LBNL-41432

Energy-Efficiency and Renewable Energy Options For Risk Management and Insurance Loss Reduction: An Inventory of Technologies, Research Capabilities, and Research Facilities at the U.S. Department of Energy's National Laboratories

Edward Vine, Evan Mills, and Allan Chen

Environmental Energy Technologies Division
Ernest Orlando Lawrence Berkeley National Laboratory
Berkeley, CA 94720 USA

August 1998

This work was supported by the Assistant Secretary for Energy Efficiency and Renewable Energy of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

Table of Contents

Technical Appendices (bound under separate cover)

List of Tables

Acronyms and Abbreviations

ANL	Argonne National Laboratory
BI	Business Interruption
BM	Boiler and Machinery
BNL	Brookhaven National Laboratory
BR	Builder's Risk
CGL	Comprehensive General Liability
CLC	Contractors Liability Coverage
CO	Completed Operations
CPI	Commercial Property Insurance
CRADA	Cooperative Research and Development Agreement
DOE	U.S. Department of Energy
EL	Environmental Liability
EPA	U.S. Environmental Protection Agency
GIS	Geographic Information System
H	Health/Life
HO	Homeowners
IBHS	Institute for Business and Home Safety
IPMVP	International Performance Measurement and Verification Protocols
INEEL	Idaho National Engineering and Environmental Laboratory
LBNL	Lawrence Berkeley National Laboratory
Liab	Third-party liability
LLNL	Lawrence Livermore National Laboratory
NREL	National Renewable Energy Laboratory
ORNL	Oak Ridge National Laboratory
PD	Property Damage
PFL	Professional Liability
PI	Personal Injury
PL	Personal Line
PLC	Product Liability Coverage
PNNL	Pacific Northwest National Laboratory
PV	Photovoltaic
RI	Refrigeration Insurance
RICOWI	Roofing Industry Committee on Wind Issues
SI	Service Interruption
SNL	Sandia National Laboratories
WC	Workers Compensation

Executive Summary

The promotion of technologies and services for insurance loss reduction and loss prevention is as old as the fields of insurance and risk management. This report addresses a new category of risk management opportunity involving technologies and procedures that use energy more efficiently or supply renewable energy. While the economic benefits of these measures are of interest to energy consumers seeking to reduce their energy expenditures, we have found that they also offer a novel and largely untapped pathway for achieving traditional risk management objectives.

Most of the technologies described in this report were supported by government-sponsored RD&D programs over many years of effort. These technologies have many benefits, including insurance loss reduction and prevention. The insurance and risk management communities could take advantage of these technologies, either independently or in cost-sharing partnerships with existing R&D programs.

In this report, we present a compilation of energy-efficiency and renewable energy projects (e.g., energy-efficient halogen torchiere replacements) and techniques (e.g., infrared cameras to detect fire hazards) that are currently being investigated at the U.S. Department of Energy's national laboratories and which the insurance and risk management communities could encourage their customers to use to address their short-term and long-term needs. Once the loss-prevention benefits of these technologies and techniques (many of which are not yet available in the marketplace) are sufficiently demonstrated, insurers can promote their use through informational programs and perhaps financial incentives (e.g., risk-adjusted insurance premium schemes) through the insurance regulatory and rate-making processes.

We identified 78 technologies and techniques being investigated by nine national laboratories which can help to reduce insurance losses and manage risks, especially those associated with power failures, fire and wind damage, and home or workplace indoor air quality hazards (Table ES-1). All help to reduce insurance losses in one or more of the following categories: boiler and machinery, builder's risk, business interruption, commercial property insurance, completed operations liability, comprehensive general liability, contractors liability, environmental liability, product liability, professional liability, service interruption, workers' compensation, health/life insurance, and homeowners insurance.

We identify examples of existing collaborations between the national laboratories and the insurance industry, and indicate research activities being conducted by the insurance and risk management communities that would benefit from the work of the national laboratories. We also describe some of the risk factors associated with energy-efficient and renewable energy technologies.

For the future, significant progress could be made through interdisciplinary collaborative applied research (i.e., integrating the actuarial sciences with the "physical" or "engineering" sciences). This collaboration could be sponsored jointly by the U.S. Department of Energy and the insurance and risk management communities (as well as working through the insurance regulatory and rate-making processes).

Table ES-1. Physical Perils and Insurance Coverage Addressed by Energy-Efficiency and Renewable Energy Technologies & Strategies

	Number of measures offering benefit[1]
Physical Perils	
Extreme Temperature Episodes	**16**
Fire & Wind Damage	**38**
Home or Workplace Indoor Air Quality Hazards	**38**
Home or Workplace Safety Hazards	**21**
Ice & Water Damage	**17**
Outdoor Pollution or Other Environmental Hazard	**17[2]**
Power Failures	**35**
Theft and Burglary	**6**
Insurance Coverage — Commercial Lines	
Boiler & Machinery	**15**
Builder's Risk	**4**
Business Interruption	**21**
Commercial Property Insurance	**36**
Completed Operations Liability	**14**
Comprehensive General Liability	**45**
Contractors Liability	**14**
Environmental Liability	**12**
Health/Life Insurance	**39**
Product Liability	**5**
Professional Liability	**19**
Service Interruption	**21**
Workers' Compensation	**35**
Insurance Coverage — Personal Lines	
Health/Life Insurance	**35**
Homeowners Insurance	**26**

[1]The numbers in this column refer to unique technologies and covers all (i.e., including non-national laboratory) technologies in Table 4. For example, if two national laboratories are conducting research on fuel cells, this is "counted" only once under Service Interruption in Table ES-1.

[2]The environmental benefits of improving the outdoor air and reducing greenhouse gases by renewable energy resources (e.g., solar, wind, etc.) are not included in this table.

Chapter 1. Introduction

1.1. Objectives of Report

The promotion of technologies and services for insurance loss reduction and loss prevention is as old as the fields of insurance and risk management. Examples include the early fire departments established by insurance companies, the creation of the almost century-old Underwriters Laboratories, and more than 160 years of property loss prevention experience by the Factory Mutual Research Corporation. Today, automotive air bags, sophisticated security systems, fire sprinklers and alarms, and environmental monitoring equipment are familiar risk management technologies promoted by insurers. In some cases, insurers are involved with the fundamental research and development of such technologies.

This report addresses a new category of risk management opportunity involving technologies and procedures that use energy more efficiently or supply renewable energy (Mills 1996; Mills 1997; Mills and Knoepfel 1997; Mills et al. 1998). While the economic benefits of these measures are of interest to energy consumers seeking to reduce their energy expenditures, we have found that they also offer a novel and largely untapped pathway for achieving traditional risk management objectives. For example, some of the technologies discussed in our report might make a marginal risk acceptable to insurers, given acceptable controls or monitoring: from high value risks where machinery and equipment monitoring devices are critical in affecting loss performance, to homes with proper monitoring equipment that can prevent fires from furnaces or wood stoves.

In this report, we present a compilation of energy-efficiency and renewable energy projects (e.g., energy-efficient halogen torchiere replacements) and techniques (e.g., infrared cameras to detect fire hazards) that are currently being investigated at the U.S. Department of Energy's (DOE's) national laboratories and which the insurance and risk management communities could encourage their customers to use to address their short-term and long-term needs. Once the loss-prevention benefits of these technologies and techniques (many of which are not yet available in the marketplace) are sufficiently demonstrated, insurers can promote their use through informational programs and perhaps financial incentives (e.g., risk-adjusted insurance premium schemes) through the insurance regulatory and rate-making processes.

The audience for this report comprises three groups: (1) the insurance and risk management communities (in particular, insurers), (2) the research community at the national laboratories and within the insurance industry, and (3) policymakers at DOE and at the U.S. Environmental Protection Agency (EPA) that are interested in working with the insurance and risk management communities to promote energy efficiency and renewable energy technologies. We realize that other stakeholders have critical roles and responsibilities for reducing insurance losses (e.g., insurance regulatory authorities, code officials, government agencies (local, state and federal), contractors, builders and tradesmen, and property owners and managers), and we hope that this entire community will become more involved in promoting the technologies and services described in this report.

In addition to Appendix C, these projects and techniques are also available on the World Wide Web at http://eetd.lbl.gov/CBS/Climate-Insurance/welcome.html, and they will be updated periodically at this site.

1.2. Research Methodology

In this report, we describe energy-efficiency and renewable energy technologies that are primarily funded by DOE's Office of Energy Efficiency and Renewable Energy (EERE) and that are studied at DOE's national laboratories. As an indicator of the level of current activity in this field, DOE's FY 1998 budget for energy efficiency and renewable energy R&D is approximately $900 million. Due to resource constraints, we limited the scope of work to technologies and services that affected energy use in the residential and nonresidential sectors, and did not examine technologies in detail in other sectors (e.g., transportation and agriculture).

We first contacted EERE's Deputy Assistant Secretaries and their staff in the Office of Building Technologies and State and Community Programs, Office of Utility Technologies, and the Office of Industrial Technologies, and solicited the names of projects and researchers at the national laboratories. We then contacted the national laboratories (Table 1) and asked each project manager to complete a survey form on their project (Appendix A contains a copy of the survey form and survey instructions).[1] We collected the following type of information on each project: contact information, description of technology studied, avoided insurance losses, research capabilities and skills, research facilities, publications, standards/guidelines/protocols/software tools, links to World Wide Web sites, demonstration projects, international activities, future work, collaborations with the insurance industry, and suggestions for insurance-related research in their project.

Table 1. National Laboratories in Insurance Inventory

Argonne National Laboratory
Brookhaven National Laboratory
Idaho National Engineering and Environmental Laboratory
Lawrence Berkeley National Laboratory
Lawrence Livermore National Laboratory
National Renewable Energy Laboratory
Oak Ridge National Laboratory
Pacific Northwest National Laboratory
Sandia National Laboratories

To facilitate the transfer of information, we placed the survey form and instructions for completing the survey on the World Wide Web (the World Wide Web home page is: http://eetd.lbl.gov/CBS/Climate-Insurance/welcome.html). Researchers were then able to provide information on their project directly on the Web, and now readers can view it there.

After each project was put on the Web, we reviewed the project descriptions and frequently asked the laboratory contacts to provide more information or clarify existing data on their projects. The completed surveys are in Appendix C and on the World Wide Web.

A few caveats are in order. First, we tried to be comprehensive but realize that we have not covered all of the projects at the national laboratories. We did not

[1]In four cases, the national laboratories recommended that their subcontractors would be the best persons to respond, and as a result, the Florida Solar Energy Laboratory, the University of Delaware, and the Portland Energy Conservation, Inc. are included in the inventory.

interview all of the staff at DOE (due to resource limitations), and not all of our national laboratory contacts were able to complete the survey (due to time constraints and other priorities). Second, the insurance and risk management communities have yet to systematically quantify the types of losses considered here. We present some examples from several countries of losses that are partly associated with energy-using equipment, however, potential losses need to be comprehensively identified and analyzed. Third, because the concept of avoided insurance losses via energy-efficiency and renewable energy technologies is relatively new, most of the national laboratory researchers had never considered how their technologies would reduce insurance losses and, therefore, most analyses of insurance losses are qualitative. Fourth, due to resource limitations, we focused our research on the residential, commercial and industrial sectors and did not look at other sectors, such as agriculture and transportation. And fifth, we have tried to be nonrestrictive if we thought a research project could be useful for reducing insurance losses: we have eliminated purely speculative cases, however, much research still needs to be undertaken for many products and services to illustrate their usefulness to the insurance industry.

1.3. Organization of Report

In Chapter 2, we present an overview of the types of avoided insurance losses that are addressed in this report. For each insurance loss, we provide examples of how energy-efficiency and renewable energy technologies that are included in the inventory help to reduce insurance losses or manage risks. We also present a detailed listing of all the energy-efficiency and renewable energy technologies and services in the inventory and their links to risk management and reduced insurance losses. We provide a listing of facilities at the national laboratories that are available to the insurance and risk management communities for conducting insurance-related research on particular technologies and services. We also suggest some research topics as a first step in developing a national research agenda for the national laboratories. We identify selected examples of collaborations between the national laboratories and the insurance industry and indicate areas of research activities being conducted by the insurance community that would benefit the work of the national laboratories. We conclude this chapter by describing some of the risk factors associated with energy-efficient and renewable energy technologies.

In Chapter 3, we present examples from several countries of property and health losses that are partly associated with energy-using equipment. In the last chapter (Chapter 4), we describe the opportunities for conducting collaborative applied research between the national laboratories and the insurance and risk management communities and a process for promoting this collaboration.

Chapter 2. Energy-Efficiency and Renewable Energy Technologies

In this chapter, we present an overview of the types of avoided insurance losses that are addressed in this report. For each insurance loss, we provide examples of how energy-efficiency and renewable energy technologies that are included in the inventory help to reduce insurance losses. We then present a detailed listing of all the energy-efficiency and renewable energy technologies and services in the inventory and their links to risk management and reduced insurance losses. We also provide a listing of research facilities at the national laboratories and suggest some research topics as a first step in developing a national research agenda for the national laboratories. We then identify selected examples of collaborations between the national laboratories and the insurance industry and indicating areas of research activities being conducted by the insurance and risk management communities that would benefit the work of the national laboratories. We conclude this chapter by describing some of the risk factors associated with energy-efficient and renewable energy technologies.

2.1. Avoided Insurance Losses

Energy-efficiency and renewable energy technologies have the potential of reducing insurance losses involving property, health, life, or liability in the residential and nonresidential sectors. A list of insurance categories is presented in Table 2; these categories are defined in greater detail in Appendix B. In Table 3, we summarize the energy-efficiency and renewable energy technologies that are in the inventory and that reduce these losses. In this section, we present examples of these technologies.

We relate insurance losses to eight types of physical perils (hazards) in our report:

1. **Extreme temperature episodes:** e.g., freezing temperatures can result in broken water pipes, while very hot temperatures can lead to "urban heat catastrophes" and loss of life. As an example, over 5,300 summer heat deaths have occurred from a dozen urban heat storms in U.S. cities (Whitman et al. 1997).

2. **Fire and wind damage:** e.g., malfunctioning heating or lighting equipment can lead to fires, severe property damage, and loss of life, and high winds from tornadoes and hurricanes can also lead to severe property damage and loss of life. Approximately $2 billion in insured losses occurs annually from fires attributed to heating or electrical equipment in buildings (see Chapter 3).

Table 2. Insurance Terms and Coverages[1]

Commercial Lines
Boiler and machinery risk
Builder's risk
Business interruption coverage
Commercial property insurance
Completed operations liability coverage
Comprehensive general liability coverage
Contractor's liability coverage
Environmental liability
Health/life insurance
Product liability coverage
Professional liability
Service interruption coverage
Workers' compensation
Personal Lines
Health/life Insurance
Homeowners Insurance

[1]Definitions of many of these terms are provided in Appendix B. These insurance terms and coverage are taken from "The Complete Glossary of Insurance Coverage Explanations" found on the World Wide Web page: http://www.lcgroup.com/explanations.

Table 3. Physical Perils and Insurance Coverage Addressed by Energy-Efficiency and Renewable Energy Technologies & Strategies

	Number of measures offering benefit[1]
Physical Perils	
Extreme Temperature Episodes	**16**
Fire & Wind Damage	**38**
Home or Workplace Indoor Air Quality Hazards	**38**
Home or Workplace Safety Hazards	**21**
Ice & Water Damage	**17**
Outdoor Pollution or Other Environmental Hazard	**17**[2]
Power Failures	**35**
Theft and Burglary	**6**
Insurance Coverage — Commercial Lines	
Boiler & Machinery	**15**
Builder's Risk	**4**
Business Interruption	**21**
Commercial Property Insurance	**36**
Completed Operations Liability	**14**
Comprehensive General Liability	**45**
Contractors Liability	**14**
Environmental Liability	**12**
Health/Life Insurance	**39**
Product Liability	**5**
Professional Liability	**19**
Service Interruption	**21**
Workers' Compensation	**35**
Insurance Coverage — Personal Lines	
Health/Life Insurance	**35**
Homeowners Insurance	**26**

[1]The numbers in this column refer to unique technologies and covers all (i.e., including non-national laboratory) technologies in Table 4. For example, if two national laboratories are conducting research on fuel cells, this is "counted" only once under Service Interruption in Table 3.

[2]The environmental benefits of improving the outdoor air and reducing greenhouse gases by renewable energy resources (e.g., solar, wind, etc.) are not included in this table.

3. **Home or workplace indoor air quality hazards**: e.g., carbon monoxide from improperly installed ducts and malfunctioning appliances can cause illness or death. Each year, about 1,500 deaths result from CO poisonings in the U.S.

4. **Home or workplace safety hazards:** e.g., energy-efficient lighting often leads to less fixtures being installed as well as fewer changes in fixtures and lamps, thus reducing the safety hazards associated with lamp and fixture replacement. As an example, compact fluorescent lamps last ten times as long as incandescent bulbs, and LED exit lights are known to last much longer than incandescent exit lights.

5. **Ice and water damage**: e.g., repeated melting and re-freezing of snow can cause the formation of icicles and ice dams on roof eaves. Melting water tends to pond on the rooftop, behind the ice dam, often damaging the roof and the building interior. As an example, losses from frozen water pipes in the U.S. resulted in losses of $450 million/year during 1985-95 (Tharpe 1996). These losses occur during average seasonal temperatures (differentiating this physical peril from the first hazard associated with extreme temperatures).

6. **Outdoor pollution or other environmental hazards:** e.g., oil from transformers, mercury from lamps, and heavy metals from metal processing can harm both the environment as well as the workers handling these materials. In the steel industry, approximately $150 million is spent each year for environmental compliance.

7. **Power failures:** e.g., when power service is disrupted due to storms or other events, service interruptions often result. Losses from service interruptions can account for 20-40% of total insured losses.

8. **Theft and burglary:** e.g., poorly designed windows can facilitate theft and burglary in homes.[1]

---

[1] Theft involves the taking of personal property from an individual, and burglary is the felonious breaking and entering of a building.

As seen in Table 3, the most common physical perils were those associated with power failures, fire and wind damage, and home or workplace indoor air quality hazards. More examples of the potential value of avoided losses are presented in Chapter 3.

Given our understanding of these perils, we examine the types of risk associated with these perils and the types of energy-efficiency and renewable energy technologies and services that could reduce insurance losses associated with these risks (this is not an exhaustive list of technologies and services, just exemplary). Some of these links are strong and have been demonstrated in practice, while others are weaker and need to be examined in greater detail.

2.1.1. Boiler and machinery risk

This form of insurance provides important mechanical breakdown coverage generally not available under any other insurance policy. A Boiler and Machinery policy can protect an insured against the effects of catastrophic property loss, such as steam boiler explosion or an expensive breakdown of machinery and equipment. Mechanical breakdown coverage encompasses much more than just boilers and pressure vessels. It also can include refrigeration equipment, air-conditioning equipment, various types of piping, turbines, engines, pumps, compressors, blowers, gearing, shafting, electric motors, generators, transformers and assorted other types of mechanical and electrical equipment. In fact, many policies are written for insureds who do not own or operate boilers or pressure vessels, but yet have sizable mechanical and electrical exposures.

One of the best ways of avoiding mechanical breakdowns is making sure the equipment is designed and installed properly and that any equipment is in compliance with existing standards or guidelines, the focus of building code development and compliance (see LBNL-6 and PNNL-1).

Once a building has been constructed and the equipment is operating, integrated information technologies are needed to assure building performance by carefully examining the process by which buildings are designed, built, commissioned, and operated (LBNL-22). The key elements of integrated information technology are software tools, building commissioning protocols, data, and energy management and control systems, i.e., products and services that can be used in buildings to reduce insurance losses. These elements will collect, document, and communicate important information about the building's design, the state of its operations, and its intended and actual performance. These tools will also allow their users to detect and diagnose discrepancies between intended and actual performance, and feed lessons back to building designers about design and operations problems.

Key integrated information technologies in the inventory include: energy management and control systems (EMCS), building commissioning, architectural and infrastructure surety, and measurement and verification protocols. EMCS control energy use, building comfort and other factors and can be used to optimize factors that affect the energy use and productivity of employees in commercial buildings (LBNL-21). Building commissioning is a process by which a building's energy service systems are tested and calibrated to make sure the building system is in full working order (LBNL-5, ORNL-10, PNNL-3). The principles of architectural and infrastructure surety (SNL-3) can be used to avoid mechanical breakdowns by applying risk management approaches to facility designs through the process of identifying, assessing, analyzing and mitigating risks in residential and commercial equipment. And measurement and verification protocols provide a uniform method of determining how much energy is saved by energy-efficiency measures (LBNL-9). These protocols encourage that the equipment is installed properly and that the building will be constructed as designed.

The insurance inventory contains other tools that can help to reduce these kinds of losses. For example, infrared thermography is a tool that is used by some insurance companies to detect leaks in working fluids in refrigeration systems (LBNL-27). And explosion prevention technologies can prevent significant damage to property and buildings (ORNL-4).

2.1.2. Builder's risk

Builder's risk insurance indemnifies for loss of, or damage to, a building under construction. Insurance is normally written for a specified amount on the building and applies only in the course of construction. Coverage customarily includes fire, extended coverage, vandalism, and malicious mischief. One of the best ways for reducing builder's risk is through building code development and compliance (LBNL-6 and PNNL-1), as well as many of the integrated information technologies described in Section 2.1.1: integrated information technology (LBNL-21), energy management and control systems (LBNL-21), building commissioning (LBNL-5, ORNL-10, PNNL-3), architectural and infrastructure surety (SNL-3), and measurement and verification protocols (LBNL-9).

2.1.3. Business interruption coverage

This form of insurance provides loss of income coverage for a business by replacing operating income during the period when damage to the premises or other property prevents income from being earned. It is by means of the operating income that a business meets its expenses of payroll, light, heat, advertising, telephone service, etc., and from which a profit is derived. If business interruption is suffered and one has to close for several months or operate at a reduced pace because of fire or other perils, this income will cease or be reduced. The business interruptions are due to fire, lightning, water damage, etc. If the business interruption is due to an interruption in "incoming services" (e.g., electricity and gas), then this is classified as service interruption (see Section 2.1.12).

Several technologies covered in this can be used to reduce insurance losses from business interruptions. Explosion prevention technologies can prevent significant damage to property and buildings, avoiding business interruptions (ORNL-4). Ultraviolet water purification (LBNL-3) can produce emergency potable water during disaster situations, so that businesses can still operate. Refractories in glass production furnaces can maximize the service life and minimize the down time of these kinds of furnaces (ORNL-11). Similarly, the reduction of cracking in recovery boilers in pulp and paper mills will also maximize the service life and minimize the down time of these mills (ORNL-12).

2.1.4. Commercial property insurance

Commercial property insurance policies provide indemnification to the policyholder for direct damage to insured structures and business personal property

(Lecomte 1998). Direct damage to insured structures and business personal property includes payment for the repair or replacement of the damaged property.

Many of the integrated information technologies and services described in Section 2.1.1 help to reduce commercial property insurance: e.g., integrated information technology (LBNL-21), energy management and control systems (LBNL-21), building commissioning (LBNL-5), architectural and infrastructure surety (SNL-3), and measurement and verification protocols (LBNL-9). Other examples of energy-efficient technologies that can reduce commercial property insurance include: efficient duct systems (LBNL-4), light-colored roofs (LBNL-7), energy-efficient torchieres (LBNL-1), explosion prevention technologies (ORNL-4), wind-resistant building envelopes (ORNL-5), durable roof coating materials (ORNL-6), and efficient motors (LBNL-26 and ORNL-14).

As an example, halogen floor lamps (torchieres) are extremely energy intensive (300 Watts) and operate at very high temperatures (~1000 °F), creating a significant fire hazard in homes and dormitories (LBNL-1). About 100 fires occurred at U.S. colleges and universities in 1996 and 1997. A safer, energy-efficient torchiere has recently been developed and can be used as a replacement for the halogen floor lamp based on compact fluorescent technology. This replacement lamp consumes only 60-80 Watts to provide the same amount of light output, and operates at significantly lower temperatures (only 100 °F), limiting or decreasing the risk of fire hazards.

2.1.5. Completed operations liability

This form of liability insurance provides coverage for bodily injury and property damage arising from completed or abandoned operations, provided the incident occurs away from premises owned or rented by the insured. The best way of avoiding these problems is making sure the equipment is designed and installed properly, the focus of building code development and compliance (LBNL-6 and PNNL-1) as well as standard measurement and verification protocols (LBNL-9). Furthermore, once a building has been constructed and the equipment is operating, several of the integrated information technologies described in Section 2.1.1 can ensure that equipment will not result in bodily injury or property damage:

integrated information technology (LBNL-21), energy management and control systems (LBNL-21), and building commissioning (LBNL-5, ORNL-10, PNNL-3).

Because indoor air quality illnesses can result in large insurance losses (see Chen and Vine 1998; Fisk and Rosenfeld 1997), reducing the strength of indoor pollutant sources is commonly the best (i.e., the simplest, most effective and economical) method to reduce indoor air pollution (LBNL-10). For example, radon is a naturally occurring radioactive gas that is responsible for about 12,000 deaths annually in the United States. Radon-resistant housing reduces the liability of the builder and the real estate owner from exposing occupants to high levels of indoor radon (LBNL-19).

2.1.6. Comprehensive general liability

Under this form of insurance, the insurance company will pay all sums the insured becomes legally obligated to pay as damages due to bodily injury and property damage. Comprehensive general liability provides coverage for damages incurred by third parties (individuals, companies, firms, corporations, etc.) when the insured is legally liable, but does not cover property damage in commercial buildings to the insured (see commercial property insurance, Section 2.1.4). The technologies included under commercial property insurance are also good examples for this type of insurance (see Section 2.1.4).

2.1.7. Contractors liability

Contractors are liable for damages resulting from bodily injury and/or property damage caused by an insured peril and arising out of the ownership, maintenance, or use of premises and operations in progress. They are also liable for bodily injury and/or property damage after their work is completed and they have left the job site. This type of insurance covers people who are working on a particular construction site, in contrast to professionals (e.g., architects and engineers) who may not be at the construction site (see Professional Liability).

Many of the integrated information technologies and services described in Section 2.1.1 help to reduce contractors liability (e.g., building code development and compliance (LBNL-6 and PNNL-1), measurement and verification protocols (LBNL-9), energy management and control systems (LBNL-21), building commissioning (LBNL-5, ORNL-10, PNNL-3)), as well as reduction of indoor air pollution (LBNL-10), and radon-resistant housing (LBNL-19). In the area of combustion (oil or gas), appliance installation, repair and sizing are important: improper sizing and specification, improper installation, negligence, improper maintenance procedures during service, etc. can lead to carbon monoxide poisoning. As more and more vent-free (unvented) gas heaters enter the market (sales approaching a million/year in the U.S.), the long-term safety of these appliances is problematic, since they do not vent their combustion products outside of the living space. Carbon monoxide sensors (LBNL-17) would help warn people about safety problems with these appliances.

Geographic information systems (GIS) (LBNL-8, ORNL-13) can also be used to make contractors aware of certain types of risk (e.g., water-pipe freeze damage or ice dam formation in insufficiently insulated roofs). Finally, the principles of architectural and infrastructure surety (SNL-3) can be used by applying risk management approaches to facility designs through the process of identifying, assessing, analyzing and mitigating risks in residential and commercial construction.

2.1.8. Environmental liability

Several energy-efficiency technologies and services help to reduce environmental liability risks. For example, by replacing oil-filled transformers with superconducting transformers, there may be fewer liability concerns with the handling and leakage of oil, as well as problems with transformers that are cooled with oil (ORNL-2). Similarly, the replacement of chlorofluorocarbons (CFCs) by advanced thermal insulation (e.g., evacuated panel superinsulations and non-HCFC-blown plastic foam insulation) will reduce potential liability claims related to the handling and/or leakage of CFCs in buildings (ORNL-3). Recovering zinc from galvanized scrap metal results in cleaner scrap metal that can be recycled, purified zinc that can be resold, and a reduction in the amount of heavy metals and caustic solutions that need to be handled and disposed (ANL-2). Installing composite wall systems reduces the exposure of children to lead poisoning hazards in residential housing (ANL/ORNL-1). Finally, sulfur lamps do not use mercury, thereby eliminating insurance claims related to the handling or disposal of mercury (LBNL-12).

2.1.9. Health/Life insurance (Commercial)

Examples of technologies and services that reduce losses under health/life insurance include the following: building commissioning and building code enforcement (LBNL-5, LBNL-6, PNNL-1), light-colored roofs and surfaces (LBNL-7), daylighting (LBNL-28, ORNL-7), technologies for clean rooms (LBNL-14), radon resistant housing (LBNL-19), composite walls (ANL/ORNL-1), and energy-efficient torchieres (LBNL-1). Other technologies not previously described include the improvement of oil-fired combustion systems, including the reduction of fouling and corrosion of heat exchangers (BNL-1), as well as the training and certification of oil-fired heating system service personnel to make sure the equipment is operating as designed (BNL-4).

2.1.10. Product liability

Product liability is the liability for bodily injury or property damage incurred by a merchant or manufacturer as a consequence of some defect in the product sold or manufactured, or the liability incurred by a contractor after he has completed a job as a result of improperly performed work.

Building commissioning is a process that should reduce product liability claims by making sure that equipment (and the building) is operating as designed (LBNL-5, ORNL-10, PNNL-3). Energy-efficient torchieres (instead of halogen torchieres) represent a specific technology that will significantly reduce product liability claims, since halogen torchieres account for about 10% of residential lighting use in the United States (LBNL-1). As noted in Section 2.1.4, halogen torchieres create a significant fire hazard in homes and dormitories. In addition to the 100 fires that occurred at U.S. colleges and universities in 1996 and 1997, halogen torchieres are one of the primary causes of lighting-related fires in homes: 189 fires have been reported since 1991. A safer, energy-efficient torchiere has recently been developed and can be used as a replacement for the halogen floor lamp based on compact fluorescent technology. This replacement lamp consumes only 60-80 Watts to provide the same amount of light output, and operates at significantly lower temperatures (only 100 °F), limiting or decreasing the risk of fire hazards.

2.1.11. Professional liability

Professional liability insurance is coverage for liability resulting from errors or omissions in the performance of professional duties. This is applicable as a general rule to professional business activities, typically not at the construction site (see Contractors Liability, Section 2.1.7).

In addition to the integrated information technologies described in Section 2.1.1 (e.g., integrated information technology (LBNL-21), energy management and control systems (LBNL-21), building commissioning (LBNL-5, ORNL-10, PNNL-3), architectural and infrastructure surety (SNL-3), and measurement and verification protocols (LBNL-9)), several energy-efficiency technologies and services help to reduce contractors liability: reduction of indoor air pollution (LBNL-10), radon-resistant housing (LBNL-19), and geographic information systems (LBNL-8, ORNL-13).

2.1.12. Service interruption coverage

Similar to business interruption coverage, this form of insurance provides loss of income coverage for a business by replacing operating income during the period when damage to the premises or other property prevents income from being earned. It is by means of the operating income that a business meets its expenses of payroll, light, heat, advertising, telephone service, etc., and from which a profit is derived. If business interruption is suffered and one has to close for several months or operate at a reduced pace because of fire or other perils, this income will cease or be reduced. The service interruption is due to an interruption in "incoming services" (e.g., electricity and gas). If the interruptions are due to fire, lightning, water damage, etc., then this is classified as business interruption (see Section 2.1.3).

Energy-efficient technologies consume less energy than their counterparts and, therefore, can operate more effectively under minimum power conditions, reducing the negative impacts of business interruptions. For example, light-colored roofs (LBNL-7) reduce air-conditioning use during peak power periods lessening the risk of power failures. Similarly, cool storage systems (LBNL-30 and ORNL-8) are used in commercial buildings to shift the cooling load of a building to offpeak periods during the day; if a building's chiller or refrigeration system were to fail and the storage system could provide more than 12 hours of air conditioning without chiller operation, this would provide time for the chiller to be repaired or for alternative cooling arrangements to be completed. Any insured losses associated with building operation might be avoided. If the storage system provides less than 12 hours of air conditioning without chiller operation, benefits would still accrue, as uninsured or self-insured losses would be less.

Renewable energy technologies can provide power to a building when power service is disrupted: examples in our inventory include flywheel storage (ANL-4, INEEL-3, LLNL-1, and ORNL-15), fuel cells (ANL-6, INEEL-1, LBNL-23, and LLNL-2), advanced batteries (ANL-3, LBNL-29), photovoltaic (PV) systems (NREL-3, NREL-5, NREL-6, and SNL-4), parabolic troughs for solar electric power (NREL-2), and, where available and appropriate, wind, geothermal, and biomass (NREL-7, SNL-1). For example, fuel cells can convert the chemical energy of nonpetroleum fuels (e.g., hydrogen, methanol or ethanol) to electricity with little or no pollution and with greater efficiency than heat engines and can provide this power continuously and reliably. Solar heating and cooling technologies (SNL-1 and SNL-2) also reduce a building's reliance on the conventional power grid, reducing the impact of business interruptions when power service is down.

2.1.13. Worker's compensation

Workers compensation insurance protects the employee and the employer from the expenses and liabilities associated with a work-related accident. The legal requirements for obtaining this insurance vary widely from state to state, with wages paid or hours worked usually the defining item.

Many energy-efficiency technologies and services help to reduce worker's compensation claims: for example, building commissioning and energy management and control systems ensure that equipment is operating as designed (LBNL-5, ORNL-10, PNNL-3, and LBNL-21). The reduction of indoor pollutant sources should reduce worker's compensation claims by improving the indoor air quality and health of workers (LBNL-10). Specific technologies also should reduce this type of insurance claims. For example, a lightweight vest intended for workers in spray booths and walk-in fume hoods reduces a worker's exposure to paint fumes and should result in fewer worker's compensation and health insurance claims (LBNL-11). Similarly, technologies for clean rooms can be used to control particles in cleanrooms (which are used extensively in the manufacturing of integrated circuits, in the biological and pharmaceutical industries, and in medical facilities), keeping contaminants to a minimum (LBNL-14); the air quality may be the same, but with lower energy use, or air quality could improve, but with higher energy use. The use of organic coatings may prevent the onset of explosions in the metals casting industry which can lead to the loss of lives and serious injuries (ORNL-4). Recovering zinc from galvanized scrap metal results in a reduction in the amount of time that people are in contact with heavy metals and caustic solutions (ANL-2).

2.1.14. Health/life insurance and personal liability (Residential)

Many of the energy efficiency technologies and services that reduce commercial lines of coverage also reduce exposures under personal lines of coverage, especially with respect to health and life insurance and personal liability. Examples include the following technologies and services: building commissioning and building code enforcement (LBNL-5, LBNL-6, PNNL-1), light-colored roofs and surfaces (LBNL-7), daylighting (LBNL-28, ORNL-7), technologies for clean rooms (LBNL-14) (see section 2.1.12), radon resistant housing (LBNL-19), composite walls (ANL/ORNL-1), energy-efficient torchieres (LBNL-1), the improvement of oil-fired combustion systems, including the reduction of fouling and corrosion of heat exchangers (BNL-1).

2.1.15. Homeowners insurance

Several energy efficiency technologies and services can help reduce homeowners' insurance claims: e.g., light-colored roofs and surfaces (LBNL-7) and energy-efficient torchieres (LBNL-1). Duct systems in houses typically leak 15-30% of the air passing through them, impacting safety, energy use, indoor air quality, personal comfort and the environment. Improving the performance of duct systems (BNL-2) and using aerosol sealing for internally sealing air leaks in heating and cooling ducts (LBNL-4). can avoid fires caused by furnace flame roll-out. The training, testing and certification of service technicians has aided in the safe long-term operation of oil-fired heating equipment (BNL-4).

2.1.16. Summary

As summarized in Table 3, the energy-efficiency and renewable energy technologies and services in the inventory impact thirteen types of commercial lines of insurance and two types of personal lines of insurance (Health/Life and Homeowners). Of the commercial lines of insurance, the top four categories are Comprehensive General Liability, Health/Life, Commercial Property, and Workers Compensation. These were closely followed by Business Interruption and Service Interruption. In Section 2.2, we look more closely at the linkages between technologies/services and insurance loss reductions for all of the cases in the inventory. We also encourage the reader to look at each of the project descriptions in Appendix C (as well as the World Wide Web) to gain a better understanding of these technologies and services.

2.2. Inventory Overview

Table 4 presents a detailed listing of the energy-efficiency and renewable energy technologies and services in the inventory and their links to reduced insurance losses (based on Mills and Knoepfel 1997). Some of these links are strong and have been demonstrated in practice, while others are weaker and need to be examined in greater detail. Similarly, some of these technologies are just beginning to be researched (e.g., advanced batteries, fuel cells, flywheel energy storage), some are being actively demonstrated (e.g., ceramicrete, zinc recovery, composite walls), and others are ready to be commercialized (e.g., IPMVP). Most of the projects in the inventory fall into the first two categories and are not ready to be commercialized. At the end of the table, we have also included several technologies that are not currently being researched by the national laboratories but which could be conducted at these institutions.

Table 4. Overview of Lab Projects and Avoided Insurance Losses

		Physical Perils & Events								Insured Risks Mitigated		
Inventory ID No.	**Loss-Prevention Measure**	Fire & Wind Damage	Ice & Water Damage	Extreme Temperature Episodes	Theft & Burglary	Power Failures	Home or Workplace Safety Hazards	Home or Workplace Indoor Air Quality Hazards	Outdoor Pollution or Other Environ-mental Hazards			
	TOTALS (all entries) TOTALS (unique tech's)	**44** 38	**21** 17	**21** 16	**7** 6	**47** 35	**26** 21	**39** 38	**18** 17			
ANL-1											EL CGL CPI	CL
ANL-2							√		√			CL
ANL-3												
ANL-4												
ANL-5												
ANL/ORNL-1												
BNL-1		√						√			H HO CGL CPI BM	CL PL
BNL-2											HO BM CGL CPI	CL PL
BNL-3		√						√			HO BM CGL CPI H WC	CL PL

Insurance Type: Liab = Third-party Liability; PD = Property Damage; **Insurance Line**: PL = Personal Line; CL = Commercial Line
Insurance Coverage: BI = Business Interruption; BM = Boiler & Machinery; BR = Builder's Risk; CGL = Comprehensive General Liability; CLC = Contractors Liability Coverage; CO = Completed Operations; CPI = Commercial Property Insurance; EL = Environmental Liability; H = Health/Life; HO = Homeowners; PFL = Professional Liability; PLC = Product Liability Coverage; SI = Service Interruption; WC = Workers' Compensation

Table 4 Continued. Overview of Lab Projects and Avoided Insurance Losses

		Physical Perils & Events								Insured Risks Mitigated		
Inventory ID No.		Fire & Wind	Ice & Water	Extreme Temperature	Theft &	Power	Home or Workplace Safety	Home or Workplace Indoor Air Quality	Outdoor Pollution or Other Environ-			
BNL-4		√						√			WC HO BM CGL CPI PFL H	CL PL
INEEL-1												
INEEL-2								√				CL
INEEL-3						√						
INEEL-4								√				CL PL
LBNL-1		√									HO CGL CPI PLC H	CL PL
LBNL-2											HO PFL CGL CPI H	CL PL
LBNL-3											BI H	CL PL

Insurance Type: Liab = Third-party Liability; PD = Property Damage; **Insurance Line**: PL = Personal Line; CL = Commercial Line
Insurance Coverage: BI = Business Interruption; BM = Boiler & Machinery; BR = Builder's Risk; CGL = Comprehensive General Liability; CLC = Contractors Liability Coverage; CO = Completed Operations; CPI = Commercial Property Insurance; EL = Environmental Liability; H = Health/Life; HO = Homeowners; PFL = Professional Liability; PLC = Product Liability Coverage; SI = Service Interruption; WC = Workers' Compensation

Table 4 Continued. Overview of Lab Projects and Avoided Insurance Losses

		Physical Perils & Events								Insured Risks Mitigated		
Inventory ID No.		Fire & Wind	Ice & Water	Extreme Temperature	Theft &	Power	Home or Workplace Safety	Home or Workplace Indoor Air Quality	Outdoor Pollution or Other Environ-			
LBNL-4		√	√					√			WC PFL HO H CGL CPI BM	CL PL
LBNL-5											WC CGL CPI BR CO CLC BM PFL PLC H	CL
LBNL-6											HO H BI BM CGL CPI CLC CO PFL	CL PL
LBNL-7												CL PL

Insurance Type: Liab = Third-party Liability; PD = Property Damage; **Insurance Line**: PL = Personal Line; CL = Commercial Line
Insurance Coverage: BI = Business Interruption; BM = Boiler & Machinery; BR = Builder's Risk; CGL = Comprehensive General Liability; CLC = Contractors Liability Coverage; CO = Completed Operations; CPI = Commercial Property Insurance; EL = Environmental Liability; H = Health/Life; HO = Homeowners; PFL = Professional Liability; PLC = Product Liability Coverage; SI = Service Interruption; WC = Workers' Compensation

Table 4 Continued. Overview of Lab Projects and Avoided Insurance Losses

		Physical Perils & Events								Insured Risks Mitigated		
Inventory ID No.		Fire & Wind	Ice & Water	Extreme Temperature	Theft &	Power	Home or Workplace Safety	Home or Workplace Indoor Air Quality	Outdoor Pollution or Other Environ-			
LBNL-8		√	√	√	√	√	√	√	√		HO H BI BM CGL CPI CLC CO PFL WC	CL PL
LBNL-9		√	√				√	√	√		BI BM PFL CLC CO CGL CPI WC BR EL	CL
LBNL-10												CL PL
LBNL-11												CL
LBNL-12							√		√			CL

Insurance Type: Liab = Third-party Liability; PD = Property Damage; **Insurance Line**: PL = Personal Line; CL = Commercial Line
Insurance Coverage: BI = Business Interruption; BM = Boiler & Machinery; BR = Builder's Risk; CGL = Comprehensive General Liability; CLC = Contractors Liability Coverage; CO = Completed Operations; CPI = Commercial Property Insurance; EL = Environmental Liability; H = Health/Life; HO = Homeowners; PFL = Professional Liability; PLC = Product Liability Coverage; SI = Service Interruption; WC = Workers' Compensation

Table 4 Continued. Overview of Lab Projects and Avoided Insurance Losses

		Physical Perils & Events								Insured Risks Mitigated		
Inventory ID No.		Fire & Wind	Ice & Water	Extreme Temperature	Theft &	Power	Home or Workplace Safety	Home or Workplace Indoor Air Quality	Outdoor Pollution or Other Environ-			
LBNL-13												CL
LBNL-14											WC H SI CGL CPI	CL
LBNL-15												CL PL
LBNL-16				√		√		√	√			
LBNL-17												CL PL
LBNL-18												CL PL
LBNL-19												PL
LBNL-20												

Insurance Type: Liab = Third-party Liability; PD = Property Damage; **Insurance Line**: PL = Personal Line; CL = Commercial Line
Insurance Coverage: BI = Business Interruption; BM = Boiler & Machinery; BR = Builder's Risk; CGL = Comprehensive General Liability; CLC = Contractors Liability Coverage; CO = Completed Operations; CPI = Commercial Property Insurance; EL = Environmental Liability; H = Health/Life; HO = Homeowners; PFL = Professional Liability; PLC = Product Liability Coverage; SI = Service Interruption; WC = Workers' Compensation

Table 4 Continued. Overview of Lab Projects and Avoided Insurance Losses

		Physical Perils & Events								Insured Risks Mitigated		
Inventory ID No.		Fire & Wind	Ice & Water	Extreme Temperature	Theft &	Power	Home or Workplace Safety	Home or Workplace Indoor Air Quality	Outdoor Pollution or Other Environ-			
LBNL-21		√			√	√					CGL BM SI WC CLC CO H CGL CPI PFL	CL
LBNL-22		√	√	√		√	√		√		H WC CGL CPI BR CO CLC BM PFL EL	CL
LBNL-23												
LBNL-24						√		√				CL
LBNL-25		√				√					HO WC H CGL CPI CO PFL	CL PL

Insurance Type: Liab = Third-party Liability; PD = Property Damage; **Insurance Line**: PL = Personal Line; CL = Commercial Line
Insurance Coverage: BI = Business Interruption; BM = Boiler & Machinery; BR = Builder's Risk; CGL = Comprehensive General Liability; CLC = Contractors Liability Coverage; CO = Completed Operations; CPI = Commercial Property Insurance; EL = Environmental Liability; H = Health/Life; HO = Homeowners; PFL = Professional Liability; PLC = Product Liability Coverage; SI = Service Interruption; WC = Workers' Compensation

Table 4 Continued. Overview of Lab Projects and Avoided Insurance Losses

		Physical Perils & Events								Insured Risks Mitigated		
Inventory ID No.		Fire & Wind	Ice & Water	Extreme Temperature	Theft &	Power	Home or Workplace Safety	Home or Workplace Indoor Air Quality	Outdoor Pollution or Other Environ-			
LBNL-26											CGL CPI SI BM WC PLC H	CL
LBNL-27												CL PL
LBNL-28											SI WC H CGL CPI PFL	CL
LBNL-29												CL
LBNL-30												CL
LLNL-1												
LLNL-2	Zinc-air fuel cell					√		√		PD	SI	CL
NREL-1											H BI SI HO WC CGL CPI	CL PL
NREL-2						√						

Insurance Type: Liab = Third-party Liability; PD = Property Damage; **Insurance Line**: PL = Personal Line; CL = Commercial Line
Insurance Coverage: BI = Business Interruption; BM = Boiler & Machinery; BR = Builder's Risk; CGL = Comprehensive General Liability; CLC = Contractors Liability Coverage; CO = Completed Operations; CPI = Commercial Property Insurance; EL = Environmental Liability; H = Health/Life; HO = Homeowners; PFL = Professional Liability; PLC = Product Liability Coverage; SI = Service Interruption; WC = Workers' Compensation

Table 4 Continued. Overview of Lab Projects and Avoided Insurance Losses

		Physical Perils & Events								Insured Risks Mitigated		
Inventory ID No.		Fire & Wind	Ice & Water	Extreme Temperature	Theft &	Power	Home or Workplace Safety	Home or Workplace Indoor Air Quality	Outdoor Pollution or Other Environ-			
NREL-3												
NREL-4		√	√	√		√					H SI HO WC CGL CPI	CL PL
NREL-5												CL
NREL-6						√						
NREL-7												
ORNL-1		√							√			CL PL
ORNL-2												CL
ORNL-3												
ORNL-4											CGL CPI WC BI	CL
ORNL-5		√										CL PL

Insurance Type: Liab = Third-party Liability; PD = Property Damage; **Insurance Line**: PL = Personal Line; CL = Commercial Line
Insurance Coverage: BI = Business Interruption; BM = Boiler & Machinery; BR = Builder's Risk; CGL = Comprehensive General Liability; CLC = Contractors Liability Coverage; CO = Completed Operations; CPI = Commercial Property Insurance; EL = Environmental Liability; H = Health/Life; HO = Homeowners; PFL = Professional Liability; PLC = Product Liability Coverage; SI = Service Interruption; WC = Workers' Compensation

Table 4 Continued. Overview of Lab Projects and Avoided Insurance Losses

		Physical Perils & Events								Insured Risks Mitigated		
Inventory ID No.		Fire & Wind	Ice & Water	Extreme Temperature	Theft &	Power	Home or Workplace Safety	Home or Workplace Indoor Air Quality	Outdoor Pollution or Other Environ-			
ORNL-6												CL
ORNL-7											BI SI CGL PFL WC H	CL
ORNL-8												CL
ORNL-9												PL
ORNL-10											WC CGL BR CO CLC BM PFL PLC H	CL
ORNL-11		√				√			√		BI EL CGL CPI	CL

Insurance Type: Liab = Third-party Liability; PD = Property Damage; **Insurance Line**: PL = Personal Line; CL = Commercial Line
Insurance Coverage: BI = Business Interruption; BM = Boiler & Machinery; BR = Builder's Risk; CGL = Comprehensive General Liability; CLC = Contractors Liability Coverage; CO = Completed Operations; CPI = Commercial Property Insurance; EL = Environmental Liability; H = Health/Life; HO = Homeowners; PFL = Professional Liability; PLC = Product Liability Coverage; SI = Service Interruption; WC = Workers' Compensation

Table 4 Continued. Overview of Lab Projects and Avoided Insurance Losses

		Physical Perils & Events								Insured Risks Mitigated		
Inventory ID No.		Fire & Wind	Ice & Water	Extreme Temperature	Theft &	Power	Home or Workplace Safety	Home or Workplace Indoor Air Quality	Outdoor Pollution or Other Environ-			
ORNL-12		√				√	√	√			BI SI CGL CPI PFL CLC	CL
ORNL-13		√	√	√	√	√	√		√		HO H BI BM CGL CPI CLC CO PFL WC	CL PL
ORNL-14											CGL CPI SI BM WC PLC H	CL
ORNL-15												
ORNL/NREL-1	Electricity from wood from forests	√	√					√	√			
ORNL/NREL-2	Advanced desiccant air conditioning technology							√				PL CL

Insurance Type: Liab = Third-party Liability; PD = Property Damage; **Insurance Line**: PL = Personal Line; CL = Commercial Line
Insurance Coverage: BI = Business Interruption; BM = Boiler & Machinery; BR = Builder's Risk; CGL = Comprehensive General Liability; CLC = Contractors Liability Coverage; CO = Completed Operations; CPI = Commercial Property Insurance; EL = Environmental Liability; H = Health/Life; HO = Homeowners; PFL = Professional Liability; PLC = Product Liability Coverage; SI = Service Interruption; WC = Workers' Compensation

Table 4 Continued. Overview of Lab Projects and Avoided Insurance Losses

		Physical Perils & Events								Insured Risks Mitigated		
Inventory ID No.		Fire & Wind	Ice & Water	Extreme Temperature	Theft &	Power	Home or Workplace Safety	Home or Workplace Indoor Air Quality	Outdoor Pollution or Other Environ-			
PNNL-1		√	√	√			√				HO H BI BM RI CGL CPI CLC CO PFL	CL PL
PNNL-2						√		√			SI BM	CL
PNNL-3											WC CGL CPI BR CO CLC BM PFL PLC H	CL
SNL-1												CL
SNL-2												CL PL

Insurance Type: Liab = Third-party Liability; PD = Property Damage; **Insurance Line**: PL = Personal Line; CL = Commercial Line
Insurance Coverage: BI = Business Interruption; BM = Boiler & Machinery; BR = Builder's Risk; CGL = Comprehensive General Liability; CLC = Contractors Liability Coverage; CO = Completed Operations; CPI = Commercial Property Insurance; EL = Environmental Liability; H = Health/Life; HO = Homeowners; PFL = Professional Liability; PLC = Product Liability Coverage; SI = Service Interruption; WC = Workers' Compensation

Table 4 Continued. Overview of Lab Projects and Avoided Insurance Losses

		Physical Perils & Events								Insured Risks Mitigated		
Inventory ID No.		Fire & Wind	Ice & Water	Extreme Temperature	Theft &	Power	Home or Workplace Safety	Home or Workplace Indoor Air Quality	Outdoor Pollution or Other Environ-			
SNL-3		√	√	√	√	√	√				HO BI BM BR CGL CPI CLC CO PFL H WC	CL PL
SNL-4												
SNL/NREL-1												
Not covered by labs												
	Compact fluorescent lamps					√	√			Liab		CL PL
	Efficient commercial food refrigeration					√						CL
	Efficient outdoor lighting				√		√				CGL HO H	CL PL
	Electrochromic glazings				√					PD		CL PL
	Electronic fluorescent lighting ballasts	√					√	√			CGL WC H	CL PL

Insurance Type: Liab = Third-party Liability; PD = Property Damage; **Insurance Line**: PL = Personal Line; CL = Commercial Line
Insurance Coverage: BI = Business Interruption; BM = Boiler & Machinery; BR = Builder's Risk; CGL = Comprehensive General Liability; CLC = Contractors Liability Coverage; CO = Completed Operations; CPI = Commercial Property Insurance; EL = Environmental Liability; H = Health/Life; HO = Homeowners; PFL = Professional Liability; PLC = Product Liability Coverage; SI = Service Interruption; WC = Workers' Compensation

Table 4 Continued. Overview of Lab Projects and Avoided Insurance Losses

		Physical Perils & Events								Insured Risks Mitigated		
Inventory ID No.		Fire & Wind	Ice & Water	Extreme Temperature	Theft &	Power	Home or Workplace Safety	Home or Workplace Indoor Air Quality	Outdoor Pollution or Other Environ-			
	Energy audits & diagnostics	√	√				√				BM BI CGL CPI HO H PFL	CL PL
	Extra interior gypsum board	√								PD		CL PL
	Fuel switching from electric to gas cooking	√				√		√				CL PL
	Heat-recovery ventilation		√								CGL HO H WC	CL PL
	Insulated water pipes		√	√							HO CGL CPI BI	CL PL
	LED exit signs					√	√			Liab		CL
	Mitigating ice dam formation		√	√			√	√			HO CGL H	CL PL
	Natural ventilation			√		√					WC BI H	CL PL

Insurance Type: Liab = Third-party Liability; PD = Property Damage; **Insurance Line**: PL = Personal Line; CL = Commercial Line
Insurance Coverage: BI = Business Interruption; BM = Boiler & Machinery; BR = Builder's Risk; CGL = Comprehensive General Liability; CLC = Contractors Liability Coverage; CO = Completed Operations; CPI = Commercial Property Insurance; EL = Environmental Liability; H = Health/Life; HO = Homeowners; PFL = Professional Liability; PLC = Product Liability Coverage; SI = Service Interruption; WC = Workers' Compensation

Table 4 Continued. Overview of Lab Projects and Avoided Insurance Losses

		Physical Perils & Events								Insured Risks Mitigated		
Inventory ID No.		Fire & Wind	Ice & Water	Extreme Temperature	Theft &	Power	Home or Workplace Safety	Home or Workplace Indoor Air Quality	Outdoor Pollution or Other Environ-			
	Radiant barriers	√								PD	HO	PL
	Reduced mercury in lighting						√	√	√	Liab		CL PL
	Sealed-combustion appliances	√									CGL CPI PFL HO H WC	CL PL

Insurance Type: Liab = Third-party Liability; PD = Property Damage; **Insurance Line**: PL = Personal Line; CL = Commercial Line
Insurance Coverage: BI = Business Interruption; BM = Boiler & Machinery; BR = Builder's Risk; CGL = Comprehensive General Liability; CLC = Contractors Liability Coverage; CO = Completed Operations; CPI = Commercial Property Insurance; EL = Environmental Liability; H = Health/Life; HO = Homeowners; PFL = Professional Liability; PLC = Product Liability Coverage; SI = Service Interruption; WC = Workers' Compensation

2.3. Research Facilities at the National Laboratories

The U.S. Department of Energy's national laboratories have many facilities available to the insurance and risk management communities for conducting research on energy-efficient and renewable energy technologies. In Table 5, we have organized the research facilities by type of project. Multiple laboratory listings are presented under each project and referenced with a project identification number (if one is interested in obtaining more information about a particular research facility, the reader can go to Appendix C or the World Wide Web at http://eetd.lbl.gov/CBS/Climate-Insurance/welcome.html). We realize that this is not an exhaustive list of all of the research facilities at the national laboratories, since the list was based on the input from researchers who contributed to this project. However, Table 5 does capture the breadth and diversity of research facilities available to the insurance and risk management communities.

Table 5. Research Facilities at the National Laboratories

Project	Research Facility	Reference
Composite Wall Systems	Envelope research facility	ANL/ ORNL-1
Oil-Fired Combustion Systems	Extensive laboratory facilities and instrumentation dedicated to combustion, efficiency, and emission testing of heating equipment.	BNL-1
Thermal Distribution Systems	Extensive laboratory facilities and instrumentation dedicated to combustion, efficiency, and emission testing of heating equipment.	BNL-2
Venting Technology	Extensive laboratory facilities and instrumentation dedicated to combustion, efficiency, and emission testing of heating equipment.	BNL-3
Technical Support for Oil-Fired Heating Systems	Extensive laboratory facilities and instrumentation dedicated to combustion, efficiency, and emission testing of heating equipment.	BNL-4
Lighting	LBNL lighting laboratory.	LBNL-1 LBNL-12
	Optical materials & characterization labs, fiber optics R&D labs, Center of Manufacturing Technology, sensors/controls labs, etc.	ORNL-7
Energy-Efficient Windows	Infrared (IR) laboratory: unique facility to measure the surface temperatures of window products. MoWitt laboratory: measures field performance of window by measuring heat flow through two side-by-side window samples. Coating laboratory: facility to manufacture and analyze coatings. Optics laboratory: custom devices are developed to measure optical properties of glazings.	LBNL-2
UV Water Purifier	LBNL has dedicated research facilities for improving the UV Waterworks system design and operation.	LBNL-3

Table 5 Continued. Research Facilities at the National Laboratories

Project	Research Facility	Reference
Aerosol-Based Duct Sealing Technology	Duct research laboratory with technologies for air flow and pressure measurement.	LBNL-4
Building Commissioning	Advanced data visualization tools, database systems, and data collection gateways.	LBNL-5
	Case study database, library of commissioning publications and tools.	ORNL-10 PNNL-3
Building Code Compliance	LBNL has developed extensive computer programs to model the behavior of buildings under different compliance regimes: e.g., DOE-2, PEAR, REM, COMMEND, and the Home Energy Saver.	LBNL-6
Light Surfaces and Urban Trees	Facilities for studying the solar reflectivity of building and paving materials.	LBNL-7
Geographic Information Systems	The GIS Lab consists of SUN workstations, including a SPARC 20 and SPARC 1, as well as a Calcomp 9500 digitizer, and several types of GIS software, primarily ARC/View, ARC/Info and Earth Resources Data Analysis System. ARC/Info is a vector-based GIS program produced by the Environmental Systems Research Institute; the ERDAS is a raster-based system.	LBNL-8
	GIS research and development activities are carried out by different groups located within the Energy, Computational Physics and Engineering, and Environmental Sciences Divisions at ORNL. Each group has laboratory as well as office space dedicated to GIS hardware and software operations. Hardware platforms include SUN SPARC and Apple workstations and Windows-based PCs. Various devices for printing and plotting color maps, both large and small, are available. Various commercial GIS software are in use (e.g. ARC/Info, Intergraph, MapInfo, GisPlus/Transcad, AutoCAD). ORNL staff also develop in-house GIS code when required for project specific applications, working with both vector - and raster-based systems.	ORNL-13

Table 5 Continued. Research Facilities at the National Laboratories

Project	Research Facility	Reference
Indoor Pollutant Source Reduction	Air-chemistry laboratory facility, fully instrumented room size stainless-steel lined emissions chamber, mechanical ventilation diagnosis equipment and laboratory, ducts laboratory, computational and modeling research facilities, radon research laboratory, full-sized experimental facility for interzonal air and pollutant transport under a variety of indoor environmental conditions.	LBNL-10
Air Jacket	Air-chemistry laboratory facility, fully instrumented room-size stainless-steel lined emissions chamber, mechanical ventilation diagnosis equipment and laboratory, ducts laboratory, computational and modeling research facilities, full-sized experimental facility for interzonal air and pollutant transport under a variety of indoor environmental conditions.	LBNL-11
Indoor Air Quality-Related Illnesses (including CO, environmental tobacco smoke)	Indoor Environment Program researchers use single and multi-room environmental chamber facilities as controlled indoor environments to study the behavior of a variety of indoor pollutants ranging from cigarette smoke to volatile organic compounds (VOCs) from new carpets. The program also has laboratories and extensive instrumentation for indoor pollutant and ventilation rate measurements.	LBNL-15 LBNL-17 LBNL-18
Radon Resistant Housing	LBNL has substantial research facilities (on and off site) and instrumentation for conducting research on indoor radon.	LBNL-19
Reducing Aerosol Deposition on Electronic Circuits	LBNL has experimental facilities and advanced instrumentation	LBNL-24
Infrared Thermography	The Infrared Thermography Facility at LBNL has been developed to aid solving technical problems related to heat transfer in building envelope components such as windows and insulation.	LBNL-27

Table 5 Continued. Research Facilities at the National Laboratories

Project	Research Facility	Reference
Daylighting	The *sky simulator* is a 24-foot-diameter dome that researchers use to measure the illuminance levels in building models fitted with various daylighting systems. By testing these models, they can determine how well a building design or daylighting technology permits light to enter under conditions of varying time of day and season, building orientation, or geographic location. The *bidirectional radiometric scanner* is a tool for accurately measuring the solar heat gain of any window system, which can include shades, blinds, drapes, and a variety of glazings, tints, coatings, and glass thickness. Scientists in the Building Technologies Program developed this device to improve research on window systems and to develop a universal rating system for solar heat gain from windows.	LBNL-28
	Optical materials & characterization labs, fiber optics R&D labs, Center of Manufacturing Technology, sensors/controls labs, etc.	ORNL-7
Natural Refrigerants and Advanced Desiccants in U. S. Air Conditioning and Refrigeration Equipment	Roof climate simulator, large-scale wall calibrated hot box, HVAC system and appliance environmental chambers, heat exchanger test facility/calorimeter, water-to-water heat pump refrigeration and air conditioning equipment test loops, absorption heat and mass transfer loops, instrumented desiccant A/C system test loop, and corrosion test laboratory.	ORNL-1 ORNL/NREL-2
CFC-Free Thermal Insulation	Heat flow meter apparatuses. Apparatuses for measuring total hemispherical emittance, air-flow permeability through permeable insulation, coefficients of gas diffusion through closed-cell foams, permeance of gases through plastic films. Equipment for producing prototype evacuated panel insulation. Air-jet grinding mill.	ORNL-3

Table 5 Continued. Research Facilities at the National Laboratories

Project	Research Facility	Reference
Durable Roof Coating Materials	The Roof Thermal Research Apparatus (RTRA) is utilized to expose samples of roof coatings to the environment and to simulate actual applications. The RTRA has substantial data acquisition capabilities, including energy, temperature, load, and meteorological sensors.	ORNL-6
Cool Storage Systems	Cool storage test facility.	ORNL-8
Microtechnology-Based Absorption Heat Pump	PNNL has established the micro thermal systems and micro chemical systems laboratories for the development of miniature energy and chemical systems. These facilities include specialized equipment and instrumentation for the fabrication, assembly and testing of microtechnology based thermal and chemical systems and components.	PNNL-2
Architectural and Infrastructure Surety	Relevant laboratory facilities that are available at Sandia include: Component Modeling and Characteristics Laboratory, Microelectronics Development Laboratory, Intelligent Systems and Robotics Center, Materials and Process Diagnosis Facility, and Explosive Components Facility.	SNL-3
Efficient Motor-Driven Systems	Motor testing laboratory (NAVLAP) accredited for motor tests up to 500 horsepower. Power electronics laboratory for development of advanced power electronics and motors.	ORNL-14
Superconducting Transformers	Physical properties measurements laboratories. High temperature superconductivity materials laboratory. Pulsed laser and electron beam deposition facilities. Superconducting cable test facility. Cryogenic dielectrics research laboratory. High temperature materials laboratory.	ORNL-2

Table 5 Continued. Research Facilities at the National Laboratories

Project	Research Facility	Reference
Advanced Batteries	Battery Analysis and Diagnostic Laboratory	ANL-3
	High-resolution electron microscopy, scanning tunneling microscopy, synchrotron X-ray source, NMR, inert-atmosphere boxes, computer-controlled cell cycling equipment, electrochemical impedance spectroscopy, FTIR spectroscopy, photothermal deflection spectroscopy, ellipsometry, porous electrode preparation facilities, and others.	LBNL-29
Flywheels	Two vacuum-chamber apparatuses to test the rotational losses of HTS bearings. One is a glass bell-jar test chamber with an oil-diffusion pump. This apparatus is capable of testing bearings with rotating mass up to ~1 kg. The second apparatus is a stainless steel chamber with a turbomolecular vacuum pump capable of testing rotating masses of >100 kg. Safely enclosed underground area to actively test rotating flywheels.	ANL-4
	Laboratory capable of testing full-scale, uncontained flywheel systems, electrical loads of up to 100 kW available. Multiple gas gun and x-ray facilities for containment development.	LLNL-1
	Test facilities are available for safely testing large flywheels.	ORNL-15
Fuel Cells	Fuel cell testing facility. Synchrotron X-ray facility to study anode reactions in real time. X-ray spectroscopic facilities.	ANL-5
	In the Energy Storage Technologies Laboratory, controlled tests examine the performance of energy storage devices (e.g., fuel cells). The National Institute of Standards and Technology's Calibration Laboratory supports the Energy Storage Laboratory and calibrates test equipment within the Energy Storage Laboratory.	INEEL-1

Table 5 Continued. Research Facilities at the National Laboratories

Project	Research Facility	Reference
Fuel Cells	High-resolution electron microscopy, scanning tunneling microscopy, synchrotron X-ray source, NMR, inert-atmosphere boxes, computer-controlled cell cycling equipment, electrochemical impedance spectroscopy, FTIR spectroscopy, photothermal deflection spectroscopy, ellipsometry, porous electrode preparation facilities, and others.	LBNL-23
Passive Solar Energy Systems	Thermal Test Facility with a variety of thermal science labs. Large scale environmental chamber. Flow visualization lab. Wind tunnel. HVAC testing lab. Solar thermal outdoor test lab. Air quality field test lab. Tracer gas field test lab.	NREL-1 NREL-4
Photovoltaics	Photovoltaics outdoor test lab.	NREL-3 NREL-5
	CEEP has a computer laboratory and PV experimental facility (Solar One) which it jointly uses with the IEC. There is a PV manufacturing facility close by (Newark, DE).	NREL-6
Parabolic Troughs	Collector testing facilities.	NREL-2
Small Wind Turbine System	National Wind Technology Center	NREL-7
Renewable Energy Projects	PV fabrication labs, PV outdoor test facilities, the National Solar Thermal Test Facility, and a number of indoor labs used for energy R&D.	SNL-1 SNL-2 SNL-4
	High Flux Solar Furnace	SNL / NREL-1
Electricity from Wood Removed from Forests to Reduce Fuel Buildup	The Alternative Fuels User Facility at NREL includes a pilot plant for evaluating biofuels technologies and supporting laboratory facilities. ORNL and NREL have Geographic Information System facilities for doing spatial analyses.	ORNL / NREL-1

Table 5 Continued. Research Facilities at the National Laboratories

Project	Research Facility	Reference
Explosion Prevention Technology	The steam explosion triggering studies (SETS) facility was developed to provide a means for testing various coated and uncoated surfaces for their ability to prevent or initiate steam explosions. This facility permits (at vastly reduced cost) the study of the initiation process without attendant safety issues involved with conventional means.	ORNL-4
Ceramicrete Phosphate Ceramic	Double planetary mixer (for 55 gallon drums). Feeder-hopper system. Water line.	ANL-1
Recovering Zinc from Galvanized Scrap	Stripping facilities that contain caustic solutions. 400 gallon tank to perform electrolytic stripping tests.	ANL-2
Refractories	Refractory creep testing facilities to 1700°C. Modulus of elasticity and extensometry capabilities to 1700°C. Catholuminescence imaging (via subcontract with UM-Rolla).	ORNL-11
Recovery Boilers	Transmissions electron microscopy facilities. Neutron and X-ray residual stress facilities. Parallel computing facilities for finite element modeling. Thermal mechanical fatigue facilities. Corrosion laboratory.	ORNL-12

2.4. Developing a National Insurance Loss Reduction and Risk Management Research Agenda for the National Laboratories

During the review of this report, reviewers were asked for suggestions for developing a research agenda for their particular project. We were particularly interested in how the work at the national laboratories could be extended to address the reduction of insurance losses (we were <u>not</u> interested in simply expanding these existing projects). We received suggestions from many (but not all) of the researchers (see project descriptions in Appendix C) and a few general suggestions that fell outside of the projects that were in the inventory.

These suggestions are indicative rather than comprehensive. They provide the first step in developing a national research agenda for the national laboratories. The suggestions are quite brief but do provide information on where each project is expected to proceed.

For prioritizing these research areas, as well as for developing new ideas, we recommend that representatives from the insurance and risk management communities, the national laboratories, and the U.S. Department of Energy convene a meeting to review the projects in the inventory and the suggested next steps for each project.

In addition to specific project suggestions, some researchers and members of the insurance and risk management communities offered the following general suggestions to consider during the development of a national insurance and risk management research agenda.

1. Continue to quantify the insurance benefits of low-risk technologies, such as energy efficiency and renewable energy.

2. Conduct an analysis of different policy options to promote energy efficiency and renewables for their value in avoiding insurance losses (i.e., which policies would have the most effect in avoiding different categories of insurance loss and what would be the actuarial, economic, and environmental value of these avoided losses).

3. Conduct an economic analysis of the investments for energy efficiency, loss prevention, and insurance under different scenarios using various deductibles and limits. An under-educated, risk-averse, and short-term oriented public is not likely to be motivated to make prudent investments. An understanding of consumer behavior could be enhanced by developing a model of consumer behavior from a purely theoretical standpoint or from an empirical point of view (e.g., based on consumer surveys).

4. Conduct an analysis of innovative heating appliance designs that continue to provide heat in the event of an electrical outage. This study would cover a range of designs from inefficient pilot lights and thermocouple generators, to sophisticated designs of auxiliary rankine cycle generators, to fuel cells and cogeneration.

2.5. National Laboratory Collaborations with the Insurance Industry

LBNL is leading a national effort to involve the insurance industry as a partner in the research and implementation of energy-efficient and renewable energy technologies. The primary emphasis is on the insurance loss prevention benefits of selected technologies. Core sponsors are DOE and EPA. LBNL has developed partnerships with five insurance organizations (Institute for Business and Home Safety, UNEP Insurance Industry Initiative for the Environment, Reinsurance Association of America, American Insurance Association, and the Society of Insurance Research) and five insurance companies (Arkwright Mutual Insurance, Developers Professional Insurance Company, Swiss Reinsurance Company, Employers Reinsurance Company, and Factory Mutual). The key activities being conducted in this effort are:

- Helping to implement and carry out a Memorandum of Understanding between DOE and the Institute for Business and Home Safety

- Conducting an inventory of DOE National Lab capabilities potentially transferable to the insurance industry (i.e., this report)
- Development of a research agenda based on Inventory task results (preliminary steps have been taken – see Section 2.4 and Research Agenda items in project descriptions in Appendix C)
- Assembling data that help quantify the "insurance value" of EERE technologies (see Chapter 3 of this report)
- Identifying new energy-efficient and renewable energy technologies that prevent insurance losses
- Evaluating and supporting insurance industry participation in climate change deliberations
- Data collection on the insurance industry as a player in real estate markets

For example, LBNL conducted a demonstration project and training workshop at Northeastern University with Arkwright Mutual Insurance Company on the benefits of using energy-efficient torchieres instead of halogen torchieres (LBNL-1). Halogen torchieres account for about 10% of residential lighting use in the U.S., are energy intensive, and operate at very high temperatures, creating a significant fire hazard in homes and in dormitories. The energy-efficient torchiere not only saves energy (over 70% energy savings) in providing the same amount of light output, but also operates at significantly lower temperatures, eliminating the fire hazard. LBNL is planning to conduct similar workshops at other universities with Arkwright.

In support of the Memorandum of Understanding between DOE and the insurance industry's Institute for Business and Home Safety (IBHS), LBNL is collaborating with IBHS to encourage the manufacture and use of UV Waterworks for disaster recovery (LBNL-3). UV Waterworks is a small, simple, inexpensive device that uses ultraviolet light to quickly and cheaply disinfect water from the viruses and bacteria that cause cholera, typhoid, dysentery and other deadly diarrheal diseases. As a disaster relief technology, UV Waterworks could shorten periods of business interruptions for affected communities and reduce health care costs by ensuring adequate clean water supply.

LBNL is actively discussing the merits of building commissioning with the two largest U.S. providers of professional liability insurance for architects and engineers (LBNL-5). Building commissioning is a process by which a building's energy service systems are tested and calibrated to advance the building system from static installation to full working order. Building commissioning could improve indoor air quality (leading to reduced health claims and improved labor productivity), reduces system and equipment design and failure (leading to reduced property damages), and also reduces professional liability claims for all participants in the design/build community.

In addition to these technology-specific activities, LBNL has been involved in a number of support activities for the insurance industry and DOE. LBNL's Center for Building Science recently completed a study on the costs of indoor air quality illnesses with significant input from the insurance industry (Chen and Vine 1998) (LBNL-10 and LBNL-15). LBNL is also assisting DOE in establishing an insurance industry advisory group for improvements to the International Performance Measurement and Verification Protocols (IPMVP). The IPMVP is a consensus document for measuring and verifying energy savings from energy-efficiency projects and is being expanded to include indoor air quality issues (Kromer and Schiller 1996).

We came across only one other example of a national laboratory actively collaborating with the insurance industry. ORNL has a Cooperative Research and Development Agreement (CRADA) with the Roofing Industry Committee on Wind Issues (RICOWI) to investigate the durability of residential and commercial roofing systems after a major wind event strikes the U.S. (ORNL-5). RICOWI includes all major roofing trade associations in North America and various insurance partners (the Institute for Business and Home Safety, State Farm Insurance, Chubb Insurance and insurance consultants). The aim of this cost-shared project is to analyze mechanisms of roof failure during severe windstorms and to identify specific ways in which energy-efficiency detailing can enhance roof structural integrity in the face of such storms.

2.6. Research from the Insurance Industry

Remarkably little nonproprietary research on the role of energy efficiency and renewable energy technologies is conducted within the insurance industry. The insurance companies are in a very competitive business and are reluctant to share information. Thus, most of their research is proprietary, in order to keep their competitive edge.

Frank Nutter, President of the Reinsurance Association of America, calls for the need to integrate research from the natural sciences with the actuarial sciences, and indicates the need for more work on energy efficiency measures (Nutter 1996). Increased insurance industry research in this area has also been recommended by Mills and Knoepfel (1997).

The founding of the Underwriters Laboratory (UL) early in this century stands as a precedent for organizing insurance-sponsored research.[1] UL has been involved recently in scrutinizing the halogen torchiere light fixtures that have been linked to many fires in homes and in dormitories (LBNL-1). Their work in redefining the safety test procedures for this product is an example of insurance-driven research that also has implications for energy use and efficiency.

Similarly, the work of Factory Mutual Research Corporation (FMRC) has guided research in property loss prevention for over 160 years.[2] Owned by three property insurers (Allendale Insurance, Arkwright, and Protection Mutual Insurance), FMRC has the world’s largest scientific complex dedicated solely to property loss prevention testing. Advanced research topics include: fire protection, seismic bracing, building materials, and structural dynamics. FMRC works with

---

[1] The organization that later became UL was founded by William Henry Merrill, a Boston electrical inspector, with financial backing provided by the insurance industry. Specifically, the Chicago Board of Fire Underwriters and the Western Insurance Association provided funds to support the Merrill lab, which then became the Underwriter's Electrical Bureau. It was later renamed the Electrical Bureau of the National Board of Fire Underwriters when it received national support, and then renamed Underwriters Laboratories, Inc. in 1901 when it was chartered in Illinois. Their World Wide Web page is: http://www.ul.com

[2] FMRC is a nonprofit scientific organization committed to property loss reduction. For more than 160 years, FMRC has evaluated devices, assemblies, materials and services that are designed to help prevent and control property losses. Their World Wide Web page is: http://www.factorymutual.com.

insurance companies so that they use the technologies and services recommended by FMRC.

We have identified a few examples of insurance-sponsored research in energy efficiency and renewable energy technologies, and these examples are summarized below. As is the case with the National Laboratory examples described previously, these span the areas of direct technology development, to procedural techniques such as inspections, to market-oriented research designed to gather basic statistics.

We reviewed the index of research review articles appearing in the *Journal of the Society of Insurance Research* from 1980 through mid-1996. The articles cover issues including market assessment, demographics, financial analysis, forecasting, market segmentation, health, and risk management.[1] Articles by Nutter (1996) and Mills (1996) were the only items found which dealt with the issues treated in this report.

An example of joint research between the energy and insurance communities is the Cooperative Research and Development Agreement (CRADA) with the Roofing Industry Committee on Wind Issues (RICOWI) to investigate the durability of residential and commercial roofing systems after a major wind event strikes the U.S. (ORNL-5) (see Section 2.5). The aim of this cost-shared project is to analyze mechanisms of roof failure during severe windstorms and to identify specific ways in which energy-efficiency detailing can also enhance roof structural integrity in the face of such storms.

The Institute for Business and Home Safety (IBHS) has conducted or cosponsored several relevant projects. These include participating in the above-mentioned collaborative effort with the U.S. Department of Energy’s Oak Ridge National Laboratory (ORNL-5). IBHS has also investigated losses from frozen water pipes (IIPLR 1996a) and ice dams (IIPLR 1997), both of which have remedies involving energy-efficiency measures. Swiss Re has also investigated the dynamics of frozen water pipes, and has tabulated historical losses for two European countries (Swiss Re 1992).

---

[1] This journal is available via http://connectyou.com/sir/subject.htm

Arkwright Mutual Insurance Company has worked with Lawrence Berkeley National Laboratory to design and execute a field study to assess the potential for energy savings and risk reduction through the replacement of halogen torchiere light fixtures (LBNL-1) with energy-efficient and fire-safe compact fluorescent variants. The site was student dormitories at Northeastern University (Avery et al. 1998).

Some engineering-oriented insurers have conducted field studies that, while not technical research in the purest sense, serve as an example of empirical studies of techniques that relate energy and risk management issues. A prime example is the work by Chubb on the use of infrared (IR) cameras (LBNL-27). Chubb's aim is to identify risk factors such as otherwise undetectable electrical shortcircuits and refrigeration equipment problems. Some of their applications have identified energy savings opportunities, such as the repair of previously undetected broken district heating lines and problems involving heating, refrigeration, and air-conditioning systems in buildings.

Another example of applicable techniques is the research being conducted by the professional liability division of DPIC Companies on the causes of claims among its architect and engineering customers (Brady 1995; Thomson 1997). This work has involved analysis of closed claims, and an assessment of how energy-oriented building commissioning can help avoid these losses (LBNL-5).

Many insurance-sponsored studies involve field inspections (another example of techniques as distinct from technologies) to determine the causes of losses. For example, Hartford Steam Boiler recently examined 200 buildings, and identified deferred maintenance as a key cause of fire losses (Prince 1997).

Insurers have also begun to investigate the use of indoor air quality protocols as a means of avoiding related claims (*IEQ Strategies Magazine* 1997). These protocols are based on indoor air quality studies, similar to those underway at the national laboratories (e.g., see LBNL-10 and LBNL-15).

2.7. Risk Factors Associated with Energy-Efficiency and Renewable Energy Technologies

Not all energy-efficiency and renewable energy technologies offer insurance benefits. In fact, some may lead to elevated insurance risks. While we believe that the vast majority of connections are positive, it is important that future insurance/energy research activities be tailored to reduce or even eliminate these risk factors through better design and application of these technologies.

In the past, the sporadic debate between the insurance and energy-efficiency communities has often been limited to single applications (lacking a systematic approach) characterized by misunderstandings. For example, the insurance industry was very concerned at an early stage that insulation materials for residential buildings would increase fire risk. It took many years for those concerns and related misunderstandings to be resolved. Halven (1983) cautioned against the use of insulation, asserting that it is a volatile fuel for fire, but went on to note that it is in fact the improper application of insulation (e.g., too close to combustion appliances) that is the core problem. Thus, the issue shifts to one of poor construction practices and code enforcement, rather than energy efficiency per se. In another example, some insurance groups believe that tight buildings are more vulnerable to pressure build-up and explosion during intense windstorms, while others are not (IIPLR 1996b). In any event, these potentialities must be identified, analyzed, and mitigated.

Following are some illustrations of legitimate concerns:

1. Vinyl windows (a popular energy efficiency measure owing to the reduced heat loss through the window frame) can easily melt in the presence of fire. If the window then falls out, the fire is nourished with additional oxygen.

2. There are cases where substitution of natural gas for electricity is desirable from an energy cost standpoint, and increased fire hazards may result.

3. Improper application of building infiltration controls in the construction of building envelopes can lead to moisture damage.

4. Certain phase change materials (used as a thermal storage medium in certain solar heating designs) are flammable.

5. Rooftop solar water heating systems can lead to water damages if pipes are ruptured due to freeze or earthquake.

While some legitimate problems exist, care should be taken to separate these from poorly reasoned or sensationalized concerns. For example, the popular media has fomented public misconceptions about the connection between energy efficiency and indoor air quality problems. The scientific record shows that while misapplications of efficient technologies can indeed contribute to indoor air quality (IAQ) problems, this is not a necessary consequence of energy efficiency. In fact, energy-efficiency strategies can also be synonymous with improved IAQ.

Chapter 3. The Insurance Value of Energy-Efficient and Renewable Energy Technologies

The insurance and risk management communities have yet to formally and systematically quantify the types of losses considered in this report, but a review of the energy and insurance literature has uncovered a cross-section of examples from several countries of losses that are partly associated with energy-using equipment (Tables 6 and 7).

Some notable U.S. examples of property losses from structural fires that might be mitigated partially through energy efficiency include 178,000 fires, 750 deaths, and $1.8 billion in insured losses annually stemming from heating or electrical equipment in buildings. Some relevant U.S. examples for health and life insurance include 6,000 to 18,000 radon-related lung-cancer deaths annually, 1,500 carbon monoxide deaths (and 12,000 carbon monoxide-related poisonings), and over 5,300 deaths from the largest urban heat catastrophes from 12 hot summers in recent history.

Another example of the loss-prevention benefits of energy-saving strategies concerns fuel switching in certain residential appliances. For most household appliances, the loss frequencies (e.g., fires per 1000 homes) vary considerably depending on the choice of fuel. We find that the prospective combined annual loss reduction achievable by switching between electricity and natural gas for space heating, water heating, and cooking in U.S. homes amounts to about 30,000 fires (22% reduction from the baseline), $300 million in property losses (40% reduction), 2,200 civilian injuries (34% reduction), and 135 civilian deaths (21% reduction).[1]

[1] The avoided losses are computed as the difference of (1) the total losses were all homes to have the least safe fuel for the end use in question and (2) the total losses were all homes to have the safer fuel. Thus, some of the savings (typically one-third to one-half) have already implicitly been "captured" as a result of existing instances where the safer fuel is used in the housing stock.

Table 6. Examples of Insured Property Losses that Can be Reduced by Proper Application of Energy-Efficiency and Indoor-Environmental-Quality Technologies and Practices.

Losses from ice damage to roofs (ice dams)

- U.S.: $20 to $30 million from one storm in 1995 (total damages, including ice dams) (Levick 1996).

Losses from frozen water pipes

- U.S. (1985-1995): $450 million/year (Tharpe 1996).
- Switzerland (1988): US$29 million/year (36 million Swiss francs)--residential only (this year was not considered a particularly severe winter in terms of freeze damage to buildings) (Swiss Re 1992).
- West Germany (1989): US$84 million/year (141 Million DM)--residential only (this year was not considered a particularly severe winter in terms of freeze damage to buildings) (Swiss Re 1992).

Fires caused by heating equipment

- Switzerland (1995): US$14 million (17.8 million Swiss francs) (Swiss Re 1992).
- U.S. (1994): 75,100 structural fires (17% of total), 490 fire-related deaths (14% of total), 1,970 injuries (10% of total), $622 million fire-related losses (14% of total) (Consumer Product Safety Commission n/d). Residential buildings carry about 80% of the insured losses, and nearly all of the fires, deaths, and injuries.
- Canada (1994): 5,331 structural fires (8% of total), 17 fire-related deaths (4.5% of total), 219 injuries (6.2% of total), $72 million fire-related losses [$97 million C$] fire-related losses (8.4% of total (Association of Canadian Fire Marshals and Fire Commissioners 1994).

Residential structural fires caused by electrical equipment and appliances

- U.S. (1994): 178,400 structural fires (40% of total), 750 fire-related deaths (22% of total), 7,330 injuries (37% of total), $1.2 billion fire-related losses (28% of total) (Consumer Product Safety Commission n/d). Residential buildings carry about two-thirds of the insured losses, and a considerably higher share of number of fires, deaths, and injuries.

Table 6 Continued. Examples of Insured Property Losses that Can be Reduced by Proper Application of Energy-Efficiency and Indoor-Environmental-Quality Technologies and Practices.

- U.S. (1994): 8,700 fires, 50 related deaths, and 300 related injuries from lamps and light fixtures, costing $102 million (Consumer Product Safety Commission n/d). Nearly 232 reported house fires and 12 related deaths from torchiere fixtures (6-year period), and over 100 torchiere fires in college dorms during a recent 18-month period. Litigation for the three largest house fires involves over $6 million in claims.
- Canada: At least 10 fires from torchiere light fixtures (Alberta Labour 1997).
- United Kingdom (1995): $28 million (£ 46.6 million) from electrical equipment (of which 32% caused by electric lighting) (*Fire Prevention* 1996).
- Switzerland (1995): $57 million (71.1 million Swiss francs) (of which 34% caused by cables/installation, 31% caused by appliances, 24% caused by incorrect use of appliances, 11% others) (Vereinigung Kantonaler Feuerversicherungen 1995).
- Canada (1994): 8,387 structural fires (13% of total), 17 fire-related deaths (5% of total), 394 injuries (11% of total), US$125 million ($168 million $C) fire-related losses (15% of total) (Association of Canadian Fire Marshals and Fire Commissioners 1994). [Includes electrical distribution equipment such as wiring; does not include cooking equipment].
- Canada, U.S., United Kingdom (various): Cooking fires were found to be four times more common in homes with electric stoves (238 per 100,000 households) than for relatively energy-efficient gas stoves (58 per 100,000 households) (Wijayasinghe and Makey 1997). The same ratio was found in a study conducted in the UK (Whittington and Wilson 1980). In the U.S., 104,800 residential fires (25% of the total) were attributed to cooking equipment, with gas-fueled systems responsible for 85 per 100,000 households and electric systems for nearly 100 per 100,000 households.

<u>Premature failure of electronic equipment caused by poor indoor air quality</u>

- U.S.: 20% of circuit board failures--$200 million per year in U.S. telephone switching offices (Litvak et al., 1995).
- West Germany (1984): US$80 million computer premiums; US$240 million telecommunications and low-voltage equipment premium (Swiss Re 1987).
- Switzerland (1984): US$10 million computer premiums (Swiss Re 1987).

Table 6 Continued. Examples of Insured Property Losses that Can be Reduced by Proper Application of Energy-Efficiency and Indoor-Environmental-Quality Technologies and Practices.

Avoided U.S. Residential Fire Losses from Fuel Switching Between Electricity and Natural Gas[1]

- U.S. (1990-1994 average): Avoided space heating fires – 18,019 fires (44% reduction), $132 million in property damage (34%), 356 civilian injuries 21%), 198 deaths (44%). (Hall 1996; Wenzel et al. 1997)

- U.S. (1990-1994 average): Avoided water heating fires – 7,032 fires (65%), $94 million in property damage (-80%), 720 civilian injuries (92%), 67 deaths (94%). (Hall 1996; Wenzel et al. 1997)

- U.S. (1990-1994 average): Avoided cooking fires – 4,561 fires (5%), $71 million in property damage (22%), 1,170 civilian injuries (24%), -130 deaths (71% increase). (Smith and Long n/d; Wenzel et al. 1997)

[1] Avoided losses are computed as difference of (1) the total losses were all homes to have the least safe fuel for the end use in question and (2) the total losses were all homes to have the safer fuel. Thus, some of the savings (typically one-third to one-half) have already implicitly been "captured" as a result of existing instances where the safer fuel is used in the housing stock. Based on a comparison of primary energy use, gas is more energy-efficient for cooking and space heating; electricity is more efficient for water heating based on heat pump water heater technology. In each case, the more efficient fuel choices correspond to lower loss rates. Heat pump space heating is not evaluated here because the losses apply to central as well as room heating, and because the effect of that particular equipment change on fire rates is not known. Where available, five-year averages are used to dampen year-to-year fluctuations in loss frequencies.

Table 7. Examples of Insured Health and Life Losses that Can be Reduced by Proper Application of Energy-Efficiency and Indoor-Environmental-Quality Technologies and Practices.

<u>Deaths from extreme temperature episodes</u>

- U.S. (various): Over 5,300 summer heat deaths from a dozen urban heat storms in U.S. cities (Whitman et al. 1997).
- U.S. (1995): More than 46 deaths caused by cold waves (Swiss Re 1996).

<u>Deaths or illness from carbon monoxide poisoning in homes</u>((Chen 1995)

- U.S.: Each year, about 1,500 deaths result from CO poisonings. Of these about 1,000 are from CO emissions caused by malfunctioning, incorrectly installed, or misused combustion appliances such as furnaces and gas ranges, by the improper indoor use of outdoor appliances like barbecues, and by operating automobiles or generators in garages. Centers for Disease Control in Atlanta suggests that the lifetime risk of unintentional fatal CO poisoning indoors is about one in 3,000. Malfunctioning indoor combustion appliances are the primary cause of CO poisonings.
- U.S. (1993): CO poisonings: More than 12,000 non-fatal carbon monoxide poisonings were reported to the American Association of Poison Control Centers in 1993, but the Association believes this represents only a fraction of the actual number of events; often, nonfatal poisonings are often misdiagnosed as flu or other afflictions.

<u>Deaths or illness from radon gas in homes</u>

- U.S.: 4 million homes (6% of the entire housing stock) above US Environmental Protection Agency safe levels; estimated 6,000 to 18,000 lung cancer deaths annually. Associated medical and life insurance costs not quantified.
- Norway: 200 deaths annually (Storebrand 1997).

<u>Workers compensation losses caused by "sick building syndrome" or bad indoor air quality</u>

- U.S.: studies report that from 5 to 40% of workers report problems, cost estimated at $50 billion annually (Fisk and Rosenfeld 1996). Largest U.S. insurance sick building syndrome claim to date is $29.9 million.

Table 7 Continued. Examples of Insured Health and Life Losses that Can be Reduced by Proper Application of Energy-Efficiency and Indoor-Environmental-Quality Technologies and Practices.

Litigation costs as a result of "sick building syndrome" or bad indoor air quality

- U.S.: (1) a new Polk County, Florida courthouse was found to cause a number of cases of sick building syndrome, and the insurance company was forced to pay $35 million in damages; (2) a courthouse in Martin County, Florida, experienced indoor air quality problems, and the construction company and three insurance companies were forced to pay $13.7 million in damages; and (3) respiratory problems experienced by employees in the U.S. Environmental Protection Agency's headquarters building resulted in a jury awarding nearly $1 million to five plaintiffs (Chen and Vine 1998).

Health insurance costs of asthma (partially related to indoor air quality)

- U.S.: $13 billion annually (Fisk and Rosenfeld 1996).
- West Germany: About 8 million German citizens suffer from asthma. Among children the asthma rate is 12 to 15 %, and it is the most common chronic childhood illness. Since the end of World War II the number of children to suffer from asthma has increased tenfold. About 6,000 children die each year of asthma in Germany (GERmNews, n/d).

Chapter 4. Next Steps in Supporting Research Efforts

In Chapter 2, a number of promising technologies and services were identified, including the development of energy-efficient and fire-resistant windows, light fixtures, improved indoor air quality monitoring devices, methods to reduce airborne disease transmission in office buildings, building commissioning, energy management control systems, and building code enforcement. While not technology development per se, there is a need for improved research on many fundamental building science issues, such as ice dam formation and mitigation, and the causes of Sick Building Syndrome. Other research opportunities include definitive studies on the connections between indoor environmental factors (e.g., air quality, lighting, and thermal comfort) and worker productivity and health (Chen and Vine 1998; Fisk and Rosenfeld 1997).

The energy efficiency and renewable energy community and the insurance and risk management communities (e.g., researchers, insurance companies, government, energy service companies, and utility companies) need to work together in the following ways:

1. Participate in strategic research, development and demonstration (RD&D) activities necessary to move new loss-reducing technologies into the marketplace.

2. For those energy-efficiency and renewable energy technologies that are commercially available, encourage customers to employ technologies and practices that reduce the likelihood of insured health, property, and liability losses.

The focus of this report has been on the development of new products and services. But basic market research is also needed on the particular types of losses potentially addressed by energy-efficient and renewable energy technologies. There is currently a remarkable lack of basic data on specific loss categories of interest for these technologies (e.g., fires caused by halogen light fixtures (LBNL-1)). New categories of insurance loss statistics need to be collected, so that it may be easier to quantify the potential loss reductions from the types of measures described in this report.

Most of the technologies described in this report were supported by government-sponsored RD&D programs over many years of effort. These technologies have many benefits, including insurance loss reduction and prevention and risk management. The insurance and risk management communities could take advantage of these technologies, either independently or in cost-sharing partnerships with existing R&D programs. Insurance industry support of strategic energy-related RD&D has been endorsed by the Reinsurance Association of America (Nutter 1996).

The cost for conducting research on the technologies and services described in this report is significant. Accordingly, we recommend that representatives from the insurance and risk management communities, the national laboratories, and the U.S. Department of Energy convene a meeting to review the projects in the inventory and develop a national insurance research agenda for the national laboratories in order to prioritize the type of research that needs to be conducted and to discuss potential collaborations (see Section 2.4).

Past experience in the energy sector could offer a model for interdisciplinary insurance industry R&D in this area. The Electric Power Research Institute (EPRI) and the Gas Research Institute (GRI) spend $1 billion a year on technology and market research for energy utilities (about 1/500th of their members' revenues). They provide a common knowledge base for large and small energy companies and serve as an interface among the numerous energy utility companies, regulatory bodies, and providers of energy technologies. A research fund based on 1/10,000th of property casualty premium revenues would represent a $6 million annual program, which we suggest could be matched by the U.S. Department of Energy. Insurance regulators would need to approve this proposal. In the U.S., the insurance industry's Institute for Business and Home Safety (IBHS) is one venue where such research could take place. IBHS's mission is to reduce deaths, injuries, and loss of property resulting from natural disasters.

The activities of the Bermuda Biological Station for Research are also worth noting.[1] While this insurer-funded program focuses on global climate change and natural disasters (rather than on energy issues), this is a good model for how insurers can pool resources in order to conduct research of strategic importance.

[1] The World Wide Web page is: http://www.bbsr.edu.

Acknowledgments

This work was supported by the Assistant Secretary for Energy Efficiency and Renewable Energy of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098. We are especially grateful for the individuals who assisted us in this effort at the U.S. Department of Energy, the national laboratories, and in the insurance industry. In particular, we would like to thank Bill Becker, Cathy Ghandehari, Ann Deering, and Mark Ginsberg for their support and assistance. We would also like to express our appreciation for the following people who reviewed an earlier draft of this report: Hashem Akbari, Mike Apte, Bill Becker, Mary Breighner, John Byrne, Elton Cairns, Chris Cameron, Jim Cavallo, Terry Cooper, Paul Croce, Joan Daisey, Andre Desjarlais, Kevin Drost, Paul Eichamer, David Faulkner, Helmut Feustel, Bill Fisk, Cathy Ghandehari, Steve Greenberg, Brent Griffith, Donna Hawkins, Robert Hawsey, Sue Hock, Greg Kats, Peter Kelly, Do Kim, Ivo Knoepfel, Richard Krajewski, Eugene Lecomte, Jerry Lopes, Jim McMahon, Mark Mehos, Rudolph Matalucci, David Menicucci, Jeff Muhs, Mary Ann Piette, Art Rosenfeld, Jim Russell, Jim Sand, Ray Smith, John Talbott, Rusi Taleyarkhan, Frank Tokarz, David Unnewehr, Ken Wilkes, Bill Young, and Warren Zurn.

References

Alberta Labour, Fire Commissioner's Office. 1997. *Alberta Fire News.* (May).

Association of Canadian Fire Marshals and Fire Commissioners. 1994. *Annual Report: Fire Losses in Canada*, p. 22.

Association of Canadian Fire Marshals and Fire Commissioners. 1994. *Annual Report: Fire Losses in Canada,* Table 5.

Avery, D, E. Mills, M. Breighner, and J. Naylis. 1998. "Lighting Efficiency Options for Student Residential Living Units: A Study Conducted at Northeastern University," Arkwright Mutual Insurance Company and Lawrence Berkeley National Laboratory. (Forthcoming).

Brady, R. 1995. "Commissioning Services Can Reduce Professional Liability Losses," *Proceedings of the Third National Conference on Building Commissioning*. Portland Energy Conservation Inc., Portland, OR.

Chen, A. 1995. "An Inexpensive CO Sensor," *Center for Building Science News* #6, Spring.

Chen, A. and E. Vine. 1998. "A Scoping Study on the Costs of Indoor Air Quality Illnesses: An Insurance Loss Reduction Perspective," Report No. 41919. Lawrence Berkeley National Laboratory, Berkeley, CA.

Consumer Product Safety Commission. (n/d). "1994 Residential Fire Loss Estimates." Washington, D.C.

Fire Prevention, Nr. 295 (Dec. 1996), page 35.

Fisk, W.J. and A.H. Rosenfeld. 1996. "Improved Productivity and Health from Better Indoor Environments," Report No. 39596. Lawrence Berkeley National Laboratory, Berkeley, CA.

Fisk, W.J. and A.H. Rosenfeld. 1997. "Estimates of Improved Productivity and Health from Better Indoor Environments," *Indoor Air* 7:158-172.

GERmNews (German news service), based on an announcement by the German asthma association.

Hall, J.R. 1996. *U.S. Home Heating Fire Patterns and Trends Through 1994*, National Fire Protection Association, Quincy, MA.

Fire Analysis and Research Division, National Fire Protection Association. (October)

Halven, F.C. 1983. "Building Energy Efficiency and the Fire Problem," *Proceedings of the Second International PLEA Conference*, Crete, Greece, 28 June – 1 July. (Pergamon Press): 811-818, London, UK.

IEQ Strategies Magazine. 1997. "Building Owners May Soon Be Able to Buy IAQ Insurance Policy," pp. 15-16, (October).

Insurance Institute for Property Loss Reduction (now the Institute for Business & Home Safety). 1996a. "Freezing and Bursting Pipes," *Natural Hazard Mitigation Insights*, No. 2, Boston, MA.

Insurance Institute for Property Loss Reduction (now the Institute for Business & Home Safety). 1996b. "Tornadoes," *Natural Hazard Mitigation Insights*, No. 3, Boston, MA.

Insurance Institute for Property Loss Reduction (now the Institute for Business & Home Safety). 1997. "Ice Dams," *Natural Hazard Mitigation Insight*s, No 6. Boston, MA.

Kromer, J. and S. Schiller, 1996. "National Measurement and Verification Protocols," *Proceedings of the 1996 ACEEE Summer Study*, Vol. 5, pp. 141-146. American Council for an Energy-Efficient Economy, Washington, D.C.

Lecomte, E. 1998. Personal communication, April 13, 1998.

Levick, D. 1996. “Insurers in State Awash in Claims Related to Water Damage,” *The Hartford Courant*, Jan. 20, Hartford, CT.

Litvak, A., A. Gadgil, and W.J. Fisk. 1995. “Electronics Reliability and Indoor Air Quality,” (Berkeley CA: Lawrence Berkeley National Laboratory, October) Internal Memorandum.

Mills, E. 1996. “Energy-Efficiency: No-Regrets Climate Change Insurance for the Insurance Industry,” *Research Review: Journal of the Society of Insurance Research*, 9(3):21-58.

Mills, E. 1997. “Going Green Reduces Losses,” *Reinsurance*, 27(12):4..

Mills, E. and I. Knoepfel. 1997. “Energy-Efficiency Options for Insurance Loss Prevention,” LBNL Report LBNL-40426, Lawrence Berkeley National Laboratory, Berkeley, CA.

Mills, E., A. Deering, and E. Vine. 1998. “Energy Efficiency: Proactive Strategies for Risk Managers,” *Risk Management* 45(3):12-16.

Nutter, F. 1996. “Insurance and the Natural Sciences: Partners in the Public Interest,” *Research Review: Journal of the Society of Insurance Research*, 9(3):15-19.

Prince, M. 1997. “Study Sparks Inspections,” *Business Insurance*, (May 12, p. 3).

Smith, L. and K. Long. n/d. *1994 Residential Fire Loss Estimates*. Consumer Products Safety Commission, Washington, D.C.

Storebrand. 1997. Environmental Annual Report.

Swiss Re. 1996. *Sigma 2/1996*. “Natural Catastrophes and Major Losses in 1995”, Zurich, Switzerland.

Swiss Re. 1992. “Pipes and Water Damage,” Report No. RD/RM 2500e 9/94, Zurich, Switzerland.

Swiss Re. 1987. “Computer Insurance,” p 24. Report 1000e/9/90, Zurich, Switzerland.

Tharpe, G. 1996. "Avoid Chilling Prospect of Frozen Pipes," *The Atlanta Journal/The Atlanta Constitution*, February 19, p. E2, citing statistics from the Institute for Business and Home Safety.

Thomson, J. 1997. "Can Commissioning Impact Professional Liability Claims Made against Architects and Consulting Engineers?" In the *Proceedings of the 1997 Building Commissioning Conference.*, Portland Energy Conservation, Inc., Portland, OR.

Vereinigung Kantonaler Feuerversicherungen: "Auszug aus der Schadenstatistik 1995," Bern, Switzerland.

Wenzel, T., J. Koomey, G. Rosenquist, M. Sanchez, and J. Hanford. 1997. *Energy Data Sourcebook for the U.S. Residential Sector*. LBNL Report 40297, Lawrence Berkeley National Laboratory, Berkeley, CA.

Whitman, S., et al. 1997. "Mortality in Chicago Attributed to the July 1995 Heat Wave," *American Journal of Public Health.*

Whittington, C. and J.R. Wilson. 1980. "Fat Fires: A Domestic Hazard," *Fires and Human Behaviour*, John Wiley & Sons, Ltd. New York.

Wijayasinghe, M.S. and T. B. Makey. 1997. "Cooking Oil: A Home Fire Hazard in Alberta, Canada," *Fire Technology Journal.* Vol. 33, No. 2.