CONSENT CALENDAR

April 14, 2022

HOUSE OF REPRESENTATIVES

REPORT OF COMMITTEE

The Committee on Science, Technology and Energy to which was referred SB 270,

AN ACT (New Title) establishing a low-moderate income community solar program. Having considered the same, report the same with the following amendment, and the recommendation that the bill OUGHT TO PASS WITH AMENDMENT.

Rep. JD Bernardy

FOR THE COMMITTEE

Original: House Clerk
Cc: Committee Bill File

COMMITTEE REPORT

Committee:	**Science, Technology and Energy**
Bill Number:	**SB 270**
Title:	**(New Title) establishing a low-moderate income community solar program.**
Date:	**April 14, 2022**
Consent Calendar:	**CONSENT**
Recommendation:	**OUGHT TO PASS WITH AMENDMENT 2022-1444H**

STATEMENT OF INTENT

This bill, as amended, requires electric distribution utilities to generate a list of low to moderate income customers potentially eligible to receive the benefits from a community solar project. The Department of Energy is required to develop a process by which developers can be officially designated as community solar developers and then enroll low to moderate income households from the utilities' lists. Low to moderate income households stand to benefit from the cost savings associated with the community solar program.

Vote 21-0.

Rep. JD Bernardy
FOR THE COMMITTEE

Original: House Clerk
Cc: Committee Bill File

CONSENT CALENDAR

Science, Technology and Energy

SB 270, (New Title) establishing a low-moderate income community solar program. **OUGHT TO PASS WITH AMENDMENT.**

Rep. JD Bernardy for Science, Technology and Energy. This bill, as amended, requires electric distribution utilities to generate a list of low to moderate income customers potentially eligible to receive the benefits from a community solar project. The Department of Energy is required to develop a process by which developers can be officially designated as community solar developers and then enroll low to moderate income households from the utilities' lists. Low to moderate income households stand to benefit from the cost savings associated with the community solar program. **Vote 21-0.**

Original: House Clerk
Cc: Committee Bill File

Rep. Cali-Pitts, Rock. 30
April 12, 2022
2022-1444h
10/05

Amendment to SB 270

Amend the bill by replacing section 1 with the following:

1 Net Energy Metering; Community Solar Program. RSA 362-A:9, XIV(d) and (e) are repealed and reenacted to read as follows:

(d) The electric distribution utilities shall establish a list of potential low-moderate income residential customers who qualify to benefit from the low-moderate income community solar addition. This list shall consist of residents who have enrolled in or are on the waitlist for the state Electric Assistance Program.

(e) Within 90 days of the effective date of this subparagraph, the department of energy shall develop a process by which community solar developers can apply for designation as a community solar project. Such projects designate their production for the benefit of households on the list required in subparagraph (d). Such projects will qualify for the low-moderate income solar addition as established in subparagraph (c) and shall specify the amount of on-bill credit they can offer to low-moderate income homeowners. Annually, the number of projects designated as low-moderate income community solar shall not exceed a total nameplate capacity rating of 6 megawatts in the aggregate. If more than 6 megawatts of projects apply for designation, the department of energy shall select the projects that offer the largest on-bill credit.

(f) Each year, the department of energy, in consultation with the electric distribution utilities, shall select a means by which to enroll households as off-takers for these low-moderate income community solar projects. Customers shall be enrolled on an opt-out basis, notified by mail of their enrollment, and informed of the details of the project from which they are receiving credit. Once enrolled, such customers shall receive on-bill credits until such time as they no longer qualify for the Electric Assistance Program, or until they opt out from receiving credits.

(g) All reasonable and prudently-incurred costs incurred by the electric distribution utilities related to this program, including but not limited to, costs of implementation, billing, and administrative activities, shall not be borne by the utilities, but shall be recovered from customers.

(h) Utility owned projects that are designated as community solar projects shall not count against the limitation on the maximum allowed distributed energy resources as established by RSA 374-G:4.

(i) Nothing in this chapter shall preclude low-moderate income solar community projects from enrolling customers through any other method besides the process described in subparagraphs (d)-(f). A description of any alternative method used shall be filed with department of energy.

(j) The department is authorized to petition the commission to assess fines against, revoke the registration of, and prohibit from doing business in the state, any group host which violates the requirements of this paragraph and rules adopted for this paragraph pursuant to paragraph X. The commission is authorized to grant or deny such petitions.

HOUSE COMMITTEE ON SCIENCE, TECHNOLOGY AND ENERGY

EXECUTIVE SESSION on SB 270

BILL TITLE: (New Title) establishing a low-moderate income community solar program.

DATE: April 12, 2022

LOB ROOM: 306 - 308

MOTIONS: **OUGHT TO PASS**

Moved by Rep. Lewicke	Seconded by Rep. Cambrils	Vote: 18-0

MOTIONS: **RECONSIDERATION**

Moved by Rep. Harrington	Seconded by Rep. McGhee	Vote: 18-0

MOTIONS: **OUGHT TO PASS**

Moved by Rep. Harrington	Seconded by Rep. Somssich	AM Vote: 0-18

MOTIONS: **OUGHT TO PASS WITH AMENDMENT**

Moved by Rep. Cali-Pitts	Seconded by Rep. Harrington	AM Vote: 21-0

Amendment # 2022-1444h

Moved by Rep. Lewicke	Seconded by Rep. Cambrils	Vote: 21-0

CONSENT CALENDAR: YES

Statement of Intent: Refer to Committee Report

Respectfully submitted,

Rep Fred Plett, Clerk

OFFICE OF THE HOUSE CLERK

1/10/2022 9:10:42 AM
Roll Call Committee Registers Report

2022 SESSION

Science, Technology and Energy

Bill #: SB270 Motion: OTP/A AM #: _____ Exec Session Date: 4/12/22

Members	YEAS	Nays	NV
Vose, Michael Chairman	21		
Thomas, Douglas W. Vice Chairman	1		
Harrington, Michael D.	2		
~~Notter, Jeanine M.~~ Rep. Long	3		
Merner, Troy E.	4		
~~Plett, Fred R. Clerk~~ Rep. Sheehan	5		
Berezhny, Lex	6		
Bernardy, JD	7		
Cambrils, Jose E.	8		
Ploszaj, Tom	9		
White, Nick D.	10		
Somssich, Peter F.	11		
Cali-Pitts, Jacqueline A.	12		
Mann, John E.	13		
Oxenham, Lee Walker	14		
Lewicke, John	15		
Vincent, Kenneth S. (not here)			
McGhee, Kat	16		
~~McWilliams, Rebecca J.~~ Rep. Gotting	17		
~~Chretien, Jacqueline H.~~ Rep. LaFlamme	18		
Pimentel, Roderick L.	19		

OFFICE OF THE HOUSE CLERK

1/10/2022 9:10:42 AM
Roll Call Committee Registers Report

2022 SESSION

Science, Technology and Energy

Bill #: _____ **Motion:** _____ **AM #:** _____ **Exec Session Date:** _____

Parshall, Lucius		20	
TOTAL VOTE:		21	0

OFFICE OF THE HOUSE CLERK

1/10/2022 9:10:42 AM
Roll Call Committee Registers Report

2022 SESSION

Science, Technology and Energy

Bill #: SB 270 Motion: OTP AM #: 2022-1444h Exec Session Date: 4/12/22

Members	YEAS	Nays	NV
Vose, Michael Chairman	21		
Thomas, Douglas W. Vice Chairman	1		
Harrington, Michael D.	2		
~~Notter, Jeanine M.~~ Rep. Long	3		
Merner, Troy E.	4		
~~Plett, Fred R. Clerk~~ Rep. Sheehan	5		
Berezhny, Lex	6		
Bernardy, JD	7		
Cambrils, Jose E.	8		
Ploszaj, Tom	9		
White, Nick D.	10		
Somssich, Peter F.	11		
Cali-Pitts, Jacqueline A.	12		
Mann, John E.	13		
Oxenham, Lee Walker	14		
Lewicke, John	15		
Vincent, Kenneth S. (not here)			
McGhee, Kat	16		
~~McWilliams, Rebecca J.~~ Rep. Gottling	17		
~~Chretien, Jacqueline H.~~ Rep. Laflamme	18		
Pimentel, Roderick L.	19		

OFFICE OF THE HOUSE CLERK

1/10/2022 9:10:42 AM
Roll Call Committee Registers Report

2022 SESSION

Science, Technology and Energy

Bill #: _____ **Motion:** _____ **AM #:** _____ **Exec Session Date:** _____

Parshall, Lucius	20		
TOTAL VOTE:	21	0	

OFFICE OF THE HOUSE CLERK

1/10/2022 9:10:42 AM
Roll Call Committee Registers Report

2022 SESSION

Science, Technology and Energy

Bill #: SB 270 Motion: OTP AM #: _____ Exec Session Date: 4/12/22

Members	YEAS	Nays	NV
Vose, Michael Chairman		18	
Thomas, Douglas W. Vice Chairman			
Harrington, Michael D.		1	
~~Notter, Jeanine M.~~ Rep. Long			
Merner, Troy E.		2	
~~Plett, Fred R. Clerk~~ Rep. Sheehan		3	
Berezhny, Lex		4	
Bernardy, JD		5	
Cambrils, Jose E.		5	
Ploszaj, Tom		6	
White, Nick D.		7	
Somssich, Peter F.		8	
Cali-Pitts, Jacqueline A.		9	
Mann, John E.		10	
Oxenham, Lee Walker		11	
Lewicke, John		12	
Vincent, Kenneth S.			
McGhee, Kat		13	
~~McWilliams, Rebecca J.~~ Rep. Gottling		14	
Chretien, Jacqueline H. Rep. Laflamme		15	
Pimentel, Roderick L.		16	

OFFICE OF THE HOUSE CLERK

1/10/2022 9:10:42 AM
Roll Call Committee Registers Report

2022 SESSION

Science, Technology and Energy

Bill #: _____ **Motion:** _____ **AM #:** _____ **Exec Session Date:** _____

Parshall, Lucius		17	
TOTAL VOTE:	0	18	

OFFICE OF THE HOUSE CLERK

1/10/2022 9:10:42 AM
Roll Call Committee Registers Report

2022 SESSION

Science, Technology and Energy

Bill #: SB270 Motion: Reconsider AM #: _____ Exec Session Date: 4/12/22

Members	YEAS	Nays	NV
Vose, Michael Chairman	18		
Thomas, Douglas W. Vice Chairman			
Harrington, Michael D.	1		
~~Notter, Jeanine M.~~ Rep. Fang			
Merner, Troy E.	2		
~~Plett, Fred R. Clerk~~ Rep. Sheehan	3		
Berezhny, Lex	4		
Bernardy, JD			
Cambrils, Jose E.	5		
Ploszaj, Tom	6		
White, Nick D.	7		
Somssich, Peter F.	8		
Cali-Pitts, Jacqueline A.	9		
Mann, John E.	10		
Oxenham. Lee Walker	11		
Lewicke, John	12		
Vincent, Kenneth S.			
McGhee, Kat	13		
~~McWilliams, Rebecca J.~~ Rep. Gottling	14		
~~Chretien, Jacqueline H.~~ Rep. LaFlamme	15		
Pimentel, Roderick L.	16		

OFFICE OF THE HOUSE CLERK

1/10/2022 9:10:42 AM
Roll Call Committee Registers Report

2022 SESSION

Science, Technology and Energy

Bill #: _____ **Motion:** _____ **AM #:** _____ **Exec Session Date:** _____

Parshall, Lucius	17		
TOTAL VOTE:	18	0	

OFFICE OF THE HOUSE CLERK

1/10/2022 9:10:42 AM
Roll Call Committee Registers Report

2022 SESSION

Science, Technology and Energy

Bill #: SB 270 Motion: OTP AM #: _____ Exec Session Date: 4/12/22

Members	YEAS	Nays	NV
Vose, Michael Chairman	18		
Thomas, Douglas W. Vice Chairman	1		
Harrington, Michael D.	2		
~~Notter, Jeanine M.~~ Rep. Long			
Merner, Troy E.	3		
~~Plett, Fred R. Clerk~~ Rep. Sheehan	4		
Berezhny, Lex			
Bernardy, JD			
Cambrils, Jose E.	5		
Ploszaj, Tom	6		
White, Nick D.	7		
Somssich, Peter F.	8		
Cali-Pitts, Jacqueline A.	9		
Mann, John E.	10		
Oxenham, Lee Walker	11		
Lewicke, John	12		
Vincent, Kenneth S.			
McGhee, Kat	13		
~~McWilliams, Rebecca J.~~ Rep. Gottling	14		
~~Chretien, Jacqueline H.~~ Rep. Laflamme	15		
Pimentel, Roderick L.	16		

OFFICE OF THE HOUSE CLERK

1/10/2022 9:10:42 AM
Roll Call Committee Registers Report

2022 SESSION

Science, Technology and Energy

Bill #: _____ **Motion:** _____ **AM #:** _____ **Exec Session Date:** _____

Parshall, Lucius	17		
TOTAL VOTE:	18	0	

HOUSE COMMITTEE ON SCIENCE, TECHNOLOGY AND ENERGY

PUBLIC HEARING ON SB 270

BILL TITLE: **(New Title) establishing a low-moderate income community solar program.**

DATE: **April 11, 2022**

LOB ROOM: **306-308** **Time Public Hearing Called to Order:** **11:00 a.m.**

Time Adjourned: **12:00 p.m.**

Committee Members: Reps. Vose, Thomas, Harrington, Notter, Merner, Berezhny, Bernardy, Cambrils, Ploszaj, Somssich, Cali-Pitts, Mann, Oxenham, Lewicke, Vincent, McGhee, McWilliams, Chretien, Pimentel and Parshall

Bill Sponsors:

Sen. Watters	**Sen. Avard**	**Sen. Perkins Kwoka**
Sen. D'Allesandro	**Sen. Bradley**	**Sen. Hennessey**
Sen. Whitley	**Sen. Rosenwald**	**Sen. Soucy**
Sen. Gannon	**Sen. Sherman**	**Sen. Giuda**
Rep. Cali-Pitts	**Rep. McGhee**	

TESTIMONY

* Use asterisk if written testimony and/or amendments are submitted.

Senator Watters: We missed a couple of technical corrections Department of Energy spotted. Brought forth by Clean Energy NH. What can we do to help the community solar program? It passed; it is in statute . What can we do to get people enrolled in program? Eversource had a program in CT that works, and that was the model for this bill. It anonymized account numbers and then provided them, then create likely clusters to get bang for the buck, work through local Community action programs. Line 16 starts new language; Department of Energy will be the entity to work with utilities to identify means to select participants. Efficient process. As it is now, if you are able, it is opt-out. Let me note changes. Line 6, we forgot to take out administered by the Commission, because it is administered by the Department, so that need elision. On line 22, for (g), recommended by utilities and department, insert "and all reasonable and prudently incurred costs". Last subsection on page 2, we need to repeat the existing statute there – "The Department is authorized to petition the Commission to assess fines against, revoke the registration of, and prohibit from doing business in the state any group host which violates this paragraph and rules adopted pursuant to Paragraph x. Bottom line we have an efficient program. Harrington – As I read this, another wealth transfer bill, everybody pays more to give subsidies to select few. Is that so? Answer – funding already exists in statute. This is simply an efficient way to make it work. Philosophy of whether we should be doing anything at all is outside this scope – it was decided in previous legislation. This helps low income people get benefit. Ploszaj – potential customers opt in? Ansswer - These customers already identified. This says if you qualify, you could get benefit lowering your bills. Don't have enough to go around. If you don't want benefit you can opt out. Somssich – how does this work? Answer – save for others to answer. Harrington – line 15, total nameplate capacity 6 MW. What is significance – When you get to that size project, economy of scale, could be cheaper. This would allow others to come in to get a better price.

Griffin Roberge, Department of Energy – With fixes discussed by Senator Watters, we are fine – we are neutral. Amendment 1396S fixes.

***Sam Evans- Brown**, Clean Energy NH – This was not my idea, it was Eversource's. Takes CT program, scales to NH market size. Governor stated in State of State – said if we are going to have

net metering, we should make it flows to low income. Defined as 300% of federal level. As required b legislation already, Eversource created this pilot program. This puts it into legislation. Eversource supports. Very modest program. The bill as written does this. McGhee – Question is to create an administrative procedure that is an improvement? Answer - Yes. McGhee - Governor requested State of State, that benefit flows to low income? Answer - Yes. Lewicki – Understand where capital comes from? Solar developers will need to find capital, gets paid back normally, through a host or a third-party who could take advantage of credits. Thomas – Could Eversource come up? Answer – that is up to Eversource. Harrington – confused how works? What is 6 MW? Answer – cap on program, not any one project. Harrington – where do credit come from? Production percentage allocated to the account. Each customer by design gets $240 per year. F/U – Project developed by third party, on-site load to offset, energy sold to EAP list. Up to 100 kW, full cost, over that avoided cost? Yes. Cali-Pitts – concern was privacy – single homes only? Answer – could flow to any account receiving benefits under EAP, which is not public. Could be an apartment. Bill intends to leave that mechanism up to Department of Energy. Parshall – If I am not receiving benefit, could I apply if income eligible? Yes – EAP will be granted to income eligible people. Harrington – in handout, no projects have been done, but you said one? Correct – Testimony is in error.

SIGN UP SHEET

To Register Opinion If Not Speaking

Bill # SB270 Date 4/11/22

Committee Science

**** Please Print All Information ****

Name	Address	Phone	Representing	Pro	Con
Rep. Timothy Hornigan			Stratford 6	✓	

House Remote Testify

Science, Technology and Energy Committee Testify List for Bill SB270 on 2022-04-11

Support: 49 Oppose: 0 Neutral: 0 Total to Testify: 0

Export to Excel

Name	City, State Email Address	Title	Representing	Position	Testifying	Non-Germane	Signed Up
Perkins Kwoka, Senator Rebecca	Portsmouth, NH Rebecca.PerkinsKwoka@leg.state.nh.us	An Elected Official	Myself	Support	No	No	3/30/2022 3:08 PM
Hennessey, Erin	Senate District 1, NH peter.oneill@leg.state.nh.us	An Elected Official	Myself	Support	No	No	4/5/2022 10:31 AM
Bradley, Jeb	SD3, NH jeb.bradley@leg.state.nh.us	An Elected Official	SD3	Support	No	No	4/6/2022 9:40 AM
Lazinsky, Craig	Derry, NH craiglazinsky@comcast.net	A Member of the Public	Myself	Support	No	No	4/8/2022 9:47 AM
Coder, William	Bedford, NH wcoder@aol.com	A Member of the Public	Myself	Support	No	No	4/8/2022 9:50 AM
Fournier, Suzanne	Milford, NH BroxEnvironCitizens3@gmail.com	A Member of the Public	Myself	Support	No	No	4/8/2022 10:54 AM
Beck, Gerald	Holderness, NH bentrimone@gmail.com	A Member of the Public	Myself	Support	No	No	4/8/2022 11:18 AM
Oxenham, Evan	Plainfield, NH evan.oxenham@gmail.com	A Member of the Public	Myself	Support	No	No	4/8/2022 11:26 AM
Nute, Dana	Sanbornton, NH dnute@resilientbuildingsgroup.com	A Member of the Public	Myself	Support	No	No	4/8/2022 11:29 AM
Nichols, Patricia	Meredith, NH Patty4541@yahoo.com	A Member of the Public	Myself	Support	No	No	4/8/2022 11:44 AM
Dickinson, Chris	Laconia, NH cdickinson68@gmail.com	A Member of the Public	Myself	Support	No	No	4/8/2022 11:44 AM
Mure, Lisa	Holderness, NH Lisamure@gmail.com	A Member of the Public	Myself	Support	No	No	4/8/2022 12:17 PM
Steven-Hubbard, S	Manchester, NH salsh2000@hotmail.com	A Member of the Public	Myself	Support	No	No	4/8/2022 12:20 PM

Rosenwald, Cindy	Nashua, NH cindy.rosenwald@leg.state.nh.us	An Elected Official	SD 13	Support	No	No	4/8/2022 12:22 PM
Beffa-Negrini, Patricia	Nelson, NH pbeffa@me.com	A Member of the Public	Myself	Support	No	No	4/8/2022 8:32 PM
Field, Bryan	PETERBOROUGH, NH brysciguy@gmail.com	A Member of the Public	Myself	Support	No	No	4/9/2022 8:10 AM
Liebowitz, Susan	Plainfield, NH supawli@hotmail.com	A Member of the Public	Myself	Support	No	No	4/9/2022 9:44 AM
Jernstedt, Margaret	Hanover, NH Margaret.Jernstedt@comcast.net	A Member of the Public	Myself	Support	No	No	4/9/2022 2:51 PM
Bassett, Aaron	Laconia, NH abassett@gmail.com	A Member of the Public	Myself	Support	No	No	4/9/2022 3:03 PM
Saum, Judith	Rumney, NH judithsaum@gmail.co,	A Member of the Public	Myself	Support	No	No	4/10/2022 7:16 AM
Glass, Jonathan	Cornish, NH jglass1063@gmail.com	A Member of the Public	Myself	Support	No	No	4/10/2022 11:03 AM
Crandell-Glass, Jane	Cornish, NH bostonjane@me.com	A Member of the Public	Myself	Support	No	No	4/10/2022 11:11 AM
Torpey, Jeanne	Concord, NH jtorp51@comcast.net	A Member of the Public	Myself	Support	No	No	4/10/2022 12:51 PM
Keeler, Margaret	New London, NH peg5keeler@gmail.com	A Member of the Public	Myself	Support	No	No	4/10/2022 2:31 PM
Hackmann, Kent	Andover, NH hackmann@uidaho.edu	A Member of the Public	Myself	Support	No	No	4/10/2022 3:27 PM
Fudge, Kim Marie	NORTH CONWAY, NH kimfudge20@gmail.com	A Member of the Public	Myself	Support	No	No	4/10/2022 3:47 PM
Hurley, Paula	Concord, NH graffymanor@comcast.net	A Member of the Public	Myself	Support	No	No	4/10/2022 3:56 PM
Moore, Susan	Franconia, NH susan.moore.franconia@gmail.com	A Member of the Public	Myself	Support	No	No	4/10/2022 4:01 PM
Hatcher, Phil	Dover, NH phil.hatcher@gmail.com	A Member of the Public	Myself	Support	No	No	4/10/2022 4:21 PM
MacGregor, Leslie	Grantham, NH lsmacgregor@gmail.com	A Member of the Public	Myself	Support	No	No	4/10/2022 4:30 PM
Winslow, Dalton	Grantham, NH dwinslow04736@gmail.com	A Member of the Public	Myself	Support	No	No	4/10/2022 4:31 PM

Cahill-Yeaton, Miriam	Epsom, NH nmyeaton.mims@yahoo.com	A Member of the Public	Myself	Support	No	No	4/10/2022 5:16 PM
Keegan, jJohn	Boscawen, NH peoresnada@tds.net	A Member of the Public	Myself	Support	No	No	4/10/2022 6:01 PM
Moore, Ellen	Danville, NH elliemore@comcast.net	A Member of the Public	Myself	Support	No	No	4/10/2022 7:51 PM
Brennan, Nancy	Weare, NH burningnan14@gmail.com	A Member of the Public	Myself	Support	No	No	4/10/2022 8:10 PM
Richman, Susan	Durham, NH susan7richman@gmail.com	A Member of the Public	Myself	Support	No	No	4/10/2022 8:25 PM
kwasnik, joseph	concord, NH jkwasnik25@gmail.com	A Member of the Public	Myself	Support	No	No	4/10/2022 8:43 PM
Perencevich, Ruth	Concord, NH rperence@comcast.net	A Member of the Public	Myself	Support	No	No	4/10/2022 9:07 PM
Hershey, Jane	Rindge, NH janelhershey@gmail.com	A Member of the Public	Myself	Support	No	No	4/10/2022 9:30 PM
Verschueren, James	Dover, NH jd.verschueren@gmail.com	A Member of the Public	Myself	Support	No	No	4/10/2022 10:00 PM
Thomas, Anne	Rindge, NH annethomasjazz@gmail.com	A Member of the Public	Myself	Support	No	No	4/10/2022 10:20 PM
Hayes, Randy	Canterbury, NH rcompostr@gmail.com	A Member of the Public	Myself	Support	No	No	4/10/2022 10:38 PM
Reed, Barbara	North Swanzey, NH BDReed74@gmail.com	A Member of the Public	Myself	Support	No	No	4/10/2022 11:53 PM
Smith, Julie	Nashua, NH cantdog@comcast.net	A Member of the Public	Myself	Support	No	No	4/11/2022 5:19 AM
Leahy, Matt	Concord, NH mleahy@forestsociety.org	A Lobbyist	Society for the Protection of NH Forests	Support	No	No	4/11/2022 6:47 AM
Ellermann, Maureen	Concord, NH ellermannf@aol.com	A Member of the Public	Myself	Support	No	No	4/11/2022 6:52 AM
Lucas, Janet	Campton, NH janluca1953@gmail.com	A Member of the Public	Myself	Support	No	No	4/11/2022 6:57 AM
Dewey, Karen	NEWPORT, NH pkdewey@comcast.net	A Member of the Public	Myself	Support	No	No	4/11/2022 7:10 AM
Baucom, Pam	Walpole, NH ptubridybaucom@gmail.com	A Member of the Public	Myself	Support	No	No	4/11/2022 7:47 AM

Environmental Pollution 242 (2018) 643–658

Contents lists available at ScienceDirect

Environmental Pollution

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Thermal and non-thermal health effects of low intensity non-ionizing radiation: An international perspective☆

Dominique Belpomme [a, b, 1], Lennart Hardell [a, c, 1, 2], Igor Belyaev [a, d, e, 1], Ernesto Burgio [a, f], David O. Carpenter [a, g, h, *, 1]

[a] European Cancer Environment Research Institute, Brussels, Belgium
[b] Paris V University Hospital, Paris, France
[c] Department of Oncology, Orebro University Hospital, Faculty of Medicine, Orebro, Sweden
[d] Department of Radiobiology, Cancer Research Institute, Biomedical Research Center, Slovak Academy of Science, Bratislava, Slovak Republic
[e] Laboratory of Radiobiology, Institute of General Physics, Russian Academy of Science, Moscow, Russian Federation
[f] Instituto Scientifico Biomedico Euro Mediterraneo, Mesagne, Italy
[g] Institute for Health and the Environment, University at Albany, Albany, NY, USA
[h] Child Health Research Centre, The University of Queensland, Faculty of Medicine, Brisbane, Australia

ARTICLE INFO

Article history:
Received 6 April 2018
Received in revised form
31 May 2018
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ABSTRACT

Exposure to low frequency and radiofrequency electromagnetic fields at low intensities poses a significant health hazard that has not been adequately addressed by national and international organizations such as the World Health Organization. There is strong evidence that excessive exposure to mobile phone-frequencies over long periods of time increases the risk of brain cancer both in humans and animals. The mechanism(s) responsible include induction of reactive oxygen species, gene expression alteration and DNA damage through both epigenetic and genetic processes. *In vivo* and *in vitro* studies demonstrate adverse effects on male and female reproduction, almost certainly due to generation of reactive oxygen species. There is increasing evidence the exposures can result in neurobehavioral decrements and that some individuals develop a syndrome of "electro-hypersensitivity" or "microwave illness", which is one of several syndromes commonly categorized as "idiopathic environmental intolerance". While the symptoms are non-specific, new biochemical indicators and imaging techniques allow diagnosis that excludes the symptoms as being only psychosomatic. Unfortunately standards set by most national and international bodies are not protective of human health. This is a particular concern in children, given the rapid expansion of use of wireless technologies, the greater susceptibility of the developing nervous system, the hyperconductivity of their brain tissue, the greater penetration of radiofrequency radiation relative to head size and their potential for a longer lifetime exposure.

1. Introduction

Electromagnetic fields (EMFs) are packets of energy that have no mass. They vary in frequency and wavelength. At the high end of the electromagnetic spectrum there are cosmic and X-rays that have enough energy to cause ionization, and therefore are known as ionizing EMFs. Below in frequency and energy are ultraviolet, visible light and infrared EMFs. Excessive exposure to ultraviolet EMFs poses clear danger to human health, but life on earth would not be possible without visible light and infrared EMFs. Below these forms of EMF are those used for communications (radiofrequency or RF-EMFs, 30 kHz-300 GHz) and those generated by electricity (extremely low-frequency or ELF-EMFs, 3 Hz-3 kHz). These EMFs do not have sufficient energy to directly cause ionization, and are therefore known as non-ionizing radiation. RF-EMFs at sufficient intensity cause tissue heating, which is the basis of operation of the microwave oven. However the question to be addressed here is human health effects secondary to exposures to non-ionizing EMFs at low intensities that do not cause measureable heating.

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In spite of a large body of evidence for human health hazards from non-ionizing EMFs at intensities that do not cause measureable tissue heating, summarized in an encyclopedic fashion in the Bioinitiative Report (www.bioinitiative.org), the World Health Organization (WHO) and governmental agencies in many countries have not taken steps to warn of the health hazards resulting from exposures to EMFs at low, non-thermal intensities, nor have they set exposure standards that are adequately health protective. In 2001 the International Agency for Research on Cancer (IARC, 2002), part of the WHO, declared ELF-EMFs to be "possibly carcinogenic to humans", and in 2011 they made a similar declaration for RF-EMFs (Baan et al., 2011; IARC, 2013). The classification of RF-EMFs as a "possible" human carcinogen was based primarily on evidence that long-term users of mobile phones held to the head resulted in an elevated risk of developing brain cancer. One major reason that the rating was not at "probable" or "known" was the lack of clear evidence from animal studies for exposure leading to cancer. The US National Toxicology Program has released preliminary results of a study of long term exposure of rats to cell phone radiation which resulted in a statistically significant increase in brain gliomas, the same cancer found in people after long-term cell phone use, and schwannomas, a tumor similar to the acoustic neuroma also seen after intensive mobile phone use (Wyde et al., 2016). Similar results in rats have been reported in an independent study at the Ramazzini Institute with exposures similar to those from a mobile phone base station (Falcioni et al., 2018). This evidence, in conjunction with the human studies, demonstrates conclusively that excessive exposure to RF-EMF results in an increased risk of cancer. In light of this new evidence for cancer in rodents in response to prolonged exposure to mobile phone frequencies, the IARC rating should be raised at least to "probable" (Group 2A) if not "known" (Group 1).

Unfortunately the International EMF Project of the WHO, which is part of the Department of Public Health, Environment and Social Determinants of Health in Geneva, has consistently minimized health concerns from non-ionizing EMFs at intensities that do not cause tissue heating (WHO, 2014). In this regard WHO has failed to provide an accurate and human health-protective analysis of the dangers posed to health, especially to the health of children, resulting from exposure to non-thermal levels of electromagnetic fields. The Department of Public Health, Environment and Social Determinates of Disease takes its advice on the issues related to human health effects of non-ionizing EMFs from the International Commission on Non-ionizing Radiation Protection (ICNIRP). Almost all members of the core group preparing the new Environmental Health Criteria (EHC) document for the WHO are members of ICNIRP (Starkey, 2016; Hardell, 2017), a non-goverment organization (NGO) whose members are appointed by other members. In spite of recent efforts to control for conflicts of interest, ICNIRP has a long record of close associations with industry (Maisch, 2006). When queried as to why the WHO would take recommendations from such a group, WHO staff replied that ICNIRP is an official NGO which works closely with the WHO. Why this should exclude other scientific research groups and public health professionals is unclear, particularly since most members of ICNIRP are not active researchers in this field. We are particularly concerned that a new WHO EHC document on RF-EMFs is scheduled to be released soon, and that the members of the EHC Core Group and the individuals whose assistance has been acknowledged are known to be in denial of serious non-thermal effects of RF-EMFs in spite of overwhelming scientific evidence to the contrary (Starkey, 2016; Hardell, 2017).

Others have dismissed the strong evidence for harm from ELF- and RF-EMFs by arguing that we do not know the mechanism whereby such low energetic EMFs might cause cancer and other diseases. We have definitive evidence that use of a mobile phone results in changes in brain metabolism (Volkow et al., 2011). We know that low-intensity ELF- and RF-EMFs generate reactive oxygen species (ROS), alter calcium metabolism and change gene expression through epigenetic mechanims, any of which may result in development of cancer and/or other diseases or physiological changes (see www.bioinitiative.org for many references). We do not know the mechanisms behind many known human carcinogens, dioxins and arsenic being two examples. Given the strength of the evidence for harm to humans it is imperative to reduce human exposure to EMFs. This is the essence of the "precautionary principle".

There are a number of reasons for our concern. In the past the major exposure of the general population to RF-EMFs came from radio and television signals. Now there are almost as many mobile phones as there are people in the world, all of them being exposed to RF-EMFs. There are mobile phone towers everywhere, and in many developing countries there are no land-lines that allow communication without exposure to RF-EMFs. There is rapid movement in many developed countries to place small cell transmitting devices (5G) operating at higher frequencies (24–70 GHz) every approximately 300 m along sidewalks in residential neighborhoods. There are other significant sources of exposure, coming from WiFi, smart meters and soon from automobiles operating without a human driver. Therefore human exposure has increased dramatically in recent years, and continues to increase rapidly. While we already are seeing harm from these exposures, the degree of harm will only increase with time because of the latency that is known to occur between exposure and development of diseases such as cancer.

Standards for protection of human health from EMFs vary greatly around the world. Many countries set standards based on the false assumption that there are no adverse health effects of RF-EMFs other than those that are caused by tissue heating. This is the case in North America, Australia and some European countries. Many countries from the former Soviet Union have much more restrictive standards. However information from cellular and human studies show biological effects that constitute hazards to human health at exposure levels that are often exceeded during daily life.

This report follows a recent non-official meeting in Geneva with WHO representives, where the authors urged WHO to acknowlege low intensity effects of ELF-EMFs and non-thermal health effects of RF-EMFs. This report does not attempt to present a complete overview of the subject [see the Bioinitiative Report (www.bioinitiative.org) for that] but rather to provide a holistic picture of the processes explaining most or all of the adverse effects of EMF exposures. It summarizes the evidence for cancer resulting from exposure to EMFs, and identifies other diseases or pathological conditions such as Alzheimer's disease and hypofertility that have been shown to be associated with excesive exposure to low-intensity EMFs. We also focus on electrohypersensitivity (EHS) in both children and adults and cognitive and behavioural problems in children resulting from the increasing exposure. Finally we discuss what is known about the mechanisms whereby non-thermal EMF radiation can cause disease with special reference to EMF-related free radical production and epigenetic and genetic mechanisms.

2. Mobile phone use and the risk for glioma, meningioma and acoustic neuroma

The brain is the main target for exposure to RF-EMF radiation during use of handheld wireless phones, both mobile and cordless phones (Cardis et al., 2008; Gandhi et al., 2012). An increased risk for brain tumors has been of concern for a long time. The results of the Swedish National Inpatient Register have documented an

increasing incidence of brain tumors in recent years (Carlberg and Hardell, 2017). In May 2011 RF radiation in the frequency range 30 kHz–300 GHz was evaluated to be a Group 2B, i.e. a "possible" human carcinogen, by IARC (Baan et al., 2011; IARC, 2013). This was based on an increased risk for glioma and acoustic neuroma in human epidemiological studies. In the following an updated summary is given of case-control studies on brain and head tumors; glioma, meningioma and acoustic neuroma. The Danish cohort study on 'mobile phone users' (Johansen et al., 2001; Schüz et al., 2006) is not included due to serious methodological shortcomings in the study design, including misclassification of exposure (see Söderqvist et al., 2012a).

2.1. Glioma

Glioma is the most common malignant brain tumor and represents about 60% of all central nervous system (CNS) tumors. Most of these are astrocytic tumors that can be divided into low-grade (WHO grades I-II) and high-grade (WHO grades III-IV). The most common glioma type is glioblastoma multiforme (WHO grade IV) with peak incidence in the age group 45–75 years and median survival less than one year (Ohgaki and Kleihues, 2005). Three research groups have provided results in case-control studies on glioma (Interphone, 2010; Coureau et al., 2014; Hardell and Carlberg, 2015). Hardell and colleagues have published results from case-control studies on use of wireless phones and brain tumor risk since the end of the 1990s (Hardell et al., 1990; for more discussion see Carlberg and Hardell, 2017).

A random effects model was used for meta-analyses of published studies, based on test for heterogeneity in the overall group ("all mobile"). Note that only the Hardell group also assessed use of cordless phones. Thus their reference category included cases and controls with no use of wireless phones in contrast to the other studies investigating only mobile phone use. In Table 1 results for highest cumulative use in hours of mobile phones is given. All studies reported statistically significant increased risk for glioma and the meta-analysis yielded an odds ratio (OR) = 1.90 [95% confidence interval (CI) = 1.31–2.76]. For ipsilateral mobile phone use the risk increased further to OR = 2.54 (95% CI = 1.83–3.52) in the meta-analysis based on 247 exposed cases and 202 controls.

Carlberg and Hardell (2014) found shorter survival in patients with glioblastoma multiforme associated with use of wireless phones compared with patients with no use. Interestingly mutation of the p53 gene involved in disease progression has been reported in glioblastoma multiforme in patients with mobile phone use ≥3 h per day. The mutation was statistically significantly correlated with shorter overall survival time (Akhavan-Sigari et al., 2014). Further support for the increased risk of glioma associated with mobile phone use has been obtained in additional analyses of parts of the Interphone study (Cardis et al., 2011; Grell et al., 2016; Momoli et al., 2017).

2.2. Meningioma

Meningioma is an encapsulated, well-demarked and rarely malignant tumor. It is the most common benign tumor and accounts for about 30% of intracranial neoplasms. It develops from the pia and arachnoid membranes that cover the CNS. It is slowly growing and gives neurological symptoms by compression of adjacent structures. The most common symptoms are headaches and seizures. The incidence is about two times higher in women than in men. Meningioma develops mostly among middle aged and older persons (Cea-Soriano et al., 2012). Carlberg and Hardell (2015) included meningioma in their case-control studies. The results of the meta-analysis for cumulative exposure in the highest category are given in Table 2. In total there was an increased (but not statistically significant) risk for cumulative exposure but the increased risk was statistically significant for ipsilateral use of mobile phones (OR = 1.49, 95% CI = 1.08–2.06).

2.3. Acoustic neuroma

Acoustic neuroma, also called vestibular schwannoma, is a benign tumor located on the eighth cranial nerve from the inner ear to the brain. It is usually encapsulated and grows in relation to the auditory and vestibular portions of the nerve. It grows slowly and due to the narrow anatomical space may give compression of vital brain stem structures. First symptoms of acoustic neuroma are usually tinnitus and hearing problems. Results for use of mobile phones in Interphone (2011) and Hardell et al. (2013) are given in Table 3. Statistically significant increased risk was found for cumulative ipsilateral use ≥1640 h yielding OR = 2.71 (95% CI = 1.72–4.28).

The study by Moon et al. (2014) was not included in the meta-analysis because data on cumulative mobile phone use with numbers of cases and controls were not given. Support of an increased risk was seen in the case-case part of the study (Moon et al., 2014) and also in the report by Sato et al. (2011). Pettersson et al. (2014) made a case-control study on acoustic neuroma in Sweden not overlapping the Hardell et al. (2013) study. An increased risk for the highest category of cumulative use of both mobile phone (≥680 h OR = 1.46, 95% CI = 0.98–2.17) and cordless phone (≥900 h OR = 1.67, 95% CI = 1.13–2.49) was found.Pettersson et al. (2014) was not included in the meta-analysis due to the many scientific shortcomings in the study, e.g. laterality analysis was not made for cordless phone, the numbers in the laterality analysis for mobile phone are not consistent in text and tables and the 'unexposed' reference category included subjects using either mobile and cordless phone, which is clearly not correct (Hardell and Carlberg, 2014).

Table 1
Numbers of exposed cases (Ca) and controls (Co) and odds ratio (OR) with 95% confidence interval (CI) for glioma in case-control studies in the highest category of cumulative hours of mobile phone use.

	All			Ipsilateral		
	Ca/Co	OR	95% CI	Ca/Co	OR	95% CI
Interphone 2010						
Cumulative use ≥1640 h	210/154	1.40	1.03–1.89	100/62	1.96	1.22–3.16
Coureau et al., 2014						
Cumulative use ≥896 h	24/22	2.89	1.41–5.93	9/7	2.11	0.73–6.08
Carlberg and Hardell, 2015						
Cumulative use ≥1640 h	211/301	2.13	1.61–2.82	138/133	3.11	2.18–4.44
Meta-analysis						
Longest cumulative use	445/477	1.90	1.31–2.76	247/202	2.54	1.83–3.52

Table 2
Numbers of exposed cases (Ca) and controls (Co) and odds ratio (OR) with 95% confidence interval (CI) for meningioma in case-control studies in the highest category of cumulative hours of mobile phone use.

	All			Ipsilateral		
	Ca/Co	OR	95% CI	Ca/Co	OR	95% CI
Interphone 2010						
Cumulative use ≥1640 h	130/107	1.15	0.81–1.62	46/35	1.45	0.80–2.61
Coureau et al., 2014						
Cumulative use ≥896 h	13/9	2.57	1.02–6.44	6/4	2.29	0.58–8.97
Carlberg and Hardell 2015						
Cumulative use ≥1640 h	141/301	1.24	0.93–1.66	67/133	1.46	0.98–2.17
Meta-analysis						
Longest cumulative use	284/417	1.27	0.98–1.66	119/172	1.49	1.08–2.06

Table 3
Numbers of exposed cases (Ca) and controls (Co) and odds ratio (OR) with 95% confidence interval (CI) for acoustic neuroma in case-control studies in the highest category of cumulative hours of mobile phone use.

	All			Ipsilateral		
	Ca/Co	OR	95% CI	Ca/Co	OR	95% CI
Interphone 2011						
Cumulative use ≥1640 h	77/107	1.32	0.88–1.97	47/46	2.33	1.23–4.40
Hardell et al., 2013						
Cumulative use ≥1640 h	27/301	2.40	1.39–4.16	19/133	3.18	1.65–6.12
Meta-analysis						
Cumulative use ≥1640 h	104/408	1.73	0.96–3.09	66/179	2.71	1.72–4.28

2.4. In summary

Based on case-control studies there was a consistent finding of increased risk for glioma and acoustic neuroma associated with use of mobile phones. Similar results were found for cordless phones in the Hardell group studies, although such use was not reported by the other study groups. The findings are less consistent for meningioma although somewhat increased risk was seen in the meta-analysis of ipsilateral mobile phone use. A longer follow-up time is necessary for this type of slow growing tumor.

The results on glioma and acoustic neuroma are supported by results from animal studies showing co-carcinogenic and tumor promoting effects from RF-EMF (Tillmann et al., 2010; Lerchl et al., 2015). Recent results from the National Toxicology Program (NTP) study showed genotoxicity of RF radiation in rats and mice exposed to RF-EMF (Smith-Roe et al., 2017). That result supports previous findings of DNA strand breaks in rat brain cells exposed to RF-EMF (Lai and Singh, 1997).

Of importance also is that the results in the NTP and Ramazzini studies both demonstrated an increased incidence of tumors of the same type, glioma and malignant schwannoma, as has been seen in humans with mobile phone use (Wyde et al., 2016; Falcioni et al., 2018). Acoustic neuroma (vestibular schwannoma) is a similar type of tumor as malignant schwannoma, although benign. In fact, rates of brain tumors are increasing in Sweden and use of wireless phones has been suggested to be the cause (Hardell and Carlberg. 2017).

3. Other diseases and pathological conditions attributed to exposure to low-intensity EMFs

The evidence for harm from RF-EMF is strongest for cancer as a consequence of intensive mobile phone use, especially gliomas, glioblastomas and acoustic neuromas. But there is other evidence for elevation in risk of leukemia among children living near to very high intensity radio transmission towers (Michelozzi et al., 2002; Ha et al., 2007). This is particularly interesting because leukemia is the cancer most associated with elevated exposure to ELF-EMFs arising from power lines (Ahlbom et al., 2000; Greenland et al., 2000). There is some evidence for elevations in breast cancer risk among women who wear their mobile phones in their bra (West et al., 2013). Heavy use of a mobile phone was associated with significantly elevated rates of ipsilateral parotid tumors in studies from both Israel (Sadetzki et al., 2007) and China (Duan et al., 2011). No increased risk was found in a Swedish study, but the results were limited by low number of participants and lack of data on heavy and long-term use of wireless phones (Söderqvist et al., 2012b).

There are other significant human health hazards of concern. There is strong animal and human evidence that exposure to RF-EMFs as well as ELF-EMFs reduces fertility in both males (reviewed by McGill and Agarwal, 2014) and females (Roshangar et al., 2014). An association between spontaneous abortion and non-thermal EMF exposure including ELF-EMFs was reported in several case-control studies (Dodge, 1970; Juutilainen et al., 1993; Li et al., 2017). The increased use of mobile phones and increased exposure coming from WiFi, smart meters and other wireless devices has been paralled in time with male hypofertility and sperm abnormalities in semen (Rolland et al., 2013). These effects may be related to holding an active wireless laptop in a man's lap or having an active mobile phone on their belt, but more study is needed. There is evidence that isolated human sperm exposed to RF-EMFs are damaged by generation of reactive oxygen species (Agarwal et al., 2009).

There are other diseases or physiologic alterations which have been reported to be associated with exposure to non-thermal EMFs in humans and in animals (Belyaev et al., 2016). Alzheimer disease has been shown to be significantly associated with chronic ELF-EMF occupational exposure in prospective epidemiological studies (García et al., 2008; Davanipour and Sobel, 2009). Exposure to RF-EMFs has been reported to increase neuropsychiatric and behavioural disorders (Johansson et al., 2010; Divan et al., 2012), trigger cardiac rhythm alteration and peripheral arterial pressure instability (Havas, 2013; Saili et al., 2015), induce changes in immune system function (Lyle et al., 1983; Grigoriev et al., 2010; Sannino et al., 2011, 2014) and alter salivary (Augner et al., 2010) and

thyroid (Koyu et al., 2005; Mortavazi et al., 2009; Pawlak et al., 2014) function. There is an urgent need for more study of these diseases or biological alterations in relation to exposure to both ELF- and RF-EMFs.

4. An emerging concern: cognitive and neurobehavioral problems in children

Children, and especially fetuses, are more vulnerable than adults for most environmental exposures (Sly and Carpenter, 2012). This is because their cells are rapidly dividing and their organ systems are not mature. As a result, events that perturb cellular function early in life can result is abnormalities that last. There is a building body of evidence indicating that exposure to RF-EMFs has adverse effects on cognition and neurobehavior, especially in children and adolescents. Concern about the particular sensitivity of children to RF-EMFs emitted from mobile phone was first raised in 2000 by a British independent expert group (IEG, 2000) that noted that the increased sensitivity to EMFs of children could be due not only to the natural vulnerability of the developing nervous system, but also to the smaller head size and thickness of the skull. These factors, plus the higher conductivity of the young nervous system, result in greater penetration of RF-EMFs into the brain (Gandhi et al., 1996). Of concern is the fact that any adverse effects during development may have life-long consequences and that young people, because they will have a longer life span, will receive a greater cumulative exposure than adults (Kheifets et al., 2005; Hansson Mild et al., 2006).

There are several reasons to be concerned. Animal studies have shown that *in utero* RF-EMF exposure from mobile phones affects fetal programming and leads to alteration in neurodevelopment and behavior of offsprings (Aldad et al., 2012; Zhang et al., 2015). Exposure of young rats to non-thermal intensities impairs learning and spatial memory secondary to a deleterious impact of EMFs on hippocampal, pyramidal or cortical neurons. Similar detrimental cognitive and behavioural defects were also observed in adult animals exposed to low-intensity.

EMFs (Bas et al., 2009; Deshmukh et al., 2015; Kumari et al., 2017; Shahin et al., 2017). The exposure induces markers of oxidative stress and inflammation in the brain (Dasdag et al., 2012; Megha et al., 2015).

There are human data consistent with these animal studies. Divan et al. (2008) reported that prenatal and to a lesser degree postnatal exposure to cell phones is associated with emotional and hyperactivity problems in 7-year old children. This finding was confirmed in a second replicative study involving different participants (Divan et al., 2012). Birks et al. (2017) used data from studies in five cohorts from five different countries (83,884 children) and concluded that maternal mobile phone use during pregnancy increased the risk that the child will show hyperactivity and inattention problems. A meta-analysis involving 125,198 children (mean age 14.5 years) reported statistically significant associations between access to and use of portable screen-based media devices (e.g. mobile phones and tablets) and inadequate sleep quality and quantity and excessive daytime sleepiness (Carter et al., 2016). Early life exposure to lead has long been known to cause a reduction in cognitive function and shortened attention span (Needleman et al., 1979). Two studies have shown that prenatal (Choi et al., 2017) or postnatal (Byun et al., 2017) mobile phone exposure results in greater neurobehavioral effects in children with elevated lead levels than those seen with elevated lead alone. These results raise concern that EMFs may have synergistic actions with other environmental contaminants known to cause a reduction in intelligence quotient (IQ) and attention, such as polychlorinated biphenyls, methyl mercury, environmental tobacco smoke and probably others (Carpenter, 2006).

Finally the problem should be considered at the societal, worldwide level. Many adolescents (Lenhart, 2015) and even very young children and infants (Kabali et al., 2015) use cordless devices immoderately, to such a point that the common intensive use of devices in children and adolescents has been ascribed as an addiction (Paz de la Puente and Balmori, 2007; Roberts et al., 2014).

The specific absorption rate (SAR)-based ICNIRP safety limits were established on the basis of simulation of EMF energy absorption using standardized adult male phantoms, and designed to protect people only from the thermal effects of EMFs. These assumptions are not valid for two reasons. Not only do they fail to consider the specific morphological and bioclinical vulnerabilities of children, but also they ignore the effects known to occur at non-thermal intensities. The same criticisms apply to other so called “independent” advisory groups or agencies, such as the Advisory Group of Non-Ionizing Radiation in the UK (AGNIR, 2012), the French Agency for Food, Environmental and Occupational Health & Safety in France (ANSES, 2013), and the Scientific Committee on Emerging Newly Identified Health Risk (SCENIHR, 2009), all of whom deny the detrimental health effects of low intensity, non thermal EMF exposure and make recommendations based only on thermal SAR considerations.

Although several scientific authorities, such as the US American Academy of Pediatrics (AAP, 2013), and the Russian National Committee on Non-Ionizing Radiation Protection (RNCNIRP, 2011) have made specific recommendations to not allow the use of mobile phones by children and to limit their use by adolescents, unfortunately these age categories remain a target for marketing of mobile phone devices [http://www.who.int/peh-emf/project/mapnatreps/RUSSIA%20report%202008.pdf]. The RNCNIRP has warned that if no rational, health-based safety limits are adopted for children and adolescents and no measures are taken to limit the use of cordless devices, we can expect disruption of memory, decreases in learning and cognitive capabilities, increases in irritability, sleep disturbance, and loss of stress adaptation in this population. There will also be long-term effects, including an increase in brain cancer, infertility, EHS, Alzheimer disease and other neurodegenerative diseases (RNCNIRP, 2011; Markov and Grigoriev, 2015). National and international bodies, particularly the WHO, will bear major responsiblity for failing to provide specific science-based guidance and recommendations so as to avoid such global health threats.

5. Electrohypersensitivity, microwave illness or idiopathic environmental intolerance attributed to electromagnetic fields

There is a segment of the human population that is unusually intolerant to EMFs. The term “electromagnetic hypersensitivity” or “electrohypersensitivity (EHS)” to describe the clinical conditions in these patients was first used in a report prepared by a European group of experts for the European Commission (Bergqvist et al., 1997). Santini et al. (2001, 2003) reported similar symptoms occurring in users of digital cellular phones and among people living near mobile phone base stations.

In 2004, because of the seemingly increasing worldwide prevalence, WHO organized an international scientific workshop in Prague in order to define and characterize EHS. Although not acknowledging EHS as being caused by EMF exposure, the Prague working group report clearly defined EHS as “a phenomenon where individuals experience adverse health effects while using or being in the vicinity of devices emanating electric, magnetic or electromagnetic fields” (www.who.int/pehemf/EHS_Proceedings_June2006.pdf). Following this meeting, WHO acknowledged EHS as an adverse health condition (WHO, 2005).

According to the Prague Workshop recommendations, it was proposed to use the term “idiopathic environmental intolerance (IEI) attributed to electromagnetic fields” (IEI-EMF) because of the lack of a proven causal link with EMF exposure (Hansson Mild et al., 2006). This pathological disorder is identical to what has been previously described under the term “microwave illness” (Carpenter, 2015).

This syndrome is characterized by fatigue, chronic pain and impaired cognitive function (see the Paris appeal, http://appel-de-paris.com/?lang=en). The precise mechanism(s) whereby environmental exposure to either ELF- or RF-EMFs can cause the development of this syndrome are still uncertain. However several lines of experimental and clinical data are sufficiently strong so as to indicate that ELF-EMFs and RF-EMFs exposure is associated with adverse biological and clinical health effects in humans as well as animals (Rea et al., 1991; McCarty et al., 2011; Belpomme et al., 2015; Hedendahl et al., 2015; Irigaray et al., 2018a). The prevalence of EHS has been estimated to range 1–10% in developed countries (Hallberg and Oberfeld, 2006) but appears today to be around 3% (Huang et al., 2018).

Since WHO official reports on mobile phone exposure and public health (WHO, 2014) and more particularly on EHS (WHO, 2005), much clinical and biological progress has been made to identify and objectively characterize EHS, as was summarized during the international scientific consensus meeting of the 5th Paris Appeal Congress that took place in May 2015 in Brussels at the Royal Belgium Academy of Medicine (ISD, 2015). EHS has many characteristics in common with other IEI pathological disorders, including chronic fatigue syndrome, fibromyalgia, Gulf War Illness and especially the syndrome of multiple chemical senssitvity (MCS), which Belpomme et al. (2015) have shown to be associated with EHS in many patients who report being electrohypersensitive.

5.1. Bioclinical identification and characterisation of electrohypersensitivity

In a prospective study involving systematic face-to-face questionnaire-based interviews and clinical physical examinations of nearly two thousand patients who self-reported having EHS or EHS and MCS, Belpomme and colleagues reported that EHS is a well-defined clinico-biological entity, characterized by the progressive occurrence of neurologic symptoms, including headache, tinnitus, hyperacusis, superficial and/or deep sensibility abnormalities, fibromyalgia, vegetative nerve dysfunction and reduced cognitive capability. These symptoms are repeatedly reported by the patients to occur each time they are exposed to EMFs, even of weak intensity. They result in chronic insomnia, fatigue, emotional lability and depressive tendency (Belpomme et al., 2015; Irigaray et al., 2018b).

Table 4 presents the detailed symptomatic picture which was obtained during face-to-face interviews with subjects with EHS in comparison to those with both EHS and MCS and to a series of apparently healthy control subjects that showed no evidence of EHS and/or MCS. As shown in the Table, the symptoms reported are consistent with those in other published questionnaire-based studies of EHS patients (Dodge, 1970; Johansson et al., 2010; Nordin et al., 2014; Medeiros and Sanchez, 2016; Röösli, 2008). The clinical symptoms observed in EHS or EHS/MCS patients are statistically significantly much more frequent that those in apparently normal controls. Although many of these symptoms are non-specific, the general clinical picture resulting from their association and frequency strongly suggests that EHS can be recognized and identified as a specific neurological disorder.

Because of the multiple and relatively common symptoms and the lack of recognized objective diagnosis criteria, studies on EHS were left with only the patient's self-reported interpretation for many years. As a result, EHS has unfortunately been considered to be a psychiatric disease of unknown origin. This helps explain why most mainstream public health and societal bodies claim there is not sufficient data proving that the clinical symptoms experienced and reported by EHS patients are caused by EMF exposure. Therefore they refuse to acknowledge EHS as a true neuropathological disorder. This negative point of view was supported by some blind or double blind studies showing that most individuals who report they suffer from EHS were not able to identify when they were exposed to either EMFs or sham controls (Rubin et al., 2011; Eltiti et al., 2015). However other studies have found that EHS subjects can identify EMF exposure in a statistically significant manner when they are blinded to whether or not the exposure was on (Rea et al., 1991; McCarty et al., 2011).

To account for these seemingly negative results a nocebo effect was suggested (ANSES, 2017). However there is presently no consensus on a biological mechanism through which a nocebo effect could occur (Medeiros and Sanchez, 2016; Chrousos and Gold, 1992; Jakovljevic, 2014). Moreover, results obtained in a carefully designed psycho-clinical study in self-reporting EHS patients are not consistent with an initial nocebo response to perceived EMF exposure, even though it is plausible that after the onset of the disease such phenomena may intervene secondarily through an acquired learning and conditioning process (Dieudonné, 2016). In addition, a meta-analysis of cross sectional studies has documented a 38% greater risk of development of headaches among mobile phone users than non-users, and an increasing risk of headache with longer daily call duration (Wang et al., 2017).

Belpomme, Irigaray and colleagues recently identified several biomarkers in EHS and/or MCS patients which allow physicians to identify and objectively characterize EHS as a true somatic pathological disorder, discounting the hypothesis of a causal psychosomatic or nocebo-related process. These came in part from a prospective clinical and biological analysis of a series of several hundred consecutive cases of individuals who self-reported that they suffered from EHS or both EHS and MCS (Belpomme et al., 2015) and more recently from the prospective anlaysis of an additional series of EHS patients (Irigaray et al., 2018a). Table 5 summarizes the different biomarkers that have been measured in the peripheral blood of these patients and the results which have been obtained based on the EHS and EHS/MCS patient groups. Note that among the different markers, the 6-hydroxymelatonin sulfate/creatinine ratio in urine appears to be the best marker to be used in medical practice since it has been found to be decreased in all cases evaluated to date (Belpomme et al., 2015).

By measuring different major oxidative stress-related biomarkers, such as thiobarbituric acid reactive substances (TBARS), oxided glutathione (GSSG) and nitrotyrosine (NTT) in EHS patients, Irigaray et al. (2018b) have recently shown that near 80% of the EHS patients present with detectable oxidative stress biomarkers (Fig. 1). More than 40% of EHS patients present with at least one positive biomarker, 20% with two and 15% will all three of the biomarkers investigated. This indicates that in addition to the inflammation-related biomarkers previously associated with EHS, EHS patients are also characterized by exhibiting biomarkers of oxidative stress (Belpomme et al., 2015; Irigaray et al., 2018a,b).

The significance of the different biomarkers measured in the peripheral blood of EHS and EHS/MCS patients is that these results imply that these patients present with some degree of oxidative/nitrosative stress, inflammation and autoimmune response. Increased levels of several of these markers (notably protein S100B and NTT) may reflect hypoxia-associated oxidative stress-induced blood brain barrier (BBB) opening. It has been previously hypothesized that opening of the BBB can be caused by environmental

Table 4
Clinical symptom occurrence in EHS and EHS/MCS patients in comparaison with normal controls[a].

	EHS	EHS/MCS	p[b]	Normal controls	p[c]	p[d]
Headache	88%	96%	0.065	0%	<0.0001	<0.0001
Dysesthesia	82%	96%	0.002	0%	<0.0001	<0.0001
Myalgia	48%	76%	<0.0001	6%	<0.0001	<0.0001
Arthralgia	30%	56%	<0.001	18%	0.067	<0.0001
Ear heat/otalgia	70%	90%	<0.001	0%	<0.0001	<0.0001
Tinnitus	60%	88%	<0.0001	6%	<0.0001	<0.0001
Hyperacousis	40%	52%	0.118	6%	<0.0001	<0.0001
Dizziness	70%	68%	0.878	0%	<0.0001	<0.0001
Balance disorder	42%	52%	0.202	0%	<0.0001	<0.0001
Concentration/Attention deficiency	76%	88%	0.041	0%	<0.0001	<0.0001
Loss of immediate memory	70%	84%	0.028	6%	<0.0001	<0.0001
Confusion	8%	20%	0.023	0%	0.007	<0.0001
Fatigue	88%	94%	0.216	12%	<0.0001	<0.0001
Insomnia	74%	92%	0.001	6%	<0.0001	<0.0001
Depression tendency	60%	76%	0.022	0%	<0.0001	<0.0001
Suicidal ideation	20%	40%	0.003	0%	<0.0001	<0.0001
Transitory cardiovascular abnormalities	50%	56%	0.479	0%	<0.0001	<0.0001
Occular deficiency	48%	56%	0.322	0%	<0.0001	<0.0001
Anxiety/Panic	38%	28%	0.176	0%	<0.0001	<0.0001
Emotivity	20%	20%	1	12%	0.176	0.176
Irritability	24%	24%	1	6%	<0.001	<0.001
Skin lesions	16%	45%	<0.0001	0%	<0.0001	<0.0001
Global body dysthermia	14%	8%	0.258	0%	<0.0001	<0.007

[a] This data results from the clinical analysis of the 100 first clinically evaluated cases issued from the already published series of EHS and/or MCS patients who have been investigated for biological markers [Belpomme et al., 2015]. It has been compared symptomatically with data obtained from a series of 50 apparently normal subjects matched for age and sex, used as controls.
[b] Significance levels (p values) obtained for compararison between the EHS and EHS/MCS groups.
[c] Significance levels (p values) obtained for compararison between the EHS and normal control groups.
[d] Significance levels (p values) obtained for compararison between the EHS/MCS and normal control groups.

Table 5
Patient mean values and standard deviations of biomarker levels in comparison with normal reference values as well as the percentage of patients with abnormal values in the peripheral blood in subjects with EHS or both EHS and MCS (Belpomme et al., 2015).

Biomarker and Normal reference values	Patients groups			
	EHS Mean ± SD	% Above normal	EHS/MCS Mean ± SD	% Above Normal[a]
hs-CRP < 3 mg/l	10.3 ± 1.9	15%	6.9 +/1.7	14.3%
Vitamine D > 30 ng/ml	20.6 ± 0.5	69.3%	14.5 ± 1.3	70.1%
Histamine< 10 nmol/l	13.6 ± 0.2	37%	13.6 ± 0.4	41.5%
IgE< 100 UI/ml	329.5 ± 43.9	22%	385 ± 70	24.7%
S100B < 0.105 μg/l	0.20 ± 0.03	14.7%	0.17 ± 0.03	19.7%
Hsp 70 < 5 ng/ml	8.2 ± 0.2	18.7%	8 ± 0.3	25.4%
Hsp 27< 5 ng/ml	7.3 ± 0.2	25.8%	7.2 ± 0.3	31.8%
Anti-O-myelin auto-antibodies[b]	Positive	22.9%	Positive	23.6%
24-h urine 6-OHMS/creatinine ratio >0.8[c]	0.042 ± 0.003	100%	0.048 ± 0.006	100%

hs-CRP, high-sensitivity C-reactive protein; IgE, Immunoglobulin E; S100B, S 100 calcium binding protein B; Hsp 27, heat shock protein 27; Hsp 70, heat shock protein 70; anti-O-myelin auto-antibodies, auto-antibodies against O-myelin; 6-OHMS, 6-hydroxymelatonin sulfate.
[a] There is no statistically significant difference between the two groups of patients for the different biomarkers analyzed, suggesting that EHS and MCS share a common pathological mechanism for genesis.
[b] Qualitative test.
[c] Data restricted to those not on neuroleptic medication as the simultaneous use of several psychotherapeutic drugs may also be associated with a decrease of this 24-h urine ratio by modifying melatonine metabolism.

stressors, be they chemicals or EMFs. This may have occurred in these patients, as has been shown to occur in several (but not all) animal experiments involving EMF exposure (Oscar and Hawkins, 1977; Persson et al., 1997; Eberhardt et al., 2008; Sirav and Seyhan, 2009). Comparable data using metabolic and genetic biomarkers were also obtained in another large series of EHS patients (De Luca et al., 2014). Overall these data indicate that the clinical use of biomarkers allows the objective characterisation and identification of EHS and MCS as two etiopathologic facets of a unique pathological disorder, and also allows insight into the genesis of these two diseases.

The development of new imaging techniques has also greatly increased our ability to objectively characterize EHS and MCS. Using ultrasonic cerebral tomosphygmography (UCTS) (Parini et al., 1984), EHS- and EHS/MCS-patients were found to have a statistically significant decrease in mean pulsometric index in several middle cerebral artery-dependant portions of the temporal lobes, especially in the capsulo-thalamic area, which is part of the limbic

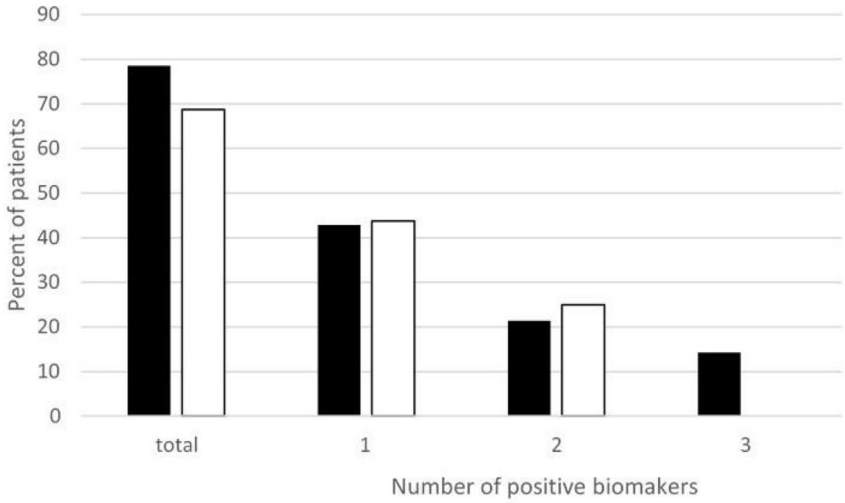

Fig. 1. Percentage of EHS self-reporting patients having positive TBARs, GSSG and/or NTT oxidative stress biomarkers measured in the peripheral blood. "Positive" biomarkers correspond to marker levels above the upper normal limit; "total" corresponds to the patients with one or more positive biomarker levels. Black bars show the percentage of patients with one, two or all three of the biomarkers for TBARS, GSSG and NTT. The white bars show the percentage of patients with either TBARs or GSSG or both oxidative stress markers.

system and the thalamus. This suggests that EHS and EHS/MCS may be associated with a brain blood flow (BBF) deficiency and/or neuronal dysfunction in these brain structures (Belpomme et al., 2015; Irigaray et al., 2018a,b). Irigaray et al. (2018c) have recently confirmed that UCTS is the best imaging technique to diagnose EHS and to follow patients treated for EHS and/or MCS.

In addition, using positron emission tomography (PET) it has been shown that short term exposure to pulse-modulated RF-EMF causally affects regional BBF in normal subjects using a mobile phone (Aalto et al., 2006; Huber et al., 2005), a finding that may account for the modifications observed in the sleep and waking EEG (Huber et al., 2002). By use of functional MRI (fMRI) in EHS patients exposed chronically to ELF-EMFs, regional BBF changes have been reported in the frontal lobes, such as abnormal default mode network and more particularly a decrease in BBF and cerebral metabolism. These observations indicate that fMRI may also be a tool for diagnosis of EHS and clinical follow up of patients (Heuser and Heuser, 2017). A decreased BBF-associated pulsometric index decrease in both hemispheres was also recently observed by the Belpomme group by using transcranial Doppler ultrasound (TDU) (Purlauastja and Sorond, 2012) applied to the middle cerebral artery in a study involving 120 EHS and/or MCS patients. This study revealed a decrease in pulsatility index and an increase in diastolic flow velocity in 70% of the 120 cases investigated to date.

In summary it is the strong opinion of the authors that there is presently sufficient clinical, biological and radiological data emanating from different independent international scientific research groups for EHS, whatever its causal origin, to be acknowledged as a well-defined, objectively characterized pathological disorder. As a result, patients who self-report that they suffer from EHS should be diagnosed and treated utilizing presently available objective biological tests, among which are the concentration of peripheral blood biomarkers and the use of imaging techniques such as PET, fMRI and TDU and, when available, UCTS. Whatever its etiological origin and mechanism of action, EHS should be acknowledge by the WHO as a real and distinct neurological and pathological disorder (McCarty et al., 2011; Hedendahl et al., 2015) and thus be included in the International Classification of Diseases.

5.2. Possible etiopathogenic processes involved in genesis of electrohypersensitivity

EMFs, both RF-EMFs at non-thermal intensities and ELF-EMFs, have been found to cause persistent adverse biological effects in microorganisms (Fojt et al., 2004), plants (Roux et al., 2008; Maffei, 2014), birds (Balmori, 2005; Balmori and Hallberg, 2007; Frey, 1993), and mammals. Therefore the effects observed in humans cannot be due to only a nocebo or psychosomatic effect. These biological effects may be due both to the pulsed and polarised characteristics of man-made EMFs emitted by electric or wireless technologies as opposed to the terrestrial non-polarised and continuously emitted natural EMFs (Blackman, 2009; Belyaev, 2015; Panagopoulos et al., 2015).

The inflammatory and oxidative/nitrosative states that have been documented in EHS patients are remarkable since they confirm the data obtained experimentally in animals exposed to non-thermal EMFs (Esmekaya et al., 2011; Burlaka et al., 2013), and especially in the brain (Megha et al., 2015; Kesari et al., 2011). The limbic system–associated capsulo-thalamic abnormalities that the Belpomme group has observed by using UCTS in EHS and/or MCS patients (Belpomme et al., 2015; Irigaray et al., 2018a,c) may likely correspond to the hippocampal neuronal alterations caused by EMF exposure in the rats (Bas et al., 2009; Furtado-Filho et al., 2015; Deshmukh et al., 2013). Fig. 2 summarizes our hypothesis regarding the inflammation and oxidative stress-related mechanisms which may account for EMF- and/or chemically-related health effects in the brain and consequently for EHS genesis.

6. Mechanisms whereby low intensity electromagnetic fields cause biological effects and harm

Arguments used in the past to attempt to discount the evidence showing deleterious health effects of ELF-EMFs and RF-EMF exposure at non-thermal SAR levels were based on the difficulties encountered in understanding the underlying biological effects and the lack of recognized basic molecular mechanisms accounting for these effects. This is no longer the case. There are a number of well-documented effects of low intensity EMFs that are the mechanistic basis behind the biological effects documented above (www.

bioinitiative.org). These include induction of oxidative stress, DNA damage, epigenetic changes, altered gene expression and induction including inhibition of DNA repair and changes in intracelluar calcium metabolism. Both low-intensity ELF-EMF and non-thermal RF-EMF effects depend on a number of physical parameters and biological variables and physical parameters, which account for the variation in health outcomes (Belyaev, 2015; Belyaev et al., 1999). Importantly, the most severe health effects are observed with prolonged chronic exposures even when intensities are very low (Belyaev, 2017). The physics of non-equilibrium and non-linear systems and quantum mechanics are at least in part the basis of the physical mechanisms responsible for the non-thermal molecular and biological effects of non-thermal EMF radiation (Belyaev, 2015), although a detailed report on these actions is beyond the scope of this review.

Lower RF-EMF intensity is not necessarily less bioactive or less harmful. Non-thermal EMF effects can be observed at intensities which are very close to ordinary background levels and quite similar to intensities emitted by mobile phone base stations. There are time windows for observation of non-thermal EMF effects which may be dependent upon the endpoint measured, the cell type and the duration and power density of exposure. Non-thermal RF-EMF effects are affected by static magnetic fields and electromagnetic stray fields, which result in the variation of non-thermal EMF effects from mobile phones because of adjacent electrical appliances, power lines and other sources of ELF and static magnetic fields, including changes in the geomagnetic field (Gapeev et al., 1999a and b).

Cell-to-cell interactions potentiate the response to non-thermal EMFs (Belyaev et al., 1996). Biological responses to EMFs have been shown to be influenced by sex and age (Zhang et al., 2015; Sirav and Seyhan, 2016). Physiological parameters such as the stage of cell growth, oxygen, divalent ions and temperature are important variables affecting cellular responses to EMFs (Liburdy and Vanek, 1987; Sannino et al., 2011).

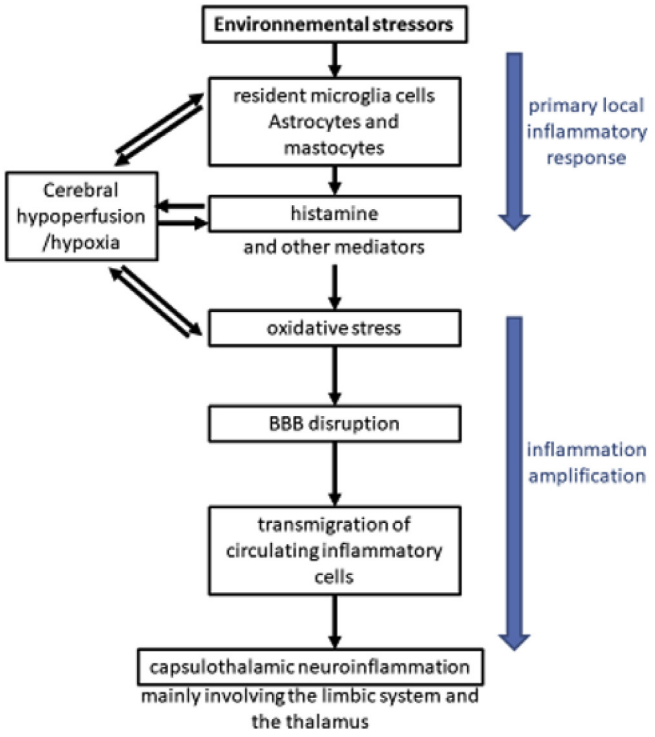

Fig. 2. Hypothetical EHS/MCS common etiopathogenic model based on neuroinflammation and oxidative/nitrosative stress-induced blood brain barrier disruption (Belpomme et al., 2015).

6.1. Combined exposures

EMFs at non-thermal intensities may interfere with other environmental stressors, showing an interplay of molecular pathways and resulting in either beneficial or detrimental health effects, depending on the nature and conditions of co-exposures (Novoselova et al., 2017; Ji et al., 2016). One example is the demonstration that RF-EMF exposure modulates the DNA damage and repair induced by ionizing radiation (Belyaev et al., 1993). Another example is the synergistic of exposure to lead and EMFs on cognitive function in children described above (Choi et al., 2017; Byun et al., 2017). These co-exposure factors should be considered when assessment of detrimental effects, including carcinogenicity, is performed.

Not all of the effects of EMFs on the nervous system and other organs are necessarily harmful. The best example of a positive effect is the well-documented and clinically useful benefit of applied magnetic fields to promote bone healing (Bassett, 1994). Both ELF-EMF (Zhang et al., 2015) and RF-EMF (Arendash et al., 2010) have been reported to slow cognitive decline in rodent models of Alzheimer's disease. Some human studies report a facilitating effects of cognitive performance (Lee et al., 2001) while Koivisto et al. (2000) reported an increase in response time and vigilance tasks but a decrease in mental arithmetic tasks. These studies clearly show that EMFs have biological effects at non-thermal intensities, but suggest that not all biological effects are necessarily harmful.

6.2. Duration of exposure and dose intensity

Such parameters as power density, dose, and duration of exposure have been analyzed for development of reliable safety standards, which would protect against the detrimental health effects of chronic exposure to RF-EMFs at non-thermal intensities. Some studies show no effect under fixed short-term exposures, but this does not imply that there are no effects from longer-term exposures (Choi et al., 2014). Exposure in studies showing RF-EMF effects was on average twice the duration as those with no significant effects (Cucurachi et al., 2013). The response to non-thermal EMFs depends on both power density and duration of exposure. Importantly, the same response is observed with lower power density but prolonged exposure as at higher power density and shorter exposure (Nordenson et al., 1994). While SAR is a good surrogate for thermal RF effects from acute exposures, many studies have shown that SAR should be either replaced by “dose-specific absorption” or power density complimented by duration of exposure for description of non-thermal RF effects (Belyaev, 2015). Recent studies have provided more evidence for the greater importance of dose and duration of exposure than SAR alone for biological and health effects from long-term exposures to non-thermal RF-EMFs (Furtado-Filho et al., 2015).

6.3. Oxidative stress

Non-ionizing radiation does not have sufficient energy to directly break chemical bonds, and therefore the DNA damage that occurs with non-ionizing EMF exposures is primarily a consequence of generation of reactive oxygen species (ROS), resulting in oxidative stress. There are numerous animal experiments which clearly demonstrate that non thermal EMFs can cause oxidative stress (Esmekaya et al., 2011; Burlaka et al., 2013), particularly in the brain (Shahin et al., 2017; Dasdag et al., 2012; Megha et al., 2015; Furtado-Filho et al., 2015). Oxidative stress is known to

play a central role in development of cancer and aging and serves as a signaling agent in the inflammatory response (Holmstrom and Finkel, 2014).

The brain is a particularly important organ for sensitivity to EMFs. Brain cancer resulting from EMF exposures is a serious concern, and EHS is a disease of the central nervous system. Several mechanisms at the cellular and molecular levels have been reported that may be the basis of these non-thermal RF-EMF effects on brain function. ELF- and/or RF-EMF exposure at embryonic or early postnatal stages can alter *in vivo* synaptic efficacy and plasticity of neurons (Balassa et al., 2014), a finding which was further supported by *in vitro* studies showing a significant decrease in the differentiation of neural stem cells into neurons (Eghlidospour et al., 2017), the alteration of transcript levels of neuronal differentiation-related genes and impairment of neurite outgrowth of embryonic neural stem cells exposed to ELF- or RF-EMFs (Ma et al., 2014). These observations support the conclusion that low-intensity but prolonged exposure to non-thermal EMFs may have adverse effects on neurogenesis during development and indicate how important it is to protect the fetus and young child from excessive exposure to all mobile devices.

Animal studies have documented that 900 MHz or 2.45 GHz non thermal RF-EMF exposure in rats, either short term or chronic, can trigger neuronal dysfunction and even apoptosis of hippocampal pyramidal cells (Bas et al., 2009; Shahin et al., 2017) and cerebellum Purkinje cells (Sonmez et al., 2010) through induction of oxidative stress. Exposure of pregnant dams elicited EMF oxidative stress-induced neuronal pathologic changes in offspring (Odaci et al., 2016). Such pathological changes could be due to ROS-induced opening of the BBB (Nordal and Wong, 2005) and/or to ROS-associated brain hypoxia caused by a decrease in EMF-induced BBF and/or EMF-induced hemoglobin deoxygenation (Mousavy et al., 2009; Muehsam et al., 2013). The resulting hypoxia may induce metabolic neuronal dysfunction as in the case of EHS patients (Belpomme et al., 2015) but also neuronal cell death by either apoptosis or necrosis as in the case of Alzheimer's disease and other forms of dementia (Bell and Zlokovic, 2009).

While some consider the laboratory data on EMFs as being inconsistent, showing either detrimental or no effects and on occasion even beneficial effects, the vast majority still show detrimental effects. For example Henry Lai in the Bioinitiative Report Research Summaries Update of November 2017, Chapter 6 on Genotoxic Effects, reported that i) of 46 studies on ELF genotoxicity with the comet assay as the end point, 34 studies (74%) showed detrimental effects, ii). Of 189 total studies on ELF and oxidative stress, 162 (87%) showed a positive correlation, and iii) of 200 studies on RF and free radicals, 180 (90%) showed detrimental effects. One reason for variability between laboratory studies is the strong dependence on low-threshold EMF effects on a number of physical and biological variables (Belyaev, 2010).

6.4. Genetic and epigenetic mechanisms

Genetic effects are the most direct cause for carcinogenicity. This is true both for genotoxic changes caused by exposure to EMFs and existing polymorphic genetic differences within a population that increase susceptibility to cancer. DNA can no longer be considered to be unaffected by environmental EMF levels, as many studies have shown that DNA can be activated and damaged by EMFs at levels that have been considered to be safe (Blank and Goodman, 1999).

The primary mechanism through which low-intensity EMFs can alter DNA is through ROS production. Lai and Singh (2004) first reported that a 2 h exposure of rats to 60 Hz EMFs at 0.1–0.5 mT resulted in DNA strand breaks in neurons, and provided evidence that this effect was mediated by free radical formation and blocked by free radical scavengers. Vijayalaxmi and Prihoda (2009) in a meta-analysis of 87 publications found a biologically small but statistically significant difference between DNA damage in ELF-EMF-exposed somatic cells as compared to controls, and reported evidence for epigenetic changes for some outcomes. For ELF-EMFs this breakage effect was stronger when exposure was intermittent rather than continuous (Nordenson et al., 1994).

Yang et al. (2008) have reported an OR = 4.31 (95% CI = 1.54–12.08) for leukemia in children living within 100 m of a high voltage powerline if they had a certain polymorphism of a DNA repair gene.

Exposure to RF-EMFs can also induce DNA damage under specific conditions (Markova et al., 2005). Tice et al. (2002) and Vijayalaxmi et al. (2013) reported DNA damage and micronuclei formation in cultured human leukocytes and lymphocytes upon exposure to RF-EMF signals of at least 5 W/kg. Not all cell types showed similar responses. Schwartz et al. (2008) reported micronucleus changes in fibroblasts but not lymphocytes exposed to 1950 MHz EMFs. Kesari et al. (2014) also demonstrated DNA strand breaks in the brains of rats exposed for 2 h per day for 60 days to a 3G mobile phone. Changes in DNA secondary structure (Semin, 1995; Diem et al., 2005) and chromosome instability (Mashevich, 2003) have been observed upon exposure to RF-EMFs emitted by mobile phones.

Epigenetic changes, rather than genetic changes in DNA, may underlie many or even most of the biological effects of non-thermal EMFs (Sage and Burgio, 2017). Non-thermal EMFs are epigenetic stressors which can alter gene expression by acting through physical or biochemical processes and be reflected as chromatin remodeling (Belyaev et al., 1997), histone modification (Wei et al., 1990) or altered microRNA (Dasdag et al., 2015) at intensities far below those that cause measureable tissue heating.

Chromatin plays a key regulatory role in controlling gene expression and, more particularly, the access of transcription factors to DNA. It has been shown that extremely low intensity RF-EMF exposure, i.e. at intensities comparable to that of mobile phone and towers, results in changes in chromatin conformation and gene expression (Belyaev et al., 1997; Belyaev and Kravchenko, 1994; Belyaev et al., 2006; Belyaev et al., 2009). In a large number of cells and tissues, compaction of chromatin in specific loci may lead to gene silencing, loss of histone regulatory effects and DNA repair capacity (Wei et al., 1990). Belyaev and collaborators (Markova et al., 2005; Belyaev et al., 2009) have shown that exposure to RF-EMFs emitted by GSM mobile phone alters chromatin conformation in human lymphocytes and inhibits formation of p53-binding protein 1 (53BP1) and phosphorylated histone H2AX (γ-H2AX) DNA repair foci.

EMFs in both the ELF and RF ranges may epigenetically affect DNA by inducing the expression of stress response genes and consequently the synthesis of chaperone stress proteins (Blank and Goodman, 2011a and b). A specific gene sequence has been identified that acts as a sort of antenna, specifically sensitive and responsive to EMFs (Blank and Goodman, 2011b). This is a gene sequence coding for HSP70, a protein belonging to a family of conserved, ubiquitously expressed “heat shock proteins” that sense danger signals and protect cells from the most disparate stress conditions. This is an unambiguous demonstration that EMF exposure even at non-tissue heating intensities has the potential to be harmful to cells and organisms. The HSP70 promotor contains different DNA regions that are specifically sensitive to diverse stressors, thermal and non-thermal. The EMFs are specifically perceived by the sequences sensitive to non-thermal stimuli. During the process of HSP70-response induction, EMFs can activate directly the HSP70 gene promoter (Rodrequez-De la Fuente et al.,

2010) which contains a magnetic field-responsive domain (Lin et al., 1999, 2001).

EMF-related HSP70 and HSP27 stress responses have been detected in the hippocampus of rats exposed to non-thermal EMFs (Yang et al., 2012). Shahin et al. (2017) reported that mice exposed to 2G mobile phones continuously for four months showed elevated ROS, lipid peroxidation, total nitrate and nitrite concentrations and malondialdehyde levels in homogenates of different tissues, and decreased levels of several antioxidant enzymes. These observations justify the use of these markers to characterize EHS in patients who report that they are sensitive to EMFs.

The EMF effects have been suggested to be mediated by the mitogen-activated protein kinase (MAPk) cascades, which is a central signaling transduction pathway which governs all stress-related cellular processes occurring in response to extracellular stimuli (Friedman et al., 2007). It has been shown that long term exposure of cells to mobile phone frequencies or to ELF-EMFs (Goodman et al., 2009) activates the extracellular-signal regulated kinase (ERK), which is one of the four MAPk cascades so far identified.

Non-thermal RF-EMFs may also alter expression of other genes. As long ago as Byus et al., 1988 showed that 450 MHz RF increased ornithine decarboxylase activity in hepatoma cells. Markova et al. (2005) exposed human fibroblasts and mesenchymal stem cells to mobile phone RF-EMFs with analysis of tumor suppressor p53 binding protein 1. Formation of 53BP1 foci was inhibited in both cells types, but the stem cells always showed a greater response. Fragopoulou et al. (2011) exposed mice to either a typical mobile phone or a wireless DECT base station and analyzed the brain proteome. They found significant alteration in 143 specific proteins (ranging from a 0.003 fold downregulation to up to a 114-fold overexpression.) Luo et al. (2013) exposed pregnant women undergoing a first trimester abortion to a mobile phone applied to the abdomen and performed a proteomic analysist of placental villous tissue. They report 15 proteins which were significantly altered by at least 2- to 2.5-fold in exposed women as compared to control women. Twelve of these proteins were identified. Yan et al. (2008) exposed rats to mobile phones 6 h per day for 126 days, and found upregulation of specific mRNAs that regulated several proteins, including calcium ATPase, neural cell adhesion molecule, neural growth factor and vascular endothelial growth factor. EMFs at non thermal levels may not only alter the expression of many proteins but also may directly affect protein conformation (Fragopoulou et al., 2011; Bohr and Bohr, 2013; Beyer et al., 2013) and modify enzyme activity (Vojisavljevic et al., 2010), so altering the regulating capacity of the epigenome. These are epigenetic, not genetic, effects (Sage and Burgio, 2017).

Non-thermal EMF exposure can epigenetically interfere with the differentiation and proliferation programs of stem cells in fetal and adult tissues through ROS production (Wolf et al., 2007; Falone et al., 2007; Ayşe et al., 2010; Park et al., 2014). Stem cells are the most sensitive cells to EMF exposure (Eghlidospour et al., 2017; Markova et al., 2010) and this is particularly the case for neural stem cells of the hippocampus (Leone et al., 2014).

The endogenous natural ionic currents and electrical fields in the human body (Jaffe and Nuccitelli, 1977) are vulnerable to the oscillary properties of non-thermal EMFs. These consequently may cause detrimental effect on cell differentiation and proliferation in adult tissues (Levin, 2003) in addition to the effects on cell differentiation, proliferation and migration in the fetus (Wolf et al., 2007; Ayşe et al., 2010; Leone et al., 2014). Fetal programming cannot be reduced to only genetic programs. Developmental processes are essentially epigenetic (Leone et al., 2014), and exposure to epigenetic stressors such as non-thermal EMFs are much more dangerous for the fetus than for the adults.

6.5. Calcium regulation

There has long been evidence that EMFs alter several aspects of calcium function. This is important because calcium regulates many different aspects of cell function. Bawin and Adey (1976) reported that very weak ELF-EMFs trigger efflux of calcium from isolated chick brain, although the implications of this observation were not clear. Later they reported a similar action of RF-EMFs (Adey et al., 1982). Pulsed low-frequency EMFs promote bone healing and promote calcium uptake into bone (Spadaro and Bergstrom, 2002) and osteoblasts (Zhang et al., 2010). 50 Hz EMFs increase the number of voltage-gated calcium channels in neuroendocrine cells (Grasso et al., 2004) and presynaptic nerve cell terminals (Sun et al., 2016). Wei et al. (2015) found that ELF-EMFs also altered the frequency of calcium transients in cardiomyocytes and decreased calcium concentrations in sarcoplasmic reticulum. These changes in calcium in heart muscle may be the basis for the cardiovascular effects reported in humans on exposure to EMFs (Havas, 2013). In spite of numerous studies reporting altered calcium metabolism upon exposure to both ELF- and RF-EMFs, the overall implications of these effects are still not clear. However, some have suggested (Ledoigt and Belpomme, 2013) that calcium activation of proteins could be the initial event that results in altered protein configuration, leading to generation of ROS and ultimately activating the molecular pathways to cancer.

7. Public Health Implications of Human Exposure to EMFs

The incidence of brain cancer in children and adolescents has increased between 2000 and 2010 (Ostrom et al., 2015). Gliomas are increasing in the Netherlands (Ho et al., 2014), glioblastomas are increasing in Australia (Dobes et al., 2011) and England (Philips et al., 2018) and all brain cancers are increasing in Spain (Etxeberrua et al., 2015) and Sweden (Hardell and Carlberg, 2017). The latency period between initial exposure and clinical occurrence of brain cancer is not known but is estimated to be long. While not all reports of brain cancer rates show an increase, some do. The continually increasing exposure to EMFs from all sources may contribute to these increases. The prevalence of EHS is unknown, but various reports suggest that it is between 1 and 10% of the population (Hallberg and Oberfeld, 2006; Huang et al., 2018). Male fertility has been declining (Geoffroy-Siraudin et al., 2012; Levine et al., 2017). EMFs increase the risk of each of these diseases and others. Alzheimer's disease is increasing in many countries worldwide and its association with ELF-EMF occupational exposure has been clearly demonstrated through several independent epidemiological studies (Davanipour and Sobel, 2009; Sobel et al., 1996; Qiu et al., 2004) and a meta-analysis of these studies (García et al., 2008). A recent meta-analysis (Huss et al., 2018) has reported an increased risk of amyotrophic lateral sclerosis in workers occupationally exposure to ELF-EMFs.

Safety limits for RF exposure have been based (until today) on the thermal effects of EMFs. But these standards do not protect people, particularly children, from the deleterious health effects of non-thermal EMFs (Nazıroğlu et al., 2013; Mahmoudabadi et al., 2015). Each of these diseases is associated with decrements in health and quality of life. Brain cancer patients often die is spite of some improvement in treatment, while EHS patients present with increased levels of distress, inability to work, and progressive social withdrawal. The ability for humans to reproduce is fundamental for the maintenance of our species.

The scientific evidence for harm from EMFs is increasingly strong. We do not advocate going back to the age before electricity or wireless communication, but we deplore the present failure of public health international bodies to recognize the scientific data

showing the adverse effects of EMFs on human health. It is encouraging that some governments are taking action. France has removed WiFi from pre-schools and ordered Wi-Fi to be shut off in elementary schools when not in use (http://www.telegraph.co.uk.news/2017/12/11/france-ipose-total-ban-mobile-phones-schools/). The State of California Department of Public Health has issued a warning on use of mobile phones and offered advice on how to reduce exposure (State of California, 2017). There are many steps that are neither difficult nor expensive that can be taken to use modern technology but in a manner that significally reduces threats to human health.

It is urgent that national and international bodies, particularly the WHO, take this significant public health hazard seriously and make appropriate recommendations for protective measures to reduce exposures. This is especially urgently needed for children and adolescents. It is also important that all parts of society, especially the medical community, educators, and the general public, become informed about the hazards associated with exposure to EMFs and of the steps that can be easily taken to reduce exposure and risk of associated disease.

Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.envpol.2018.07.019.

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SB 270 - AS AMENDED BY THE SENATE

02/16/2022 0667s

2022 SESSION

22-3025
10/04

SENATE BILL ***270***

AN ACT establishing a low-moderate income community solar program.

SPONSORS: Sen. Watters, Dist 4; Sen. Avard, Dist 12; Sen. Perkins Kwoka, Dist 21; Sen. D'Allesandro, Dist 20; Sen. Bradley, Dist 3; Sen. Hennessey, Dist 1; Sen. Whitley, Dist 15; Sen. Rosenwald, Dist 13; Sen. Soucy, Dist 18; Sen. Gannon, Dist 23; Sen. Sherman, Dist 24; Sen. Giuda, Dist 2; Rep. Cali-Pitts, Rock. 30; Rep. McGhee, Hills. 27

COMMITTEE: Energy and Natural Resources

AMENDED ANALYSIS

This bill establishes a program for low-moderate income electric customers to participate in qualifying community solar projects.

Explanation: Matter added to current law appears in ***bold italics.***
Matter removed from current law appears [~~in brackets and struckthrough.~~]
Matter which is either (a) all new or (b) repealed and reenacted appears in regular type.

STATE OF NEW HAMPSHIRE

In the Year of Our Lord Two Thousand Twenty Two

AN ACT establishing a low-moderate income community solar program.

Be it Enacted by the Senate and House of Representatives in General Court convened:

1 Net Energy Metering; Community Solar Program. RSA 362-A:9, XIV(d) and (e) are repealed and reenacted to read as follows:

(d) The electric distribution utilities shall establish a list of potential low-moderate income residential customers who qualify to benefit from the low-moderate income community solar addition. This list shall consist of residents who have enrolled in or are on the waitlist for the state Electric Assistance Program administered by the commission.

(e) Within 90 days of the effective date of this subparagraph, the department of energy shall develop a process by which community solar developers can apply for designation as a community solar project. Such projects designate their production for the benefit of households on the list required in subparagraph (d). Such projects will qualify for the low-moderate income solar addition as established in subparagraph (c) and shall specify the amount of on-bill credit they can offer to low-moderate income homeowners. Annually, the number of projects designated as low-moderate income community solar shall not exceed a total nameplate capacity rating of 6 megawatts in the aggregate. If more than 6 megawatts of projects apply for designation, the department of energy shall select the projects that offer the largest on-bill credit.

(f) Each year, the department of energy, in consultation with the electric distribution utilities, shall select a means by which to enroll households as off-takers for these low-moderate income community solar projects. Customers shall be enrolled on an opt-out basis, notified by mail of their enrollment, and informed of the details of the project from which they are receiving credit. Once enrolled, such customers shall receive on-bill credits until such time as they no longer qualify for the Electric Assistance Program, or until they opt out from receiving credits.

(g) All costs incurred by the electric distribution utilities related to this program, including but not limited to, costs of implementation, billing and administrative activities, shall not be borne by the utilities, but shall be recovered from customers.

(h) Utility owned projects that are designated as community solar projects shall not count against the limitation on the maximum allowed distributed energy resources as established by RSA 374-G:4.

(i) Nothing in this chapter shall preclude low-moderate income solar community projects from enrolling customers through any other method besides the process described in subparagraphs (d)-(f). A description of any alternative method used shall be filed with department of energy.

(j) The department of energy is authorized to assess fines against, revoke the registration of, and prohibit from doing business in the state, any group host which violates the requirements of this paragraph or rules adopted for this paragraph by the department pursuant to paragraph X.

2 Effective Date. This act shall take effect 60 days after its passage.