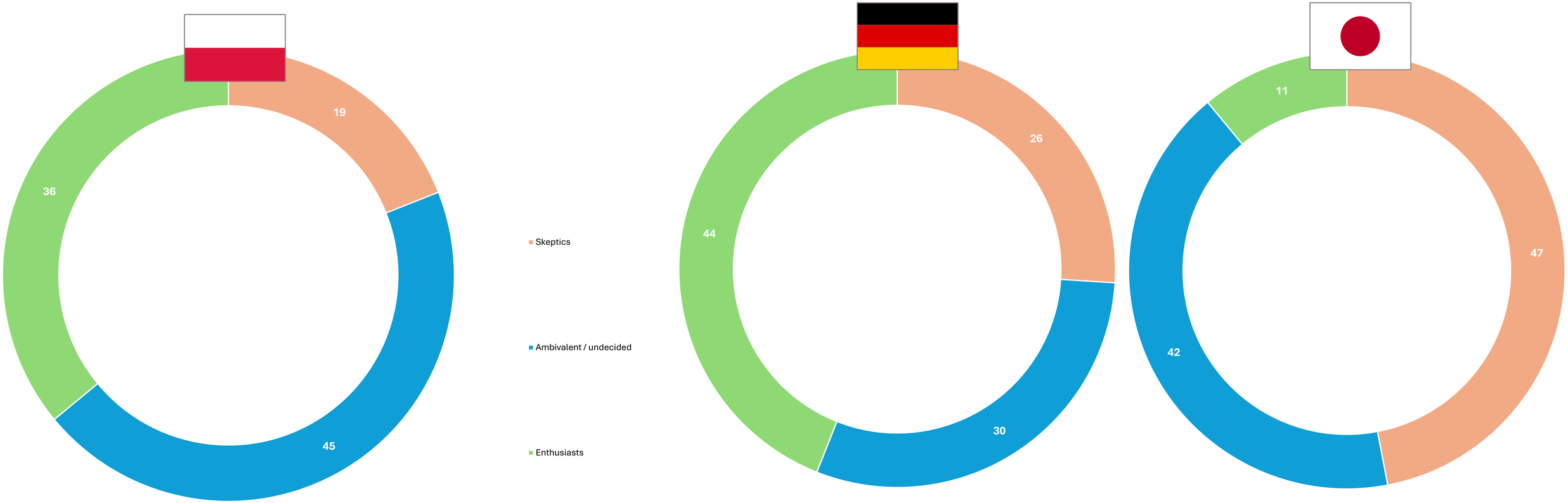
Self-assessment of technical competence

Q5D2. How well do you usually understand technical matters?
When answering, please again use a scale from 1 to 5, where **“1” means you do not understand technical matters at all**, and **“5” means you understand technical matters very well**. *Base: Respondents aged 15+, N=1015/2000/6000 (PL/GER/JPN), in %*



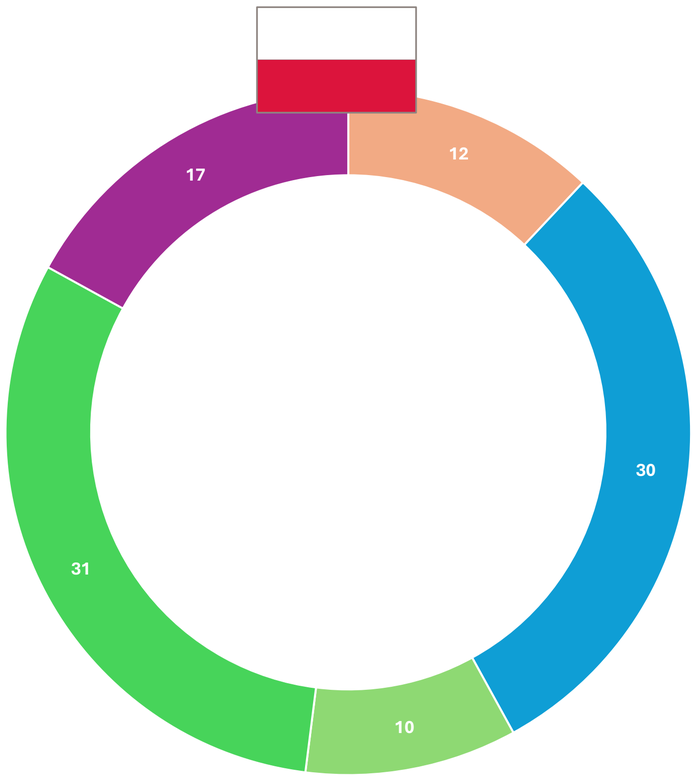
Attitude toward technology

Q5D3. What is your attitude toward technology?
When answering, please again use a scale from 1 to 5, where **“1” means your attitude toward technology is not enthusiastic at all**, and **“5” means your attitude toward technology is very enthusiastic**. *Base: Respondents aged 15+, N=1015/2000/6000 (PL/GER/JPN), in %*

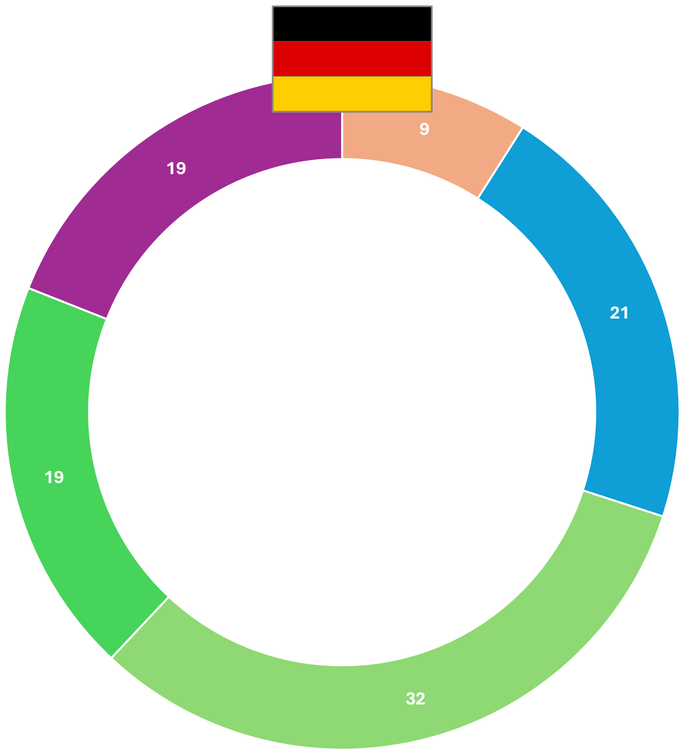


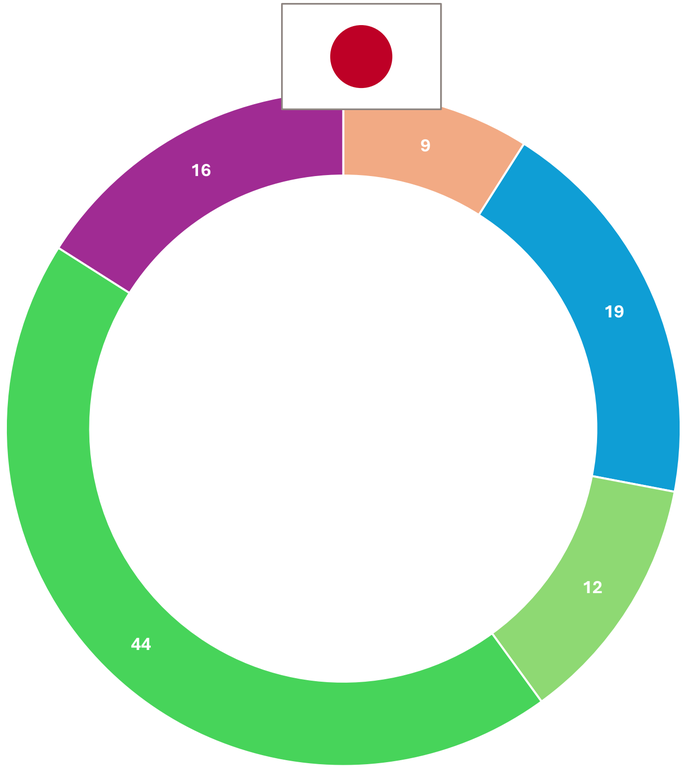
Knowledge about the strength of EMF impact

Q2C. An electric, magnetic, or electromagnetic field can be emitted by power lines or radio antennas.
In your opinion, how does the strength of this field change if the distance from the current-carrying conductor or the antenna is doubled?



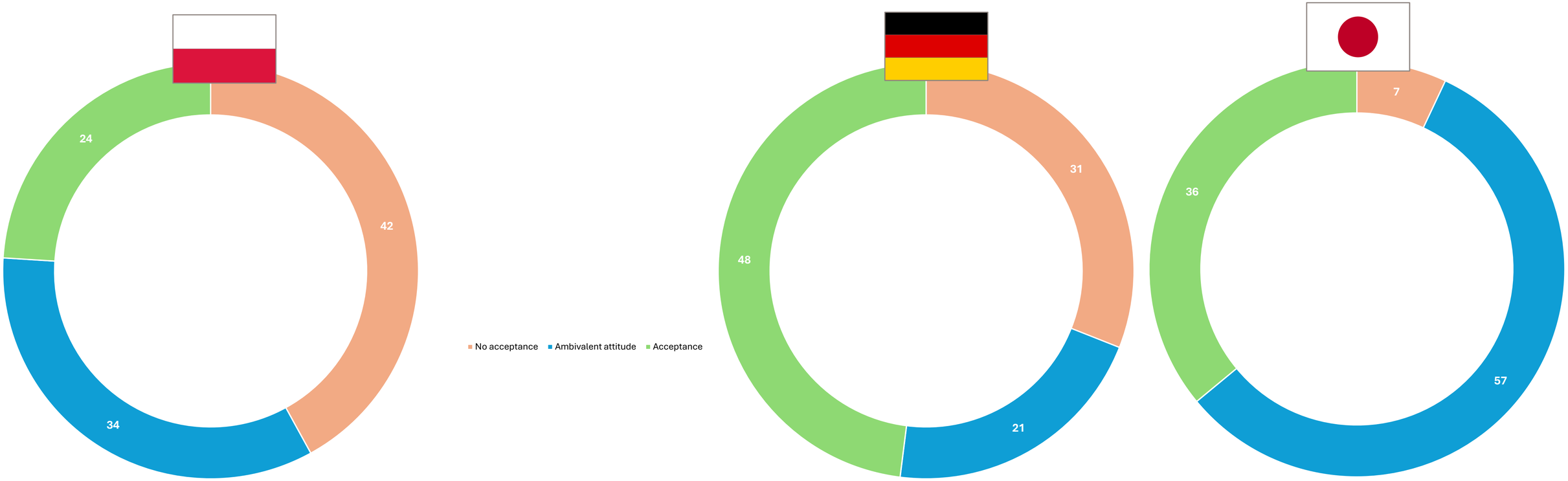
- The strength of this field doubles
- The strength of this field decreases by half
- The strength of this field decreases to one-fourth
- I am not sure
- Hard to say





Acceptance of transmitter construction

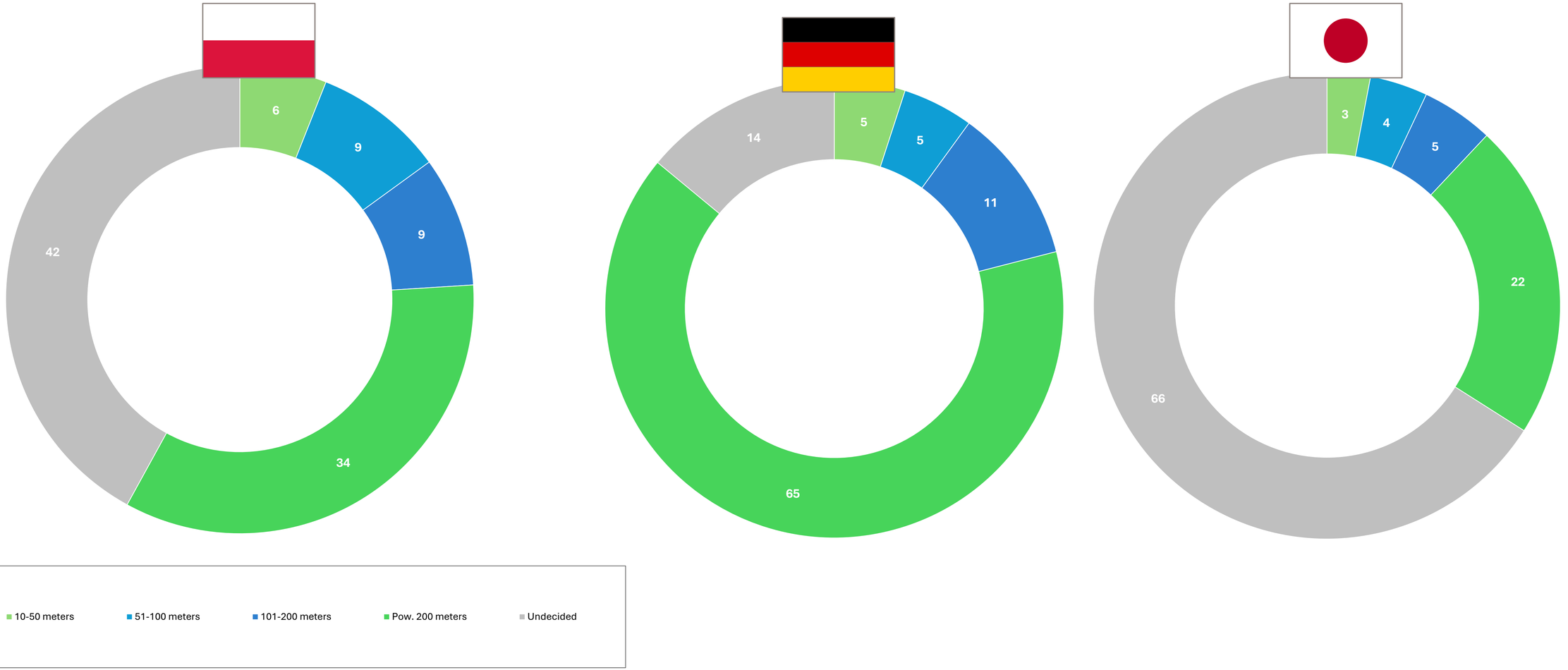
Q1B. Would you agree to the construction of mobile network antennas/transmitters within 500 meters of your place of residence if it increased your mobile network coverage?
When answering, please use a scale from 1 to 5, where **“1” means you would definitely not agree**, and **“5” means you would definitely agree**.
Base: Respondents aged 15+, N=1015/2000/6000 (PL/GER/JPN), in %



Acceptance Index:
Poland = 2.62
Germany = 3.27
Japan = 3.42
The acceptance index is the average rating on the scale.
The higher the score, the greater the acceptance.

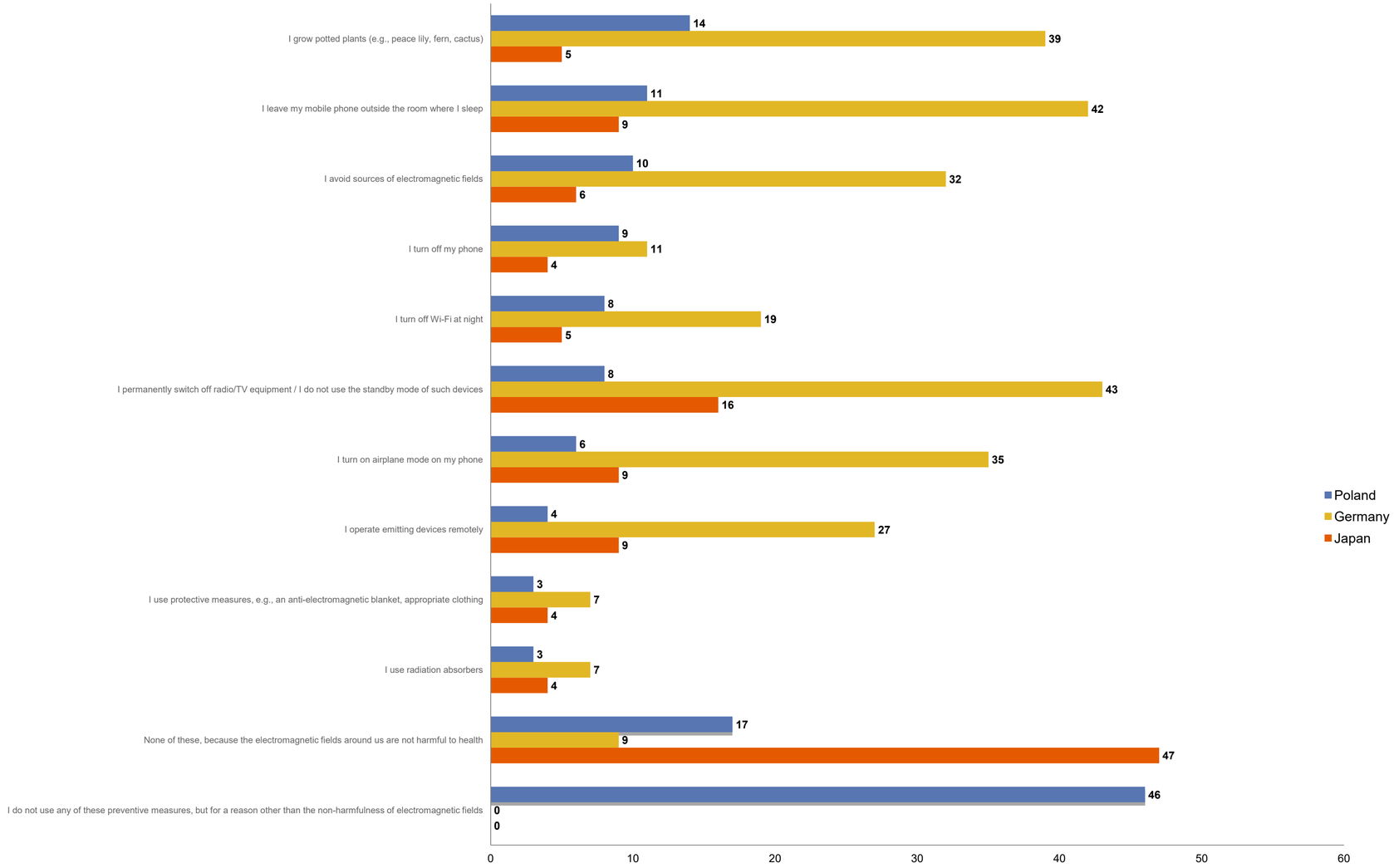
Perception of distance to the nearest HVPL (High-Voltage Power Line)

Q1C. What do you think is the approximate distance from your place of residence to the nearest high-voltage power line?
Base: Respondents aged 15+, N=1015/2000/6000 (PL/GER/JPN), in %



Use of EMF preventive measures

Q2D. What preventive measures, if any, do you take to reduce exposure to electromagnetic fields?
Base: Respondents aged 15+, N=1015/2000/6000 (PL/GER/JPN), in %



Average number of preventive measures used:
Poland = 0.7
Germany = 2.6
Japan = 0.7**

Research Results in an International Perspective

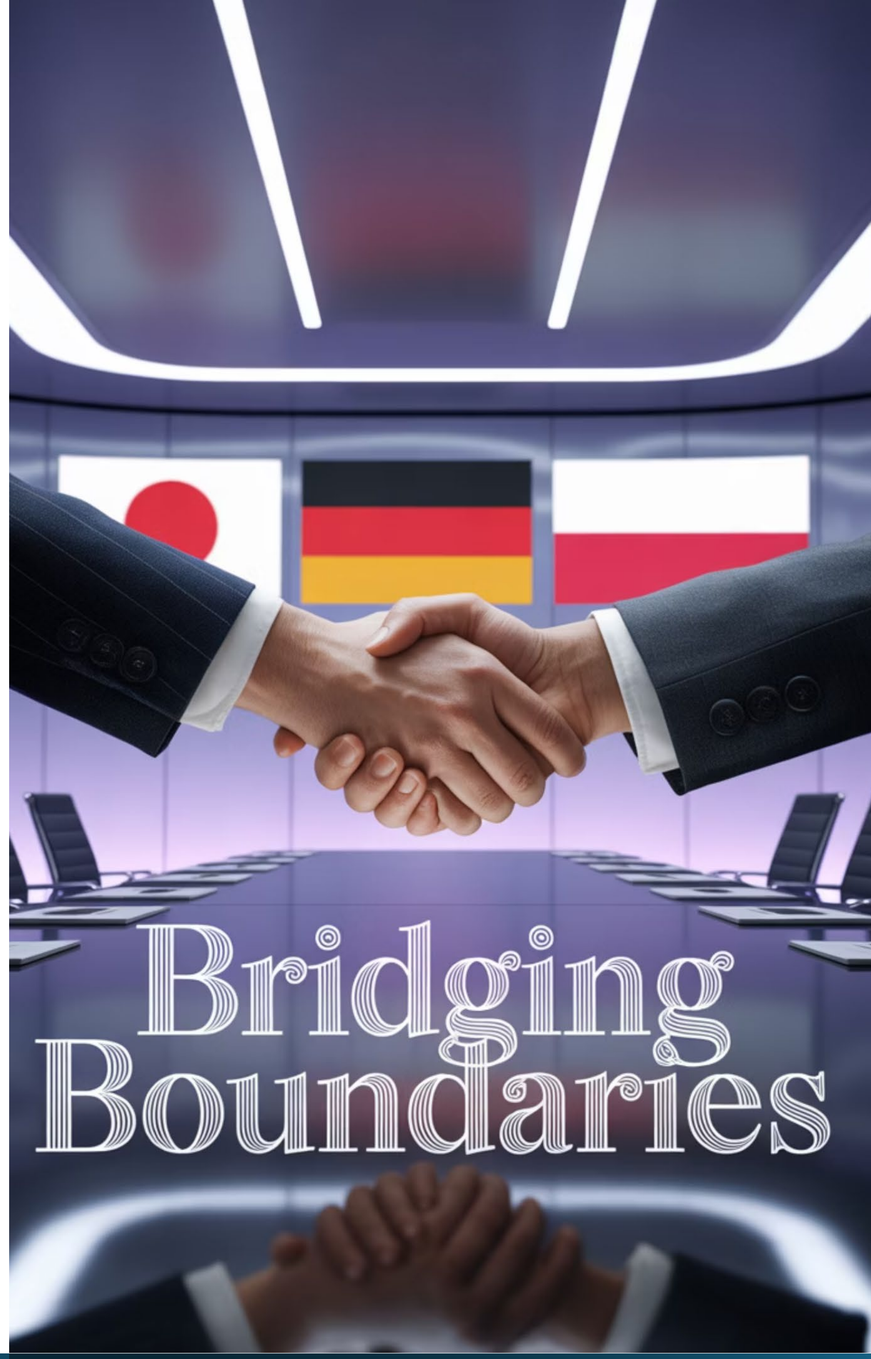
- **Concerns about EMF:**
  - Poles are more worried than respondents in Germany and Japan.
  - In all three countries, nuclear power plants and artificial UV radiation are among the top 5 concerns.
  - Only in Poland: electromagnetic waves and high-voltage power lines are in the top 5.
- **Acceptance of infrastructure:**
  - Highest in Japan.
  - Lowest in Poland.
- **Perception of EMF sources:**
  - Japan: least likely to see studied devices/phenomena as EMF sources.
  - Top 3 in all countries: high-voltage power lines, mobile base stations.
  - Country specifics:
    - Poland: computers, monitors, TVs.
    - Germany: mobile phone headsets.
    - Japan: household electrical devices.
- **Perceived health effects:**
  - Poles attribute more negative effects than Germans or Japanese.
  - Top 3 in all countries: headaches/migraines, insomnia.
  - Specific to Poland: brain cancer linked to EMF.

Research Results in an International Perspective

- **Preventive measures:**
  - Used mainly in Germany.
- **Trust in sources of information:**
  - Poles trust media and personal sources more than Germans or Japanese.
  - In all countries: scientific journals, books, and publications enjoy highest media trust.
  - Germany: highest trust in institutions.
  - In all countries: universities and public research institutes top trusted institutional sources.
  - Scientists/experts and healthcare professionals are the most trusted personal sources everywhere.
- **Preferred channels of information:**
  - Japan: calls for more information from all three types of sources.
  - Poland & Japan: mainly TV/radio and internet.
  - Germany: scientific journals, books, quality newspapers/magazines.
  - In all three: universities, international organizations, scientists/experts, and healthcare professionals are desired sources.

Thank you for your attention!

This comprehensive international study provides valuable insights into public perception of electromagnetic fields across three diverse countries, informing future risk communication strategies and policy development.



National experiences in addressing public concern related to base station siting

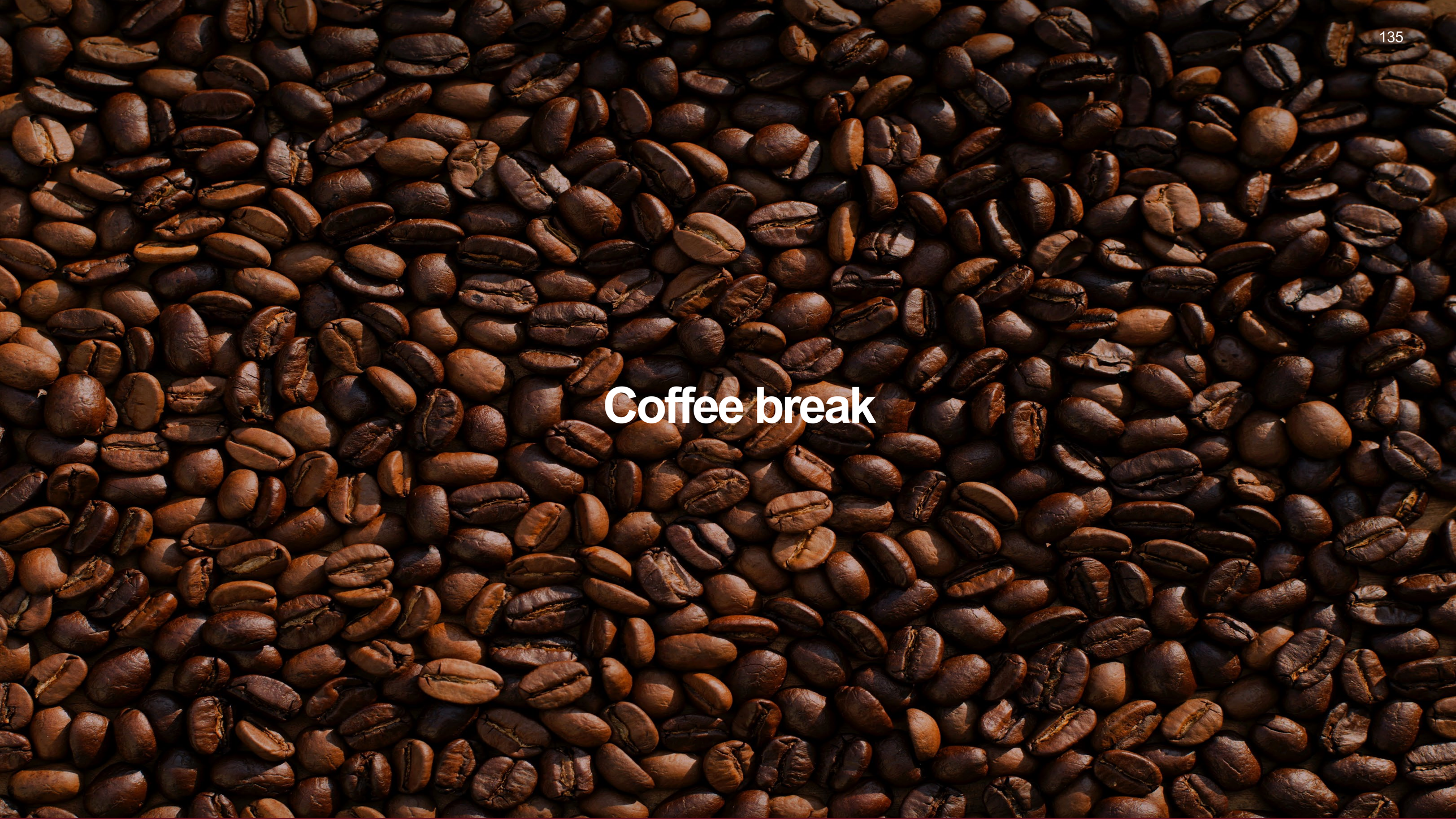
Margit Kropik
Forum Mobilkommunikation, Austria

George Stefanopoulos
EEKT, Greece

Lisa Kelly
Optus, Australia

Hamish MacLeod
Mobile UK

Isabel María Álvaro Alonso
Telefónica, GSMA EMF and Health Delegate


Coffee break

An RF-EMF perspective of the mobile technology evolution roadmap

Christer Törnevik
Head of EMF and Health,
Ericsson Research

Patricia Martigne
Orange,
GSMA EMF and Health Delegate

EMF implications of next-generation mobile technology (6G)

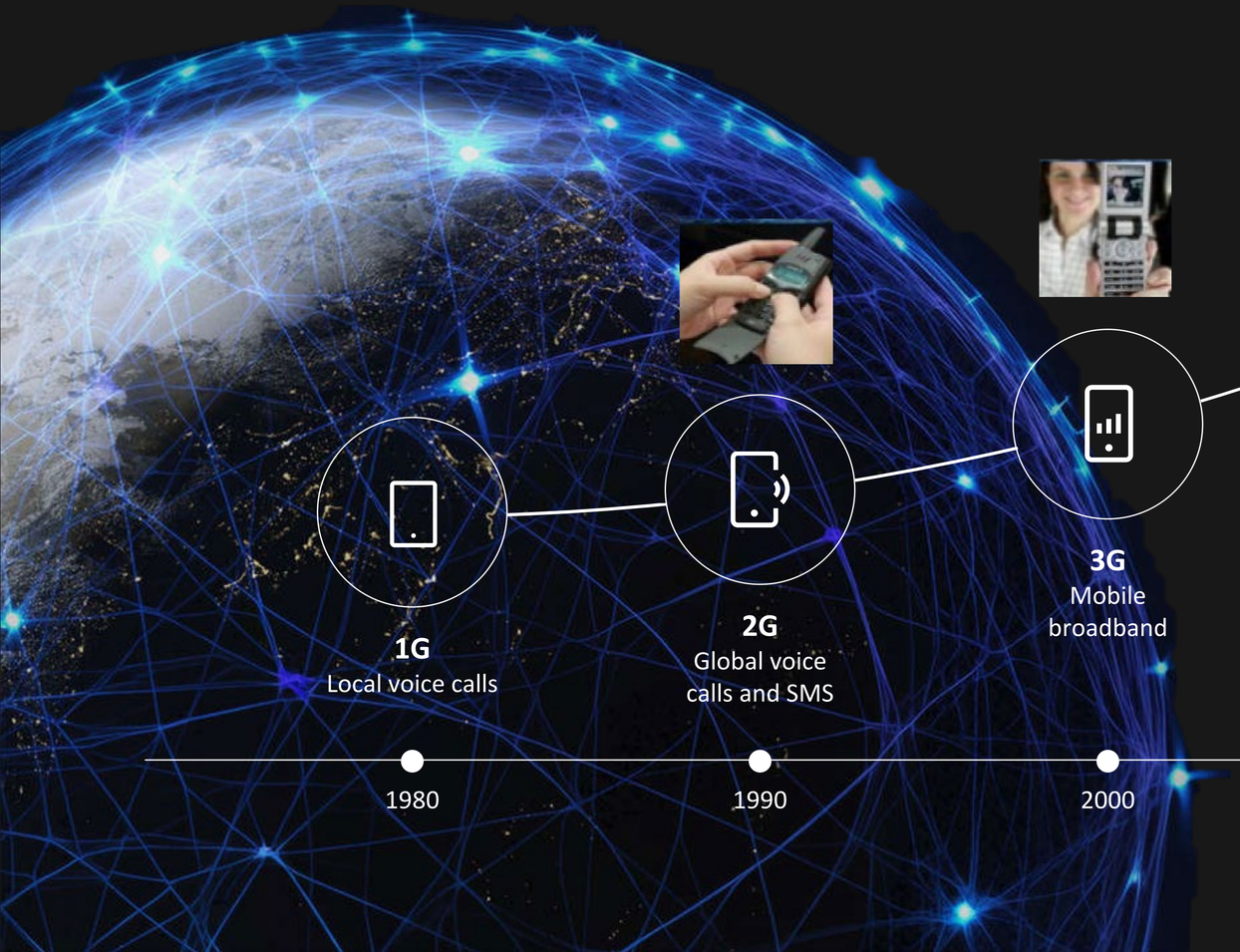
GSMA EMF Forum, September 30, 2025

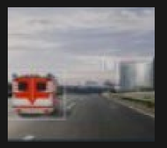
Christer Törnevik
Ericsson Research

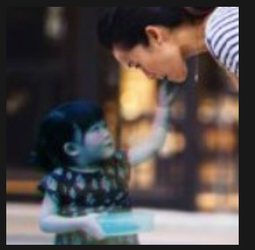
Mobile Network Evolution

1,000,000×

Data speed increase in 30 years







1G
Local voice calls

2G
Global voice calls and SMS

3G
Mobile broadband

4G
App economy

5G
Digitalization of societies and industries

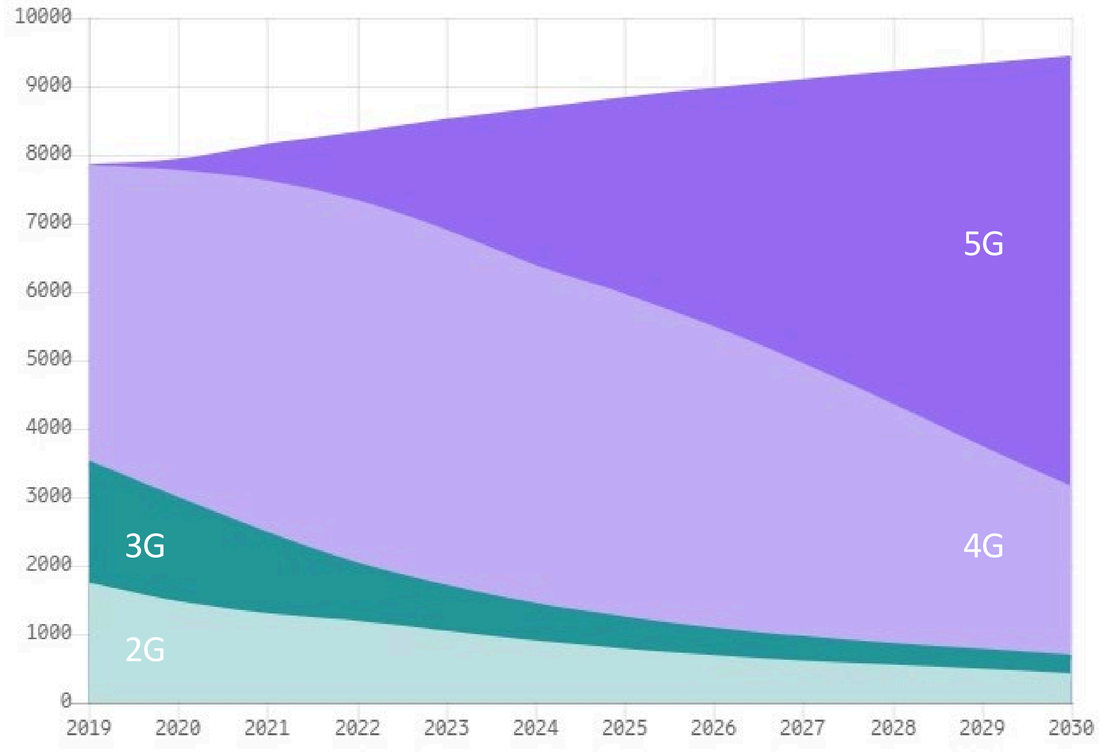
6G
Cyber-physical interaction

Typical maximum environmental EMF exposure levels have remained below 1% of international limits

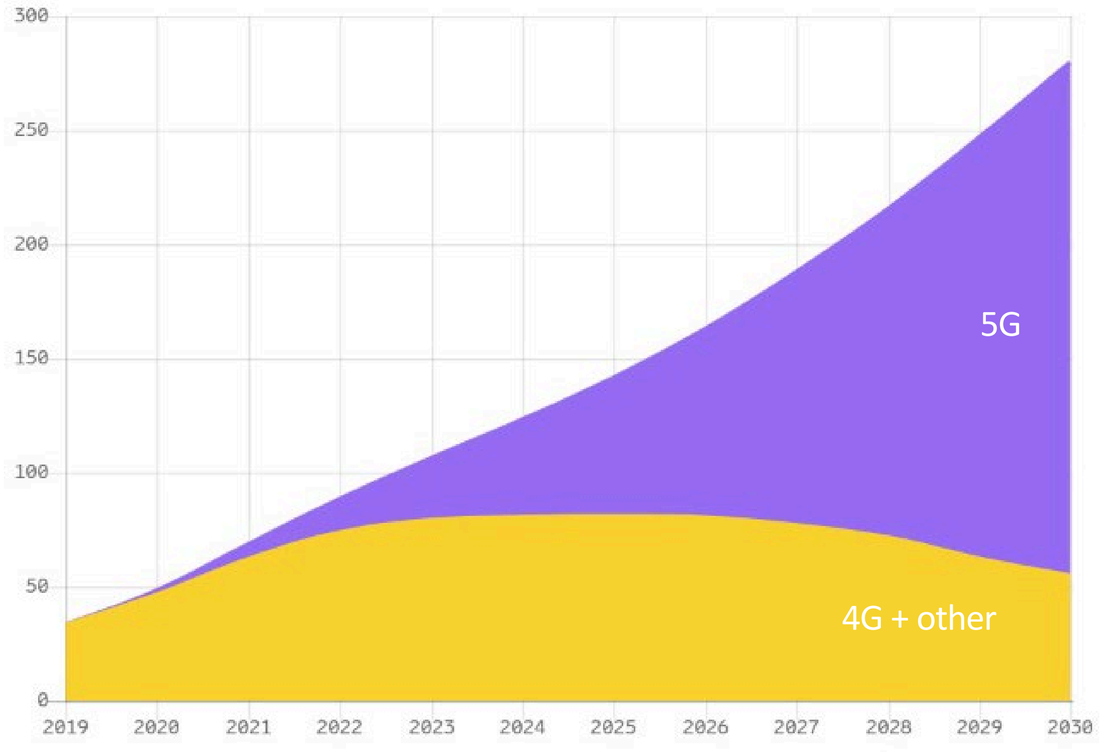
1980 1990 2000 2010 2020 2030

5G mobile subscriptions to reach 6.3 billion in 2030, when 6G will be introduced

Mobile subscriptions by technology (million)



Mobile data traffic (EB/month)



Source: Ericsson Mobility Report, June 2025

A new mobile technology generation leads to new questions related to RF-EMF

Proactive information

Need of fact-based and timely information answering questions about RF-EMF safety

Applicable technical standards

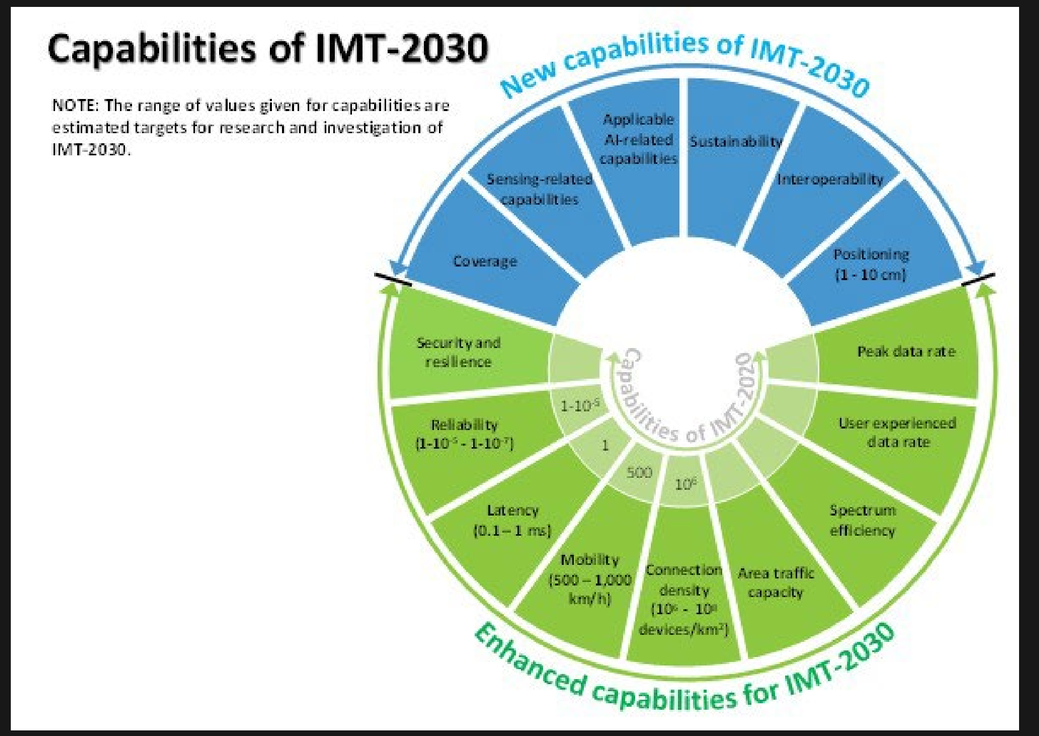
Need to review international standards to ensure applicability for RF-EMF compliance assessments before rollout

From 1G to 5G: RF-EMF implications

Compliance assessment and communication needs

	Examples of technology changes impacting EMF assessments	Examples of public questions and concern
1G -> 2G	• From analog (FM) to digital and from FDMA to TDMA/CDMA • New frequency bands above 1 GHz (e.g., 1800/1900 MHz) • Dual-band transmission	• Digital (pulsed) signals • More base stations on buildings and near homes
2G -> 3G	• Wideband signals with rapid variations (W-CDMA) • Only narrow-band pilot signal continuously transmitted • First frequency bands above 2 GHz	• Roll-out of many new base stations • Additional sites in new locations near homes, schools, etc. (on walls, lamp posts, etc.)
3G -> 4G	• MIMO (Multiple Input Multiple Output) and OFDM introduced • Several new bands and multi-band/multi-technology transmission – actual maximum approach for accurate EMF assessments introduced • Small cells – simplified EMF evaluation process for installation	• Perceived higher levels of RF-EMF exposure • RF-EMF exposure from small-cells
4G -> 5G	• Advanced antenna systems with beamforming and beam steering • New bands in the millimeter-wave range (e.g., 26-28 GHz, 39 GHz) • Introduction of methodology to monitor and control the power/EIRP to enable the use of the actual maximum approach	• Exposure from beamforming (massive MIMO) • “High” frequencies (millimeter-waves) • Base station densification in urban areas

Will there be any EMF implications of 6G/IMT-2030?



3GPP A GLOBAL INITIATIVE

Technical specifications

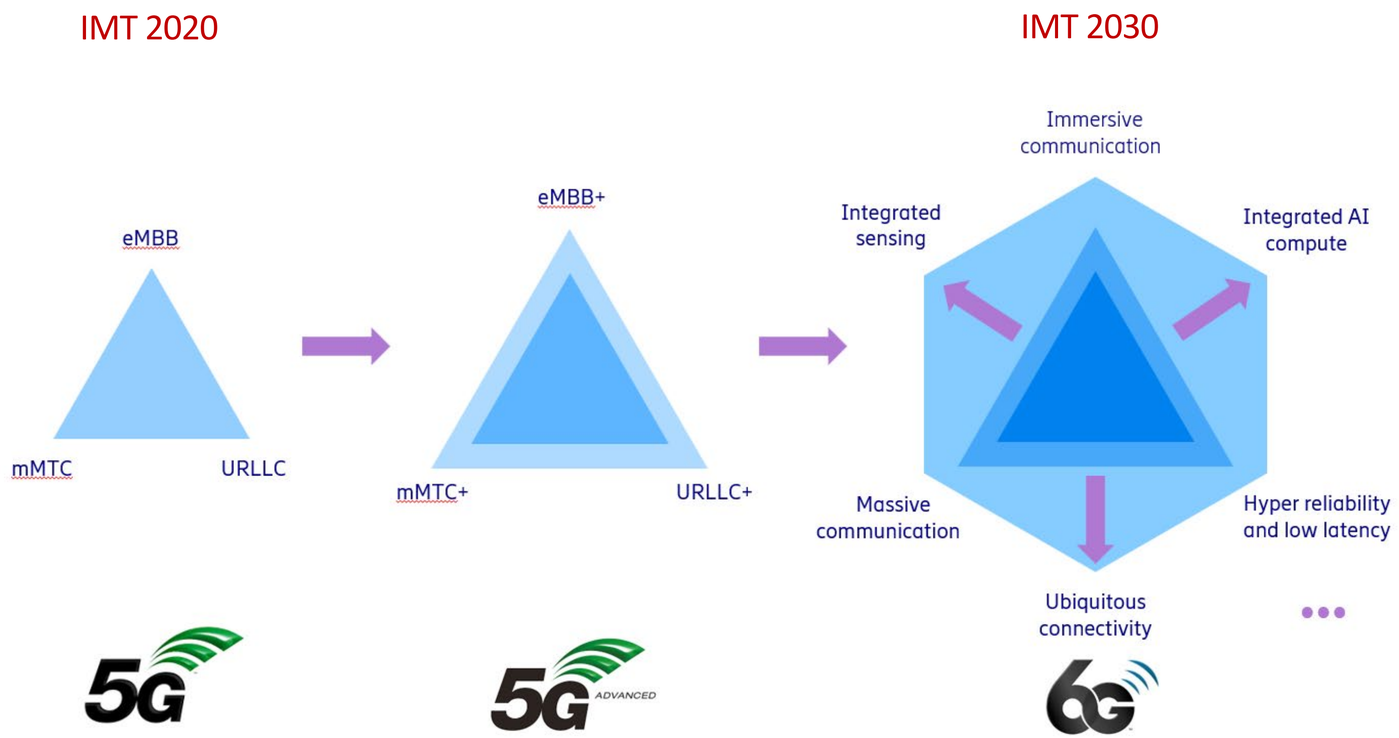
Including device and base station RF power classes with EMF considerations

ITU

Performance requirements

Including global vision and spectrum allocations

International Telecommunication Union (ITU) and 3GPP framework for the evolution towards 6G



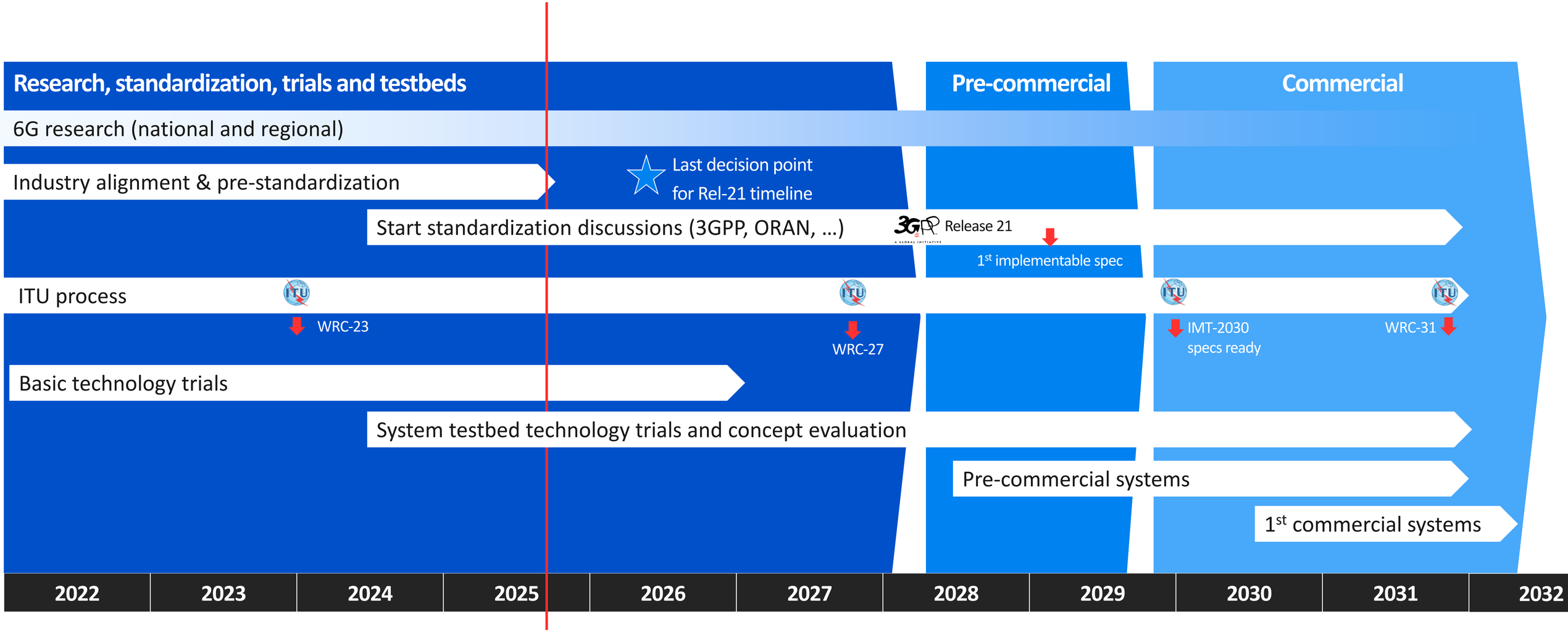
6G is an **evolution** of

- enhanced mobile broadband (eMBB)
- massive machine type communication (mMTC)
- ultra reliable low latency communication (URLLC)

with added capabilities supporting new use cases

High-level 6G timeline (indicative)

Standardization has started

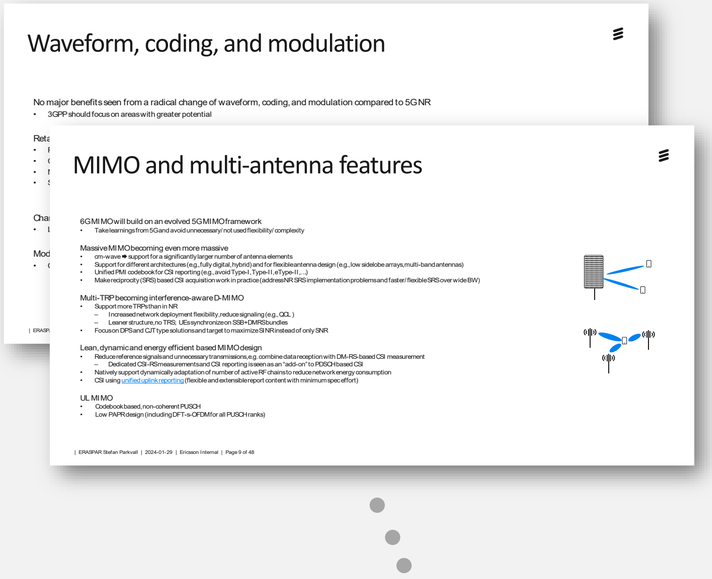


Overall 6G design guidelines

Technology-wise, 6G will inherit much from 5G

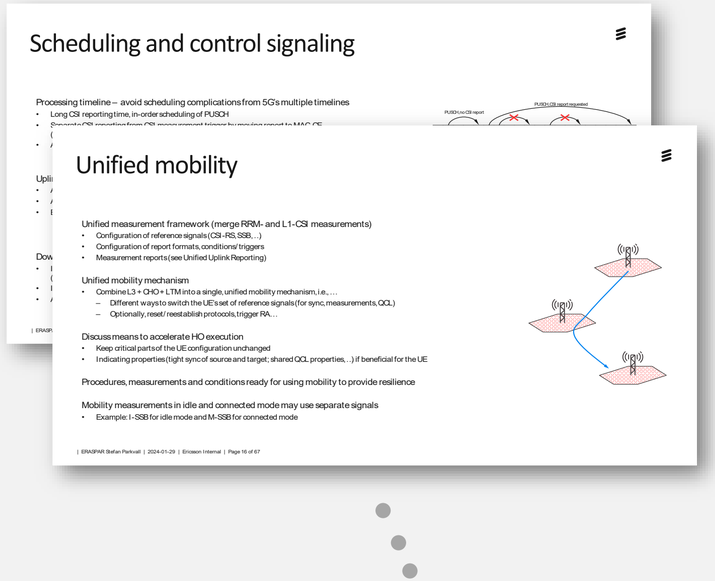
Keep

things that work well



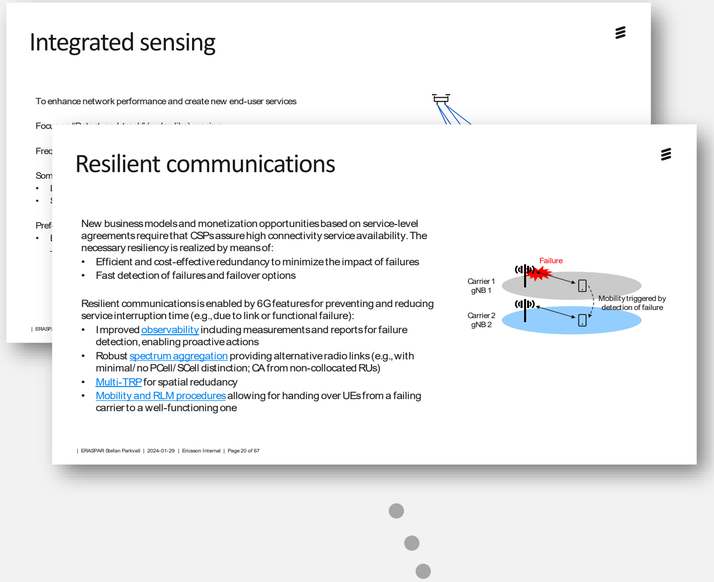
Change

when motivated



Add

functionality for new use cases



6G Radio Access Network (RAN) focus areas

Energy Performance

Evolved/New Technologies

More Uplink Capacity

Spectrum Utilization

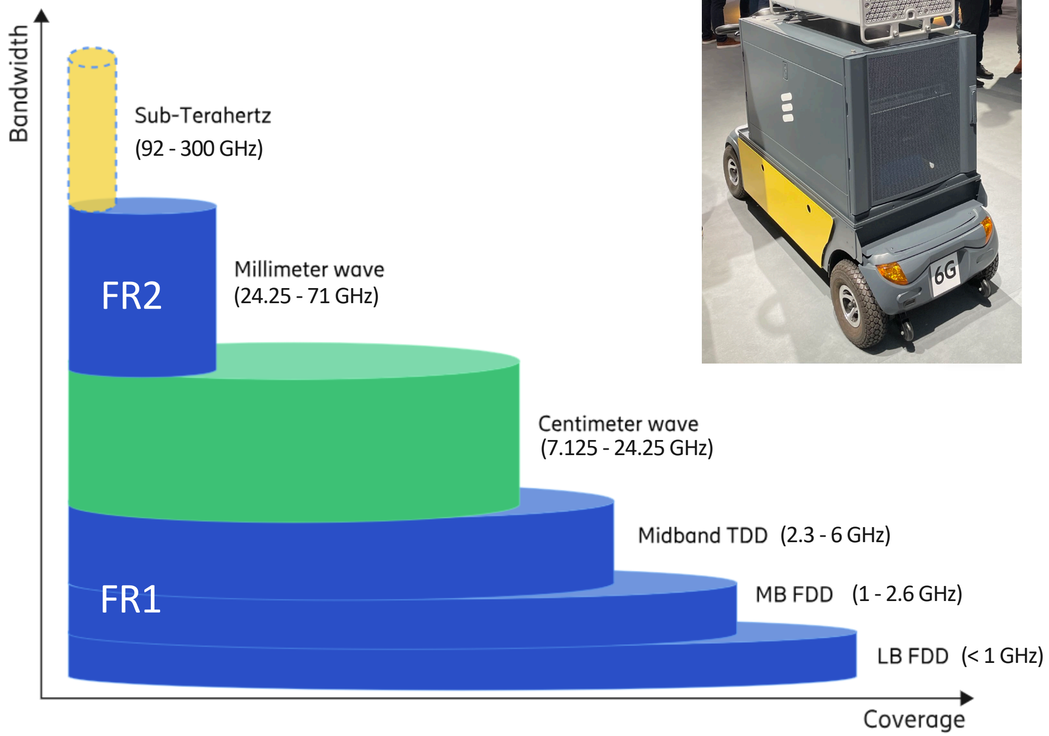
Expanded Device Categories

Cost Optimization

Opportunity for ***large improvements***

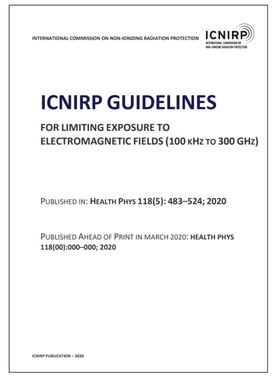
Frequency bands for 6G

- All current frequency bands used for mobile networks
  - Frequency Range 1: “Sub-6 GHz”, 410 MHz - 7.125 GHz
  - Frequency Range 2: “Millimeter-wave”, 24.25 - 71 GHz
- New spectrum, currently not used by 3GPP systems
  - “Centimeter-wave” (“FR3”): 7.125 - 24.25 GHz – essential for 6G (main focus on lower part, 7.125 - 8.400 GHz)
  - “Sub-THz”: 92 - 300 GHz – possibly for later 6G releases (currently mainly academic interest)



International EMF assessment standards (e.g., IEC 62232:2025) cover the entire frequency range from 110 MHz to 300 GHz, i.e., all bands to be used by 6G networks.

International EMF limits (ICNIRP, IEEE C95.1) are technology-neutral and cover all frequency bands.


INTERNATIONAL COMMISSION ON NON-IONIZING RADIATION PROTECTION ICNIRP

ICNIRP GUIDELINES

FOR LIMITING EXPOSURE TO ELECTROMAGNETIC FIELDS (100 kHz TO 300 GHz)

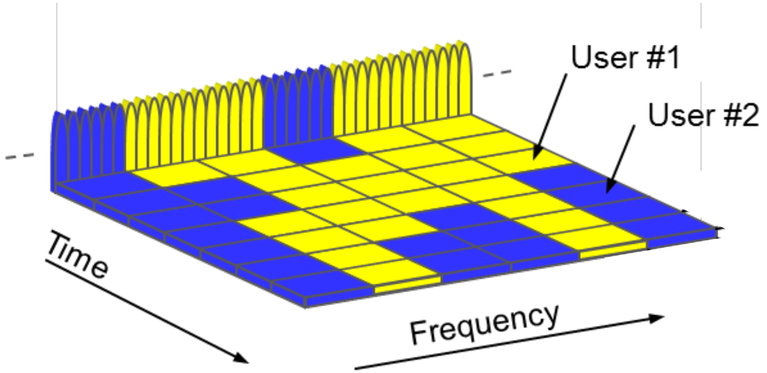
PUBLISHED IN: HEALTH PHYS 118(5): 483–524; 2020

PUBLISHED AHEAD OF PRINT IN MARCH 2020: HEALTH PHYS 118(00):000–000; 2020

ICNIRP PUBLICATION – 2020

Waveform and modulation of radio signals

- The high spectral-efficiency modulation and multiplexing technique OFDM (Orthogonal Frequency Division Multiplexing) used in 5G (and 4G) will be the basis also for 6G
- The structure for transmitting and receiving signals in time and frequency (“numerology”) will probably be retained to allow efficient 5G/6G spectrum sharing
- The design of the periodically transmitted SSB (Synchronization Signal Block) used to extrapolate 5G EMF levels to the maximum may be evolved to further improve energy efficiency (SSB sent only when needed or with different periodicity during low traffic)

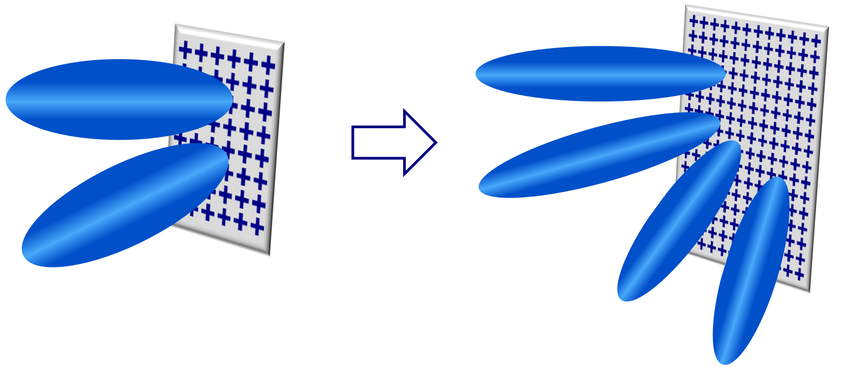


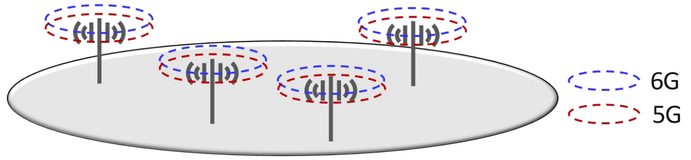
Expected minimal difference from 5G waveform means no expected EMF compliance methodology implications.

New revision of IEC 62232 (edition 5) with any needed 6G considerations to be finalized before 2030.

Multi-antenna transmission (massive MIMO)

- Large antenna arrays (larger area, more antenna elements) will be an essential component of 6G
- Will enable the use of centimeter-wave bands to boost capacity and data throughput
- Narrower beams with higher gain will allow centimeter-wave radio deployments on existing network sites

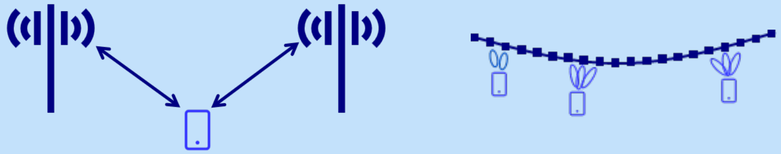




The maximum EMF exposure will be similar to that of 5G massive MIMO (midband) and with lower average levels.

Other 6G capabilities

Multi-point transmission (distributed MIMO)

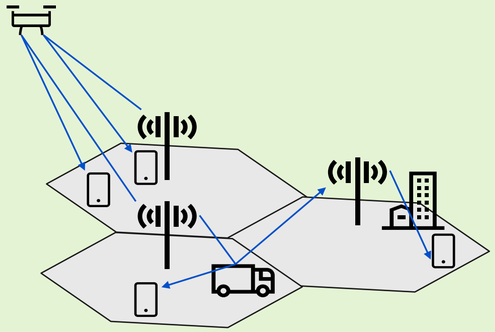


Macro deployments

Indoor deployments

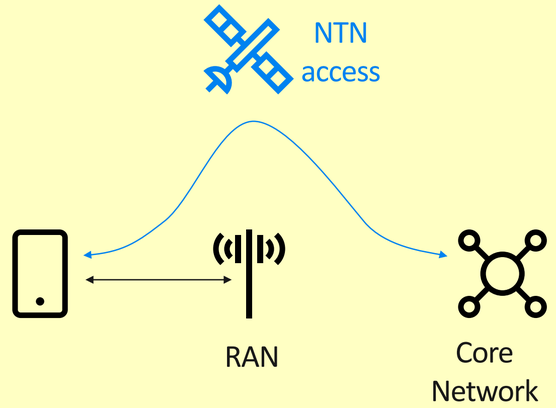
Coordinated and simultaneous transmission from multiple radio units

Integrated Sensing and Communication (ISAC)



Spatial awareness also of unconnected objects

Non-Terrestrial Networks (NTN)



Connectivity in remote regions (without GNSS) and resilience

No implication on EMF exposure due to low power (D-MIMO, ISAC) and large distance (NTN).
Proactive and fact-based information may be needed to avoid misunderstandings and unnecessary concern.

6G performance potential – some early examples

Energy efficiency

Up to **77%**

reduction in network energy consumption

at low loads by reducing the transmission of always-on signals

Up to **35%**

reduction in modem energy consumption

by wake-up signals and other power-saving mechanisms

Capacity and throughput

Up to **+200%**

downlink capacity increase

by adding cm-wave M-MIMO on the existing site grid

Up to **+25%**

uplink throughput

by using AI native channel estimator

Uplink performance

Up to **+56%**

experienced uplink data rates for small packets

by redesigning and streamlining scheduling and control signaling

Up to **10X**

uplink throughput for cell-edge users at low load

by selecting the frequency band independently for uplink and downlink

New service opportunities

Up to **+23%**

positioning accuracy

using AI-based positioning algorithms capable of learning and exploring the environment

2-3m

average error in ISAC drone tracking

in horizontal location using a live test communication network

5G-6G **spectrum sharing** with **<3% overhead**

For more details see: [6G taking radio access technologies to new heights - Ericsson]

Summary

- 6G standardization has started and commercial systems are expected around 2030
- 6G will be an evolution of 5G with much of the technology inherited
- Multi-antenna transmission (beamforming) will continue to be essential and will enable reusing the existing network grid for new centimeter wave frequency bands
- Technology neutral international EMF exposure guidelines (ICNIRP, IEEE C95.1) apply to 6G and cover all frequency bands
- International EMF compliance assessment standards (e.g., IEC 62232) largely apply to 6G and some additional considerations will be included in next edition
- Need for timely and fact-based information about 6G from national authorities and industry to address questions and avoid potential EMF concern


ERICSSON

Summary and conclusions

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