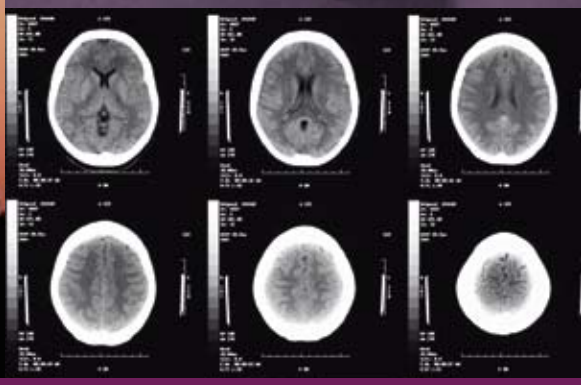
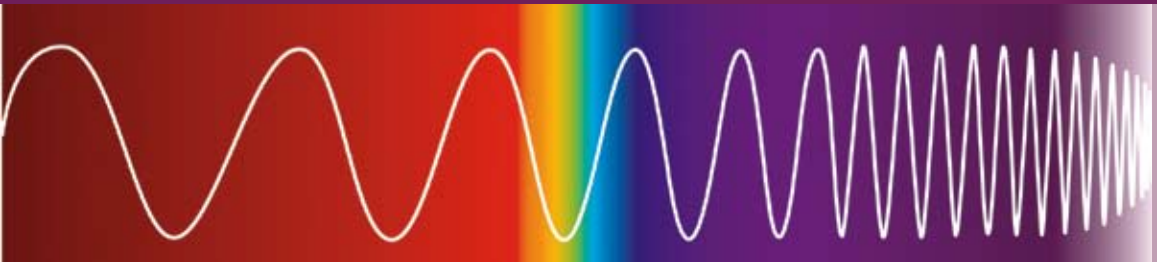


Radiation and Cancer



A NEED FOR ACTION

Radiation and cancer: A need for action

All of us are exposed to a spectrum of radiation from both natural and human-made sources. Radiation can have beneficial uses but exposures also carry health risks, depending on the level and duration of exposure, among other factors. Medical uses of radiation to diagnose and treat disease have important benefits for patients but also involve health risks, including cancer. Nuclear power may be useful for producing electricity; yet increased risk of cancer has been documented along the entire spectrum of the nuclear fuel cycle. Moreover, nuclear weapons use remains an inherent risk of nuclear energy production and may not be reflected adequately in the assessment of costs and benefits. Wireless technologies such as cellular/cordless phones, cell phone towers, and wi-fi transmitters that emit non-ionizing radiation have added greater convenience to our lives, but these devices may also pose health risks, including cancer.

To reduce cancer risk, public policy measures are needed to mitigate unnecessary and involuntary exposures to sources of radiation now affecting millions of people around the world.

Radiation: What is it?

The electromagnetic spectrum of radiation includes both *ionizing* and *non-ionizing* radiation. *Ionizing* radiation is any form of radiation with enough energy to detach electrons from atoms or molecules (to ionize them). This type of radiation includes alpha particles, beta particles, neutrons, gamma rays, and cosmic rays, which differ in energy levels and the extent to which they can penetrate cells. Ionizing radiation can damage DNA, either through direct interaction between radiation and DNA or via damage produced by free radicals. Changes in the DNA could lead to cell death or, if the altered DNA is not repaired, to cancer or other health effects. Important sources of ionizing radiation include medical diagnostic x-rays, computed tomography (CT) scans, fluoroscopy, other medical and dental radiological procedures, emissions from nuclear power plants, radioactive fall-out from use or testing of nuclear weapons as well as naturally occurring radioactive compounds such as radon.

Non-ionizing radiation (also referred to as electromagnetic fields or EMF) is a type of low-frequency radiation without enough energy to knock electrons from their orbits around atoms and ionize them. The two principal types of EMF discussed in this paper are extremely low-frequency electromagnetic fields (ELF-EMF), which are produced when electrical power is transmitted and distributed, and radiofrequency/microwave radiation (RF), which is produced by cellular phones, cordless phones, other wireless devices, and the towers and antennas that support them.

Sources of ELF-EMF include high voltage power transmission lines (usually on metal towers) carrying

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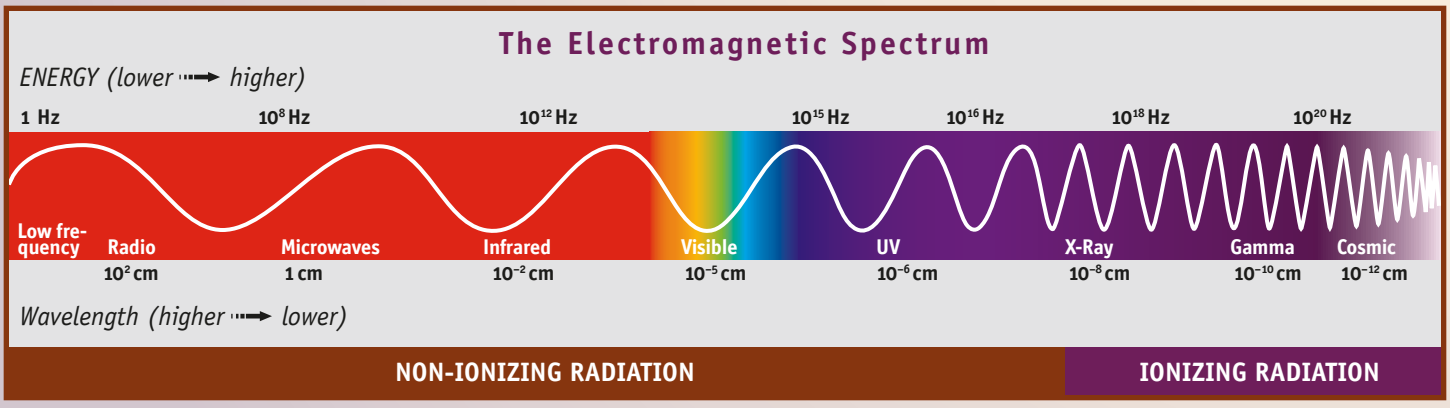
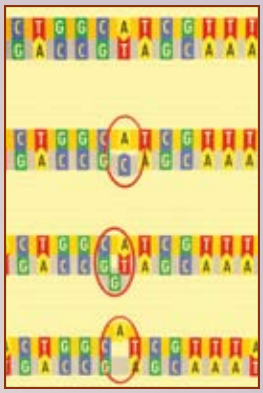






electricity from power generating plants to communities, and power distribution lines (usually on wooden poles), that bring electricity into houses, schools and workplaces. Electric lighting generates ELF-EMF. Fluorescent lighting and other low-voltage lighting produce higher levels than incandescent lighting. Other sources of ELF-EMF include electrical wiring in buildings, electrical appliances, such as radios, televisions, hair dryers, food processors, microwave ovens, electric blankets, etc.

Radiation and cancer: What do we know?

Ionizing radiation

Ionizing radiation causes cancer. It is the best-studied and longest-known cause of human cancer. Hundreds of studies and comprehensive reviews by national and international bodies have found convincing evidence that most sites in the human body are susceptible to the carcinogenic effect of ionizing radiation and some including the thyroid, bone marrow (white blood cells), breast and lung are particularly sensitive.[1–6] Odorless, tasteless, and largely invisible, ionizing radiation is a stealth carcinogen, disrupting our DNA and increasing our risk of cancer. Moreover, radiation damage to our DNA is cumulative over a lifetime.[7]

Four primary bodies of evidence support ionizing radiation as a human carcinogen: (1) studies of atomic bomb survivors; (2) studies of individuals medically irradiated for diagnostic or therapeutic purposes; (3) occupational studies of workers exposed to radiation in healthcare, manufacturing, mining or among the various sectors of the nuclear weapons/nuclear power industries; and (4) environmental epidemiological studies of communities exposed to indoor radon and to radiation across the nuclear fuel cycle.[8] For example:

- Numerous studies of atomic bomb survivors provide substantial evidence that radiation dramatically increases the risk of leukemia.[1]
- Evidence from studies of atomic bomb survivors,[1,8] female radiologic technologists,[9] as well as those examining the use of X-rays among tuberculosis and scoliosis patients[10,11] have documented significant increases in breast cancer risk.
- Studies of childhood cancer show that nuclear fallout in some communities from weapons testing is associated with acute leukemias,[12] contamination from Chernobyl nuclear reactor accident is associated with thyroid cancers,[13] and according to one meta-analysis, living near nuclear facilities is associated with a 7–21% increase in the risk of leukemia.[14]
- Studies of uranium miners show significant elevations of lung cancer from exposure to radon.[15,16]

Although findings are specific to the type of radiation exposure (e.g. X-rays, alpha particles, etc), the evidence is overwhelmingly clear: there is no "safe" level of ionizing radiation, including exposure to low doses.[4,17] The question of risk of cancer at low doses has been a widely debated issue. One theory suggests that exposure to low doses of ionizing radiation imparts a beneficial, "hormetic" effect. However, the National Research Council's 2005 review of available low-dose risk estimates concluded that there is no beneficial exposure to ionizing radiation—a small risk of cancer exists even at low doses and risk increases proportionally with each increase in dose.[4] A highly significant remaining question requiring further study is whether continuous exposure to low

doses of ionizing radiation produces a different type of cancer risk. Some evidence suggests that chronic low-level exposure to ionizing radiation may carry a higher risk than previously suggested.[18,19]

Some argue that there are still scientific uncertainties in the low dose cancer risk estimates given the difficulty in measuring such risks. While the debate continues, one key issue is whether current policies do enough to protect the public from potential effects of low dose ionizing radiation exposures in the face of scientific uncertainty. Extensive scientific evidence demonstrates that the risks of radiation are real. Many scientists believe that ignoring the evidence on low dose exposures undermines our national efforts to prevent cancer. Given that cancer risk increases with each dose of radiation, the prudent course forward is to minimize radiation exposure wherever and whenever possible.

Non-ionizing radiation

A growing body of evidence suggests that chronic, low-level exposure to non-ionizing radiation from radiofrequency/microwave (RF) and extremely low frequency electromagnetic fields (ELF-EMF) sources may increase the risk of cancer in children and adults.[20] In 1997, distinguished epidemiologist John Goldsmith wrote, "The notion that non-ionizing radiation, and in particular RF radiation, was harmless—the assumption of innocence—is no longer tenable."[21] Hundreds of studies since that time have confirmed his assertion.

Substantial evidence suggests that ELF-EMF and RF can damage DNA, modify gene expression, and

Strength of the evidence linking specific cancers with human exposure to IONIZING radiation[6]

A-bomb survivors ■ **STRONG:** bladder, breast (female), colon, esophageal, leukemia, lung, ovary, salivary gland, skin, stomach, thyroid ■ **SUSPECTED:** liver, myeloma

Medical irradiation procedure patients ■ **STRONG:** bladder, bone, brain (CNS), breast (female), esophageal, leukemia, liver, lung, rectum, salivary gland, skin, stomach, thyroid, uterine ■ **SUSPECTED:** kidney, lymphoma, myeloma, pancreatic, prostate

Occupational studies ■ **STRONG:** bone, leukemia, lung, skin ■ **SUSPECTED:** breast (female), myeloma, thyroid

Environmental epidemiological studies ■ **STRONG:** lung, thyroid ■ **SUSPECTED:** leukemia

Strength of the evidence linking specific cancers with human exposure to NON-IONIZING radiation[23,26–28,31,76]

Radio frequencies (e.g. cell phones) ■ **SUSPECTED:** brain (CNS), salivary gland

ELF-EMF ■ **SUSPECTED:** leukemia, breast (male and female)

lead to altered cellular function as well as cancer.[20] Evidence of increased cancer risk is based on studies in human populations including: studies of (a) RF exposure from cellular and cordless phone use and (b) exposure to ELF-EMF from the transmission and distribution of electrical power.

Cellular and cordless phone use has been studied by experts in many countries only since about 1995. Prior to that time, cellular phones and their supporting infrastructure were not in widespread use. Yet, even in this short time, results from the largest international cell phone studies conducted under the World Health Organization (WHO) Interphone Study Group are finding an increased risk of malignant brain tumors (glioma). These tumors are found at double the expected rate, at only 10+ years latency (time between exposure and diagnosis of cancer) when phones are used predominantly on one side of the head (laterality).[22] Additional evidence has also emerged:

- Studies in Sweden and other countries in which cellular/cordless phones have been used longer than in the United States also show a consistent pattern of elevated risk of acoustic neuroma (a tumor on a nerve that passes from the inner ear to the brain related to hearing and balance) and glioma after 10 or more years of use when used principally on one side of the head.[23–25]
- Meta-analyses of studies with appropriate latency (more than 10 years), degree of use and laterality (phone held on predominantly on one or on both sides of the head) all show nearly a doubling of brain tumor risk.[23,26]

The International Association for Research on Cancer (IARC) classifies ELF-EMF as a Group 2B carcinogen (Possible Human Carcinogen). The IARC classification is based on more than more than 25 years of study examining the association between exposure to ELF-EMF and the risk of childhood leukemia, including the following key findings:

- Two comprehensive meta-analyses using different pooling techniques found essentially the same conclusion: high and prolonged average levels of ELF-EMF exposure were associated with increased risk of childhood leukemia.[27,28] High levels of ELF-EMF as defined by these studies (above 4 milligauss [mG]) are very rare, affecting fewer than 1% of children.
- Additional evidence suggests an increased risk of childhood leukemia following maternal occupational exposure to ELF-EMF during pregnancy.[29]
- Men who work in electrical occupations have an elevated risk of breast cancer, even though the disease is rare among men.[30–32] Two studies in Sweden[33,34] found that women who had both occupational and residential exposure to high-voltage power lines had a higher risk of breast cancer than those exposed only at home.

Given IARC's classification and evidence to date, stronger federal standards and precautionary measures are warranted to reduce exposure to ELF-EMF.

Continued controversy about the links between leukemia and ELF-EMF is due in part to incomplete evidence from animal studies and an incomplete understanding of how ELF-EMF contributes to cancer. However, a new study from China suggests that genetic variability in DNA repair mechanisms may make some children more susceptible to leukemia when chronically exposed to ELF-EMF during prenatal development.[35]

Over the past quarter century the amount of ionizing radiation the U.S. population receives each year from medical imaging has increased five-fold.[36]

Exposure to every type of radiation is increasing

Research shows that exposure to radiation is increasing across the electromagnetic spectrum, from non-ionizing radiation to ionizing radiation.

According to the American College of Radiology, over the past quarter century the amount of ionizing radiation the U.S. population receives each year from medical imaging has increased five-fold.[36] Evidence among Medicare populations show that trends for conventional radiography and fluoroscopy use are going down. However, use of mammography, CT scans and nuclear imaging is on the rise.[37] The most worrisome aspect of these exposures is the widespread use of CT scans on children, particularly in emergency departments. Although CT scans provide valuable diagnostic information, they deliver 100 to 1000 times the radiation dose compared to traditional X-rays—radiation levels that are similar to the low-dose range shown to increase cancer among atomic-bomb survivors.[38] Exposing children to CT scans raises their risk of developing cancer later in life because children are more sensitive than adults to the carcinogenic and other health effects associated with radiation exposure,[39,40] as well as having a longer latency period in which to develop disease. The U.S. Food and Drug Administration estimates that one abdominal CT scan for an adult may be associated with a life-time risk of cancer of 1 in 2000 patients;[41] the equivalent estimated cancer risk for a 1-year old child is much higher: 1 in 550.[42]

Ionizing radiation has long been known to cause breast cancer. As one scientist wrote, "It is likely that the breast is the organ most sensitive to radiation carcinogenesis in post-pubertal women."[43]

Despite this evidence of potential harm, mammography remains the "gold standard" for breast cancer screening. Official guidelines now recommend mammography screening for women ages 40–49 and even for women in their 30s who are at high risk for breast cancer. Some of these women may also have increased radiation sensitivity.[44,45] Undoubtedly mammography is an important early detection tool that has contributed to the survival of many women with breast cancer. Yet there is growing international debate about whether mammography screening in large populations actually reduces breast cancer mortality rates or, instead, increases the risk of harm, particularly among premenopausal women.[46–49] This debate underscores the urgent need for a non-radiologic screening technology that would be effective for women of all ages.

Public exposure to non-ionizing radiation also has increased dramatically in the last 20 years, particularly to RF radiation. For the first time in the history of the world, more than 4 billion people are holding microwave transmitters (cellular/cordless phones) next to their heads for minutes or even hours every day.[50] Moreover, individuals sit in workplaces, public spaces, homes and schools using wireless laptops, personal data assistants (PDAs), and pagers. Wireless technologies have intensified the electromagnetic environment with unprecedented levels of RF that have risen ten-fold to a hundred-fold in many urban areas due to wireless transmission for cellular phones.[51–52] In addition, wi-fi networks blanket entire cities with RF.

Children face higher risk from exposures

The timing of exposure matters. Prenatal and childhood exposure to ionizing radiation pose a greater cancer risk than comparable exposure during adulthood.[53–54]

Evidence from medical irradiation studies clearly indicates an increased risk of leukemia among children exposed to ionizing radiation *in utero*.[55] Adolescence is another window of vulnerability for radiation-induced cancer, as evidenced among survivors of Hodgkin's lymphoma treated with radiation to the chest as teenagers. These survivors have a high risk of breast cancer in their 30s and 40s.[56]

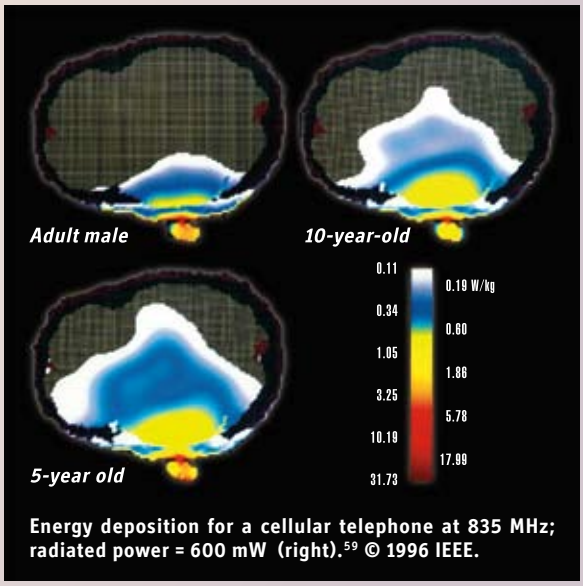
The current weight of evidence suggests that children also are at greatest risk of harm from EMF exposure. More than a dozen high quality epidemiological studies have linked childhood leukemia to EMF-ELF electromagnetic field exposure.[20,26–28,35] Early indications suggest that children and adolescents also face a greater risk of harm than adults from RF exposures from the use of cellular/cordless phones.[57,58] Researchers have suggested a biological basis for these observations: since children's brains are still developing, their skulls are smaller and thinner than adults, thus RF radiation is able to penetrate farther into the brain, which may increase their risk of brain cancer in early adulthood.[58,59]

In June 2008, an international panel of physicians and scientists led by Dr. David Servan-Schreiber and Dr. Annie Sasco endorsed an Appeal in Relation to the Use of Mobile Phones. The Appeal included an analysis of recent studies and ten precautionary measures.[60] This Appeal led Dr. Ronald Herberman, Director of the University of Pittsburgh Cancer Research Center (UPCRC), to issue a cautionary statement to the UPCRC community concerning the use of cellular phones, including limiting children's use of the devices.[61] In September 2008, Dr. Herberman and public health expert Dr. David Carpenter testified at a Congressional hearing on behalf of a precautionary approach to cell phone use by children.[62] The governments of Germany,[63] France,[64] Austria[65] and the U.K.,[66] the European Environment Agency[67] and the Russian National Committee on Non-Ionizing Radiation Protection[68] have also warned the public to reduce wireless exposures and warned against cell phone use by children.

Don't we have regulations and technologies to protect us?

Many existing federal radiation protection standards are based on average lifetime exposure or on a hypothetical adult Caucasian male, 20–30 years of age, weighing 154 pounds. As discussed above, children's bodies are not the same as those of adult men in their response to ionizing radiation or EMF. Despite President Clinton's Executive Order 13045 on the Protection of Children from Environmental Health Risks and Safety Risks directing federal agencies to ensure their policies address the disproportionate vulnerability of children, appropriate changes have not been made in radiation standards.

Early indications suggest that children and adolescents also face a greater risk of harm than adults from use of cellular/ cordless phones.[57,58]



Energy deposition for a cellular telephone at 835 MHz; radiated power = 600 mW (right).[59] © 1996 IEEE.

"The current lack of uniform educational standards nationwide for operators of radiologic equipment poses a hazard to the public."[69] —American Society of Radiologic Technologists

Besides the lack of appropriate testing and establishment of standards to ensure the safety of children, current safety standards within our health care system fail to ensure that medical exposure to ionizing radiation is minimized for all patients wherever possible. Currently, seven states have no licensure or regulatory provision for radiologic personnel and six more regulate only partially.[69] Most states only have recommended quality assurance (QA) standards—if they have standards at all. Moreover, many medical and dental offices do not perform the tests required to ensure that the standards are maintained. According to the American Society of Radiologic Technologists, "the current lack of uniform educational standards nationwide for operators of radiologic equipment poses a hazard to the public. State and federal standards will ensure a minimum level of education, knowledge and skill for the operators of radiologic equipment."[69] Legislation to establish federal educational standards for operators of radiologic equipment has been introduced in each session of Congress for the past decade but has never been signed into law. The Consistency, Accuracy, Responsibility, and Excellence in Medical Imaging and Radiation Therapy (CARE) bill (HR583 and S1042) passed the U.S. House of Representatives in June 2008, but the Senate has yet to act on the bill. Unfortunately, this bill excludes x-ray, fluoroscopy, ultrasound and radiation therapy.

All physicians who perform radiologic procedures, particularly those with office-based imaging equipment, need to be educated and credentialed to minimize unnecessary radiation exposure to themselves, to staff and to patients during procedures. For example, radiologists have extensive expertise in radiation safety. However, this is not always true for other specialists such as surgeons and cardiologists. These specialists have been allowed to perform radiologic procedures for more than a decade. However, the first recommended guidelines for safer use of fluoroscopy by these practitioners were not published until 2004.[70]

Minimizing patient exposure to medical radiation also means that standards of care need to change, particularly in regard to computed tomography (CT) scans. CT scans are a primary concern because although they represent about 12% of the diagnostic radiological procedures in hospitals, they "contribute an estimated 45% of the effective radiation dose to the public from all medical x-ray examinations."[71] As detailed earlier, this is particularly worrisome for children given their increased sensitivity to the carcinogenic effects of ionizing radiation. Moreover, given the evidence that CT scan doses can increase cancer risk,[41,42] standards of care need to be in place to ensure that medical practitioners: (1) consider a patient's full medical radiation history before recommending additional radiologic procedures; (2) continuously evaluate whether the benefits of the CT scan outweigh the assumed radiation risk; (3) consider the availability of safer diagnostic alternatives such as MRIs and ultrasounds; and (4) discuss these issues with the patient or their caregiver. The role of ionizing and non-ionizing radiation in carcinogenesis also needs to be introduced explicitly into all stages of medical and nursing education.

Safety standards for non-ionizing radiation are also inadequate to protect public health. Existing standards are based on acute exposure and on thermal effects alone. This outdated, erroneous concept assumes that unless EMF exposure is strong enough to heat human tissue within 30 minutes, it is safe. Moreover, there are no federal standards for EMF

exposure based on long-term, chronic exposure or on non-thermal effects, which are the most common types of exposure and the most likely to cause human health effects, including cancer. In addition, existing U.S. standards for EMF-ELF are set at 904 milligauss even though more than two decades of science show that cancer risk may begin to increase at only 2 milligauss.[28] Standards for personal wireless devices such as cell phones also are based solely on absorbed heat, measured by a unit called the Specific Absorption Rate (SAR). The U.S. standard for cell phones is 1.6 watts per kilogram [W/kg], which is not sufficiently protective given evidence that health effects may occur at lower levels.[72]

Standards are necessary to mandate control of cancer-causing exposures. However, we also need to drive innovation and create technologies that reduce or eliminate radiation exposures. For example, we need to support the development of technologies for energy production that rely on safe, renewable energy sources rather than technologies that carry the risks associated with nuclear power. Similarly we need to develop new technologies to reduce medical radiological risks. Eliminating radiation risks at their source through redesigning technologies that are inherently safe is an essential element of any cancer prevention agenda.

Why aren't EMF exposures better regulated?

As John Goldsmith wrote in 1995, "There are strong political and economic reasons for wanting there to be no health effect of RF/MW [radiofrequency/microwave] exposure, just as there are strong public health reasons for more accurately portraying the risks. Those of us who intend to speak for public health must be ready for opposition that is nominally but not truly scientific."[73]

Two powerful factors interfere with governments taking action to set biologically based exposure guidelines for non-ionizing radiation that acknowledge the current evidence of risk. First, modern societies depend on use of electricity and radiofrequency communications. Anything that restricts use has potentially significant economic consequences. Second, electric utility and communications industries have enormous political influence, and even provide support for a major fraction of the research on health effects of EMF. This financial support for EMF research may influence how that research is reported to the public.[74]

These factors protect the status quo and lead to scientific publications with conclusions that do not always reflect the findings of the research. A Swiss analysis of cellular phone studies found that the source of research funding affected the reporting of results. Those studies funded by industry were least likely to report a statistically significant result.[75] In other words, when industry science manufactures "doubt" and "controversy," prudent public health policy actions are delayed. Some analysts suggest this process mirrors the distortion of science pioneered by the tobacco, lead, and asbestos industries.

How Can We Prevent Cancer Linked to Radiation?

A comprehensive U.S. cancer prevention agenda will need to safeguard workers and the public, particularly children, from avoidable exposures to ionizing and non-ionizing forms of radiation. Here are six ways we can prevent cancer linked to radiation exposure.

- **SUPPORT** research on cancer risk from continuous low-level ionizing radiation exposures as well as the risk of low-level non-ionizing radiation, especially at biologically relevant exposure levels. This is particularly important with respect to cell phone exposures, since cell phones are now used by over 4 billion people worldwide, including growing numbers of young children. Even if cell phone use results in a relatively modest percentage increase in cancer, the global breadth of exposure could result in an increase of incidence of some cancers of significant public health concern.

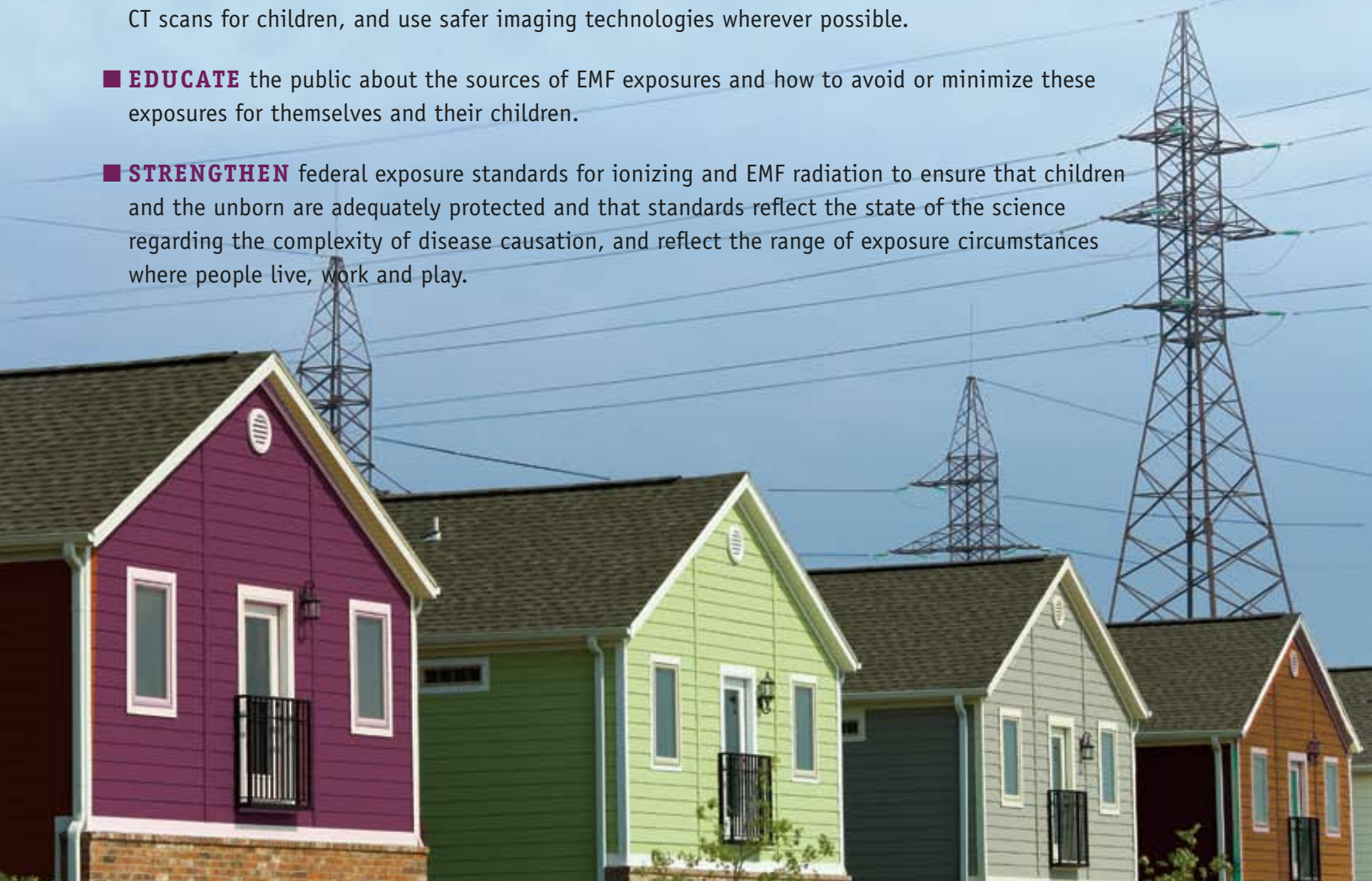
- **ENCOURAGE** adoption of technologies and practices that reduce workers' and the public's lifetime exposure to ionizing and non-ionizing radiation across all sectors of our economy, including safer cell phone usage practices, exposures throughout the nuclear fuel cycle, and exposures in health care. We especially need to find a more effective method for screening and detection of breast cancer that does not expose women to ionizing radiation, a method that will replace mammography and be effective for women of all ages.

- **SUPPORT** legislation to establish federal standards for education and credentialing of personnel requesting and performing medical imaging and radiation therapy, and quality assurance regulations that meet or exceed standards currently in place for mammography facilities.

- **EDUCATE** the public about the risks as well as the benefits of radiological medical procedures, particularly CT scans for children, and use safer imaging technologies wherever possible.

- **EDUCATE** the public about the sources of EMF exposures and how to avoid or minimize these exposures for themselves and their children.

- **STRENGTHEN** federal exposure standards for ionizing and EMF radiation to ensure that children and the unborn are adequately protected and that standards reflect the state of the science regarding the complexity of disease causation, and reflect the range of exposure circumstances where people live, work and play.



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