Designation: E1074 – 15

Standard Practice for Measuring Net Benefits and Net Savings for Investments in Buildings and Building Systems[1]

This standard is issued under the fixed designation E1074; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

INTRODUCTION

The net benefits (NB) and net savings (NS) methods are part of a family of economic evaluation methods that provide measures of economic performance of an investment over some period of time. Included in this family of evaluation methods are life-cycle cost analysis, benefit-to-cost and savings-to-investment ratios, internal rates of return, and payback analysis.

The NB method calculates the difference between discounted benefits and discounted costs as a measure of the cost effectiveness of a project. The NS method calculates the difference between life-cycle costs as a measure of the cost-effectiveness of a project. The NB and NS methods are sometimes called the net present value method. The NB and NS methods are used to decide if a project is cost effective (net benefits greater than zero, or net savings greater than zero), or which size, or design, competing for a given purpose is most cost effective (the one with the greatest net benefits, or the one with the greatest net savings).

1. Scope

1.1 This practice covers a recommended procedure for calculating and interpreting the net benefits (NB) and net savings (NS) methods in the evaluation of building designs and systems.

1.2 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E631 Terminology of Building Constructions
E833 Terminology of Building Economics
E917 Practice for Measuring Life-Cycle Costs of Buildings and Building Systems
E964 Practice for Measuring Benefit-to-Cost and Savings-to-Investment Ratios for Buildings and Building Systems
E1057 Practice for Measuring Internal Rate of Return and Adjusted Internal Rate of Return for Investments in Buildings and Building Systems
E1121 Practice for Measuring Payback for Investments in Buildings and Building Systems
E1185 Guide for Selecting Economic Methods for Evaluating Investments in Buildings and Building Systems
E1369 Guide for Selecting Techniques for Treating Uncertainty and Risk in the Economic Evaluation of Buildings and Building Systems
E1765 Practice for Applying Analytical Hierarchy Process (AHP) to Multiattribute Decision Analysis of Investments Related to Buildings and Building Systems
E1946 Practice for Measuring Cost Risk of Buildings and Building Systems and Other Constructed Projects
E2204 Guide for Summarizing the Economic Impacts of Building-Related Projects

2.2 *Adjuncts:*[3]

Discount Factor Tables Adjunct to Practices E917, E964, E1057, E1074, and E1121

[1] This practice is under the jurisdiction of ASTM Committee E06 on Performance of Buildings and is the direct responsibility of Subcommittee E06.81 on Building Economics.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from ASTM International Headquarters. Order Adjunct No. ADJE091703.

3. Terminology

3.1 *Definitions*—For definitions of general terms related to building construction used in this practice, refer to Terminology E631; and for general terms related to building economics, refer to Terminology E833.

4. Summary of Practice

4.1 This practice is organized as follows:

4.1.1 *Section 2, Referenced Documents*—Lists ASTM standards referenced in this practice.

4.1.2 *Section 3, Definitions*—Addresses definitions of terms used in this practice.

4.1.3 *Section 4, Summary of Practice*—Outlines the contents of the practice.

4.1.4 *Section 5, Significance and Use*—Explains the application of the practice and how and when it should be used.

4.1.5 *Section 6, Procedures*—Summarizes the steps in making NB (NS) analysis.

4.1.6 *Section 7, Compute NB (NS)*—Describes calculation procedures for NB (NS).

4.1.7 *Section 8, Anaylsis of NB (NS) Results and the Decision*—Discusses the decision criterion and the treatment of uncertainty, risk, and unqualified effects.

4.1.8 *Section 9, Applications*—Explains circumstances under which the NB (NS) method is appropriate.

4.1.9 *Section 10, Report*—Identifies information that should be included in a report of a NB (NS) analysis.

5. Significance and Use

5.1 The NB (NS) method provides a measure of the economic performance of an investment, taking into account all relevant monetary values associated with that investment over the investor's study period. The NB (NS) measure can be expressed in either present value or equivalent annual value terms, taking into account the time value of money.

5.2 The NB (NS) method is used to decide if a given project is cost effective and which size or design for a given purpose is most cost effective when no budget constraint exists.

5.3 The NB (NS) method can also be used to determine the most cost effective combination of projects for a limited budget; that is, the combination of projects having the greatest aggregate NB (NS) and fitting within the budget constraint.

5.4 Use the NB method when the focus is on the benefits rather than project costs.

5.5 Use the NS method when the focus in on project savings (that is, reductions in project costs).

6. Procedures

6.1 The recommended steps for applying the NB (NS) method to an investment decision are summarized as follows:

6.1.1 Make sure that the NB (NS) method is the appropriate economic measure (see Guide E1185),

6.1.2 Identify objectives, alternatives, and constraints,

6.1.3 Establish assumptions,

6.1.4 Compile data,

6.1.5 Convert cash flows to a common time basis (discounting),

6.1.6 Compute NB (NS)[4] and compare alternatives, and

6.1.7 Make final decision, based on NB (NS) results as well as consideration of risk and uncertainty, unquantifiable effects, and funding constraints (if any).

6.2 Since the steps mentioned in 6.1.2 – 6.1.5 are treated in detail in Practice E917 and briefly in Practices E964 and E1121, they are not discussed in this practice. In calculating NB (NS), these four steps should be followed exactly as described in Practice E917. The remainder of this practice focuses on the computation, analysis, and application of the NB (NS) measure. A comprehensive example of the NB method applied to a building economics problem is provided in Appendix X1. A comprehensive example of the NS method applied to a building economics problem is provided in Appendix X2.

7. NB (NS) Computation

7.1 Computation of NB for any given project requires the estimation, in dollar terms, of differences between benefits, and differences between costs, for that project relative to a mutually exclusive alternative. Computation of NS for any given project requires the estimation, in dollar terms, of the difference between life-cycle costs for the project relative to a mutually exclusive alternative. The mutually exclusive alternative may be a similar design/system of a different scale, a dissimilar design/system for the same purpose, or the do nothing case. Denote the alternative under consideration as A_j and the mutually exclusive alternative to be used for purposes of comparison as A_k. Alternative A_k is typically the do nothing case or the project with the lowest first cost, which may or may not be the same project. But the analyst can choose any of the mutually exclusive alternatives as the base case against which to compare alternatives. Benefits can include (but are not limited to) revenue, productivity, functionality, durability, resale value, and tax advantages. Costs can include (but are not limited to) initial investment, operation and maintenance (including energy consumption), repair and replacements, and tax liabilities.

7.2 Eq 1 is used to compute the present value of net benefits ($PVNB_{j:k}$) for the proposed project relative to its mutually exclusive alternative.

$$PVNB_{j:k} = \sum_{t=0}^{N} \left(B_t - \bar{C}_t\right)/(1+i)^t \qquad (1)$$

where:

B_t = dollar value of benefits in period t for the building or system being evaluated, A_j, less the counterpart benefits in period t for the mutually exclusive alternative against which it is being compared, A_k,

$\bar{C}_t$ = dollar costs, including investment costs, in period t for the building or system being evaluated, A_j, less the counterpart costs in period t for the mutually exclusive alternative against which it is being compared, A_k,

[4] The NIST Building Life-Cycle Cost (BLCC) Computer Program helps users calculate measures of worth for buildings and building components that are consistent with ASTM standards. The program is downloadable from http://www.eere.energy.gov/femp/information/download_blcc.html.

N = number of discounting time periods in the study period, and
i = the discount rate per time period.

7.3 Use Eq 2 to convert the present value of net benefits to annual value terms, where N is the number of years in the study period and i is the discount rate.

$$AVNB_{j:k} = PVNB_{j:k} \cdot [(i(1+i)^N)/((1+i)^N - 1)] \quad (2)$$

where $AVNB_{j:k}$ = annual value of net benefits.

7.4 Use Eq 3 to compute the present value of net savings ($PVNS_{j:k}$) for the proposed project, A_j, relative to its mutually exclusive alternative, A_k. The terms appearing in Eq 3 are based on the life-cycle cost (LCC) method, Practice E917. Subtract from project costs in the year in which they occur any pure benefits (for example, increased rental income due to improvements) in the LCC calculation.

$$PVNS_{j:k} = LCC_k - LCC_j \quad (3)$$

where:

LCC_j = the life-cycle costs of the alternative under consideration, A_j, and
LCC_k = the life-cycle costs of the mutually exclusive alternative, A_k.

7.5 Use Eq 4 to convert the present value of net savings to annual value terms, where N is the number of years in the study period and i is the discount rate.

$$AVNS_{j:k} = PVNS_{j:k} \cdot [(i(1+i)^N)/((1+i)^N - 1)] \quad (4)$$

where:

$AVNS_{j:k}$ = annual value of net savings.

7.6 For a given problem and data set, solutions in either present value or annual value terms will be time equivalent values (although different in actual dollar values) and will result in the same investment or design decisions, provided annual values are calculated using Eq 2 for net benefits and Eq 4 for net savings.

7.7 A simple application of Eq 1 is presented in Table 1 for an initial investment of $10 000 that yields an uneven yearly cash flow over four years. (Implicitly, the mutually exclusive alternative is the *do nothing* case.) Assuming a discount rate of 15 %, the discounted cash flows yield a PVNB of $1823. (Note that the sum of net cash flows, $7000, is a much larger value, since it fails to account for the eroding value of money over time.) The larger the PVNB for a given project, the more economically attractive it will be, other things being equal.

7.8 To find the AVNB that is time equivalent to $1823, use Eq 2. The equivalent AVNB is $639.

8. Analysis of NB (NS) Results and the Decision

8.1 Use the results of the NB (NS) computation to rank order alternatives from highest to lowest NB (NS). The alternative with the highest NB (NS) is the most cost effective.

8.2 In the final investment decision, take into account not only the numerical values of NB (NS), but also uncertainty of investment alternatives relative to the risk attitudes of the investor, the availability of funding and other cash-flow constraints, any unquantified effects attributable to the alternatives, and the possibility of noneconomic objectives. (These topics are discussed in Section 10 of Practice E917.)

8.2.1 Decision makers typically experience uncertainty about the correct values to use in establishing basic assumptions and in estimating future costs. Guide E1369 recommends techniques for treating uncertainty in parameter values in an economic evaluation. It also recommends techniques for evaluating the risk that a project will have a less favorable economic outcome than what is desired or expected. Practice E1946 establishes a procedure for measuring cost risk for buildings and building systems, using the Monte Carlo simulation technique as described in Guide E1369. Practice E917 provides direction on how to apply Monte Carlo simulation when performing economic evaluations of alternatives designed to mitigate the effects of natural and man-made hazards that occur infrequently but have significant consequences. Practice E917 contains a comprehensive example on the application of Monte Carlo simulation in evaluating the merits of alternative risk mitigation strategies for a prototypical data center.

8.2.2 Describe any significant effects that remain unquantified. Explain how these effects impact the recommended alternative. Refer to Practice E1765 for guidance on how to present unquantified effects along with the computed values of NB (NS) or any other measures of economic performance.

9. Applications

9.1 The NB (NS) measure indicates that a given project is cost effective if the PVNB (PVNS) is greater than zero. If the PVNB (PVNS) is less than zero, then the project is not cost effective.

9.2 How large an investment to make (that is, what is the most economically efficient scale) is generally answered with NB (NS) analysis. The size or scale of investment is increased

TABLE 1 Calculation of Net Benefits

Year, t	Benefits, B_t, dollars	Costs, $\bar{C}_t$, dollars	Net Cash Flow $B_t - \bar{C}_t$, dollars	SPV Factor[A] for i = 15 %	PVNB, dollars
0	0	10 000	–10 000	1.000	–10 000
1	4 000	3 000	+1 000	0.8696	+870
2	11 500	4 500	+7 000	0.7561	+5 293
3	10 000	4 000	+6 000	0.6575	+3 945
4	8 000	5 000	+3 000	0.5718	+1 715
Total	33 500	26 500	+7 000		+1 823

[A] To find the PVNB of the net cash flow for each discounting period, the single present value (SPV) discount factor is multiplied times the net cash flow. For an explanation of discounting factors and how to use them, see Discount Factor Tables.

until the PVNB (PVNS) is maximized. Typical size or scale examples from the building industry include *(1)* how large a building to construct, *(2)* how large a dam to construct, *(3)* how much insulation to put in a house, and *(4)* how many square feet of collector area to install in a solar energy system.

9.3 Fig. 1 illustrates graphically how the NB method is used to choose the economically efficient level of energy conservation in a building (that is, where the PVNB is maximized). Conservation costs, in present value terms, are shown to increase at an increasing rate as the physical quantity of inputs to conserve energy (Q_i) is increased (for example, increased insulation). Conservation benefits (in present value terms), as measured by dollar energy savings, also increase with additional inputs to energy conservation, but at a decreasing rate. The difference between these dollar conservation benefits and costs at any given level of conservation inputs is the PVNB. The level of energy conservation where the PVNB is maximized is Q_e. Any smaller (Q_1) or larger investments (Q_2 or Q_3) than Q_e would be economically inefficient, because the potential PVNB (profit) is greatest at Q_e (Note 1). Therefore, when using PVNB as a guide, the economically efficient level of insulation for a building is found by increasing applications of insulation until the PVNB is maximized.

NOTE 1—The efficient size could be smaller than Q_e if the investment budget were limited and if other projects were available with incremental benefit-to-cost ratios greater than one.

9.4 Fig. 1 also illustrates the application described in 9.1. That is, any level of conservation inputs portrayed in Fig. 1 within the bounds of zero and Q_3 would be a cost-effective investment.

9.5 The NB (NS) method is also used to compare projects or designs competing for the same purpose to see which is most economically efficient. Typical examples from the building industry include: (*1*) how to select between single, double, or triple glazing; (*2*) how to choose between a solar energy system and a conventional energy system; and (*3*) how to choose between a large dam and a small dam with levees to provide flood control. The most economically efficient project in each case would be the one with the greatest PVNB or PVNS, depending on the method utilized (Note 2). Applying Eq 1, for

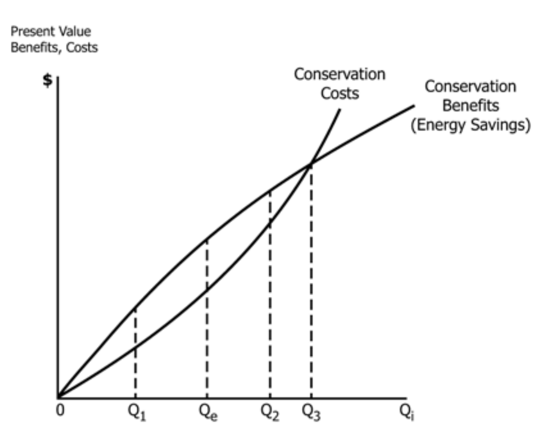

FIG. 1 Finding the Level of Energy Conservation That Maximizes the PVNB

example, to the selection of a flood control project, if PVNB is greater for the small dam and levees than for the large dam, then the small dam and levees are the economically preferred system.

NOTE 2—In these applications of NB (NS) analysis, it is assumed that the initial cost of the alternatives considered does not exceed the available budget.

9.5.1 In using PVNB (PVNS) to compare mutually exclusive projects (that is, a set of projects from which one alternative can be selected), a common study period is required for a valid economic comparison.

9.5.1.1 In comparing projects competing for the same purpose, the analyst must sometimes normalize the PVNB (PVNS) with respect to time in order to have a valid economic comparison. The PVNB (PVNS) of projects with identical expected lives can be compared directly. If the expected lives are different, however, adjustments are required. A common adjustment is to convert each project's life to the least common multiple of the lives of all projects under consideration. By making assumptions about reinvestment costs and earnings, a time-normalized PVNB (PVNS) can then be calculated for each project for comparison over the common study period.

9.5.1.2 A second approach is to select the relevant time horizon of the investor as the length of the study period. Then use replacements and residual values to evaluate each alternative within the common study period.

9.5.1.3 A third approach for comparing projects with unequal lives is to convert the PVNB calculated on the basis of each project's life to an annual value of net benefits (AVNB) using Eq 2. To convert the PVNS calculated on the basis of each project's life to an annual value of net savings (AVNS), use Eq 4. The AVNB (AVNS) will yield a valid economic comparison if the costs and benefits of each project are replicated exactly with each replacement.

9.6 Aggregate PVNB (PVNS) can be used to determine the most cost effective allocation of a limited budget among non-mutually exclusive projects. In general, the combination of projects with the greatest aggregate PVNB (PVNS) fitting within the budget constraint is the most cost effective allocation. In order to aggregate the NB (NS) of non-mutually exclusive projects, they must all be computed over the same study period.

10. Report

10.1 A report of a NB (NS) analysis should include the following information:

10.1.1 The objective and the alternatives considered.

10.1.2 Key assumptions and data including:

10.1.2.1 Discount rate,

10.1.2.2 Study period,

10.1.2.3 Cost data,

10.1.2.4 Benefits (savings) data,

10.1.2.5 Grants, tax deductions, and

10.1.2.6 Financing terms.

10.1.3 The tax status of the investor together with the method of treating inflation.

10.1.4 Any significant effects that are not quantified in the NB (NS) measure.

10.2 Guide E2204 presents a generic format for reporting the results of a NB (NS) analysis. It provides technical persons, analysts, and researchers a tool for communicating results in a condensed format to management and non-technical persons. The generic format calls for a description of the significance of the project, the analysis strategy, a listing of data and assumptions, and a presentation of the computed values of NB (NS) or any other measures of economic performance.

11. Keywords

11.1 benefit-cost analysis; building economics; economic evaluation methods; engineering economics; life-cycle cost analysis; net benefits; net savings

APPENDIXES

(Nonmandatory Information)

X1. USING PRESENT VALUE NET BENEFITS TO EVALUATE RESIDENTIAL SPRINKLER SYSTEMS[5]

X1.1 *Background*—Appendix X1 uses the net benefits method to measure the expected economic performance of a fire sprinkler system installed in a newly constructed, single-family dwelling in the United States. Two alternatives are considered: (1) a dwelling equipped with smoke alarms, and (2) an identical dwelling equipped with smoke alarms and a sprinkler system. The objective is to determine if the purchase of the automatic fire sprinkler system is cost-effective. Three prototypical house types are considered for analyzing the economic performance of a residential sprinkler system: (1) a two-story colonial with basement, but not including the garage; (2) a three-story townhouse with basement; and (3) a single-story ranch.

TABLE X1.1 Data and Assumptions for Analysis of Residential Sprinklers

Study Period	30 Years
Discount Rate (Real)	4.80 %
Base Year	2005
Investment Cost Data	
Colonial	$2 075
Townhouse	$1 895
Ranch	$829
Benefits per	
Fatality Averted	$7.94 million
Injury Averted	$171 620
Direct Property Loss Averted	$4 398
Indirect Costs Averted	$880
Insurance Credit (Annual)	$60

X1.2 *Data and Assumptions*—The benefits experienced by residents of single-family dwellings with sprinkler systems include reductions in the following: the risk of owner/occupant fatalities and injuries, homeowner insurance premiums, uninsured direct property losses, and uninsured indirect costs. The primary costs examined are for initial purchase and installation of the sprinkler system. The measure of economic performance, the PVNB, compares differently timed benefit and cost cash flows, accruing to an owner/occupant, by discounting them to a reference point in time. All dollars presented are in 2005 constant dollars. PVNB is calculated by subtracting present value costs from the present value benefits. Data and assumptions needed to evaluate the decision are summarized in Table X1.1.

X1.2.1 *Analysis Strategy*—Two types of analyses are used to evaluate the merits of residential sprinklers. First, a baseline analysis is performed in which all values are fixed. Second, a sensitivity analysis employing Monte Carlo simulation is performed in which key input variables are allowed to vary in combination according to an experimental design (see Guide E1369). These analysis types complement and reinforce each other.

X1.2.2 *Benefits*—The quantified benefits of a fire sprinkler system used in a single-family dwelling are based on reported fire incident data contained within the U.S. Fire Administration's National Fire Incident Reporting System 5.0 (NFIRS 5.0) (**2**),[6] and calibrated with reported data based on the National Fire Protection Association's annual survey of fire departments (Hall and Harwood, 1989) (**3**), over the period of 2002 to 2005 (Ahrens, 2007) (**4**). This study period was selected due to the relative completeness of fire incident records nationwide, thus ensuring that the nationwide trends and patterns used in this analysis are representative of U.S. fire risks. Over the 2002 to 2005 study period, houses equipped with smoke alarms and a wet-pipe sprinkler system (that is, a system fully-charged with water at all times) experienced 100 % fewer owner/occupant fatalities, 57 % fewer owner/occupant injuries, and 32 % less direct property losses and indirect costs resulting from fire than houses equipped only with smoke alarms. In addition, homeowners of dwellings with fire sprinkler systems received an added bonus of an 8 % reduction in their homeowner insurance premium per year. The monetized value of a residential fire sprinkler system, over a 30-year analysis period, yields homeowners $4994 in present value benefits. In the baseline analysis, the colonial, townhouse, and ranch-style house were all assigned the same economic benefits from installation of a residential fire sprinkler system. The assignment of equal economic benefits was due to an inability to identify differential benefits among the

[5] Appendix X1 is based largely on a National Institute of Standards and Technology (NIST) report (Butry, Brown, and Fuller, 2007) (**1**).[6]

[6] The boldface numbers in parentheses refer to a list of references at the end of this standard.

three house types. This is because the NFIRS 5.0 data did not differentiate housing type or number of stories, other than indicating it was a one- to two-family dwelling. However, one might expect more benefits to be gained with sprinklers in a two-story house, due to the increased potential for keeping exit routes open. Two key benefits—the value of a statistical life and the value of a statistical injury—merit a closer examination. Assigning a dollar value to a statistical life saved or injury averted has become a generally accepted part of economic methodology. The magnitude of the values is often a critical input to economic analysis because a reduction of the risk of death or injury may be a substantial benefit component. However, empirical estimates of the value of life continue to be subject to controversy and inconsistency. For example, basing the value of a life on the present value of earnings potential—a measure that is sometimes used—tends to result in comparatively low values for the young and the old and, in our present economy, for women and non-Caucasians. Using court-assigned values for death, pain, and injury inflicted—another approach—results in widely variable amounts. The value of saving lives and reducing pain and injury implicitly assigned by government programs also vary widely.

X1.2.2.1 *Value of a Statistical Life*—One approach that is considered to be consistent with economic theory is based on the willingness-to-pay concept. Willingness-to-pay values are computed according to how much decision makers are willing to invest to reduce their risk of death or injury by a certain fraction. Using evidence on labor and product market choices that involve implicit tradeoffs between risk and wage or between risk and price, economists have developed estimates of the value of a statistical life typically ranging from $4 million to $9 million with a median value of about $7 million (in 2000 dollars) (Viscusi and Aldy, 2003) (**5**). The inflation adjusted median value of a statistical life, $7.94 million (in 2005 dollars), is used in this analysis.

X1.2.2.2 *Value of a Statistical Injury*—The same willingness-to-pay approach that is used to estimate the value of a statistical life saved can be used to estimate the value of a statistical injury averted. In a survey of 31 studies from the U.S. labor market and eight studies of labor markets outside the United States, Viscusi and Aldy (2003) (**5**) found estimates ranging up to $191 000 with most of the estimates between $20 000 and $70 000 (in 2000 dollars). The U.S. estimates are mostly based on job-related injury rates and lost workday rates from the Bureau of Labor Statistics and not specifically on fire-related injuries. The U.S. Consumer Product Safety Commission (CPSC) conducted two studies of residential fire injuries associated with mattresses and upholstered furniture. These two studies found estimates of $150 000 (in 2005 dollars) per injury from fires involving mattresses and $187 000 (in 2004 dollars) per injury from fires involving upholstered furniture (Zamula, 2005) (**6**). CPSC therefore recommended the amounts of $150 000 and $187 000 as reasonable and reliable estimates of the value of a fire-related injury averted (Zamula, 2004; Zamula, 2005; Ray et al., 1993) (**7**, **6**, **8**). As the value of an injury averted, the inflation adjusted middle value between CPSC studies on mattresses and upholstered furniture of $171 620 is used in this analysis.

X1.2.3 *Costs*—The quantified costs of a fire sprinkler system are based on the findings of NISTIR 7277 (**9**). NISTIR 7277 documented the design and installation costs of four different wet-pipe sprinkler systems within three prototypical house types. Of the alternative sprinkler systems examined in NISTIR 7277, the multipurpose network system was generally the least costly (life-cycle cost) across the three house types. The multipurpose network system was therefore selected as the fire sprinkler system examined in this analysis. The costs associated with installation of a multipurpose network sprinkler system are based on the minimum standard required by NFPA 13D (**10**). The three prototypical house types considered are: (1) a 3338 ft^2 (310 m^2) two-story colonial with basement, but not including the garage; (2) a 2257 ft^2 (210 m^2) three-story townhouse with basement; and (3) an 1171 ft^2 (109 m^2) single-story ranch. The present value costs of installation of a multipurpose network sprinkler system are estimated to be $2075 for the colonial, $1895 for the townhouse, and $829 for the ranch.

X1.3 *Baseline Analysis*—The baseline analysis uses the "best available information" to construct a fixed set of input values. These inputs are used to estimate benefits and costs.

X1.3.1 *Estimated Benefits of Multipurpose Network Sprinkler Systems in Residential Dwellings*—Table X1.2 summarizes the data used to calculate the present value benefits for the five classes of benefits described in X1.3.1.1 – X1.3.1.5. It includes benefits from fatalities averted, injuries averted, direct property losses averted, indirect costs averted, and an insurance credit due to sprinkler use within residential properties. The uniform present worth factor of 15.729 for annually recurring amounts is based on a 30-year study period and a real discount rate of 4.8 %, which reflects the real, after-tax annual rate of return on large-cap stocks over the period 1925 to 2005 (Ibbotson Associates, 2005) (**11**). Installation of a sprinkler system is expected to yield a present value benefit of $4994, over the 30-year study period. Each benefit component is detailed below.

X1.3.1.1 *Fatalities Averted*—One- and two-family dwellings with a wet-pipe sprinkler system were found to have zero fatalities in reported fires over the study period 2002 to 2005. However, field tests indicate sprinklers fail to activate 3 % of the time (Hall, 2007) (**12**), so a 100 % reduction in fatalities, over dwellings with only smoke alarms, may be too optimistic. Section X1.4 deals with this uncertainty and its effects on the results of the analysis. The value of a fatality averted is estimated at $7.94 million. Thus, a 100 % reduction in the fatality rate results in an expected present value benefit of $3726.

X1.3.1.2 *Injuries Averted*—One- and two-family dwellings with a wet-pipe sprinkler system were found to have a 57 % reduction in injuries in reported fires over dwellings equipped with only smoke alarms. The value of an injury averted is estimated at $171 620. The 57 % reduction in the injury rate results in an expected present value benefit of $225.

X1.3.1.3 *Direct Uninsured Property Loss Averted*—One- and two-family dwellings with a wet-pipe sprinkler system were found to have a 32 % reduction in direct property