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United States Nuclear Regulatory Commission

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NUREG-1530, Rev. 1

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

Draft Report for Comment

Office of Nuclear Reactor Regulation

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Draft Report for Comment

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ABSTRACT

This proposed revision to NUREG-1530, "Reassessment of NRC's Dollar per Person-Rem Conversion Factor Policy," revises the dollar per person-rem conversion factor (NRC, 1995a). NUREG-1530 was initially published in December 1995. The U.S. Nuclear Regulatory Commission (NRC) uses the dollar per person-rem conversion in cost-benefit analyses to determine the monetary valuation of the consequences associated with radiological exposure and establishes this factor by multiplying a value of a statistical life coefficient by a nominal risk coefficient.[1] The 1995 version of NUREG-1530 set the dollar per-person rem value at $2,000.[2] This number resulted from the multiplication of the value of a statistical life ($3 million) by the risk coefficient for stochastic health effects (7.3×10^{-4} per person-rem).[3] NUREG-1530 instructs the staff to round the dollar per person-rem conversion factor to the nearest $1,000 value.

This revision to NUREG-1530 makes five changes to the previous version. First, it updates the dollar per person-rem conversion factor to $5,100 per person-rem. The value is based on an updated value of a statistical life of $9.0 million and a nominal risk coefficient factor of 5.7×10^{-4} per person-rem. Second, it uses low and high estimates of a statistical life value instead of a single value. Third, it directs the staff to round the conversion factor to two significant figures instead of simply rounding to the nearest $1,000 value. Fourth, it establishes a method for keeping the dollar per person-rem conversion factor current. Finally, it provides guidance to the staff on when to use a higher dollar per person-rem conversion factor.

[1] The International Commission on Radiological Protection defines nominal risk coefficient as the "sex-averaged and age-at-exposure-averaged lifetime risk estimates for a representative population." This coefficient combines the cancer risks and heritable risks from radiation exposure (ICRP, 2007).

[2] In order to be consistent with the Commission's policy on metrication (57 FR 46202), the conversion factor should be expressed in dollars per person-sievert (Sv) with the value in English units following parenthetically. Note that a sievert (Sv) is equal to 100 rem. Therefore, for example, $2,000 per person-rem is equal to $200,000 per person Sv. However, for purposes of continuity and to facilitate review, dollars per person-rem shall be the unit used throughout this report.

[3] Stochastic health effects refer to the likelihood that effects will occur from long-term, low-level exposure to radiation.

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ABBREVIATIONS AND ACRONYMS

10 CFR	Title 10 of the *Code of Federal Regulations*
ADAMS	Agencywide Documents Access and Management System
AEA	Atomic Energy Act, 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 Statements
E.O.	Executive Orders
EPA	U.S. Environmental Protection Agency
FDA	U.S. Food and Drug Administration
FR	*Federal Register*
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
NRPB	National Radiological Protection Board
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
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 BACKGROUND

For all activities regulated by the U.S. Nuclear Regulatory Commission (NRC), the Commission has the authority to require safety improvements necessary to ensure adequate protection of the health and safety of the public. The NRC uses various tools to determine whether a safety improvement is needed, including a cost-benefit analysis. The NRC's cost-benefit analyses rely, in part, on monetizing the health detriment of radiation exposure. The NRC monetizes the total health detriment of radiation as dollars per person-rem of collective dose.[1]

For approximately the last two decades, the NRC has used a conversion factor of $2,000 per person-rem 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 in order to allow a quantitative comparison of the costs and benefits associated with a proposed regulatory decision.

This value has been used as a reference point in NRC regulatory analyses including those involving: (1) routine liquid and gaseous effluent releases, (2) accidental releases, (3) Title 10 of the *Code of Federal Regulations* (10 CFR), Part 20, "Standards for Protection Against Radiation," in dose minimization programs, (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 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 improve decisions made by NRC managers and the Commission. Regulatory actions needed to ensure adequate protection of the health and safety of the public or the common defense and security from the operation of production and utilization facilities do not require a regulatory analysis.[2] Thus the $2,000 per person-rem conversion factor does not apply to these actions, except in assessing alternative approaches to achieving adequate protection.

The NRC has become aware of alternative estimates and methods for arriving at a conversion factor. In addition, the continued validity of the $2,000 per person-rem conversion factor has been questioned because estimates and bases for the value of a statistical life (VSL) and nominal risk coefficients are different since the NRC published NUREG-1530, "Reassessment of NRC's Dollar per Person-Rem Conversion Factor Policy," in 1995 (NRC, 1995a).

The NRC's revision is based on the logic in which the new dollar per person-rem conversion factor attempts to capture a reasonable dollar value of the total health detriment resulting from

[1] Total health detriment combines both mortality (e.g., fatal cancers) and morbidity effects (e.g., nonfatal cancers and hereditary effects).

[2] See section 182(a) of the Atomic Energy Act, as amended, (AEA) and 10 CFR 50.109(a)(4)(ii).

radiation exposure. As such, the proposed dollar per person-rem factor considers the VSL and a nominal risk coefficient that establishes the nominal probability for stochastic health effects attributable to radiological exposure. The nominal risk coefficient takes into account fatal and nonfatal cancers and hereditary effects. The resulting dollar per person-rem conversion factor is not applicable to deterministic health effects, including early fatalities, which would result from acute high doses to particular individuals.[3] Thus, the conversion factor is compatible with the Commission's reactor safety goal policy that states, "[t]he Commission wants to make clear that no death attributable to nuclear power plant operation will ever be 'acceptable' in the sense that the Commission would regard it as a routine or permissible event" (NRC, 1986).

[3] Deterministic health effects in humans can result from general or localized tissue irradiation causing an amount of cell killing that cannot be compensated for by the proliferation of viable cells. The resulting loss of cells can cause severe and clinically detectable impairment of function in a tissue or organ (ICRP, 1991).

2 HISTORY

The NRC and its predecessor agency, the Atomic Energy Commission, have a long history with the dollar per person-rem conversion factor. 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 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." 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." Published studies that were mentioned in the record for rulemaking 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 (E.O.) issued during the Ford administration (E.O. 11821 and E.O. 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 the "Reactor Safety Study: An Assessment of Accident Risks in U.S. Commerical Nuclear Power Plants (WASH-1400)," and recommended that the person-rem averted from proposed changes be multiplied by $1,000 per person-rem in order 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 "A Prioritization of Generic Safety Issues," NUREG-0933 (NRC, 1982b). NUREG-0933 used $1,000 per person-rem value 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 these contexts, the $1,000 per person-rem value has been the figure of merit and one factor in the respective assessments.

In February 1981, President Reagan issued E.O. 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, E.O. 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 E.O. 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 E.O. 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. This E.O. was later superseded by E.O. 12866.

In January 1983, the NRC published NUREG/BR-0058, "Regulatory Analysis Guidelines of the U.S. Nuclear Regulatory Commission" (identified in the rest of this document as the "Guidelines") followed in December 1983 by publication of NUREG/CR-3568, "A Handbook for Value-Impact Assessment" (NRC, 1983a and 1983b, respectively). These documents were issued to formalize NRC's policies and procedures for analyzing the costs and benefits of proposed regulatory actions. The $1,000 per person-rem figure was not mentioned in the first revision of the Guidelines issued in May 1984, 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 1983, the NRC issued an interim Policy Statement on Safety Goals for the Operation of Nuclear Power Plants for use during a two-year trial period (NRC, 1983c). In this 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 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 two-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 on Safety Goals when published in August 1986 (NRC, 1986).

In 1985, the NRC 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 a memorandum from the NRC Executive Director for Operations to the Commissioners dated October 23, 1985 (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 eighty 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 Third U.S. 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). NRC staff subsequently evaluated SAMDA analyses for Limerick, Comanche Peak, and Watts Bar nuclear power plants prior to 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, NRC staff used the $1,000 per person-rem value as a screen to compare costs and benefits.

In September 1993, President Clinton issued E.O. 12866. The NRC, as an independent agency, is not required to comply with the E.O. However, the revision reflects the intent of the E.O., in part, because of the Commission's previously expressed desire to meet the spirit of Executive Orders related to regulatory reform and decisionmaking. As a result, the NRC issued revision 2 to the Guidelines (NRC, 1995b). Revision 2 reflected the experience accumulated by the NRC in implementing the first revision of the Guidelines and changes to NRC's regulations since 1984.

In 1995, the NRC revisited the $1,000 per person-rem value and issued "Reassessment of NRC's Dollar per Person-Rem Conversion Factor Policy," 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 are now necessary to account for impacts beyond human health impacts. This revision does not address impacts beyond human health impacts, such as offsite property damage costs. The dollar per person-rem estimate was derived from the 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.[1] 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 Radiation Protection (ICRP) Publication No. 60 (ICRP, 1991). This risk

[1] As discussed in NUREG-1530, revision 0, 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.

coefficient utilizes a nominal coefficient that includes both mortality (e.g., fatal cancers) and morbidity (e.g., nonfatal cancers and hereditary effects).

In January 1997, the NRC issued the "Regulatory Analysis Technical Evaluation Handbook," NUREG/BR-0184, herein referred to as the "Handbook" (NRC, 1997). The Handbook expands upon policy concepts included in the Guidelines and provides data and methods to support regulatory analyses.

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

In 2010, the NRC 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 NUREG-1530 (NRC, 2012a). In the Staff Requirements Memorandum (SRM) to SECY-12-0110, the Commission approved the NRC staff's recommendations (NRC, 2013a). While updating NUREG-1530, the NRC staff has used the $2,000 per person-rem value from the original revision of NUREG-1530 and, on a case-by-case basis, used other dollar per person-rem values to understand the sensitivity of this parameter on the resulting cost and benefit estimates.[2]

[2] For example, the staff used $2,000 and $4,000 per person-rem values in the regulatory analyses performed for COMSECY-13-0030, "Staff Evaluation and Recommendation 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) has applied the dollar per person-rem conversion factor in a variety of regulatory applications including the evaluation of routine effluent releases from nuclear power plants, accident releases, and radiation protection practices, as well as regulatory analyses, backfit analyses, and environmental analyses.

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' for Radioactive Material in Light-Water-Cooled Nuclear Power Reactor Effluents," (Section II, Paragraph D) in a paragraph related to items to be included in a license applicant's radioactive waste system. That regulation states, in part:

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

The conversion factor cited in this regulation has not been updated since the rule was promulgated in 1975 (NRC, 1975a).[3] Since this conversion factor is a regulatory requirement, the staff and applicants have been using the $1,000 per total body man-rem and $1,000 per man-thyroid-rem in their evaluations and not the $2,000 per person-rem of NUREG-1530 or NUREG/BR-0058.[4]

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 man-rem and $1,000 per man-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 such that when added sequentially and in order of diminishing cost-benefit returns can effect 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. As discussed in the Handbook, when calculating accident-related attributes, the NRC staff draws from risk/reliability assessments or statistically-based analyses (NRC, 1997). As further discussed in the Regulatory Analyses and Backfit Analyses sections

[3] The NRC staff notes that the NRC staff and licensees shall use this conversion factor of $1,000 per total body man-rem and $1,000 per man-thyroid-rem for applying for design approvals for radioactive waste systems, and not the values discussed in this report.

[4] 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. They are equivalent for the purposes of radiological effects.

below, the NRC staff calculates the incremental change in public risk that would result from the proposed regulatory action and converts it to a dollar per person-rem value using discounted factors.

3.3 10 CFR Part 20 ALARA Program

As required by 10 CFR 20.1101(b), licensees should make every reasonable effort to keep radiation exposures, and releases of radioactive materials, as low as is reasonably achievable (ALARA). This regulation applies to all 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 Part 20 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 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 licenses that they should consider engineering options to achieve ALARA goals in the release of effluents and that modifications should be implemented unless an analysis indicates that a substantial reduction in collective dose would not result or the costs are considered unreasonable. One basis for reasonableness identified in this regulatory guide is a quantitative cost-benefit analysis which requires the use of a dollar value per unit dose averted. RG 8.37 recommends the use of $1,000 per person-rem, and acknowledges that a wide range of values could be justified (NRC, 1993).

3.4 Regulatory Analyses

NRC staff guidance for preparing regulatory analyses is discussed in NUREG/BR-0058, "Regulatory Analysis Guidelines of the U.S. Nuclear Regulatory Commission." When preparing regulatory analyses, 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).

NUREG/BR-0058, revision 4, 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).

NUREG/BR-0184 translates the policy concepts in NUREG/BR-0058 into six steps for preparing regulatory analysis into implementable methodologies for the analyst. NUREG/BR-0184 instructs the staff to use the $2,000 per person-rem value for the year in which the exposure is expected to occur and then discounted to present value for purposes of evaluating benefits and costs (NRC, 1997).

3.5 Backfit Analyses

Backfitting is defined by 10 CFR 50.109(a)(1)[5] 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), 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). Similar to backfitting, 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants," includes provisions on issue finality. Issue finality is defined in 10 CFR 52.39 for early site permits, 10 CFR 52.63 for standard design certifications, 10 CFR 52.98 for combined licenses, 10 CFR 52.145 for standard design approvals, and 10 CFR 52.171 for manufacturing licenses. Moreover, 10 CFR Part 52 defines requirements, under Section VIII for each certified design appended in the regulations, in initiating processes for changes and departures to a specific design.

The Handbook discusses how to perform a backfit analysis (NRC, 1997). In order 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 protection. In order to quantify the benefit of averted dose, the dollar per person-rem conversion factor is used.

3.6 Environmental Analyses

An analysis of Severe Accident Mitigation Alternatives (SAMAs) is included as part of the environmental review conducted for license renewal if it had not been considered earlier for the facility. For new reactors, an analysis of SAMDAs is included as part of the environmental review for construction permits, design certifications, and combined licenses. The SAMA review is an evaluation of alternatives to mitigate severe accidents. Severe accidents are those that could result in substantial damage to the reactor core, whether or not there are serious offsite consequences. NRC staff reviews and evaluates SAMAs to ensure that changes that could improve severe accident safety performance are identified and evaluated. Potential improvements could include hardware modifications, changes to procedures, and changes to the training program (NRC, 2006).

"Standard Review Plans for Environmental Reviews for Nuclear Power Plants," NUREG-1555, Section 7.3 (NRC, 2007) for new reactors and NUREG-1555, Supplement 1, revision 1 (NRC, 2013c) for operating license renewal, provides guidance on the analysis and assessment of SAMAs. The guidance instructs NRC staff on how to evaluate the estimated cost, risk reduction, and dollar benefits for selected SAMAs and the assumptions used to make these

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5 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 ("issue finality" provisions). Backfit provisions applicable to material licenses and regulatory approvals, are defined in 10 CFR 70.76, 72.62, and 76.76.

estimates. The cost-benefit comparison is further evaluated to determine if it is consistent with the cost-benefit balance criteria and methodology given in NUREG/BR-0184 (NRC 1997) and NUREG/BR-0058, revision 4, (NRC 2004). In addition, during license renewal reviews, any SAMAs 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 benefit-cost criterion, NRC staff uses the $2,000 per person-rem averted amount for health effects from NUREG/BR-0058 (NRC, 1999).

As required by 10 CFR 51.71(d), NRC environmental impact statements (EISs) are required to "include a consideration of the economic, technical, and other benefits and costs of the proposed licensing action and alternatives." 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 except if 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.[6]

Other than directing NRC staff to "obtain data relative to the costs of postulated accidents," environmental reviews do not utilize the dollar per person-rem factor in cost-benefit analyses conducted for new reactor EISs (NRC, 2007). This is because the dollar per person-rem factor is used in SAMA and SAMDA analyses. In addition, NUREG-1555, Sections 10.4.1 "Benefits" and 10.4.2 "Costs," do not reference NUREG/BR-0058, NUREG-0184, or NUREG-1530 (NRC, 2007). Conversely, since SAMA/SAMDA analyses are not conducted as part of the materials license environmental review, guidance in NUREG-1748, "Environmental Review Guidance for Licensing Actions Associated with NMSS Programs," Sections 5.7 and 6.7, Cost-Benefit Analysis, includes references to both NUREG/BR-0058 and NUREG-1530 for more detailed guidance in determining public health and safety impact valuations (NRC, 2003).

[6] As required by 10 CFR 51.95(c).

4 VALUE OF A STATISTICAL LIFE

The concept of 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. Office of Management and Budget (OMB) Circular A-4 provides guidance for communicating the concept of VSL in regulatory analyses. 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 x 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.

4.1 Approaches to Calculate VSL

NUREG-1530, revision 0, provides an overview of different methods of calculating VSL.[7] In that report, the U.S. Nuclear Regulatory Commission (NRC) chose the WTP method resulting in a VSL of $3 million. The NRC chose this value because:

> 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.[8]

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[7] The methods analyzed were 1) the human capital method, 2) the willingness-to-pay 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.

[8] 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. Further, NUREG-1530, revision 0, analyzed three different methods by which WTP can be calculated.[9]

In preparing this report, the NRC staff analyzed three different methods for calculating WTP. Two of the methods for calculating WTP are shown in Figure 1 (Breidert et al., 2006). The third, meta-analysis, is discussed below.

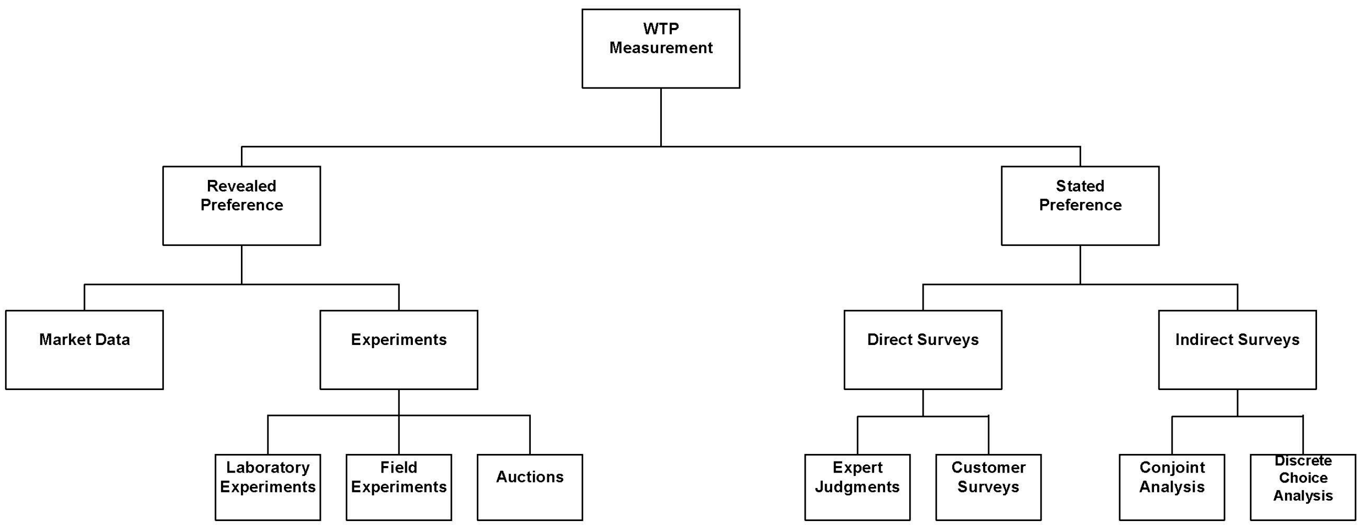

Figure 1 Classification Framework for Methods to Measure Willingness-to-Pay

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 wage studies to estimate the value of life.[10] 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

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9 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.

10 Hedonic means of or relating to utility. 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.

(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 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.[11] 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 affect risks to homes). 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 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 also could result in the estimated VSL being lower than that for labor market studies. These other characteristics include possible selection bias inherent in some product markets, and the fact that several consumer market studies are based on inferred, instead of observed, price-risk tradeoffs, which introduces 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, 2008). However, because stated preference studies are based on hypothetical scenarios, results may

[11] Endogeneity is defined as a correlation between an independent variable and the error term in a statistical equation. In the discussion above, wages 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, ceteris paribus.

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*.,* 2007). 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.*, 2007). Meta-analyses can utilize estimates that employ revealed preference and/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

In addition, the NRC staff performed a literature review to benchmark the values other Federal agencies have used for statistical life. Below is a discussion of each agency's VSL practices and methodologies. The NRC staff inflated VSL values using formulas and guidance provided by other agencies. In the absence of such guidance, the NRC staff used the consumer price index (CPI) to inflate the values to 2014 dollars. The NRC staff notes that combining other factors with CPI (e.g., real income growth, income elasticity, etc.) to inflate VSL values to 2014 dollars would typically increase these estimates.

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). EPA derived its value from 26 studies that were compiled as part of EPA's first retrospective analysis of the Clean Air Act (EPA, 1999). EPA used meta-analyses to calculate its VSL amount. The EPA selected the set of studies for its VSL calculation that the EPA deemed to be the most relevant to its policy concerns. 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, EPA included five of these studies in its VSL estimation due to the quality and policy relevance of those particular studies (EPA, 1999).

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). 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 this revision taking into account recent VSL studies and, in particular, new meta-analyses. In 2008, EPA issued revised "Guidelines for Preparing Economic Analyses," which recommended the use of a $7.0 million (2006 dollars) VSL for regulatory analysis (EPA, 2008b). In 2010, EPA revised *"*Guidelines for Preparing Economic

Analyses" and updated its VSL to $7.9 million in 2008 dollars (EPA, 2010). The value was adjusted using the 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.

Currently, EPA does not use low and high alternative VSL values in regulatory analyses (EPA, 2014). Historically, EPA has determined that a single, peer-reviewed VSL estimate should be applied.[12] This is because EPA staff recommendations are vetted and endorsed by EPA's Science Advisory Board (SAB) (EPA, 2010).[13]

EPA is in the process of updating its VSL estimate. 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 would update using a gross domestic product (GDP) deflator for inflation, real income growth factor (e.g., CPI), and an income elasticity factor. In 2011, the SAB agreed with EPA staff recommendations to begin crafting guidance that would allow EPA staff to use multiple VSL factors because a single value for mortality risk is not appropriate for all contexts (EPA, 2011c). EPA also recommended that the term "value of a statistical life" be replaced by "value of risk reduction" because of the misunderstanding of the VSL term, which the SAB endorsed (EPA, 2011c).

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, 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, DOT adjusted the value to $3 million (2001 dollars). Subsequently, 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," 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 Consumer Price Index-for All Urban Consumers (CPI-U) (Duvall, 2008).[14]

In 2014, DOT updated its guidance to have its VSL set at $9.2 million in 2013 dollars. This amount was an average based off of nine meta-analyses that provided a broad cross-section of

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[12] In it's response to the 2000 *Guidelines For Preparing Economic Analyses*, the 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 a central, point estimate is reasonable, so long as the EPA staff discusses the limitations of the estimate (EPA, 2000).

[13] Congress directed the EPA to establish the SAB in 1978. The SAB provides scientific advice to the EPA Administrator.

[14] CPI-U measures the CPI value for urban consumers, which constitute the majority of the U.S. population.

the United States population.[15] In the guidance, DOT establishes a formula for future VSL amounts (DOT, 2014). The formula is:

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

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

DOT also uses high and low alternative VSL values. DOT's current values for a 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 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, 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). DHS adopted this value, but reports it in 2008 dollars (OMB, 2014). The report also recommends that DHS update its values using CPI-U to measure for inflation (current year CPI-U divided by 1997 CPI-U that is indexed at 160.5), real income growth factor (median usual weekly earnings current year/median usual weekly earnings for 1997 indexed at 503), and an income elasticity factor (DHS, 2008). The VSL base year number is $4.7 million in 1997 dollars and income elasticity is 0.47 (DHS, 2008). The formula is stated below:

$$\mathrm{VSL}_{\mathrm{Current\ year}} = \mathrm{VSL}_{\mathrm{base\ year\ (1997)}}\ \mathrm{x\ Inflation\ x\ real\ income\ growth}^{\mathrm{VSL\ Income\ Elasticity}}$$

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 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 DHS' 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 their 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

[15] DOT focused on different categories of people. Examples include males versus females, older workers vs younger workers, smokers vs non-smokers, etc.

2003 and 2008 FDA used best estimate VSL values ranging from $5 million to $6.5 million in estimating benefits (DOT, 2008). In a 2011 rulemaking, the FDA used $7.9 million is 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.

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. Due to FDA's statutory requirements and mission, FDA typically analyzes risks that are age specific and only uses VSL when ages are unknown. Instead, 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. Ocupational Safety and Health Administration (OSHA) VSL estimates vary depending on whether they are addressing mortality risks from workplace accidents or from illnesses. OSHA has not developed formal guidance on estimating VSL and the agency appears to have improved its approach to VSL over time (CRS, 2010). In a 2001 rule, OSHA did not assign a monetary value to reductions in mortality risk. In 2006, however, 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 similar fashion to EPA's approach (OSHA, 2006 and CRS, 2010). In a 2012 rule, OSHA used a VSL of $8.7 million in 2010 dollars (OSHA, 2012). Therefore, if using CPI to inflate this value, OSHA's estimate of VSL would be $9.0 million in 2014 dollars.

4.2.6 U.S. Office of Management and Budget

In 1996, the U.S. Office of Management and Budget (OMB) described best practices for valuing health and safety risk reduction benefits (OMB, 1996). 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 OMB found theoretical advantages to using the value of a statistical life-years-extended, it also concluded that research did not provide a definitive way of developing appropriate estimates of VSLY. OMB found drawbacks with options for deriving the VSLY from VSL. For example, 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, OMB encouraged agencies to explore use of both metrics.

Subsequent OMB guidelines (2000) 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 approved the use of VSL and VSLY estimates for Federal agency use. Since its draft report to Congress in 2002, 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, OMB issued Circular A-4 which endorsed, for the first time, explicit VSL estimates between $1 million and $10 million 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). OMB drew on two journal articles and an analysis prepared by 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

In the United Kingdom (U.K.), the National Radiological Protection Board (NRPB) 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 note that VSLs range from United States 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 suspect the large numbers come from risk measures and other unobservable factors plus large worker compensation differences.

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

4.4 Representative VSL for NRC Activities

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

In order to align with practices of other Federal agencies, the NRC will adopt low and high VSL estimates for sensitivity analyses. Each Federal agency identified in this report has adopted VSL estimates based on that agency's mission and within its own processes. The NRC staff recognizes that if it performed similar research as these other Federal agencies, the NRC staff's estimates would be roughly similar. Therefore, the NRC staff will adopt the median value of the three agencies who have low and high VSL estimates. The NRC will adapt a low value of $5.3 million and a high value of $13.2 million, in 2014 dollars, for use in sensitivity analyses. These estimates are analyzed in Table 1.

Table 1 Low and High VSL Values in 2014 Dollars

Agency[16]	Low	High
DOT	$5.3 million	$13.2 million
DHS	$6.8 million	$10.8 million
OMB	$1.3 million	$13.3 million
Median	*$5.3 million*	*$13.2 million*

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

5 NOMINAL 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 risk coefficient that establishes the nominal probability for stochastic health effects attributable to radiological exposure.

Since 1928, the International Commission on Radiological Protection (ICRP) has developed, maintained, and elaborated the International System of Radiological Protection that is used as a common basis for radiological protection standards, guidelines, and programs.

ICRP has published more than one hundred reports on all aspects of radiological protection. Most address a particular area within radiological protection, but a handful of publications describe the overall system of radiological protection. The International System of Radiological Protection has been developed by ICRP based on: (1) the current understanding of the science of radiation exposures and effects, and (2) value judgments. These value judgments take into account societal expectations, ethics, and experience gained in application of the system.

The U.S. Nuclear Regulatory Commission's (NRC's) current dollar per person-rem conversion factor in NUREG-1530, revision 0, is based on the recommendations in ICRP Publication Number 60, published in 1991 (ICRP, 1991). In general, for doses to the population, the ICRP recommendation is a 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 this way, the value of a statistical life is applicable across all contributors to the total health risk coefficient.

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. 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 Publication 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, but in ICRP Publication Number 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. 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].

As discussed earlier in this NUREG, WTP approaches are meant for small reductions in only mortality risk. ICRP Publication No. 60 and ICRP Publication No. 103 combine both morbidity and mortality into their nominal coefficient numbers (ICRP, 1991, 2007).

EPA uses a mortality-only coefficient with a value of 5.8×10^{-4} per rem (EPA, 2011b).[1] Using EPA's value would align the cancer risk coefficient with the underlying definition of WTP and the value is slightly greater than the ICRP nominal risk coefficient. The U.S. National Academies estimated the total risk for all classes of genetic diseases to be about 3,000-4,700 cases per million first-generation progeny per gray of low dose rate low-LET radiation (NAS, 2006). This numerical estimate (0.4×10^{-4} per rem) is defined relative to the "genetically significant dose," (i.e., the combined dose received by both parents prior to conception). However, changing the nominal risk coefficient from total detriment to a mortality/heritable effects-only factor may not adequately consider the full range of consequences associated with public radiation exposure. This EPA adjusted factor (6.2×10^{-4} per rem) still may underestimate the U.S. nominal risk coefficient because it is not weighted to include cancer incidence data weighted for lethality and life impairment. Thus, by not accounting for cancer morbidity, the NRC may underestimate the benefits of a proposed action (e.g., medical costs averted, value of lost production, etc.) by as much as another 20 percent.

Neither an EPA mortality-only coefficient nor an EPA mortality-adjusted coefficient is adopted for use in the VSL estimates. The NRC staff prefers to achieve greater alignment with ICRP Publication 103 and adopt the nominal risk coefficient of 5.7×10^{-4} per rem with the understanding this coefficient may underestimate the U.S. population risk by as much as 30 percent. Use of the ICRP-103 nominal risk coefficient in the NRC's dollar per person/rem conversion factor will update the NRC's estimates consistent with similar ongoing updates to other calculations and methods being proposed for use or contained in NRC guidance in implementing the provisions of existing regulatory programs. However, the final dollar per person-rem calculated using either the EPA or ICRP is not practically different.

Table 2 Comparison of ICRP Publication No. 103 and ICRP Publication No. 60 Detriment Adjusted Nominal Risk Values (10^{-4} person-rem)

Exposed Population[2]	**Cancer**		**Heritable Effects**		**Nominal**	
	ICRP 103	ICRP 60	ICRP 103	ICRP 60	ICRP 103	ICRP 60
Whole	5.5	6.0	0.2	1.3	5.7	7.3
Adult	4.1	4.8	0.1	0.8	4.2	5.6

[1] As stated above, EPA does not use ICRP derived dose conversion factors. Instead, EPA creates U.S. specific dose conversion factors based on U.S. census data which includes morbidity and mortality information related to cancer statistics for the U.S. population.

[2] The term "exposed population" is an idealized group for whom organ or tissue equivalent doses are calculated. The whole population is intended to be a representation of a population of both sexes and all ages. These values are from Tables A.4.1a and A.4.1b of ICRP Publication 103 and from ICRP Publication Number 60.

The NRC staff recommendation to use the nominal risk coefficient value is for the whole population.[3] For simplicity, the NRC staff does not recommend low and high nominal risk coefficient factors for use in sensitivity analyses.

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[3] In certain scenarios (e.g., occupational health (routine) or occupational health (accident) as defined in NUREG/BR-0184), the NRC staff could use the nominal risk value of 4.2 x 10-4 because workers at nuclear power plants are adults.

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 nominal risk coefficient. Based on the preceding recommendations concerning VSL ($9.0 million) and the use of the International Commission on Radiological Protection (ICRP) Publication Number 103 total detriment coefficient (5.7×10^{-4} per rem), the dollar conversion factor would be equal to $5,100 in per person-rem 2014 dollars.[1] A low dollar per person-rem value of $3,000 per person-rem and $7,500 for a high dollar per person-rem value will be adopted.

Thus, the U.S. Nuclear Regulatory Commission (NRC) will adopt the above dollar per person-rem estimates to be used for routine effluent releases, accidental releases, 10 CFR Part 20 as low as is reasonably achieveable (ALARA) programs (i.e., occupational exposures), regulatory analyses, backfit analyses, and environmental analyses. Pertaining to occupational exposures, the NRC staff acknowledges that, for ALARA determinations, many licensees may employ conversion factors in excess of $5,100 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 given a 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. Thus, it would be reasonable to expect an analyst to include alternative valuations in regulatory analyses in order to show the decision maker the sensitivities of the proposed action to relevant considerations. However, the base case computations in a regulatory analysis will use the recommended best estimate dollar conversion factor of $5,100 per person-rem, and apply the low and high estimates in illustrating sensitivity and in bounding the range and direction of the impacts.

The dollar per person-rem conversion factor is for stochastic effects only and is not to be applied to deterministic effects. It should also not be applied to any individual dose that could result in an early fatality. These omissions are consistent with 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

[1] See Appendix B of this report for discussion on adjusting the cancer risk coefficient, and hence the dollar per person-rem conversion factor, for high rate exposure scenarios.

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.

Table 3 Dollar per Person-Rem Summary Inputs

Estimate	VSL	Nominal Risk Coefficient	Dollar per Person-Rem
Best	$9.0 Million	5.7×10^{-4} per rem	$5,100
Low	$5.3 Million	5.7×10^{-4} per rem	$3,000
High	$13.2 Million	5.7×10^{-4} per rem	$7,500

6.1 Number of Significant Figures

Historically, NRC has rounded this number to the nearest thousand dollars for the purposes of dollar per person-rem estimates. 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. In the future to allow for a more frequent adjustment for maintaining alignment with economic changes, the NRC staff should round this number to two significant figures. These characteristics are shown in Figure 2

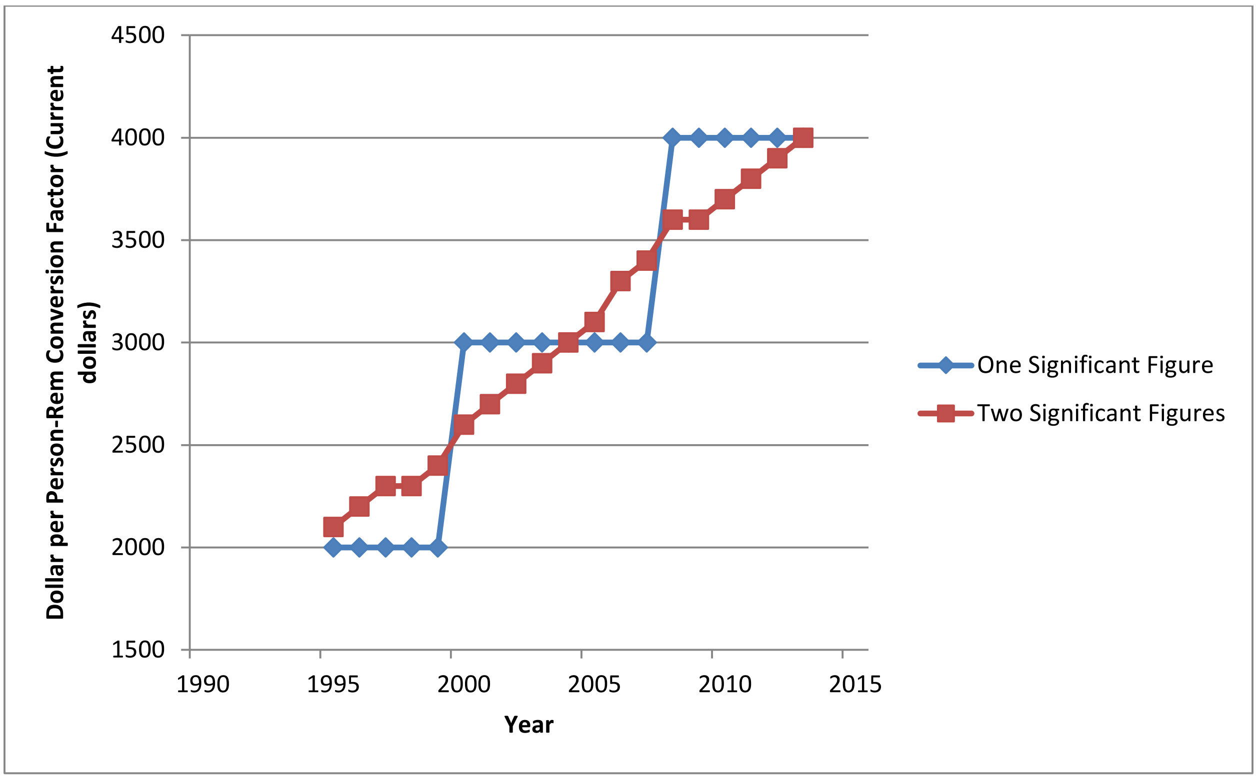

Figure 2 Difference Between Rounding to One and Two Significant Figures

7 METHODOLOGY FOR MAINTAINING THE CONVERSION FACTORS CURRENT

The U.S. Nuclear Regulatory Commission (NRC) staff should use the formulas and procedures provided below to maintain the dollar per person-rem conversion factor up-to-date. Appendix A to this report provides a worksheet the NRC staff can use to calculate updated values.

7.1 Updating VSL

The NRC staff should use the following to calculate the value of a statistical life (VSL) annually. This formula incorporates the methods used by the U.S. Deparment of Homeland Security, but with a different base year for VSL.

$$\mathrm{VSL}_{\text{Current year}} = \mathrm{VSL}_{\text{base year (2014)}} \text{ x Inflation x real income growth}^{\text{VSL Income Elasticity}}$$

In updating VSL, the NRC staff will annually calculate changes in inflation and real income growth. Changes in the VSL base year and income elasticity won't 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 should use the data from the U.S. Bureau of Labor Statistics' CPI-U [factor with 2014 as the base year (indexed at 236.7)].[2] To adjust for real income growth, the NRC staff should use percent change in BLS' median usual weekly earnings (MUWE) from the base year [factor with 2014 as the base year (indexed at 791)] to the current year (BLS, 2014c).[3] The NRC staff will adopt the Environmental Protection Agency's (EPA) recommendation of 0.5 as the income elasticity factor (EPA, 2011a), which was reviewed and approved by EPA's Science Advisory Board (SAB).[4]

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2 Value is from BLS, 2014a.

3 MUWE measures median weekly earnings of the U.S. full-time wage and salary workers by surveying a sample of households (approximately 15,000) in all 50 states and the District of Columbia. Self-employed workers are not included in the survey. Usual weekly earnings indicate earnings before taxes and other deductions and include overtime pay, commissions, and tips (BLS, 2014b). When comparing MUWE between years, the BLS compares the numbers using CPI-U.

4 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% increase in demand for a good and a 10% 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).

Table 4 Sources and Calculations for Factors into VSL

	Inflation (2014 = 236.7)	Real Income Growth[5] (2014 = 791)	Income Elasticity
Source[6]	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

7.2 Updating Nominal Risk Coefficient

The NRC staff should periodically update the nominal risk coefficient used in the dollar per person-rem conversion factor when the ICRP provides new recommendations for its conversion factor.

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 should reevaluate its baseline values for VSL (to account for structural changes in the economy) and nominal risk coefficient approximately every five years, and update guidance and regulations as needed. 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 complete such updates, including notification of the public and the Commission.

[5] Value is from BLS, 2014c.

[6] 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. The series identifier has a maximum length of 17 characters" (BLS, 2014d).

8 IMPLICATIONS OF REVISED CONVERSION FACTOR POLICY

The $5,100 per person-rem conversion factor discussed in this report reflects an increase of about 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 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 NRC described the role that the dollar per person-rem conversion factor plays and is expected to exert in future NRC regulatory decisions. First, with regard to regulatory decisions concerning radioactive waste system design alternatives for nuclear power plants (10 CFR Part 50, Appendix I), the NRC staff involved in those assessments have indicated that increases in the conversion factor of at least an order of magnitude would be necessary to justify any reassessment of these decisions. Thus, the changes in the conversion factor policy as considered in this report would not bring into question these past decisions. Moreover, applicants for reactor licenses under Part 50 and Part 52, and the 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 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 NRC is not proposing that previous decisions be reviewed or updated based on this revised conversion factor policy. Furthermore, even for regulatory decisions involving safety enhancements for severe power reactor accidents following the Fukushima accident where the potential difference in total dollar valuation could be large, the NRC used $4,000 per person-rem as an alternative value estimate and does not propose revisiting these past regulatory decisions unless, on a case-specific basis, an unanticipated need to do so arises (NRC, 2012b). There are several reasons for this position.

First, the $2,000 per person-rem value has been used by the NRC as a figure of merit, and as one input among many in the regulatory decision. Second, in recognition of the uncertainties inherent in such a figure of merit, NRC staff and decisionmakers 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 the cost of modifying a licensed facility. Updated cost-benefit analysis results 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 $5,100 per person-rem conversion factor and related changes in the U.S. Nuclear Regulatory Commission's (NRC's) conversion factor policy will be incorporated into a future revision of the Guidelines. 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 will be considered.

The NRC recognizes that updating the dollar per person-rem conversion factor may be appropriate for the future. The value should be updated using the process discussed in this NUREG 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 report, except for regulatory applications discussed in Section 3.1, "Routine Liquid and Gaseous Effluent Releases from Nuclear Power Plants." The values discussed in 10 CFR Part 50, Appendix I shall be used until they are changed through rulemaking. For non-10 CFR Part 50 Appendix I reviews, licensees may use other dollar per person-rem factors with adequate justification. 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 apply for an exemption under 10 CFR 50.12 or 10 CFR 52.7.

10 REFERENCES

10 CFR Part 20. *Code of Federal Regulations,* Title 10, *Energy,* Part 50, “Standards for Protection against Radiation.” Washington, D.C.

10 CFR Part 50. *Code of Federal Regulations,* Title 10, *Energy,* Part 50, “Domestic Licensing of Production and Utilization Facilities.” Washington, D.C.

10 CFR Part 51. *Code of Federal Regulations,* Title 10, *Energy,* Part 51, “Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions.” Washington, D.C.

10 CFR Part 52. *Code of Federal Regulations,* Title 10, *Energy,* Part 52, “Licenses, Certifications, and Approvals for Nuclear Power Plants.” Washington, D.C.

39 FR 41501. November 27, 1974. “Executive Order 11821: Inflation Impact Statements.” *Federal Register,* Office of the President, Washington, D.C.

42 FR 1017. January 5, 1977. “Executive Order 11949: Economic Impact Statements.” *Federal Register,* Office of the President, Washington, D.C.

42 USC 2011 et seq. Atomic Energy Act of 1954, as amended.

42 USC 5801 et seq. Energy Reorganization Act, as amended.

46 FR 13193. February 17, 1981. “Executive Order 12291: Federal Regulation.” *Federal Register,* Office of the President, Washington, D.C.

58 FR 51735: October 4, 1993. ”Executive Order 12866: Regulatory Planning and Review.” *Federal Register,* Office of the President, Washington, D.C.

Andersson, Henrik and Treich, Nicolas. 2008. The Value of a Statistical Life. A. de Palma, R. Lindsey, E. Quinet, and R. Vickerman (Eds.) *A Handbook of Transport Economics*, 2011, chapter 17, pages 396-424.

Bellavance, F., G. Dionne, and M. Lebeau. 2007. *The Value of Statistical Life: A Meta-Analysis with a Mixed Effects Regressions Model*. Canada Research Chair in Risk Management Working paper 06-12.

Blumenschein, K., G.C. Blomquist, M. Johannesson, N. Horn, and P. Freeman. 2007. Eliciting Willingness to Pay without Bias: Evidence from a Field Experiment. *The Economic Journal*, 118:114-137.

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

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

Dockins C, K. Maguire, N. Simon, and M. Sullivan. 2004. "Value of Statistical Life Analysis and Environmental Policy: A White Paper." U.S Environmental Protection Agency National Center for Environmental Economics.

Duvall, T. 2008. Memorandum to Secretarial Officers, Modal Administrators. "Treatment of the Economic Value of a Statistical Life in Departmental Analyses." U.S. Department of Transportation. http://ostpxweb.ost.dot.gov/policy/reports/080205.htm.

Limerick Ecology. 1989. *Limerick Ecology Action, Inc., v. NRC,* 869 F2d 719 (Third Circuit. 1989).

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

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

International Commission on Radiological Protection (ICRP). 2007. *The 2007 Recommendations of the ICRP.* ICRP Publication No. 103, Elsevier, Amsterdam.

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

U.S. Bureau of Labor Statistics (BLS). 2014a. "CPI Detail Report: Data for December 2014". December 2014. Accessed at http://www.bls.gov/cpi/cpid1412.pdf.

U.S. Bureau of Labor Statistics (BLS). 2014b. "Usual Weekly Earnings of Wage and Salary Workers: Fourth Quarter 2014," USDL-15-0071. January 21, 2015.

U.S. Bureau of Labor Statistics (BLS). 2014c. "Median usual weekly earnings (second quartile, Employed full time, Wage and salary workers: Median usual weekly earnings – in current dollars (second quartile)," Series ID LEU0252881500, updated quarterly.

U.S. Bureau of Labor Statistics (BLS). 2014d. "Help & Tutorials: Series ID." July 19, 2008. http://www.bls.gov/help/hlpform3.htm.

U.S. Congressional Research Services (CRS). 2010. "How Agencies Monetize "Statistical Lives" Expected to Be Saved By Regulations." March 24, 2010. Accessed at http://assets.opencrs.com/rpts/R41140_20100324.pdf.

U.S. Department of Homeland Security (DHS). 2008. "Valuing Mortality Risk Reductions in Homeland Security Regulatory Analyses: Final Report." June 2008. Accessed at http://www.regulatory-analysis.com/robinson-dhs-mortality-risk-2008.pdf.

U.S. Department of Transportation (DOT). 2008. "Guidance on Treatment of the Economic Value of Statistical Life in the U.S. Department of Transportation Analyses." February 5, 2008. Accessed at http://www.sra.org/sites/default/files/u32/VSL_Guidance_20031809a.pdf.

U.S. Department of Transportation (DOT). 2013. "Guidance on Treatment of the Economic Value of Statistical Life in the 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.

U.S. Department of Transportation (DOT). 2014. "Guidance on Treatment of the Economic Value of Statistical Life in the 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.

U.S. Environmental Protection Agency (EPA). 1999. "The Benefits and Costs of the Clean Air Act: 1990-2010: EPA Report to Congress." November, 1999. Accessed at http://www.epa.gov/cleanairactbenefits/1990-2010/chap1130.pdf.

U.S. Environmental Protection Agency (EPA). 2000. "Guidelines for Preparing Economic Analyses." September 2000. Accessed at http://yosemite.epa.gov/ee/epa/eerm.nsf/vwAN/EE-0228C-07.pdf/$file/EE-0228C-07.pdf.

U.S. Environmental Protection Agency (EPA). 2008a. 73 FR 37096 (June 30, 2008) "Control of Emissions of Air Pollution from Locomotive Engines and Marine Compression Ignition Engines Less than 30 Liters Per Cylinder."

U.S. Environmental Protection Agency (EPA). 2008b. "Guidelines for Preparing Economic Analyses." September 12, 2008. Accessed at http://yosemite.epa.gov/ee/epa/eerm.nsf/vwAN/EE-0516-01.pdf/$file/EE-0516-01.pdf.

U.S. Environmental Protection Agency (EPA). 2010. "Guidelines for Preparing Economic Analyses." December 17, 2010. Accessed at http://yosemite.epa.gov/ee/epa/eerm.nsf/vwAN/EE-0568-50.pdf/$file/EE-0568-50.pdf.

U.S. Environmental Protection Agency (EPA). 2011a. "Valuing Mortality Risk Reductions for Environmental Policy: A White Paper." January, 2011. Accessed at http://yosemite.epa.gov/ee/epa/eerm.nsf/vwAN/EE-0563-1.pdf/%24file/EE-0563-1.pdf.

U.S. Environmental Protection Agency (EPA). 2011b. EPA *Radiogenic Cancer Risk Models and Projections for the U.S. Population*. April, 2011. Accessed at http://epa.gov/rpdweb00/docs/bluebook/bbfinalversion.pdf.

U.S. Environmental Protection Agency (EPA). 2011c. 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)," dated July 29, 2011. EPA-SAB-11-011. Accessed at http://yosemite.epa.gov/sab/sabproduct.nsf/298E1F50F844BC23852578DC0059A616/$File/EPA-SAB-11-011-unsigned.pdf.

U.S. Environmental Protection Agency (EPA). 2014. "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 http://www2.epa.gov/sites/production/files/2014-06/documents/20140602ria-clean-power-plan.pdf .

U.S. Environmental Protection Agency (EPA). 2014. EPA Science Advisory Board (SAB) Home Page. Updated on 12/1/2014. Accessed on 12/2/2014. http://yosemite.epa.gov/sab/sabpeople.nsf/WebCommittees/BOARD.

U.S. Food and Drug Administration (FDA). 2003. 68 FR 41433 (July 11, 2003) "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.* U.S. Food and Drug Administration, Washington D.C. Accessed at http://www.fda.gov/OHRMS/DOCKETS/98fr/03-17525.htm.

U.S. Food and Drug Administration (FDA). 2005. 70 FR 33998 (June 10, 2005) Electronic products; performance standard for diagnostic x-ray systems and their major components; final rule. *Federal Register.* U.S. Food and Drug Administration, Washington D.C. .Accessed at http://www.gpo.gov/fdsys/pkg/FR-2005-06-10/pdf/05-11480.pdf.

U.S. Food and Drug Administration (FDA). 2011. Food Labeling: Nutrition Labeling of Standard Menu Items in Restaurants and Similar Retail Food Establishments Notice of Proposed Rulemaking. Docket No. FDA-2011-F-0172. March 2011. Accessed at http://www.fda.gov/downloads/Food/LabelingNutrition/UCM249276.pdf.

U.S. Nuclear Regulatory Commission (NRC). 1975a. 40 FR 19439, 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,* U.S. Nuclear Regulatory Commission, Washington, D.C.

U.S. Nuclear Regulatory Commission (NRC). 1975b. "Reactor Safety Study: An Assessment of Accident Risks in U.S. Commercial Nuclear Power Plants (WASH-1400)." NUREG-75/014, Washington D.C. ADAMS Accession No. ML072350618.

U.S. Nuclear Regulatory Commission (NRC). 1977. SECY-77-388A, "Value-Impact Analysis Guidelines," ADAMS Accession No. ML12234B122.

U.S. Nuclear Regulatory Commission. 1982a. 47 FR 2286 (January 15, 1982),. "Licensing Requirements for Pending Construction Permit and Manufacturing License Applications; Final Rule." *Federal Register,* U.S. Nuclear Regulatory Commission, Washington, D.C.

U.S. Nuclear Regulatory Commission (NRC). 1982b. "Resolution of Generic Safety Issues (Formerly entitled A Prioritization of Generic Safety Issues): Main Report with Supplements 1-34." NUREG-0933. Washington D.C.

U.S. Nuclear Regulatory Commission (NRC). 1983a. "Regulatory Analysis Guidelines of the U.S. Nuclear Regulatory Commission." NUREG/BR-0058, revision 0, Washington D.C. ADAMS Accession No. ML15027A412.

U.S. Nuclear Regulatory Commission (NRC). 1983b. "A Handbook for Value-Impact Assessment." NUREG/CR-3568, Washington D.C. ADAMS Accession No. ML062830096.

U.S. Nuclear Regulatory Commission (NRC). 1983c. NUREG-0880, revision 1, "Safety Goals for Nuclear Power Plant Operation," ADAMS Accession No. ML071770230.

U.S. Nuclear Regulatory Commission (NRC). 1984. “Regulatory Analysis Guidelines of the U.S. Nuclear Regulatory Commission.” NUREG/BR-0058, revision 1, Washington D.C. ADAMS Accession No. ML15027A413.

U.S. Nuclear Regulatory Commission (NRC). 1985a. Memorandum, W.J. Dirks to Commission, “Basis for Quantifying Off-Site Property Losses,” dated October 23, 1985. ADAMS Accession No. ML15050A141.

U.S. Nuclear Regulatory Commission (NRC). 1985b. General Electric Standard Safety Analysis Report. Washington D.C. ADAMS Accession No. ML15014A502.

U.S. Nuclear Regulatory Commission. 1986. 51 FR 28044 (August 4, 1986), as revised by 51 FR 30028 (August 21, 1986). “Safety Goals for the Operations of Nuclear Power Plants; Policy Statement.” *Federal Register,* U.S. Nuclear Regulatory Commission, Washington, D.C.

U.S. Nuclear Regulatory Commission (NRC). 1988. Individual Plant Examination for Severe Accident Vulnerabilities – 10 CFR 50.54(f) Generic Letter No. 88-20. Washington D.C. ADAMS Accession No. ML031150465.

U.S. Nuclear Regulatory Commission (NRC). 1990. “Backfitting Guidelines.” NUREG-1409, Washington D.C. ADAMS Accession No. ML032230247.

U.S. Nuclear Regulatory Commission (NRC). 1993. *Regulatory Guide 8.37 – ALARA Levels for Effluents from Materials Facilities.* Washington D.C. ADAMS Accession No. ML003739553.

U.S. Nuclear Regulatory Commission (NRC). 1995a. “Reassessment of NRC’s Dollar Per Person-Rem Conversion Factor Policy.” NUREG-1530, revision 0, Washington D.C. ADAMS Accession No. ML063470485.

U.S. Nuclear Regulatory Commission (NRC). 1995b. “Regulatory Analysis Guidelines of the U.S. Nuclear Regulatory Commission.” NUREG/BR-0058, revision 2, Washington D.C. ADAMS Accession No. ML111180434.

U.S. Nuclear Regulatory Commission. 1996a. 61 FR 28467 (June 5, 1996). “Environmental Review for Renewal of Nuclear Power Plant Operating Licenses.” *Federal Register,* U.S. Nuclear Regulatory Commission, Washington, D.C.

U.S. Nuclear Regulatory Commission (NRC). 1996b. “Generic Environmental Impact Statement for License Renewal of Nuclear Plants.” Volumes 1 and 2, NUREG-1437, Washington D.C. ADAMS Accession Nos. ML040690705.

U.S. Nuclear Regulatory Commission (NRC). 1997. “Regulatory Analysis Technical Evaluation Handbook: Final Report.” NUREG/BR-0184, Washington D.C. ADAMS Accession No. ML050190193.

U.S. Nuclear Regulatory Commission (NRC). 1999. “Standard Review Plans for Environmental Reviews for Nuclear Power Plants, Volume 2.” NUREG-1555, Washington D.C. ADAMS Accession No. ML003701937.

U.S. Nuclear Regulatory Commission (NRC). 2000. "Regulatory Analysis Guidelines of the U.S. Nuclear Regulatory Commission." NUREG/BR-0058, revision 3, Washington D.C. ADAMS Accession No. ML023290519.

U.S. Nuclear Regulatory Commission (NRC). 2003. "Environmental Review Guidance for Licensing Actions Associated with NMSS Programs." NUREG-1748, Final Report, Washington D.C. ADAMS Accession No. ML032450279.

U.S. Nuclear Regulatory Commission (NRC). 2004. "Regulatory Analysis Guidelines of the U.S. Nuclear Regulatory Commission." NUREG/BR-0058, revision 4, Washington D.C. ADAMS Accession No. ML042820192.

U.S. Nuclear Regulatory Commission (NRC). 2006. "U.S. Nuclear Regulatory Commission Frequently Asked Questions on License Renewal of Nuclear Power Reactors." NUREG-1850, Final Report, Washington D.C. ADAMS Accession No. ML061110022.

U.S. Nuclear Regulatory Commission (NRC). 2007. "Standard Review Plans for Environmental Reviews for Nuclear Power Plants: Environmental Standard Review Plan for New Site/Plant Applications." NUREG-1555, Revised Sections, Washington, D.C. http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1555/updates.html.

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

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

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

U.S. Nuclear Regulatory Commission (NRC). 2013b. "Regulatory Analysis for Japan Lessons-Learned Tier 3 Issue on Expedited Transfer of Spent Fuel," ADAMS Accession No. ML13273A628.

U.S. Nuclear Regulatory Commission (NRC). 2013c. "Standard Review Plans for Environmental Review for Nuclear Power Plants: Supplement 1: Operating License Renewal." NUREG-1555, Supplement 1, revision 1, Final Report, Washington D.C. ADAMS Accession No. ML13106A246.

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

U.S. Occupational Safety and Health Administration (OSHA). 2001. 66 FR 5196 (January 18, 2001) "Safety Standards for Steel Erection; Final Rule." *Federal Register*. U.S. Department of Labor, Washington D.C. Accessed at http://www.gpo.gov/fdsys/pkg/FR-2001-01-18/html/01-979.htm.

U.S. Occupational Safety and Health Administration (OSHA). 2006. 71 FR 100998 (February 28, 2006) “Occupational Exposure to Hexavalent Chromium.” *Federal Register*. U.S. Department of Labor, Washington D.C. Accessed at https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_id=18599&p_table=federal_register.

U.S. Occupational Safety and Health Administration (OSHA). 2012. 77 FR 17574 (March 26, 2012) “Hazard Communication; final rule.” *Federal Register.* U.S. Food and Drug Administration, Washington D.C. Accessed at https://www.osha.gov/dsg/hazcom/GHSfinal-rule.pdf.

U.S. Office of Management and Budget (OMB). 1993. “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, U.S. Government Printing Office, Washington D.C.

U.S. Office of Management and Budget (OMB). 1996. “Economic Analysis of Federal Regulations under Executive Order 12866.” January 11, 1996. Accessed at http://www.whitehouse.gov/omb/memoranda_rwgmemo/.

U.S. Office of Management and Budget (OMB). 2000. “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.

U.S. Office of Management and Budget (OMB). 2002. “2002 Draft Report to Congress on the Costs and Benefits of Federal Regulations.” Accessed at http://www.whitehouse.gov/sites/default/files/omb/assets/omb/inforeg/cbreport.pdf.

U.S. Office of Management and Budget (OMB). 2003. “Regulatory Analysis,” Circular No. A-4. September 17, 2003. Accessed at http://www.whitehouse.gov/omb/circulars_a004_a-4/.

U.S. Office of Management and Budget (OMB). 2014. “2014 Draft Report to Congress on the Benefit and Costs of Federal Regulations and Unfunded Mandates on State, Local, and Tribal Entities.” Accessed at http://www.whitehouse.gov/sites/default/files/omb/inforeg/2014_cb/draft_2014_cost_benefit_report-updated.pdf.

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

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

APPENDIX A: SAMPLE WORKSHEET USED TO UPDATE THE DOLLAR PER PERSON-REM CONVERSION FACTOR

Sample Worksheet Used to Update the Dollar Per Person-Rem Conversion Factor

This appendix provides a sample worksheet that the NRC may adopt to adjust the dollar per person-rem conversion factor based on indexing the VSL to the current year dollars for each analysis which uses the factor. See Section 7 of this report for details.

Step 1: Fill in the blanks

- Current year: _____________
- Base year of VSL:[1] _____________
- Inflation:[2] _____________
- Real Income Growth:[3] _____________
- VSL Income Elasticity:[4] _____________

Step 2: Calculate the adjusted VSL (i.e., $\boldsymbol{VSLcurrent\ year}$) using the following equation:

$$\boldsymbol{VSLcurrent\ year} = \boldsymbol{VSLbaseyear} \times \boldsymbol{Inflation} \times \boldsymbol{Real\ Income\ Growth}^{\boldsymbol{VSLincome\ elasticity}}$$

Step 3: Calculate updated dollar per person-rem conversion factor:

$$\boldsymbol{Dollar\ Per\ PersonRem\ current} = \boldsymbol{VSLcurrent\ year} \times \boldsymbol{NominalRisk\ Coefficent}$$

Step 4: Complete sensitivity table below, based on the above values and references.

Parameter	Best	Low	High
Original VSL			
Inflation			
Real Income Growth			
VSL Income Elasticity			
Fully Adjusted VSL			
Nominal Risk Coefficient[5]			
Adjusted Dollar per Person-Rem Conversion Factor			

[1] Based on the recommendations in this report, the base year would be 2014 and would be valued at $9.0 million for the best estimate, $5.3 million for the low estimate, and $13.2 million for the high estimate.

[2] This value is the change in inflation from base year to current year using CPI-U. Based on the recommendations in this report, the base value is indexed at 236.7.

[3] This value is the change in income growth from base year to current year, using MUWE. Based on the recommendations in this report, the base value is indexed at 791.

[4] 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 report, the income elasticity value is 0.5.

[5] Based on the recommendations in this report, the nominal risk coefficient is 5.7×10^{-4} per rem.

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

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

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). The ICRP uses a DDREF of two to reduce the risk per unit dose in the coefficient for radiation protection purposes in the low dose and dose rate exposure range. The ICRP applies the DDREF for all equivalent doses resulting from absorbed doses below 0.2 Grays (20 rad) and from higher absorbed doses when the dose rate is less than 0.1 Grays per hour (10 rad per hour). In most NRC applications, the dose will be from low linear-energy transfer radiation and thus the DDREF would apply to scenarios with an equivalent dose lower than 200 mSv (20 rem) and for doses higher, at a dose rate below 100 mSv per hour (10 rem per hour) 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, the Hiroshima and Nagasaki 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). For exposure scenarios where the dose and dose rate are not considered low, but they are not in the acute health effects range, the DDREF should be removed from the risk coefficient to account for the higher risk per unit dose.

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

NUREG/BR-0184 provides guidance for affected attributes where the DDREF could be removed on a case-by-case basis. Two attributes in regulatory analyses where for the removal of the DDREF may be appropriate could be in the analysis of an occupational health (accident) and public health (accident) scenarios.[1] For example, if a reactor accident scenario results in an instantaneous individual dose of 30 rem to a portion of the affected population. Using the latest ICRP detriment coefficient of 5.7×10^{-4} per rem, a revised value of 1.1×10^{-3} 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 risk coefficient multiplied by a factor of two). As a consequence, the dollar per person-rem value would also double 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 dollar per person-rem would use $10,200 per person-rem for high dose-rate and high dose scenarios instead of the $5,100 per person-rem value being proposed for low dose rate and low dose exposure scenarios in this report.

As part of the cost-benefit guidance update process discussed in SECY-14-0002, “Plan for Updating the U.S. Nuclear Regulatory Commission's Cost-Benefit Guidance,” the NRC staff will incorporate specific guidance on how and to use this value in cost-benefit analyses performed throughout the NRC (NRC, 2014).

[1] Page 5.10 of NUREG/BR-0184 (NRC, 1997).

NRC FORM 335 (12-2010) NRCMD 3.7 U.S. NUCLEAR REGULATORY COMMISSION **BIBLIOGRAPHIC DATA SHEET** *(See instructions on the reverse)*	1. REPORT NUMBER (Assigned by NRC, Add Vol., Supp., Rev., and Addendum Numbers, if any.) NUREG-1530, Rev. 1
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10. SUPPLEMENTARY NOTES

11. ABSTRACT (200 words or less)

This revision to NUREG-1530 makes five changes to the previous version. First, it updates the dollar per person-rem conversion factor to $5,100 per person-rem. The value is based on an updated value of a statistical life of $9.0 million and a nominal risk coefficient factor of 5.7 x 10 4 per person-rem. Second, it uses low and high estimates of a statistical life value instead of a single value. Third, it directs the staff to round the conversion factor to two significant figures instead of simply rounding to the nearest $1,000 value. Fourth, it establishes a method for keeping the dollar per person rem conversion factor current. Finally, it provides guidance to the staff on when to use a higher dollar per person rem conversion factor.

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