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3. Policy Design for Earthquake Hazard Mitigation: Lessons from Energy Conservation, Radon Reduction, and Termite Control

Peter J. May, M.EERI, Raymond J. Burby, M.EERI, and Howard Kunreuther

The failure of homeowners to invest in mitigation measures for reducing potential losses from earthquakes presents a major obstacle to stemming economic losses. The design of earthquake risk reduction policies requires an understanding of the appropriate combination of institutional and individual incentives for inducing investment in mitigation. We address the challenges of inducing protective actions by considering the experiences with energy conservation, radon reduction, and termite control. We examine the institutional design of relevant policies and programs, the role of various intermediaries, and the involvement of third parties in creating markets for services. From this, we draw lessons about the leveraging of governmental resources, fostering of markets for services, and carrying out of programs for outreach and education.

INTRODUCTION

A central component of efforts in the United States to reduce losses posed by earthquakes and other natural hazards is to encourage efforts by homeowners to adopt various protective measures. Among other protective actions for minimizing earthquake damage, homeowners can bolt foundations to their frames, increase lateral strength, brace water heaters, and reduce weakness associated with soft, first stories. Related measures for reducing damage from floods, high winds, and hurricanes include reinforcement of roofs, elevation of homes, and installation of storm shutters.

Various studies suggest that these protective actions are not commonly undertaken. With respect to investing in measures to reduce earthquake damage, Risa Palm and her colleagues (1990) found from a survey of 3,500 homeowners in four California counties that only between 5 and 9 percent of the respondents in each of these counties reported adopting any loss reduction measures. In a 1993 follow-up survey, Palm (1995) found that between 20 to 25 percent of the homes in the two counties affected by the 1989 Loma Prieta earthquake (Santa Clara and Contra Costa) had bolted their house to the foundation. Less than 10 percent of homeowners in the two southern counties in the survey (Los Angeles and San Bernadino) had undertaken this measure. In addressing flood risks, Shirley Laska (1991) found that only 15 percent of homeowners in flood-prone areas of Illinois and Wisconsin had undertaken protective

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behavior to flood proof homes prior to noteworthy floods. The Insurance Institute for Property Loss Reduction (1995) found in a survey undertaken after Hurricane Andrew that only 37 percent of homeowners living in six hurricane-prone areas of the southeastern United States had undertaken actions to protect their homes from hurricane damage.

This record of homeowners in failing to undertake protective behavior presents a major challenge for policymakers. It is clear that reduction of losses from disasters, particularly economic loss, can only come about with concerted action by homeowners to mitigate against future events. It is also evident that there is a rather unsatisfying understanding of how to induce appropriate action with limited resources and in an era of limited intervention in private decisions. Complicating the problem is uncertainty about the types of mitigation that are cost-effective from the point of view of both homeowners and society. A common refrain is to call for new incentives and for public and private partnerships to instill greater efforts to mitigate against disaster losses.

The puzzle is to figure out how to put together the right combination of institutional and individual incentives. There are different ways to solve this puzzle. One strategy is to experiment with different arrangements and distill what works best. This is implicit in the current Project Impact program of the Federal Emergency Management Agency. Under this program to date 57 communities have been selected to demonstrate the benefits of local efforts to promote hazard mitigation (Federal Emergency Management Agency 1998). A similar demonstration program is the Showcase Community project of the Institute for Business and Home Safety, a consortium of insurance companies working to promote hazard mitigation.

Another strategy is to undertake research in order to provide an understanding of the choices that homeowners and others make about mitigation. The extensive literature about decision processes and choices for adjustments to hazards provides important insights (see Lindell 1997). But, because this literature does not address the influences of public policy in decision-making about adjustments, there is an unsatisfying understanding of the appropriate policy designs for inducing mitigation.

A third strategy is to look for analogies from which lessons can be drawn about institutional arrangements and use of individual incentives. We adopt this approach in asking what can be learned from energy conservation, radon reduction, and termite control for the design of earthquake hazard mitigation policies. Each of these exemplars entails decision-making by homeowners to make investments in order to protect their homes from harm and to provide future benefits. Each exemplar seems to have had at least moderate success in bringing about changes of the type that are required for earthquake hazard mitigation. From examining the use of incentives and the role of different entities in fostering such change, we draw lessons about the design of earthquake hazard mitigation programs.

We followed a similar methodology in studying each of the three exemplars. We examined available documents about governmental policies and programs, collected relevant articles and books, and undertook extensive searches of electronic sources of information with particular attention to the involvement of nongovernmental organizations. From these secondary accounts we identified state or local programs that have gained reputations of having successful outcomes. For each of these, we undertook interviews with relevant
individuals. These various sources provided a basis for assembling case studies of each exemplar.

In what follows, we first consider the choices of homeowners when deciding to invest in energy conservation measures, protect against radon, control termite infestation, or invest in earthquake hazard mitigation measures. We next consider the different institutional arrangements involving governmental and nongovernmental entities. This leads to discussion of the emergence of private markets for these services. We finally turn to the lessons about policy design and the limits in translating the exemplary experiences to earthquake hazard mitigation.

**DECISION-MAKING FOR UNCERTAIN BENEFITS**

Decisions about investment in energy conservation, protection against radon, termite control, and earthquake hazard mitigation entail similar sets of considerations. When considering whether to invest in mitigation measures, homeowners often find that they cannot justify the expenditures that are required for such measures. In the sections that follow, we consider the attributes of decision processes about adoption of mitigation measures.

**ATTRIBUTES OF PROTECTIVE DECISION-MAKING**

Decisions about investment in energy conservation, protection against radon, termite control, and earthquake mitigation share common attributes. Each entails a potential harm or loss for which there are varying degrees of uncertainty about the timing and amount. Energy conservation involves consideration of economic losses associated with wasted energy use. The energy losses depend on the energy efficiency of a home, weather conditions, and the prices of energy. Radon reduction entails uncertainty about the extent of radon exposure for a particular house and the cumulative consequences of that exposure for the health of household members. Termite control involves uncertainty about the extent of infestation, the potential for future infestation, the degree of harm to a structure done by termites, and the potential for difficulty in selling the dwelling. Earthquake risk reduction involves uncertainty about the timing and damage associated with future events. From the perspective of individual homeowners, the uncertainties associated with each of these harms can be quite large. Yet, the associated losses can also be quite large especially for potential catastrophic earthquakes.

Each of the investments requires initial costs, and in most cases, smaller expenditures over time in order to secure future benefits. Energy conservation measures include weatherization of homes through use of better insulation, double-pane windows, caulking and weather stripping. Average weatherization costs in 1989 dollars for older, energy inefficient homes range from $750 in hot climates to $2,300 in cold climates (Brown et al. 1993). Costs may be greater, however, if households also replace older heating and cooling systems with newer, more energy efficient equipment.

Radon reduction entails installation of either a passive system for venting radon gasses from the soil to the atmosphere or an active system that involves installation of fans and other devices to vent radon gases. The Environmental Protection Agency (1992) cites investments
of $500 to $2500 as typical for such systems with active systems entailing additional yearly expenditures for operating the reduction system of $75 to $100.

Termite control entails installation of chemical barriers and use of treated materials, extermination of infested areas of a home, replacement of infested wood, and ongoing costs for inspection and treatment against infestation. The cost of chemical barriers and other mitigation measures are similar to those of passive radon reduction systems. If infestation is discovered, termite elimination costs range from $500 to $5000. This is just for termite removal not for repairs to any damage that has been done. The costs of repair of termite damage will depend on the extent of the damage, the construction type, length of infestation, and structural integrity of the house. In the case of collapse of part of the structure, repair costs can exceed 50 percent of the house value. If the homeowner chooses to purchase an annual renewable contract for termite control, typical costs are $100 to $500 per year.

Mitigation measures for earthquakes include strengthening of foundations, bolting house frames to foundations, bracing of water heaters, and adding support to exterior walls. The costs for these measures vary considerably depending on the extent of mitigation that is undertaken, who does the work, and whether it is undertaken as part of new home construction or as part of a renovation. The costs ranges from $20 or less for the bracing of water heaters to tens of thousands of dollars for foundation work. The Federal Emergency Management Agency estimates costs between $1500 and $2500 for bolting house frames to the foundation.

Another common attribute is the existence of a variety of combinations of potential mitigation measures that present different levels of uncertainty about their effectiveness. The appropriate measures often depend on site-specific conditions for which the best combination for one house may not be the same as for another. For existing construction, this necessitates on-site inspections to determine the extent of the problem and options for mitigation. The inspections consist of energy audits for energy conservation, radon testing for radon reduction, termite inspections for termite control, and geotechnical and structural engineering evaluations for earthquake risks. Typical costs of such inspections vary between $20 for a home-testing radon kit to $500 or more for extensive earthquake evaluations.

Two levels of uncertainty are introduced as part of such evaluations. One is the adequacy of the diagnosis of the potential harm. For example, radon testing results can be affected by the type of testing device employed, duration of the test, timing of the test, location of the testing device, and adequacy of the lab analysis of test results. A second uncertainty is the effectiveness of the steps taken to mitigate the harm or provide the desired benefits. Here there are issues related to the adequacy of the measures and of the quality of installation of those measures.

Mitigation measures provide a stream of benefits over the life of a house in improved energy efficiency (reduced energy costs), reduced exposure to radon gases (reduced illness), avoidance of termite infestation (avoided losses), and reduced earthquake damage (reduced losses and harm). Because of the uncertainty about both the potential harm and the effectiveness of the chosen mitigation measures, the timing and amount of benefits associated with the investments are often uncertain. The benefits associated with energy conservation are more certain, and thus they are likely to be viewed more attractively than investments in risk mitigation. The effectiveness of different energy-saving measures is fairly well known.
and future savings can be calculated given assumptions about costs of energy and length of
residence. The least certain benefits are those associated with radon reduction and with
earthquake mitigation. The certainty of benefits of measures for termite control falls in-
between.

There is also uncertainty about the resale value of investments in mitigation measures
when selling a dwelling. On the one hand, a homeowner may be more ready to undertake
mitigation if costs can be recouped at the time of sale of the property. On the other hand, if
like the cost of a swimming pool, mitigation costs cannot be passed along to future buyers,
then homeowners may be reluctant to undertake them. This is particularly true if the
homeowner is uncertain about gaining benefits from the investment while living in the home.

DEcision-making constraints

There are a variety of factors that constrain individuals when making decisions about
mitigation measures. Perhaps most important are the uncertainties about the investments. The
unknown timing of future benefits requires making assumptions about the likelihood that
benefits will accrue in any given, future year. A long line of research, beginning with
pioneering work by Tversky and Kahneman (1974) and including study by Kunreuther
(1978) of household decisions to purchase flood or earthquake insurance, explores how
individuals judge probabilistic outcomes. This research shows substantial misperception of
probabilities by individuals when making decisions involving low probabilities. People
distort information that is given to them about the probabilities of events like earthquakes by
making simplifying assumptions or by reacting to their biased recall of salient events—what
Tversky and Kahneman (1974) have labeled as an availability bias. In many instances, low
probabilities are reduced to zero probabilities thereby creating a situation in which mitigation
measures have no value to a homeowner.

Also at issue is the inability of people to think in terms of the long run. Studies of
decisions to purchase energy efficient appliances by Hausman (1979) and experiments by
Kunreuther and his colleagues (in press) about people’s willingness to install dead bolts for
protecting against crime or invest in earthquake mitigation measures reach similar
conclusions about people’s time horizons. People tend to be myopic in only thinking about
the next few months or years, even when the benefits of investments occur over much longer
periods. The consequence of this is an under valuation of protective measures leading,
everything else equal, to less willingness to make the necessary investments.

The preceding points suggest some of the key limits to framing decisions to invest in
mitigation measures. More research is needed to improve the understanding of how people
make decisions about such investments and what can be done to influence those decisions.
The clear policy implication at present is that desired mitigation action by homeowners is
unlikely to follow from simply providing them with information about earthquake hazards or
about the costs and benefits of appropriate actions. This is evident from the experience with
efforts as part of energy conservation programs to provide homeowners, through energy
audits, with information about the costs and benefits of energy improvements. In reviewing
actions taken by households after energy audits in a range of programs undertaken in the
early 1980s, Stern and his colleagues (1985) found wide variation in follow-up by
homeowners in installing the recommended conservation measures.
CONSIDERING INSTITUTIONAL ARRANGEMENTS

The exemplars we consider vary with respect to the involvement of different levels of government and the roles undertaken by nongovernmental intermediaries. A key issue for the institutional design of policies for these and analogous programs is one of understanding relationships between governmental and nongovernmental entities and ways to harness the interests of third parties in promoting protective behaviors.

GOVERNMENTAL ROLES

The programs we consider illustrate the differences in involvement and approaches of government entities in bringing about change. Table 1 summarizes these differences.

Table 1. Governmental roles in motivating homeowner actions

<table>
<thead>
<tr>
<th></th>
<th>Energy Conservation</th>
<th>Radon Reduction</th>
<th>Termite Control</th>
<th>Earthquake Mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Federal</strong></td>
<td><em>Extensive</em>—energy code research and development; outreach and funding for weatherization programs; funding for state and local programs; mandates for utility involvement</td>
<td><em>Moderate</em>—risk standards; model building practices; certification for radon testing, inspection and remediation; funding for state and local programs</td>
<td><em>Limited</em>—federal requirements for certification of pesticides applicators, certification of pesticides; research on pesticides</td>
<td><em>Moderate</em>—research for seismic provisions of building codes; Project Impact demonstration communities; education and outreach programs; funding of state programs</td>
</tr>
<tr>
<td><strong>Government</strong></td>
<td>$150 million for state and local programs; $570 million overall</td>
<td>$19 million for all EPA radiation programs</td>
<td>No funds specific to termite; $115 million for EPA pesticide programs</td>
<td>$28 million for all mitigation programs</td>
</tr>
<tr>
<td><strong>State</strong></td>
<td><em>Extensive mandated role</em>—state energy plans; adoption of energy provisions for buildings; outreach programs; mandates for utility involvement</td>
<td><em>Extensive induced role</em>—radon offices; some states with direct regulation and disclosure requirements</td>
<td><em>Limited induced role</em>—states can take on training and certification of applicators</td>
<td><em>Limited induced role</em>—earthquake programs under federal funding; few states with extensive programs</td>
</tr>
<tr>
<td><strong>Local</strong></td>
<td><em>Extensive</em>—active involvement of municipal utilities; enforcement of energy codes where adopted</td>
<td><em>Limited</em>—enforcement of radon related code provisions where adopted; outreach programs undertaken by some localities</td>
<td><em>Limited</em>—enforcement of termite related code provisions where adopted</td>
<td><em>Moderate</em>—enforcement of seismic provisions of building codes where adopted; retrofit and other incentive programs undertaken by some localities</td>
</tr>
</tbody>
</table>
The programs vary from an extensive federal program for energy conservation, to a moderate federal program that promotes radon reduction, to a more limited federal presence in termite control. At present, the degree and type of federal involvement in earthquake mitigation falls between the moderate role for radon reduction and the more limited role for termite control. Each of these programs relies on states as key conduits for bringing about change, but they differ in the ways that they induce state action. Under the federal energy conservation program states are mandated to take particular actions while also receiving funds for discretionary programs. The other programs gain state participation by making grants to the states for various activities. The key points to keep in mind when considering the governmental roles are the ways in which other levels of government and nongovernmental entities foster participation.

Energy conservation serves as an exemplar of an extensive federal role in bringing about change using a mix of mandates and grant programs. In response to the energy crisis of the early 1970s a number of federal programs were created and subsequently updated through other legislation with the most recent being the Energy Policy Act of 1992 (PL 102-486). These acts mandated state planning for energy use, funded state energy offices, funded extensive research on model energy code provisions and energy efficiency, mandated state adoption of energy codes, provided tax incentives for homeowners to install energy conservation measures, and provided grants or low-interest loans for weatherization of residences of low-income individuals. A key requirement enacted as part of the National Energy Conservation Policy Act of 1978 (PL 95-619) was that large electric and gas utilities offer free or low-cost energy audits to eligible residential customers. The utilities were further required to help with the installation and financing of recommended energy conservation measures. For the federal fiscal year 1997, the Department of Energy spent $570 million on energy conservation programs. Of this, $150 million went for state and local programs, including weatherization programs and energy audits. Local governments also have a role in enforcing the provisions of energy codes in a majority of the states (see May et al. 1995).

The federal approach to radon reduction is an exemplar of an indirect regulatory approach to inducing action combined with strong public education and outreach efforts. The current federal role was established by the Indoor Radon Abatement Act of 1988 (PL 100-551). It called for research about radon dangers and appropriate action levels, assistance to states in development of radon reduction programs, and provision of public information. A key component of the federal regulatory role is the development of a program for certifying individuals and firms involved in the delivery and analysis of radon tests and in installation of radon mitigation systems. States with mandatory certification requirements for radon firms have adopted these certification programs. In addition, the Environmental Protection Agency (1994) has developed a set of standards that specify the types of systems and materials for radon reduction. Some states have adopted these as requirements that must be met when installing radon reduction systems. The key aspects of the federal outreach for radon reduction are the development of an extensive set of education materials, public service announcements, and funding for state and local outreach. State programs are highly varied with most states having minimal programs emphasizing information provision by public health departments. An Environmental Protection Agency report (1990) lists eleven states as having moderate or extensive radon reduction programs. These involve a combination of
certification requirements for radon firms and disclosure requirements of test results as part of the sale of residences. Local governments also have a role in enforcing radon related provisions of building codes as they apply to single family dwellings. Their role is more limited than in the case of energy codes because fewer states require local enforcement of the radon related code provisions and the provisions generally only apply to new construction (see National Conference of States on Building Codes and Standards 1994).

The termite control exemplar entails very limited federal and state roles combined with an extensive private market for termite inspection and control. Under provisions of the Federal Insecticide, Fungicide, and Rodenticide Act, as amended most recently in 1996 (PL 104-170), the Environmental Protection Agency is charged with licensing pesticides, establishing guidelines for workers who handle pesticides, and certifying applicators of pesticides. States, in turn, may undertake the certification of applicators. The key policy objective of these regulations is to ensure the safety and health of workers and of individuals residing where pesticides are used (see Bosso 1987). This differs from those for radon certification for which the policy objective is to ensure accurate testing and remediation. Concern about the use of termiteicides led the Environmental Protection Agency to issue a regulation in 1996 that requires a minimum number of years of proven effectiveness of termiticides and new labeling requirements about their effectiveness. The local governmental role in enforcing termite related code provisions is the same as that of enforcing radon related code provisions.

The federal and state role in earthquake mitigation has elements of each of the exemplars we consider. In terms of overall scope, the federal role most closely resembles the radon reduction program. It entails what May (1991) has labeled a limited regulatory role in fostering seismic provisions for building codes in conjunction with efforts to mobilize attention to earthquake risks. The latter includes documentation of the extent of earthquake risks, education and outreach programs, funding for key partnerships, and the initiation of Project Impact in designating communities to serve as laboratories for effective mitigation programs. With the exception of the extensive state program in California, state involvement in addressing earthquake hazards is induced through federal grants that are primarily used to fund state earthquake program offices and programs. California’s risk reduction program entails a broad mix of mandates, regulations, education and outreach efforts that stand alone from the federal policies that form the basis of our comparisons. Local governments have important roles among the 25 states that mandate local governmental enforcement of seismic provisions of building codes (see May et al. 1995). In addition, particularly in California, a number of local governments have established education and incentive programs to encourage seismic mitigation by homeowners. In some instances, these have included tax reductions or other financial incentives.

**ROLES OF NONGOVERNMENTAL INTERMEDIARIES**

A variety of nongovernmental entities have strong stakes in the outcomes of energy conservation, radon reduction, and termite control programs. We focused on the roles of the insurance industry, financial institutions including mortgage companies, electric and gas utilities, and real estate firms. We expected substantial roles for one or more of these intermediaries for various aspects of each exemplar. In practice, however, with the exception of utilities, we found the roles to be more limited and less formal than anticipated.
 Nonetheless, several of the nongovernmental intermediaries have greater involvement than is currently the case for earthquake mitigation programs. Table 2 summarizes the roles of various nongovernmental intermediaries.

Table 2. Nongovernmental roles in motivating homeowner actions

<table>
<thead>
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<th>Earthquake Mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Insurance Industry</strong></td>
<td>No role</td>
<td>Indirect role—radon related illnesses may be covered by health insurance policies</td>
<td>No role—termite damage not covered by property insurance policies; termite eradication contracts act as a form of insurance</td>
<td>Uncertain role—clouded by issues of availability and affordability; mitigation not emphasized as part of insurance</td>
</tr>
<tr>
<td><strong>Financial Institutions</strong></td>
<td>Emerging role—promote energy efficient mortgages (EEM) and energy improvement mortgages (EIM)</td>
<td>Moderate role—some require radon testing before issuing mortgages</td>
<td>Extensive role—many require termite inspections before issuing mortgages</td>
<td>Limited role—may require inspection before issuing mortgage</td>
</tr>
<tr>
<td><strong>Real Estate Industry</strong></td>
<td>Limited role—energy efficiency as marketing advantage</td>
<td>Moderate role—key players in disclosure and recommending testing</td>
<td>Moderate role—key players in disclosure and recommending inspection</td>
<td>Limited role—tend to downplay earthquake risks</td>
</tr>
<tr>
<td><strong>Utilities</strong></td>
<td>Extensive mandated role—energy utilities promote adoption of energy conservation measures</td>
<td>Limited—some participate in campaigns to raise awareness of radon</td>
<td>None</td>
<td>Limited—participate in campaigns to raise public awareness of earthquake risk and preparedness actions</td>
</tr>
<tr>
<td><strong>Third party Suppliers and Service Deliverers</strong></td>
<td>Well developed market involving utilities, architects, engineers, contractors and suppliers</td>
<td>Moderately developed market involving firms that undertake radon testing, analysis, and mitigation</td>
<td>Extensive market involving firms that undertake inspection, control, and repair for termite infestation</td>
<td>Emerging market in some areas for residential inspection and rehabilitation involving design professions and contractors</td>
</tr>
</tbody>
</table>

The strongest role for nongovernmental entities is that of utility companies in promoting energy conservation. As noted above, their role was mandated with the establishment of a set of requirements in 1978 that mandated, under state supervision, that electric and gas utilities
undertake programs of energy audits of residences and follow-up installation of energy conservation measures. Several state utility commissions have also mandated utility programs to foster household investment in energy conservation measures. Eric Hirst (1984) reports that despite utilities incurring costs of $100 or more per audit, about one million audits were conducted at no or low cost to qualified homeowners each of the first two years of the program. Hirst’s evaluation of the program and other reviews by Stern and his colleagues (1992) note the wide variation in number of homeowners willing to submit to the audits and variation in follow-up with conservation measures. These outcomes were relatively immune to differences in the availability of various low-interest loans and grant programs.

The key point for institutional design is that many of the utilities that initially were opposed to a role in promoting energy conservation eventually embraced the roles and became key players in the process. Robert Hemphill and Edward Myers (1986) attribute this to a fundamental adjustment of attitude on the part of management of utilities. This came about with the recognition by a number of utilities that it was within their interests to manage demand through energy conservation. This provided one means for coping with high fuel costs for power plants and to reduce the need for capital expansion. Although it is clear that some utilities had already ventured down this path, it took the federal requirement in combination with aggressive action on the part of state utility commissions to make this happen on a wide scale.

The property insurance industry has minimal involvement for these exemplars. The closest parallel to earthquake hazards from a property insurance perspective is that of termite infestation. Both entail potential for sizeable damage to residences. Industry estimates are that damage from termites amounts to more than one billion dollars per year. This likely inflated dollar figure is about one-half of the dollar value of the yearly average over the past two decades for earthquake losses in the United States. Both termite and earthquake hazards present problems for the insurance industry in establishing premiums that reflect the risks involved while also providing sufficiently affordable coverage to attract more than those that are most at risk. The California experience is instructive in this regard as documented by Richard Roth, Jr. (1998). In the early 1990s, the California State Insurance Commissioner mandated that earthquake insurance be made available as an option for homeowners. This led insurers in the state to consider canceling policies and resulted in the formation of a state-run fund for earthquake insurance provision (the California Earthquake Authority). This has resulted in less availability of private insurance and in substantially increased rates over those initially presented by the public authority, leading to continued concern about the coverage and affordability of earthquake insurance in California.

These issues are moot for property insurance and termite infestation because damage from termites (and other insects) is not covered by conventional homeowner insurance policies. This is one reason why termite control has become such a major industry. Stated differently, a homeowner’s annual contract for termite control in conjunction with the supplier’s warranty serve as a form of insurance for termite control. Important issues, however, are the willingness of termite control companies to provide such services and follow through on their guarantees. Our interviewees noted the rapidly increasing costs that such companies face for their liability insurance amounting to some 10 percent of revenues.
As a consequence, the number of firms providing termite control has declined and inspectors are reluctant to provide written reports because of liability concerns.

Financial institutions would also seem to have important roles in making sure that mortgage investments are not jeopardized because of the presence of radon or termite and because of the potential for noteworthy damage from earthquakes. They have paid limited attention to earthquake hazards when approving for loans for residential structures. This is because of assumptions that loan defaults will not be extensive and that risk-bearing will be spread through secondary markets. From a survey of lenders conducted in the early 1980s, Risa Palm and her colleagues (1983) report that 10 percent of lenders in Washington state and 24 percent of lenders in California consider seismic risk when evaluating residential loans. Typically this involved inspection for certain classes of construction and in areas with steep slopes or near known fault lines along with requirements for purchase of earthquake insurance. Such inspection and other requirements are more common for commercial and multi-family residential structures, prompted in part by requirements from the secondary mortgage market.

In contrast to earthquake hazards for which relatively few lenders have special requirements, it is very common for lenders to require inspections and repair for termite infestation before issuing mortgages. Although not a requirement of the secondary mortgage market, the concern reported by lenders that we interviewed is of substantial devaluing of property because of termite infestation. This provides a curious contrast to the situation for earthquake hazards since both perils have potential for substantial property damage. The key differences are the greater recognition by lenders of the termite problem and the lack of availability of property insurance to cover that peril. In addition, there is greater concern by homebuyers about termite problems than risks posed by earthquakes. This probably reflects greater awareness brought about by mortgage lending requirements and possibly more perceived certainty of damage from termite infestation than from earthquake hazards. The commercial market providing termite inspections and control reinforces this message. The lending situation with respect to radon hazards is more like that for earthquake hazards. Some lenders require testing for radon and remediation if present. The general reaction of lenders we spoke with is that radon is a health risk and not a risk to property.

A different form of involvement of the financial sector is the emerging role of new forms of financing for energy conservation initiated under provisions of the 1992 Energy Policy Act. Two different forms of lending are available. Energy efficient mortgages are used to qualify for a larger mortgage loan if the home to be purchased or refinanced is certified as energy efficient. Lenders take into account the savings associated with lower energy costs in calculating ability to repay loans. The second form of loan is an energy improvement mortgage that is a form of loan, folded into mortgage payments, for financing energy conservation improvements. The requirement is that the expected dollar monthly energy cost savings from the improvements must exceed the added monthly mortgage payment for the improvements. Both loan programs are made possible by the involvement of the secondary mortgage market in backing these financial instruments, the presence of standards for energy efficiency, and the availability of systems for rating the operating cost savings of energy improvements (see Luboff 1995).

Another sector with a potentially strong stake with these issues is the real estate industry. The involvement of this industry also varies for the exemplars we study. Of particular interest
is the differing role of the real estate industry in carrying out state requirements that hazards be identified as part of real estate transactions. A study of disclosure requirements under California’s Alquist-Priolo Act for homes located in designated areas near earthquake faults in California by Risa Palm (1981) found that the mandated disclosure was common but had little effect on buyer behavior or market performance. One limitation was that disclosure of the earthquake hazard tended to come only after homebuyers had made a decision to purchase a home, so that the potential buyer was psychologically locked into the decision. More recent legislation in California (Assembly Bill 1195) that went into effect in June 1998 strengthens the disclosure requirements through use of a new form and by requiring seller and agent signatures on the form. A more fundamental consideration affecting disclosure of earthquake hazards is the misperception of buyers that any home in the same geographic area is subject to similar earthquake risks.

The involvement of the real estate industry and impact of disclosure requirements are much greater for termite infestation and radon hazards. State requirements for disclosure of prior problems from pests (including termites) and of results from radon testing are common. As has been the case for disclosure requirements for earthquake hazards, the real estate industry had been reluctant to endorse requirements that radon testing results be disclosed prior to the sale of a home. That attitude has changed in some states. Pennsylvania officials were able to gain greater involvement of the real estate profession by modifying licensing requirements to include courses addressing radon risks. Perhaps more noteworthy is the potential liability that real estate professionals incur from failing to disclose these hazards in the form of fines or license removal.

As important as the actual disclosure is the effect it has on buyer behavior. The Environmental Protection Agency (1993) estimates that between 15 and 20 percent of all homes that are sold are tested for radon. Mitigation is undertaken for some 25 to 50 percent of those found to exceed the Environmental Protection Agency’s recommended action level. Although we found no data on termite inspections, our interviews suggest that testing for and disclosure of termite problems are de facto requirements for completing home purchases. In comparison to earthquakes, for termites and radon there appears to be greater acceptance of the need for action.

Taken together these observations about the role of nongovernmental intermediaries suggest an interplay of highly fragmented industries that leads to different patterns of involvement for each exemplar. Earthquake hazards are noteworthy because of the relative absence of involvement of third parties for which the stakes would appear to be quite large. Termite control is interesting because of the role that lenders have undertaken in requiring inspection and repair and the willingness of real estate professionals to facilitate that process despite the potential for undermining home sales. The involvement of these intermediaries in radon reduction is similar to that for earthquake hazards. Key difference are state requirements for disclosure of testing results and the involvement of the real estate profession in recommending testing for radon. The widespread publicity about radon risks in areas with known concentrations of radon and fears about health consequences appear to be important factors motivating demands by buyers for this. The involvement of nongovernmental intermediaries for energy conservation has been largely stimulated by federal requirements and incentives that over time have led to changes in attitudes on the part of key entities such as energy utilities.
EMERGENCE OF MARKETS

The scale of activity for the issues we have considered is such that governmental programs alone are clearly insufficient to accomplish widespread change. The preceding section discussed how nongovernmental entities have been important actors in extending the reach of governmental policies. This is especially true for energy conservation and to a more limited extent for radon reduction. Also relevant is the degree to which public purposes can be accomplished through private means as facilitated by the emergence of markets that promote protective actions. The last row of Table 2 summarizes the status of such markets and the role of third parties in service delivery.

There are major differences in the nature and extent of markets for each of the exemplars. The most developed and varied set of markets is the extensive involvement in energy conservation of utilities, contractors, suppliers of materials, and nonprofit groups. The providers include manufacturers of energy conservation materials, firms that sell insulation material and specialize in installing it, and nonprofit and other organizations that conduct energy audits and provide outreach to low-income households. The markets for inspection, testing, and remediation of radon and for the inspection and control of termites are also extensive, but they are more focused than those of energy conservation. Not surprisingly, active markets for radon reduction exist only in those states with noteworthy radon hazards. As of 1997, Pennsylvania, one of the states with higher levels of naturally occurring radon, had certified 425 firms for testing, 53 firms for analysis, and 104 firms for installation of radon reduction systems. The market for termite inspection and control is also extensive but, in comparison to that of energy conservation, has less variety in service provision. Orkin, the largest firm involved in the termite control business, lists 400 branches nationwide serving 1.6 million customers. There is a large supply of firms involved in geotechnical and structural inspections for seismic safety and an emerging supply, primarily in the Los Angeles and San Francisco areas, of firms that specialize in seismic rehabilitation of residential structures. The latter market, however, is not nearly as developed as those for the exemplars that we have studied.

One usually thinks of private markets as arising because of the willingness of entrepreneurs to fulfill the consumer demand for a given good or service. The market for termite control comes closest to fulfilling this idealized model. For the other exemplars the extent of consumer demand is less clear and the means for fulfilling it was at least initially sufficiently problematic to prevent natural emergence of markets. This is also the case for earthquake hazard reduction measures. Of interest is the way in which governmental and nongovernmental entities have fostered markets for energy conservation and radon reduction. As elaborated upon in what follows this has entailed stimulating demand, targeting consumers, fostering and certifying relevant technology, facilitating homeowner investments, and ensuring the quality of services.

The creation of concerted consumer demand required overcoming misunderstanding of the personal consequences posed by inefficient use of energy or by extended exposure to radon. Both topics have entailed extensive media campaigns to change attitudes and behaviors. The consensus from research on this topic for energy conservation is that the campaigns were only marginally effective (see Kempton et al. 1992). A key to increasing demand appears to have been the ability to concretely demonstrate the consequences to be addressed. Energy audits accomplish this by showing homeowners the costs associated with
current actions and the savings associated with conservation measures. Rising energy costs in the 1970s and 1980s clearly facilitated this increased awareness. Radon testing also gets at the personal effects of radon gases by providing homeowners with specific measures of the extent of radon hazard and a standard for recommended action.

Two factors are important for the design and implementation of information programs. One is the creation of a rating system or scale with which the problem can be gauged. In the case of radon this entailed development of protocols for measuring radon gases and certification of measurement devices and laboratories for analyzing test results. For energy conservation, this entailed the development of devices for measuring heat loss and formulation of energy rating systems that could be converted into simple calculations for use as part of energy audits. The second component in the information programs is a set of standards for determining different levels of action. This has been more clear-cut in the case of energy conservation, once relevant information is at hand, since the decision can be cast in terms of dollar savings. After extensive research on the health effects of radon, the Environmental Protection Agency established an “action standard” for which homeowners are advised to undertake more thorough testing and consider remediation. However, that standard is controversial given the fact that no level of radon is safe and that different standards are used by other agencies and other countries.

The information programs are only useful to the extent that homeowners are willing to participate in energy audits or test for radon. Thus a second aspect that has been important in fostering demand for these services is extensive marketing of the services. Much of the difference in participation rates in the utility-sponsored residential conservation programs has been attributed to variation in the quality of marketing of those services (see Burby et al. 1985, Hirst 1984). Marketing of radon reduction and energy conservation also has entailed extensive outreach through various community groups, nonprofit organizations, and schools. Relevant as well has been targeting of programs to those likely to benefit the most. One example of successful marketing of radon testing has been the provision in Pennsylvania of radon test-kits to parents of newborn. With the cooperation of participating hospitals, the parents are provided information about radon harm and home test kits for which the state provides free analysis of the results. The extensive involvement of electric and gas utilities has aided marketing energy conservation services since utility bills can be used to target marketing toward households using a large amount of energy.

A third aspect for development of markets has been the fostering and certification of relevant technology. For energy conservation this has entailed considerable research on materials and conservation approaches. These have been incorporated into model energy standards adopted as part of building codes and as components of energy conservation education programs for builders and contractors. For radon reduction this has also entailed development of mitigation standards that specify appropriate systems for reducing radon gases. This has helped foster the development of a market of firms that supply the recommended systems.

A fourth aspect of markets for energy conservation and for radon reduction has been facilitating homeowner investments in the desired measures. Extensive marketing of low-cost or free energy audits and radon testing has often been undertaken in order to engage homeowners in thinking about relevant investments. Utilities absorbed much of the initial costs of marketing and performing energy audits or at least passed on their costs to the entire

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customer base. Some states, under federal funding, have subsidized testing and analysis for radon. The more important financial aspects have been different programs for subsidizing energy conservation measures, including a mix of tax credits, low-interest loans, and outright grants. Yet, as noted by Stern and his colleagues (1985), the anticipated positive effects of such incentives in bringing about greater adoption of energy conservation were often not realized due to the inappropriate design or targeting of incentives. The shift in financial incentives for energy conservation from direct governmental guarantees to the use of government-backed mortgage instruments introduces new issues about the effectiveness of financial inducements. Apart from making available free testing kits and some short-lived low-cost loan programs, financial incentives have not been available for financing radon reduction measures. But, as we noted earlier, the costs of radon reduction measures are substantially lower than energy conservation measures.

A fifth aspect that has been important for each of the markets for the exemplars we consider is ensuring the quality of services. This is particularly important for instilling consumer confidence and willingness to use the services. Stern and his colleagues (1992) note that the credibility of organizations that promoted energy audits was a factor that affected the success of energy conservation programs. Complaints about pest control services are commonly voiced to consumer offices of state attorney generals. Indeed, we noted earlier the steps that the Environmental Protection Agency has taken to require certification of the performance of termicidies. A key concern of consumers is that radon testing firms falsely identify problems in order to generate sales of radon reduction systems. Ensuring quality inevitably necessitates some form of certification or standards. These exist in different forms and to different degrees for firms involved in energy conservation, radon testing and reduction, and termite control. Ensuring quality also inevitably involves some form of training and education of inspectors, which also exist to different degrees as part of requirements for certification.

The more problematic part of a system of quality standards for third party provision of services is monitoring adherence to those standards. This entails some form of external monitoring by regulators, self-policing by industry groups, or use of liability or financial mechanisms that foster compliance with standards (see Vining and Weimer 1997). The monitoring by governmental regulators of firms involved in energy conservation, radon reduction, and termite inspection occurs mainly in response to complaints from consumers. Officials in Pennsylvania report that monitoring is aided by certified inspection firms filing complaints about firms undertaking radon inspections without proper certification. This acts as a form of self-policing. Other forms of self-policing are the standardization of procedures and guarantees by large firms like Orkin that provide pest control services. A key mechanism for reducing the potential for fraud is the requirement that firms undertaking remedial services cannot be the same as those conducting evaluations or tests, and encouragement of re-testing or evaluation. None of these is perfect and our review uncovered little information about the extent to which certification requirements or quality standards are violated.

The legal system operates as another form of policing of adherence to quality standards through imposition of liability for nonperformance or negligence in performance by third party service providers (see Bardach and Kagan 1982). This clearly raises a thorny set of issues that have generated much commentary by legal scholars particularly with respect to liability for radon exposure. As summarized in a comprehensive review of the legal issues for
radon by Robert King (1993), the ability to impose liability is complicated by the variability of performance standards, the difficulty of proving negligence, and the difficulty of demonstrating harm due to the latency and other potential sources of cancer. Our interviews suggested that firms providing such services and real estate professionals charged with disclosing hazards are very aware of potential liability. But in practice the cases of liability that were recounted were ones for which there were obvious tampering with testing devices, mistakes in conveying test results, or defects in product installation.

An important counter force to the liability system that acts to undermine compliance is the highly competitive nature of the services we consider. Indeed, this may be a key drawback of extensive markets for these services. In order to gain competitive advantages by lowering prices, firms are tempted to cut corners by using less expensive materials or through less thorough testing. Because of the technical nature of the services, consumers are often unaware of the differences. The net result is that economic competition tends to lower standards while concerns about liability tend to increase standards. How these forces balance out no doubt varies depending on the extent of competition and the degree of oversight. This dynamic can exist for less mature markets as evidenced by the findings of May and Stark (1992) about the adherence of the design professions to seismic standards.

A final consideration when thinking about market response is the need for a safety net to accommodate the needs of those unable to pay for mitigation, such as low income and elderly households. In this case, experience with energy conservation programs offers some useful lessons. Because low income households use relatively little energy, they do not attract much interest from utilities. Similarly, income constraints do not make them a particularly lucrative target for vendors of energy conservation services or equipment. To deal with this problem the Department of Energy established energy efficiency programs that target low income households. The largest and best known of these is the Weatherization Assistance Program for which federal spending in fiscal year 1997 was $121 million. This is a decentralized, formula grant program under which local government agencies and nonprofit community groups weatherize homes at little or no cost to eligible low-income households. The involvement of nonprofit community groups has been cited in program reviews (Brown and Berry 1993, 1994) as an invaluable aspect to this partnership given the familiarity of such groups with needs in their community and the trust that such groups have established with the target audiences.

LESSONS FOR DESIGN OF HAZARD MITIGATION PROGRAMS

We now turn to the lessons that we draw from energy conservation, radon reduction, and termite control for the design of earthquake hazard mitigation policies. This leads us to consider the key aspects of each exemplar in bringing about change and the limits of each for earthquake hazard mitigation. We conclude with lessons for policy design for mitigation policies.

SUMMARY AND LIMITATIONS

Each of the exemplars entails decision-making by homeowners to make investments in order to protect their homes from harm and to provide future benefits. As the preceding discussion has shown, the exemplars differ with respect to the institutional design of relevant
policies and programs and with respect to the role of various intermediaries and third parties. Table 3 summarizes key features of the exemplars and the limits of each for drawing lessons for mitigation programs.

Table 3. Summary of exemplars and their limits

<table>
<thead>
<tr>
<th>Exemplar</th>
<th>Energy Conservation</th>
<th>Radon Reduction</th>
<th>Termite Control</th>
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<tr>
<td><strong>Key Institutional Changes</strong></td>
<td>Direct governmental role leveraged through involvement of utilities and third parties in carrying out programs</td>
<td>Indirect governmental role in promoting outreach and public education, along with certification programs</td>
<td>Limited governmental role with extensive third party involvement in marketing and carrying out programs</td>
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| **Key Elements** | Energy utilities willingness to promote energy conservation and enrollment of local governments and community groups to provide assistance to low income households | Increased public awareness and involvement of the real estate profession and community groups in raising awareness of radon | Homeowner and financial institution acceptance of problem |

| Limits as Parallel to Earthquake Mitigation | Benefit stream more certain making return on investment easier to calculate | Differences in fears associated with health risks and lower costs of protective behavior | Differences in perception of control of termites versus earthquake hazards |

- Research to identify feasible, cost-effective conservation measures
- Energy audits
- Energy rating systems
- Financial instruments (EEM, EIM)
- Research to identify effective reduction measures
- Certification program
- Radon action level
- Outreach programs
- Research to identify effective treatments
- Certification program

Up-front costs often reduced because of loans or grants

Up-front costs lower than for earthquake mitigation

The three exemplars illustrate a range of governmental involvement in promoting particular ends. The most extensive involvement is that of energy conservation for which the federal government has played a very active role. That role has been greatly enhanced by the involvement of energy utilities and third parties that market and install energy conservation measures, and by community groups that promote weatherization for low income households. The radon reduction exemplar illustrates a more indirect federal role in funding and promoting outreach programs and in certifying firms for radon testing, analysis, and
mitigation. The termite control exemplar illustrates a limited governmental role in regulating a vibrant market for protection of homes from damage by termites and other pests.

Each exemplar seems to have had at least moderate success in bringing about changes in homeowner investments in protective or energy-conserving measures. In comparison to the relatively limited success in homeowner investment in protective measures for earthquake hazards, large numbers of homeowners have installed energy conservation measures, undertaken radon testing, and contracted with private services for termite control. Key intermediaries have been important in bringing about these actions by homeowners. The effectiveness of energy conservation programs has hinged on the willingness of energy utilities to promote conservation and to market programs for homeowners. Increased commitment of homeowners and willingness of the real estate industry to promote radon testing have enhanced the impact of programs for radon reduction. Homeowner and financial industry concern about potential harm from termites have been critical factors in fostering an active market for these services.

Each of the exemplars has also been successful in creating markets for nongovernmental provision of protective or energy-conserving measures. Several innovations have been important in this regard. Energy conservation has been promoted by providing homeowners with energy audits that provide specific information about the costs and benefits of various measures. Such information alone, however, often has been insufficient to prompt investment in energy conservation. Financial incentives and direct assistance have been necessary to overcome the myopic decision-making of homeowners and constraints due to insufficient financial resources. These have included community action programs and various loan and grant programs combined with the use of innovative financial instruments involving “energy efficient” and “energy improvement” mortgage financing. Certification programs for third party services have been key innovations for radon reduction and termite control programs. These help foster networks of service providers while maintaining control over the quality of service.

It is also interesting to note the role of grass-roots constituencies in helping to foster efforts in energy conservation and radon reduction. Consumer and environmental groups became strong advocates of energy conservation in the early 1970s, helping to promote enactment of key legislation and to educate homeowners about available options. Similarly, health groups drew broader attention to radon hazards in the mid 1980s with similar involvement to that of the energy related constituencies. It is a curious contrast that similar grass-roots constituencies have not developed for earthquake hazards. This has had the obvious consequence of lessening pressure for governmental action.

There are, of course, limits to the extent that the exemplars are direct analogs for earthquake hazard mitigation. Chief among these is the often-cited differences in fears that people attach to different risks. In this regard, the findings of Paul Slovic (1987) about people’s sense of dread and control are especially relevant. Although both earthquake hazards and radon gasses are commonly perceived as being largely uncontrollable and as having uncertain impacts, the dread of cancer from exposure to radon far surpasses the fear of harm from earthquakes. Termites present a very different situation. In part because of effective marketing by termite control firms, termites are viewed as controllable evils as long as protective action is undertaken. The presence of termites is not viewed as life threatening, so the only fear generated by the risk is a financial one. These differences in perception
suggest that for different reasons homeowners are more willing to attend to risks posed by radon or termites than those posed by earthquake hazards. Yet, it is also clear that a key aspect of radon reduction programs has been a well-designed program of public education.

Also relevant are the differences in streams of costs and benefits for the exemplars and those for mitigation of earthquake hazards. Because rating systems for energy efficiency provide a clear basis for valuing energy conservation measures, the returns on investment are more certain than for the other exemplars or for the mitigation of earthquake hazards. This, in turn, suggests that the rates of participation in energy conservation programs serve as an upper bound of participation rates for mitigation of earthquake hazards. The lower costs of radon reduction and some energy conservation measures also facilitate greater involvement of homeowners.

**DESIGN LESSONS FOR EARTHQUAKE HAZARD MITIGATION**

We think useful lessons can be drawn from the exemplars for the design of earthquake hazard mitigation programs. Given the limitations noted in the preceding discussion and the differences in the nature of governmental approaches to addressing the problems, none of the exemplars stands out as an exact parallel for inducing earthquake mitigation. Yet broader lessons can be drawn about the leveraging of governmental resources, fostering markets for services, assisting low income households, and carrying out outreach and education.

A key issue for the institutional design of hazard mitigation policies is harnessing the interests of nongovernmental entities in order to bring about desired homeowner investments in mitigation measures. The clearest illustration of this is the critical role that energy utilities play in energy conservation. The insurance and financial industries are often touted as becoming major actors in promoting the mitigation of earthquake hazards. However, their involvement to date has been limited. Given the concern about earthquake damage to energy and water lifelines, it is also appropriate to consider utilities as prospective allies in promoting earthquake mitigation for homeowners. This involvement would provide a close parallel to the role utilities have undertaken in promoting energy conservation. Regardless of the specifics, the general lesson is that the interests of nongovernmental entities need to be mobilized in order to leverage governmental resources.

Also important for the design of hazard mitigation programs is fostering a market for third party services for home inspection and rehabilitation for earthquake risks. We noted several elements from the exemplars that facilitated the development of such markets. One key element is the provision of information to homeowners. This has been facilitated by standardized rating systems and the use of computer programs for rating structures and for estimating payback periods for investments. The parallel for earthquake hazard mitigation is the creation of a standardized building rating system that provides clear indication of the earthquake risk for a given home and the cost-effectiveness of different mitigation measures in reducing that risk. A second key element in fostering third party services has been the certification of firms involved in testing and mitigating different harms. This could also be undertaken for earthquake hazard mitigation under a national certification program modeled after those created for radon reduction. A third key element is available financial incentives and financing for homeowners to invest in mitigation measures modeled after the use of energy conservation tax credits and energy-related mortgage financing instruments. In combination, the rating systems and financial measures would help to create a demand for
earthquake hazard mitigation while the certification program would help to create a supply of services.

Clearly, outreach and public education are important aspects in fostering the demand for mitigation of earthquake hazards. The lessons from radon reduction and energy conservation programs in working through community groups and in targeting assistance for low income households are appropriate in this regard. The limited impact of mass public information campaigns undertaken by the Environmental Protection Agency for radon reduction reinforces the limitations of such campaigns (see Weiss and Tischarhart 1994). Recognition of these limits prompted a change from emphasizing mass public information to creating targeted outreach programs. It is also sobering to note that the high degree of variation in the effectiveness of energy conservation programs has been attributed to differences in outreach and marketing. The key lesson is that design of effective outreach and education programs for hazard mitigation requires multiple channels and partners involving highly targeted programs with care as to how the information is presented.

These directions necessitate new roles for government agencies involved in hazard mitigation. One role is that of inducing action by nongovernmental intermediaries either under the auspices of mandates or through partnerships. These might entail utilities, the insurance and financial industries, or architects, engineers and the building trades. A second role is that of stimulating markets for hazard mitigation through the various mechanisms that we have outlined. A key aspect of this is development of technical information and standards. A third role is regulating those markets by providing oversight of the certification of firms supplying mitigation services. A fourth role is that of public education and outreach.

Some of these directions are already underway. However, there are gaps in fostering markets for hazard mitigation services that we think can be filled. The experiences with the exemplars we consider demonstrate the importance of markets for third party services in stimulating protective actions by homeowners.

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