NOTATION VOTE

RESPONSE SHEET

TO: Annette Vietti-Cook, Secretary

FROM: Commissioner Wright

SUBJECT: SECY-17-0017: Proposed Revision to NUREG-1530, "Reassessment of NRC's Dollar Per Person-Rem Conversion Factor Policy"

Approved _X_ Disapproved ____ Abstain ____ Not Participating ____

COMMENTS: Below ____ Attached _X_ None ____

David A. Wright
Digitally signed by David A. Wright
Date: 2021.11.19 10:18:43 -05'00'

SIGNATURE

Entered in "STARS"
Yes _X_ No ____

November 19, 2021

DATE

Commissioner Wright's Comments on SECY-17-0017, "Proposed Revision to NUREG-1530, 'Reassessment of NRC's Dollar Per Person-Rem Conversion Factor Policy'"

I appreciate the staff's effort to revise the dollar per person-rem conversion factor that the NRC uses in cost-benefit analyses to determine the monetary valuation of the cancer mortality risk associated with radiological exposure. As outlined in the paper, this conversion factor is established by multiplying a value of a statistical life (VSL) by a cancer mortality risk coefficient. The concept of a VSL, which is used throughout the Federal government to monetize the health benefits of a safety regulation, is not a value placed on a human life, but a value that society would be willing to pay for small reductions in the risk of premature death for a given population.

I agree with my colleagues that the NRC's factor should be credible and up to date. I appreciate the staff's efforts to benchmark with other agencies to develop its recommended changes and the Advisory Committee on Reactor Safeguards' (ACRS) review and feedback on the revised methodology. The staff proposes to update its VSL from $3.0 million (constant dollars) to $9.0 million (2014 dollars) by averaging the VSL's of the U.S. Environmental Protection Agency (EPA) ($8.7 million in 2014 dollars) and the U.S. Department of Transportation ($9.3 million in 2014 dollars), and to update this value annually to account for inflation. The staff also proposes to adopt the EPA's cancer mortality risk coefficient of 5.8×10^{-4} per person-rem. Therefore, the staff proposes both a change to the VSL and the framework for the cancer risk coefficient (i.e., a shift from the use of the International Commission on Radiological Protection's (ICRP) nominal risk coefficient to EPA's cancer mortality risk coefficient). For the reasons discussed below, I approve the staff's proposed changes and final publication of NUREG-1530, Revision 1, subject to the attached edits. I also approve the publication of a notice in the *Federal Register* informing the public of the availability of NUREG-1530, Revision 1.

Value of a Statistical Life

The staff's recommendation to increase the VSL is based on changes in the estimates and bases for the VSL and dollar per person-rem conversion factor since the initial revision of NUREG-1530 was published in 1995. The VSL uses the willingness to pay method that can be calculated by analyzing (1) tradeoffs between risk and benefits that people make in their consumptive decisions, (2) observed wage differentials in occupations of varying risks, and (3) responses to questions that postulate hypothetical market choices. These studies' results may vary significantly by country. The staff's proposed VSL continues to be based on willingness to pay studies specific to U.S. populations. I find this reasonable as it should represent the preferences of the population the NRC regulates.

A VSL using the willingness to pay method is dependent on the studies used to support the analysis. After benchmarking with other agencies and doing literature reviews, the staff determined that each Federal agency discussed in this NUREG has adopted VSL estimates with mean values in the $7-9 million range (2014 dollars) based on that agency's mission and within its own processes. Many of these agencies also adjust their VSL based on inflation and other factors. The staff notes that if it performed its own analysis, its VSL estimate would be similar because it would use the same set of peer-reviewed studies that are specific to the U.S. as the basis of its analyses. In response to my questions on this paper, the staff noted that this set of studies does not include studies specific to the nuclear industry or its associated risks and that there is not sufficient data to determine a differential for reductions in cancer mortality versus other modes of mortality. For this reason, the staff chose to average the EPA and DOT's VSLs, which are well-supported and include studies most applicable to the NRC's work. While the Office of Management and Budget allows for significant differences in the VSL used, I agree that it is reasonable for the NRC's VSL to align with those of its Federal counterparts. I also find it reasonable for the NRC to update the VSL based on inflation. This adjustment would not affect the stability of regulatory bases because the staff will continue its practice of expressing all costs and benefits in terms of a common year. The adjustment is also not expected to change the outcome of cost beneficial determinations because the cost of modifying a licensed facility would be similarly affected by inflation.

The staff has committed to periodically reevaluate its baseline values for the VSL and cancer mortality risk coefficient and provide a recommendation to the Commission whether to update guidance and regulations if the conversion factor is expected to change by more than $1,000 per person-rem. Given the significance of this value in NRC decisionmaking, it is important for the Commission to ultimately decide whether an update to the guidance or regulations, beyond accounting for inflation, is necessary. As part of its periodic review and to support any recommendation to the Commission on a possible update, the staff should monitor the availability of studies specific to NRC regulated industries, associated risks, and affected populations and notify the Commission if sufficient data become available to develop a VSL specific to the risks associated with the commercial use of nuclear material.

Cancer Mortality Risk Coefficient

The staff also proposes to shift from the use of the ICRP nominal risk coefficient and adopt the EPA's cancer mortality risk coefficient of 5.8×10^{-4} per person-rem. The ICRP nominal risk coefficient includes a global average risk of fatal cancers, non-fatal cancers, and severe heritable effects while the EPA cancer mortality risk coefficient only monetizes mortality. I agree that the use of the EPA's cancer mortality coefficient is appropriate because it is specific to the U.S. population and, like the proposed VSL, only monetizes mortality. The staff will account for morbidity from nonfatal cancers separately and is developing detailed guidance on monetizing these risks as an appendix to NUREG/BR-0058, Revision 5.

However, I am concerned that NUREG-1530, Revision 1 references guidance documents that the staff plans to rescind. NUREG/BR-0058, Revision 5, which is currently before the Commission, also consolidates several guidance documents on cost-benefit analyses. To the extent practicable, the staff should coordinate the issuance of NUREG-1530, Revision 1, and NUREG/BR-0058, Revision 5, and ensure that the cross-references and narrative in each document are up to date and consistent. The staff should also update NUREG-1530, Revision 1, to reflect the recent revision to Management Directive 8.4.

High and Low Dollar Per Person-Rem Conversion Factor Estimates and ACRS Recommendation

Because the dollar per person-rem conversion factor impacts whether rules are cost beneficial and whether additional requirements are imposed on licensees, I had questions about possible impacts of adopting this revised factor, especially given the uncertainty inherent in the VSL and cancer mortality risk coefficient. However, the staff has used other dollar per person-rem values to understand the sensitivity of this parameter on cost and benefit estimates. For example, the staff used $2,000 and $4,000 per person-rem in the regulatory analyses performed for COMSECY-13-0030 and has been using the proposed $5,200 per person-rem in sensitivity analyses for several years to ensure that decisions would not need to be revisited should the Commission approve finalizing NUREG-1530, Revision 1. To date, the staff has not identified any changes to recommendations based on the use of these alternate conversion factors.

Therefore, I do not anticipate that the revised dollar per person-rem conversion factor would significantly impact cost beneficial determinations going forward. To confirm this, the staff should perform a sensitivity analysis using $2,000 per person-rem (in constant dollars) for the first ten actions using the new dollar per person-rem conversion factor and provide a Commissioner Assistant's Note describing how, if at all, the use of the revised conversion factor resulted in a change in the break-even cost beneficial determination for these actions.

Finally, the ACRS recommended that the staff characterize and quantify the uncertainty in the dollar per person-rem value in a future revision of NUREG-1530. I appreciate the staff's commitment to reconsider the treatment of uncertainty in light of this recommendation, brief ACRS on any proposed changes, and to work with the ACRS to revise its methodology and quantification of the uncertainty in the conversion factor. The implementation of these actions would align with the guidance in NUREG/BR-0058, Revision 5, with respect to the quantification of uncertainty for other elements of cost-benefit analyses.

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

DAW Edits

NUREG-1530
Revision 1

Reassessment of NRC's Dollar per Person-Rem Conversion Factor Policy

Final Report

Office of Nuclear Reactor Regulation

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U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

NUREG-1530
Revision 1

Reassessment of NRC's Dollar per Person-Rem Conversion Factor Policy

Final Report

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Pamela Noto, NRC Project Manager

Office of Nuclear Reactor Regulation

ABSTRACT

The U.S. Nuclear Regulatory Commission (NRC) uses the dollar per person-rem conversion factor in developing cost-benefit analyses to determine the monetary valuation of the consequences associated with radiological exposures. In 1995, the NRC issued NUREG-1530, "Reassessment of NRC's Dollar per Person-Rem Conversion Factor Policy," which updated the dollar per person-rem conversion factor from $1,000 to $2,000 (in constant dollars) (NRC, 1995a). The $2,000 per person-rem conversion factor serves only as a proxy for the health effects associated with a person-rem of dose. This number resulted from the multiplication of the value of a statistical life (VSL) ($3 million in 1995) by the risk coefficient for stochastic health effects (7.3×10^{-4} per person-rem), rounded to the nearest thousand. The NRC believes that a reevaluationcontinued validity of the $2,000 per person-rem conversion factor has been questionedis appropriate because estimates and bases for the VSL and cancer mortality risk coefficients have changed since the NRC published NUREG-1530 in 1995.

Revision 1 to NUREG-1530 incorporates updates to the dollar per person-rem conversion factor and establishes a method for keeping this factor up-to-date. The dollar per person-rem conversion factor has been updated from $2,000 (in constant dollars) to $5,200 in 2014 dollars based on the application of an updated best estimate VSL of $9.0 million and the U.S. Environmental Protection Agency's cancer mortality risk coefficient of 5.8×10^{-4} per person-rem. Revision 1 to NUREG-1530 directs the NRC staff to round theuses a conversion factor to with two significant figures instead of rounding to the nearest $1,000 value and provides guidance to the staff on when to use a higher dollar per person-rem conversion factor.

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ACKNOWLEDGMENTS

The authors of this report thank the U.S. Nuclear Regulatory Commission staff members, industry representatives, staff from other Federal agencies, and members of the public who helped to develop this report. We appreciate the willingness shown by all parties to collaborate in updating the dollar per person-rem conversion factor policy.

ABBREVIATIONS AND ACRONYMS

10 CFR	Title 10 of the *Code of Federal Regulations*
ADAMS	Agencywide Documents Access and Management System
AEA	Atomic Energy Act of 1954, as amended
ALARA	as low as is reasonably achievable
BLS	U.S. Bureau of Labor Statistics
CPI	Consumer Price Index
CPI-U	Consumer Price Index – for All Urban Customers
CRS	Congressional Research Services
DDREF	dose and dose-rate effectiveness factor
DHS	U.S. Department of Homeland Security
DOT	U.S. Department of Transportation
EIS	environmental impact statement
EO	Executive Order
EPA	U.S. Environmental Protection Agency
FDA	U.S. Food and Drug Administration
FR	*Federal Register*
FY	fiscal year
GDP	gross domestic product
ICRP	International Commission on Radiological Protection
MUWE	median usual weekly earnings
NAS	National Academy of Sciences
NEPA	National Environmental Policy Act
NRC	U.S. Nuclear Regulatory Commission
NUREG	NRC technical report designation
OSHA	U.S. Occupational Safety and Health Administration
OMB	U.S. Office of Management and Budget
PRA	probabilistic risk assessment
Q	calendar quarter

RG	Regulatory Guide
SAB	U.S. Environmental Protection Agency Science Advisory Board
SAMA	severe accident mitigation alternative
SAMDA	severe accident mitigation design alternative
SRM	staff requirements memorandum
Sv	sievert
U.K.	United Kingdom
VSL	value of a statistical life
VSLY	value of a statistical life-year
WTP	willingness to pay

1 REGULATORY BACKGROUND

For all activities regulated by the U.S. Nuclear Regulatory Commission (NRC), the Commission has the authority to take action it deems necessary to ensure adequate protection of public health and safety. Additionally, for NRC-regulated activities, the Commission has discretionary authority to require safety improvements, beyond those necessary to achieve adequate protection, that will increase the protection of public health and safety. The NRC uses various tools to determine whether such a safety improvement is justified, including a cost-benefit analysis. To compare the incremental costs and benefits, all attributes considered in the cost-benefit analysis must be expressed in common units, typically dollars. Therefore, person-rems of averted exposure, a measure of safety value, is converted to dollars by monetizing the health detriment of radiation exposure. The NRC monetizes the cancer mortality risk of radiation exposure as dollars per person-rem of collective dose.

The NRC establishes the dollar per person-rem conversion factor by multiplying a value of a statistical life (VSL) coefficient by a cancer mortality risk coefficient. The U.S. Environmental Protection Agency's (EPA) summary cancer mortality risk coefficient is a gender-averaged value, calculated for a stationary U.S. specific population (defined by the 2000 U.S. vital statistics) (EPA, 2011b). The VSL is not a value placed on a human life, but a value that society would be willing to pay for reducing health risk. The concept of a VSL is used throughout the Federal government to monetize the health benefits of a safety regulation.

For approximately the last two decades, the NRC has used a conversion factor of $2,000 per person-rem (in constant dollars) as the monetary valuation of the consequences associated with radiological exposure. That is, an increase or decrease in person-rem is valued at $2,000 per person-rem to allow a quantitative comparison of the costs and benefits associated with a proposed regulatory decision. In the initial publication of NUREG-1530, "Reassessment of NRC's Dollar per Person-Rem Conversion Factor Policy," in 1995, the NRC established this conversion factor from the multiplication of the VSL ($3 million) by the risk coefficient for stochastic health effects (7.3×10^{-4} per person-rem) (NRC, 1995a). Stochastic health effects are health effects that occur by chance and may occur without a threshold level of dose, whose probability is proportional to the dose and whose severity is independent of the dose.

This conversion value has been used as a reference point in NRC regulatory analyses including: (1) evaluation of routine liquid and gaseous effluent releases; (2) evaluation of accidental releases; (3) evaluation of radiation protection practices, as provided for in Part 20 of Title 10 of the *Code of Federal Regulations* (10 CFR), "Standards for Protection Against Radiation"; (4) backfit analyses; and (5) environmental analyses.

The NRC prepares regulatory analyses for proposed actions that would impose requirements on NRC licensees. The analyses include an examination of the benefits and costs associated with alternative approaches to meeting the particular regulatory objectives. The NRC requires a regulatory analysis for a broad range of regulatory actions. In general, all mechanisms used by the NRC staff to establish or communicate generic requirements, requests, or staff positions, that would effect a change in the use of resources by the licensees will include an accompanying regulatory analysis. These mechanisms include rules, ~~bulletins, generic letters~~generic communications, cost-benefit guidance, regulatory guides, orders, standard review plans, branch technical positions, enforcement guidance memoranda, interim staff guidance documents, NUREG publications, and standard technical specifications that establish modify, or withdraw staff positions or guidance for applicants or licensees. The conclusions and recommendations included in a regulatory analysis are neither final nor binding, but rather are intended to inform decisions made by the NRC staff and the Commission.

The continued validityNRC believes a reevaluation of the $2,000 per person-rem conversion factor has been questionedis appropriate because estimates and bases for the VSL and cancer mortality risk coefficients have changed since the NRC published NUREG-1530 in 1995 (NRC, 1995a).

Revision 1 to NUREG-1530 incorporates updates to the dollar per person-rem conversion factor and establishes a method for keeping this factor up-to-date. The dollar per person-rem conversion factor has been updated from $2,000 (in constant dollars) to $5,200 (in 2014 dollars) based on the application of an updated best estimate VSL of $9.0 million and the EPA's cancer mortality risk coefficient of 5.8×10^{-4} per person-rem. Revision 1 to NUREG-1530 directs the staff to round the conversion factor to two significant figures instead of rounding to the nearest $1,000 value and provides guidance to the staff on when to use a higher dollar per person-rem conversion factor. Consistent with SECY-20-0074, the NRC staff is developing detailed guidance on monetizing the risks associated with the morbidity from nonfatal cancers using quality-adjusted life years as an appendix to Revision 5 to NUREG/BR-0058.

The NRC's Revision 1 to NUREG-1530 continues the practice of calculating a dollar per person-rem conversion factor based on the VSL and a cancer mortality risk coefficient that establishes the probability for cancer mortality health effects attributable to radiological exposure. The resulting dollar per person-rem conversion factor is expected to apply to situations where populations are exposed to low doses that collectively result in calculated excess cancers.

2 HISTORY

The U.S. Nuclear Regulatory Commission (NRC) and its predecessor agency, the Atomic Energy Commission, have implemented a dollar per person-rem conversion factor for over four decades. The issue of assigning a monetary value to radiation dose in regulatory decisionmaking arose in 1974, during the hearing for a rulemaking addressing routine effluent releases from nuclear power reactors. The subsequent rule was Part 50 of Title 10 of the *Code of Federal Regulations* (10 CFR), “Domestic Licensing of Production and Utilization Facilities,” Appendix I, “Numerical Guides for Design Objectives and Limiting Conditions for Operation To Meet the Criterion ‘As Low As Is Reasonably Achievable’ for Radioactive Material in Light-Water-Cooled Nuclear Power Reactor Effluents.” In adopting design criteria for limiting routine effluent releases from power plants, the Commission advanced the use of a cost-benefit test (NRC, 1975a):

> Such a cost-benefit analysis requires that both the costs and the benefits from the reduction in dose levels to the population be expressed in commensurate units, and it seems sound that these units be units of money. Accordingly, to accomplish the cost-benefit balancing, it is necessary that the worth of a decrease of a person-rem be assigned monetary values.

The Commission stated that “the record, in our view, does not provide an adequate basis to choose a specific dollar value for the worth of decreasing the population dose by a man-rem” (NRC, 1975a). Published studies that were mentioned in the rulemaking record gave values ranging from $10 to $980 per person-rem. The Commission concluded that “there is no consensus in this record or otherwise regarding the proper value for the worth of a man-rem,” and that “we also recognize that selection of such values is difficult since it involves, in addition to actuarial considerations that are commonly reduced to financial terms, aesthetic, moral, and human values that are difficult to quantify” (NRC, 1975a). The final outcome was a Commission decision to adopt as an interim measure, the value of $1,000 per person-rem for cost-benefit evaluations (NRC, 1975a).

Two executive orders (EOs) issued by President Gerald R. Ford, Jr. (EOs 11821 and 11949) encouraged Federal agencies to perform value-impact (now called cost-benefit) evaluations of proposed regulatory requirements to demonstrate adequate justification for new requirements. The NRC adopted this type of evaluation and issued SECY-77-388A, “Value-Impact Analysis Guidelines,” in December 1977 (NRC, 1977). This document referred to the techniques and detailed consequence analyses used in WASH-1400, “Reactor Safety Study: An Assessment of Accident Risks in U.S. Commercial Nuclear Power Plants,” and recommended that the person-rem averted from proposed changes be multiplied by $1,000 per person-rem to place the benefit in the same units as the costs (NRC, 1975b).

In 1977, Congress added Section 210 to the Energy Reorganization Act of 1974, directing the NRC to develop a plan for the identification and analysis of unresolved safety issues relating to nuclear reactors. In response, the NRC developed a program for the prioritization and resolution of unresolved safety issues and generic issues. In 1982, the NRC issued guidance relating to the assignment of priorities with the publication of NUREG-0933, “A Prioritization of Generic Safety Issues” (NRC, 1982b). In NUREG-0933, the $1,000 per person-rem value was used in setting the priority of unresolved safety issues and generic issues. Issues identified as high priority were then subject to resolution employing a more detailed cost-benefit analysis that also applied the $1,000 per person-rem value. In both contexts, the $1,000 per person-rem value has been the figure of merit and one of the factors in the respective assessments.

In February 1981, President Ronald W. Reagan issued EO 12291, which directed executive agencies to prepare a regulatory impact analysis for all major rules and stated that regulatory actions should be based on adequate information concerning the need for and consequences of any proposed actions. Moreover, EO 12291 directed that actions were not to be undertaken unless they resulted in a net positive benefit to society. As an independent agency, the NRC was not required to comply with EO 12291. The Commission, however, noted that its established regulatory review procedures included an evaluation of proposed and existing rules in a manner consistent with the regulatory impact analysis provisions of EO 12291. The Commission determined that clarifying and formalizing the existing NRC cost-benefit procedures for the analysis of regulatory actions would advance the purposes of regulatory decisionmaking. EO 12291 was later superseded by EO 12866 in October 1993, which did not affect NUREG-1530.

The NRC published NUREG/BR-0058, Revision 0, “Regulatory Analysis Guidelines of the U.S. Nuclear Regulatory Commission,” in January 1983 and published Revision 1 in May 1984 (NRC, 1983a and 1984, respectively). The NRC then published NUREG/CR-3568, “A Handbook for Value-Impact Assessment” in December 1983 (NRC, 1983b). These documents were issued to formalize the NRC’s policies and procedures for analyzing the costs and benefits of proposed regulatory actions. These initial revisions of NUREG/BR-0058 did not mention the $1,000 per person-rem figure; however, NUREG/CR-3568 recommended that the analyst use a range of values, one of which should be the $1,000 per person-rem value. As NUREG/CR-3568 provides the implementation guidance for performing regulatory analyses, it became standard practice of the NRC staff to apply this guidance whenever a quantitative regulatory analysis or cost-benefit analysis was performed.

In May 1983, the NRC issued an interim policy statement on “Safety Goals for Nuclear Power Plant Operation” for use during a 2-year trial period (NRC, 1983c). In this policy statement, the Commission adopted qualitative and quantitative design goals for limiting individual and societal risks from severe accidents. Also in this policy statement, the Commission stated that the benefit of an incremental reduction of societal mortality risks should be compared with the associated costs on the basis of $1,000 per person-rem averted as one consideration in decisions on safety improvements. The value proposed was in 1983 dollars and was to be modified to reflect general inflation in the future. At the end of the 2-year interim period, a number of comments were received on this value. These comments proposed values ranging from $100 per person-rem to values exceeding $1,000 per person-rem. Respondents who believed the $1,000 value was too low did not provide another number, but merely indicated that the value should be raised. As a result, the $1,000 per person-rem value was deleted in the final policy statement, “Safety Goals for the Operations of Nuclear Power Plants,” when published in August 1986 (NRC, 1986).

In 1985, the staff revisited the $1,000 per person-rem valuation and its use in regulatory analyses of nuclear power plant improvements designed to enhance safety. Although the monetary value of averted person-rem of radiation exposure up to that time referred only to averted health effects (such as averted latent cancer fatalities), the use of $1,000 per person-rem was evaluated and defined at that time as a surrogate for all averted offsite losses, such as health and property. The basis for this determination is in an October 1985 memorandum from the NRC Executive Director for Operations to the Commissioners (NRC, 1985a).

An example of the use of value-impact analysis occurred in February 1982, as part of the Three Mile Island Action Plan. The Commission promulgated 10 CFR 50.34(f)(1)(i), which requires certain nuclear power plant reactor license applicants to prepare a plant-specific probabilistic risk assessment (PRA) to identify significant and practical improvements in the reliability of core and containment heat removal systems that do not impact excessively on the plant (NRC, 1982a). As a result of this rule, cost-benefit analyses were prepared in 1985 for the U.S. Advanced Boiling Water Reactor design and reported in the General Electric Standard Safety Analysis Report (NRC, 1985b). These cost-benefit analyses analyzed 80 design-specific enhancements using $1,000 per person-rem. PRAs are now widely used for existing operating nuclear power plant licensing actions and are required for new reactor designs and licenses issued under 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants."

In a February 1989 decision, the U.S. Third Circuit Court of Appeals directed the NRC to consider severe accident mitigation design alternatives (SAMDAs) as part of the NRC's environmental review process under the National Environmental Policy Act (NEPA) before granting reactor operating licenses to owners of nuclear power plants (Limerick Ecology, 1989). The staff subsequently evaluated SAMDA analyses for the Limerick, Comanche Peak, and Watts Bar nuclear power plants before issuing operating licenses (NRC, 1996a). The economic consequences of severe accidents and the need for SAMDAs were evaluated for the "Generic Environmental Impact Statement for License Renewal of Nuclear Plants," originally issued in 1996 (NRC, 1996b). In each of these instances, the staff used the $1,000 per person-rem value as a screen to compare costs and benefits.

In October 1993, President William J. Clinton issued EO 12866 requiring all executive branch agencies to perform regulatory analyses for all significant rules. A significant (or major) rule is defined by EO 12866 as:

> … any regulatory action that is likely to result in a rule that may: (1) have an annual effect on the economy of $100 million or more or adversely affect in a material way the economy, a sector of the economy, productivity, competition, jobs, the environment, public health or safety, or State, local, or tribal communities; (2) create a serious inconsistency with an action taken or planned by another agency; (3) materially alter the budgetary impact of entitlements, grants, user fees, or loan programs or the rights and obligations of the recipients thereof; or (4) raise novel legal or policy issues arising out of legal mandates, the President's priorities, or the principles set forth in this Executive order.

The NRC, as an independent agency, is not required to comply with EO 12866. However, Revision 1 to NUREG/BR-0058 already reflected the intent of the EO, in part because of the Commission's previously expressed desire to meet the spirit of EOs related to regulatory reform and decisionmaking. Revision 2 to NUREG/BR-0058 reflected the experience accumulated by the NRC in implementing Revision 1 to NUREG/BR-0058 and changes to the NRC's regulations since 1984 (NRC, 1995b).

In 1995, the NRC revisited the $1,000 per person-rem value and issued NUREG-1530 (NRC, 1995a). This report updated the dollar per person-rem conversion factor to $2,000 per person-rem. The $2,000 per person-rem conversion factor served only as a dollar proxy for the health effects associated with a person-rem of dose. Offsite property damage costs were no longer included within the $2,000 per person-rem value. Separate estimates of the offsite costs became necessary to account for impacts beyond human health impacts. The dollar per person-rem estimate was derived from the value of a statistical life (VSL) (estimated at $3 million in 1995) multiplied by the risk coefficient for stochastic health effects (7.3×10^{-4} per person-rem) rounded to the nearest thousand. The VSL amount was derived using a willingness-to-pay (WTP) method that reflected median values estimated in many studies. As discussed in the 1995 NUREG-1530, assuming a market for "buying" safety, WTP would yield the price the average consumer would pay to reduce the probability of death or what they would accept to have that probability increased. This process was similar to the approaches used by other Federal agencies responsible for public health and safety (NRC, 1995a). The risk coefficient for stochastic health effects was derived from the International Commission on Radiological Protection (ICRP) Publication No. 60 (ICRP, 1991). This risk coefficient uses a nominal coefficient that includes both mortality (e.g., fatal cancers) and morbidity (e.g., non-fatal cancers and severe heritable effects).

In January 1997, the NRC issued NUREG/BR-0184, "Regulatory Analysis Technical Evaluation Handbook" (NRC, 1997). In NUREG/BR-0184, the NRC expanded upon policy concepts included in NUREG/BR-0058 and provided data and methods to support regulatory analyses. NUREG/BR-0184 instructed the staff to use the $2,000 per person-rem value to convert person-rem exposure to a monetary value. This value is then discounted for the purpose of calculating net benefits (NRC, 1997).

In July 2000, the NRC issued Revision 3 to NUREG/BR-0058 (NRC, 2000), which addressed the NRC's policy concerning the treatment of industry initiatives in regulatory analyses. In September 2004, the NRC issued Revision 4 to NUREG/BR-0058 (NRC, 2004). Revision 4 to NUREG/BR-0058 reflects guidance provided in the Office of Management and Budget's (OMB's) Circular A-4 on regulatory analysis, published in September 2003 (OMB, 2003).

In 2009, the staff began conducting research and outreach to Federal agencies on their process for implementing VSL. As discussed in SECY-12-0110, "Consideration of Economic Consequences within the U.S. Nuclear Regulatory Commission's Regulatory Framework," the staff recommended updating numerous guidance documents, including the 1995 NUREG-1530 (NRC, 2012a). In the staff requirements memorandum for SECY-12-0110, the Commission approved the staff's recommendations (NRC, 2013a) to update the dollar per person-rem conversion factor and establish a method for keeping this factor current. During this reassessment of the dollar per person-rem value, the staff used the $2,000 per person-rem value from the 1995 NUREG-1530 without a base year for the dollar per person-rem conversion factor or a provision for indexing. On a case-by-case basis, the staff used other dollar per person-rem values to understand the sensitivity of this parameter on cost and benefit estimates. For example, the staff used $2,000 and $4,000 per person-rem values in the regulatory analyses performed for COMSECY-13-0030, "Regulatory Analysis for Japan Lessons-Learned Tier 3 Issue on Expedited Transfer of Spent Fuel" (NRC, 2013b).

3 REGULATORY APPLICATIONS

The U.S. Nuclear Regulatory Commission (NRC) applies the dollar per person-rem conversion factor in a variety of regulatory applications that require the determination of the monetary valuation of the consequences associated with radiological exposures. This includes the evaluation of routine effluent releases from nuclear power plants, accidental releases, and radiation protection practices, as well as regulatory analyses, backfit analyses, and environmental analyses. Details of each of these regulatory applications are addressed below.

3.1 Routine Liquid and Gaseous Effluent Releases from Nuclear Power Plants

The dollar per person-rem conversion factor value appears in the NRC's regulations only in Title 10 of the *Code of Federal Regulations* (10 CFR), Part 50, "Domestic Licensing of Production and Utilization Facilities," Appendix I, "Numerical Guides for Design Objectives and Limiting Conditions for Operation To Meet the Criterion 'As Low as Is Reasonably Achievable' [ALARA] for Radioactive Material in Light-Water-Cooled Nuclear Power Reactor Effluents" (Section II, Paragraph D), in a paragraph related to items to be included in a license applicant's radioactive waste system. That regulation states, in part:

> As an interim measure and until establishment and adoption of better values (or other appropriate criteria), the values $1,000 per total body man-rem and $1,000 per man-thyroid-rem (or such lesser values as may be demonstrated to be suitable in a particular case) shall be used in this cost-benefit analysis.

The terminology for population dose was changed in the 1980's from "man-rem" to "person-rem" to be more in line with societal expectations. The conversion factor cited in this regulation has not been updated since the rule was promulgated in 1975 (NRC, 1975a). The NRC staff and licensees are required use this conversion factor of $1,000 per total body person-rem and $1,000 per person-thyroid-rem in applying for design approvals for radioactive waste systems, and not the values discussed in this report and in NUREG/BR-0058.

In designing radioactive waste processing systems, licensees and applicants are not required to install additional effluent controls to reduce routine effluent releases below 3 millirem per year for liquid effluents and 5 millirem per year for gaseous effluents, if the cost of the resultant reduction in the population exposure within 50 miles of the reactor is greater than $1,000 per total body person-rem and $1,000 per person-thyroid-rem (NRC, 1975a). In considering the installation of additional radioactive waste processing equipment, licensees and applicants must include all items of reasonably demonstrated technology that can affect reductions in population doses.

3.2 Accidental Releases

The dollar per person-rem conversion factor value is used frequently when accidental radiological releases are a consideration. Accidental releases are factored into safety enhancement considerations. When calculating accident-related attributes, the NRC staff draws from risk and reliability assessments or statistically-based analyses (NRC, 1997). As further discussed in the Regulatory Analyses and Backfit Analyses sections below, the NRC staff calculates the incremental change in public risk that would result from the proposed regulatory action and converts it to a dollar per person-rem value using discounted factors.

3.3 10 CFR Part 20 ALARA Program

As required by 10 CFR 20.1101(b), licensees should make every reasonable effort to keep radiation exposures and releases of radioactive materials ALARA. This regulation applies to all the NRC licensees and is concerned with the release of radioactive material and associated occupational and public dose incurred as a result of normal licensee activities.

ALARA, as defined at 10 CFR 20.1003, "Definitions," means making every reasonable effort to maintain radiation exposure as far below the dose limits set forth in 10 CFR Part 20, "Standards for Protection against Radiation," as is practical, taking into account the current state of technology, the economics of improvements in relation to benefits to the public health and safety, and other societal and socioeconomic considerations, and the utilization of nuclear energy and licensed materials in the public interest. Given this definition, it would appear that a dollar per person-rem value should be an important factor in cost-benefit tradeoffs used in establishing reasonableness under the ALARA program. In this regard, the NRC is aware that current industry practice, particularly within power reactors, is to voluntarily value an averted person-rem at a higher dollar value owing to manpower constraints and other labor cost considerations that are integral to licensees' cost-benefit tradeoffs.

Regulatory Guide (RG) 8.37, "ALARA Levels for Effluents from Materials Facilities," advises materials licensees that they should consider engineering options to achieve ALARA goals in the release of effluents and that modifications should be implemented unless an analysis indicates that a substantial reduction in collective dose would not result or the costs are considered unreasonable. One basis for reasonableness identified in this regulatory guide is a quantitative cost-benefit analysis, which requires the use of a dollar value per unit dose averted. RG 8.37 recommends the use of $1,000 per person-rem, and acknowledges that a wide range of values could be justified (NRC, 1993).

3.4 Regulatory Analyses

The NRC staff guidance for preparing regulatory analyses is discussed in Revision 4 to NUREG/BR-0058. When preparing regulatory analyses, Revision 4 to NUREG/BR-0058 instructs the NRC staff to use a conversion factor that can place all values and impacts (i.e., benefits and costs) on a common basis (NRC, 2004).

Revision 4 to NUREG/BR-0058 discusses the policy concepts for regulatory analysis and instructs the NRC staff to use the dollar per person-rem conversion factor to calculate a common monetary value of radiation exposure. This value captures the health effects attributable to radiological exposure and does not capture other consequences, such as non-health impacts and offsite property damage (NRC, 2004).

In NUREG/BR-0184, the NRC expanded upon policy concepts included in NUREG/BR-0058 and provided data and methods to support regulatory analyses. NUREG/BR-0184 instructed the NRC staff to use the $2,000 per person-rem value to convert person-rem exposure to a monetary value. This value is then discounted for the purpose of calculating net benefits (NRC, 1997).

As of the date of publication of this report, NUREG/BR-0058 is being updated and restructured to discuss the NRC's regulatory analyses and National Environmental Policy Act (NEPA) analyses. Information contained in NUREG/BR-0184 will be incorporated into NUREG/BR-0058. NUREG/BR-0058 will also be updated to reflect the policy described in this report.

3.5 Backfit Analyses

Backfitting is defined by paragraph (a)(1) of 10 CFR 50.109, "Backfitting," as:

> the modification of, or addition to, systems, structures, components, or design of a facility; or the design approval or manufacturing license for a facility; or the procedures or organization required to design, construct or operate a facility; any of which may result from a new or amended provision in the Commission's regulations or the imposition of a regulatory staff position interpreting the Commission's regulations that is either new or different from a previously applicable staff position.

Except as required under 10 CFR 50.109(a)(4), the NRC regulations require backfitting only when it determines that there is a cost-justified substantial safety or security enhancement. The decision criterion in a backfit analysis is whether the proposed backfit is a "substantial increase" in protection to public health and safety or common defense and security and that the costs are justified by the benefit (NRC, 1990).

Concepts relating to backfitting are discussed in NUREG-1409, "Backfitting Guidelines" (NRC, 1990). Analogous backfitting provisions applicable to nuclear power licenses and regulatory approvals, differing in some regards from those in 10 CFR 50.109 are set forth in 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants," including provisions on issue finality. Issue finality is defined in 10 CFR 52.39, "Finality of Early Site Permit Determinations;" 10 CFR 52.63, "Finality of Standard Design Certifications;" 10 CFR 52.98, "Finality of Combined Licenses; Information Requests;" 10 CFR 52.145, "Finality of Standard Design Approvals; Information Requests;" and 10 CFR 52.171, "Finality of Manufacturing Licenses; Information Requests," as a provision that the Commission may not modify, rescind, or impose new requirements unless acceptable criteria is met. Moreover, 10 CFR Part 52 defines requirements, under Section VIII for each certified design appended in the regulations, for making changes and departures to a specific design. Backfit provisions applicable to material licenses and regulatory approvals, are defined in 10 CFR 70.76, 10 CFR 72.62, and 10 CFR 76.76, all titled "Backfitting."

Discussion on how to perform a backfit analysis can be found in NUREG/BR-0184 (NRC, 1997). To impose a backfit, the NRC staff must demonstrate that there is a substantial increase in the overall protection of the public health and safety or the common defense and security derived from the backfit and that the direct and indirect costs of implementation for the subject facility are justified in view of this increase in protection. In order to quantify the benefit of averted dose, the dollar per person-rem conversion factor is used. The NRC staff ~~is integrating~~ integrated NUREG/BR-0184 into Revision 5 of NUREG/BR-0058, which is under ~~development~~ consideration by the Commission as of the date of publication of this report.

3.6 Environmental Analyses

The NEPA requires Federal agencies to prepare a "detailed statement for major Federal actions significantly affecting the quality of the human environment." The identification, characterization, and analysis of both monetized costs and benefits (e.g., those measured in dollars) and qualitative costs and benefits (e.g., functional or non-monetized) are essential for the evaluation and selection of the preferred alternative. Unless exempted in 10 CFR 51.71, “Draft environmental impact statement—contents,” or 10 CFR 51.75, “Draft environmental impact statement—construction permit, early site permit, or combined license,” the NEPA requires NRC staff to include an analysis that considers “the economic, technical, and other benefits and costs of the proposed action and alternatives” in an environmental impact statement (EIS). In addition, current NRC policy developed after the decision in Limerick ~~decision~~ Ecology Action, Inc. v. NRC (869 F.2d 719, 1989) requires consideration of alternatives to mitigate the consequences of severe accidents in an EIS prepared at the operating license stage.

The NRC staff reviews and evaluates severe accident mitigation alternatives (SAMAs) to ensure that changes that could improve severe accident safety performance are identified and evaluated. Severe accidents are those that could result in substantial damage to the reactor core, whether or not there are serious offsite consequences. Potential improvements could include hardware modifications, changes to procedures, and changes to the training program (NRC, 2006). A SAMA analysis is included as part of the environmental review conducted for license renewal if a site-specific SAMA analysis had not been previously performed. For new reactors, a severe accident mitigation design alternative (SAMDA) analysis, which is a subset of the SAMA analysis, is also included as part of the environmental review for construction permits, design certifications, and combined licenses.

Section 7.3 of NUREG-1555, “Standard Review Plans for Environmental Reviews for Nuclear Power Plants” (NRC, 2007), for new reactors; and Section 5.2 to NUREG-1555, Supplement 1, Revision 1 (NRC, 2013c), for license renewal, provide guidance on the analysis and assessment of SAMAs. The guidance instructs the NRC staff on how to evaluate the estimated cost, risk reduction, and dollar benefits for SAMAs and the assumptions used to make these estimates. The cost-benefit comparison is further evaluated to determine if it is consistent with the cost-benefit balance criteria and methodology given in NUREG/BR-0184 (NRC 1997) and Revision 4 to NUREG/BR-0058 (NRC 2004). In addition, during license renewal reviews, any SAMA with estimated implementation costs within a factor of 2 to 5 of the estimated dollar benefits is further analyzed to ensure that a sufficient margin is present to account for uncertainties in assumptions used to determine the cost and benefit estimates (NRC, 2013c). To evaluate each cost-benefit criterion, the NRC staff uses the NRC’s current dollar per person-rem averted amount for health effects.

The NRC’s regulations, 10 CFR 51.71(d), require~~s~~ the NRC staff to include an analysis that considers the economic, technical, and other benefits and costs of the proposed licensing action and alternatives in an EIS. However, supplemental EISs prepared at the license renewal stage are not required to discuss the economic or technical benefits and costs of either the proposed action or alternatives unless benefits and costs are either essential for a determination regarding the inclusion of an alternative in the range of alternatives considered or relevant to mitigation as required by 10 CFR 51.95(c).

Environmental reviews conducted for new reactors use the dollar per person-rem factor in cost-benefit analyses to obtain the averted costs of postulated accidents (NRC, 2004 and NRC, 2007). The factor is used because the offsite radiological impact upon persons is calculated as a cost component in the SAMA and SAMDA analyses, which are part of the EIS.

SAMA and SAMDA analyses are not conducted as part of the materials license environmental review. Sections 5.7 and 6.7, “Cost-Benefit Analysis,” of NUREG-1748, “Environmental Review Guidance for Licensing Actions Associated with NMSS Programs,” include references to both

NUREG/BR-0058 and NUREG-1530 for more detailed guidance in determining public health and safety impact valuations (NRC, 2003).

4 VALUE OF A STATISTICAL LIFE

The concept of the value of a statistical life (VSL) is used throughout the Federal government to monetize the health benefits of a safety regulation. The analyses generally begin with a risk assessment that estimates the change in mortality risks likely to be experienced by the affected population. These assessments do not predict which individuals might die if the hazard is not abated; they estimate only the change in mortality risk over a defined period for members of the affected population. It is important to note that VSL (and therefore the associated dollar per person-rem conversion factor) corresponds to society's willingness-to-pay (WTP) for small reductions in a particular mortality risk. In other words, VSL is not a measurement or valuation of a human life. The Office of Management and Budget (OMB) Circular A-4, "Regulatory Analysis," provides guidance for communicating the concept of VSL in regulatory analyses. The OMB Circular A-4 states (OMB, 2003):

> Some describe the monetized value of small changes in fatality risk as the "value of statistical life" (VSL) or, less precisely, the "value of a life." The latter phrase can be misleading because it suggests erroneously that the monetization exercise tries to place a "value" on individual lives. You should make clear that these terms refer to the measurement of willingness to pay for reductions in only small risks of premature death. They have no application to an identifiable individual or to very large reductions in individual risks. They do not suggest that any individual's life can be expressed in monetary terms. Their sole purpose is to help describe better the likely benefits of a regulatory action.
>
> Confusion about the term "statistical life" is also widespread. This term refers to the sum of risk reductions expected in a population. For example, if the annual risk of death is reduced by one in a million for each of two million people, that is said to represent two "statistical lives" extended per year (2 million people × 1/1,000,000 = 2). If the annual risk of death is reduced by one in 10 million for each of 20 million people, that also represents two statistical lives extended.

The following sections provide an overview of different methods and models to calculating VSL along with a discussion of other Federal agencies' VSL practices and methodologies.

4.1 Approaches to Calculate VSL

The 1995 NUREG-1530 provides an overview of different methods for calculating VSL. The methods analyzed were (1) the human capital method, (2) the WTP method, (3) values implied by government agency expenditures, (4) inferences from values implied by regulatory requirements imposed by government agencies, and (5) values based on radiation protection activities in foreign countries. In the 1995 NUREG-1530, the NRC chose the WTP method, resulting in a VSL of $3 million. According to OMB:

> This value is (1) consistent with results from the WTP approach, which is recommended by OMB and the Administrative Conference of the United States and is most favored in the literature studied; (2) reflects median values of a statistical life estimated in many studies; (3) is representative of values used by other Federal agencies responsible for public health and safety; (4) is in general agreement with values used for regulatory decisionmaking in other countries;

(5) is specifically cited by OMB as the “best estimate” for the value of statistical life using the WTP approach (OMB, 1993).

As discussed in OMB Circular A-4, WTP is the most appropriate measure for comparing monetized health costs for health and safety risks. The 1995 NUREG-1530 analyzed three different methods by which WTP can be calculated. The methods analyzed for calculating WTP are (1) consumer market studies that examine the tradeoffs between risk and benefits that people make in their consumptive decisions, (2) wage-risk compensation that presumes the value that workers place on their lives is measurable based on observed wage differentials in occupations of varying risks, and (3) contingent valuation studies that involve survey techniques to elicit responses to questions that postulate hypothetical market choices.

In preparing this report, the NRC staff analyzed three different methods for calculating WTP. Two of the methods (i.e., revealed preference and stated preference) for calculating WTP are shown in Figure 1 (Breidert et al., 2006), and are addressed in Sections 4.1.1 and 4.1.2. The third method, meta-analysis, is discussed in Section 4.1.3.

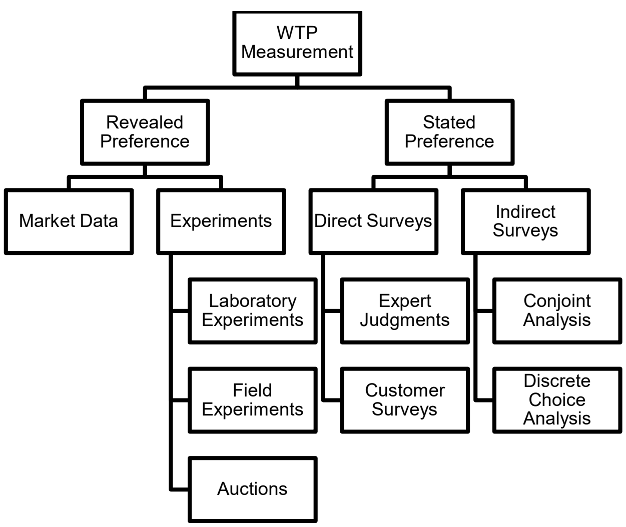

Figure 1 Classification Framework for Methods to Measure Willingness-to-Pay

4.1.1 Revealed Preference Models

As a concept, “revealed preference models” use data obtained from situations where individuals make market decisions on how they trade changes in wealth for changes in physical risk. This method includes the use of data drawn from labor markets or consumer markets.

Data from labor markets and occupational risks are analyzed in hedonic (of or relating to utility) wage studies to estimate the value of life. A hedonic model is one where the independent variables are related to quality (e.g., the quality of a product that one might buy or the quality of a job one might take). Hedonic models of wages correspond to the idea that there are compensating differentials—that workers would get higher wages for jobs that were more unpleasant. Similarly, hedonic pricing is a model identifying price factors according to the premise that price is determined by internal characteristics of the good being sold and external factors affecting it. This method is based on the concept that the value a worker places on life is measurable by the level of wages required to accept the occupational risk of a particular industry and position. Hedonic wage studies are drawn from observable risk levels (i.e., from occupational fatality statistics) and from published wage statistics. Hedonic wage studies suffer from bias introduced by three different sources. First, these studies can suffer from measurement error due to incomplete reporting of the U.S. Bureau of Labor Statistics (BLS) data, which is the basis for many hedonic wage studies. A second source of bias results from the researcher failing to control all of the relevant determinants of a worker's wage (e.g., omitted variable bias). Third, hedonic wage studies suffer from what is known as "endogeneity of fatality risk," where, for example, the wages for a given job may reflect both the risk of the job and the productivity of workers. Endogeneity is defined as a correlation between an independent variable and the error term in a statistical equation. In the discussion above, the worker's wage is the dependent variable and productivity is the independent variable. Productivity is endogenous to risk, which is part of the error term. Increases in risk and productivity would most likely cause an increase in wages. For example, there is a phenomenon called "coolheadedness," where workers in riskier positions who are more alert, and thus more productive than workers in other jobs, have higher earnings (Viscusi and Aldy, 2003). To the degree that the riskiness of a job is correlated with productivity and thus with potential earnings, bias is introduced into the analysis of wage-risk tradeoffs that workers make. Despite these potential sources of bias, many researchers consider hedonic wage studies as the most promising source for VSL estimation.

Studies based on consumer markets infer VSL based on consumer market transactions. This method is based on the concept that the value consumers place on their lives is measurable by knowing prices paid for goods (e.g., home security systems that may reduce the risk of losses due to theft). Similarly, analyzing housing transactions in terms of price and location in proximity to a hazard (e.g., airport) can yield estimates of WTP for increased safety. Consumer market methods are similar to labor market studies, except that a "hedonic price function" is estimated instead of a "hedonic wage function."

A common example of the hedonic pricing method is in the housing market in which the price of a property is determined by the characteristics of the house (e.g., size, appearance, features, condition) as well as the characteristics of the surrounding neighborhood (e.g., accessibility to schools and shopping, level of water quality and air pollution, value of other nearby homes, vicinity of nearby hazards). The hedonic pricing model is used to estimate the extent to which each factor affects the price. However, limited research data using this method are available.

Comparisons of results from labor market and consumer market studies have generally found the VSL estimates to be of the same order of magnitude, but with the values from consumer market studies being slightly lower. The lower estimates obtained by consumer market studies is thought to primarily relate to the fact that many decisions consumers make in product markets are discrete in nature as compared to labor market decisions, which are often continuous. In the case of a discrete choice, the estimated VSL represents a lower bound estimate of the actual value (Viscusi and Aldy, 2003). Other characteristics of consumer market studies could result in the estimated VSL being lower than that for labor market studies. These studies could introduce possible selection bias inherent in some product markets. In addition, several consumer market studies are based on inferred, instead of observed, price-risk tradeoffs. These characteristics introduce uncertainty into the resulting estimates (Viscusi and Aldy, 2003).

4.1.2 Stated Preference Methods

Stated-preference methods employ public opinion surveys involving hypothetical tradeoffs between wealth and risk, and are used in situations where actual market data are not available. A benefit of stated preference methods is their large degree of flexibility, which allows the researcher to tailor the study to the exact risk of interest (Andersson and Treich, 2011). However, because stated preference studies are based on hypothetical scenarios, results may suffer from "hypothetical bias" due to survey respondents lacking an incentive to respond accurately or being unable to place an accurate value on the scenarios presented to them (Blumenschein et al*.,* 2008).

Applications of stated preference methods have been found to be particularly problematic in the valuation of small changes in risk, due to the difficulty that survey respondents have in conceptualizing what very small changes in risk are actually worth to them (Carson et al*.,* 2001). These very small changes in risk are most often the kind of changes of interest for benefit estimation.

4.1.3 Meta-Analysis

A popular approach for WTP estimation for VSL is the use of meta-analysis. Meta-analysis involves applying statistical methods to a set of study results with the objective of synthesizing and making full use of the information contained in the studies (Bellavance et al., 2009). Meta-analyses can use estimates that employ revealed preference or stated preference measures, although published meta-analyses generally have favored the use of revealed preference studies due to the problems with stated preference methods as described above.

4.2 VSLs Used by Other Federal Agencies

The NRC staff performed a literature review to benchmark the values other Federal agencies have used for statistical life. A discussion of each agency's VSL practices and methodologies is provided in this section.

4.2.1 U.S. Environmental Protection Agency

The U.S. Environmental Protection Agency (EPA) selected a VSL of $4.8 million (1990 dollars) adjusted for inflation using the gross domestic product (GDP) deflator for its regulatory analyses starting in 1999 when the agency updated its "Guidelines for Preparing Economic Analyses" (EPA, 2000). The EPA derived its value from 26 studies that were compiled as part of the EPA's first retrospective analysis of the Clean Air Act (EPA, 1999). The EPA used meta-analyses to calculate its VSL amount. The EPA selected the set of studies for its VSL calculation that it deemed to be the most relevant to its policy concerns. The EPA used 21 revealed preference studies using labor market data (i.e., hedonic wage studies), and the remaining five studies used stated preference methods. The primary reliance on hedonic wage studies reflects the agency position that revealed preference methods provide the most accurate and reliable VSL estimates. Despite possible problems with stated preference studies, the EPA included five of these studies in its VSL estimation because of the quality and policy relevance of those particular studies (EPA, 1999).

The EPA updates its VSL estimate for inflation. For example, the $4.8 million value (1990 dollars) was later updated to $7.8 million (2003 dollars). The EPA began work on revising and updating its "Guidelines for Preparing Economic Analyses" in 2004 and re-evaluated its approach to valuing mortality risk reductions as part of Revision 1 taking into account recent VSL studies and, in particular, new meta-analyses. In 2008, the EPA issued revised "Guidelines for Preparing Economic Analyses," which recommended the use of a $7 million (2006 dollars) VSL for regulatory analysis (EPA, 2008b). In 2010, the EPA issued revised "Guidelines for Preparing Economic Analyses" and updated its VSL to $7.9 million in 2008 dollars (EPA, 2010). The value was adjusted using the Consumer Price Index (CPI) from the base year 1990 dollar amount of $4.8 million. The NRC staff estimates that the EPA's VSL amount would be $8.7 million in 2014 dollars using CPI to inflate the value.

As of the date of publication of this report, the EPA does not use low and high alternative VSL values in regulatory analyses (EPA, 2014). Historically, the EPA has determined that a single, peer-reviewed VSL estimate should be applied. In its response to the 2000 Guidelines for Preparing Economic Analyses, the EPA's Science Advisory Board (SAB) preferred the use of a central point estimate, but recommended the EPA staff to "show the age distribution of lives saved or the quantity of life at risk" and to perform a sensitivity analysis when policies do not affect the entire population equally. The SAB indicated that a central point estimate is reasonable, so long as the EPA staff discusses the limitations of the estimate (EPA, 2000).

The EPA is in the process of updating its VSL estimate. In a 2010 draft white paper on VSL, the EPA recommended that the agency "update all study estimates to a common year, including the effect of real income growth over time and the estimates income elasticity of the VSL" (EPA, 2011). The EPA indicated that it would update study estimates using a GDP deflator for inflation, real income growth factor (e.g., CPI), and an income elasticity factor. In 2011, the SAB agreed with the EPA staff recommendations to begin crafting guidance that would allow the EPA staff to use multiple VSL factors because a single value for mortality risk is not appropriate for all contexts (EPA, 2011c). The EPA also recommended that the term "value of a statistical life" be replaced by "value of risk reduction" because of the misunderstanding of the VSL term, which the SAB endorsed (EPA, 2011c).

Commented [DAW1]: The staff should update this paragraph to include the most recent EPA documents and decisions.

4.2.2 U.S. Department of Transportation

The U.S. Department of Transportation (DOT) has established and revised guidance on VSL benchmarks. In 1993, the DOT established a VSL of $2.5 million and directed that periodic adjustments be made for inflation using the GDP implicit price deflator. The principal empirical basis for the $2.5 million VSL was a literature survey that yielded a likely VSL of $2.2 million (1988 dollars). By 2002, the DOT adjusted the value to $3 million (2001 dollars). Subsequently, the DOT determined that recent literature and a comparison with the practices of other Federal agencies demonstrated that the $3 million value was outdated. Based on "improved understanding of the academic research literature," the DOT determined that the best estimate of VSL was $5.8 million (2007 dollars), which is the mean value of five studies (including three meta-analyses) adjusted to 2007 dollars by the CPI for All Urban Consumers (CPI-U) (Trottenberg and Rivkin, 2015). CPI-U measures the CPI value for urban consumers, which constitute the majority of the U.S. population.

In 2014, the DOT updated its guidance to have its VSL set at $9.2 million in 2013 dollars (DOT, 2014). This amount was an average based on nine meta-analyses that provided a broad cross-section of the U.S. population. The DOT focused on different categories of people. Examples include males versus females, older workers vs. younger workers, smokers vs. non-smokers,

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etc. In the guidance, the DOT establishes a formula for future VSL amounts (DOT, 2014). The formula is:

$$\mathrm{VSL}_{2013+\mathrm{N}} = \mathrm{VSL}_{2013} \times 1.0118^{\mathrm{N}}$$

The formula is similar to the recommendations from the EPA draft white paper. However, the DOT guidance looked at the next 30 years of forecasted real median wage growth rate and estimated it at 1.0118 percent a year. Each of these values is updated annually. $\mathrm{VSL}_{2013+\mathrm{N}}$ stands for the VSL value N years after 2013 and VSL_{2013} is the VSL value in 2013 (i.e., $9.2 million). Using the formula above, the NRC staff estimates that the DOT's best estimate VSL in 2014 dollars is approximately $9.3 million. The baseline for the VSL is in 2014 dollars because the most comprehensive set of data available is from 2014.

The DOT also uses high and low alternative VSL values. The DOT's current values for low and high alternative VSL values are $5.2 million and $13 million (in 2013 dollars), respectively (DOT, 2014). Using the formula above, the NRC staff estimates the DOT's low estimate VSL is approximately $5.3 million and the high estimate is approximately $13.2 million, respectively, in 2014 dollars. Instead of treating alternative VSL values in terms of a probability distribution, the DOT guidance instructs analysts to use a sensitivity analysis to analyze the effects of using alternative VSL values (DOT, 2014).

4.2.3 U.S. Department of Homeland Security

In 2008, the U.S. Department of Homeland Security (DHS) issued "Valuing Mortality Risk Reductions in Homeland Security Regulatory Analysis." This report recommended a best estimate VSL of $6.3 million in 2007 dollars (DHS, 2008). The DHS adopted this value, but reports it in 2008 dollars (OMB, 2014). The report also recommends that the DHS update its values using CPI-U to measure for inflation (current year CPI-U divided by 1997 CPI-U that is indexed at 160.5), real income growth factor (median usual weekly earnings current year/median usual weekly earnings for 1997 indexed at 503), and an income elasticity factor (DHS, 2008). The VSL base year number is $4.7 million in 1997 dollars and income elasticity is 0.47 (DHS, 2008). The formula is stated below:

$$\mathrm{VSL}_{\text{Current year}} = \mathrm{VSL}_{\text{base year}} \times \text{Inflation} \times \text{real income growth}^{\text{VSL Income Elasticity}}$$

The DHS uses low and high alternative VSL values of $4.9 million and $7.9 million in 2008 dollars (CRS, 2010). The 1997 (base year) values of these low and high VSL estimates are $3.7 million and $5.9 million. These estimates were derived from a 95-percent confidence interval from an empirical distribution of VSL estimates in 1997 dollars (DHS, 2008). Using the DHS formula above, the NRC staff estimates that the DHS's best estimate would equal $8.6 million and the low and high estimates would be $6.8 million and $10.8 million, respectively, in 2014 dollars.

4.2.4 U.S. Food and Drug Administration

The U.S. Food and Drug Administration (FDA) also periodically issues economically significant rules that include quantified estimates of mortality risk reductions. The FDA has not developed formal guidance for estimating its VSL and value of a statistical life year (VSLY) amounts but cites several literature reviews and meta-analyses as the sources of its estimates. Between 2003 and 2008, the FDA used best estimate VSL values ranging from $5 million to $6.5 million in estimating benefits (DOT, 2009). In a 2011 rulemaking, the FDA used $7.9 million as its VSL in 2010 dollars (FDA, 2011). The NRC staff estimates this value to be approximately $8.6 million using CPI to inflate the value in 2014 dollars.

The FDA estimated the value of preventing a fatal disease as (1) the sum of the VSL multiplied by the expected number of averted fatalities, plus (2) the avoided medical costs during illness and (3) the value of the reduced ability of the ill person to function at home and at work. Because of the FDA's statutory requirements and mission, the FDA typically analyzes risks that are age-specific and only uses VSL when ages are unknown. Instead, the FDA uses VSLY to monetize each additional year of life added on to a single person's life. In the regulatory analyses analyzed, the FDA used a range of $100,000 to $532,000 for each VSLY (Duval, 2008 and FDA, 2011).

4.2.5 U.S. Occupational Safety and Health Administration

The U.S. Occupational Safety and Health Administration (OSHA) estimates of VSL vary depending on whether the OSHA is addressing mortality risks from workplace accidents or from illnesses. The OSHA has not developed formal guidance on estimating VSL (CRS, 2010). In a 2001 rule, the OSHA did not assign a monetary value to reductions in mortality risk (OSHA, 2001). In 2006, however, the OSHA used a base VSL of $6.8 million, in 2003 dollars, that was adjusted for latency, changes in real income, and added the value of averted medical costs in a similar fashion to the EPA's approach (OSHA, 2006 and CRS, 2010). In a 2012 rule, the OSHA used a VSL of $8.7 million in 2010 dollars (OSHA, 2012). The NRC staff estimates that the OSHA VSL would be $9.0 million in 2014 dollars when using the CPI to inflate this value.

4.2.6 U.S. Office of Management and Budget

In 1996, the OMB described best practices for valuing health and safety risk reduction benefits (OMB, 1996). The OMB stated that reductions in fatality risks are best monetized using WTP approaches to VSL; alternatively, reductions in fatality risks can be expressed in terms of the value of a statistical life-years-extended using VSLY.

Although the OMB found theoretical advantages to using the value of the statistical life-years-extended, it also concluded that research did not provide a definitive way of developing appropriate estimates of VSLY. The OMB found drawbacks with options for deriving the VSLY from VSL. For example, the OMB stated that annualizing the VSL using an appropriate discount rate and average life years remaining does not provide an independent estimate of VSLY. Nevertheless, the OMB encouraged agencies to explore use of both metrics (OMB, 1996).

In 2000, OMB guidelines stated, with respect to VSLY, that:

> The adoption of a value for the projected reductions in risk of premature mortality is the subject of continuing discussion…. A considerable body of academic literature is available on this subject. The methods used and the resulting estimates vary substantially across these studies (OMB, 2000).

The OMB approved the use of VSL and VSLY estimates for Federal agency use. Since its draft report to Congress in 2002, the OMB started using a value of $5 million (the NRC staff estimates this value to be $6.7 million in 2014 dollars using CPI to inflate the value) per fatality averted (i.e., VSL) as a default value when agencies had not supplied any value (OMB, 2002).

In September 2003, the OMB issued Circular A-4 that reported VSL estimates between $1 million to $10 million per statistical life in 2001 dollars (the NRC staff estimates these values to be $1.3 million to $13.3 million in 2014 dollars using CPI to inflate the value). The OMB drew on two journal articles and an analysis prepared by the EPA's SAB in selecting these values (Viscusi and Aldy, 2003 and Mrozek and Taylor, 2002). Circular A-4 replaced both the 1996 "best practices" (OMB, 1996) and the 2000 guidance (OMB, 2000).

4.3 VSL Values Based on Radiation Protection Activities in Other Countries

The NRC studies and considers the approaches used by other countries to inform the NRC decisions on regulatory activities and agency guidance. The discussion in this section provides information on other countries' best practices. In addition, the studies authored by Viscusi and Aldy, which were used by other countries, were used in the NRC's new VSL calculations. Therefore, it is beneficial to consider how other countries use these studies.

In the United Kingdom (U.K.), the National Radiological Protection Board approved the recommendation to set a VSL between $3 million and $4.5 million in 1990 dollars (between approximately $5.4 million and $8.2 million in 2014 dollars using CPI to inflate this value), using the WTP approach.

Viscusi and Aldy (2003) analyzed approximately 20 labor market studies, published since 1990, for both developed and developing countries. They analyzed studies in labor markets in Australia, Austria, Canada, Japan, the U.K., Hong Kong, India, South Korea, and Taiwan. The authors noted that VSLs range from U.S. currency values of $200,000 to $69 million in 2000 dollars ($275,000 to approximately $95 million in 2014 dollars using CPI-U to inflate this value) depending on the risk to workers, the country's income levels, and the methodologies performed in the studies analyzed. Viscusi and Aldy note that the higher numbers tend to come from studies performed in the U.K. The authors noted that they suspected the large numbers come from risk measures and other unobservable factors plus large worker compensation differences.

Viscusi and Aldy (2003) also noted that Canada has placed a significant focus on hedonic labor market analyses. They also noted that the Canadian analyses tend to be similar to those analyzed in the U.S. labor markets as opposed to those in the U.K. labor markets. The majority of VSLs tend to fall between $3 million and $6 million in 2003 dollars (between $4.1 million and $9.7 million in 2014 dollars using CPI to inflate the values).

4.4 Representative VSL for NRC Activities

Given the lessons learned from this literature review and outreach, the NRC staff will update its VSL base year value best estimate to $9.0 million (2014 dollars). Given the extensive resources spent by other Federal agencies on this topic, specifically the EPA and the DOT, the NRC staff believe it is prudent to leverage these resources and align its VSL recommendations with those of its Federal counterparts for this revision. This estimate is derived from the average of the DOT's VSL ($9.3 million) and the EPA's VSL ($8.7 million) in 2014 dollars.

In order to align with practices of other Federal agencies, the NRC will adopt a low and a high VSL estimate for use in sensitivity analyses. Each Federal agency identified in this report has adopted VSL estimates, in 2014 dollars, based on that agency's mission and within its own processes. The staff recognizes that if it performed similar research as other Federal agencies, the staff's estimates would likely be roughly similar because it would use the same set of peer reviewed studies that are specific to the United States as the basis of its analysis. Therefore, the staff will adopt the a low and high VSL values (in 2014 dollars) that envelop the DHS values and are bounded by the OMB values as shown in Table 1 for use in sensitivity analyses as discussed further in Section 6.

Table 1 Low and High VSL Values in 2014 Dollars

Agency	Low	High
DOT	$5.3 million	$13.2 million
DHS	$6.8 million	$10.8 million
OMB	$1.3 million	$13.3 million

As discussed above, the DOT and the DHS low and high estimates are inflated using those agencies' formulas for keeping their VSL estimates up to date. The OMB does not have a systematic method of updating their formula, and therefore, the NRC staff inflated the OMB's values using the CPI.

5 EPA'S CANCER MORTALITY RISK COEFFICIENT

Once an appropriate value of a statistical life (VSL) has been estimated, the parameter needed to convert that value to a dollar per person-rem figure is the cancer mortality risk coefficient, which establishes the probability for cancer mortality attributable to radiological exposure.

The U.S. Nuclear Regulatory Commission's (NRC) dollar per person-rem conversion factor in the 1995 revision of NUREG-1530 is based on the recommendations in International Commission on Radiological Protection (ICRP) Publication Number 60 (ICRP, 1991). In general, for doses to the population, the ICRP recommendation is a nominal risk coefficient value of 7.3×10^{-4} per rem. This coefficient accounts for the probability of occurrence of a harmful health effect and a judgment of the severity of the effect. The coefficient includes allowances for fatal and nonfatal cancers and for severe hereditary effects. The nonfatal cancers and hereditary effects are translated into loss-of-life measures based on a perceived relationship between quality of life and loss of life.

In the ICRP recommendation in Publication Number 103 (ICRP, 2007), the ICRP total risk coefficient decreased by about 20 percent, from 7.3×10^{-4} per rem in 1991 to 5.7×10^{-4} per rem in 2007. The ICRP states that this change is due primarily to improved methods in the calculation of heritable risks and significant advances in understanding of the mutational process. Also, the ICRP calculated its values differently in ICRP 103 than ICRP 60. In ICRP 60, nominal cancer risks were computed based on fatal cancer risk weighted for nonfatal cancer, relative life lost for fatal cancer, and life impairment for nonfatal cancer. However, in ICRP 103, risk estimates are based principally on cancer incidence data weighted for lethality and life impairment. The reason for the change is that cancer incidence data provide a more complete description of the cancer burden than do mortality data, particularly for cancers that have a high survival rate. The ICRP 103 provides the following information:

> It is important to note that the detriment-adjusted nominal risk coefficient for cancer estimated here has been computed in a different manner from that of Publication 60. The present estimate is based upon lethality/life-impairment-weighted data on cancer incidence with adjustment for relative life lost, whereas in publication 60 detriment was based upon fatal cancer risk weighted for non-fatal cancer, relative life lost for fatal cancers and life impairment for non-fatal cancer. In this respect it is also notable that the detriment-unadjusted nominal risk coefficient for fatal cancer in the whole population that may be projected from the cancer incidence-based data of Table A.4.1a is around 4% per Sv [per 100 rem] as compared with the Publication 60 value of 5% per Sv [per 100 rem]. The corresponding value using cancer mortality-based models is essentially unchanged at around 5% per Sv [per 100 rem] (ICRP, 2007).

As such, the ICRP coefficients are based on global averages of background cancer risk that include the United States, but are not specific to a U.S. population. In addition, the non-mortality effects are not monetized in the VSL portion of the calculation. To address these issues, the NRC staff selected the EPA's cancer mortality risk coefficient of 5.8×10^{-4} per rem (90 percent confidence interval: 2.8×10^{-4} to 1.0×10^{-3}). This value was published in EPA 402-R-11-001, "EPA Radiogenic Cancer Risk Models and Projections for the U.S. Population" (EPA, 2011b). The EPA's value aligns the coefficient with the underlying definition of WTP used in the VSL value that only addresses mortality. NUREG/BR-0058 is being revised as of the date of publication of this document and will address the calculation of radiation-induced morbidity and heredity effects. The value is slightly greater than the ICRP nominal risk coefficient due, in part, to the differences of the underlying background cancer risks in the United States for the EPA's coefficient versus the global averaging of the risks for the ICRP coefficient. The EPA developed a dose and dose-rate effectiveness factor (DDREF) of 1.5 for low-dose and dose rate exposure scenarios. The DDREF should be removed from the risk coefficient to account for higher dose or dose-rate exposure scenarios when the total accumulated effect is not in the acute health effects range (see Appendix A).

Table 2 presents a comparison of the EPA 2011 cancer mortality risk coefficient to the ICRP total detriment coefficients.

Table 2 Comparison of the EPA 2011 Cancer Mortality Risk Coefficient with ICRP Publications No. 103 and No. 60 Total Detriment Coefficients

Coefficient (10^{-4} person-rem)		
EPA 2011	**ICRP 103 (2007)**	**ICRP 60 (1991)**
5.8	5.7	7.3

6 DOLLAR PER PERSON-REM CONVERSION FACTOR

The dollar per person-rem conversion factor for health effects is calculated as the product of the value of a statistical life (VSL) and the cancer mortality risk coefficient. Based on the U.S. Nuclear Regulatory Commission's (NRC) preceding recommendations concerning VSL ($9.0 million) in Section 4.4 of this NUREG and the use of the U.S. Environmental Protection Agency (EPA) cancer mortality risk coefficient (5.8×10^{-4} per rem), the dollar conversion factor would be equal to $5,200 in per person-rem 2014 dollars. For sensitivity analyses, a low dollar per person-rem value of $2,600 and a high dollar per person-rem value of $7,800 will be adopted. See Appendix A of this report for a discussion on adjusting the cancer mortality risk coefficient, and hence the dollar per person-rem conversion factor, for high rate exposure scenarios.

Therefore, the NRC will adopt the above dollar per person-rem estimates to be used for routine effluent releases, accidental releases, radiation protection programs required by Title 10 of the *Code of Federal Regulations* (10 CFR), Part 20, "Standards for Protection against Radiation," regulatory analyses, backfit analyses, and environmental analyses. Pertaining to occupational exposures, the NRC staff acknowledges that, for determinations of levels of radiation that are as low as is reasonably achievable (ALARA) per 10 CFR Part 20, many licensees may employ conversion factors in excess of $5,200 per person-rem. This is particularly true in non-design ALARA determinations where licensees consider tradeoffs between occupational dose and alternative technologies and procedures (e.g., use of additional shielding, remote or robotic tools for a given plant maintenance evolution). These higher values are typically influenced by utility-specific manpower constraints and other labor cost considerations in employing workers with unique skill sets. These are valid utility considerations in evaluating occupational exposures, and licensees are ~~expected~~ anticipated to continue to use these higher conversion factors. Further, such estimates are not necessarily inconsistent with the NRC's estimates that only capture health effects, as other impacts such as labor cost considerations can be treated as additive elements in the NRC's cost-benefit analysis.

The NRC acknowledges that there may be unique circumstances where other dollar conversion factors may warrant consideration. For example, doses to a population whose age distribution is not representative of the general population could be subject to a different risk coefficient because health risks are directly related to the age distribution of the affected population. Further, recognizing the uncertainties inherent in establishing a representative conversion factor, alternative values to capture the uncertainties may be warranted. Therefore, it would be reasonable to expect an analyst to include alternative valuations in regulatory analyses in order to show the decisionmaker the sensitivities of the proposed action to relevant considerations. However, the base case computations in a regulatory analysis will use the recommended best estimate dollar conversion factor of $5,200 per person-rem, and apply the low and high estimates in illustrating sensitivity and uncertainty in the range and direction of the impacts.

The dollar per person-rem conversion factor is for stochastic effects only and is not to be applied to deterministic health effects. Deterministic health effects in humans can result from general or localized tissue irradiation, killing cells in a manner that causes severe and clinically detectable impairment of function in a tissue or organ. It should also not be applied to any individual dose that could result in an early fatality. These omissions are consistent with the NRC's view that the monetizing of mortality effects, as it relates to the value of any single individual's life, is not appropriate. Rather, its use is as an estimate of the value of small reductions in the probability of total detriment for a given population. From a practical perspective, the NRC believes that regulatory issues involving deterministic effects and/or early fatalities would be very rare and can be addressed on a case-specific basis, as the need arises.

Consistent with best practice, the NRC staff provides a range of dollar per person-rem conversion factors for use in sensitivity analyses. These analyses are performed to evaluate the impact on cost-benefit analysis results of using plausible alternative values for this conversion factor. For this purpose, the NRC staff recommends varying the dollar per person-rem conversion factor by plus or minus 50 percent. This results in a range of conversion factors with a low value of $2,600 per person-rem and a high value of $7,800 per person-rem. When applying an alternative dollar per person-rem value, the analyst must document the reasons and basis for using the alternative.

These lower and upper bound estimates for the dollar per person-rem conversion factor can be used in sensitivity analyses to evaluate the impact of variability in the conversion factor that can arise from two independent sources: (1) use of plausible alternative values for the VSL or (2) uncertainty about the cancer mortality risk coefficient. Varying the conversion factor by 50 percent in each direction is equivalent to independently varying the VSL estimate or cancer mortality risk coefficient by 50 percent in each direction for one-way sensitivity analyses. For the VSL estimate, this is equivalent to using low and high VSL estimates of $4.5 million and $13 million (2014 dollars), respectively, based on a cancer mortality risk coefficient of 5.8×10^{-4} per person-rem. This range of VSL values is nearly the same as the low and high VSL estimates the NRC staff identified from other Federal agency practices of $5.3 million and $13.2 million (2014 dollars), respectively. For the cancer mortality risk coefficient, this is equivalent to using low and high risk coefficients of 2.9×10^{-4} per rem and 8.7×10^{-4} per rem, respectively. By comparison, the 90 percent confidence interval for the EPA cancer mortality risk coefficient is 2.8×10^{-4} per rem and 1.0×10^{-3} per rem.

The NRC staff has thus determined that using a low value of $2,600 per person-rem and a high value of $7,800 per person-rem in sensitivity analyses is reasonable for evaluating the impacts of using plausible alternative values for the VSL estimate or the cancer mortality risk coefficient (see Table 3).

Table 3 The NRC Dollar per Person-Rem Summary Inputs

Estimate	Dollar per Person-Rem (2014 dollars)	VSL Sensitivity Values (2014 dollars)[a]
Best	$5,200	$9.0 Million
Low	$2,600	$4.5 Million
High	$7,800	$13 Million

[a] The VSL sensitivity values are calculated by dividing the dollar per person-rem value by the cancer mortality risk coefficient of 5.8×10^{-4} per person-rem.

6.1 Number of Significant Figures

Historically, the NRC has rounded the dollar per person-rem conversion factor to the nearest thousand dollars for the purposes of estimating monetary valuation. Given the large uncertainties inherent in this approach, annual updates would have little to no impact on this value between periodic baseline reviews because a change could not be made until there was the need for a $1,000 step change. To properly account for updated values in the conversion factor and enable a more gradual change in the factor over time, the NRC should round this number to two significant figures. For purposes of illustration, Figure 2 shows the effect of updating the NRC's 1995 VSL using the historical consumer price index – for all urban customers (CPI-U) inflation rate, real income growth factor, and an income elasticity factor and reporting the results to one and two significant figures. The choice to express the conversion factor to two significant figures is needed to properly account for updated values. Additionally, input parameters used by other Federal agencies to calculate dollar per person-rem estimates are known to at least two significant figures, which allows for the rounding change. CPI-U to measure for inflation (current year CPI-U divided by 1997 CPI-U that is indexed at 160.5), real income growth factor (median usual weekly earnings current year divided by median usual weekly earnings for 1997 indexed at 503), and an income elasticity factor (DHS, 2008).

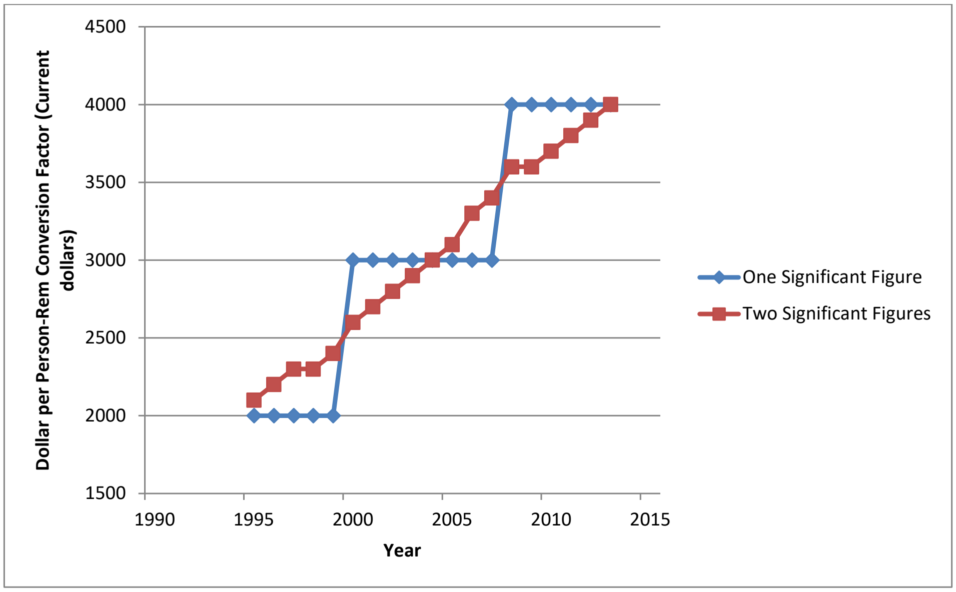

Figure 2 Difference between Rounding to One and Two Significant Figures

7 METHODOLOGY FOR MAINTAINING CONVERSION FACTORS

The U.S. Nuclear Regulary Commission (NRC) staff uses the formulas and procedures provided below to keep the dollar per person-rem conversion factor up-to-date. An example of the NRC's methodology to update the dollar per person-rem conversion factor from fiscal year (FY) 2014 to FY 2016 dollars is also provided below.

7.1 Updating the Dollar per Person-Rem Conversion Factor

The NRC staff uses the following equation to calculate the dollar per person-rem conversion factor annually. This formula incorporates the methods used by the U.S. Department of Homeland Security (DHS) (DHS, 2008). For the current year value, the average value for the most recent full year of data is used.

$$\text{Dollar per Person} - \text{Rem}_{\text{Current year}} = \text{Dollar per Person} - \text{Rem}_{\text{ base year}} \times (Inflation) \times (Real\ Income\ Growth)^{income\ elasticity}$$

In updating the dollar per person-rem, the NRC staff will annually calculate changes in inflation and real income growth using the DHS's formula for establishing future dollar per person-rem values (DHS, 2008). The underlying VSL base year and income elasticity will not change unless there is a structural change to the formula above during re-baselining as discussed in Section 7.3 of this report.

To calculate inflation, the NRC staff uses the data from the U.S. Bureau of Labor Statistics (BLS) consumer price index – for all urban customers (CPI-U) table with 2014 as the base year (BLS, 2014a). To adjust for real income growth, the staff uses the percent change in the BLS's median usual weekly earnings (MUWE) values between the base year and the current year (BLS, 2014c). MUWE measures median weekly earnings of the U.S. full-time wage and salary workers by surveying a sample of households (approximately 15,000) in all 50 states and the District of Columbia. Self-employed workers are not included in the survey. Usual weekly earnings indicate earnings before taxes and other deductions and include overtime pay, commissions, and tips (BLS, 2014b). When comparing MUWE between years, the BLS compares the numbers using CPI-U.

The NRC staff will adopt the U.S. Environmental Protection Agency's (EPA) recommendation of 0.5 as the income elasticity factor (EPA, 2011a), which was reviewed and approved by the EPA's Science Advisory Board (SAB) (EPA, 2011c). Income elasticity of demand (ϵD) measures the responsiveness of the proportionate change in demand for a good or service (Q) to the proportionate change in the income of the consumer demanding the good (I). The formula can be written as:

$$\epsilon \text{D} = \frac{\partial \text{Q}}{\partial \text{I}} \times \frac{I}{Q}$$

For example, a 5 percent increase in demand for a good and a 10 percent increase in income over the same time frame, would lead to an income elasticity of demand equal to 0.5. EPA's review found a range of income elasticities from 0.08 to 1.0, with a triangular distribution. The mean was approximately 0.5 (EPA, 2011a). The value is consistent with Viscusi and Aldy findings of income elasticity between 0.5 and 0.6 (Viscusi and Aldy, 2003). An example is provided below.

Example of the NRC's Methodology in Calculating the Dollar per Person-Rem Conversion Factor from FY 2014 to FY 2016 Dollars

Step 1: Summarize base year input parameters and specify current year.

- Current year: 2016
- Base year of Dollar per Person-Rem: 2014
  - Base year Low Dollar per Person-Rem: $2,600
  - Base year Best Dollar per Person-Rem: $5,200
  - Base year High Dollar per Person-Rem: $7,800
- Base year CPI-U: 236.736
- Base year MUWE: 791
- Income Elasticity:[1] 0.5

Table 4 Sources and Calculations for Factors into VSL

Description	Inflation (2014 = 236.7)	Real Income Growth[2] (2014 = 791)	Income Elasticity
Source[3]	Series: CPI-U. Series ID: CUUR0000SA0	Series: MUWE. Series ID: LEU0252881500	EPA, 2011a.
Calculation	Current Year Index Value/236.7	Current Year Index Value/791	0.5

Step 2: Collect current year CPI-U factors. The CPI-U factor is found in Table 24 of the most recent monthly CPI Detailed Report on the BLS website (BLS, 2014a). CPI-U is reported in half-year averages. Use the average values for the most recent two half-years of data.

Most Recent Half-Year CPI-U	238.782
Previous Half-Year CPI-U	237.769
Current Year CPI-U (average)	**238.2755**

Step 3: Calculate the change in inflation rate from base year to current year using the Consumer Price Index – for all Urban Customers. Based on the recommendations in this document, the base value is indexed at 236.736.

$$Inflation\ rate\ change\ (percent) = \frac{CPI_{current\ year}}{CPI_{base\ year}}\ x\ 100\%$$

$$\frac{238.2755}{236.736}\ x\ 100\% = 100.65032\%$$

[1] This value measures the responsiveness of the proportionate change in demand for a good or service to the proportionate change in the income of the consumer demanding the good. Based on the recommendations in this guidance, the income elasticity value is 0.5.

[2] Value is from BLS, 2014c.

[3] The BLS has significant data sets for different economic variables that are called "Series." They are identified using a "set of alpha-numeric characters that identify specific series, which are discrete variables for which data observations are available over regular time intervals, usually monthly" (BLS, 2014d).

Step 4: MUWE data is reported quarterly. The MUWE factors are found in the economic news release (http://www.bls.gov/bls/newsrels.htm). In the usual weekly earnings of wage and salary workers, go to Table 1, which is the MUWE table. The column that contains the MUWE data for this calculation is the "Total $" column, in current dollars (BLS, 2014c). Collect the most recent four quarters of MUWE and calculate the average.

Most recent Quarter MUWE (2Q 2016)	828
First Previous Quarter MUWE (1Q 2016)	823
Second Previous Quarter MUWE (4Q 2015)	820
Third Previous Quarter MUWE (3Q 2015)	811
Current Year MUWE (average)	**820.5**

Step 5: Calculate the real income growth from base year to current year.

$$Real\ Income\ Growth = \frac{MUWE_{current\ year}}{MUWE_{base\ year}}\ x\ 100\%$$

$$= \frac{820.5}{791} = 103.729\%$$

Step 6: Calculate the adjusted dollar per person-rem for Low, Best, and High values. The calculated dollar per person-rem conversion factors are rounded to two significant figures.

$$\text{Dollar per Person} - \text{Rem}_{\text{Current year}} = \text{Dollar per Person} - \text{Rem}_{\text{base year}} \times (Inflation) \times (Real\ Income\ Growth)^{income\ elasticity}$$

Low: $\text{Dollar per Person} - \text{Rem}_{current} = \$2{,}600 \times (1.0065032) \times (1.03729)^{0.5} = \$2{,}700$

Best: $\text{Dollar per Person} - \text{Rem}_{current} = \$5{,}200 \times (1.0065032) \times (1.03729)^{0.5} = \$5{,}300$

High: $\text{Dollar per Person} - \text{Rem}_{current} = \$7{,}800 \times (1.0065032) \times (1.03729)^{0.5} = \$8{,}000$

7.2 Updating the Cancer Mortality Risk Coefficient

The NRC staff will inform the Commission if the EPA adopts a new cancer mortality risk coefficient and make a recommendation whether to adopt this coefficient in establishing the NRC's dollar per person-rem conversion factor. Following Commission direction, the NRC staff would update the cancer mortality risk coefficient used in the dollar per person-rem conversion factor policy.

7.3 Re-Baselining Dollar per Person-Rem Conversion Factor

Although accounting for changing economic conditions (e.g., inflation and income growth) can provide a more realistic estimate of VSL (and, therefore, the dollar per person-rem conversion factor), economic adjustments alone do not account for the full change in VSL over time. Therefore, the NRC staff will periodically ~~consider~~ reevaluat~~e~~ing its baseline values for VSL and the cancer mortality risk coefficient, and provide a recommendation to the Commission for ~~will~~ updat~~e~~ing guidance and regulations if the conversion factor would change by more than $1,000 per person-rem. This practice is consistent with other Federal agencies' initiatives to establish formalized processes for re-baselining VSL (and, therefore, dollar per person-rem). Established processes will be used to request Commission approval for such updates and to include public participation during the update.

8 IMPLICATIONS OF REVISED CONVERSION FACTOR POLICY

The $5,200 per person-rem conversion factor in 2014 dollars discussed in this report reflects an increase of a factor of approximately 2.6 from the $2,000 per person-rem conversion factor that has been used by the U.S. Nuclear Regulatory Commission (NRC) since 1995.

As part of the NRC's update of the dollar per person-rem conversion factor, the NRC staff considered the potential impact of any change from the $2,000 per person-rem factor on current regulations and past regulatory decisions. In the introductory sections of this report, the staff describes how the dollar per person-rem conversion factor is used in NRC regulatory decisions.

First, with regard to regulatory decisions concerning radioactive waste system design alternatives for nuclear power plants (Title 10 of the *Code of Federal Regulations* (10 CFR), Part 50, "Domestic Licensing of Production and Utilization Facilities," Appendix I, "Numerical Guides for Design Objectives and Limiting Conditions for Operation To Meet the Criterion 'As Low As Is Reasonably Achievable' for Radioactive Material in Light-Water-Cooled Nuclear Power Reactor Effluents"), the staff involved in those assessments has indicated that increases in the conversion factor of at least an order of magnitude would be necessary to justify any reassessment of those decisions. Therefore, the changes in the conversion factor policy, as considered in this report, would not ~~bring into question~~impact those past decisions. Moreover, applicants for reactor licenses under 10 CFR Part 50 and 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants," and the NRC staff in its review of such applications, are still required to use the current conversion factor ($1,000 per total body man-~~-~~rem and $1,000 per man-thyroid-rem) in Section II.D of 10 CFR Part 50, Appendix I, until it is formally changed through a rulemaking.

Second, for all other regulatory applications where $2,000 per person-rem has been used by the NRC, the staff is not proposing that previous decisions be reviewed or updated based on this revised conversion factor~~ policy~~. Furthermore, even for regulatory decisions involving safety enhancements for severe power reactor accidents proposed following the accident at Fukushima Dai-ichi where the potential difference in total dollar valuation could be large, the staff used $4,000 per person-rem as an alternative value estimate (NRC, 2012b). The NRC staff does not propose revisiting those past regulatory decisions. There are several reasons for this position. First, the $2,000 per person-rem value has been used by the staff as a figure of merit, ~~and~~ but only as one input among many in the regulatory decision. Second, ~~in~~ recognizing~~tion of~~ the uncertainties inherent in such a figure of merit, the NRC would typically rely more heavily on other considerations when the break-even cost-beneficial determination was close (e.g., within a factor of five). Finally, the factors that justify an increase in the dollar per person-rem conversion factor have had a similar effect on increasing the cost of modifying a licensed facility. In conclusion, updated cost-benefit analyses would most likely result in little, if any, change to past regulatory decisions.

9 PROCESS TO INCORPORATE THE REVISED DOLLAR PER PERSON-REM VALUE AS NRC POLICY

The $5,200 per person-rem conversion factor in 2014 dollars and related changes in the U.S. Nuclear Regulatory Commission's (NRC) conversion factor policy will be incorporated into Revision 5 of NUREG/BR-0058. This is in accordance with the plan discussed in SECY-14-0002, "Plan for Updating the U.S. Nuclear Regulatory Commission's Cost-Benefit Guidance" (NRC, 2014). The deletion of all references to the present $1,000 and $2,000 per person-rem values in existing regulations and guidance is planned with the exception discussed below.

The NRC staff recognizes that updating the dollar per person-rem conversion factor may be appropriate in the future. The value should be updated using the process discussed in this Revision 1 to NUREG-1530 under Section 7, "Methodology for Maintaining the Conversion Factors Current."

With respect to implementation, the NRC staff, licensees, and applicants may begin using the revised conversion factor in all regulatory applications discussed in Section 3 of this document, other than the exception discussed below. Licensees may propose using other dollar per person-rem factors than the factor presented in this guidance.

Commented [DAW3]: For licensing actions in progress when NUREG-1530, Revision 1, is issued, the staff should clarify that it would not reevalute the licensing action using the updated conversion factor.

For example, regulatory applications discussed in Section 3.1, "Routine Liquid and Gaseous Effluent Releases from Nuclear Power Plants," the values discussed in Title 10 of the *Code of Federal Regulations* (10 CFR), Part 50, "Domestic Licensing of Production and Utilization Facilities," Appendix I, "Numerical Guides for Design Objectives and Limiting Conditions for Operation To Meet the Criterion 'As Low As Is Reasonably Achievable' for Radioactive Material in Light-Water-Cooled Nuclear Power Reactor Effluents," must be used until they are changed through rulemaking. If a licensee or applicant chooses to use values other than those provided in 10 CFR Part 50, Appendix I, for radioactive waste system designs, they must request an exemption under 10 CFR 50.12 or 52.7, both titled "Specific Exemptions."

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Commented [DAW4]: Please upate references as needed.

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APPENDIX A: ADJUSTING THE CANCER MORTALITY RISK COEFFICIENT FOR HIGH-RATE EXPOSURE SCENARIOS — THE DOSE AND DOSE-RATE EFFECTIVENESS FACTOR

Adjusting the Cancer Mortality Risk Coefficient for High-Rate Exposure Scenarios — the Dose and Dose-Rate Effectiveness Factor

Most human evidence and risk estimates of radiation health effects are developed from epidemiology studies of high-dose and dose rate exposed populations. For example, atomic bomb survivors provide strong evidence that radiation is a carcinogen at high doses delivered at near instantaneous dose rates (NAS, 2006). In contrast, most radiation protection situations involving planned activities that include exposures over a longer period of time (e.g., a single year or career). The dose and dose rate effectiveness factor (DDREF) is defined by the International Commission on Radiological Protection (ICRP) as a judged factor that generalizes the usually lower biological effectiveness (per unit of dose) of radiation exposures at low doses and low dose rates as compared with exposures at high dose rates (ICRP 60 and 103). For exposure scenarios where the dose is greater than 20 rad (0.2 grays) or the dose-rate is greater than 10 rad (0.1 grays) per hour and the total accumulated effect is not in the acute health effects range, then a DDREF factor is removed from the risk coefficient to account for the higher risk per unit dose. The EPA uses a judged DDREF of 1.5 (NAS, 2006 and EPA, 2011b).

There are some affected attributes where the DDREF could be removed on a case-by-case basis. Two attributes in regulatory analyses where the removal of the DDREF may be appropriate are occupational health (accident) and public health (accident). For example, consider a reactor accident scenario resulting in an instantaneous individual dose of 30 rem to a portion of the affected population. Using the latest EPA cancer mortality risk coefficient of 5.8×10^{-4} per rem, a revised value of 8.7×10^{-4} per rem should be used in the risk calculation to account for the higher risk per unit dose as a result of the higher dose and dose rate (i.e., the product of the original cancer mortality risk coefficient multiplied by a factor of 1.5). As a consequence, the dollar per person-rem value should account for exposed individuals who have received a high dose greater than 20 rem or greater than 10 rem per hour, but less than a fatal exposure. In such a scenario, the NRC staff would use a dollar per person-rem of $7,800 per person-rem for high dose-rate and high dose scenarios instead of the $5,200 per person-rem value in 2014 dollars being proposed for low dose rate and low dose exposure scenarios.

NRC FORM 335 U.S. NUCLEAR REGULATORY COMMISSION (12-2010) NRCMD 3.7 **BIBLIOGRAPHIC DATA SHEET** *(See Instructions on the reverse)*	1. REPORT NUMBER (Assigned by NRC, Add Vol., Supp., Rev., and Addendum Numbers, If any.) NUREG-1530, Rev. 1
2. TITLE AND SUBTITLE Reassessment of NRC's Dollar per Person-Rem Conversion Factor Policy	3. DATE REPORT PUBLISHED MONTH YEAR [TBD] 4. FIN OR GRANT NUMBER
5. AUTHOR(S)	6. TYPE OF REPORT Technical 7. PERIOD COVERED (Inclusive Dates)
8. PERFORMING ORGANIZATION - NAME AND ADDRESS (If NRC, provide Division, Office or Region, U.S. Nuclear Regulatory Commission, and mailing address; if contractor, provide name and mailing address.) U.S. Nuclear Regulatory Commission Office of Nuclear Reactor Regulation Division of Policy and Rulemaking, MS: 0-12D20 Washington, DC 20555-0001	
9. SPONSORING ORGANIZATION - NAME AND ADDRESS (If NRC, type "Same as above"; if contractor, provide NRC Division, Office or Region, U.S. Nuclear Regulatory Commission, and mailing address.) Same as above	
10. SUPPLEMENTARY NOTES	
11. ABSTRACT (200 words or less) Revision 1 to NUREG-1530 incorporates updates to the dollar per person-rem conversion factor and establishes a method for keeping this factor up-to-date. The dollar per person-rem conversion factor has been updated from $2,000 to $5,200 based on the application of an updated best estimate VSL of $9 million and the U.S. Environmental Protection Agency's cancer mortality risk coefficient of 5.8 x 10^{-4} per person-rem. Revision 1 to NUREG-1530 directs the staff to round the conversion factor to two significant figures instead of rounding to the nearest $1,000 value and provides guidance to the staff on when to use a higher dollar per person-rem conversion factor.	
12. KEY WORDS/DESCRIPTORS (List words or phrases that will assist researchers in locating the report.) Dollar per person-rem, regulatory analysis, backfit analysis, value of statistical life, cost-benefit analysis	13. AVAILABILITY STATEMENT unlimited 14. SECURITY CLASSIFICATION *(This Page* unclassified *(This Report)* unclassified 15. NUMBER OF PAGES 16. PRICE

DAW Edits

NRC Response to Public Comments

NUREG-1530, Revision 1:
"REASSESSMENT OF NRC'S DOLLAR PER PERSON-REM CONVERSION FACTOR POLICY"

ADAMS Accession No. ML16147A501
[ENTER DATE HERE]

I. INTRODUCTION

This document presents the responses from the U.S. Nuclear Regulatory Commission (NRC) to written public comments received on Draft NUREG-1530, Revision 1, "Reassessment of NRC's Dollar per Person-Rem Conversion Factor Policy", in response to publication in the *Federal Register* (FR) (80 FR 53585, September 4, 2015). The updated final draft of NUREG-1530, Revision 1, was provided for Commission approval (Agencywide Documents Access and Management System (ADAMS) Accession No. ML16147A392).

II. OVERVIEW OF COMMENTERS AND COMMENTS

The NRC staff received 11 comment submissions with a total of 38 individual comments. Table 1 presents information on the commenters who submitted comments on the draft NUREG-1530, Revision 1.

Table 1. Information on Commenters

Name	Affiliation	ADAMS Accession No.		Identifier
		Incoming	Annotated	
Jerry Kurtz	-	ML15292A335	ML16006A021	JK-1
James Slider	Nuclear Energy Institute (NEI)	ML15310A058	ML16006A020	NEI-2
Jason Schwartz	Institute for Policy Integrity	ML15323A318	ML16006A019	JS-3
Pia Jensen	-	ML15323A319	ML16006A018	PJ-4
Anonymous	-	ML15323A320	ML16006A017	AA-5
Bill Anonymous	-	ML15323A321	ML16006A016	BA-6
Dr. Goodheart	-	ML15323A323	ML16006A015	DG-7
Anonymous	-	ML15323A324	ML16006A014	A2A-8
Steven Olsen	MSME Michigan	ML15323A403	ML16006A012	SO-9
James Barstow	Exelon	ML15336A939	ML16006A011	JB-10
Dr. Edwin S. Lyman	Union of Concerned Scientists	ML16020A335	ML16035A391	EL-11

Similar comments were grouped, as appropriate, to facilitate providing NRC responses.

Comments were binned into the following categories:

a. Comments Related to the Cancer Mortality Risk Coefficient
b. Comments Related to the Dollar per Person-Rem Conversion Factor
c. Comments Related to the Methodology
d. Comments Related to the Dose and Dose-Rate Effectiveness Factor (DDREF)
e. Comments Related to the Value of Statistical Life (VSL)
f. Other Comments

a. *Comments Related to the Cancer Mortality Risk Coefficient*

Comment a1 (combined NEI, JB, and JS): Page 22, lines 23 and 28, Section 5, Nominal Risk Coefficient RE: [line 23] "Thus, by not accounting for cancer morbidity, the NRC may underestimate the benefits of a proposed action (e.g., medical costs averted, value of lost production, etc.) by as much as another 20 percent." [line 28] "The NRC staff prefers to achieve greater alignment with ICRP Publication 103 and adopt the nominal risk coefficient of 5.7×10^{-4} per rem with the understanding this coefficient may underestimate the U.S. population risk by as much as 30 percent."

The significance of the potential overestimation of benefits or underestimation of risk and the net effect of these potential uncertainties is not explained. It should be. [NEI-2-1, JB-10-1]

Page 22, lines 32-33, Section 5, Nominal Risk Coefficient RE: "However, the final dollar per person-rem calculated using either the EPA or ICRP is not practically different."

The statement that there is not a practical difference between the use of the ICRP risk coefficient and the EPA value is not supported by evidence. In the interest of full disclosure, the staff should consider providing some indication of the sensitivity of the final figure to this difference. For example, if the EPA values were used, the best estimate value would be more similar to the high estimate, and the low and high estimates similarly increased. [NEI-2-2, JB-10-1]

NRC should reconsider its choice of risk coefficient to better account for morbidity effects.

The NRC proposes to adopt the ICRP 2007 estimate of the risk of health effects from radiological exposure. The ICRP's risk coefficient translates nonfatal cancers and heredity effects into loss-of-life measures "based on a perceived relationship between quality of life and loss of life. In this way, the value of a statistical life is applicable across all contributors to the total health risk coefficient." NRC should explain more thoroughly how morbidity effects are translated into mortality effects, because this translation is potentially problematic. This translation sounds related or analogous to the methodology for valuing quality-adjusted life-years. The QALY [quality adjusted life-year] method is problematic for several reasons, as discussed in Richard Revesz and Michael Livermore's 2008 book *Retaking Rationality*. Importantly, there is a risk of over-counting the costs of certain types of morbidity effects because there is a false assumption that people will not adapt to their altered health states. At the same time, it is not clear whether ICRP's risk coefficient captures all the morbidity effects of fatal and nonfatal cancers, including the dread experienced by people with slow-developing cancers.

Curiously, ICRP's risk coefficient (5.7×10^{-4} per rem), which is meant to include nonfatal and heredity effect, is lower than the EPA's 2011 mortality-only risk coefficient (5.8×10^{-4} per rem). NRC dismisses the EPA number and selects the ICRP figure with little discussion. Though harmonization with international bodies is an admirable goal, so is harmonization with other U.S. federal agencies. NRC seems concerned that using EPA's mortality-only figure could cause NRC to underestimate the benefits of a proposed action by as much as 20 percent, but NRC admits that the ICRP figure it selects "may underestimate the U.S. population risk by as much as 30%." NRC should explain why it believes that ICRP's risk coefficient is preferable.

The NRC claims that the choice between EPA's figures and ICRP's would result in "not practically different" benefit valuations, but the math does not support that claim. For example, adding the U.S. National Academies estimate of genetic effects (0.4 x 10^{-4} per rem) to EPA's mortality-only risk coefficient, and then adjusting the sum up by an additional 20% to account for morbidity effects, results in a morbidity/heredity-adjusted EPA-based risk coefficient of 7.44 x 10^{-4} per rem. If then multiplied by the $9 million VSL estimate, the central conversion factor would be $6,696, which is significantly higher than NRC's estimate of $5,100.

Alternatively, NRC could apply the EPA-adjusted risk coefficient for sensitivity analysis. Multiplying a 7.44 x 10^{-4} per rem risk coefficient by the high VSL derived above of $10.9 million would yield a high conversion factor of $8,110, which is significantly higher than NRC's high conversion factor of $7,500 (multiplying this high risk coefficient by NRC's proposed high VSL of $13.2 million would yield an even higher conversion factor of $9,821). NRC says it is not adopting low and high risk coefficient factors for sensitivity analysis "for simplicity," but as this simple math demonstrates, multiplying a high VSL by a high risk coefficient to derive a high conversion factor for use in sensitivity analysis is no more complex than using a single risk coefficient for all calculations.

Whether selecting the EPA figure or the ICRP figure, NRC's plans to update the coefficient as new recommendations are published is appropriate. [JS-3-3]

Page 23, lines 2-3, Section 5, Nominal Risk Coefficient RE: "For simplicity, the NRC staff does not recommend low and high nominal risk coefficient factors for use in sensitivity analyses."

Simplicity alone is insufficient justification for not including the range of risk coefficient factors in sensitivity analyses. If the NRC has a stronger justification, it should be provided. Otherwise, the NRC should reexamine the proposed high and low values of the dollar per person-rem conversion factor to ensure they adequately bound uncertainties in the nominal risk coefficient. [NEI-2-3, JB-10-1]

NRC Response: The NRC agrees with this comment that the use of the International Commission on Radiological Protection (ICRP) nominal risk coefficient has produced confusion. The ICRP value includes a global average risk of fatal cancers, non-fatal cancers, and severe heritable effects. However, on the VSL portion of the calculation, only mortality is monetized. Therefore, to reduce confusion and to increase coherence between the risk coefficient and VSL, the staff has decided to use the U.S. Environmental Protection Agency (EPA) cancer mortality risk coefficient of 5.8 × 10^{-4} per rem to better align with the monetized mortality value of the VSL. Additionally, the EPA cancer mortality risk value is specific to a U.S. population and not averaged over a larger portion of the world population. The use of the EPA cancer mortality risk coefficient instead of the ICRP detriment coefficient results in a comparable dollar per person-rem conversion factor. Selecting the EPA cancer mortality risk coefficient also strengthens the basis for the risk coefficient value and is consistent with what is being monetized in the VSL value.

In regard to the uncertainty of the EPA point estimate value of 5.8 x 10^{-4} per rem, the EPA reports a 90 percent confidence interval around the estimate of 2.8 x 10^{-4} to 1 x 10^{-3}. The point estimate and confidence intervals around the estimates will be added to NUREG-1530, Revision 1.

The NRC disagrees with the comments regarding the potentially significant difference in results between using the ICRP total detriment coefficient and the EPA cancer mortality risk coefficient. As discussed in NUREG-1530, Revision 1, Section 5, the use of the EPA cancer mortality risk coefficient results in a dollar per person-rem conversion factor that is approximately the same as that calculated with the ICRP total detriment coefficient.

b. *Comments Related to the Dollar Per Person-Rem Conversion Factor*

Comment b1 (combined NEI and JB): Page 25, line 28, Section 6: “The NRC acknowledges that there may be unique circumstances where other dollar conversion factors may warrant consideration.”

This sentence could be interpreted to mean that NRC will choose whatever value of dollar per person-rem it wishes in any particular case. The paragraph is not clear on how the analyst should select other values based on “unique circumstances”. The document should provide additional guidance to ensure the consideration of unique circumstances does not become an excuse for using arbitrary values. If the NRC uses a different value of the dollar per person-rem conversion factor in a specific application, the staff should clearly document the basis for the use of that different value. [NEI-2-4, JB-10-1]

Page 25, lines 28-38, Section 6: “The NRC acknowledges that there may be unique circumstances where other dollar conversion factors may warrant consideration. For example, doses to a population whose age distribution is not representative of the general population could be subject to a different risk coefficient because health risks are directly related to the age distribution of the affected population. Further, recognizing the uncertainties inherent in establishing a representative conversion factor, alternative values to capture the uncertainties may be warranted. Thus, it would be reasonable to expect an analyst to include alternative valuations in regulatory analyses in order to show the decision maker the sensitivities of the proposed action to relevant considerations. However, the base case computations in a regulatory analysis will use the recommended best estimate dollar conversion factor of $5,100 per person-rem, and apply the low and high estimates in illustrating sensitivity and in bounding the range and direction of the impacts.”

By suggesting that alternative risk coefficients might be important to consider, this section again begs the question about including alternate risk coefficients in the sensitivity analysis. [NEI-2-5, JB-10-1]

NRC Response: The NRC agrees with the comments that clearly documenting the basis for the use of other dollar per person-rem conversion factors is necessary. The NRC will clarify in Section 6, NUREG-1530, Revision 1, that the basis for any other dollar per person-rem conversion factor should be documented.

Comment b2: Should allow for specific licensee amendment of specified values for other tangible costs such as loss of experience of dosed out worker, training costs associated with replacement workers, etc. In other words, they cannot go below these guidelines but can go above factoring other costs. Here at our DOE project, we use $11,000/Person-Rem as our number because of those other costs. [JK-1-1]

NRC Response: The NRC considers this comment to be outside the scope of NUREG-1530, Revision 1. Other costs such as those mentioned in the comment are treated explicitly in calculating incremental labor costs for implementing (e.g., planning and performing the activity, training costs) and therefore should not be used to arbitrarily increase this conversion factor. After considering this comment, no change was made to NUREG-1530, Revision 1.

Comment b3: NRC should incorporate its new conversion factors into any retrospective reviews.

The commenter indicated that the NRC is not proposing that previous decisions be reviewed or updated based on this revised conversion factor policy. Further, the commenter stated that the NRC gives several reasons, including the assumption that the same factors that justify an increase in the dollar per person-rem conversion factor have had a similar effect on the cost of modifying a licensed facility, and that therefore, updated cost-benefit analysis results would most likely result in little, if any, change to past regulatory decisions. This assumption may not necessarily hold true. For example, technological innovation and increased productivity could simultaneously lead to income growth resulting in higher willingness to pay for the value of a statistical life, while also decreasing compliance costs.

The NRC should incorporate its new conversion factors into any retrospective reviews of existing regulations. The NRC has developed a retrospective review plan pursuant to EO 13579. That EO called for independent agencies to follow the principles of EO 13563, which requires executive branch agencies to "use the best available techniques to quantify anticipated present and future benefits and costs as accurately as possible." Consistent with these principles, NRC should recalculate the benefits of rules undergoing retrospective review by using the "best available techniques" – namely, the updated conversion factors. Incorporating the new conversion factors should be a simple mathematical calculation requiring very little work from agency staff, and the results might point out the need for more stringent regulation. Even if the new factors would not change the regulatory outcome, regulatory analysis is conducted to promote public transparency as well as to aid decision making, and an updated evaluation of the health benefits would help the public better understand the importance of NRC's existing regulations. [JS-3-4]

NRC Response: The NRC agrees with this comment that the updated dollar per person-rem conversion factor should be used in future retrospective reviews. The NRC uses the guidance in NUREG-1530, Revision 1, when conducting a cost-benefit analysis of a new policy or regulation that may affect public health or safety. The cost-benefit analysis compares the total willingness to pay for the averted health risk reductions from these policies to the additional costs that will be incurred if the policies are adopted. Consistent with the quoted statement from Executive Order (EO) 13563, the NRC would apply the NUREG-1530, Revision 1, conversion factor in evaluating regulations currently being considered and those to be considered in the future.

For retrospective reviews, EO 13563 instructs agencies to periodically review "existing significant regulations to determine whether any such regulations should be modified, streamlined, expanded, or repealed so as to make the agency's regulatory program more effective or less burdensome in achieving the regulatory objectives." The NRC would use the guidance in NUREG-1530, Revision 1, to perform these retrospective reviews. After considering this comment, no change was made to NUREG-1530, Revision 1.

Comment b4: Even the IMF [International Monetary Fund] considers medical costs from radioactive pollution an unfair subsidy to the energy sector, which should be factored in, and they have pointed this out repeatedly. Ignoring the cost of healthcare is wrong.

Why isn't the medical cost of radioactive pollution factored into the equation?

The NRC allows the nuclear utilities-industry to externalize the true cost upon society. Cancer is not simply an individual problem, but has heavy social and economic costs to society as a whole –individuals and taxpayers. And, cancer is not the only costly radiation induced health problem. [JS-3-5]

NRC Response: The NRC considers this comment to be outside the scope of NUREG-1530, Revision 1. The other factors mentioned in the comment are addressed externally to the dollar per person-rem factor and are captured in a different element of the cost-benefit analysis. After considering this comment, no change was made to NUREG-1530, Revision 1.

Comment b5: Human capital is ignored: NRC makes VSL of older, educated, experienced people less, because they are more likely to get cancer due to age. [JS-3-6]

NRC Response: The NRC disagrees with this comment. The EPA VSL value reflects the U.S. population based on decennial census figures and is based on small, incremental changes in risk. It is not a value assigned to an individual life. After considering this comment, no change was made to NUREG-1530, Revision 1.

Comment b6 (combined DG, A2A, and SO): According to BEIR [Biological Effects of Ionizing Radiation] VII, for those who die, the life-shortening effects are on the order of 14 to 15 years. Currently the average monthly cost of new cancer medications, according to Memorial Sloane-Kettering, is around $10,000 per month (median), which is $120,000 per year, and thus $1.8 million for 15 years, if the prices don't rise, but the prices have been rising and rapidly so. This is cost of medication alone, and excludes the cost of doctors, hospitals, and social or financial cost of caregivers for the ill, and loss of "free" caregivers for children and the elderly, by loss of those who are middle aged, through illness and/or death. In short, it excludes value of work done, whether paid or unpaid. Women are disproportionately impacted by radiation induced cancers, as well, and women as a whole do much of the unpaid work, which allows continuing functioning of a household, and without which there may need a maid. Already the high cancer drug prices are being decried, even by some with ties to big pharma, it's so bad. Life-boat ethics is kicking in. For instance, some cancer drugs are unavailable in the UK Public Health System due to high price and cost-cutting (even while they, like the U.S., find money to subsidize the mostly foreign nuclear industry). Even where people have private insurance, there are limitations in coverage; bankruptcy may have to be declared, and the taxpayer most likely picks up cost (or the person doesn't get the needed care).

Where is the value of paid and unpaid labor? Loss of middle-aged people means someone must pay for caregiving of children and elderly, as well as for the middle-aged with cancer. Women are more likely to get cancer and be caregivers. Who pays?

This is also discriminatory and probably illegal. It means that nuclear reactors near middle aged and senior citizens will not be as likely to upgrade to protect against nuclear accident. If the utility does not plan to evacuate elderly-disabled people, this violates the ADA and probably the

Civil Rights Act. On p. 25 NRC says: “doses to a population whose age distribution is not representative of the general population could be subject to a different risk coefficient because health risks are directly related to the age distribution of the affected population.” Does the “N” in NRC stand for Nazi? They exterminated the disabled to save money. Those involved were tried for “Crimes against humanity.” However, that was arguably more humane than the radiation poisoning, cancer, blindness, etc. which the NRC proposes for the elderly and disabled.

Your use of cost-benefit is fraudulent because costs and benefits accrue to different groups. It is public health vs. utility/corporate profit. Your use of “willingness to pay” is fraudulent for the same reasons. Clearly, you did not ask people if utilities should pay, but if they would pay. You didn’t give a death free renewables option either.

Americans increasingly turn to high cost fertility treatment in order to have children. But, the ICRP considers the first 2 weeks of baby lives expendable. Yet, those getting fertility treatment are not notified of this, and even mortgage their homes for repeated attempts to have a baby. This is not factored in. But how to quantify extermination of one’s genes anyway?

Stochastic is incorrectly defined in your document. Stochastic refers to the randomness of radiation damage, which can lead to long-term health impacts. Because damage is random, increased exposure increases risk. The more bullets shot at you, the more likely you are to be fatally shot.

Contrary to what NRC says, VSL is about the value of real people’s lives. Just like in mass shootings, it is real people who are killed. Statistics are the odds of being killed. The more you allow the nuclear industry to pollute, the more real people will be killed. [DG-7-1, A2A-8-2, SO-9-5]

NRC Response: The NRC disagrees with this comment regarding the value assignment per life and that stochastic is incorrectly used in NUREG-1530. The EPA VSL value reflects the U.S. population based on decennial census figures and is based on small, incremental changes in risk. It is not a value assignment per life. After considering this comment, the NRC staff clarified the definition of “stochastic health effects” in NUREG-1530, Revision 1. The remaining points in this comment are outside the scope of NUREG-1530, Revision 1.

Comment b7 (combined DG and SO): Why not use real numbers, instead of made up ICRP numbers?

Just before BEIR VII was completed in 2005, a 15 country study of nuclear workers was published, which showed that the cancer risks were much higher than stated in the BEIR report, In an Appendix, BEIR VII says that they did not have time to take it into consideration. Additionally, there is a very recent 3 country INWORKS study of nuclear workers, which suggests that excess cancer rates from ionizing radiation are around 10 times higher than concluded by the BEIR report. Frighteningly, this appears a middle of the road number, which sits between BEIR VII and the 15 country INWORKS study. Using the ICRP model instead of taxpayer funded BEIR VII is just a way to lowball the cost. The ICRP model is flawed. [DG-7-2, SO-9-3]

NRC Response: The NRC agrees that the use of the ICRP nominal risk coefficient has produced confusion. See NRC response to comment a1. Comments regarding the validity of the ICRP values are outside the scope of NUREG-1530, Revision 1, because the NRC has adopted the EPA cancer mortality risk coefficient values.

Comment b8: $5,100 per person rem conversion factor is not updating VSL to $9 million, but to $5.1 million if you use excess cancer risk (morbidity) rather than only death (mortality), and use U.S. government funded BEIR VII (2005). Using U.S. government funded INWORKS, excess cancer rates are 10 times higher than BEIR. INWORKS give excess cancer deaths at 51-58% per Sv. Excess cancer cases are roughly double (52% of those with cancer die). Thus, 99 to 100% excess cancers per Sv. BEIR VII excess cancer risk (morbidity) is 0.001 per person rem (10mSv). This excludes other diseases, such as cataracts, and inherited defects. INWORKS excess cancer risk (morbidity) is approximately 0.01 per person rem, so VSL is $510,000 or less, using NRC proposed [dollar] per person rem conversion factor of $5,100. The $ per person rem conversion factor must be $90,000 (INWORKS) to really be $9 million; $9,000 for BEIR.

The current $1,000 conversion factor puts VSL at $100,000 (INWORKS) or $1,000,000 (BEIR VII). [A2A-8-1]

NRC Response: The NRC disagrees with this comment, which concerns VSL calculations, discounting, and the cost of cancer treatment. As a policy, the NRC does not use morbidity directly in the manner described by the commenter. BEIR VII is used by the EPA in its current VSL and risk coefficient calculations, and NUREG-1530, Revision 1, leverages those EPA values. The NRC disagrees that the ICRP model is flawed and that the NRC should use the 2015 INWORKS study alone. BEIR VII and ICRP use a conglomeration of studies and then take into account specific background radiation exposure data applicable to the U.S., whereas the INWORKS studies mentioned in the comment are individual studies and are, or will become, part of the aggregate studies considered in the future. After considering this comment, no change was made to NUREG-1530, Revision 1.

Comment b9: A “recommendation” of NRC claims to use $2,000 person rem conversion factor. However, NRC discounts this $2,000 backwards from the theoretical date of an accident, with a 7% discount rate (NUREG/BR-0184). In 25 years, e.g. in NUREG/BR-0184, pp. B-3-4, the $2,000 reduces to $368! This reduces VSL to $36,800 (INWORKS) or $368,000 (BEIR VII). Meanwhile NRC pretends VSL is $3 million. [A2A-8-1]

NRC Response: The NRC disagrees with this comment based on a misinterpretation of discount factor usage. The discount factor does not “reduce” any cost amount or benefit that occurs in the future. The future cost remains the same, and in the event of an insurance payout or settlement, or other remuneration, the cost in the future is not reduced by the discount factor. The purpose of the discount factor is to determine how a future cost of a certain amount economically affects the industry at a particular, nearer time, thought of as the “present” time (in the term “Net Present Value”). If a certain cost will be incurred 25 years in the future, because of inflation and investments and other economic realities, the effect “now,” or at the “present time,” will not be as high as the full future value, which will be undiminished should the future cost be incurred. After considering this comment, no change was made to NUREG-1530, Revision 1.

Comment b10 (combined A2A and SO): Cost of life-extending cancer drugs is $120,000 to $207,000 per additional year of life and is increasing at 10% per year even adjusting for inflation. 14 to 15 years is the average life-shortening effects of the radiation induced cancer (BEIR).

Thus, $9 million will not pay even for 14 to 15 years of cancer drugs in the future. There are other medical costs. Who pays? [A2A-8-1, SO-9-1]

NRC Response: The NRC considers this comment to be outside the scope of NUREG-1530, Revision 1, as the cost of illness is estimated in a different element of the cost-benefit analysis. As to the final point that the VSL is not enough to cover specific cancer drugs for the mentioned "average life-shortening effects of the radiation induced cancer," this is not the intent of the VSL. After considering this comment, no change was made to NUREG-1530, Revision 1.

Comment b11 (combined DG and SO): Why is there a backwards discount, which does not make any sense?

It is disingenuous at best to use a discount rate to discount the current value of life from a future value, absurdly created by an accident of unknown date that "you can't prove." We don't know inflation going forward, but with no end in sight to money printing, regardless of jawboning to give confidence in holding T-bills, but we can easily assume that the value of U.S. dollars will continue to go down as we overspend on the government budget. This is exactly the same as printing, therefore the cost of a future cancer should not be discounted backwards, but should be inflated forwards. Even if we accepted the "discount backwards" model, using a rate of 7% is absurd, when is the last time you thought you could get a 7% return on any investment? [DG-7-3, SO-9-2]

NRC Response: The NRC considers this comment to be outside the scope of NUREG-1530, Revision 1, which does not provide guidance on discounting or on choosing a discount rate. In addition, the NRC disagrees with this comment because discounting is used to render costs and benefits that occur in different time periods comparable by expressing their values in present terms. In practice, it is accomplished by multiplying the changes in future consumption by a discount factor. At a summary level, discounting reflects that people prefer consumption today to future consumption, and that invested capital is productive and provides greater consumption in the future. After considering this comment, no change was made to NUREG-1530, Revision 1.

Comment b12: The proposed approach the NRC staff uses to choose an updated value of a statistical life appears generally reasonable. The best estimate value of $9 million in 2014 dollars, as well as the low and high estimates for use in sensitivity analyses, was chosen to be consistent with the current VSL values used by other agencies.

However, UCS [Union of Concerned Scientists] has concerns about the NRC staff's choice of radiation risk coefficient, which is the other parameter that is used to derive the conversion factor. The underlying risk coefficient of 5.7×10^{-4} per rem, chosen to be consistent with ICRP publication 103, is supposed to represent the weighted risk associated with both fatal and nonfatal cancers, as well as heritable effects. However, the parameter is smaller than the risk coefficient for cancer mortality alone recommended by the National Academy of Sciences' BEIR VII committee, which is approximately 5.8×10^{-4} per rem, and well below the BEIR VII recommendation for cancer incidence, 1.16×10^{-3} per rem. Moreover, the coefficient does not take into account the risks associated with other diseases now understood to be associated with ionizing radiation exposure, such as cardiovascular disease. NUREG-1530 Rev. 1 itself concedes that its choice of risk coefficient "may underestimate the U.S. population risk by as much as 30 percent," but does not explain why that is acceptable.

Consequently, UCS believes that the best estimate parameter for exposure to low-dose and low-dose-rate low-linear-energy-transfer (LET) radiation of $5,100 per person-rem (2014 dollars) is not clearly justified and is likely too low.

UCS also strongly endorses the adjustment of the conversion factor to take into account high dose and high dose rate scenarios, as well as exposure to high-LET radiation, where appropriate, as outlines in Appendix B of NUREG-1530, Rev. 1. NRC currently does not take these important considerations into account in its regulatory analyses. In fact, the MACCS [MELCOR Accident Consequence Code System] code used in the NRC analyses does not compute separate population dose values for those exposures where a DDREF should not be used. Thus, these analyses generally underestimate the magnitude of cancer induction associated with a given population exposure. [EL-11-3]

NRC Response: The NRC agrees with this comment that the use of the ICRP nominal risk coefficient has produced confusion. See NRC response to comment a1.

The NRC disagrees in part with this comment. Although the MACCS code does not calculate and report separate population dose values for groups of individuals who may be exposed to ionizing radiation at higher doses or dose rates, the NRC disagrees that this will necessarily result in underestimating the magnitude of cancer induction associated with a given population exposure.

The MACCS cancer risk model uses the following piecewise linear cancer risk function to calculate the risk of cancer induction in a specified target organ as a function of radiological dose:

$$R(D) = \alpha \cdot \frac{D}{DDREFA} \quad D < DDTHRE$$
$$R(D) = \alpha \cdot D \quad D \geq DDTHRE$$

where:

R(D)	=	risk of cancer induction in a specified target organ for dose D
D	=	50-year lifetime dose commitment to the specified target organ
α	=	cancer risk coefficient
DDREFA	=	analyst-specified dose-dependent reduction factor
DDTHRE	=	analyst-specified dose threshold level

Within MACCS, the analyst specifies the value of the DDREFA parameter for each type of latent cancer effect and target organ. This parameter represents the dose-dependent reduction factor that is used to reduce the organ-specific cancer risk by a specified value, if certain conditions are met. In particular, if the organ-specific 50-year lifetime dose commitment incurred by a representative individual within each spatial element during the early (emergency) phase

exposure period is less than the analyst-specified dose threshold level represented by the DDTHRE parameter, the risk of cancer induction in that target organ from exposure to ionizing radiation is reduced by a factor of DDREFA. For the intermediate and late (recovery) phase exposure periods—which typically represent the periods after an accident has been brought under control and there are no more radiological releases to the atmosphere—MACCS assumes that all organ-specific 50-year lifetime dose commitments will be less than DDTHRE, and therefore applies the DDREFA parameter to reduce the organ-specific cancer risk.
The NRC acknowledges that it is theoretically possible for an organ-specific 50-year lifetime dose commitment to exceed the dose threshold level represented by the DDTHRE parameter during the intermediate or late phases. However, the NRC disagrees that assumptions underlying the MACCS cancer risk model necessarily (or generally) result in underestimating the magnitude of cancer induction associated with a given population exposure. Moreover, even if the organ-specific risk of cancer induction were underestimated, this would not affect the calculation of population dose that provides input to the calculation of benefits for each alternative evaluated as part of a regulatory analysis.

Finally, as stated in Appendix B of the draft report, NRC staff will incorporate specific guidance on how and when to use the dose and DDREF in the cost-benefit analyses in other elements of the cost-benefit guidance update process discussed in SECY-14-0002, "Plan for Updating the U.S. Nuclear Regulatory Commission's Cost-Benefit Guidance."

c. *Comments Related to the Methodology*

Comment c1: UCS does not support the use of regulatory cost-benefit analysis based on overly narrow definitions of costs and benefits and reductionist formulas to monetize the public health benefits of regulations. The federal government should undertake a comprehensive reform of these practices. However, as long as the NRC and other federal agencies continue to rely on such analyses, it is imperative that the methodology they use is rigorous and is based on technically sound quantitative data. [EL-11-2]

NRC Response: The NRC partially agrees with the comment and believes that the use of the dollar per person-rem conversion factor in NRC's cost-benefit methodology is rigorous and is based on technically sound quantitative data.

The NRC disagrees with the comment that the NRC's cost-benefit analysis is "overly narrow" and "reductionist" and that these practices need a comprehensive reform. Additionally, this comment is outside the scope of NUREG-1530, Revision 1. After considering this comment, no change was made to NUREG-1530, Revision 1.

Comment c2 (combined NEI and JB): Page 28, lines 5-7, Section 7.2: "The NRC staff should periodically update the nominal risk coefficient used in the dollar per person-rem conversion factor when the ICRP provides new recommendations for its conversion factor."

The text sounds as if the staff's intent is to require an update be timely made following receipt of a new ICRP recommendation for the value of nominal risk coefficient.

Certainly, the NRC staff should stay informed of changes in ICRP recommendations. It may also make sense for the NRC to consider evaluating the effect of a new ICRP recommendation on the NRC's dollar per person-rem calculation. However, it does not follow that the NRC necessarily must adopt the latest ICRP recommendation as its own within a specific timeframe, or revise the NRC's dollar per person-rem value every time the ICRP value changes. The critical question is what effect the ICRP change has on public health and safety. Slavish congruence with international recommendations that yields little or no benefit to public health and safety is no virtue, particularly if achieving it would require the allocation of NRC and industry resources that could be used to greater benefit in other areas. [NEI-2-7, JB-10-1]

NRC Response: The NRC agrees that periodic reviews of the scientific literature should be performed. The NRC staff has revised Section 7.2, NUREG-1530, Revision 1, to clarify how the NRC should consider revisions to the cancer mortality risk coefficient.

Comment c3 (combined NEI and JB): Page 28, lines 5-7, Section 7.2: "The NRC staff should periodically update the nominal risk coefficient used in the dollar per person-rem conversion factor when the ICRP provides new recommendations for its conversion factor."

The text is unclear whether the NRC will seek public involvement in future updates to the nominal risk coefficient used in the dollar per per-rem conversion factor. We strongly urge the NRC to solicit public input if and when future updates are considered. The draft NUREG-1530, Rev. 1 and whatever NRC administrative procedures are used to implement this requirement should be revised to reflect this imperative. [NEI-2-8, JB-10-1]

NRC Response: The NRC agrees with this comment and will continue to solicit public input in future updates to NUREG-1530 using established processes.

Comment c4 (combined NEI and JB): Page 28, lines 14-16, Section 7.3: "Therefore, the NRC staff should reevaluate its baseline values for VSL (to account for structural changes in the economy) and nominal risk coefficient approximately every five years, and update guidance and regulations as needed."

It is not clear what "structural changes in the economy" the staff thinks might affect VSL and, more specifically, what structural changes are relevant to nuclear safety regulations. If there are specific economic factors in the basis for VSL that the NRC believes it needs to reevaluate every five years, those factors and the criteria on which the NRC will reevaluate them ought to be stated clearly in NUREG-1530. At the same time, if those factors are so dynamic and have such a profound effect on VSL, the NRC should consider choosing a different value for VSL or determining a different basis for updating its chosen value of VSL that is less influenced by factors so dynamic that they are likely to change significantly within the proposed reevaluation period. [NEI-2-9, JB-10-1]

The document offers no evidence to support the recommendation to reevaluate the baseline value for VSL and the nominal risk coefficient every five years. For example, the document does not mention how many of the NRC's past regulatory analyses would reach different conclusions if the dollar per person-rem conversion factor changed by as much as NRC expects the factor to change in its proposed five-year updates. The document is silent on how such a requirement would be captured in the NRC's administrative controls. The document is silent on the impacts the reevaluation would impose on NRC and industry resources, and on the potential benefits to public health and safety the NRC expects to accrue from reevaluating the conversion factor on the proposed five-year interval. [NEI-2-10, JB-10-1]

Updating guidance and regulations after every five-year reevaluation of the conversion factor could be enormously burdensome to NRC and the entities subject to NRC regulations. In addition, such updates of guidance and regulations could take years due to public notice and comment requirements. Given the resources, stakes, and timescales involved, it would be imprudent to undertake an update of guidance and regulations on the proposed five-year frequency of reevaluating the dollar per person-rem conversion factor. With the nuclear industry's long planning horizons, cementing into place an additional factor to drive change in guidance and regulations as often as every five years would add even greater uncertainty to the regulatory environment. We recommend that any reevaluation be triggered by the magnitude of the change in the conversion factor, rather than the passage of time or the publication of a new ICRP recommendation. As the staff itself mentions on page 29, lines 13-15, current experience indicates "…increases of at least an order of magnitude would be necessary to justify any reassessment of [past] decisions." [NEI-2-11, JB-10-1]

NRC Response: The NRC agrees with the comments and the recommendation provided. NUREG-1530, Revision 1, has been revised to remove the reference to structural changes and the five-year periodicity.

d. *<u>Comments Related to Dose and DDREF</u>*

Comment d1 (combined NEI and JB): Page B-1, line 27, Appendix B: "Organizations such as the National Academies' Biological Effects of Ionizing Radiation Committee VII and the U.S. Environmental Protection Agency (EPA) also developed risk coefficients that use a different judged DDREF of 1.5 in their derivations (NAS, 2006 and EPA, 2011b). Thus any high dose-dose rate corrections to a coefficient should be based on the DDREF developed by that particular organization."

It would be appropriate to insert before the last sentence an acknowledgment of the continued uncertainty about the shape of the dose response curve and the value of DDREF. We suggest something like the following: "It should be noted that considerable debate continues regarding the shape of the dose-risk response curve for low doses, and thus the value of a DDREF to be applied." [NEI-2-14, JB-10-1]

NRC Response: The NRC acknowledges that there is debate regarding the shape of the dose response curve at low doses. The NRC agrees with the comment and has adopted the EPA cancer mortality risk coefficient (DDREF value of 1.5) in NUREG-1530, Revision 1, which is consistent with the National Academy of Sciences recommendation.

Comment d2 (combined NEI and JB): Appendix B does not mention guidance contained in ICRP Publication 103 about aggregation and uncertainty in estimating population radiation exposures. Paragraph 221 of ICRP 103 cautions: "When exposures occur over large populations, large geographical areas, or long time periods, the total collective effective dose is not a useful tool for making decisions because it may aggregate information inappropriately and could be misleading for selecting protective actions. To overcome the limitations associated with collective effective dose, each relevant exposure situation must be carefully analyzed to identify the individual characteristics and exposure parameters that best describe the exposure distributions among the concerned population for the particular circumstance. Such an analysis – by asking when, where and by whom exposures are received – results in the identification of various population groups with homogeneous characteristics for which collective effective doses can be calculated within the optimization process…In practical optimization assessments, collective doses may often be truncated…" This means that the determination of offsite radiation exposures in a regulatory analysis should reflect the identification of appropriate population groups for which collective effective doses can be calculated and, depending on uncertainty and other characteristics, truncated. This does not appear to be addressed in the revision of NUREG-1530. [NEI-2-15, JB-10-1]

NRC Response: The NRC is aware of this guidance and the concern of the misuse of collective dose, especially when over-aggregating small doses and calculating a total population latent cancer fatality number from an activity. As part of its regulatory analysis, the NRC staff performs area-specific analyses that do contain the potential to over-aggregate small doses. Also, when conducting its regulatory analysis, the NRC staff does not calculate a total population mortality number, but instead compares the incremental reduction in risk to the cost of some action. These incremental reductions in risk can be used in comparing various regulatory options and associated costs. Additionally, this comment is outside the scope of NUREG-1530, Revision 1. After considering this comment, no change was made to NUREG-1530, Revision 1.

e. *Comments Related to the VSL*

Comment e1: Harmonizing the VSL with other federal agency estimates is appropriate, but NRC should not give weight to the range described without endorsement by OMB in its 2003 Circular A-4 Guidance.

NRC calculates its central or "best" estimate of the VSL ($9 million) by taking the simple mean of the EPA's VSL ($8.7 million) and DOT's VSL ($9.3 million). Relying on the expertise of these two agencies in estimating the VSL is appropriate, and not only because it saves NRC the cost of duplicating their sophisticated efforts. Harmonizing regulatory analysis across federal agencies is valuable in itself, increasing the rationality and transparency of regulatory analysis. Any significant disparity between agencies' VSLs, without justification, suggests that some agencies may be under- or over-regulating and makes it difficult to compare the value of life-saving regulations across agencies. NRC should consider coordinating more explicitly and continually with EPA, DOT, and other agencies, and could even call for an interagency working group on VSL estimates.

NRC calculates its low and high estimates of the VSL by taking the median of the low and high values reported by three sources: DOT, DHS, and OMB. There are at least three issues with this methodology. First, NRC claims that OMB "endorsed" in its 2003 Circular A-4 a range of VSL estimates from $1 million to $10 million. In fact, the Circular A-4 does not explicitly recommend agencies use numbers in that range. In a paragraph discussing the "considerable body of academic literature" on the VSL, OMB merely reports – descriptively, not prescriptively – that "a substantial majority of the resulting estimates of VSL (from the literature) vary from roughly $1 million to $10 million per statistical life." Far short of "endorsing" or "selecting" this range, OMB cautions that "the literature-based VSL estimates may not be entirely appropriate for the risk being evaluated." The $1 million estimate, for example, may simply have been an outlier from the literature and not a value OMB was recommending for agency use. As NRC notes, on occasions when OMB has used the VSL itself, it has used a much higher number ($6.7 million), and in OMB's 2011 Primer on Circular A-4, OMB instead discussed a range of $5 million to $9 million as representing current agency practices. Moreover, the literature OMB cites in Circular A-4 – principally the work of Viscusi and Aldy – has been relied upon more specifically and carefully in other agencies' estimates of the VSL. At best, by including the OMB range in its estimates along with other agencies' work, NRC may be double counting the literature, at worst, NRC may be giving weight to outlying, outdated data points.

Second, NRC does not explain why it is taking the median value for its low and high estimates, while it took the simple mean for its "best" estimate. Third, after choosing EPA's estimates as an input into its calculation of the "best" VSL, NRC excludes EPA from the calculation of low and high estimates, presumably because EPA uses only a single VSL estimate ($8.7 million) instead if a range with lows and highs. However, an alternate way to look at EPA's analysis is to conclude that $8.7 million is both EPA's low and high estimate, as well as its best estimate. Taking the simple mean of the low and high estimates from DOT, DHS, and EPA – and excluding OMB's non-prescriptive reference to the literature – would give a low estimate of $6.9 million (as opposed to the $5.3 million figure NRC calculated) and a high estimate of $10.9 million (as opposed to $13.2 million). [JS-3-1]

NRC Response: The NRC agrees with this comment that relying on the expertise of the EPA and DOT estimates of VSL is a best practice for the reasons given, and agrees that the NRC should not give weight to the OMB reported values. NUREG-1530, Revision 1, uses the DOT low and high VSL values provided in Table 1 of the revised NUREG, which envelop the DHS values. The wording in NUREG-1530, Revision 1, has also been revised to clarify that OMB Circular A-4 reported VSL estimates between $1 million and $10 million per statistical life.

The NRC disagrees with the portion of the comment that $8.7 million is EPA's low, best, and high estimate for its VSL estimate. As explained in EPA's Guidelines for Preparing Economic Analyses, updated May 2014, Table B.1 of that document contains the VSL estimates that form the basis of the EPA's recommended central VSL estimate. Fitting a Weibull distribution to these estimates yields a central estimate (mean) of $7.4 million (in 2006 dollars) with a standard deviation of $4.7 million. After considering this part of the comment, no change was made to NUREG-1530, Revision 1.

Comment e2: The formula to adjust VSL for inflation and growth is appropriate, but NRC should more explicitly coordinate its updates with any VSL updates from EPA, DOT, or DHS.

Prospectively adopting a system to allow for automatic updates to the VSL to account for inflation and growth is a positive step that should help NRC avoid the problem of being stuck for years with an outdated valuation. NRC's plan to review conversion factors every five years is also prudent. However, because NRC is relying on EPA, DOT, and DHS for its estimates, NRC should further provide for updates in coordination with any subsequent work by those three agencies on their VSL estimates—just as NRC proposes to update its risk coefficient as ICRP does so. Harmonizing regulatory analysis across federal agencies is valuable. NRC should explicitly coordinate with EPA, DOT, and other agencies on an ongoing basis, and could consider calling for an interagency working group on VSL estimates. [JS-3-2]

NRC Response: The NRC agrees with this comment that coordination with other Federal agencies to estimate the VSL is appropriate because it saves NRC the cost of duplicating their efforts, increases the rationality and transparency of NRC regulatory analyses, and provides a basis to compare costs and benefits of proposed regulations across Federal agencies. After considering this comment, no change was made to NUREG-1530, Revision 1.

Comment e3: UCS strongly supports the proposal to update the badly outdated $2,000-per-person-rem conversion factor and to develop a process for periodic review. The NRC continues to rely on a parameter that has not been updated in 20 years and is based on a value of statistical life far lower than the values used by other federal agencies. Use of this dated and out-of-step parameter is simply bad regulatory practice and leads to flawed analyses that undermine the credibility of NRC decisions. It is essential that federal agencies strive to achieve consistency in their respective regulatory analyses to engage meaningful assessment of federal actions that may have cross-cutting environmental and public health impacts across different sectors. [EL-11-1]

NRC Response: The NRC agrees with this comment, which summarizes some of the reasons this update to NUREG-1530 has been undertaken.

f. *Other Comments*

Comment f1 (combined NEI and JB): Page 26, line 12, Section 6.1, Number of Significant Figures RE: "In the future to allow for a more frequent adjustment for maintaining alignment with economic changes, the NRC staff should round this number to two significant figures."

In our view, "maintaining alignment with economic changes" is weak justification for rounding to two significant figures. If the "economic changes" contemplated are Inflation and Real Income Growth (two factors presented in the NRC's formula), they have been low for most of the past decade. With present socio-economic trends (e.g., globalization, recession or paltry real economic growth, historically low workforce participation rates, historic levels of governmental debt and deficits), they appear likely to remain low for the next decade as well. Thus "maintaining alignment" is unlikely to be a significant concern.

In addition, because of the imprecision of the overall process in which the dollar per person-rem conversion factor is used, two-digit precision in the dollar per person-rem conversion factor may be nothing but window dressing. For example, it is very difficult (i.e., effortful) to estimate costs of compliance with a proposed requirement to two significant figures. Estimates to an order of magnitude and single digit precision are typical early in the formulation of proposed new requirements. To achieve greater precision, the cost estimator must have a proposed regulatory requirement that is specific enough to enable: (a) an exact compliance solution to be defined, (b) a precise scope of work to be determined to provide that compliance solution, and (c) the timing of the work schedule to be gauged against plant outage schedules and work scopes. Thus, in a realistic assessment of the costs of compliance against the potential person-rem saved, the precision of the final answer would be controlled by the lower precision of the cost estimate. The precision of the final answer would not be improved by maintaining two-digit precision in the dose conversion factor. In other words, the supposed benefit of maintaining two-digit precision in the conversion factor is illusory when considered in context with its use.

On page 29, at lines 30-33, the NRC itself appears to acknowledge the irrelevance of two-digit precision in the cost-benefit calculation, in the following sentence: "…in recognition of the uncertainties inherent in [the dollar per person-rem value], NRC staff and decisionmakers [sic] would typically rely more heavily on other considerations when the break-even cost-beneficial determination was close (e.g., within a factor of five)."

We recommend single-digit precision in the conversion factor as sufficient and practical. [NEI-2-6, JB-10-1]

NRC Response: The NRC disagrees in part with this comment that one significant figure would be sufficient, because the use of two significant figures is needed to properly account for updated values in the conversion factor and will enable a more gradual change in the factor over time. Language has been revised in NUREG-1530, Revision 1, to clarify and provide additional explanation.

Comment f2: UCS supports the approach outlined in NUREG-1530, Rev. 1, to systematically review and update the conversion factors to keep them current by considering both changing economic conditions and new scientific developments. To that end, UCS agrees that the conversion factor should be expressed to two significant figures. However, the NRC staff should make it clear that this choice is needed to properly account for updated values but does not reflect a technical judgement that this highly approximate concept can be quantified to such precision. [EL-11-4]

NRC Response: The NRC agrees with this comment. Language has been revised in NUREG-1530, Revision 1, to clarify and provide additional explanation regarding the use of two significant figures.

Comment f3 (combined NEI and JB): Page 29, lines 19-22, Section 8: "Second, for all other regulatory applications where $2,000 per person-rem has been used by the NRC, the NRC is not proposing that previous decisions be reviewed or updated based on this revised conversion factor policy."

It is unclear how NUREG-1530, Rev. 1, would apply to licensing actions already in progress which are based on the NUREG-1530, Revision 0. If Revision 1 is published prior to a final licensing decision is made (e.g., publishing a Final Supplemental Environmental Impact Statement being issued in a license renewal scenario), the analysis made using terms of NUREG-1530, Revision 0, should not be redone. The cited statement in NUREG-1530, Revision 1, should be modified to state clearly that existing licensing actions will not be reevaluated. [NEI-2-12, JB-10-1]

NRC Response: The NRC ~~disagrees~~ agrees with this comment. While a current applicant may have voluntarily chosen to use the updated conversion factor in NUREG-1530, Revision 1, and the staff has been using it in sensitivity analyses, there is no expectation that the NRC would reevaluate licensing actions already in progress using NUREG-1530, Revision 1.~~The NRC would use the latest version of NUREG-1530 for licensing actions already in progress. However, based on standard NRC practice, the statement on page 29 is correct, "the NRC is not proposing that previous decisions be reviewed or updated based on this revised conversion factor policy."~~ Language has been revised in NUREG-1530, Revision 1, to clarify that the NRC would not reevaluate licensing actions in progress using the updated conversion factor. After considering this comment, no change was made to NUREG-1530, Revision 1.

Commented [DAW1]: The staff should revise the NRC response as shown in text and revise NUREG-1530, Revision 1, to clarify that the NRC would not reevaluate licensing actions in progress using the updated conversion factor.

Comment f4 (combined NEI and JB): Page 31, lines 16-24, Section 9: "With respect to implementation, the NRC staff, licensees, and applicants may begin using the revised conversion factor in all regulatory applications discussed in Section 3 of this report, except for regulatory applications discussed in Section 3.1, "Routine Liquid and Gaseous Effluent Releases from Nuclear Power Plants."

The term "may begin using" is unclear. The question is when the new value becomes mandatory. The NRC should choose a specific date for implementation of NUREG-1530, Rev. 1. That date should be far enough in the future that: (1) the NRC can complete its update of the full suite of guidance documents for regulatory analysis; (2) any potential slippage in completing the guidance documents would not conflict with the NUREG-1530, Rev. 1, implementation date; and (3) implementation would be unlikely to have a significant effect on licensee plans already in progress. The NRC should communicate the implementation date through an appropriate official channel, e.g., an Information Notice supported by a Commission vote on a SECY. On the above basis, we would recommend January 1, 2020, as allowing time for slippage in completing the guidance update plus some lag to allow industry to complete applications that may be planned for submittal in the next few years. [NEI-2-13, JB-10-1]

NRC Response: NUREG-1530, Revision 1 will be in effect upon Commission approval. The staff anticipates that the Commission review of NUREG-1530, Revision 1 could be complete in early 2017. Note, however, that NUREG-1530, Revision 1 is not mandatory; it is one way of meeting the regulations.

Comment f5 (combined PJ and BA): "Federal Law prohibits discrimination against disabled persons. According to 29 U.S.C. 794, no person, solely by reason of their handicap, may be subjected to discrimination by any program or activity which receives federal funds. Since most of the entities involved in evacuating a population receive federal funds, it would be a contravention of federal law MA and NH to effectuate a plan that wholly ignores persons solely by reason of their handicapped status."

I find everything the NRC does the past few years to be absolutely reprehensible. This proposal is a crime against humanity and violation of laws regarding the elderly, disabled and infirm.

Stop the idiocy now before you cause massive lawsuits demanding fulfillment of protection of environment and health. [PJ-4-1, BA-6-1]

NRC Response: The NRC considers this comment to be outside the scope of NUREG-1530, Revision 1. The purpose of NUREG-1530, Revision 1, is to determine values for the dollar per person-rem conversion factor for use in regulatory analysis. After considering this comment, no change was made to NUREG-1530, Revision 1.

Comment f6 (combined AA and DG): The NRC rule provides a VSL rated at around $36,000, and perhaps as low as $4,000 or less. When a life lost is worth so little, it actually encourages radioactive pollution. Is the NRC protecting public health, or promoting industry values that cheapen life and discount deaths.

All life is precious and priceless. There can be no dollar amount put in the grief and sadness of losing a family member to cancer, or a child sickened by cancer, or some other disease attributable to anthropogenic radiation created thru nuclear energy. [AA-5-1, DG-7-4]

NRC Response: The NRC considers this comment to be outside the scope of NUREG-1530, Revision 1. VSL concerns the small change in risk of mortality as a result of radiation exposure, and is set at $9 million. After considering this comment, no change was made to NUREG-1530, Revision 1.

Comment f7: Whenever I see the phrase “to be consistent with” my ears immediately perk up and look for the real intention…usually a deception of some sort. So when I saw “in order to be consistent with the Commission’s policy on metrication, the conversion factor should be expressed in dollars per person-Sv with the value in English units following parenthetically.”

My take on this? Using Sv is just plain wrong, it is a huge measure of radiation, and a way to minimize things to the average citizen who hasn’t studied radiation. Plus it makes the “payout” or value of life appear to be very high. It is much more appropriate to express all terms in mSv, please do so. [SO-9-4]

NRC Response: The NRC disagrees with this comment. Sv is the standard unit of radiation for the metric system, whereas rem (0.01 Sv) is the standard unit in the American system of measurement. Use of this metric unit is consistent with “Conversion to the Metric System; Policy Statement,” dated June 19, 1996 (61 FR 31169). After considering this comment, no change was made to NUREG-1530, Revision 1.

Comment f8: What about the costs related to plants and animals? This human centric view of things does limits the damage. Even if you don’t care about animals…they have value to humans and you should care about that. [SO-9-6]

NRC Response: The NRC disagrees that plants and animals are treated inappropriately and considers this comment to be outside the scope of NUREG-1530, Revision 1. The NRC has set regulatory limits related to the doses to workers and members of the public from radioactive materials released from nuclear power plants. The NRC ensures that effluents from operating plants under its oversight are within the established limits under Title 10 of the *Code of Federal Regulations* (10 CFR), Part 20 and 10 CFR Part 50, Appendix I. The NRC regulations also incorporate by reference the Environmental Protection Agency’s generally applicable environmental radiation standards set forth in 40 CFR Part 190. The regulations are set to protect workers and the public from the harmful health effects of radiation on humans, with the understanding that if levels are kept this low, they would also be protective of plants and animals.

Furthermore, in 1995, the NRC revised its dollar per person-rem conversion factor policy and limited it to human health effects. Therefore, offsite property damage costs, including effects on plants and animals, are estimated separately in order to account for impacts beyond human health concerns. These estimated costs include the impact in terms of food production, whether crop or animal food sources. After considering this comment, no change was made to NUREG-1530, Revision 1.

Comment f9: ALARA, well that will be conveniently be able to be discarded if the other NRC proposal generated from the radiation industry to throw out LNT [linear no-threshold] and then just, replace it with “hormesis, radiation is good for you” or as “doctor” Carol Marcus states…”why deprive them (the general public due to random radiation releases) of the benefits of radiation.” [SO-9-7]

NRC Response: The NRC considers this comment to be outside the scope of NUREG-1530, Revision 1. The proposal regarding LNT is a separate NRC initiative that is independent from NUREG-1530, Revision 1. After considering this comment, no change was made to NUREG-1530, Revision 1.

Comment f10: This document starts with a worthy premise, but the construct seems to be disingenuous. We all know the nuclear industry is challenged by more economic energy technologies. And even without the negative side effects of uranium mining and “normal” releases form nuclear plants, and the long term danger of nuclear waste…even without those, it would still make sense to not try to “support” an industry that has been proven to be too complex, too costly. [SO-9-8]

NRC Response: The NRC considers this comment to be outside the scope of NUREG-1530, Revision 1. The NRC mission is to regulate the civilian uses of nuclear materials in the United States to protect public health and safety, the environment, and the common defense and security. After considering this comment, no change was made to NUREG-1530, Revision 1.