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

NUREG-1530, Rev. 1

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

Final Report

Office of Nuclear Material Safety and Safeguards

AVAILABILITY OF REFERENCE MATERIALS IN NRC PUBLICATIONS

NRC Reference Material

As of November 1999, you may electronically access NUREG-series publications and other NRC records at the NRC's Library at www.nrc.gov/reading-rm.html. Publicly released records include, to name a few, NUREG-series publications; *Federal Register* notices; applicant, licensee, and vendor documents and correspondence; NRC correspondence and internal memoranda; bulletins and information notices; inspection and investigative reports; licensee event reports; and Commission papers and their attachments.

NRC publications in the NUREG series, NRC regulations, and Title 10, "Energy," in the *Code of Federal Regulations* may also be purchased from one of these two sources:

1. **The Superintendent of Documents**
   U.S. Government Publishing Office
   Washington, DC 20402-0001
   Internet: www.bookstore.gpo.gov
   Telephone: (202) 512-1800
   Fax: (202) 512-2104

2. **The National Technical Information Service**
   5301 Shawnee Road
   Alexandria, VA 22312-0002
   Internet: www.ntis.gov
   1-800-553-6847 or, locally, (703) 605-6000

A single copy of each NRC draft report for comment is available free, to the extent of supply, upon written request as follows:

Address: **U.S. Nuclear Regulatory Commission**
Office of Administration
Division of Resource Management & Analysis
Washington, DC 20555-0001
E-mail: distribution.resource@nrc.gov
Facsimile: (301) 415-2289

Some publications in the NUREG series that are posted at the NRC's Web site address www.nrc.gov/reading-rm/doc-collections/nuregs are updated periodically and may differ from the last printed version. Although references to material found on a Web site bear the date the material was accessed, the material available on the date cited may subsequently be removed from the site.

Non-NRC Reference Material

Documents available from public and special technical libraries include all open literature items, such as books, journal articles, transactions, *Federal Register* notices, Federal and State legislation, and congressional reports. Such documents as theses, dissertations, foreign reports and translations, and non-NRC conference proceedings may be purchased from their sponsoring organization.

Copies of industry codes and standards used in a substantive manner in the NRC regulatory process are maintained at—

The NRC Technical Library
Two White Flint North
11545 Rockville Pike
Rockville, MD 20852-2738

These standards are available in the library for reference use by the public. Codes and standards are usually copyrighted and may be purchased from the originating organization or, if they are American National Standards, from—

American National Standards Institute
11 West 42nd Street
New York, NY 10036-8002
Internet: www.ansi.org
(212) 642-4900

The NUREG series comprises (1) technical and administrative reports and books prepared by the staff (NUREG–XXXX) or agency contractors (NUREG/CR–XXXX), (2) proceedings of conferences (NUREG/CP–XXXX), (3) reports resulting from international agreements (NUREG/IA–XXXX),(4) brochures (NUREG/BR–XXXX), and (5) compilations of legal decisions and orders of the Commission and the Atomic and Safety Licensing Boards and of Directors' decisions under Section 2.206 of the NRC's regulations (NUREG–0750).

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

NUREG-1530, Rev. 1

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

Final Report

Manuscript Completed: February 2022
Date Published: February 2022

Pamela Noto, NRC Project Manager

Office of Nuclear Material Safety and Safeguards

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. A reevaluation of the $2,000 per person-rem conversion factor is 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 uses a conversion factor 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.

Paperwork Reduction Act

This NUREG provides voluntary guidance for implementing the mandatory information collections in 10 CFR Parts 20, 50, 51, and 52 that are subject to the Paperwork Reduction Act of 1995 (44 U.S.C. 3501 et seq.). These information collections were approved by the Office of Management and Budget, under control numbers 3150-0014, 3150-0011, 3150-0021, and 3150-0151, respectively. Send comments regarding this information collection to the FOIA, Library, and Information Collections Branch (T6-A10M), U.S. Nuclear Regulatory Commission, Washington, DC 20555-0001, or by e-mail to Infocollects.Resource@nrc.gov, and to the Desk Officer, Office of Information and Regulatory Affairs, NEOB-10202 (3150 0014, 3150 0011, 3150-0021, and 3150 0151), Office of Management and Budget, Washington, DC, 20503.

Public Protection Notification

The NRC may not conduct or sponsor, and a person is not required to respond to, a collection of information unless the document requesting or requiring the collection displays a currently valid OMB control number.

Congressional Review Act

This NUREG is a rule as defined in the Congressional Review Act (5 U.S.C. 801-808). However, the Office of Management and Budget has not found it to be a major rule as defined in the Congressional Review Act.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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, 2011a). 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, regulatory guides, orders, standard review plans, branch technical positions, and standard technical specifications. 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.

A reevaluation of the $2,000 per person-rem conversion factor is 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, "Valuing Nonfatal Cancer Risks in Cost-Benefit Analysis," 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 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. Revision 1 to NUREG/BR-0058 already reflected the intent of the EO. 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 $1000 per total body man-rem and $1000 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. As further discussed in the Section 3.4, "Regulatory Analyses," and Section 3.5, "Backfit Analyses," 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 currently 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 is incorporated into NUREG/BR-0058, Revision 5. NUREG/BR-0058, Revision 5 reflects the policy described in this report and is under consideration by the Commission as of the date of publication of 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.

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 NRC's current backfitting guidelines. 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.

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 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 NRC's current regulatory analysis guidelines. 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 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, 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.

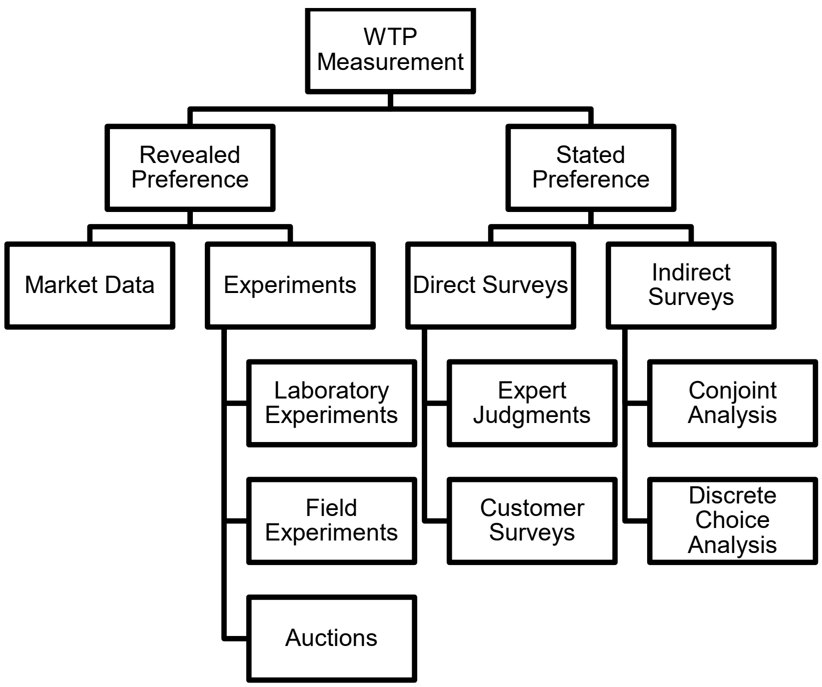

Figure 1 Classification Framework for Methods to Measure Willingness-to-Pay

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 the current state 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 2010, the EPA issued revised “Guidelines for Preparing Economic Analyses” and updated its VSL to $7.9 million in 2008 dollars (EPA, 2010a). 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).

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, 2010b). 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, 2011b). 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, 2011b).

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, 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. VSL_{2013+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:

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

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 (FDA, 2003; FDA, 2005). 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 are 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). Other Federal agencies, specifically the EPA and the DOT, have expended significant resources on developing their approaches. The NRC staff believe it is prudent to leverage the work done by these agencies 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. The NRC staff believe that averaging DOT's VSL and EPA's VSL produces a balanced and reliable VSL.

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 likely would be similar because it would use the same underlying studies as the basis of its analysis. Therefore, the staff will adopt 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, 2011a). The EPA's value aligns the coefficient with the underlying definition of WTP used in the VSL value that only addresses mortality. 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 in an appendix to NUREG/BR-0058, Revision 5. 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 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).

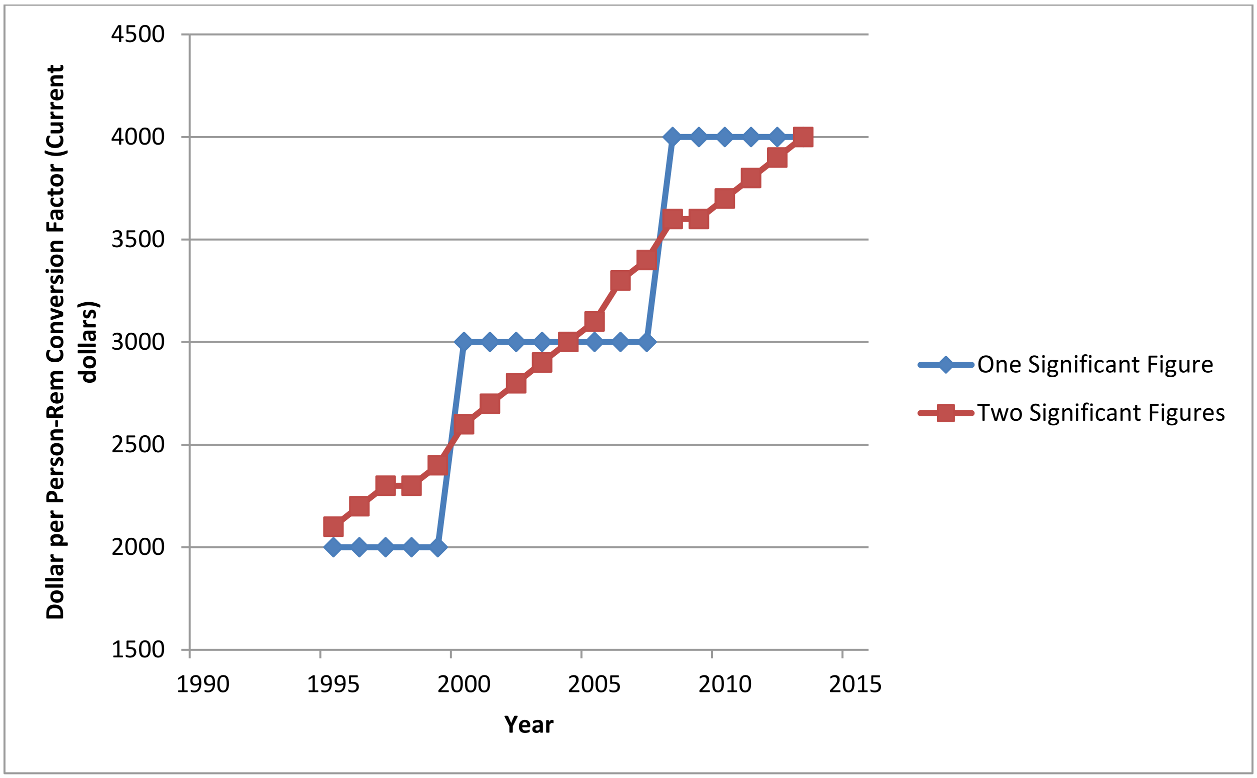

Figure 2 Difference between Rounding to One and Two Significant Figures

7 METHODOLOGY FOR MAINTAINING CONVERSION FACTORS

The U.S. Nuclear Regulatory 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, 2022a). 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, 2022b). 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. 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, 2010b), which was reviewed and approved by the EPA's Science Advisory Board (SAB) (EPA, 2011b). 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:

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

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 (mid-year)
- 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 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	238.778	2016 Half1
Previous Half-Year CPI-U	237.769	2015 Half2
Current Year CPI-U (average)	**238.2735**	

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.

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

$$\frac{238.2735}{236.736}\ x\ 100\% = 100.64946\%$$

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, 2022b.

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, 2008).

Step 4: MUWE data is reported quarterly. Collect the most recent four quarters of MUWE from BLS Series LEU0252881500 (BLS, 2022b) and calculate the average.

Most recent Quarter MUWE (2Q 2016)	824
First Previous Quarter MUWE (1Q 2016)	830
Second Previous Quarter MUWE (4Q 2015)	825
Third Previous Quarter MUWE (3Q 2015)	803
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: $\text{Dollar per Person} - \text{Rem}_{current} = \$2{,}600 \times (1.0064946) \times (1.03729)^{0.5} = \$2{,}700$

Best: $\text{Dollar per Person} - \text{Rem}_{current} = \$5{,}200 \times (1.0064946) \times (1.03729)^{0.5} = \$5{,}300$

High: $\text{Dollar per Person} - \text{Rem}_{current} = \$7{,}800 \times (1.0064946) \times (1.03729)^{0.5} = \$8{,}000$

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 reevaluate its baseline values for VSL and the cancer mortality risk coefficient, and will update 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 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. 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 as one input among many in the regulatory decision. Second, in recognition 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.

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."

10 REFERENCES

Andersson, H. and N. Treich, “The Value of a Statistical Life,” A. de Palma et al., eds., *A Handbook of Transport Economics*, Chapter 17, pages 396-424, 2011.

Atomic Energy Act of 1954, as amended, 42 United States Code (U.S.C.) 2011 et seq.

Bellavance, F., G. Dionne, and M. Lebeau, “The value of a statistical life: a meta-analysis with a mixed effects regression model,” *Journal of Health Economics*, 28(2): 444-464, 2009.

Blumenschein, K., et al., “Eliciting Willingness to Pay without Bias: Evidence from a Field Experiment,” *The Economic Journal*, 118:114-137, 2008.

Breidert, C., et al., “A Review of Methods for Measuring Willingness-to-Pay,” *Innovative Marketing.* 2(4): 8-32, 2006.

Carson, R.T., N.E. Flores, and N.F. Meade, “Contingent Valuation: Controversies and Evidence,” *Environmental and Resource Economics*, 19(2): 173-210, 2001.

Dockins, C. et al., “Value of Statistical Life Analysis and Environmental Policy: A White Paper.” U.S. Environmental Protection Agency, National Center for Environmental Economics, 2004.

Energy Reorganization Act, as amended, 42 U.S.C. 5801 et seq.

Limerick Ecology, *Limerick Ecology Action, Inc., v. NRC,* 869 F.2d 719 (3rd Cir. 1989).

Mrozek, J.R., and L.O. Taylor, “What Determines the Value of Life? A Meta-Analysis,” *Journal of Policy Analysis and Management*, 21(2): 253-270, 2002.

International Commission on Radiological Protection (ICRP), *1990 Recommendations of the International Commission on Radiological Protection,* ICRP Publication No. 60, Pergamon Press, 1991.

ICRP, *The 2007 Recommendations of the ICRP,* ICRP Publication No. 103, Elsevier, 2007.

National Academy of Sciences (NAS), “Health Risks from exposure to low levels of ionizing radiation: BEIR VII Phase 2”, *National Academies Press*, 2006.

Office of the President, “Executive Order 11821: Inflation Impact Statements,” *Federal Register,* Vol. 39, p. 41501, November 29, 1974 (39 FR 41501).

Office of the President, “Executive Order 11949: Economic Impact Statements,” *Federal Register,* Vol. 42, p. 1017, January 5, 1977 (42 FR 1017).

Office of the President, “Executive Order 12291: Federal Regulation,” *Federal Register,* Vol. 46, p. 13193, February 19, 1981 (46 FR 13193).

Office of the President, “Executive Order 12866: Regulatory Planning and Review,” *Federal Register,* Vol. 58, p. 51735, October 4, 1993 (58 FR 51735).

Trottenberg, P. and R. Rivkin, Memorandum to Secretarial Officers, Modal Administrators, “Guidance on Treatment of the Economic Value of a Statistical Life in U.S. Department of Transportation Analyses,” U.S. Department of Transportation, 2015.

U.S. Bureau of Labor Statistics (BLS), “Help & Tutorials: Series ID,” July 19, 2008. Accessed at http://www.bls.gov/help/hlpform3.htm. Last accessed date, January 13, 2022.

BLS, “CPI for All Urban Consumers (CPI-U): Series ID: CUUR0000SA0, Not Seasonally Adjusted,” 2022a. Accessed at https://data.bls.gov/timeseries/CUUR0000SA0. Last accessed date, January 13, 2022.

BLS, “Weekly and Hourly Earnings Data from the Current Population Survey: Series LEU0252881500,” 2022b. Accessed at https://data.bls.gov/timeseries/LEU0252881500. Last accessed date, January 13, 2022.

U.S. Code of Federal Regulations (CFR), “Standards for Protection against Radiation,” Part 20, Title 10, “Energy.”

CFR, “Domestic Licensing of Production and Utilization Facilities,” Part 50, Title 10, “Energy.”

CFR, “Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions,” Part 51, Title 10, “Energy.”

CFR, “Licenses, Certifications, and Approvals for Nuclear Power Plants,” Part 52, Title 10, “Energy.”

U.S. Congressional Research Services (CRS), “How Agencies Monetize ‘Statistical Lives’ Expected to Be Saved By Regulations,” March 24, 2010. Accessed at http://digital.library.unt.edu/ark:/67531/metadc812693/m2/1/high_res_d/R41140_2010Mar24.pdf. Last accessed date, January 7, 2022.

U.S. Department of Homeland Security (DHS), “Valuing Mortality Risk Reductions in Homeland Security Regulatory Analyses: Final Report,” June 2008. Accessed at https://www.researchgate.net/publication/43438929_Valuing_Mortality_Risk_Reductions_in_Homeland_Security_Regulatory_Analyses. Last accessed date, January 7, 2022.

DOT, “Guidance on Treatment of the Economic Value of Statistical Life (VSL) in U.S. Department of Transportation Analyses,” February 28, 2013. Accessed at http://www.dot.gov/sites/dot.dev/files/docs/DOT%202013%20Signed%20VSL%20Memo.pdf. Last accessed date, January 7, 2022.

DOT, “Guidance on Treatment of the Economic Value of Statistical Life (VSL) in U.S. Department of Transportation Analyses—2014 Adjustment,” June 13, 2014. Accessed at http://www.dot.gov/sites/dot.gov/files/docs/VSL_Guidance_2014.pdf. Last accessed date, January 7, 2022.

U.S. Environmental Protection Agency (EPA), “The Benefits and Costs of the Clean Air Act: 1990-2010: EPA Report to Congress,” November 1999. Accessed at https://www.epa.gov/clean-air-act-overview/benefits-and-costs-clean-air-act-1990-2010-first-prospective-study. Last accessed date, January 7, 2022.

EPA, "Guidelines for Preparing Economic Analyses," September 2000. Accessed at https://www.epa.gov/environmental-economics/guidelines-preparing-economic-analysis-2000. Last accessed date, January 7, 2022.

EPA, "Guidelines for Preparing Economic Analyses," December 17, 2010. 2010a. Accessed at https://www.epa.gov/environmental-economics/guidelines-preparing-economic-analyses. Last accessed date, January 7, 2022.

EPA, "Valuing Mortality Risk Reductions for Environmental Policy: A White Paper," December 10, 2010. 2010b. Accessed at https://www.epa.gov/environmental-economics/valuing-mortality-risk-reductions-environmental-policy-white-paper-2010. Last accessed date, January 7, 2022.

EPA, "EPA Radiogenic Cancer Risk Models and Projections for the U.S. Population," April 2011, 2011a. Accessed at https://www.epa.gov/radiation/epa-radiogenic-cancer-risk-models-and-projections-us-population. Last accessed date, January 10, 2022.

EPA, Memorandum from EPA's Science Advisory Board to the Honorable Lisa P. Jackson, Administrator, "Review of Valuing Mortality Risk Reductions for Environmental Policy: A White Paper, (December 10, 2010)," EPA-SAB-11-011, July 29, 2011, 2011b. ADAMS Accession No. ML22012A344.

EPA, "Regulatory Impact Analysis for the Proposed Carbon Pollution Guidelines for Existing Power Plants and Emission Standards for Modified and Reconstructed Power Plants," Publication No. EPA-452/R-14-002, June 2014. Accessed at https://www.epa.gov/sites/production/files/2014-06/documents/20140602ria-clean-power-plan.pdf. Last accessed date, January 10, 2022.

EPA, EPA Science Advisory Board (SAB) Home Page, Updated on January 3, 2022. Accessed at http://yosemite.epa.gov/sab/sabpeople.nsf/WebCommittees/BOARD. Last accessed date, January 10, 2022.

U.S. Food and Drug Administration (FDA), "Food labeling; trans fatty acids in nutrition labeling; consumer research to consider nutrient content and health claims and possible footnote or disclosure statements; final rule and proposed rule," *Federal Register*, Vol. 68, No. 133, July 11, 2003 (68 FR 41434). Accessed at https://www.govinfo.gov/content/pkg/FR-2003-07-11/pdf/03-17525.pdf. Last accessed date, January 10, 2022.

FDA, "Electronic products; performance standard for diagnostic x-ray systems and their major components; final rule," *Federal Register,* Vol. 70, No. 111, June 10, 2005 (70 FR 33998). Accessed at http://www.gpo.gov/fdsys/pkg/FR-2005-06-10/pdf/05-11480.pdf. Last accessed date, January 10, 2022.

FDA, "Labeling for Bronchodilators to Treat Asthma; Cold, Cough, Allergy, Bronchodilator, and Antiasthmatic Drug Products for Over-the-Counter Human Use; final rule," *Federal Register*, Vol. 76, No. 143, July 26, 2011 (76 FR 44475). Accessed at https://www.govinfo.gov/content/pkg/FR-2011-07-26/pdf/FR-2011-07-26.pdf. Last accessed date, January 11, 2022.

Limerick Ecology Action vs. NRC, 869 F.2d 719 (3rd Cir. 1989).

U.S. Nuclear Regulatory Commission (NRC), Appendix I to 10 CFR Part 50: 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, *Federal Register,* Vol. 40, p. 19439, May 5, 1975 (40 FR 19439), 1975a.

NRC, "Reactor Safety Study: An Assessment of Accident Risks in U.S. Commercial Nuclear Power Plants (WASH-1400)," NUREG-75/014, 1975b. ADAMS Accession No. ML15161A213.

NRC, "Value-Impact Analysis Guidelines," SECY-77-388A, 1977. ADAMS Accession No. ML12234B122.

NRC, "Licensing Requirements for Pending Construction Permit and Manufacturing License Applications; Final Rule," *Federal Register,* Vol. 47, p. 2286, January 15, 1982 (47 FR 2286), 1982a.

NRC, "Resolution of Generic Safety Issues (Formerly entitled A Prioritization of Generic Safety Issues): Main Report with Supplements 1-34," NUREG-0933, 1982b.

NRC, "Regulatory Analysis Guidelines of the U.S. Nuclear Regulatory Commission," NUREG/BR-0058, Revision 0, 1983a. ADAMS Accession No. ML15027A412.

NRC, "A Handbook for Value-Impact Assessment," NUREG/CR-3568, 1983b. ADAMS Accession No. ML062830096.

NRC, "Safety Goals for Nuclear Power Plant Operation," NUREG-0880, Revision 1, 1983c. ADAMS Accession No. ML071770230.

NRC, "Regulatory Analysis Guidelines of the U.S. Nuclear Regulatory Commission," NUREG/BR-0058, Revision 1, 1984. ADAMS Accession No. ML15027A413.

NRC, "Basis for Quantifying Offsite Property Losses," Memorandum from W.J. Dircks to Commission, October 23, 1985, 1985a. ADAMS Accession No. ML15050A141.

NRC, "Advanced Boiling Water Reactor Standard Safety Analysis Report," General Electric Nuclear Energy, 1985b. ADAMS Accession No. ML15014A502.

NRC, "Safety Goals for the Operations of Nuclear Power Plants; Policy Statement," *Federal Register,* Vol. 51, p. 28044, August 4, 1986 (51 FR 28044), as revised by Vol. 51, p. 30028, August 21, 1986 (51 FR 30028).

NRC, "Individual Plant Examination for Severe Accident Vulnerabilities – 10 CFR 50.54(f) (Generic Letter No. 88-20)," 1988. ADAMS Accession No. ML031150465.

NRC, "Backfitting Guidelines," NUREG-1409, 1990. ADAMS Accession No. ML032230247.

NRC, "ALARA Levels for Effluents from Materials Facilities," Regulatory Guide 8.37, 1993. ADAMS Accession No. ML003739553.

NRC, "Reassessment of NRC's Dollar per Person-Rem Conversion Factor Policy," NUREG-1530, Revision 0, 1995a. ADAMS Accession No. ML063470485.

NRC, "Regulatory Analysis Guidelines of the U.S. Nuclear Regulatory Commission," NUREG/BR-0058, Revision 2, 1995b. ADAMS Accession No. ML111180434.

NRC, "Environmental Review for Renewal of Nuclear Power Plant Operating Licenses," *Federal Register,* Vol. 61, No. 109, June 5, 1996 (61 FR 28467), 1996a.

NRC, "Generic Environmental Impact Statement for License Renewal of Nuclear Plants," NUREG-1437, Volumes 1 and 2, 1996b. ADAMS Accession Nos. ML040690705 and ML13106A242.

NRC, "Regulatory Analysis Technical Evaluation Handbook: Final Report," NUREG/BR-0184, 1997. ADAMS Accession No. ML050190193.

NRC, "Standard Review Plans for Environmental Reviews for Nuclear Power Plants," NUREG-1555, Volume 2, 1999. ADAMS Accession No. ML003701937.

NRC, "Regulatory Analysis Guidelines of the U.S. Nuclear Regulatory Commission," NUREG/BR-0058, Revision 3, 2000. ADAMS Accession No. ML023290519.

NRC, "Environmental Review Guidance for Licensing Actions Associated with NMSS Programs," NUREG-1748, Final Report, 2003. ADAMS Accession No. ML032450279.

NRC, "Regulatory Analysis Guidelines of the U.S. Nuclear Regulatory Commission," NUREG/BR-0058, Revision 4, 2004. ADAMS Accession No. ML042820192.

NRC, "Frequently Asked Questions on License Renewal of Nuclear Power Reactors," NUREG-1850, Final Report, 2006. ADAMS Accession No. ML061110022.

NRC, "Standard Review Plans for Environmental Reviews for Nuclear Power Plants: Environmental Standard Review Plan for New Site/Plant Applications," NUREG-1555, Revised Sections, 2007. Accessed at http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1555/updates.html. Last accessed date, January 11, 2022.

NRC, "Options to Revise Radiation Protection Regulations and Guidance with Respect to the 2007 Recommendation of the International Commission on Radiological Protection," Staff Requirements Memorandum to SECY-08-0197, 2009. ADAMS Accession No. ML090920103.

NRC, "Consideration of Economic Consequences within the U.S. Nuclear Regulatory Commission's Regulatory Framework," SECY-12-0110, 2012a. ADAMS Accession No. ML12173A478.

NRC, "Regulatory Analysis and Backfitting for the Consideration of Additional Requirements for Containment Venting Systems for Boiling Water Reactors with Mark I and Mark II Containments," SECY-12-0157, 2012b. ADAMS Accession No. ML12312A456.

NRC, "Consideration of Economic Consequences within the U.S. Nuclear Regulatory Commission's Regulatory Framework," Staff Requirements Memorandum to SECY-12-0110, 2013a. ADAMS Accession No. ML13079A055.

NRC, "Regulatory Analysis for Japan Lessons-Learned Tier 3 Issue on Expedited Transfer of Spent Fuel," COMSECY-13-0030, 2013b. ADAMS Accession No. ML13273A628.

NRC, "Standard Review Plans for Environmental Reviews for Nuclear Power Plants: Supplement 1: Operating License Renewal," NUREG-1555, Supplement 1, Revision 1, Final Report, 2013c. ADAMS Accession No. ML13106A246.

NRC, "Plan for Updating the U.S. Nuclear Regulatory Commission's Cost-Benefit Guidance," SECY-14-0002, 2014. ADAMS Accession No. ML13274A495.

NRC, "Valuing Nonfatal Cancer Risks in Cost-Benefit Analysis," SECY-20-0074, 2020. ADAMS Accession No. ML20058C222.

U.S. Occupational Safety and Health Administration (OSHA), "Safety Standards for Steel Erection; Final Rule," *Federal Register,* Vol. 66, No. 12, January 18, 2001 (66 FR 5196). Accessed at http://www.gpo.gov/fdsys/pkg/FR-2001-01-18/html/01-979.htm. Last accessed date, January 11, 2022.

OSHA, "Occupational Exposure to Hexavalent Chromium," *Federal Register,* Vol. 71, 71 FR 10100, February 28, 2006 (71 FR 10100). Accessed at https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_id=18599&p_table=federal_register. Last accessed date, January 11, 2022.

OSHA, "Hazard Communication; Final Rule," *Federal Register*, Vol. 77, No. 58, March 26, 2012 (77 FR 17574). Accessed at https://www.osha.gov/laws-regs/federalregister/2012-03-26. Last accessed date, January 11, 2022.

U.S. Office of Management and Budget (OMB), "Regulatory Impact Analysis Guidance, Appendix V in Regulatory Program of the United States Government: April 1, 1992 – March 31, 1993," Document No. S/N 041-001-00388-6.

OMB, "Economic Analysis of Federal Regulations under Executive Order 12866," January 11, 1996. Accessed at https://georgewbush-whitehouse.archives.gov/omb/inforeg/riaguide.html. Last accessed date, January 11, 2022.

OMB, "Guidelines to Standardize Measures of Costs and Benefits and the Format of Accounting Statements," Memorandum-00-008, March 22, 2000. Accessed at http://www.whitehouse.gov/sites/default/files/omb/assets/omb/memoranda/m00-08.pdf. Last accessed date, August 23, 2016.

OMB, "2002 Draft Report to Congress on the Costs and Benefits of Federal Regulations," 2002. Accessed at https://www.federalregister.gov/documents/2002/03/28/02-7257/draft-report-to-congress-on-the-costs-and-benefits-of-federal-regulations. Last accessed date, January 11, 2022.

OMB, "Regulatory Analysis," Circular No. A-4, September 17, 2003. Accessed at https://www.whitehouse.gov/sites/whitehouse.gov/files/omb/circulars/A4/a-4.pdf. Last accessed date, January 11, 2022.

OMB, "2014 Draft Report to Congress on the Benefit and Costs of Federal Regulations and Unfunded Mandates on State, Local, and Tribal Entities," 2014. Accessed at https://www.whitehouse.gov/sites/whitehouse.gov/files/omb/inforeg/inforeg/2014_cb/2014-cost-benefit-report.pdf. Last accessed date, January 11, 2022.

Viscusi, W.K. and J.E. Aldy, "The Value of a Statistical Life: A Critical Review of Market Estimates Throughout the World," *Journal of Risk and Uncertainty*, 27(1):5-76, 2003.

Viscusi, W.K. and J.E. Aldy, "Labor Market Estimates of the Senior Discount for the Value of a Statistical Life," *Journal of Environmental Economics and Management*, 53(3):377-392, 2007.

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, 2011a).

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, Revision 1

2. TITLE AND SUBTITLE
Reassessment of NRC's Dollar per Person-Rem Conversion Factor Policy
Final Report

3. DATE REPORT PUBLISHED

MONTH	YEAR
February	2022

4. FIN OR GRANT NUMBER

5. AUTHOR(S)
Christina England, Tina Ghosh, Antonio Gomez, Daniel Hudson, Pamela Noto, Donald Palmrose, Jeffrey Rikhoff, Aaron Sanders, Fred Schofer, Amy Sharp

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.)
Division of Rulemaking, Environmental, and Financial Support
Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
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)

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. 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 uses a conversion factor 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.

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
50

16. PRICE

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, DC 20555-0001

OFFICIAL BUSINESS

@NRCgov

NUREG-1530, Rev. 1
Final

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

February 2022