PATH TECHNOLOGY ROADMAPPING

BACKGROUND PAPER

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March, 2000

NOTICE

1. INTRODUCTION

This paper has been prepared to assist in development of "Technology Roadmaps" for use in connection with the "Partnership for Advancing Technology in Housing" (PATH), a public-private partnership that was created to improve new and existing American homes in several important ways.

Section 1 includes background information on technology roadmapping, and references to other technology roadmapping exercises including those related to homes and products used in housing. Section 2 reviews the goals underlying the PATH program, and describes the potential uses of technology roadmaps that will be developed for PATH. Section 3 includes recent information that documents the current situation in housing as it relates to each of the PATH goals.

What is Technology Roadmapping?

"Technology roadmapping" is a process of defining and organizing potential R&D activities to facilitate decisions about resource allocation and achieve specified ends. This kind of process has been and continues to be applied in many different organizations, industries and technological contexts. The types of technologies included can range from tangible new materials, products and systems to improved methods of production, software and other information technologies.

A useful Technology Roadmap will include a graphical depiction of a series of steps starting from the present state of the art and progressing up to the availability of a desirable new technology or technological capability. It will also include background information about R & D that has already been performed or is currently underway, an analysis of the technical obstacles separating the present from the future, a timeline and an analysis of the costs of individual steps. In the case of PATH it will also be important to consider the most appropriate place to perform and way to fund possible types of R & D. These answers will depend on the necessary amount of work, the skills required to perform it, and the degree to which private sector firms can realistically hope to protect the results and realize sufficient returns at a pace that will motivate up-front investment. The latter issue has been recognized as a major impediment to development of new products and methods of construction for use in home building.

What are some examples of Technology Roadmaps?

Technology roadmapping is not new, although its use seems to be on the increase, possibly related to the growing importance of technology development to the economy at large. It has been widely used in the Department of Defense; for example, in March 1995 the Defense Information Systems Agency published version 2.2 of its *Software Reuse Initiative Technology Roadmap* (see *http://dii-sw.ncr.disa.mil/ReuseIC/pol-hist/Roadmap/Vol1/V1-ToC.html)*. In May 1997 the Aluminum Association, Inc., published *Aluminum Industry Technology Roadmap*, outlining a long-term program responding to industry-wide performance targets for cost, productivity, market share, environmental and energy performance, and health and safety issues. That roadmap, along with similar efforts underway in the steel, forest products and other energy-intensive industries, was funded in part through the Department of Energy's "Industries of the

Future" initiative (see *http://www.oit.doe.gov/industries.shtml*). There have also been projects designed to improve the methodology used to develop roadmaps and ways to use roadmaps to guide decision-making. For example, Oak Ridge National Laboratory has posted information about a "Technology Roadmapping Decision Support System" at *http://ots.ornl.gov/roadmap/*, and the Office of Naval Research has a site with extensive information about "Science and Technology Roadmaps" accessible at *http://www.dtic.mil/dtic/kostoff/mapweb2index.htm*. Other citations are readily available through search engines on the World Wide Web.

What other Technology Roadmaps relevant to PATH have been developed or are under development?

Recent roadmapping exercises that have implications for buildings and have led to published progress reports include:

- Lighting technology: *http://www.eren.doe.gov/buildings/technology_roadmaps/lighting/*
- Window technology: *http://www.eren.doe.gov/buildings/technology_roadmaps/windows/*
- HVAC equipment "21st century research": *http://www.arti-21cr.org/background.html*
- Commercial Whole Buildings: *http://www.eren.doe.gov/buildings/technology_roadmaps/commercial_whole_buildings/*

These activities are in various stages of development. Each has typically begun with an executive session to set a "vision" for the future, followed by one or more workshops to bring experts together and develop plans.

How is PATH Technology Roadmapping different?

It is important to understand that while there are undoubtedly overlaps between technology roadmapping projects identified above and technology roadmapping for PATH, the latter can be distinguished in significant ways. First, PATH is focused on the simultaneous pursuit of multiple goals, as further discussed in the next section, while other roadmapping activities frequently begin by developing a vision and ultimately pursue a single goal or narrower set of goals. Second, PATH is addressing the totality of the home and all the products and systems that make it up, so it cuts across many different areas of manufacturing and product development. Third, one of the PATH goals calls for improving affordability through reducing the overall monthly cost of housing, thereby making explicit what is only implicit or altogether lacking in other roadmapping activities. Finally, while PATH is focused on the future, under PATH that future specifically includes addressing the *existing* stock of homes as well as housing that is yet to be produced.

2. TECHNOLOGY ROADMAPPING AND THE PATH GOALS

The overall PATH program has a very ambitious set of goals that were set forth when the program was created. Each of the PATH goals is defined in performance terms, without attempting to specify the technology or other means used to realize them. The specific goals, to be achieved by the year 2010, are to put technologies into the marketplace that make it possible to:

- reduce the monthly cost of new housing by 20 percent or more
- cut the environmental impact and energy use of new housing by 50 percent or more and reduce energy use in at least 15 million existing homes by 30 percent or more
- improve durability and reduce maintenance costs by 50 percent, and
- reduce by at least 10 percent the risk of loss of life, injury, and property destruction from natural hazards and decrease by at least 20 percent residential construction work illnesses and injuries.

There clearly are multiple approaches for pursuing and achieving the PATH goals. Some involve institutional change. Others revolve around education and training. Still others rely on expanding the use of products, systems and technologies that are already commercially available. All of these approaches are being pursued in one way or another through five working groups. Four of the working groups are charged with addressing financing issues, labor/quality issues, barriers/insurance issues and consumer education.

At the same time, achieving major progress in PATH is expected to require R & D leading to the demonstration, market deployment and eventually the diffusion of new technologies, as well as work to enhance other technologies that have yet to achieve market success. An aggressive but thoughtfully structured approach to R & D of many different types, together with systematic follow-up, will make a major contribution to the ultimate impact of PATH.

3. ROADMAPPING CONTEXT

Many, many ways can be imagined to identify and pursue technologies that can potentially achieve progress towards the PATH goals. No area should be considered "off limits." Technical experts will have a good sense of new technologies that can be developed with relative ease, working forward from what is known today, even if the benefits of individual actions are small relative to the goals. Many opportunities can undoubtedly be identified in this way.

There is another side to this problem. The PATH goals are expressed in performance terms. They are quantitative goals intended to be reached by multiple activities pursued in parallel. Each of the goals corresponds to some type of underlying problem. Documenting the problem, or setting a "baseline," is necessary in order to assess the degree to which any given project would help meet the PATH goals, if successfully completed. This section presents a simplified baseline for each of the PATH goals that can help in evaluating and comparing different ideas about the kinds of R&D that PATH should pursue.

The baseline information in this section is not just intended to assist in evaluating ideas. It is also designed to help direct attention at an early stage, *as ideas are being developed*, towards areas where the potential impacts and benefits of successful work would be the greatest. In other words, where the goal is to reduce cost it makes sense to look very closely at high-cost elements of the home, because the potential benefit is greater. The baseline provides information about the contributions of different items to the monthly cost of housing that can guide this process. Similarly, where the goal is to reduce energy consumption it makes sense to look closely at the largest items of energy use. Where the goal is to improve worker safety, it is logical to try and address the largest risks to workers. Using this approach of reasoning backwards from the PATH goals and identifying areas where the potential payoff may be higher (or at least making sure they are not overlooked) can stimulate ideas that are riskier and more challenging than limiting attention to technological opportunities that are clearer and simpler. High-risk projects do not represent a problem. It is perfectly acceptable for PATH to pursue high-risk opportunities if the potential benefits justify the added risk.

The baseline information in this section is organized according to each of the underlying PATH goals. Much of it has been drawn from an earlier, more elaborate baseline report prepared in 1998. The reliability of the information varies considerably, as discussed in each section.

GOAL #1: REDUCE THE MONTHLY COST OF HOUSING BY 20%

While the monthly costs for a typical owner-occupied new home are dominated by the principal and interest payments on a mortgage, other recurring costs include property taxes, homeowners' insurance, mortgage insurance, energy (electricity and gas), water and sewer represent a significant part of the total. Each one of these components is estimated for an average house and presented to help show where opportunities may exist for meeting the PATH objective of reducing the monthly cost of housing by 20%.

Estimated monthly costs for an average 2,000 square foot, single-story house on a ¼ acre lot with natural gas heat, on public water and sewer systems appears in Figure 1 below. The mortgage payment includes principal and interest, based on a purchase price of $181,000 with a 5% down payment and a 30-year fixed rate mortgage at an 8% interest rate. Since the down payment is less than 20%, mortgage insurance of ½% per year has been included.

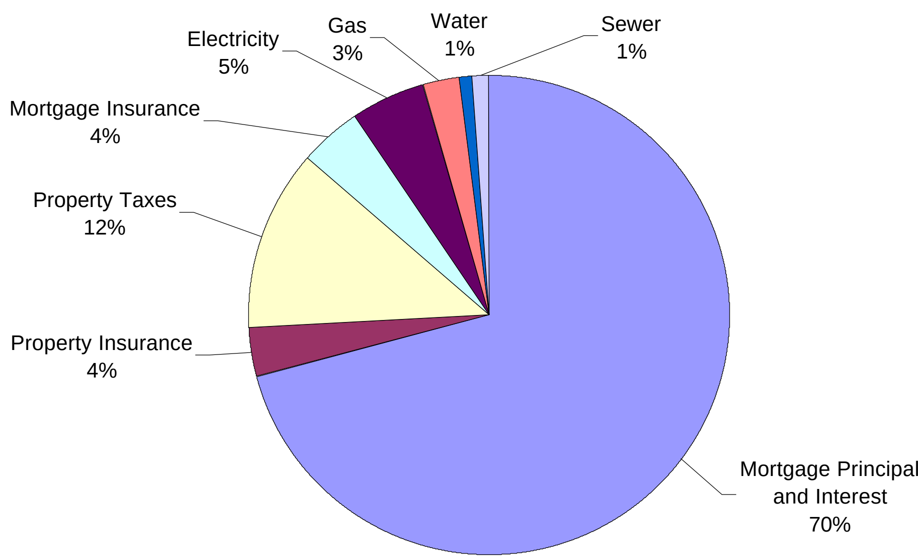


Figure 1
Monthly Expenditure for a 2,000 ft^2 New Home

Figure 1 shows that payments for mortgage principal and interest represent 70 percent of the monthly costs for an average new home, followed by property taxes (12%), electricity and gas (8%), property insurance and mortgage insurance (8%) and water and sewer (2%). Savings in any of these areas, some of which are addressed under other PATH goals, would contribute to the PATH affordability goal. The largest single item is the monthly mortgage payment, including principal and interest. While technically the 20% affordability goal could be met by reducing the interest rate from 8% to approximately 4½%, the cost of money is largely outside or entirely the scope of PATH. Reducing initial cost is the most plausible way to reduce the largest contributor to the monthly cost of housing. Initial cost can be lowered through technologies that reduce the "hard" cost of products and materials or the cost of labor, or by technological or other methods for reducing the various "soft" costs associated with operating a building company and selling houses.

A closer look at the breakdown of initial cost for an average new home is in Figure 2. This includes the estimated development costs of development, labor and materials (including all non-labor costs), broken out by major component. The largest single cost associated with a new home is the ground itself (about 25%), followed by interiors (15%), then by exterior walls (10%).

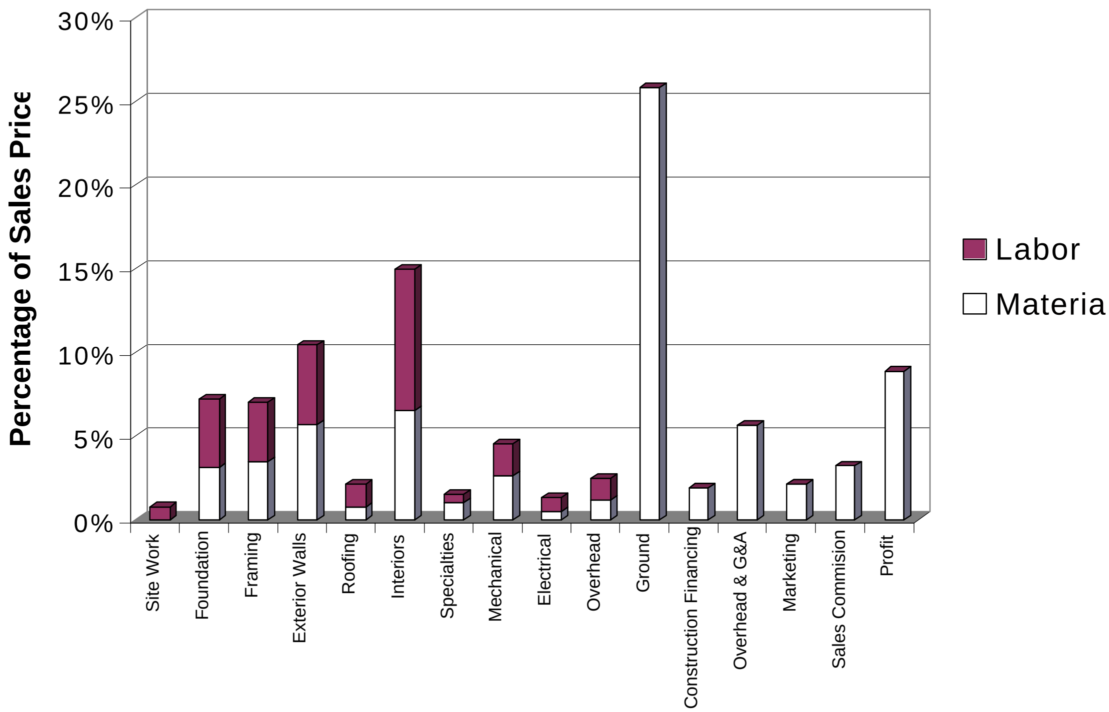


Figure 2
Average New Home Cost Components

The breakdown into labor and materials illustrates their respective contributions to total selling price of the home. For example, the 15% share of selling price represented by interior finishes (including flooring, wall coverings, doors, trim, etc.) breaks into about 60% labor and 40% materials. In fact all of the materials in a house (excluding the cost of land and development) equate to about 21% of total monthly cost, while the total labor cost to build a new home translates into about 14% of total monthly cost.

It is clear from these figures that (with the possible exception of combined land and development costs) even total elimination of any single cost component could not reduce monthly cost by the targeted 20%. Achieving 50% energy savings (see goal #2) would reduce monthly cost by about 4 percent, if it could be done without increasing first cost. Improving resistance to natural disasters by 10 percent would reduce property insurance costs much less than proportionately, representing a reduction in monthly cost of less than 1 percent. The balance of the PATH affordability goal calls for an approach that lowers the cost of land, development/infrastructure and/or multiple systems throughout the home.

GOAL #2a: REDUCE ENERGY USE IN NEW AND EXISTING HOMES

Energy use: All homes. The vast majority of energy used by both new and existing homes is in the form of electricity or natural gas. The Energy Information Administration (EIA) of the U.S. Department of Energy conducts periodic surveys documenting energy use in the residential sector. The following table presents a disaggregation of total residential electricity consumption by end use, including annual kWh consumption per household, based on the 1993 EIA survey.

Table 3.1. U.S. Residential End-Use Consumption of Electricity, 1993

End Use/Appliance	Households (millions)	Annual kWh Consumption per Household	Electricity Consumption for 1993			
			Site		Primary	
			Billion kWh	Trillion Btu	(trillion Btu)	Percent
Total Households	96.6	9,965	962	3,283	9,891	100.0
Central Air-conditioning System	41.0	2,667	109	373	1,124	11.4
Room Air Conditioners	33.1	738	24	83	251	2.5
Water Heating	37.0	2,671	99	337	1,016	10.3
Main Space-Heating System	25.0	4,541	114	387	1,167	11.8
Secondary Space-Heating	12.1	400	5	17	50	0.5
Refrigerator	115.7	1,155	134	456	1,374	13.9
Appliances (total of list below)	96.6	4,933	477	1,626	4,899	49.5
Lighting (indoor and outdoor)	96.6	940	91	310	933	9.4
TV	198.3	360	71	244	734	7.4
Clothes Dryer	54.7	875	48	163	492	5.0
Freezer	33.4	1,204	40	137	413	4.2
Range/Oven	58.3	458	27	91	274	2.8
Microwave Oven	81.3	191	16	53	160	1.6
Waterbed Heater	14.6	960	14	48	144	1.5
Dishwasher	43.7	299	13	45	135	1.4
Swimming Pool Pump	4.6	2,022	9	32	96	1.0
Clothes Washer	74.5	99	7	25	76	0.8
Dehumidifier	9.1	370	3	11	35	0.4
Well Pump	13.0	228	3	10	30	0.3
Personal Computer	22.6	77	2	6	18	0.2
Hot Tub/Spa Heater	1.9	482	1	3	9	0.1
Residual	96.6	1,364	132	450	1,354	13.7

Count of individual units within the household. Room air-conditioners are counted in this table only for units located in homes, which do not have central air-conditioning.

National survey of electric utilities conducted by the American Electric Power Service Corporation, Columbus, Ohio, in 1991.

Households that have an electric range and electric oven and reported that electricity was their main cooking fuel.

Does not include energy used to heat water coming into the washer.

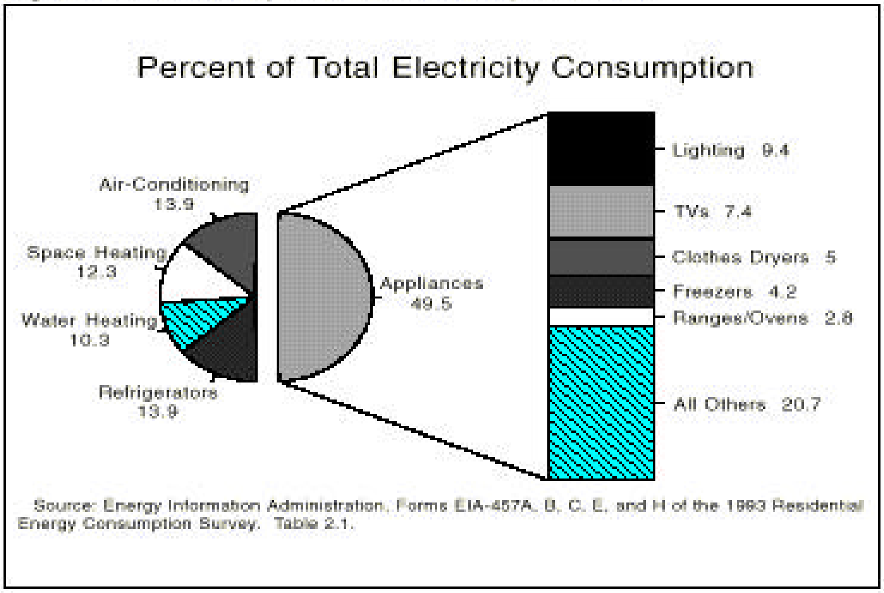
Average of two estimates from Southern California Edison.

Notes: "Residual" includes appliances not listed, such as furnace fans (404 kWh per year), heated aquariums, air cleaners, and a myriad of other small electrical appliances. "Residual" also includes errors that may be present in estimates of annual consumption. Site electricity is the amount of electricity delivered to households (3,412 Btu per kWh). Primary electricity is site electricity plus the conversion losses in the electric generation process at the utility plant (10,280 Btu per kWh). Totals may not equal sum of components due to independent rounding. This table does not reflect the interactive effects of appliance usage, especially when mixing the estimates from RECS with those from outside sources. For example, for a home with an electric oven, range, and a microwave, the use of the microwave may not add 191 kWh to the cooking consumption. For more discussion of this problem, see Appendix C, "End-Use Estimation Methodology."

Sources: Energy Information Administration, Office of Energy Markets and End Use, Forms EIA-457A-C, E, and H of the 1993 Residential Energy Consumption Survey (RECS), RECS Public-Use Data Files; American Electric Power Service Corporation, and Southern California Edison.

The next figure summarizes this graphically.

Figure 3.1. Electricity End-Use Consumption, 1993



Total residential natural gas consumption in 1993, disaggregated by end use, is in the next table.

Table 3.2. U.S. Residential End-Use Consumption of Natural Gas, 1993

Appliance/End Use	Million Households	Annual Therms[a] Consumed per Household for End Use Indicated	Natural Gas Consumption for 1993	
			Trillion Btu	Percent
Total Households Using Natural Gas	58.7	899	5,274	100
Main Space-Heating	51.4	709	3,644	69
Secondary Space-Heating	1.2	215	26	(b)
Water Heating	51.4	255	1,312	25
Air-Conditioning	0.1	238	2	(b)
Appliances	37.8	77	290	5

[a]A therm is 100,000 Btu.
[b]Less than 0.5 percent.
Note: Appliances include ranges, ovens, clothes dryers, outdoor gas lights and gas grills, hot tubs, and swimming pool heaters.
Sources: Energy Information Administration, Office of Energy Markets and End Use, Forms EIA-457 A-C and F of the 1993 Residential Energy Consumption Survey (RECS) and RECS Public Use Data Files.

Similar data exists for heating oil and other fuels, but total usage is much lower. These tables give a simplified picture of recent energy use in existing homes. The PATH goal calls for achieving improvements of 30 percent in 15 million existing homes. Aside from weatherization or adding insulation, there are two specific trends that have great potential to reduce energy consumption in existing homes over time. One is the replacement of older central heating or cooling systems (as well as other appliances such as refrigerators and water heaters) with more efficient new models. The other is replacement of old windows with new windows.

With respect to HVAC equipment, the 1993 EIA survey reported that 7.7 million replacement heating systems and 2.1 million replacement central air conditioning systems had been installed in the stock of 66.8 million single-family homes during the previous three years. Today's new furnaces and air conditioners are required to meet federal efficiency standards that make them much more efficient than typical units made as recently as the early 1990's. And with respect to windows, an NAHB Research Center national survey of consumer expenditures for repair and remodeling found that, in 1997, about 6 percent of single-family owner-occupants purchased windows. The average purchase included 4.5 replacement window units, with 85% of these windows reported to be double- or triple-glazed. To interpret this latter figure, it is helpful to know that the EIA reported that as of 1993, the average single-family detached home had a total of 15 windows, and just 36 percent of all windows were double- or triple-paned. The slow but steady turnover of major equipment and windows has been and undoubtedly will remain an important contributor to improving the energy efficiency of existing homes.

Energy Use: Newer homes. The EIA reports include comparative data showing trends in energy usage by age of home, with information on the newest homes based on a subsample of housing units built from 1988 to 1993. The results are expressed as "energy intensity", defined as kWh (or Btu) per degree-day per 1,000 square feet for heating and cooling, kWh/Btu per person for water heating, kWh per refrigerator, and kWh/Btu per household for other appliances. Energy intensity thus controls for house size and climate, and is arbitrarily scaled to a value of 100 for homes built in 1979 and before.

The next two tables show trends in energy intensity by end uses of electricity and natural gas. They clearly depict reductions for space heating (both electric and gas) and for central air conditioning. At the same time they show higher per-household consumption of both electricity and gas for all remaining household appliances. This presumably reflects the tendency of households in newer homes to own and operate more appliances than other households.

Figure 3.8. End-Use Electricity Intensities By Year of Construction, 1993

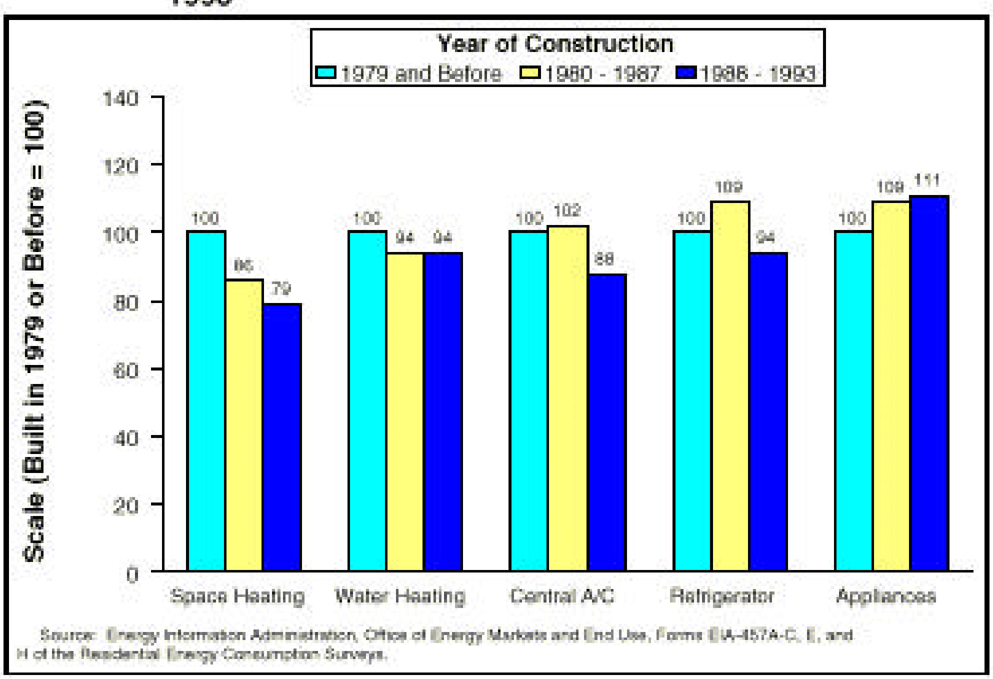
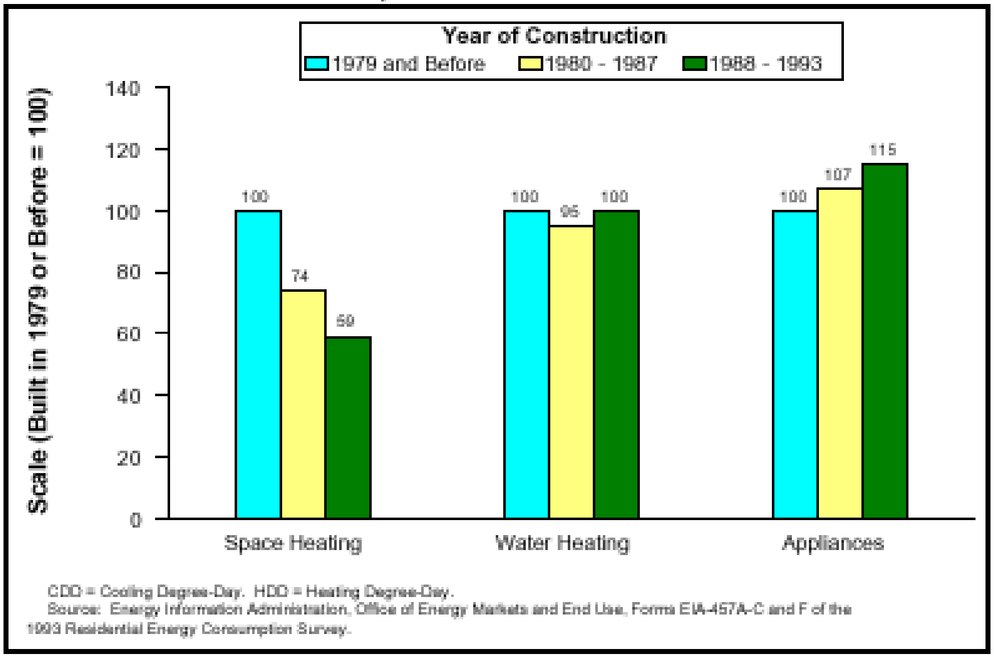


Figure 3.10. Natural Gas End-Use Intensities by Year of Construction, 1993



GOAL #2b: REDUCE THE ENVIRONMENTAL IMPACT OF NEW HOMES

While the monthly cost of housing is straightforward to analyze, and the energy use of new and existing homes is reasonably well documented, identifying and quantifying the "environmental impacts" of new homes is far more difficult. Many of these impacts, including the release of CO_2 and a variety of air pollutants, are either the direct result of on-site use of fossil fuels or are emissions from conventional power plants generating electricity to supply residential (and other) customer loads. Meeting the PATH energy goal will almost inevitably help to meet the PATH environmental goal, and some consider environmental implications the only reason to have an energy goal in the first place.

Two other categories of environmental impacts of housing that are not the direct result of energy consumption are discussed in this section: water use, and construction waste.

Water use. There is wide variability around the U.S. in the availability and cost of potable water, and in the perceived need for water conservation. But every occupied home uses water for multiple purposes, and releases water after use into public sewers or private sewage systems. What was once an issue primarily in the Western states and in rural areas or during times of drought became a national issue with the imposition of federal requirements for low-flow plumbing fixtures under the Energy Policy Act of 1992. And there is growing interest in the possibility of reducing water used by large appliances such as washing machines and dishwashers, as well as water used for lawn care and similar purposes.

A profile of daily water use by a typical urban family of four is as follows:

Typical Urban Water Use for a Family of Four

	Per Family	
Type of Household Use	**Gallons per day**	**Percentage**
Lawn watering and swimming pools (180 hours per year)	100	29
Toilets (16 flushes per day)	96	28
Bathing (4 baths or showers per day)	80	23
Laundering (6 loads per week)	34	10
Dishwasher (3 loads per week)	15	4
Automobile Washing (2 car washes per month)	10	3
Drinking and water used in kitchen	8	2
Garbage disposal unit (1 percent of all other uses)	3	1
DAILY TOTAL FOR ALL USES	346	100

Source: U.S. Water Resources Council, *Second National Water Assessment, The Nation's Water Resources 1975-2000.* Note that the table does not reflect usage of low-flow fixtures and includes no allowance for water delivery losses.

Construction waste. The building of new homes inevitably generates waste materials that must be collected and disposed of, often at local landfills and sometimes at more remote locations. A 1996 study estimated that a typical 2,000 square foot new home (assumed to have brick veneer on the front and vinyl siding on the other sides) generated about 4 tons (50 cubic yards) of waste, broken down as follows:

Estimated Construction Waste for 2,000 Square Foot House

Material	Weight (pounds)	Volume (cubic yards)
Solid-sawn wood	1,600	6
Engineered wood	1,400	5
Drywall	2,000	5
Cardboard	600	20
Metals	150	1
Vinyl	150	1
Masonry	1,000	1
Containers-paints, caulks, etc.	50	0
Other	1,050	11
TOTAL	8,000	50

GOAL #3: IMPROVE DURABILITY AND REDUCE MAINTENANCE COST

Durability. The most straightforward way to quantify the durability of homes is based on the service lives of the products and systems found in housing, particularly the more expensive items and those that are not commonly replaced for aesthetic or cosmetic reasons. Very little scientific data exists with which to quantify product lives, and there is great variability in practice due not only to the design of the product, but also to differences in the quality of installation, the level of routine preventive maintenance, and the nature and intensity of environmental exposures.

Anecdotal data from industry sources concerning typical lifetimes of different products was compiled by NAHB and published in a 1993 article in *Housing Economics*. A few figures excerpted from that report are listed below.

Asphalt composition roof shingle	15-30 years
Caulking:	8-10 years
Gas or oil furnace	18 years
Heat pump	15 years
Central A/C compressor	15 years
Electric water heater	14 years
Gas water heater	11-13 years
Standard refrigerator	17 years
Wood siding	20-50 years
Vinyl siding	50 years
Exterior paint on wood, brick, etc.	7-10 years

Maintenance Costs. Recent survey data about household expenditures for maintenance/repairs and major product replacements in single-family detached homes is in the following table, showing trends by age of home as well as total outlays per household. "Maintenance and repairs" includes items such as painting, wallpapering, finish flooring and replacement of individual parts in a larger system. "Replacement" includes major replacements of items such as a complete re-roofing, new furnace or new water heater.

	Single-Family Detached Houses Annual Cost for Maintenance/Repairs and Replacements by Year of Construction								
	Before 1960	**1960 to 1969**	**1970 to 1979**	**1980 to 1984**	**1985 to 1989**	**1990 to 1991**	**1992 to 1993**	**1994 to 1995**	**Total**
Cost per House									
Maintenance & Repairs	$445	$460	$496	$476	$491	$358	$302	$299	$453
Replacement	$131	$179	$180	$152	$78	$23	$18	$2	$135
Cost per Square Foot of Living Space									
Maintenance & Repairs	$0.25	$0.26	$0.24	$0.24	$0.22	$0.16	$0.15	$0.12	$0.24
Replacement	$0.08	$0.09	$0.09	$0.07	$0.04	$0.01	$0.01	$0.00	$0.07
Cost as a Percent of Value									
Maintenance & Repairs	0.62%	0.48%	0.47%	0.44%	0.35%	0.25%	0.23%	0.17%	0.50%
Replacement	0.20%	0.18%	0.18%	0.13%	0.06%	0.01%	0.02%	0.00%	0.16%

Source: NAHB *Housing Economics*, Nov. 1997. Based on analysis of data from the 1995 American Housing Survey.

U.S. total annual expenditures for major replacements in owner-occupied homes (averaged over the years 1994-96) are listed below in rank order by type of item replaced:

Roofing	$4.5 billion
HVAC	$3.8 billion
Windows	$2.6 billion
Plumbing	$1.7 billion
Siding	$1.3 billion
Doors	$1.0 billion
TOTAL (all categories)	$17.3 billion

U.S. total annual expenditures for maintenance and repairs, calculated and presented similarly, are below:

Painting and papering	$6.8 billion
Roofing	$2.5 billion
Plumbing	$2.5 billion
HVAC	$1.8 billion
Flooring	$1.3 billion
Windows and doors	$0.7 billion
Electrical	$0.5 billion
Siding	$0.4 billion
TOTAL (all categories)	$24.3 billion

The U.S. total annual expenditure data above (major replacements as well as maintenance/repair) are from a quarterly survey of consumer expenditures performed by the U.S. Department of Commerce. Recent studies have found the Commerce estimates to be systematically lower than estimates of expenditures based on the American Housing Survey. The U.S. totals published by the Department of Commerce are likely to be revised upwards by 10-20 percent as part of an ongoing process of reconciling data between the two sources.

GOAL #4a: REDUCE RISKS FROM NATURAL HAZARDS

For this discussion, the risks from natural hazards can be classified as loss of life, injury and property destruction, and the types of natural hazards considered include tornadoes, floods, hurricanes/tropical storms, and earthquakes.

An overview of recent U.S. experience with tornadoes, floods and hurricanes/tropical storms is in the following table.

Summary Data on Tornadoes, Floods, and Tropical Storms in the U.S.: 1986-1996

ITEM	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Tornadoes, number	764	656	702	856	1,133	1,132	1,298	1,176	1,082	1,235	1,170
Lives lost, total	15	59	32	50	53	39	39	33	69	30	25
Most in a single tornado	3	30	5	21	29	17	12	7	22	6	5
Property loss of $500,000 and over	75	38	48	60	91	64	108	72	83	n/a	n/a
Floods: Lives lost	80	71	31	85	142	61	39	103	89	79	164
Property loss (mil. dol.)	4,000	1,490	114	415	2,058	1,416	800	16,400	1,224	n/a	n/a
Hurricanes and Tropical Storms, North Atlantic	6	7	12	11	14	8	7	8	7	19	13
Hurricanes reaching U.S. mainland	2	1	1	3	-	1	1	1	-	2	2
Direct Deaths on U.S. mainland	9	-	6	56	10	17	26	9	38	29	33
Property loss in U.S. (mil. dollars)	17	8	59	7,670	57	1,500	26,500	57	973	3,729	3,600

Source: *Statistical Abstract of the United States 1998*, p.248. Most of the underlying data is from NOAA publications.

Property loss from tropical storms and hurricanes clearly fluctuates widely from year to year, and the largest losses were in years when well-known events occurred (Hurricanes Andrew in 1992 and Hugo in 1989). Obviously not all of the data shown in the table relates to housing or the way homes are built. NOAA also indicates about 1,500 injuries per year associated with tornadoes, 1,700 per year due to floods and 60 per year due to hurricanes and tropical storms..

The previous table is limited to weather-related disasters and does not include any information about earthquakes. Estimates of total insured losses from the largest earthquakes in the 1986-1996 period appear in the following table. These figures are not limited to residential construction. Data on fatalities and injuries in these events were not available.

Insured Losses from Selected Earthquakes, 1986-1996

Year	Location	Estimated Property Damage
1994	Northridge, CA	$12,500,000,000
1992	Southern California; Landers, Joshua Tree, Big Bear	$92,000,000
1992	Northern California Coast; Petrolia, Eureka	$66,000,000
1989	San Francisco Bay area	$7,000,000,000
1987	Southern California; primarily in LA-Pasadena-Whittier area	$358,000,000

Source: Insurance Information Institute

GOAL #4b: REDUCE RISKS TO RESIDENTIAL CONSTRUCTION WORKERS

The U.S. Department of Labor is the principal source of information about risks to workers, through its Bureau of Labor Statistics and the Occupational Safety and Health Administration. Unfortunately, statistics documenting fatalities, illnesses and injuries to residential construction workers (as opposed to all types of construction workers) are incomplete or unavailable. Totals for the entire construction industry totals are suggestive at best and must be interpreted very cautiously.

The only published statistics relating solely to residential construction are data on fatalities, injuries and illnesses for employees of general contractors specializing in residential construction (SIC 152). This can only tell a small part of the story since most residential construction work is performed by subcontractors. Data is available for all the principal types of subcontractors, but most of them perform both residential and non-residential work, and none of the subcontractor data separates worker risks associated with residential vs. non-residential construction (such as commercial, industrial, institutional and public works projects).

Worker Fatalities. According to the Occupational Safety and Health Administration, there are a total of about 6,000 workplace fatalities each year in the U.S. Fatality data from the period 1985-89 indicates a 5-year total of 126 fatalities among the employees of those general contractors specializing in residential building (SIC 152). The principal causes of fatalities were:

Falls:	45%
Struck by: (e.g., falling object)	23%
Caught in/between: (e.g., cave-in)	13%
Electric shock:	14%
Other:	5%

These statistics must be supplemented with information about fatalities for construction subcontractors, bearing in mind that none of the subcontractor data is limited to residential work. Total fatalities over the 5 years for different categories of subcontractors (including both residential and non-residential work), and the single greatest cause for each category, were:

Miscellaneous specialties n.i.e.:	745 fatalities	(41% from falls)
Roofing, siding and sheet metal:	238 fatalities	(73% from falls)
Electrical work:	211 fatalities	(60% from electric shock)
Plumbing, heating, air conditioning	184 fatalities	(27% from falls)
Masonry, stonework and plastering	156 fatalities	(60% from falls)
Painting and paper hanging	134 fatalities	(55% from falls)
Concrete work	87 fatalities	(40% from struck by)
Carpentry and floor work	70 fatalities	(63% from falls)
Water well drilling	15 fatalities	(33% from electric shock)

Non-Fatal Injuries and Illnesses. Based on data for the year 1996, residential general contractors experienced an average of 8.0 injuries or illnesses per 100 workers, including about 3.8 leading to lost workdays. Practically all of these incidents (95%+) reflected injuries, not illnesses. For the trade subcontractors listed above (once again lumping residential and non-residential activity together), the highest rate was for *roofing, siding and sheet metal workers* (13.9 cases per 100 workers, 7.1 leading to lost workdays) and the second highest was *masonry,* *stonework and plastering* (11.9 per 100 workers, 6.2 leading to lost workdays). The two categories of trade subcontractors with the lowest rates were *painting and paper hanging* (7.2 cases per 100 workers with 3.8 leading to lost workdays) and *water well drilling* (6.9 cases per 100 workers with 3.5 leading to lost workdays).

OSHA also publishes industry-wide tabulations indicating the "sources" of lost-work-day injuries and characterizes the type of "event or exposure" leading to lost-work-day injuries. Statistics for the Construction industry include all construction workers, whether residential or non-residential, and are expressed as annual numbers of injuries involving days away from work per 10,000 full-time workers. For 1995, the leading sources were:

Source of injury:	**Annual rate per 10,000 full-time workers:**
Parts and materials:	99
Floors, walkways, etc.	76
Worker motion	53
Tools and Equipment	44
Machinery	29
Containers	21
Vehicles	21

The type of event or exposure leading to these injuries was tabulated as follows:

Type of Event or Exposure:	**Annual rate per 10,000 full-time workers:**
Contact with objects:	138
Overexertion:	94
Struck by object:	72
Overexertion in lifting:	54
Fall to lower level:	50
Struck against object:	33
Fall to same level:	31
Exposure to harmful substances:	18
Caught in equipment:	17
Transportation accidents:	13
Slips, trips, etc. (no fall):	11