Advancing U.S. Public Acceptance of Spent Fuel Storage and Transport: Proposed Outreach Services for Ionizing Radiation Education Support

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ABSTRACT

Expansion of commercial nuclear energy could be one of the future U.S. sources for clean, safe, reliable, and economic electricity. Yet, no federal policy has effectively achieved wide acceptance of nuclear energy, such policies having fallen victim to the politics of public radiation fears from nuclear energy usage, and from spent fuel storage and transport.

Many experts have described the foundation of public fear as not so much nuclear technology, but the ionizing radiation to which people fear they might be exposed, and this issue has been talked and written about, yet gone substantially unaddressed with respect to public education for more than three decades. In the U.S., the BRC Final Report is just the latest of clear statements where such an educational need is firmly asserted. The lamentable fact is that no one has made that substantive and concerted effort to do anything about it. Indeed, the only effort seems to have been talk about "better communication," with a focus on risk-based communication. Any rejuvenation of public acceptance of commercial nuclear energy in the U.S., including spent fuel storage and transport, can only be sustained by using a different strategy from that of earlier decades.

This paper highlights professional opinion on the radiation fear issue and why current industry efforts in risk-based information for and communication with the public have not achieved the desired success. Education to expand the public's understanding of *comparative* radiation sources and exposures while ameliorating concern about radiation from nuclear energy is the proposed alternative. And here, the clear linkage between education supporting nuclear energy and facilitating necessary spent fuel storage and transport is unmistakable. The paper summarizes a concept for outreach services for ionizing radiation education support for application in the U.S., as well as key elements of such a process: its basis for success, its education content, and potential implementation approaches. Comparative radiation education of the public can prove effective using current research, which has been effective in other industries. Additionally, while this discussion addresses the U.S. situation, much of the content is likely applicable to many of the world's nuclear-energy producing countries.

INTRODUCTION

> **An important scientific innovation rarely makes its way by gradually winning over and converting its opponents, but rather because its opponents gradually die out and a new generation grows up that is familiar with it.**
> ***–Maxwell Planck***

What a wonderful quote by one of the world's most respected scientists!! All of us have dealt with this quote in our professional lives as it might relate to hope for the expansion of nuclear energy. The implication is that familiarity through education exorcises extremes of false science or supplants current understanding so that society progresses, advancing scientific truth in each generation.

But Planck's concept has not held true for nuclear energy. If the scientific innovation is nuclear energy (along with spent fuel storage and transport, herein called spent fuel management (SFM)), all being far safer than any other electricity production technology, we know, after more than two "new" generations, nuclear energy is actually further from societal acceptance than it was more than 40 years ago. The familiarity with "nuclear energy safety" through education that is implicitly necessary in

Planck's view has not occurred and, in fact, the public has been better educated about a "fearsome nature" of nuclear energy and SFM by its opposition - this in a society that is not especially adept in science to begin with. So, where has nuclear energy education fallen short of what would be necessary to achieve the outcome Planck would have so boldly anticipated? The following table summarizes areas where we have met success, or not, in building a public comfortably familiar with nuclear technology.

Nuclear Energy Subject Matter: Public Familiarization Success

Nuclear Energy Subject Matter	Successful Public Familiarization	Unsuccessful Public Familiarization
Control and Management of Nuclear Fission	X	
Nuclear Energy for Military Applications	X	
Commercial Nuclear Energy (CNE) Usage	X	
Health Effects of Ionizing Radiation (IR)		X
Credible Public IR Exposure from CNE		X
Public IR Exposure: CNE vs. Other Industries		X

This discussion presents one concept to help reverse this state of affairs in our industry and reclaim Planck's great expectation; but it is only a high level discussion of an approach that can be significant for the future of SFM and, indeed, for the expansion of nuclear energy. The approach is based upon informed research and supported opinion; it is not an instruction manual and full details are not possible here, but these contents are sufficient for stimulating discussion and refinement for implementation. Our industry has let its future be hijacked and held hostage by fear, and it needs a strategy to recover public and political nuclear acceptance, avoiding years of public and political wrangling, with countless battles in legislatures and courts, so that SFM can support the current nuclear enterprise and the necessary expansion of nuclear energy. While this discussion is reflective of the U.S. situation, it is likely that it has international application, as well.

BACKGROUND

Energy supply has consensus acknowledgment as a major challenge over the coming decades, and nuclear energy has been considered for a significant role in facing that challenge. With the climate-change culture's concern about fossil fuels for producing electricity, nuclear energy can reduce their use and enable transportation methods that require little or no petroleum. Therefore, restoring the nuclear alternative (ReNuAl) has been a potential priority action for the U.S. However, there remains a strong resistance to using nuclear energy for electricity, and much of this resistance arises from fear of release of radioactive materials to the environment from nuclear reactors, SFM systems, or repositories.

Well-informed experts have offered opinions on nuclear energy and SFM, expressing significant unanimity regarding the need to solve public fears before nuclear energy can advance as a key energy solution. These experts believe the fear of nuclear energy substantially arises from fear of exposure to IR. There are many international sources of such warnings, including major reports in the U.S. and elsewhere (see, for example [1] – [11]). Additionally, the Nuclear Energy Institute (NEI) conducted a survey in 2011, [12], showing the industry's IR-messaging did not work for 61% of the public, as seen in Figure 1. The most current recognition of public IR fear relevant to SFM occurs in the final report of the Blue

Ribbon Commission (BRC) on America's Nuclear Future. The BRC was chartered to recommend how the U.S. might solve issues involving the storage, transportation, and disposal of spent fuel to sustain the nuclear energy alternative. In its report, [13], the following notable quote addresses the IR fear issue, which is the focus herein:

> *'This task [spent fuel management] . . . is made both more challenging and more important by the fact that many Americans view the risks associated with radiation and nuclear energy as fundamentally different in nature from other kinds of risks. Radiation, in particular, has a number of properties that tend to heighten people's fear of being exposed to it: . . . better communicating information . . . must be seen as one of the core missions of a revitalized waste management program.'*

Clearly, the Achilles heel of nuclear energy and SFM acceptance is public fear of IR. Public opinion data taken from within and outside the industry reinforces this. Table 1 is from the NEI's 2013 National Tracking Survey [14], and Table 2 is from nuclear medicine research in Germany regarding nuclear medicine patient perception of the "evil" of radioactivity [15]. Clearly, a large fraction of the public readily expresses fear of IR. The lamentable fact is that industry has talked about IR fear for four decades, but no one has made a serious effort to do anything about it. Figure 2 from [16] shows that, historically, we have made no progress in 40 years with regard to public fear, and risk perception is worse now than following TMI. Discussions of and efforts at "better communication" have occurred without any substantive national effort at IR education. It seems the nuclear industry has, like the anti-terrorism and security industry, decided to react to public fears rather than attempt to change them. A preliminary conclusion appears well-founded: rejuvenation of public support for U.S. nuclear energy and for SFM can arise, but it will require a different strategy from that of earlier decades. Further, continued operation of the installed nuclear capacity, not just ReNuAl, **hinges** on the deployment of SFM services. Whether ReNuAl is successful or not, SFM **must** be unfettered from fear to permit current nuclear capacity to achieve its full lifetime. And with the competitive state of electricity generation, new reactor developments, and the resolution of the repository debate, the U.S. has perhaps 10 years to make significant headway in addressing the long term issue of public fear of nuclear energy and IR, or efforts to advance nuclear energy and SFM will likely result in disappointment.

THE NEED FOR PUBLIC IR EDUCATION

There are several bases for the public's negative risk perceptions of nuclear energy ([9], [17]) – trust, culture, values, worldviews, personal fear, societal fear, etc. While all must be addressed in dealing with opposition to nuclear, fear of IR is one of the largest reasons, as experts have noted above. Industry has never conducted broad scale public education on this topic, and the use of comparative IR education proposed herein is unique. Other reasons for opposing nuclear energy are quite often preferences arising from political, social, and cultural conditioning, and such bases are typically formed and modified only by personal experience ([9], [17]). Fear often arises from false beliefs developed from ignorance, and, while this is not always the case, public ignorance can be addressed through education [18]. Other bases for negative perception of nuclear energy are less responsive to education.

The concept of generating nuclear electricity (including SFM) is like any other conceptual construct of advanced society. It is built on layered propositions that may be called foundational truths in support of the new concept. The viability of any sophisticated concept is contingent upon the perceptions of the truth regarding the layered propositions supporting that concept. Industry and government have diligently defended many foundational truths about nuclear energy, but they have been almost non-committal on the risk of IR from the nuclear industry in comparison to far higher IR exposures from unregulated, "normal" industries, a foundational truth on which public acceptance of nuclear energy usage must rest.

IR education is necessary, then, to validate a foundational truth about nuclear energy that is not generally perceived to be true. Further, the key differentiator of the approach herein is based on the fact that credible public exposure to IR from the nuclear industry is rarely examined on a comparative basis because public knowledge of radiation from non-nuclear industries is essentially non-existent. Using such comparisons, a more focused education can solidify this foundational truth about nuclear energy and SFM.

IR fear is a major influence on opposition to nuclear energy and SFM in the U.S. and, likely, internationally, as well. U.S. nuclear industry companies and organizations have historically reached out to inform public and political stakeholders on nuclear energy/SFM, and have provided substantive information in an effort to build public "comfort" with the nuclear enterprise. The topical coverage has not focused on comparative public IR exposures with other industries in a broad public IR education effort. Further, industry efforts have been, at best, risk messaging, and would not be considered education programs involving a more extensive process with people for inculcating foundational information. The problem is not that outreach has not occurred, but that the outreach has been informational and not educational, and it has not gone to the heart of a public's gut issue - primal fear of IR. To address public IR fear will likely require substantial effort because the issue has gone without neutralization over decades, and the time for action to affect ReNuAl and SFM, certainly in the U.S., is not long.

WHY COMPARATIVE IR EDUCATION CAN MODIFY RISK PERCEPTION

By inspection, it would seem that more education will help rational public decision making, breeding greater understanding and less emotion about IR. But in situations involving fear and elevated perceptions of personal or societal risk, is that a valid conclusion? Recent work in the psychology of risk perception offers an answer to this question.

For more than three decades, many scholars have contributed a significant base of research on human risk perception. Understanding human risk perception can explain how people "decide" what is fearful and how such fear manifests, clarifying why fears may not match facts [19]. Using such information, we may be able to interact with people in ways to reshape their knowledge base and neutralize some IR fears.

Summary: Public Risk Perception and the Role of IR Education

Risk-perception research shows there are consistent characteristics that form the bases of human perceptions of, and reactions to, risk. Some of these include the perceived catastrophic and personal nature of the risk, the individual level of risk awareness, risk uncertainty, etc. These factors can be termed the roots of people's perceptions of risk, the core reasons why people become fearful of certain risks [19]. Further influencing such perceptions are factors like worldviews with aspects of society, politics, and culture that can establish which of the characteristics or factors are likely to be most dominant.

A key researcher over the last 30 years in public perceptions of risk involving nuclear energy is Dr. Paul Slovic. In [9], he describes worldviews and emotion as orienting mechanisms that help people navigate quickly through a complex world that presents fearsome risks. He discusses a subtle form of emotion called "affect," a positive or negative evaluation (feeling) that forms quickly and automatically toward some presented external situation or stimulus. Based on other cited research, Slovic further shows that for nuclear energy, the affective (rapid and automatic) values of positive and negative associations with a nuclear energy stimulus (like SFM) appear to sum in a way that is predictive of people's attitudes, perceptions, and behaviors. If the sum or balance is positive, people respond favorably; if negative, people respond unfavorably.

Over the last decade, the role of emotion and affect in human risk perception has been researched more thoroughly by a team of scholars out of Maastricht University, The Netherlands. The team has also worked with ETH Zurich's (Swiss Federal Institute of Technology) Institute for Environmental Decisions. This research, in [20], [21], [22], and [23], with Dr. Vivianne Visschers as the lead author, has application for comparative public education on IR. It shows that human risk perception consists of a dual process of risk assessment involving both associative processes and cognitive processes, each an extreme at an opposite end of a process continuum. Associative processes can be affective, the quick evaluations of situations and circumstances based on impulse, experience, gut feeling, and comparative evaluations of other risks. Further along the continuum, cognitive processes begin, in which risk information is processed more or less extensively. People can apply both processes, but one typically dominates the other in making decisions and determining behavioral responses. The rapidly-formed and affective associative process is called the Primary Evaluative Process (PEP) and the cognitive process is called the Secondary Evaluative Process (SEP). There are associative processes used in the SEP, but they are much more specific and studied or considered than those used in the PEP. This research has shown for the first time that associative processes are prominent in how people perceive risk, demonstrating the extent and importance of associative processes in risk perception - how people associate prior knowledge or beliefs with the challenge event. A few implications for IR education are offered in this research:

1. People are affected by their prior knowledge in both the PEP and SEP. They use specific associations among risks, applying knowledge of other risks to interpret new risks. These associations are <u>extremely</u> important in how people perceive and respond to risk;
2. Associated risks can function as an availability heuristic. The perceived riskiness of an already known risk serves as an indicator of the riskiness of a new or unknown risk, **<u>if</u>** the known and unknown risks share salient characteristics or have a semantic relation (e.g., radiation of food vs radiation of people, or radiation from one industry vs that of another), as can be explained by a semantic network theory. This is true for either PEP or SEP;
3. Influencing the way people evaluate risk, especially the PEP, by simple risk messaging (short, specific information on the risk or on protective instruction) is difficult. It is likely that it takes much more than simple, single messaging, such as repeated exposure or conditioning (i.e. education). Simple risk messaging (text, etc.) is not very effective in changing the PEP or SEP, especially over the long term;
4. The Mental Models Approach is a method to understand target audiences' knowledge of an unknown risk and the associations they use to interpret it (also advocated in [19]). Public interviews help identify the information (correct and erroneous) that people already use (their "mental models") to help identify information they need and want to understand a given risk.

This research confirms that education can inform and enable modification of associated risks the public may use for risk perception and response regarding IR. Also, [17] affirms that people's models evolve in interaction with new situations and that these models can become better (less wrong). While that is not always the case (where existing models involving fear are just too strong [9]), new situations can cause individuals to change their models (either perceived consequences or negative feelings about consequences), and thought processes involving successful outcomes with correct information (e.g. extended education) can improve their modeling. In other words, education achieving a better informed associative process can operate as a comparative risk assessment tool in modifying fear, a foundation for the comparative IR education approach proposed herein.

Scientific literacy and public education are important in addressing public fear [9], but other factors also play important roles in public risk perception (like risk management trust, ideologies, worldviews, and cultural, social, and political values). There is no intent herein to ignore other elements affecting public risk perception. Public education must be attuned to these other major influences, and that is why the Mental Models Approach is a necessary element for public education. Public IR education is the focus herein because it has never been widely used with nuclear energy, and research shows it may have a prospectively important role. Such education will **not** resolve all opposition to nuclear energy. Over four decades, too many social, cultural, and political factors have been learned as preferences that oppose nuclear energy. If education improves the associated risks used for individual's PEP and SEP responses, then fear is likely diminished and risk perception attenuated. Over time, such education may also improve social, cultural, and political perception influences related to nuclear energy.

Social amplification or attenuation of risk perception has been modeled, [24], linking people's initial evaluation of risk with cultural, social, media, and political influences that may also pertain. Figure 3 from [24] shows this process framework, and IR education is intended to influence the individual's use of associated risk in the Intuitive Heuristics (PEP) and Evaluation (SEP) stages of risk amplification or attenuation within the Individual Stages of Amplification on Figure 3. If fear is moderated by education, then there can be change within the Group and Individual Responses sector, attenuating other risk perception influences regarding nuclear energy over time.

Public Education Examples in Related Areas of Perceived Risk

Other industries that function under the constraints of negative public risk perception have addressed it using education and direct experience approaches to modify risk perception. Foremost among those involving fear of IR is the use of IR for medical diagnostics. Two current studies in this regard are informative, one discussing approaches in the U.S. and one reporting approaches and results from Europe.

In [25], interactive and extensive early communication with patients regarding medical radiation is discussed, driven by concern that the media's social amplification of IR fear can stigmatize medical radiation and erode public confidence. They summarize the psychology of IR risk perception and critique historical medical IR risk communications for effectiveness. While comparative risk education can be useful to illustrate dose magnitudes, the historical approach of using simple background radiation comparisons or other comparisons involving averages is viewed as ineffective. That is, the simple comparisons, based on the individual's associations and knowledge, do not align well with the greater risk from higher doses the individual perceives. To address this, [25] recommends dialogue with patients, a medical form of the Mental Models Approach, so that education can be most effective. The inference is that comparative risk education should operate to influence affect so that the associative process is helpful in reducing fear.

Freudenberg and Beyer [15] report on patients in Germany undergoing diagnostic imaging and nuclear medicine therapies using IR. They summarize IR fear education of people undergoing nuclear medicine therapies, particularly radioiodine therapy (RIT). Advocacy for and application of a variant of the Mental Models Approach is discussed, as well as an experiential validation that patients' associative processes form the strong basis for decisions on nuclear medicine IR. Additionally, education on and experience with RIT showed that patients' general fear of radioactivity was reduced as a result. Figure 4 shows patients' comparative feelings about RIT and radioactivity early in the process of undergoing RIT, indicating that the prospective help offered by RIT made its acceptability less fearful than radioactivity in general. After completion of education and long-term follow-up on the RIT process, Figure 5 shows the positive trend towards a much less fearful perception of radioactivity. The authors conclude that "it is extremely important to thoroughly and carefully educate all involved in patient work-up about radiation exposure levels . . . ," and that a Mental Models Approach ". . . must be considered before an investigation or therapy can begin."

Another issue involving public risk perception with similar characteristics to IR is harm from Electromagnetic Fields (EMF) as generated from electric power lines, cell phones and transmission towers. EMF is associated with similar harmful effects attributed to IR, but EMFs emanate continuously from the sources, not just under accident conditions. Because EMFs result from a large fraction of society's power supply, communication systems, and land usages, there has been extensive funding for public risk perception research, risk communication, and public outreach. EMF industries are at least a decade ahead of the nuclear industry's efforts to address the public's IR fear through education and risk communication, and there is much the nuclear industry can learn from EMF risk perception studies and communication programs that have been successful. From research contained in the [26] source document, extensive effort has been put into the EMF issue to address and attenuate public risk perception, and [26] provides guidance on using comparisons with other risk sources to enhance public education.

Finally, the Republic of Korea (ROK), having the world's fastest growing nuclear energy program, has made public IR education a government agency function since 1992 [27]. The Korea Nuclear Energy Promotion Agency (KONEPA), working in affiliation with professional societies, is charged with support of nuclear energy, including public IR education, media interface, and public relations and outreach. KONEPA even uses social media, developing an application for smart phones that is entitled *'Knowing About Radiation Correctly'*. The KONEPA program illustrates improved IR education outreach efforts.

COMPARATIVE IR INFORMATION FOR PUBLIC EDUCATION

People rely on upon associated risk perceptions that serve as comparisons or benchmarks for use in making judgments about IR across the full spectrum of associative and cognitive processes. Since the nuclear industry has not paralleled medical IR or EMF industries to manage and attenuate public fear, most of the public knows little about IR and harbors risk associations producing fear of IR and opposition to nuclear energy and SFM. The foundation for public IR education is to provide better associated risk information through education that tends to attenuate IR fear in support of decision-making. Secondarily, [28] shows that nuclear supporters' risk perceptions and opinions are less stable than those of firm nuclear opponents and are more affected by negative information on nuclear issues (nuclear support is more variable than its opposition's). Therefore, where nuclear and SFM decisions are being made, it is important to reinforce supporters with better associated risk information as part of the education process.

Improving associated risk perception is the essence of building a basis for attenuating public fear, and that suggests contents for a public IR education process. A Mental Models Approach should be used for identifying specific public issues for nuclear and SFM decisions at key project locations, but a successful IR education approach should contain comparative factual information suitable for use by people as associated risks. One potential success path is to structure the education around three levels of comparative IR assessments:

1. Comparative IR sources in, and releases from, the earth, relative to credible nuclear energy and SFM events;

2. Comparative IR sources in, releases from, and IR doses produced by unregulated non-nuclear industries, relative to nuclear energy and SFM;
3. Comparative IR effects on DNA relative to the effects of the body's own metabolic processes on DNA.

The following sections briefly summarize potential educational material content for this approach. However, it is simply provided for professionals to understand the breadth, depth, and flexibility of content in the comparative information available, not to offer the raw education material itself. The intent of education is not to raise the public's fear about other sources of IR more than its current fears of nuclear energy and SFM, but to provide a delicate and gentle learning process that reduces fear. Education will be effective when the public gains improved associative risk information with attenuated fear.

The Earth as a Nuclear Waste Dump, Naturally

Following introduction to IR fundamentals and terminology, it is important to explain that the formation of the earth filled it with radioactive nuclear waste materials, making it a true nuclear waste dump. Further, Mother Nature's nuclear wastes are by and large more hazardous than radionuclides from nuclear energy. And all these natural nuclear wastes make for substantial IR doses to numerous millions of the public annually, thanks to many non-nuclear industries. Key elements of content in this level of IR education would include:

- Estimates of the earth's natural nuclear waste: 600 trillion tons of uranium, thorium, and potassium-40 (U, Th, and ^{40}K) in and above the earth's upper mantle [29], and maybe 60,000 trillion tons of daughter products;
- These migrate into our soil, food, water, air, and bodies every day. From [30] and [31], all the natural radioactivity in the first foot of the earth's crust is about 7,000 to 10,000 times the radioactive material released to the environment by the TMI, Chernobyl, and Fukushima (TCF) accidents, combined, or up to 50,000 reactor accident releases worth of nuclear materials;
- A large fraction of waste in the crust is released into the food, air, water, and other liquids we ingest/inhale. The earth releases about 3,000 times the TCF accident materials into our air, food, water, and ingested liquids each year [32] (15,000 reactor accident releases of nuclear waste); the food, water and other liquids all non-plant life consumes annually contain more of earth's nuclear waste than the radioactive materials released in the TCF accidents;
- Volcanoes annually spew high levels of these nuclear wastes into the environment [48];
- The radionuclides arising from nuclear energy are less hazardous than most of the earth's natural radionuclides; from [33], Table 3 shows mortality risk coefficient ratios for natural nuclides vs cesium-137 (^{137}Cs); comparisons with other nuclides show similar results;
- Figure 6 presents a lognormal distribution of annual IR exposure in the U.S. from non-nuclear industries and natural sources, developed from information in [10] and [34] - [36]. Millions of Americans receive annual doses far higher than the average first year dose received by people around Chernobyl or Fukushima; 45+ million Americans receive annual IR doses > 10 mSv, equivalent to Spain's population and 75% larger than the population of all Nordic countries.

IR Doses to the Public from Non-Nuclear U.S. Industries

This level summarizes non-nuclear industry sources that are major contributors to the public's annual IR exposure. The public's IR fear is most related to nuclear industry accidents, suggesting an education approach discussing sources of IR from other industries for comparison with nuclear accident IR doses. Annual non-nuclear industry IR doses to the public are far higher than those from past nuclear accidents, and do not require regulation by responsible authorities. Non-nuclear industry IR doses to the public are unregulated, unmonitored, uncontrolled, unreported, and undisputed, so that their use as associated risks seems optimal.

- Table 4 from [34] shows comparative annual radiation doses from just 7 non-nuclear industries; these 7 industries have been selected because almost all Americans receive doses from at least 4 – 5 of them; ReNuAl, even assuming many more reactors, cannot produce public IR doses even approaching those of non-nuclear industries; if non-nuclear industry IR doses to the public don't merit regulation, nuclear energy does not merit public fear;
- The USNRC has evaluated the risk from extremely low-probability U.S. commercial reactor accidents; the State of the Art Reactor Consequence Analysis (SOARCA) report, [37], shows the risk of public IR doses is very low. Specifically, the report comments: 'Individual . . . risk from the selected . . . scenarios is . . . millions of times lower than the general cancer fatality risk in the United States from all causes, even assuming the LNT [Linear No Threshold] dose-response model. Using [a more realistic] dose-response model . . . results in a further reduction to the . . . risk (by a factor of 100 for smaller releases and a factor of 3 for larger releases).'; public radiation doses from credible nuclear energy events are not especially threatening;
- Other comparative examples include: the USEPA offers guidance on radon concentrations for use in the building industry that would produce annual IR doses to occupants of about 4 mSv per year, or about 200 to 300 mSv for a 50 year lifetime, greater than the average lifetime dose to the public surrounding TCF; similar doses result from other non-nuclear industries.

Metabolism vs IR as a Mutagen

The third level shows why the IR doses discussed herein for nuclear or non-nuclear industries are, at worst, a very weak carcinogen. As experts know, IR is a very good cell-killer, but a poor carcinogen. IR-produced cancer from non-nuclear industries is highly unlikely and essentially impossible from credible nuclear events. Cancer is a disease driven by our metabolic/genetic processes, not IR. Non-nuclear industries swamp the U.S. public with far more radiation than is credible from even expanded use of nuclear energy. Importantly, cancer risk from acute doses < 10 cSv from nuclear weapons' IR in Japan is well documented ([38] – [41]), showing no discernible risk;

- Atomic bomb survivor data shows very low excess leukemia and solid tumor cancer, demonstrating a very weak or nonexistent carcinogen at the dose levels considered herein;
- Chronic dose (delivered over time) is less damaging than an equal acute dose because the body repairs a substantial portion of such damage; chronic doses produce lower excess cancer risk;
- The association of cancer with mutations in DNA from metabolism and body chemistry is well documented in [42] – [45], with recent research from [46] offering confirmation; the human body's metabolism and chemistry produce huge numbers of mutations per cell per day, many thousands or millions of times greater than from nuclear event IR doses.

The conclusion of comparative IR information for public education to improve associative risk is that public IR doses from credible nuclear energy events are not a significant health threat, and doses at much higher levels to millions of Americans have resulted for decades from non-nuclear industries. Yet, even these doses have never been threatening enough to regulate. If the far higher public IR doses from the earth and non-nuclear industries don't merit regulation, nuclear energy/SFM does not merit public fear.

PUBLIC IR EDUCATION – HOW MIGHT IT BE ACCOMPLISHED?

Public IR education within the U.S. would be best initiated as a centralized, web-based education effort, whose content is applied to a specific site effort for a nuclear project proposal or expansion, owing to the size of the U.S. population and possible limitations of funding for a first effort. For the specific site effort, there are many project-specific topics for engaging the public, including the project's needs, benefits, and all the details on how the project will work with and impact the community. While the education process must interact with the public on the full array of project considerations, another purpose must be to provide the local, decision-making public with IR education so that comparative thinking can allow fear to be attenuated or neutralized, offering a much higher likelihood of project success.

Potential Organization Approaches

For IR education, there needs to be a uniformity of content and messaging for consistency and standardization. This suggests a single, centralized organization established for this purpose, what might be termed an organization providing outreach services for ionizing radiation education support (OSIRES). While a centralized OSIRES organization also suggests a U.S. federal role, such an approach seems likely be a difficult path politically. With an IR education process involving disclosure of non-nuclear industry IR doses, many of these industries would resist having their "contributions" exposed and each would likely offer strong resistance through its Congressional delegation. The same is likely true for organizations that might view such efforts as a threat to opposing viewpoints. Therefore, establishing a U.S. OSIRES federal organization could be daunting in the near term, especially in the time remaining and with no clear path for timely success.

There should be some reasonable independence of an OSIRES organization from the nuclear industry. While NEI, ANS, and others have done extensive outreach, such organizations have close ties to the industry that might serve as a detracting feature. Further, trust is a key element for successful outreach organizations on public fear issues (see [9] and [19], for example), and close industry association, as shown in [47], does not build the desired level of trust.

A private-industry OSIRES organization, with an established mechanism for funding, now seems like the best course for the likely tasks summarized above, but the funding source becomes problematical, with the need for nuclear industry independence as the source of that dilemma. However, hybrid OSIRES organizations are also credible and may be optimal. For example, each U.S. national laboratory supports local community and public outreach regarding its missions and efforts on at least a pseudo-formal basis. These efforts are funded by budgets approved by the U.S. Department of Energy (USDOE). A private enterprise/national laboratory joint venture could establish an OSIRES organization, partially or fully funded by the private company, while the national laboratory provides facilities, administrative or outreach staff, and other support or some funding. One example of what national laboratories are doing is provided by Sandia National Laboratories (SNL), in cooperation with the University of Oklahoma since 2006, to support the National Security and Nuclear Policies (NSNP) project, an advanced outreach effort on public perceptions and beliefs on nuclear energy and SFM issues, as discussed in [47]. Indeed, Figure 7 from [47] shows that national laboratories retain very high public trust on matters of SFM. Further, as the NSNP project shows, private company/university teams could also form an OSIRES organization.

In the U.S., the BRC report calls for a consent-based effort to find locales that wish to serve as sites for national SFM programs and for an independent organization to manage all national SFM efforts. The USDOE has endorsed this, laying out a tentative schedule for such a plan. The target is an operating centralized spent fuel storage facility in 10 years. Also, the USDOE and the Congress are considering a quasi-federal entity to take over SFM matters, and this organization could assume the OSIRES function. Since a clear advantage of a centralized OSIRES organization is uniformity in method and content for public education, and since it is impossible to educate anything but a limited fraction of Americans in the next decade, the argument for a quasi-federal, private-enterprise-led OSIRES organization has solid merit, especially considering that response ability is a prime characteristic for assuming or assigning responsibility. Early IR education efforts would likely be limited to on-line, web-based IR education packages, followed by IR education programs for populations in locations critical to SFM efforts, such as the prototype interim storage facility for spent fuel from stand-alone storage sites. A privately funded and operated OSIRES organization could be a natural element of such efforts.

An international OSIRES effort could also take the lead or team with discreet national organizations to manage OSIRES efforts for global consistency of approach and content. The UN may be an excellent agency for this, with the IAEA and the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) as examples of leadership organizations, but the issue of public trust and nuclear industry independence must be thoroughly considered.

Special Considerations and Needs for OSIRES

Besides organization, there are other factors for consideration in formulating the IR education approach:

- The initial focus of OSIRES organization efforts must be on developing IR education packages for application to web-based learning efforts designed for adults and for children; agreements and arrangements with national labs, universities, public institutions, and training organizations for offering the on-line IR education packages should also be set-up; these packages would form the bases for the site-specific education that follows;
- The OSIRES effort is limited to IR education; it supports web-based IR education and each project-specific public interaction team, but does not take on other project outreach efforts;
- The funding of an OSIRES organization that is reasonably independent of the nuclear industry may be a special issue that requires creative solution;
- The success rate (attenuation of IR fear) necessary for an OSIRES organization only needs to be a reasonable fraction of the people who are neither fully opposed to nor fully supportive of nuclear energy/SFM; NEI survey data over several years ([14], for example) shows that there is about 15% - 25% of the U.S public solidly opposed to nuclear energy/SFM, depending on the issue, and about 25% - 35% solidly supportive; this is displayed in Figure 8; as shown in [28], nuclear support in the mid-range 50±% is less stable than opposition, in the face of negative information, and a worthy objective is to build nuclear support to more than 50%; if a good fraction of the mid-range 50±% experiences attenuated IR fear, prospects for nuclear support are likely much improved;

- An OSIRES organization must have a broad skill base, owing to the multi-faceted nature of the IR education process development and implementation; specifically, such an organization requires expertise in key fields, including IR medical/health effects, nuclear analysis, system operations, media/web-based instruction, public outreach methods/presentation, and adult education programs, among the several; each location supported by an OSIRES organization should use the Mental Models Approach to identify optimal message and lesson content for local public education;
- The education approach must be developed, planned, reviewed, properly noticed for web-based and local participation, and implemented by education/media/outreach professionals; it cannot be *ad hoc*, but must be built on a structured, interactive set of lessons presented over time for progressive and cumulative learning; the organization must be peopled by a knowledgeable outreach cadre, trained for additional, refined effectiveness in a variety of venues with people holding beliefs having emotional content; and the messages must be founded on documented, available research (already substantially existing), supported by respected authorities within and outside of industry;
- The OSIRES process must start small for learning purposes, and its initial web-based and site-specific education efforts should precede the BRC-recommended, consent-based process for identifying SFM facilities; however, the need is great for the organization to grow so that its impact can cover a large web-based learning center and a number of site-specific engagements at once; the organization must achieve a national influence in just a few years.

Time is of the essence in the IR education program for our industry. Important decisions include: is there meaningful agreement that public IR education is a necessity for some element(s) of private enterprise and/or government; can such agreement inspire the will to make the investment and commitment; and can this be accomplished without the wrangling and endless debate that shortens schedules and marginalizes success likelihood for one of the great technological and political reversals of the industrial age? Such decisions require formidable teamwork and a leader that is not yet identifiable.

CONCLUSIONS AND IMPLICATIONS

> **No power is strong enough to be lasting if it labors under the weight of fear.**
> ***– Marcus Tullius Cicero, Roman statesman, political philosopher, orator***

Addressed herein is an issue that has been acknowledged, yet gone unresolved, for four decades, one that every person within the nuclear industry has discussed during his or her career. It may be framed in terms of how we “fix” public perception of nuclear energy and SFM, or any of a variety of other phraseologies that imply people are fearful of “our” technology and how that may be corrected. Therefore Cicero’s words should give pause to all countries using nuclear energy.

The message is that the public fears IR, not nuclear technology, and people associate fearful IR almost uniquely with nuclear energy and SFM, thanks in no small measure to generations of organizations and a complicit media having trained the public and its political class that such is true. Nuclear energy and SFM now have an entrenched opposition, routinely collaborating on enhancing public opposition through fear, and the industry and government have been ineffective in countering this fear, so that the situation is now *in extremis*. In the U.S., we have perhaps 10 years to alter the situation regarding public IR fear.

With such a background, clarifying a key foundational truth about safe nuclear energy and SFM through public IR education is advanced herein as a critical step over the next 10 years. The research on how people perceive risk supports the effectiveness of such education to form improved associative risks and attenuate fear. In summary, our industry seems to face a host or hostage dilemma: it can host and vitalize expanded outreach to reduce the public's IR fear, or it can remain hostage to fear and fear mongers, suffering on-going or increasing resistance to its technology. These seem to be our honest choices, and the host option may be the only course left for us to recapture and vitalize Maxwell Planck's expectation of so long ago. Cicero's ominous and weighty observation almost certainly now pertains more than Planck's and stands as a sobering warning if our industry continues to do what it has always done.

TABLES

Table 1
NEI: US Public Opinion
National Survey Questionnaire - February 8-10, 2013
Conducted by BISCONTI RESEARCH, INC.

What do you think are the major disadvantages of using nuclear energy as a source of electricity? Anything else? Anything else? [numbers are percent of responses collected from a sample of 1,000 responders] (abbreviated list)

Danger, accidents	**38%**
Waste	**19%**
	57%

[Courtesy of the Nuclear Energy Institute]

Table 2 (from [15])

Qualitative Evaluations of Radioactivity in Content Analysis According to Study by Freudenberg et al.

Attribute	Percentage (n = 68)
Negative	
Fear of dangers of nuclear energy	84%
Fear of malignant diseases	78%
Diffuse feeling of threat	72%
Fear of contamination	53%
Fear of changes of DNA	21%
Distrust in institutions	16%
Fear of death	6%
Neutral	
A source of energy	28%
Mutations	4%
Cosmic/natural radiation	3%
Positive	
Medical benefit	75%
Secure source of energy	37%
Source of evolution, hormesis	6%

Table 3
Relative Cancer Mortality Risk: Cesium-137 vs. Selected Natural Nuclides
(Ratio of Natural-to-Man-Made-Nuclide Mortality Risk)

Radionuclides	***Relative (Normalized) Risk****		
Man Made Radionuclide	**Inhalation**	**Ingestion**	**External**
Cesium 137 (Cs 137)	1	1	1
Natural Radionuclides			
Uranium 238	1,090	2.2	0.09
Thorium 230	3,272	3.2	1.5
Radium 226	1,320	14	40
Thorium 232	5,000	3.6	0.6
Radium 224	1,180	5.7	70
Actinium 227	10,000	7.7	0.6
Protactinium 231	5,450	6.2	260
Lead 214	4.2	0.01	1,839
Lead 212	70	0.9	968
Lead 210	311	33	2.6
Bi 214	3.4	.01	14,194
Bi 212	9.1	0.03	1,677
Bi 210	36.8	0.3	1,903
Polonium 210	1,270	64	7.4
Potassium 40	5.5	0.9	1,516

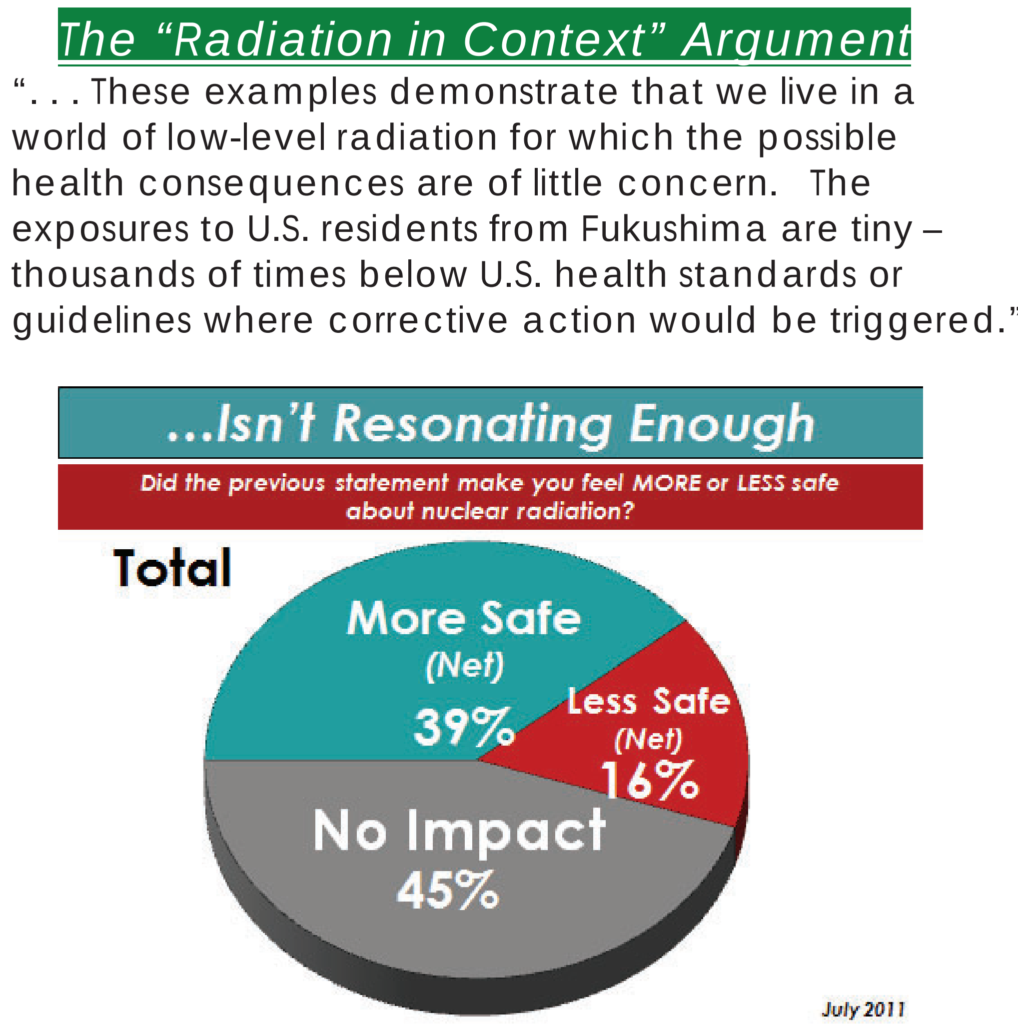
***From Federal Guidance Report No. 13, USEPA**

Table 4
Comparative Public IR Exposure in the U.S. (Collective Effective Dose Equivalent):
Nuclear Energy vs Seven Non-Nuclear Industries: Assumes Growth to 300 Reactors over 50 Years

Industry	**Current Annual CEDE (Person-cSv)**	**Highly Exposed Public: Average Annual TEDE (cSv)**	**Projected 50 Year CEDE (Person-cSv)**
Aviation	> 0.6 million	> 1	> 28 million
Building Design/Construction	> 15 million	> 15	> 750 million
Potable Water Supply	> 1.5 million	> 0.5	> 75 million
Agriculture	> 1.3 million	> 0.4	> 65 million
Construction Materials	> 2 million	> 0.4	> 100 million
Tobacco Supply	> 44 million	> 3	> 2.2 billion
CT Medical Diagnostics	> 44 million	> 3	> 2.2 billion
Total for 7 Non- Nuclear Industries	**> 108 million**	**> 15**	**> 5.4 billion**
Total for All U.S. Commercial Nuclear Energy	**< 0.03 million**	**< 0.06 TMI [< 0.8 Chernobyl]**	**< 2.6 million**

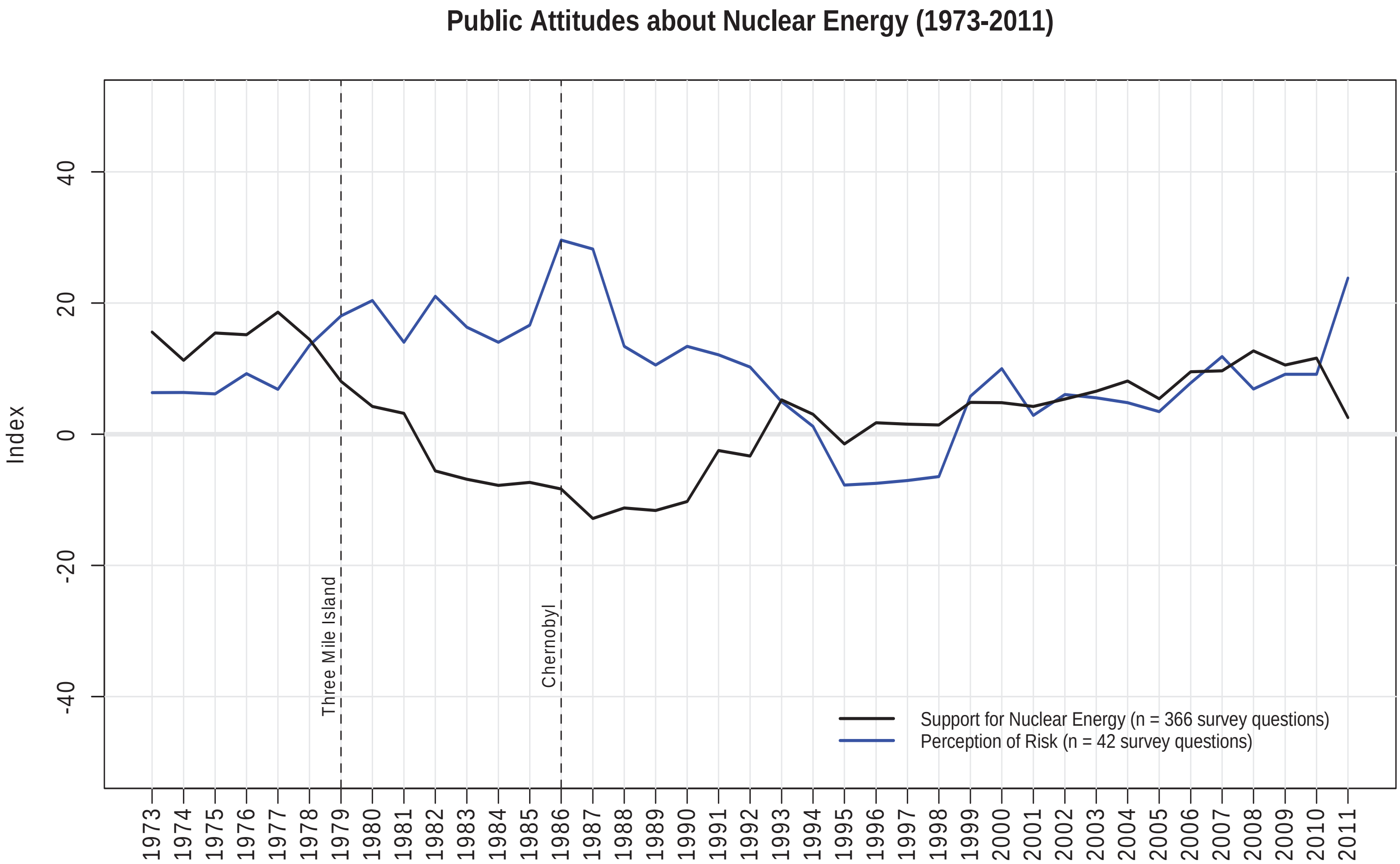
FIGURES

Figure 1
Survey Results on Public Perception of Nuclear Industry Radiation Messaging



[Courtesy of the Nuclear Energy Institute]

Figure 2 (from [16])
Historical Perceptions of Nuclear Energy Risk and Support



The graph plots two scales over time, from 1973 to 2011. The algorithm utilized produces scale values that range from 0 to 100. The plot is centered around zero: on the nuclear acceptability scale a value of 0 would indicate 50/50 support/opposition to nuclear energy, positive values more positive, and negative values more negative. For the risk scale, positive values indicate more risk, negative values less risk, and a 0 value 50/50 risk. The scales are negatively correlated at r = -0.345, p < .001.

Figure 3 [from [24])
Framework for Social Amplification and Attenuation of Risk

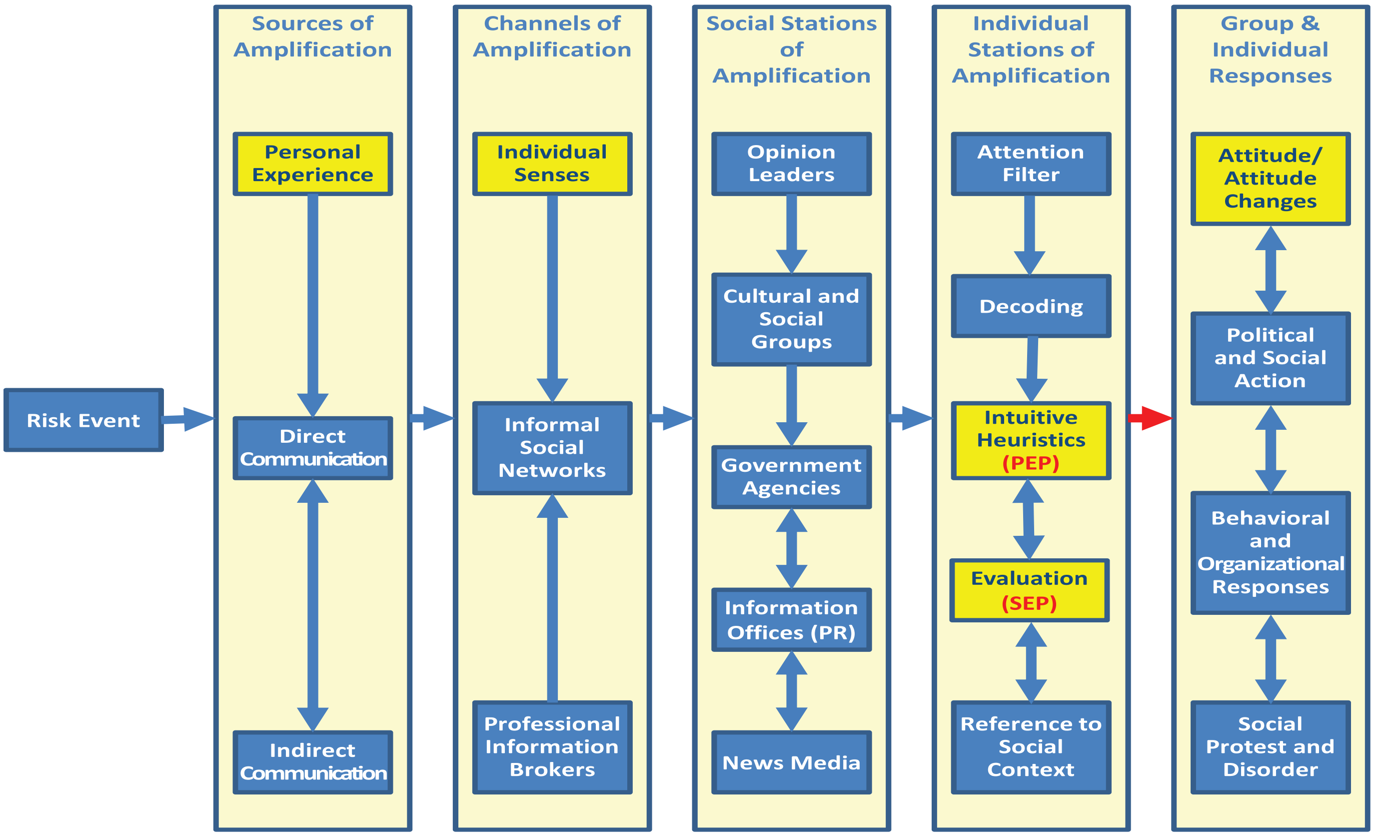


Figure 4 (from [15])

Subjective patient perception of radioactivity on a scale of 1–5 (n = 68) (1 = positive, 2 = rather positive, 3 = neutral, 4 = rather negative, and 5 = negative). Changes with means of 3.5 (general) and 2.7 (Radioiodine Treatment {RIT}) are statistically significant (P = 0.01).

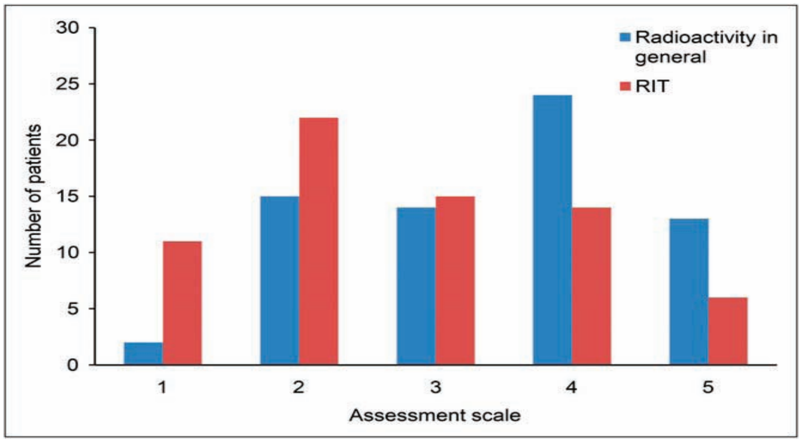


Figure 5 (from [15])

Subjective patient perception of radioactivity on a scale of 1–5 before and after RIT (n =29) (1 = positive, 2 = rather positive, 3 = neutral, 4 = rather negative, and 5 = negative). Changes with means of 2.3 and 2.0 before and after RIT, respectively, are statistically significant (P = 0.03).

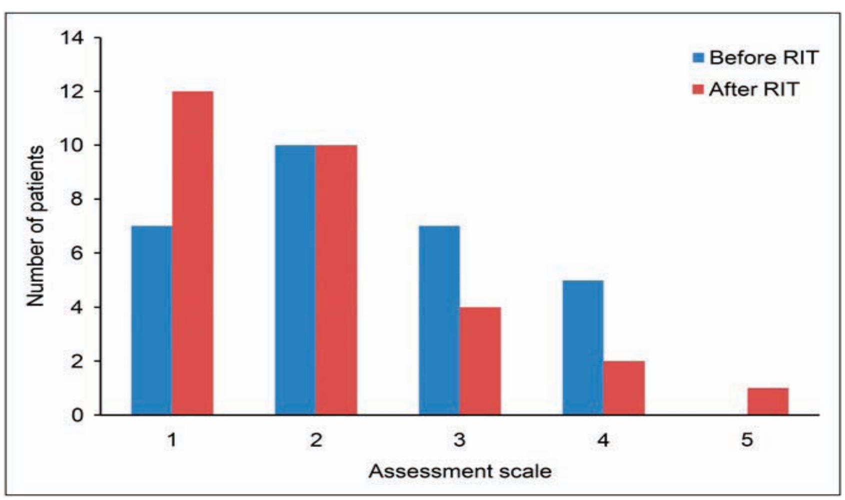
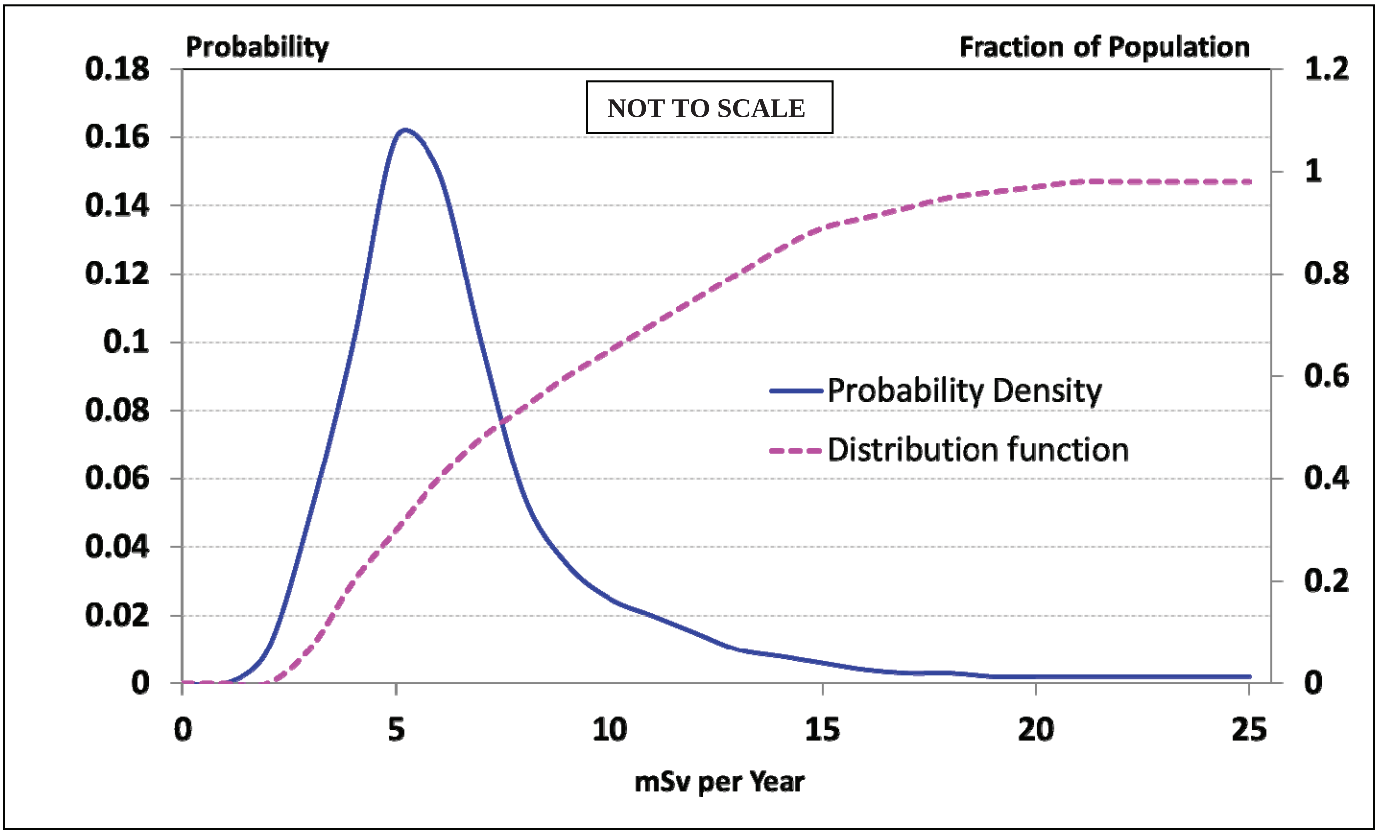


Figure 6
Log-Normal Distribution of Annual U.S. Population Radiation Doses from All Sources



► *Arithmetic mean μ = 6.2 mSv; standard deviation σ = 4.4*

► *U. S. population = 315 million; population with annual doses:*

- *> 6.2 mSv = 118 million;*
- *>10 mSv = 45 million;*
- *>15 mSv = 14 million;*
- *>20 mSv = 5+ million.*

Figure 7 [from [47]]
Relative Institutional Trust – Mean trust in information about spent fuel, by source

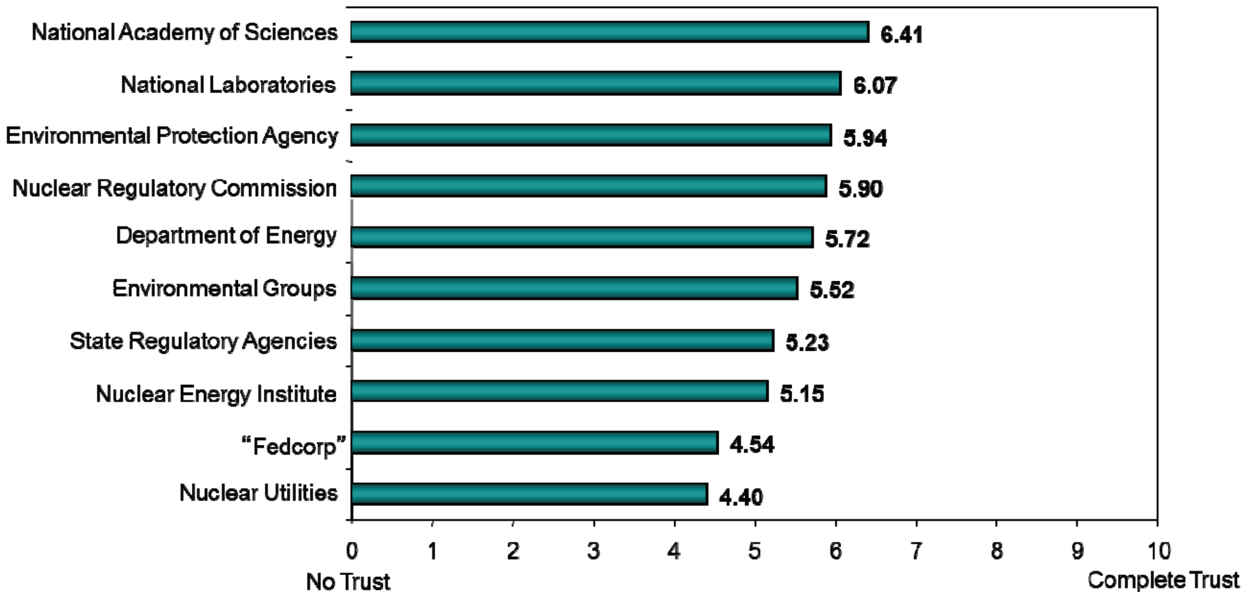
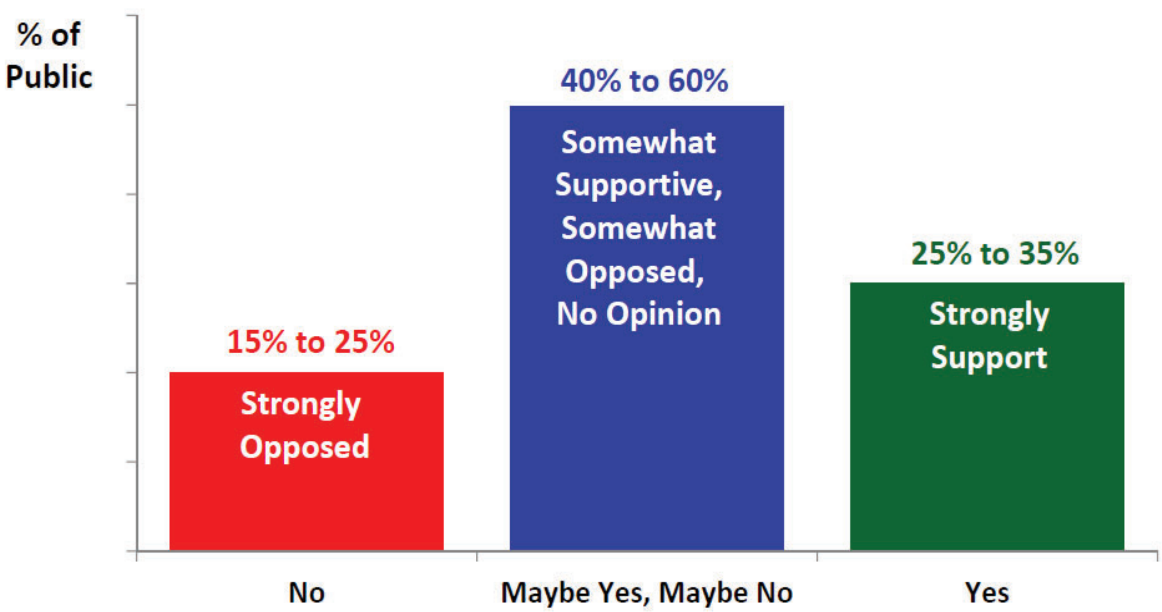


Figure 8
Nuclear Energy and Spent Fuel Management:
U.S. Support and Opposition (From NEI Surveys)



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