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Climate change, insurance and the buildings sector: technological synergisms between adaptation and mitigation

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Examining the intersection of risk analysis and sustainable energy strategies reveals numerous examples of energy-efficient and renewable energy technologies that offer insurance loss-prevention benefits. The growing threat of climate change provides an added motivation for the risk community to understand better this area of opportunity. While analyses of climate change *mitigation* typically focus on the emissions-reduction characteristics of sustainable energy technologies, less often recognised are a host of synergistic ways in which these technologies also offer *adaptation* benefits, e.g. making buildings more resilient to natural disasters. While there is already some relevant activity, there remain various barriers to expanding these efforts significantly. Achieving successful integration of sustainable energy considerations with risk-management objectives requires a more proactive orientation, and coordination among diverse actors and industry groups.

Keywords: buildings, climate change, energy efficiency, extreme weather, insurance, risk management

Lorsque l'on examine les relations entre les stratégies d'analyse du risque et d'énergie durable, on constate qu'il existe de nombreux exemples de technologies concernant le rendement énergétique et les énergies renouvelables qui offrent des avantages en matière d'assurance contre la prévention des sinistres. La menace croissante des changements climatiques est une nouvelle incitation pour les spécialistes du risque à mieux appréhender ce domaine. Alors que les analyses portant sur l'atténuation des risques entraînés par les changements climatiques se concentrent, pour l'essentiel, sur les possibilités de réduction des émissions qu'offrent les technologies relatives aux énergies durables, il existe de nombreuses synergies entre ces technologies, moins souvent reconnues, d'où se dégagent des avantages en termes d'adaptation; c'est le cas, par exemple, de la construction de bâtiments qui résistent mieux aux catastrophes naturelles. Bien qu'il existe déjà quelques activités dans ce domaine, il reste encore divers obstacles à franchir avant de parvenir à une expansion significative de ces efforts. L'intégration réussie des avantages apportés par l'énergie durable aux objectifs de gestion du risque exige une orientation qui soit plus proactive et une meilleure coordination entre les divers groupes d'acteurs et d'industriels.

Mots-clés: rendement énergétique, assurance, gestion du risque, bâtiments, changements climatiques

Introduction

> Everybody talks about the weather, but nobody does anything about it.
>
> (Charles Dudley Warner, *Hartford Courant*, 1897; quoted in Thorness, 1998)

This paper describes the significance of global climate change for the insurance industry and the particular dual role that energy-efficient and renewable energy technologies can play in mitigating greenhouse gas emissions while increasing adaptive capacity by making buildings more disaster resilient.

Natural disasters and relatively small events resulting from weather extremes have well-known consequences for the insurance and risk-management industries. These losses are on the rise (Figure 1). The dimensions

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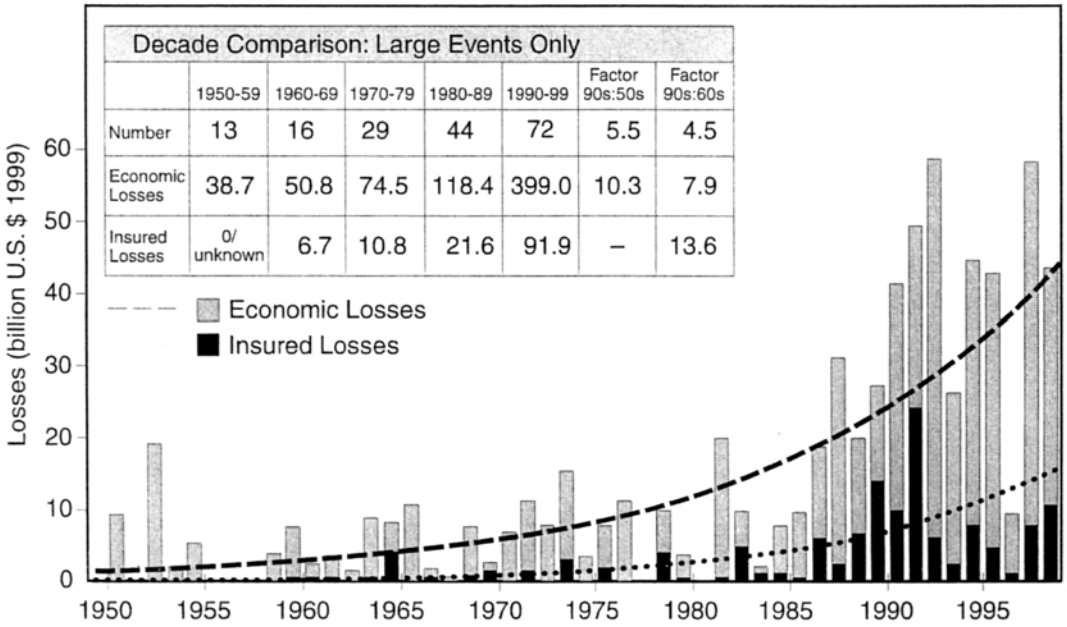


Figure 1 Weather-related disaster losses on the rise: 1950–1999. Inflation-corrected losses from natural disasters have increased dramatically since 1950. By including events of all sizes these totals would increase by approximately a factor of two. The cost data are adjusted for inflation. Population growth during 1950–1999 was 2.4-fold. Source: (Vellinga *et al.*, 2001)

of current global losses (number of events, fatalities, economic losses and insured losses) are shown in Figure 2. A larger share of losses are insured in Australia, Europe and the North/Central America than in the rest of the world. The majority of 'catastrophe' losses are due to weather-related events in all parts of the world, although the exact proportion varies considerably.

An array of associated vulnerabilities and potential impacts pervade the broader society. As such, there is considerable recognised value in establishing disaster-resistant transport, communication and energy supply systems. The buildings sector is perhaps the most vulnerable, with exposures ranging from damage to physical infrastructure to disruption of business operations to adverse health and safety consequences for building occupants (Camilleri *et al.*, 2001; Lowe, 2001a; Scott *et al.*, 2001; Vellinga *et al.*, 2001). A range of events are of concern, including windstorm, hurricane, tropical cyclone, hailstorm, flood, drought, lightning, wildfire, extreme temperature episodes, and sea-level rise and tidal surges.

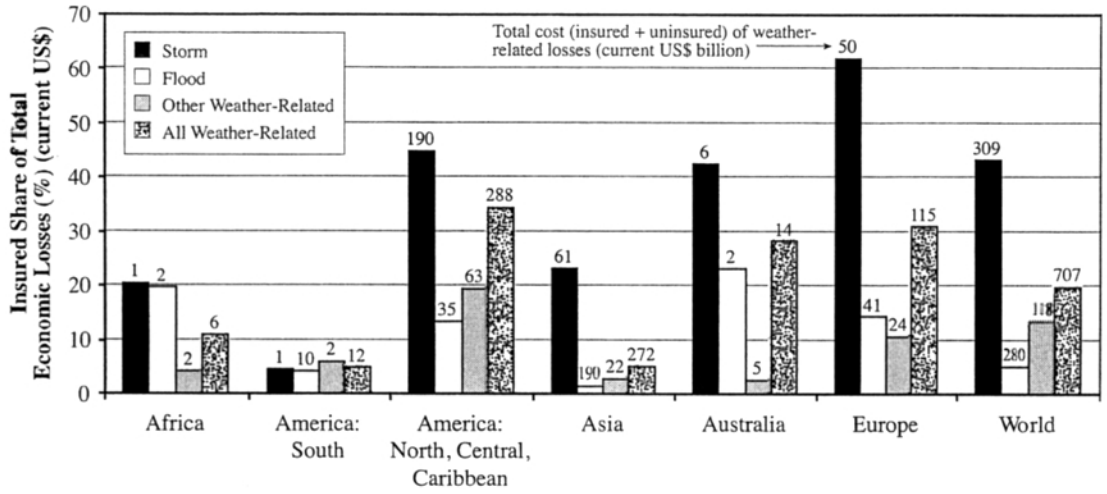
Climate change and the consequences of associated extreme weather events have provided a motivation for the insurance community to understand better and promote sustainable energy technologies. While analyses of climate change responses typically focus on the emissions-reduction ('mitigation') characteristics of renewable and demand-side energy technologies, less often recognised are a host of ways in which these technologies also offer adaptation benefits, e.g. making buildings more resilient to natural disasters (Lowe, 2001b).

Impacts of climate change on the insurance industry

Extreme weather-related events have impacted almost all types of insurance providers. The degree of vulnerability to climate change depends on the degree of climate change and by the type of insurance in question (Table 1). Low levels of climate change are expected to have mixed positive and negative impacts, with a strong trend towards net negative impacts as the degree of climate change increases (Figure 3).

Property insurers are generally believed to be more vulnerable to climate change than are life-and-health insurers (Vellinga *et al.*, 2001), although concerns have been expressed for both sides of the industry (e.g. Ross, 2000). Climate change impacts in the buildings sector are the primary concern for property insurers, given the extent of insured value represented, and the vulnerability as compared with other infrastructure.

The effects of increased losses can lead to pressure on insurance prices, sensitivity of insurers' stock value to major weather-related events and increased insolvencies (Mills *et al.*, 2001) (Figure 4a, b). Large and small insurers alike have been impacted by weather extremes and will be more so in the future if the frequency or intensity of these events increases (Vellinga *et al.*,



	Africa	America: South	America: North, Central, Caribbean	Asia	Australia	Europe	World
Number of Events	810	610	2,260	2,730	600	1,810	8,820
Weather-Related	*91%*	*79%*	*87%*	*78%*	*87%*	*90%*	*85%*
Fatalities	22,990	56,080	37,910	429,920	4,400	8,210	559,510
Weather-Related	*88%*	*50%*	*72%*	*70%*	*95%*	*96%*	*70%*
Economic Losses (current US$ billion)	7	16	433	433	16	130	947
Weather-Related	*81%*	*73%*	*84%*	*63%*	*84%*	*89%*	*75%*
Insured Losses (current US$ billion)	0.8	0.8	119	22	5	40	187
Weather-Related	*100%*	*69%*	*86%*	*78%*	*74%*	*98%*	*87%*

Figure 2 Regional insurance coverage for weather- and non-weather-related natural disasters, 1985–1999. The role of insurance in paying weather-related losses varies by event type and region, generally dominated by windstorm. 'Other' includes weather-related events such as wildfire, landslides, land subsidence, avalanches, extreme temperature events, droughts, lightning, frost, and ice/snow damages. Total costs are higher than those in Figure 1 because these include smaller events. Rounding errors apply in some data labels

2001). It follows that the continued insurability of such risks is a central question, as insurers may seek to withdraw coverage from selected areas.

Interestingly, the earliest documented statement of insurer concern about global climate change dates back 30 years (Munich Re, 1973). Insurers later participated in the intensively peer-reviewed work of the Intergovernmental Panel on Climate Change (IPCC) in 1995, leading the authorship of an entire chapter devoted to the question (Dlugolecki, 1995). Two chapters in the subsequent IPCC Assessment published 6 years later also focused a diversity of potential climate change impacts on insurers (Table 1) (Cohen *et al.*, 2001; Vellinga *et al.*, 2001).[1] Among their findings were:

- Observed upward trends in insurance losses are consistent with what would be expected under climate change
- There is high confidence that climate change and associated changes in weather-related events would increase actuarial uncertainty in risk assessment, and thus adversely affect the functioning of insurance markets, e.g. pricing and availability
- Despite isolated benefits (e.g. fewer frost days), climate change scenarios will result in elevated potential for insurer bankruptcies,[2] for large and small firms alike
- Insurability concerns in an environment of increasing natural disasters will put increasing pressure on the often-reluctant government sector to assume certain risks
- Various climate-change prevention strategies offer interesting business opportunities for insurers, e.g. insurance of contracts to reduce emissions, and synergisms between adaptation and mitigation

Irrespective of the causes of past losses, a key problem looking forward is that climate science is rarely designed to address questions of importance to insurers. The growing use of catastrophe ('CAT') models is a step in the right direction, although these models are hamstrung by virtue of being predicated largely on historical data rather than scenarios incorporating future climate change. CAT models help insurers conduct scenarios of property damage for different types of events and localities, but often fail to capture smaller scale but more

Table 1 Intergovernmental Panel on Climate Change (IPCC) findings on the impacts of climate change on the insurance industry: past (observed) changes and projected changes during the 21st century

Type of event	Changes in extreme climate phenomena	Likelihood*		Insurance impacts (high confidence)**
		Past (observed) changes	Future (projected) changes	
Temperature extremes				
Heat wave	Higher maximum temperatures, more hot days and heat waves*** over nearly all land areas	Likely (mixed trends for heatwaves in several regions)	Very likely	Health, life, property, business interruption
Heat wave droughts				Health, crop, business interruption
Frost, frost heave	Higher [increasing] minimum temperatures, fewer cold days, frost days and cold waves*** over nearly all land areas	Very likely (cold waves not treated by WGI)	Very likely	Health, crop, property, business interruption, vehicle
Rainfall and other precipitation extremes				
Flash flood	More intense precipitation events	Likely over many Northern Hemisphere mid- to high latitude land areas	Very likely, over many areas	Property, flood, vehicle, business interruption, life, health
Flood, inundation, mudslide				Property, flood, crop, marine, business interruption
Summer drought, land subsidence, wildfire	Increased summer drying and associated risk of drought	Likely, in a few areas	Likely over most mid-latitude continental interiors (lack of consistent projections in other areas)	Crop, property, health
Snowstorm, ice storm, avalanche	Increased intensity of mid-latitude storms***	Medium likelihood of increase in Northern Hemisphere, decrease in Southern Hemisphere	Little agreement among current models	Property, crop, vehicle, aviation, life, business interruption
Hailstorm				Crop, vehicle, property, aviation
Drought and floods	Intensified droughts and floods associated with El Nino events in many different regions (see also under droughts and extreme precipitation events)	Inconclusive information	Likely	Property, flood, vehicle, crop, marine, business interruption, life, health
Wind extremes				
Mid-latitude windstorm	Increased intensity of mid-latitude storms***	No compelling evidence for change	Little agreement between current models	Property, vehicle, aviation, marine, business interruption, life
Tornadoes				Property, vehicle, aviation, marine, business interruption
Tropical storms, including cyclones, hurricanes and typhoons	Increase in tropical cyclone peak wind intensities, mean and peak precipitation intensities****	Wind extremes not observed in the few analyses available insufficient data for precipitation	Likely, over some areas	Property, vehicle, aviation, marine, business interruption, life

Table 1 (continued)

Type of event	Changes in extreme climate phenomena	Likelihood*		Insurance impacts (high confidence)**
		Past (observed) changes	Future (projected) changes	
Other extremes				
Lightning	Refer to entries above for higher temperatures, increased tropical and mid-latitude storms	Refer to relevant entries above	Refer to relevant entries above	Life, property, vehicle, aviation, marine, business interruption
Tidal surge (in association with onshore gales), coastal inundation	Refer to entries above for increased tropical cyclones, Asian summer monsoon, and intensity of mid-latitude storms	Refer to relevant entries above	Refer to relevant entries above	Life, marine, property, crop
Flood and drought	Increased Asian summer monsoon precipitation variability	Not treated by IPCC	Likely	Crop, property, health, life

* Estimates of confidence developed by IPCC: very likely (90–99% chance), likely (66–90% chance). ** Probabilities between 2-in-3 and 95%. *** Information from Working Group I, Technical Summary, Section F.5. **** Changes in regional distribution of tropical cyclones are possible but have not been established.
Source: adapted from Vellinga *et al.* (2001).

frequent events of concern such as wildfire, lightning strikes, soil subsidence and localised flooding.

Increasingly variable and unpredictable patterns of extreme weather events can imply greater statistical uncertainty (unpredictability) of potential losses. This can present a material impediment to setting actuarially sound rates and making insurance available to those who need it (Peara and Mills, 1999). The prospect of rapid non-linear climate change is particularly threatening to the risk management industries. Examples include variability and transitions of hemispheric-scale ocean-thermal ('thermohaline') circulation patterns, glacial and polar ice-cap instability, biogeochemical cycles and sources/sinks of radiative gasses, radiative forcing and potential impacts on atmospheric dynamics, and a variety of potential interactions among the aforementioned phenomenon (IPCC, 1998).

> Insurers rely upon their ability to predict the economic consequences of future events. . . . In a period of changing climate, when the very basis of their decisions may be changing, then they need to have a better understanding of climate change. . . . The fact that future events may not be a linear progression of the past, but in fact may have changed as a result of natural variability, or human activity or whatever, is an important thing to be taken into consideration.
>
> (Franklin Nutter, *Business Insurance*, 1998)

Munich Re's Geosciences Group (2000) has tabulated that from 1985 to 2000, the nations of the world have endured nearly US$1 trillion in economic losses (and 170 000 fatalities) due to 8800 natural disasters. Three-quarters of the aforementioned losses were weather-related, and one-fifth were insured.

Over the past 50 years, the number of weather-related natural disasters has been steadily rising, as have the total and insured losses (Figure 1). A multitude of factors have contributed to the scale and rate of change in losses, ranging from economic and demographic trends to changes in the nature of natural disasters themselves.

One of the vexing analytical challenges facing insurers is the difficulty of quantitatively disentangling the causes of weather-related loss events. This is especially true for those potentially related to human-induced climatic change versus natural climate cycles, and those having to do with human activity that could accelerate *or* dampen the process (demographic trends, increasing property values, disaster mitigation efforts, etc.) (Hooke, 2000). It is generally agreed that the current upward trend in losses is a product of both human and climatological factors, but an in-depth understanding is hampered by technical complexity and insufficient data (Vellinga *et al.*, 2001). One effort by Munich Re (1999) ascribed about half of the past rise in losses to climate change and the remainder to socio-economic trends.

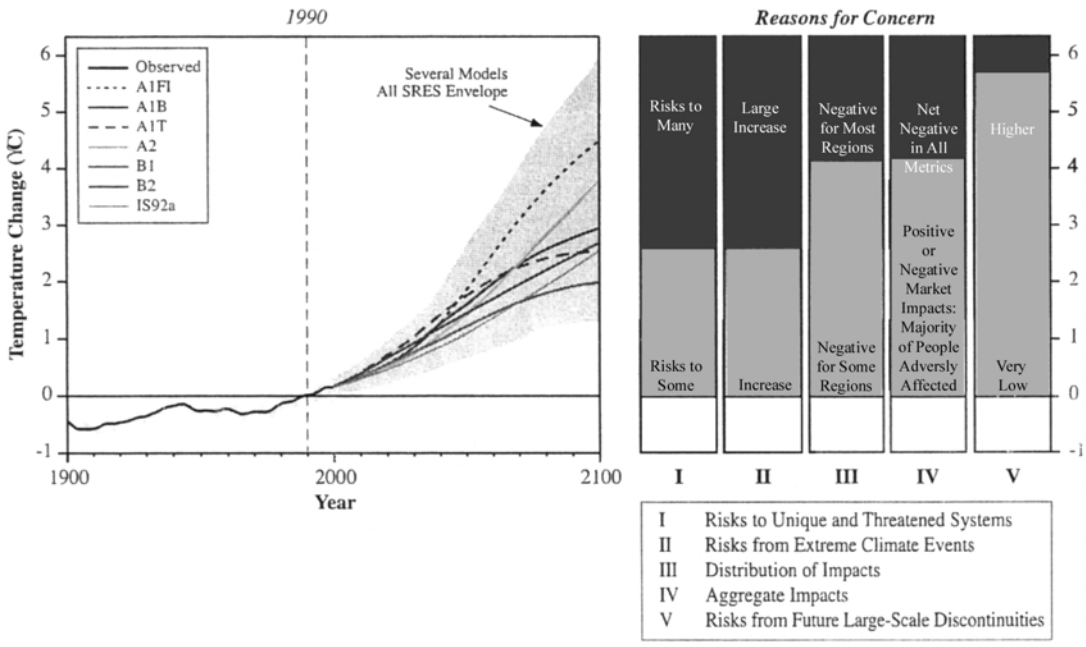


Figure 3 Level of risk under varying degrees of climate change. The left-hand chart shows the envelope of temperature-rise predictions from the latest IPCC Assessment (Watson *et al.* 2001). The right-hand chart shows the relative risks/benefits in various sectors associated with the range of projected temperature increases

After subtracting the effects of inflation, global weather-related insurance losses from *large* events escalated from a negligible level in the 1950s to an average of US$9.2 billion ($1999) per year in the 1990s – or 13.6-fold for 1960–99 where detailed base-year data are available.[3] Insured losses as a percent of Gross Domestic Product (GDP) also rose (Swiss Re, 1997), and the ratio of losses to premium revenues increased by a factor of ten (Vellinga *et al.*, 2001). A comparison of the decades since 1950 reveals that population grew by only 2.4-fold during this period.

It is clear that the costs of weather events have risen rapidly, despite significant and increasing efforts at fortifying infrastructure and enhancing disaster preparedness. These efforts have dampened to an unknown degree the observed rise in loss costs, although the literature attempting to separate natural from human driving forces has not quantified this effect.

A disproportionate amount of attention is paid to the headline-grabbing multibillion dollar loss events, given the equally large (albeit more distributed) collective costs of relatively minor events expected under climate change. For example, the average annual cost of tornadoes and associated hailstorms is larger than that of hurricanes or earthquakes (Swiss Re, 2000a). If one includes mid-sized weather-related loss events – more than 600 of which are documented every year – the economic losses cited above double (Munich Re, 2000). Large events represent only 1% of the total number of weather-related events annually.

One important yet often overlooked class of small events are those involving damage to buildings and pipelines due to soil subsidence (contraction/expansion of soil as a function of moisture content), lightning, ordinary hail- and windstorms, and coastal erosion. Subsidence losses from two droughts in the 1990s resulted in losses of US$2.5 billion in France and even more in the UK (Figure 5) (Vellinga *et al.*, 2001).

Realistic future scenarios involve multiple, coincident events, e.g. consecutive (or overlapping) natural disasters, taking place during a time of weakness in the financial markets and/or non-weather related losses. This was witnessed before in the USA with the Great Depression and the Dust Bowl. Indeed, the impact of the terrorist attacks of 11 September 2001 was amplified by a simultaneous downturn in the financial markets, the collapse of Enron, a recession, a steep decline in the securities markets, and emerging risks (e.g. toxic mould). A major weather-related catastrophe striking a US urban centre could have the same or greater economic consequences as '9/11'.

Insurance industry responses

The words 'Climate Change' stir anxieties and arouse controversies among some insurers, especially in the US (Mills *et al.*, 2001). While a number have given some attention to the issue, the vast majority of firms and most trade organisations have not publicly indicated an opinion. Some have taken definitive positions that there is a material threat, while others have

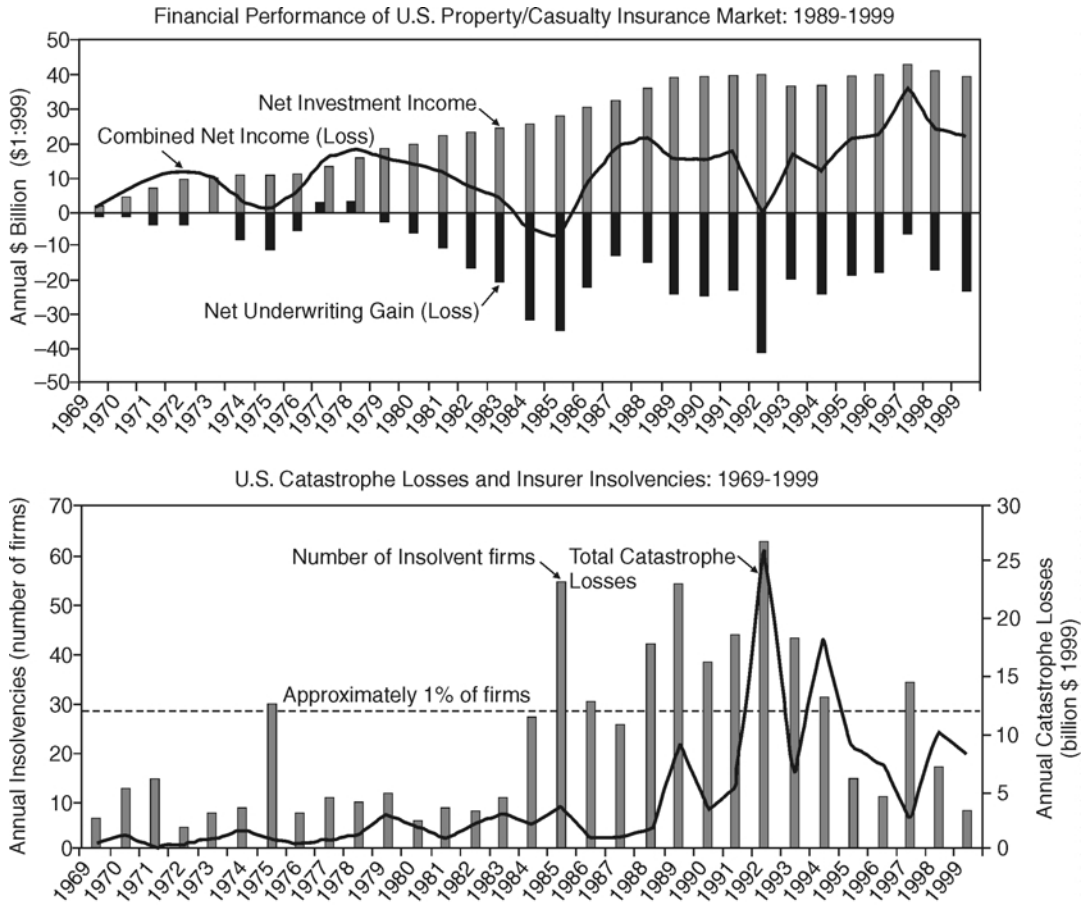


Figure 4a–b Profitability and solvency of U.S. property/casualty insurers during periods of natural disasters. (a) Sensitivity of the U.S. property/casualty insurance sector net financial results to investment income and underwriting gain/loss. Curve is the net result (b) Annual number of U.S. insolvencies (from all causes) and natural disaster losses: 1969–1999. Costs are corrected for inflation using GDP deflators. Includes only insured losses of > $5 m through 1996 and >25 million beginning in 1997. Note that due to various lag times insolvencies do not necessarily take place in the same year as the precipitating event. Sources: (Insurance Information Institute 1997, 1999, and 2000; Matthews *et al.*, 1999; Gastel 2000; PCS 2000)

adopted equally strong views to the contrary. Some have elected to pursue research while promoting disaster preparedness. Others have adopted a strictly 'wait-and-see' stance.

A core set of insurance firms have played a variety of roles in responding to the spectre of climate change, ranging from technical and economic responses to political responses. Historically, much of the activity has been focused on preparing for and responding to natural disasters. Some elements of the industry are arguing for a more proactive approach going forward.

Economic and technical responses

Many insurers have responded to the pronounced upward trend in losses by invoking traditional financial risk-management techniques, such as non-renewal of existing policies, withdrawing from high-risk markets, increasing premiums or deductibles, and limiting the maximum payouts allowed for a given claim. Insurers also purchase reinsurance, and endeavour to shift risks to self-insureds and the capital markets to protect themselves against catastrophic losses.

An additional important trend is the gradual shift towards increasing reliance on public sector insurance. This typically occurs in cases where losses are highly concentrated and unpredictable, such as flood and crop insurance. Federal and local governments, however, have repeatedly shown reluctance to increase their existing insurance exposures and liabilities for providing disaster relief. This tension is a central dilemma facing society and policymakers in the face of rising catastrophe losses. Analogous concerns have arisen concerning terrorism insurance in the wake of 9/11.

> Even the [US] government is starting to feel the financial pinch of disaster aid. . . . The enormous

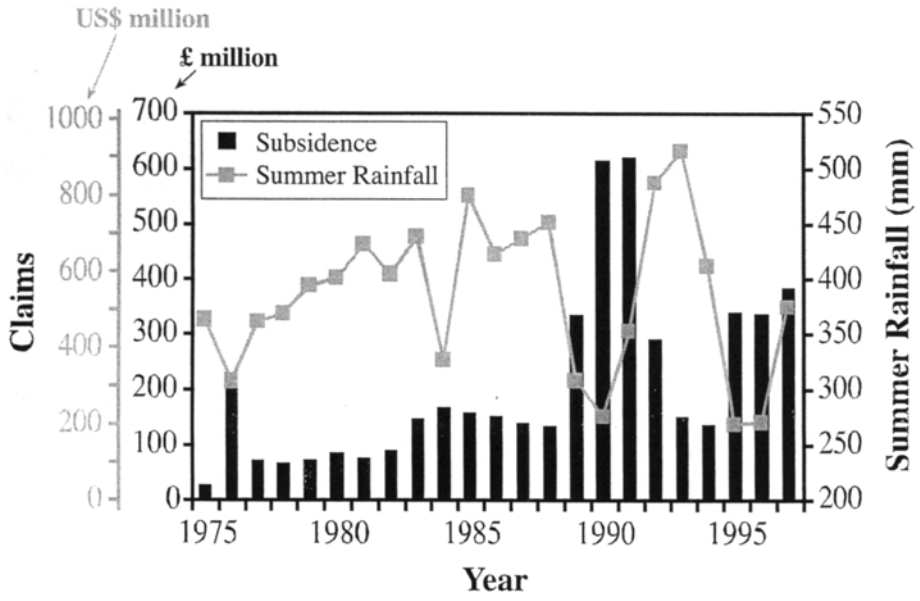


Figure 5 Correlation between soil subsidence and periods of drought. Summer rainfall and subsidence claims in the UK 1975–1997. The rainfall data are for England and Wales, April to September, from the Climatic Research Unit, University of East Anglia, Norwich, UK. The subsidence claim costs are not inflation-corrected, from the Association of British Insurers (Vellinga *et al.*, 2001)

> size of recent catastrophes and the potential for more of the same have caused the government to reevaluate its role as a provider of disaster relief.
> (Insurance Services Office, 1994)

More technically focused risk-management efforts include use of geographic information systems to better understand and pinpoint risks, land-use planning, flood control programmes, mitigation along coastlines, cloud seeding to divert hail storms, tightened zoning, improved weather forecasting and storm warning systems, and public spending on disaster preparedness and recovery. Insurers have also developed disaster preparedness and recovery plans, and participated in the formulation of building codes to make buildings more disaster resistant. Formulation of early building codes in the USA was driven by insurers aiming to reduce their fire-related exposures. The US-based Insurance Institute for Property Loss Reduction (now the Institute for Business and Home Safety) identified considerable lack of knowledge among code-inspection officials and implemented training programmes in response.

Some insurers have taken a more long-term approach, focusing on the roots of climate change rather than simply preparing for it. This includes participating in climate research either by employing climatologists or by hiring outside experts. In another example, Swiss Re and Munich Re systematically collect and analyse natural catastrophe data and have participated in the work of the Intergovernmental Panel on Climate Change. Others, e.g. Arkwright Mutual (now part of FM Global), have contributed to the literature analysing historic data in an effort to detect the climate-change 'signal' (Zeng and Kelly, 1997). Arkwright concluded that climate change is likely playing a role in the rise in flood losses, in combination with demographic trends.

A number of forward-looking insurers have explored possible involvements with energy-efficient and renewable energy technologies. We reviewed steps taken by 52 insurers and reinsurers, five brokers, and seven insurance organisations and 13 non-insurance organisations in this arena (Mills, 2002a). The approaches can be grouped into the categories of: information, education and demonstration; financial incentives; specialised policies and products; direct investment to promote energy efficiency and renewables; value-added customer services and inspections; efficient codes, standards and policies; research and development; and in-house energy management in insurer-owned properties (Table 3).

In some cases, insurers are developing green investment funds. Swiss Re has a "sustainability-based investment portfolio" approaching 100 million Swiss Francs (approximately US $60 million) in the form of venture capital and other investments (Swiss Re 2000b). As exemplified by the UK's Gerling Group, Swiss Re, Munich Re, CGU, Storebrand, and others, European insurers are more likely to adopt this perspective.

Gerling has set up a US $100-million Sustainable Investment Fund in which several other insurers have invested to date.

> Sustainable strategies and value creation are not contradictory: Sustainable strategies lead to an increase of reputation, innovative capacity and better awareness of stakeholders' and customers' perceptions and needs. They also contribute to gain in efficiency and reduce risks.
>
> (Dirk Kohler, Gerling Sustainable Development Project, 1999)

Political responses

European and Asian insurers have been particularly outspoken on the climate change issue:

> The situation we are in resembles that of a driver who approaches a wall of fog and, having only a vague impression of the stretch in front of him, looks into the rear mirror in an attempt to see in the clear view of the road behind some indication of what lies ahead.... There are some drivers on this earth that, instead of stepping on the brake, are putting their foot down firmly on the accelerator.... A further option entails active climate and environmental protection. This can lead to real win-win situations in the foreseeable future.... Mankind is in the process of performing a gigantic experiment on the earth's climate. However possible it may still be to argue about the development of climate change and particularly about its effects, there are definite indications that the risk situation will deteriorate in the future. Every effort must be made to mitigate climate change and to restrict the impact as much as possible.
>
> (Munich Re, 1999)

A few US insurers have been equally outspoken:

> Climate change is real. Proving that earth's climate is changed by human actions, namely global warming, is like statistically 'proving' the pavement exists after you have jumped out a 30 story building. After each floor your analysis would say 'so far – so good' and then, at the pavement, all uncertainty is removed.
>
> (Richard Jones, Hartford Steam Boiler Insurance & Inspection Co., 2000)

Some have ventured into the realm of public policy – even in the USA – making statements and recommendations that are clearly outside of the traditional realm in which insurers operate.

> To avoid the costs of climate disruption, a shift in priorities, credits, subsidies and incentives will be needed to help develop technologies that steer us into a renewable and energy-efficient future. The biggest surprise may be the better distributed economic opportunities produced by this transition.
>
> (Harvard Center for Health and the Global Environment & Reinsurance Association of America; Epstein and Nutter, 1997)

A number of insurers have chosen to 'lead by example', e.g. by addressing the environmental performance of their own facilities and operations. These efforts have begun to be documented by corporate 'Environmental Annual Reports'. Swiss Re's is particularly notable in the extensive integration with operating units within the company, including: services and products, investments, facilities and operations, information technology, and human resources (Swiss Re, 2000b). Swiss Re's reports include quantification of environmental indicators such as carbon dioxide emissions associated with corporate operations, and goals such as an emissions reduction of 10% per employee for business travel. Norway's Storebrand also has an impressive report, which evidences widespread penetration of environmentally oriented management practices throughout the company (Storebrand, 1999).

The most prominent political activity centres around approximately 90 insurers from 27 countries currently collaborating under the UN Insurance Industry Initiative for the Environment (UNEP, 1995). The signatories have presented a series of position papers at international negotiations under the UN Framework Convention on Climate Change, and focus on concrete actions that the insurance industry can take to help society cope with climate risks.

Differences between US and non-US insurers

With important exceptions, US insurers have devoted relatively less attention to the issue than their counterparts in Asia and Europe and few have joined the aforementioned UNEP initiative. The primary differentiating factor is the relative interest of non-US insurers in the precautionary principle, and belief that *both* natural and human-induced climate changes are at play.

> It would be prudent for the property/casualty industry to act as if that theory [global warming] is correct. Failure to act would leave the industry and its policyholders vulnerable to truly disastrous consequences
>
> (H. R. Kaufmann, Swiss Re's General Manager in 1990; quoted in Quirke, 1994)

> Risk management views the public discussion on climate change as a rabbit sitting paralysed in

> front of a snake – unaware that behind it a fox is poised to strike. There is not one problem but two: natural climate variability and the influence of human activity on the climate system.
> (Swiss Reinsurance Co., 1998)

The following points (from Mills *et al.*, 2001) illustrate some of the sources of these differences:

- Overseas insurers have been studying the question of climate change much longer than have their US counterparts (Munich Re, 1973). There is a greater tradition of science among European insurers and more staff climatologists providing analyses and corporate strategic counsel (although this work is concentrated in a few major companies). Munich Re has the largest climatology research activity within the insurance industry, with a staff of 35 people

- Debate about the scientific validity of climate change is particularly polarised in the US, and most of the highly visible 'climate sceptics' are based there

- Some of the largest US carriers do not conduct business overseas, whereas European and Asian companies typically have multi-country markets and thus experience a broader range of risks of natural disaster exposures and risk-management challenges

- Non-US reinsurers are heavily impacted by US natural-disaster insurance losses. This was illustrated by a simulation study of two US$7 billion hurricanes in the US. The surprising result showed that 5% of participating European insurers became insolvent (bankrupt) versus 1.5% of participating US insurers (AIRAC, 1986)

- 'Green' politics and ideals are far more established and influential in some overseas political systems. Accordingly, green marketing and product branding is ascribed a lower value in the US than in many other countries, especially Europe

- There is less government insurance for flood and crop losses in many other countries, and hence greater vulnerability among private insurers

- This is a 'cultural' and corporate tendency among US insurers to focus somewhat exclusively on the effects of natural disasters, whereas in some other countries there is an additional interest in focusing on and addressing causes. This is at times reflected in the very definition of terms, e.g. the Canadians include the reduction of greenhouse gases in their definition of 'mitigation' whereas US insurers would tend to limit the use of this word to disaster preparedness

- Less of an adversarial relationship exists with insurers and their regulators in many countries as compared with the situation in the US. Engagement in the climate change issue would likely invoke increased need for regulator–insurer interaction

- Tax laws pertaining to reserving for disaster reserves vary among countries. Some believe that the non-taxability of reserves in certain countries outside the US provides an extra incentive for insurers there to accept the global warming thesis. Conversely, some postulate that if US insurers voice agreement with the global warming theory that they will then be forced by their regulators to establish such (highly taxed) reserves

- Unique to the US are considerable negative lingering associations between Superfund and environmental movements. Any environmental proposition automatically invokes the spectre of Superfund. Asbestos litigation has also contributed to the industry's aversion to anything labelled 'environmental'

- The UNEP Insurance Industry Initiative did not obtain participation of US insurers during its formation and has not made a sufficiently concerted effort to reach out to US firms since that time. Nor did it attempted to recast its message in terms that clarify its relevance and value in the US insurance market and regulatory context

One frequent manifestation of the various differences between US and non-US insurer perspectives is the virtual absence of US insurer perception that climate change mitigation could offer business opportunities and other financial co-benefits for insurers (Zwirner, 2000). Overseas insurers, primarily in Europe, have, in contrast, been rather active in identifying opportunities and turning them into business realities, e.g. in thoughtfully identifying emerging markets based on the 'Flexible Mechanisms' proposed in the Kyoto Protocol (Hugenschmidt and Janssen, 1999; UNEP, 1999; Swiss Re, 2000b).

Novel approaches: integrating adaptation with mitigation in the energy sector

The insurance industry traditionally has little concern about energy issues. However, we have identified numerous examples of energy-efficient and renewable energy technologies that offer insurance loss-prevention benefits, and have mapped these opportunities onto the appropriate segments of the very diverse insurance sector (life, health, property, liability, business interruption, etc.) (Mills and Knoepfel, 1996). Our inventory revealed 78 specific examples that offered

Table 2 Physical perils and insurance coverage addressed by energy-efficiency and renewable energy technologies and strategies. Source: Vine *et al.* (1998).

	Number of measures offering benefit[1]
Physical perils	
Extreme temperature episodes	16
Fire and wind damage	38
Home or workplace indoor air quality hazards	38
Home or workplace safety hazards	21
Ice and water damage	17
Outdoor pollution or other environmental hazard	17[2]
Power failures	35
Theft and burglary	6
Insurance coverage – commercial lines	
Boiler and 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] Numbers refer to unique technologies and cover all technologies in table 4 of Vine *et al.* (1998). [2] Environmental benefits of improving the outdoor air quality, reducing vulnerabilities to power outages and reducing greenhouse gases are cross-cutting and, thus, are not included.

risk-management benefits (Vine *et al.*, 1998). We identified eight specific relevant 'physical perils' and 15 corresponding types of insurance coverage (Table 2). A subset offer benefits in the event of natural disasters.

The examples described below are highly cost effective in most applications, i.e. the net present value of the energy they save is greater than their incremental first cost (Moomaw *et al.*, 2001). Thus, no incremental cost is associated with the disaster-adaptation benefits. Policies and programmes for achieving implementation, and the potential role of insurers therein, are discussed at length by Mills (1996, 2002a).

Ice-dam-resistant construction

Repeated melting and refreezing of snow can form icicles and ice-dams on roof eaves. Melting water tends to pond on the rooftop, behind the ice-dam, often causing insured damage to the roof and the building interior. Water runoff or falling ice from rooftops can also present safety hazards. Ice-dam formation is accelerated by preventable exfiltration of warm air, insufficient insulation levels and thermal short circuits, or leaky heating ducts or light fixtures in otherwise cool attics (Figure 6). Electric heating elements often installed along rooflines are intended to provide a drainage channel for the water, but they were estimated to have resulted in 10 000–15 000 such water damage claims, with an average cost of US$2000 per home (Levick, 1996).

Renewables and energy efficiency for power disruptions

Loss of power can cause significant insured business interruptions and damage to property (Eto *et al.*, 2001; Mills, 2002a). There are a variety of ways to maintain business continuity through the use of reliable energy supplies and disaster-resilient energy service systems. All forms of energy efficiency are of value when buildings must rely upon local backup power systems during times of outages. Refrigeration offers a clear example of the benefits: High-efficiency food and pharmaceutical storage systems will maintain critical temperatures longer in the absence of power, and will be easier (less power demand) to operate on backup generators. Perished food in residential freezers was one of the larger costs faced by homeowner insurers in the great North American Ice Storm of 1998 (P. Kovacs, Insurance Bureau of Canada, personal communication, 2000). Renewable energy can also play a variety of roles, ranging from providing power for emergency shelters and schools, water purification systems, and backup for critical systems such as fuel pumps and safety lighting, although these systems are themselves vulnerable to natural disasters.

Energy-efficient windows and wall construction for wildfire and windstorm

During a fire, heat-stressed windows can shatter as a result of differential expansion near the frames, and the increased supply of air flowing through a broken window accelerates the spread of fire and toxic fumes. Efficient windows reduce the likelihood that fire will cause breakage (Kluver, 1994). Efficient multiple-pane windows or windows with retrofit films can reduce energy losses by half or more and are also more resistant to breakage by windstorms (by holding shards of broken glass together and maintaining a barrier against blowing wind and rain) and by thieves. They also block damaging UV radiation, and enhance occupant comfort (Mills and Rosenfeld, 1996). Tests conducted by Lund University's Institute of Fire Technology for the Swedish company Pilkington Glass AB identified superior performance of windows with low-emissivity (energy-efficient) coatings (Anderberg, 1985). For example, double-glazed units with one low-e coating took three-to-four times longer to break than did ordinary double-glazed units. In addition, these low-e double units performed as well or better than double units with one laminated glass layer. Efficient windows will, of course, ultimately fail

Table 3 Insurance-related activities involving energy efficiency and renewable energy

	Country	Information and education	Financial incentives	Energy savings insurance	Direct investment via markets	Technology demonstrations	Customer services and inspections	Codes and standards	Research and development	In-house energy management
Insurance and reinsurance companies										
American International Group (AIG)	USA		■	■						
American Modern Insurance Group	USA					■				
Aon Risk Services	USA			■						
Bankers Insurance Group	USA									■
Blue Cross & Blue Shield Mutual of Ohio	USA									■
Boiler Inspection & Insurance Company	CA			■						
CGNU (formerly General Accident)	UK									■
Chubb	USA			■			■		■	
Connecticut Mutual Life Insurance Home Office	USA									■
Continental Insurance	USA									■
Delta Lloyd Verzekeringsgroup NV	NL									■
Developers Professional Insurance Company (DPIC)	USA		■							
Employers Re	USA			■						
First Treasury	CA			■						
FM Global (formerly Arkwright Mutual)	USA	■				■				■
Gerling	UK				■					
Grange Mutual	USA									
Guy Carpenter and Company	USA									■
Hanover	USA		■							
Harleysville Mutual Insurance Company	USA									■
Hartford Steam Boiler (HSB/IPT & Canadian Subsidiary)	USA			■			■			■

Independent Insurance	UK									■
ITT Hartford Group, Incorporated	USA									■
Johnson & Higgins	USA									■
Lloyds of London (Nature Save Insurance)	UK	■			■		■			
Milwaukee Insurance	USA									■
Minnesota Mutual Life Insurance Company	USA									■
Munich Re	D	■								
Nationwide Mutual Insurance Company, Inc.	USA									■
New York Life Insurance & Annuity Corp.	USA									■
North American Capacity Insurance Co. (owned by Swiss Re)	USA			■						
Pennsylvania Blue Shield	USA									■
Phoenix Home Life Mutual Insurance Co.	USA									■
Progressive Auto Insurance	USA		■						■	
Provident Life & Accident Insurance Co	USA									■
Prudential Assurance	UK									■
Prudential Insurance Company of America, Inc.	USA									■
Reinland Versicherungen	D		■							
Royal Maccabees Life Insurance Company	USA									■
Safeco	USA			■						
St. Paul Fire and Marine Insurance	USA									■
Sorema Re	CA			■						
State Compensation Insurance Fund	USA									■
State Farm	USA								■	
State Farm Mutual Automobile Ins Co	USA									■
Storebrand	N				■		■			
Swiss Re	CH				■					■

Table 3 (Continued)

	Country	Information and education	Financial incentives	Energy savings insurance	Direct investment via markets	Technology demonstrations	Customer services and inspections	Codes and standards	Research and development	In-house energy management
USAA	USA	■								■
USF&G was (merged w/by St. Paul's Co.)	USA				■					■
Victoria/Ergo	D				■					
Westbend Mutual	USA								■	
Zurich American Insurance Group/Steadfast	USA			■						
Insurance brokers and agents										
AON	USA			■						
Clair Odell Group	USA			■			■			
Morris & Mackenzie	CA			■						
NRG Savings Assurance	USA			■						
Willis Corroon/Willis Canada	USA/CA			■			■			
Insurance organizations										
Advocates for Highway and Auto Safety	USA	■						■		
American Insurance Association (AIA)	USA	■								
Institute for Business and Home Safety (IBHS)	USA	■						■	■	
Institute for Catastrophic Loss Reduction	CA	■						■		
Insurance Institute for Highway Safety (IIHS)	USA	■						■		
National Association of Independent Insurers	USA	■								
United Nations Environment Programme Insurance Initiative	multi-	■								
Others										
Boston Edison Company	USA	■				■				
Building Air Quality Alliance (BAQA)	USA						■			
Building Code Assistance Project (BCAP)	USA									

Environmental Defense	USA										
Federal Highway Administration (FHA)	USA										
International Energy Agency	multi-		■			■					■
Iowa Department of Natural Resources	USA										
Pacific Gas & Electric Company	USA					■					
Roofing Industry Committee on Wind Issues (RICOWI)	USA					■				■	
U.S. Department of Energy, Denver Support Office	USA		■							■	
U.S. Department of Transportation	USA					■					
U.S. Environmental Protection Agency	USA		■								■
Waterhealth International	USA										■

Notes: CA = Canada, NL = the Netherlands, D = Germany, N = Norway, CH = Switzerland, UK = United Kingdom, USA = United States of America. Source: Mills (2000a).

in fires. And they do not prevent the ignition of fires by other mechanisms.

Improved building envelopes, e.g. with insulated concrete form (ICF) techniques, are more energy efficient and resistant to flying debris than standard timber-frame construction (Farnsworth, 2000). Reduced infiltration may also provide benefits in the event of fires.

Insulated building envelopes for frozen water pipes

In new construction, a clearly defined, continuous and highly insulated thermal envelope with all services placed inside eliminates the risk of pipe freezing and the need for ad hoc insulation arrangements. The latter are difficult, time consuming, likely to be incomplete in the first place and vulnerable to removal during subsequent repair and maintenance. As a case in point, frozen water pipes have been identified as an important cause of losses in Europe and North America (Klaus *et al.*, 1992). Cold winters correlate to significant reductions in the profitability of pipe insurance providers. The US insurance industry paid US$4.2 billion in claims over 10 years for freezing pipes (IBHS and SBA, 1999). Insulating pipes (or cold spaces where pipes run) is a simple retrofit that saves energy and reduces the likelihood of freeze damage.

Heat island mitigation for urban heat catastrophes and smog events

Large cities are typically several degrees warmer than their surroundings because of the 'urban heat island effect', even in the absence of climate change. Global climate change is expected to increase the frequency and severity of extreme-heat episodes (Watson *et al.*, 2001). This increase in temperatures results in more urban smog (and associated health costs) and increased air-conditioning energy use. Research has demonstrated that lightening the colour of roads and building rooftops, and planting urban trees can dramatically reduce average urban temperatures (Mestel, 1995). Detailed field studies have shown as much as 40–60% air-conditioning savings in a series of buildings where these strategies were used (Rosenfeld *et al.*, 1995). Lightened (or aluminised) exterior surfaces can also make a building less vulnerable to fire, especially if the materials are 'tuned' to reject near-infrared radiation. An analysis of optimised paints found a potential 3.5-fold improvement in the 'fire reflectance' of paints compared with typical white paint (Berdahl, 1995a, b). The use of trees to lower temperatures around buildings also has the side benefit of reducing the rate of water flow onto streets during downpours, and thus local flooding. Reducing urban air-shed temperatures also slows the formation of smog (Rosenfeld *et al.*, 1995), which in turn reduces health insurance claims. Figures 7a and b show how a package of measures including attic insulation, white paint on the roof and ventilation would bring the

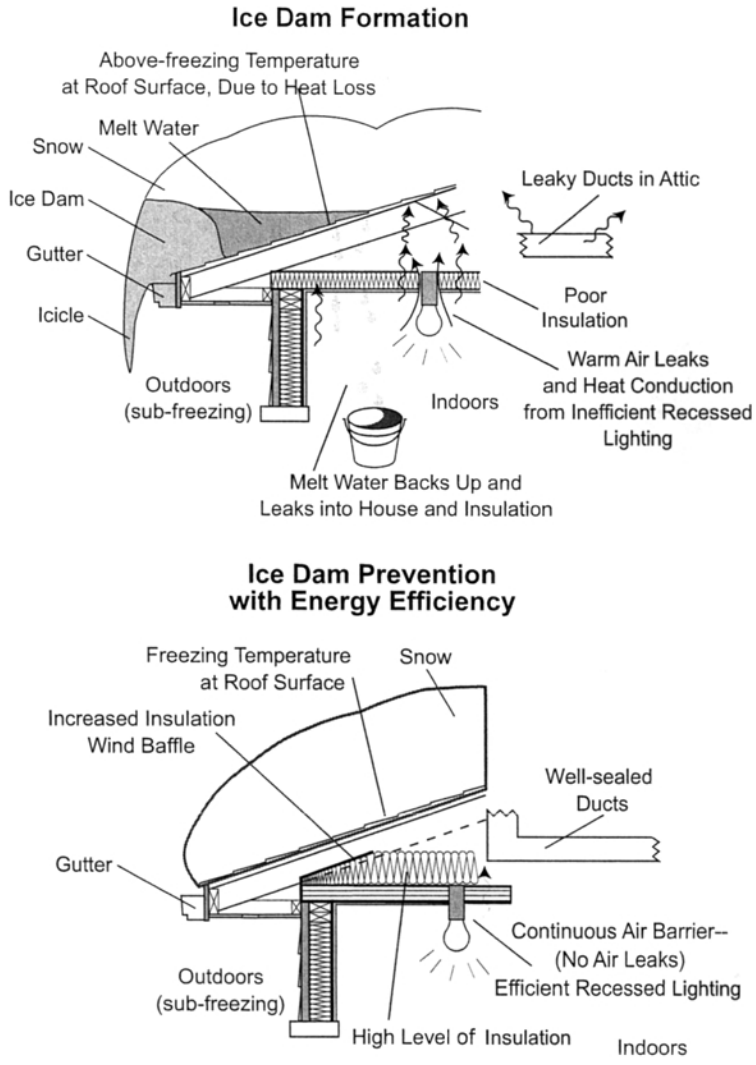


Figure 6 Energy-efficient features can contribute to reduced heat losses through roofs, and reduced risk of ice-dam formation

indoor air temperature to safe levels in the kinds of apartments in which hundreds of heat deaths occurred in Chicago in 1995. Ultra-cold weather events, of course, also pose a risk to occupants of poorly insulated buildings, and can also be mitigated by energy-efficiency measures.

Light-emitting-diode (LED) exit signs for building evacuation

LED exit signs offer energy savings more than 90% compared with traditional incandescent-based technologies (Mills, 1993; Sardinsky and Hawthorne, 1994). Their 10–20-year service life means improved reliability and availability (and thus safety during emergencies) and less maintenance. The intense red LED light is highly visible through smoke. Given their low power demand, LED exit signs will operate longer during a power outage than traditional exit signs run by the same size battery.

Integrating an insurance perspective with broader buildings sector issues

Creating energy-efficient, disaster-resilient buildings not only is a technical challenge; but also is an institutional one. An array of crises in the construction industry – ranging from construction defects liability to mould – reflect the need for better quality assurance, greater sophistication in the application of advanced technologies and greater adherence to codes and standards. In the USA today, homebuilders are facing enormous lawsuits, estimated to cost (directly and indirectly) US$200 billion a year, and to already be affecting the costs of homes (Golden, 2002). Insurers are first in line to absorb some of these costs.

Achieving successful integration of sustainable energy considerations with risk-management objectives requires a more proactive orientation, and coordination among diverse actors. For example, government entities with

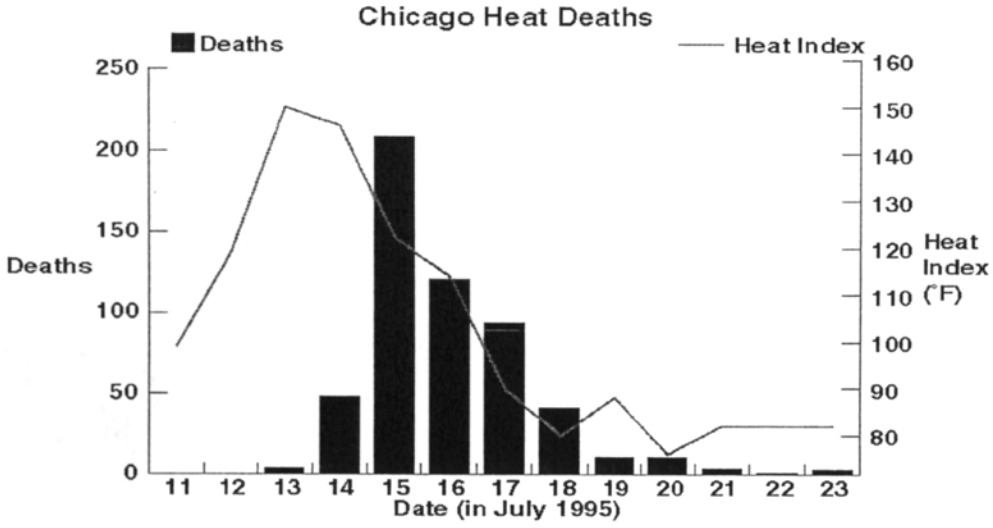


Figure 7a The bars indicate numbers of above-normal deaths each day of the July 1995 heat wave in Chicago, and the curve shows the heat index, which reflects the combined effect of temperature and humidity

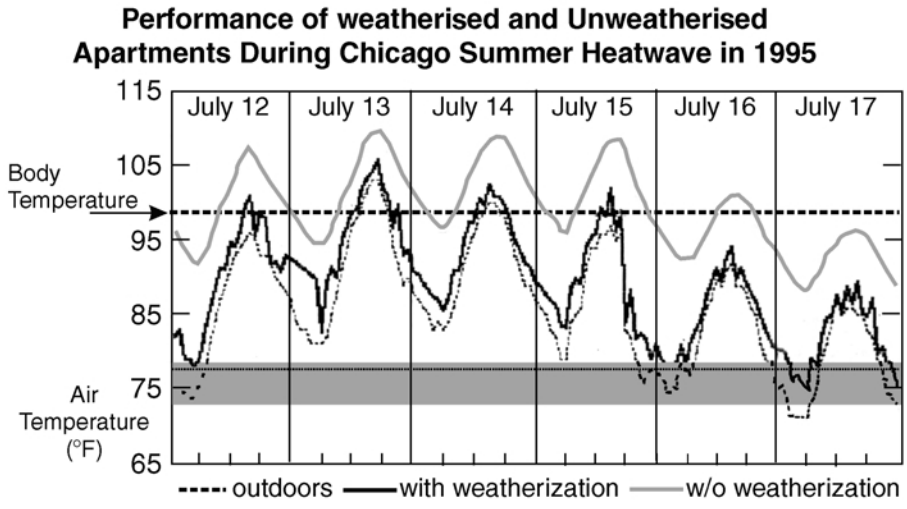


Figure 7b Computer-simulated indoor temperatures in the top floor of a prototypical 1940s two-story apartment building in Chicago during the July 1995 heatwave. In the existing building, top-floor temperatures reached 108°F (42°C) and remained high even after the outdoor temperatures had started to drop. The addition of attic insulation, white paint on the roof, and a ventilation system brought top floor temperatures in line with outdoor temperatures (Huang 1996; Meier 1996)

jurisdiction over energy and emergency management rarely coordinate concerning energy demand-side issues. This creates barriers of various sorts, such as the absence of funding, information and tolerance for rebuilding buildings in an energy-inefficient and disaster-prone manner.

A central consideration is to remodel or reconstruct buildings properly following disaster losses. Sustainable redevelopment is defined by the US Department of Energy as:

> the deliberate effort by disaster-prone communities to improve their economic health, environmental resilience, and quality of life as they plan for and recover from natural disasters.
>
> (USDOE, 1999).

Ensuring adequate knowledge and skills among building code enforcement individuals is a key need. The extensive property damage and loss of life due to inadequate codes or code enforcement has been evidenced many times following severe earthquakes in developing countries. Yet, these problems also haunt industrialised countries. For example, a survey by the US Insurance Institute for Property Loss Prevention revealed that over 75% of US code enforcement officials were inadequately equipped for this job. In the

UK, analysis of claims and weather data has shown that a large proportion of wind-related damage takes place at wind speeds lower than those to which buildings are nominally designed and are caused by failures to apply existing codes of practice (Buller, 1993).

While existing activities show that there is a remarkable level of sustainable-energy activity among insurers, there remain various barriers to expanding significantly the level of insurer participation. These barriers are summarised in Table 4 and discussed in length in Mills (2002a).

One significant barrier is that sustainable energy technologies can at times work at cross purposes to the goals of risk management (Mills and Knoepfel, 1997; Vine *et al.*, 1998). Although the use of sustainable energy technologies and strategies generally reduces insurance risks – or is risk-neutral – if applied incorrectly energy management can compromise indoor air quality, cause water damage, pose fire hazards, etc. Various entities within the insurance community have made reference to such problems. The American Insurance Association, while supportive of certain efficiency options, has also stated that certain measures could present adverse risk characteristics (Unnewehr, 1999). Even very pro-sustainability European insurers Gerling and Rheinland Versicherungen have been careful to flag potential downsides (Kohler, 1999; Zwirner, 2000). Perhaps the most widespread instance is the negative association between indoor air quality problems and energy efficiency in buildings (Frazer, 1998; Diamond, 1999). As a case in point, over US$100 million has been paid out for water damages caused by externally applied foam insulation retrofits (Deering, 2001), and mould has become a crisis that insurers say may be as great as the one posed by asbestos. The replacement of electric cooking appliances with more energy-efficient gas devices can contribute to indoor air pollution (Jarvis *et al.*, 1996). Some concerns are based on myths or misunderstandings of building science, as evidenced by the incorrect assertion that insulation exacerbates losses from frozen water pipes and ice-dams (IBHS, 2001). The legitimate problems are generally resolvable, but energy R&D organisations (public as well as private) are driven largely if not exclusively by relatively narrow energy-related objectives and do not necessarily consider risk-management issues. It is also prudent for sustainable energy enthusiasts to be thoughtful about the impacts of their proposals on the insurance sector's business environment.

The potential impacts of climate change on the buildings sector warrants the keen consideration of insurance regulators, given their dual responsibility as guardians of policyholders' interests and to assure the solvency of insurers so that they can meet their financial obligations when disaster strikes (Mills, 2002b). In doing so, regulators must look at alternatives that will lessen the financial impact on insurers at the time of loss. Regulators can play many important roles, such as ensuring the collection and analysis of necessary data, and deploying appropriate risk-management technologies and practices. Notably, insurance regulations can inadvertently impede the more efficient use of energy. For example, insurers generally need regulatory approval for providing incentives to insureds to pursue loss-prevention strategies or to invest in sustainable energy industries. Similarly, the exclusion of research and development expenses from rates in some countries may stifle innovation in this area.

Table 4 Barriers to increased insurer involvement in energy efficiency and renewable energy

Technical issues
• Lack of quantitative documentation of benefits
• Insurer involvement in technology and R&D is limited in many cases
• Adverse side-effects of improperly applied energy-efficient technologies
Nature of the insurance industry and marketplace
• Fragmentation – many types of insurers, each with different needs
• Difficult history with environmental issues, exemplified by Superfund litigation
• Regulatory hurdles to innovation, rate changes, etc.
Energy/environment community perceptions of insurers
• Perception of insurers as 'cash cow'
• Poor understanding of how insurance business works
• Assumption that insurers will promote efficiency to battle climate change
Insurer perceptions of energy/environment community
• Adversarial history between environmentalists and industry
• Perception that efficiency is being used as a 'Trojan horse' by climate change advocates

Limited R&D throughout the construction industry also generally creates barriers to identification, development and implementation of any package of measures aimed at long-term performance rather than first cost. This is a structural problem that severely restricts the ability of insurers (and indeed anybody else) to identify and advocate effective, integrated strategies for risk minimisation. The first-cost orientation of consumers reinforces this counter-productive situation.

Conclusions and policy implications

The insurance and risk-management industries are highly vulnerable to the impacts of climate change, particularly in the buildings sector. Traditional responses (raising premiums, withdrawing coverage, shifting the burden to the state, etc.), are the most likely, they are the least politically and socially acceptable. Reduced insurance availability can have a chilling effect on the construction industry and property markets. A more optimistic scenario involves truly proactive approaches to addressing the climate change problem directly. In some instances, however, the insurance and buildings industries are at odds with one another; the former seeking to minimise losses, the latter to minimise first costs and regulatory oversight.

While not a panacea, one promising avenue is represented by the tremendous potential for insurers and risk managers to become more involved in using energy efficiency and renewable energy as part of a broader strategy to make buildings more disaster-resilient. Early precedents illustrate the wide array of ways in which insurers have already participated, but barriers also remain.

The challenge for the energy community is to continue to identify and articulate the ways in which these strategies can moderate or prevent insurance losses, and to make the business case of how sustainable energy technologies can improve the competitive advantage of insurance firms. To be successful, sustainable energy proposals must address acute strategic issues faced by insurers. A good example is the rapid growth in mould, indoor air quality and construction defects claims haunting many insurers (Ruquet, 2002). Many of the claims trace back to bad design and application of energy-related systems. The growing insurance risks associated with electricity reliability are another example, which can be addressed, in part, through efficiency and distributed renewable energy supply solutions.

Lastly, a more diverse set of industry actors (agents, brokers, underwriters, risk managers, trade associations, executives) must be educated and involved in assessing and implementing the opportunities. Conversely, the energy and building science communities, as well as the building trades, require a deeper understanding of insurance and risk management.

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Endnotes

[1]In addition to a variety of climate scientists, insurance and banking, industry co-authors included representatives from CGU, Credit Suisse, The Insurance Bureau of Canada, Munich Re, and Tokyo Marine & Fire Insurance, Co., Ltd, and an actuary from the USA.

[2]The threat of insolvency (bankruptcy) is often assumed to apply exclusively to small firms. Following Hurricane Andrew, however, the US's largest homeowner property insurer, State Farm Fire & Casualty, was brought to the brink of insolvency, necessitating a rescue by its parent (State Farm Group). Allstate, the nation's second largest homeowner insurer, met the same fate (Mills *et al.*, 2001). Of the nearly 700 US insurers that became insolvent between 1969 and 1999, about 10% of the cases were primarily due to natural catastrophes, and for an unknown additional share catastrophes were a contributing but not primary factor (Matthews *et al.*, 1999).

[3]These losses exclude administrative 'loss-adjustment' costs; thus, the total cost is higher.