

An Assessment of the U. S. Residential Lighting Market

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ABSTRACT

This report provides background data upon which residential lighting fixture energy conservation programs can be built. The current stock of residential lighting is described by usage level, lamp wattage, fixture type, and location within the house. Data are discussed that indicate that 25% of residential fixtures are responsible for 80% of residential lighting energy use, and that justify targeting these fixtures as candidates for retrofit with energy-efficient fixtures. Fixtures determined to have the highest energy use are hardwired ceiling fixtures in kitchens, living/family rooms, dining rooms, and outdoors. An assessment of the market for residential fixtures shows that nearly half of new residential fixtures are imported, 61% of new fixtures sold are hardwired, and about half of all new fixtures sold are for ceiling installation.

Introduction

Residential lighting in the United States uses about 138 billion kilowatt-hours per year, accounting for between 10 and 15 percent of total residential electricity use¹. Every year, this costs U. S. citizens some \$11 billion dollars and causes emission of more than 100 million tons of carbon dioxide, the primary greenhouse gas². On a house-by-house basis, this translates to an average of almost 1600 kWh and \$115 per year on the average for each of the 96 million U. S. homes. The purpose of this market assessment is to provide the basis for the Environmental Protection Agency to design programs promoting energy-efficient lighting in these homes. To that end, this report contains:

1. A description of the current stock of lighting products (lamps and fixtures) installed in U.S. residences. This description provides insight about which lighting applications (fixture types, room types, lamp types, etc.) are responsible for the most significant energy use, and therefore have the greatest potential for pollution prevention.
2. An analysis of the current market for residential lighting products, to illuminate the market processes that are at work in the residential sector.

Residential lighting is relatively difficult to characterize because it covers a diverse set of applications, products, and usage levels. To ease the understanding of this end use we have disaggregated lighting applications by the broad categories of usage level, lamp wattage, fixture type, and location within the house. In this way, we can determine how lighting products are applied in homes and the most acceptable and effective means of reducing residential lighting energy consumption.

The consumer's selection of residential lighting products is strongly influenced by the aesthetics of both the product itself and the light it produces. Utilities have learned from past utility lighting programs that programs that promote screw-in compact fluorescent lamps are prone to misapplication, resulting in poor lighting quality and customer dissatisfaction. Program designers must carefully consider the ways in which occupants interact with the lighting products in their homes if their programs are to be successful. Providing appropriate, high quality energy-efficient residential lighting is a primary goal of LBL's dedicated CF fixture program. For this reason, this brief analysis and the snapshot that preceded it focus on the limited but detailed residential lighting use data that is available.

This study is based on four relatively small recent residential lighting surveys, each conducted in a different geographic area. A key issue in applying the results of this study of lighting stock is the degree to which these four samples can be considered representative of the United States as a whole, or to any specific subpopulation within. While we can not answer this question precisely, we believe that the consistency of the results seen in a comparison of the four studies indicates that the data provide a reasonable estimate of current residential lighting conditions in the U. S. as a whole. The data used here are the best available in the field of residential lighting, and the data tabulations and comparisons presented in this paper are the most detailed attempt yet to illustrate these patterns.

Section 2 of this paper describes the survey data sources used in the analysis. Section 3 then presents tabulations of these data and compares the results. Section 4 is a lighting market description adapted from a report by Robert Sardinsky of Rising Sun Enterprises^{i,3}.

ⁱ A brief introduction and summary of this report was presented as “A Snapshot of the Residential Lighting Market in June 1995.

Section 1: Characterization of Lighting in U. S. Residences

1.1 Past Lighting Breakdowns

Several studies of residential lighting have been conducted by utilities and energy services companies (ESCOs) around the United States in the last several years. Most were focused on compact fluorescent (CF) retrofit programs. We consulted several of these studies to create a representative picture of U. S. residential lighting. Sample size in the studies ranged from 20 (Grays Harbor) to 7,700 (Free Lighting Corporation) homes. In the study with the largest sample size, energy use was estimated from residents' self-reported hours of use while in the most detailed study (with smaller sample size) every socket in the home was equipped with a data logger that measured hours of use over a six-month period. We compared the results of the three studies for which we were able to obtain actual data and a two more whose results were presented either in published or internal reports. In this section we briefly discuss the results of those studies.

Tacoma Public Utilities (TPU)^{4,5}

The most comprehensive monitoring study for which we have been able to obtain data is being carried out by TPU in cooperation with other Northwestern utilities. The project is a baseline residential lighting study in which the long-term monitoring of 200 residences is underway. We were able to obtain access to data from the first two six-month periods. Participants include Tacoma Public Utilities (WA), Eugene Water and Electric Board (OR), Pacific County PUD #2 (WA), City of Port Angeles (WA), Portland General Electric (OR), and Peninsula Light Company (WA). The importance of this study lies in its use of light loggers to record the hours of use for each lighting fixture in every home in the study.

The aim of the study is to answer four primary research questions:

- How much energy is consumed by lighting?
- How long are lights on in specific locations?
- How does light energy consumption vary by demographic group?
- Is use during one half of the year different from use during the other half?

The monitoring is being carried out in four six-month periods from 1994 to 1996. In each period 50 houses are fully monitored, with one light logger per fixture or group of fixtures. Only 81 residences are represented in the first two periods because there is some carryover from one period to the next. Current data include homes that have been monitored for periods ranging from four months to a year. The final report from TPU will be available in late 1995 and will include data from four six-month periods. Participants in the TPU study were recruited by various meansⁱⁱ. The homes had from one to eight occupants, and a range of floor areas (data was

ⁱⁱ Each utility attempted to obtain a representative group: Two used customer characteristics surveys; one of these used a marketing firm to recruit customers to fit a customer selection script, and the other used utility employees. One utility used a "stratified random" sample based on the number of people home during the day and the square footage of the home, and had a private company make the recruitment calls. Another used utility employees and satisfied themselves that their sample was representative of their service territory. One rural utility has a list of

collected in bins of 1000 square feet; the resultant mean and median are between 2000 and 2999 square feet). There appears to be only a small correlation between number of occupants and energy use for lighting, and between house size and energy use for lighting.

An interesting, albeit intuitive, result of the TPU study that has not been studied by others is that energy use appears to drop significantly during the period when daylight hours are longer. In these months less artificial lighting is needed. Tacoma's location in the Pacific Northwest may have an effect on the differences between summer and winter lighting hours and on total amount of daylight available.

Free Lighting Corporation⁶

The Free Lighting Corporation (FLC) conducted a study of 7,700 homes in two distinct service areas (two counties in New York and two adjoining counties in New Jersey) of Orange & Rockland Utilities, Inc. Within the targeted counties, only "basic service" customers (without either electric heat or electric water heat) were included in the study. Participants were recruited by telephone, with 41% of those contacted in New York and 64% of those contacted in New Jersey agreeing to participate in the program. In New Jersey the participants accounted for 50% of the entire targeted community.

FLC's purposes were to gain an understanding of the residential lighting market and to compare two types of residential CF retrofit programs, an ESCO-designed performance contract and a utility-designed direct-install program. Before beginning their CF retrofit program, FLC performed a detailed lighting survey of the 7,700 homes in the study to establish their baseline, providing data on residential lighting not previously published or available. It is this survey that is of interest to our study.

During the survey, a trained lighting installer conducted a direct inspection of the number of incandescent bulbs (lamps) in each home. Together the homes contained 287,000 lamps, yielding an average of 37 lamps per home. The number of fixtures was not reported. The number of lamps was closely correlated with the number of rooms in the house: FLC found a "remarkably stable" (very little variation) average of 3.9 lamps per room regardless of the number of rooms. In the New York homes, hours of use were reported by participants during room-by-room surveys conducted by utility personnel.

The Free Lighting data were only available through limited tables in published reports and thus do not appear in the comparisons below.

Grays Harbor Public Utilities District (PUD)⁷

Grays Harbor PUD conducted a detailed analysis of lighting in a small sample of 20 homes (18 single-family residences and one duplex) in Grays Harbor County, Washington. One of the project's stated goals was to gather data on residential lighting to assist in demand-side planning efforts. Detailed inventories of lighting equipment were carried out in all of the homes, and six of the homes (selected on basis of homeowner interest, with varying demographic characteristics)

criteria and called people from the list of customers to that met those criteria (we do not have the criteria at this time). Another drew a "random" sample from the total list of utility customers.

were monitored using light loggers on all possible fixtures. Usage data was gathered monthly on the six monitored homes.

The homes had an average area of 1976 square feet (including garages) and 11.5 rooms. They ranged in age from a 70-year-old farmhouse to new homes, and included one- and two-story, ranch style, duplex, four-plex, speculative and custom homes. Participants included young families, singles, retirees, couples with teenagers, and empty nesters, with education levels from high school to graduate school and a broad range (\$12-\$50 thousand) of income. The sample was self-selected.

The initial inventory of light fixtures was done on a room-by-room basis by fixture type and lamp wattage. The average lighting power density was 1.24 W/ft² before CF retrofit lamps were installed. 845 total sockets were counted, for an average of 44.5 sockets per house and an average of about 3.9 sockets per room (the same result as found in the FLC study). Conversion to CF was possible in 421 sockets: 49.8% of all sockets or 58% of all incandescent sockets; 118 (14%) of the sockets were fluorescent.

*Pacific Gas & Electric (PG&E)*⁸

PG&E conducted a detailed inventory of existing lighting equipment in each of 1009 residences within its service territory. The sample of homes was evenly distributed among 250 randomly chosen meter reading routes, with 4 to 5 homes chosen along each route by random telemarketing. Efforts were made to minimize selection bias. The average house size was 1400 square feet, over a range from under 500 to over 3000 square feet.

Inventories of all accessible lamps were taken by trained evaluators, and information about wattage and number of lamps was collected by room. A total of about 25,000 lamps was found across the sample. In primary living spaces, the fixture types and switch types were recorded. Hours of use for each fixture were estimated by customers during an interview.

Fewer lamps (about 30 per home) were found in the PG&E study than in the Free Lighting Corporation and Grays Harbor studies. The typical home in the survey was found to be lit primarily by lamps of 60-75 W each. As in the other studies, most of the lamps were in ceiling fixtures (54% of all lamps in high-use areas, and >80% in hall, kitchen, and dining room). Wall fixtures and free-standing (floor & table) fixtures each accounted for 20% of lamps in high-use areas. The remaining 6% of lighting in high use areas was task lighting. Four-foot fluorescent lamps are common in kitchens and garages but were not widely found in other rooms.

*Southern California Edison (SCE)*⁹

In 1993, SCE carried out a study of residential lighting characteristics to determine the typical inventory of lighting equipment and hours of operation in residences. The study also addresses time-of-use metering. Participants received a \$50 savings bond for participating in the on-site questionnaire. A total of 692 residential customers were interviewed and their homes were inspected. Of these, 477 had a single time-of-use light logger installed in a "randomly selected socket" that operated for at least one hour per day. Participants who accepted the light loggers received an additional \$50 savings bond. The loggers were installed between November 1992 and March 1993 and were removed in September 1993. With only one logger per home we believe that the usefulness of the time-of-use data gathered is limited.

The customers were selected as a stratified random sample of active individually metered residential accounts. These accounts were stratified by annual electricity usage and building type, and were recruited by telephone.

The SCE study revealed a strong interest in energy conservation among the customers interviewed (82% responded that household energy conservation was either very important or somewhat importantⁱⁱⁱ). At the same time, respondents indicated that the strongest deterrent to purchase of compact fluorescent lamps was price.

The average number of lighting fixtures per dwelling varies considerably between single-family and multi-family dwellings. While the overall average for the study was just over 21 fixtures with an average of 100 W per fixture, the average for single-family homes was 26 fixtures and the average for multi-family was 13. The results are similar for number of rooms per household: the overall average was 11.9, the single family average was 14 and the multi-family average was 8. We calculated an average of 2.8 lamps per room and 1.8 fixtures per room from the data in the SCE report.

Hours of operation were reported by the occupants; the average of these estimates was 2.8 hours per fixture (2.8 single-family, 3.0 multi-family). Self-reported hours of operation may tend to overestimate actual use: In those homes equipped with a single time-of-use meter, the average metered bulb was used for 2.6 hours per day over the entire study period. Participants reported that they used these metered fixtures for an average of 3.8 hours per day, overestimating by an average of 1.2 hours per day.

As in other studies, ceiling fixtures were found to be the most common fixture type, representing about half of all fixtures. Wall and table luminaires make up most of the remainder. Dedicated (wall and ceiling) fixtures account for about 70% of all fixtures in the SCE study.. Lighting energy use was reported to be highest in living rooms (.75 kWh/day), kitchens/dining rooms (.63 kWh/day), and offices/dens (.50 kWh/day). Outdoor lighting use was reported to be comparatively low (.24 kWh/day).

1.2 Comparison of Residential Lighting Energy Use

The data collected by Tacoma Public Utilities is the most complete and comprehensive residential lighting data set we were able to obtain. Nevertheless, it covers only a small number of homes over one year of a two-year planned study, so it must be used with care. The TPU study is far more comprehensive than the Free Lighting and SCE studies (for which we have not been able to obtain data), and the PG&E study, and much larger than the Grays Harbor study. Its main advantages are that it includes actual monitoring of lighting hours of use for all possible fixtures and that the data is being collected over a long period of time, making it the most meaningful of the studies we reviewed. Nevertheless, the average house size in the TPU study is larger than that of any of the other studies that reported house size (see Table 1.1).

Referring to Table 1.1, the number of lamps per room shows a maximum variation of about 30% between the studies. The average lamp wattages in the were similar in Grays Harbor, PG&E,

ⁱⁱⁱ It is not clear how well such claims of interest in energy conservation are reflected in energy-conserving behavior, nor how strongly the sample may have been biased in the process of selection. Previous investment in energy-efficiency equipment may be a better indicator of interest.

TPU, and SCE studies (between 60 and 71 W). The total lighting wattages per room were similar between studies. The PG&E report did not give data by room, but the smaller average residence size was reflected in the smaller number of lamps per residence. In floor area and lamps per home, the PG&E study appears to be similar to the SCE study. Comparison of the PG&E, SCE, and Grays Harbor data (the only studies that reported floor areas) yields an approximately equal number of lamps per square foot.

Table 1.1: Comparison of Studies

	# of loggers	# of homes (sites)	fixtures per home	lamps per home	lamp wattage *	rooms per home	lamps per room	fixtures per room	calculated wattage per room	whole house area**	whole house area without garage	calculated watts per square foot	usage reporting method ***	lamp daily usage hours
Free Lighting		7700		37.6	66.3		3.9		259				self-reported	
Grays Harbor	44 valid	20	30.63	44.5	61.5	11.5	3.9	2.7	238	1976	1594	1.385	loggers on all	2.52
PG&E		1009		29.7	71.6					1400		1.504	self-reported	
TPU (prelim)	app. 2000	81 so far	31	50.9	71.4	15	3.4	2.0	242	2000-2999		1.8-1.2	loggers on all	2.12
SCE	477 total	692	over 21	34.86	60.4	11.9	2.9	1.8	177		1496	1.408	self-reported	2.8

The average lamp wattage for PG&E was computed to be 71.6 from two incandescent averages reported, weighted by the number of responses in each of the two categories. The categories were not described and this number may not be valid.

The Grays Harbor study reported floor area both with and without garage. The PG&E study did not specify whether or not garage was included. The SCE study did not include the garage. The TPU study reported area in usage bins of 1000 square foot increments with an average between 2000 and 2999 square feet.

PG&E usage data was self-reported on "high-use" fixtures; for all others 2.00 hours was assumed. Gray's Harbor and TPU installed loggers everywhere possible. SCE installed loggers on one lamp in each of 477 homes "randomly" chosen from among their larger sample.

We compared the survey results by room and fixture type for the three available data sets. Figures 1.1 and 1.2 show the results of these comparisons. In Figure 1.1 the fraction of installed wattage by room appears to be very consistent for all three studies in most of the primary high-use areas: living room, kitchen and outdoor. Bathrooms and bedrooms show more variation, and the “other” category is defined differently for each study. It may be that this category accounts for some of the variation between the TPU and PG&E data for bathrooms and bedrooms. The differences in the room definitions between the studies complicate comparisons. Installed wattage by fixture type, shown in Figure 1.2, also indicates a close correlation for the two studies for which such data were available (Grays Harbor and TPU).

Figure 1.1: Fraction of Installed Wattage, by Room

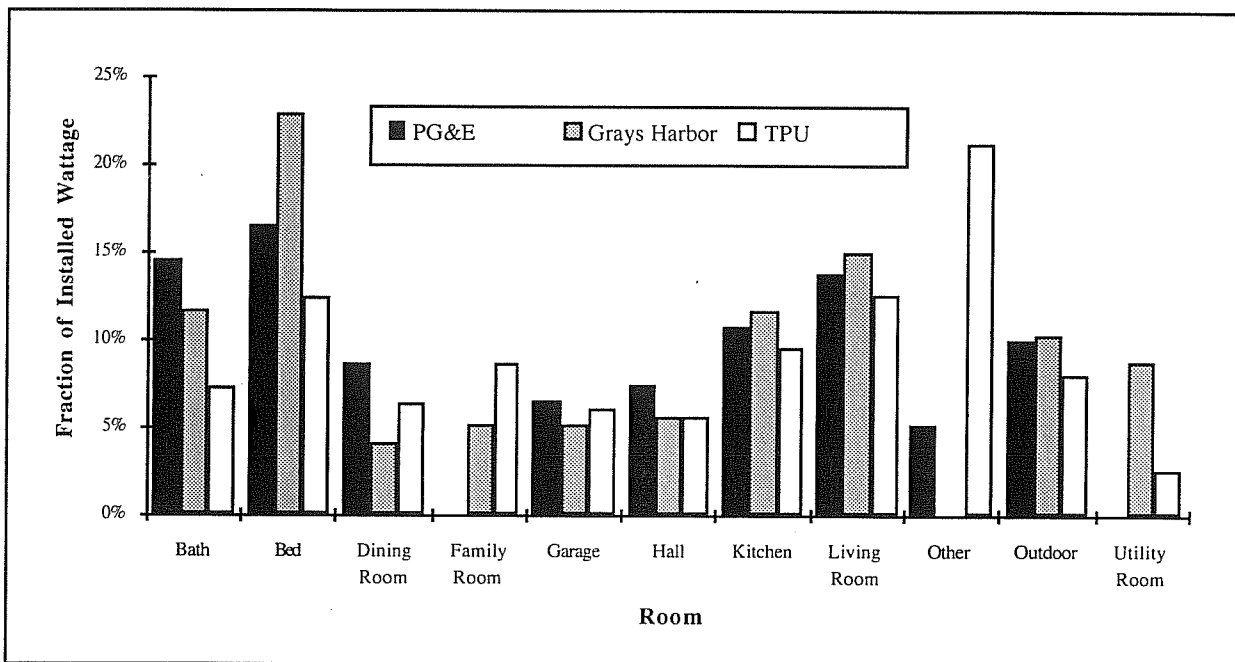


Figure 1.2: Fraction of Installed Wattage, by Fixture Type

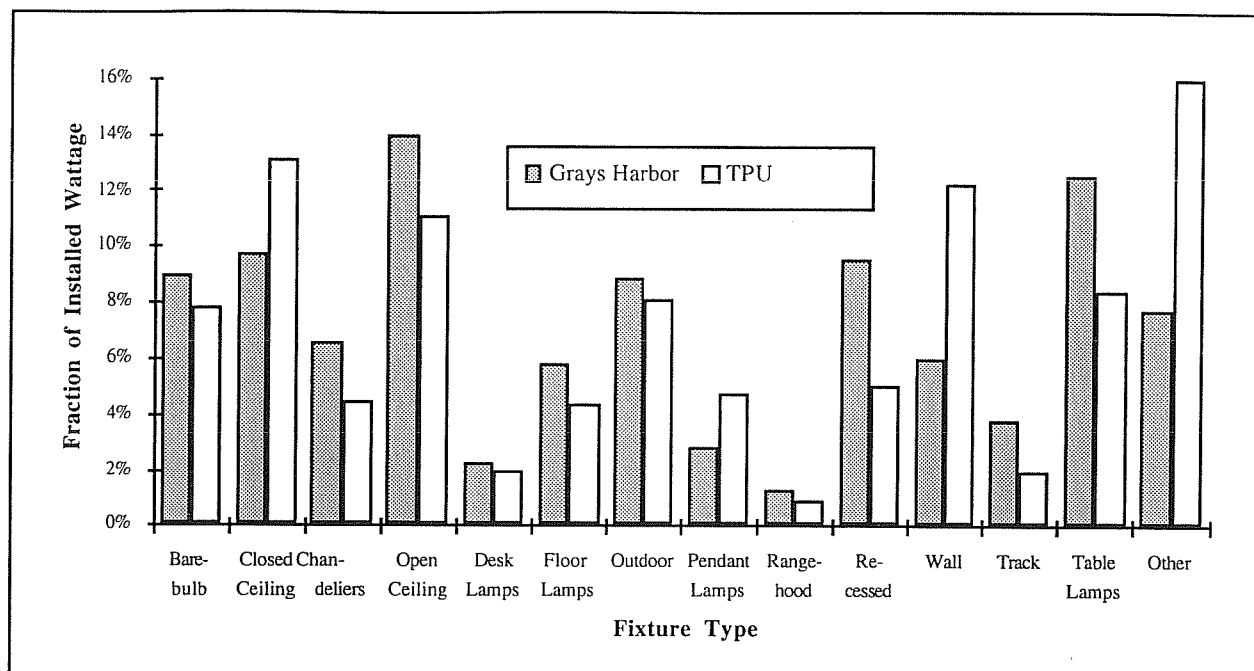


Figure 1.3 compares installed wattage with annual lighting unit energy consumption (UEC)^{iv}. For lower-use rooms such as the bedroom, bathroom, and garage (and other, which may include primarily lower-use rooms), the UEC is relatively low compared with the fraction of installed wattage. In the kitchen, living room, outdoor, and dining room the reverse is true. Utility rooms account for a small fraction of both UEC and installed wattage.

^{iv} Unit energy consumption is defined as the annual energy consumption by a particular fixture. The whole house lighting UEC is the total annual lighting energy consumption per house.

Figure 1.3: TPU Comparison of Installed Wattage and Annual Lighting UEC, by Room

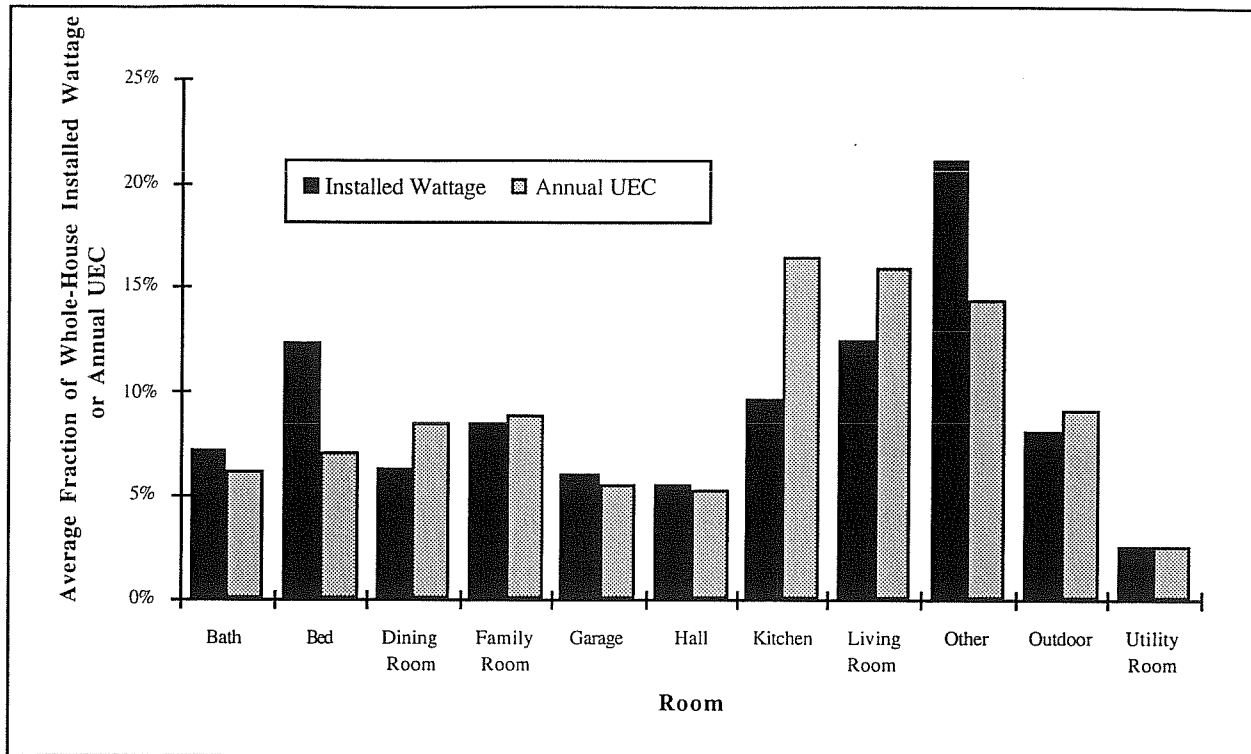
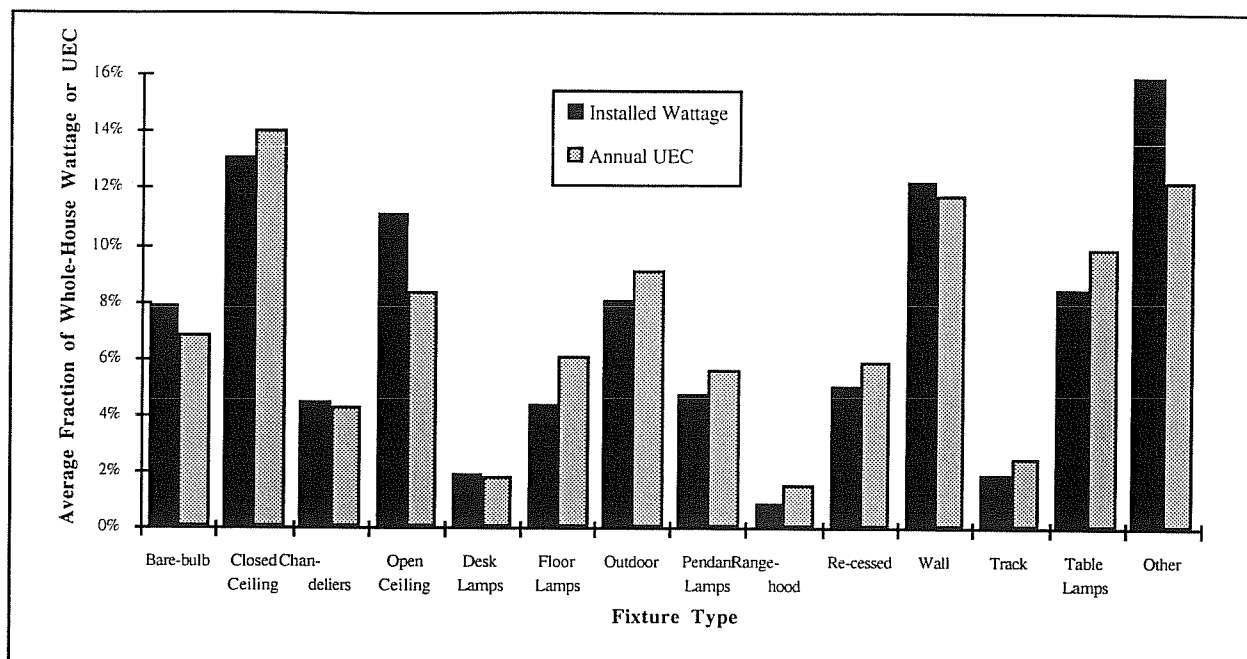


Figure 1.4 makes a similar comparison of installed wattage and annual UEC by fixture type. Ceiling fixtures, both closed and open, make up the largest fraction of lighting energy use at about 22% of all lighting energy. Wall-mounted fixtures account for another 12%, and table lamps another 10%. Portable fixtures overall use nearly 20% of total lighting energy. Outdoor fixtures use about 9% of annual lighting energy. The fixture category "Other" is not easily definable though a large fraction of annual energy consumption takes place there. In the Grays Harbor study, this category included fluorescent lamps.

Figure 1.4: TPU Comparison of Installed Wattage and Annual Lighting UEC, by Fixture Type



Fluorescent lighting appears in two distinct categories in residences, full-sized and compact fluorescent lamps. Figure 1.5 shows the saturation of full-sized and compact fluorescent lamps in the PG&E service territory. Full-sized fluorescent lamps dominate the kitchen and garage, while CF lamps are distributed more evenly throughout the house where they can substitute more readily for incandescent lamps.

Figure 1.6 shows percent of lamps by wattage and hours of use per day. All types of lamps are included, accounting for the two peaks that appear around 40 Watts (full-size fluorescents and 40-W incandescents) and between 60 and 75 Watts (average incandescent lamp sizes). Lamp wattage appears not to be strongly correlated with hours of use. Most lamps of all wattages are in use less than one hour per day, and the fraction drops off quickly with longer operating hours.

Figure 1.5: Fluorescent Lamp Saturation—PG&E Service Territory

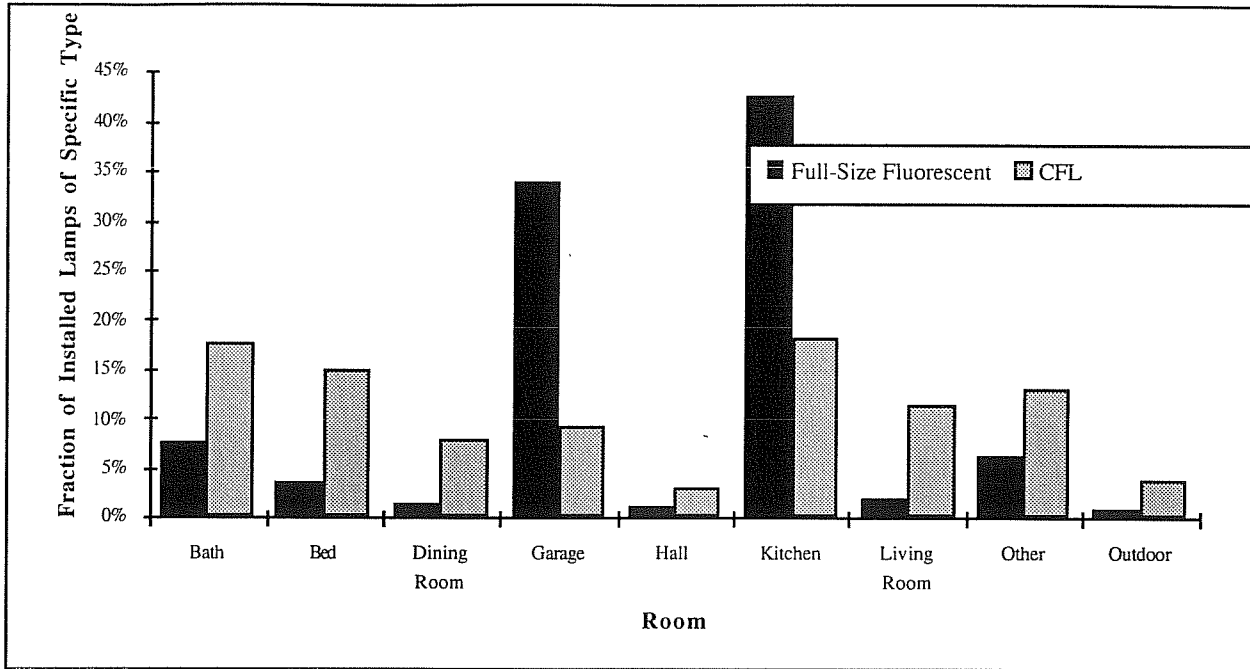
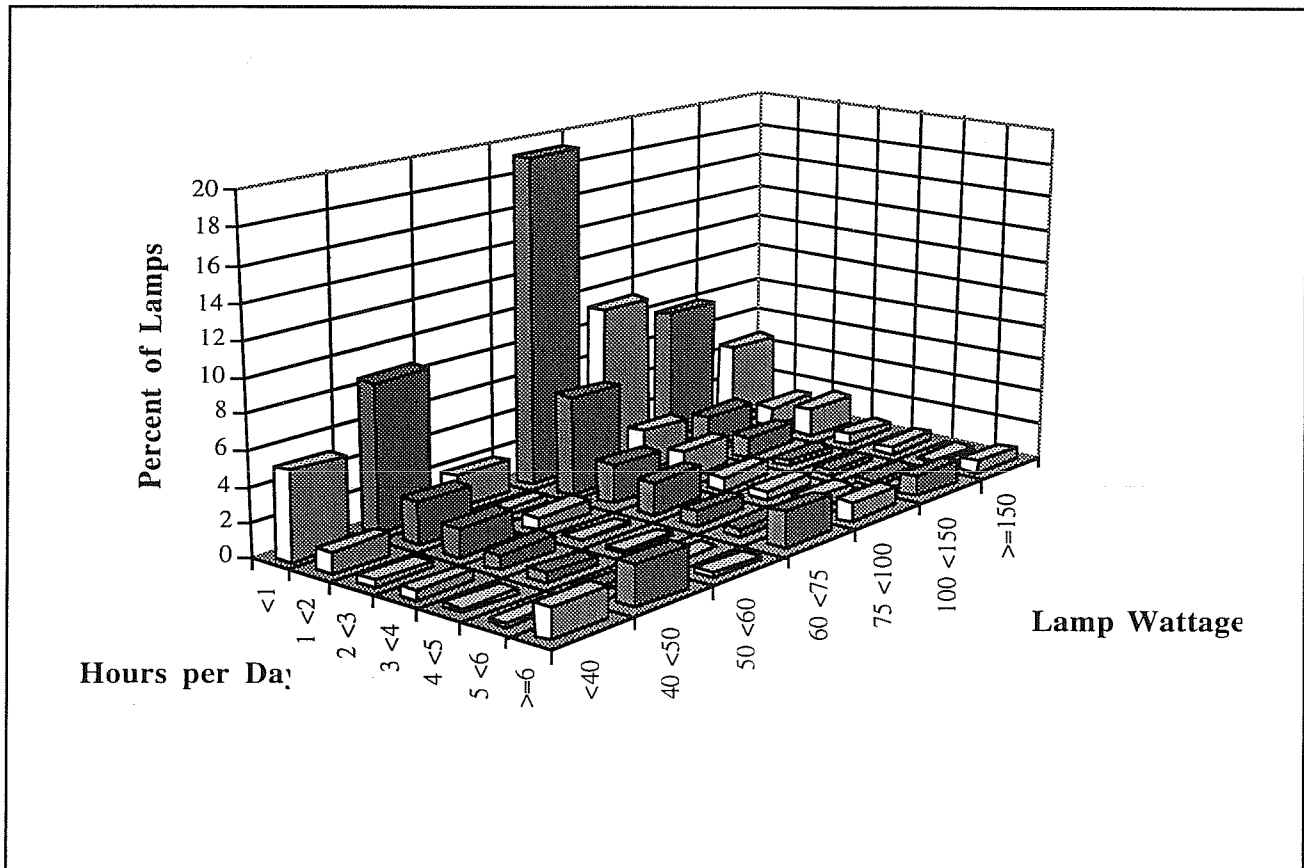
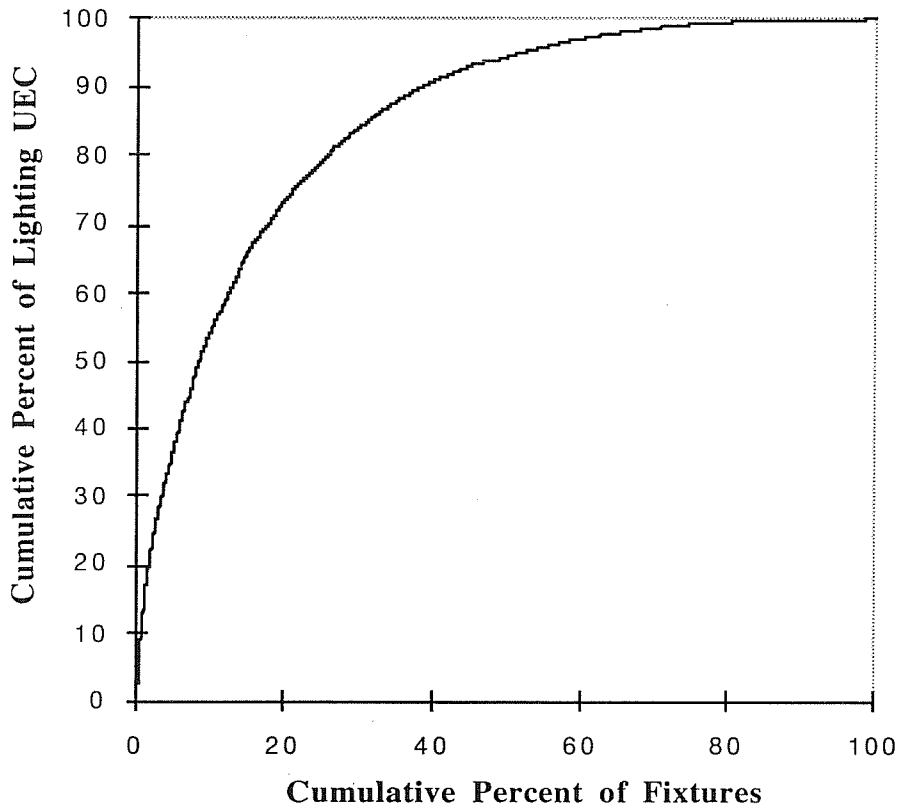


Figure 1.6: Lamp Wattage and Daily Hours of Use



We also compared the cumulative percent of unit energy consumption versus the cumulative percentage of incandescent lamps. Figure 1.7 shows that for the TPU sample 25% of the incandescent lamps are responsible for almost 80% of lighting energy use.

Figure 1.7: Cumulative Lighting UEC, by Household—TPU Data



Section 2: U.S. Residential Lighting Fixture Marketplace

Introduction

On the order of 3.5 billion light fixtures illuminate the nation's 96 million households^v. All but 15% of these fixtures are equipped with incandescent sources, typically at very low efficacies; the remaining fixtures are equipped with fluorescent sources. An estimated 21% of all electricity used for lighting nationally is consumed by residential fixtures, and between 10 and 15% of all household electricity is used for lighting. Consumers pay \$11 billion dollars annually for 138 billion kWh of electricity to power residential fixtures, while the power plants that produce that electricity emit over 100 million tons of CO₂, the primary greenhouse gas, into the environment^{10,11}. Residential lighting energy demand is forecast to continue to grow, driven by new housing and increasing lighting power densities^{vi}.

Each year, it is estimated that more than 500 domestic and foreign manufacturers collectively sell approximately 165 million light fixtures in the residential new construction and renovation/replacement marketplace, with a retail value totaling approximately \$3.4–\$4 billion.

The potential for annual energy savings from upgrading to energy-efficient fixtures is heavily dependent on daily operating hours. If the energy savings from a fixture retrofit is less than the cost of the retrofit over the fixture lifetime^{vii}, the retrofit is not considered cost-effective; however, residential light fixtures are unlikely to be purchased solely for their energy-conservation benefits. Most residential fixtures are operated for only a few hours per day. The first cost for many energy-efficient lighting products—particularly compact fluorescents—is significantly greater than for their standard incandescent counterparts, and many retrofits of low-usage fixtures are not cost-effective. Furthermore, the majority of compact fluorescent lighting products available today have not been suitably engineered to perform satisfactorily in residential applications nor have many been appropriately styled or packaged, and thus are not "consumer-friendly."

Residential applications represent a particularly demanding entree for compact fluorescent technology because consumers have become accustomed to the universal and generally carefree use of incandescents. In contrast to the performance of many compact fluorescent systems, incandescents start up instantly and at full light output, can be easily and inexpensively dimmed, are not sensitive to ambient temperature or mounting orientation, can be switched on and off frequently without significantly degrading lamp life, and do not interfere with television/radio reception or consumer remote control devices.

Nonetheless, presuming that the limited residential lighting surveys conducted to date are representative of the nation's existing residential lighting stock, then approximately 25% of the

^v Assumes 30 fixtures per household.

^{vi} Lighting power density is defined as lighting power (expressed here in Watts) per unit area (expressed here in square feet). For a room, the lighting power density can be calculated by dividing the total lighting wattage in the room by the room floor area.

^{vii} The fixture lifetime may be defined as the number of hours the purchaser will actually use the fixture; this could be the time it takes for the fixture to wear out or be replaced during redecorating, or for permanent fixtures the number of hours the fixture is used while the purchaser resides in the house.

lighting fixtures found in the average home account for 80% of the lighting energy consumption^{viii}. Because of their high energy use, these fixtures are prime candidates for replacement with compact fluorescent fixtures. New fixture design strategies are evolving rapidly. A handful of manufacturers are now offering dedicated compact fluorescent fixtures in a variety of aesthetic and utilitarian packages that integrate optimized optical, thermal, and ballast systems. With these fixtures, consumers can have energy efficiency without compromising lighting quality.

For society to achieve the significant benefits in natural resource conservation, monetary savings, and pollution prevention that energy-efficient lighting can deliver through the residential marketplace, a concerted effort by many parties, including manufacturers, researchers, regulators, designers/specifiers, distributors, retailers, builders, electrical contractors and consumers is required. Accelerating this market transformation calls for a multi-faceted strategy that fosters the simultaneous development of near-term technologies, market infrastructure, and consumer demand, as outlined in the breakdown of market transformation factors in Table 2.1.

^{viii} based on analysis of preliminary data from Tacoma Public Utilities District study of residential fixtures (see section 1).

Table 2.1: Market Transformation Factors

- New Fixture Development Requirements
 - optimized system performance
 - diverse utilitarian and decorative styling options
 - affordable pricing
 - consumer-friendliness
 - certification (safety performance, etc.)
 - manufacturer design, testing & manufacturing capabilities
- Marketplace Assessment Factors
 - sales volume
 - product mix
 - product turnover
 - decision makers
 - key players
 - distribution channels
- Residential Lighting Use Assessment
 - existing fixture/source inventory
 - operating hours
 - consumer preferences/behavior (fixture appearance, function, light output)
- Regulation
 - product efficiency standards
 - building efficiency standards/codes
- Education
 - market/application
 - benefits for market players:
 - manufacturer
 - utilities
 - distributor
 - retailer
 - specifier
 - builder
 - contractor
 - consumer
 - lighting design
- Product Distribution
 - wholesale/retail
 - marketing
 - incentives
 - financing
 - ready availability
 - selection/variety

2.1 Fixture Marketplace

In order to achieve the greatest benefits from a residential initiative for energy-efficient lighting in the shortest time and the most cost-effective way, it is critical to understand the industry's players, dynamics, orientation, and scale.

Characterizing the residential marketplace accurately is an immensely challenging task, involving great diversity of players and market drivers. The analyses presented in this report are based on data from a variety of sources along with the author's and other experts' assumptions. Because complete data were not available for all concerns or for any given year, the numbers presented here must be considered estimates. Nevertheless, they provide insight into key factors in the residential lighting market.

2.2 Data Resources

The U.S. Dept. of Commerce, Bureau of the Census maintains several key industry statistics, including the following:

Current Industrial Reports: Electric Lighting Fixtures

Surveyed quarterly and published six months later, these profiles provide the quantity and wholesale value of shipments for hardwire electric lighting fixtures and the value of shipments of imported lighting fixtures from companies shipping more than \$100,000 in product annually to the residential, commercial, and industrial sectors. Domestic and export shipments are combined, and portable lighting fixtures are not covered.

Census of Manufactures

Surveyed annually and published 3 years later (e.g., 1992 data was published in the first quarter of 1995), these profiles document the number and type of manufacturers by sales volume and fixture type, including all domestic and export shipments for hardwire and portable lighting fixtures.

Foreign Trade Division, Dept. of Commerce

This Division maintains current data on lighting fixture imports and exports by sales volume and unit volume, but these are broken out only by gross hardwire and portable shipments.

The most important organization concerned with residential lighting is the American Lighting Association (ALA), a membership trade group comprised of residential lighting fixture manufacturers, sales representatives, and retailers. However, this group maintains no marketplace statistics.

The National Electric Manufacturers Association (NEMA) maintains detailed sales information on lamp, ballast, and lighting fixture shipments by its lighting manufacturer members, but most of its membership is in the commercial and industrial sectors. Residential statistics are not maintained by NEMA.

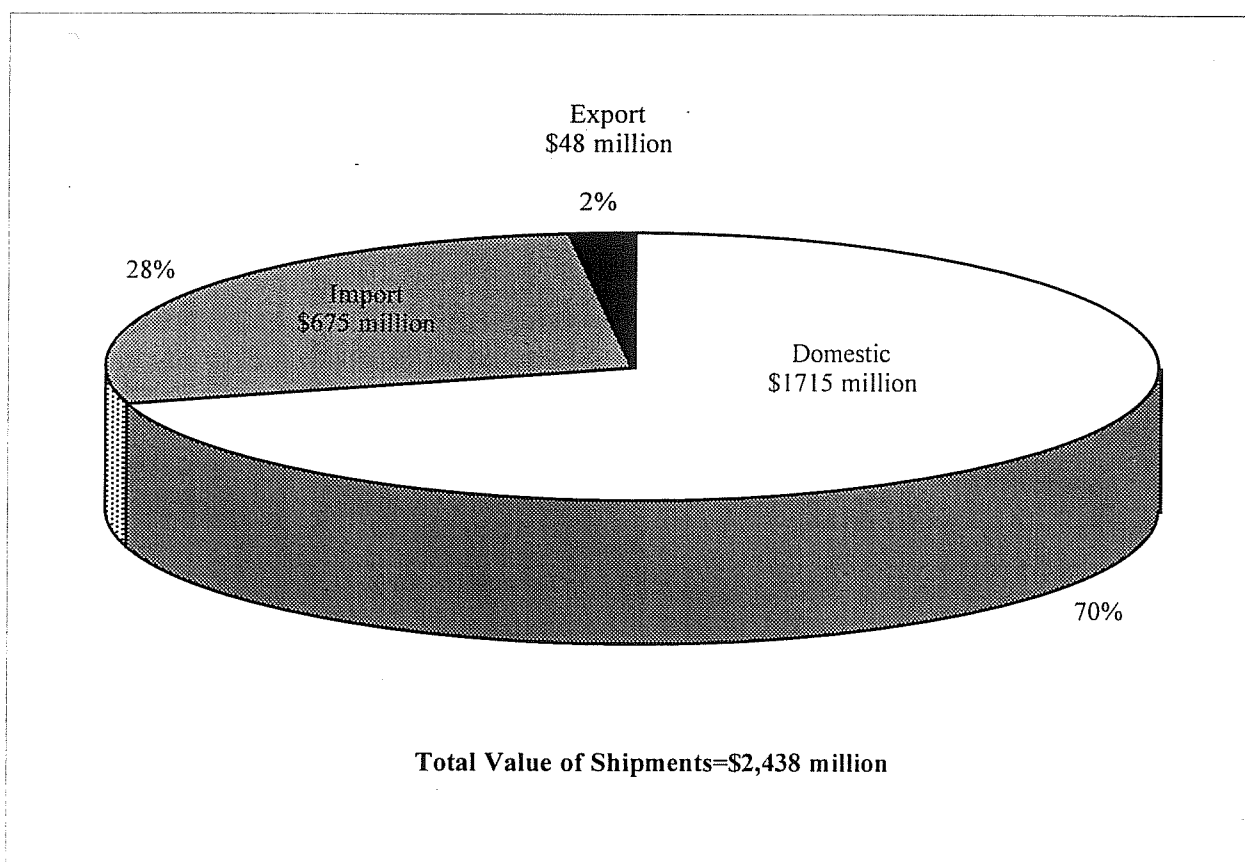
Several trade/professional magazines focus on residential lighting, notably *Home Lighting and Accessories* and *Residential Lighting*. These publications emphasize lighting trends and styles;

retailer, manufacturers' representative, and manufacturer profiles; resource listings; and product advertising.

2.3 Residential Fixture Sales

The total U.S. residential lighting fixture market represented about \$2.5 billion in annual wholesale sales in 1993-1994. Figure 2.1 shows the 1993 breakout of these sales by domestic shipments, imports, and exports. Factoring in the markups on these sales to consumers, which may range from 15% - 100+%, by distributors, contractors, and/or retailers, the retail value of these shipments total an estimated \$3.4 - \$4 billion. Note that exports amount to only 2% of all domestic sales.

Figure 2.1: Value of Residential Hardwire and Portable Lighting Fixture Shipments - 1993



Source: U.S. Census Bureau Report # MA36L935, Table 2. Quantity and Value of Shipments of Electric Lighting Fixtures: 1992 - 1993

U.S. Department of Commerce, Bureau of the Census, 1992 Census of Manufacturers, MC92-I-36C(P), issued October 1994.

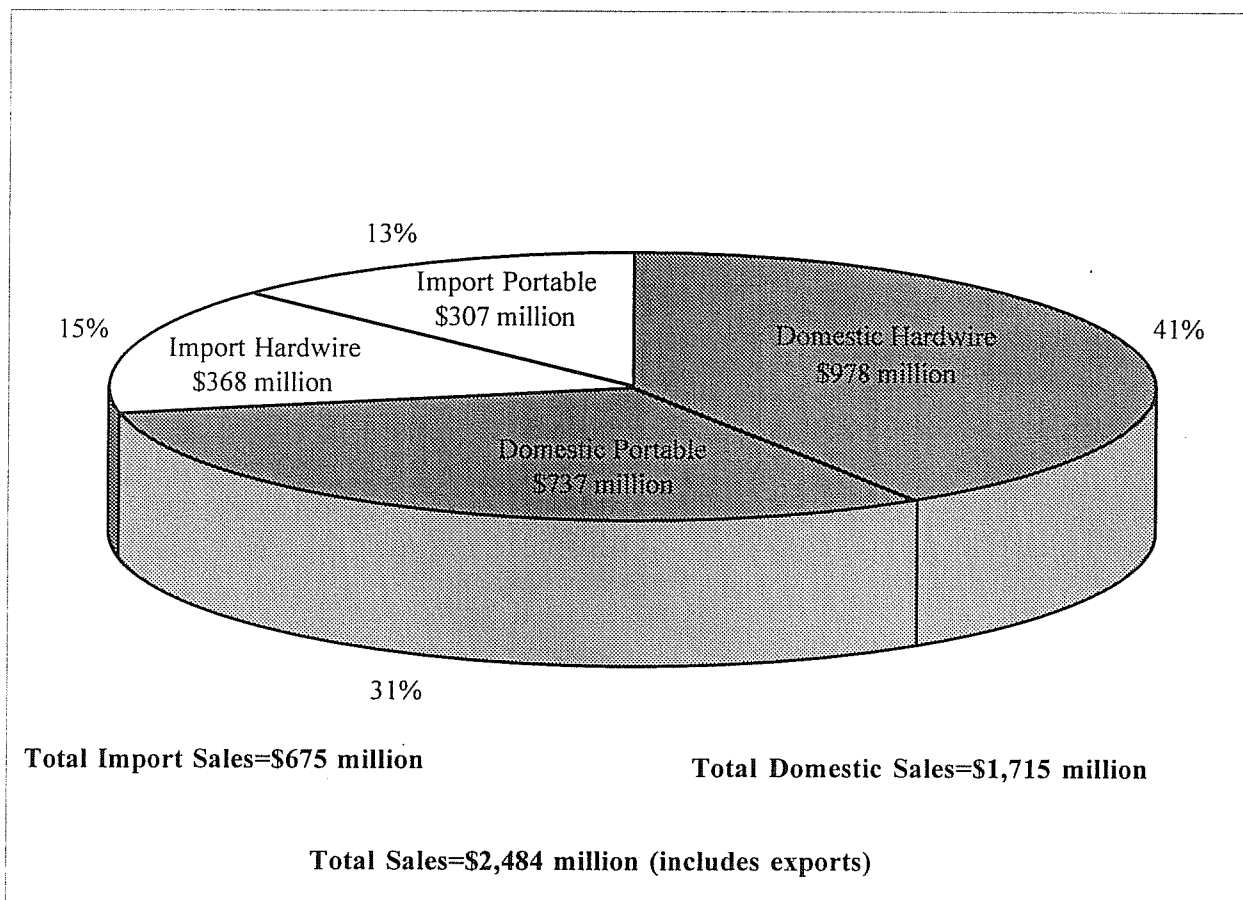
Personal communication with Foreign Trade Division, U.S. Department of Commerce, Reba, 301/457-2242, 3/20/95

Note: Value of domestic shipments are F.O.B. plant. Value of export shipments are value at port. Value of import shipments are value in foreign country.

Value of domestic shipments of portable fixtures for 1993 is estimated based on 1992 figures, and escalated to 1993 levels using the percentage increase of hardwire shipments from 1992 to 1993.

Lighting fixtures are classified in many different categories. One of the most basic distinctions is "hardwire" versus "portable." Figure 2.2 shows the breakdown of domestic and imported shipments for these two types for 1993. The distinction between the two is important, as each tends to find its way into the home through different specification and distribution channels.

Figure 2.2: Value of Residential Hardwire and Portable Lighting Fixture Shipments - 1993



Source: U.S. Census Bureau Report # MA36L935, Table 2. Quantity and Value of Shipments of Electric Lighting Fixtures: 1992 - 1993

U.S. Department of Commerce, Bureau of the Census, 1992 Census of Manufacturers, MC92-I-36C(P), issued October 1994.

Personal communication with Foreign Trade Division, U.S. Department of Commerce, Reba, 301/457-2242, 3/20/95

Note: Value of domestic shipments are F.O.B. plant. Value of export shipments are value at port. Value of import shipments are value in foreign country.

Value of domestic shipments of portable fixtures for 1993 is estimated based on 1992 figures, and escalated to 1993 levels using the percentage increase of hardwire shipments from 1992 to 1993.

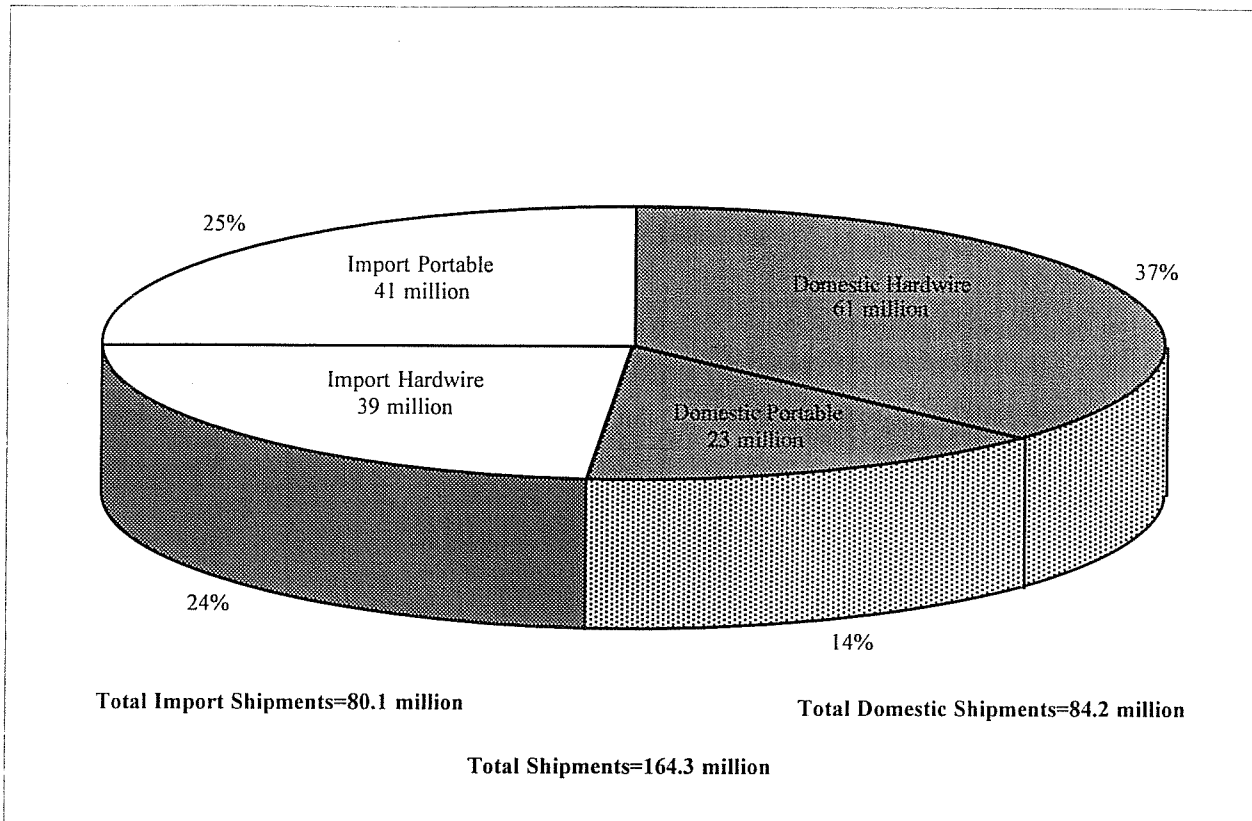
Hardwire fixtures are generally permanently connected to the wiring in a residence through a junction box set in or on a wall, ceiling, exterior overhang, or post and are bolted in place, so the

Hardwire fixtures are generally permanently connected to the wiring in a residence through a junction box set in or on a wall, ceiling, exterior overhang, or post and are bolted in place, so the fixtures are not readily moveable. In new construction, hardwire fixtures are most often specified and supplied by the developer, builder or electrical contractor; in renovation/replacement construction, they are specified by the contractor or homeowner.

Portable fixtures, in contrast, plug into ordinary electrical outlets and are easily relocated. Further, portable lighting is almost exclusively selected and procured directly by the homeowner/tenant. Generally when existing homes are sold the hardwire fixtures are left in place while portable ones are moved to the new home or discarded.

It is important to consider both domestic and import shipments, because this can help us understand the ease with which one can communicate with or influence manufacturers. While Figure 2.2 shows that imported products account for about 29% of the dollar value of all U.S. residential lighting sales, Figure 2.3 shows that these same imports account for an estimated 49% of the number of all lighting fixtures actually sold. Of the 165 million light fixtures sold in 1993, imports accounted for 39% of all hardwire fixtures and 64% of all portable lighting fixtures. Collectively, 61% of all lighting fixtures sold in the U.S. are hardwire and 39% are portable.

Figure 2.3: Quantity of Residential Hardwire and Portable Lighting Fixture Shipments - 1993



Source: U.S. Census Bureau Report # MA36L935, Table 2. Quantity and Value of Shipments of Electric Lighting Fixtures: 1992 - 1993

U.S. Department of Commerce, Bureau of the Census, 1992 Census of Manufacturers, MC92-I-36C(P), issued October 1994.

Personal communication with Foreign Trade Division, U.S. Department of Commerce, Reba, 301/457-2242, 3/20/95

Note: Number of domestic portable units is an estimate. A range was calculated based on U. S. census data¹² and Rising Sun estimates of average manufacturer sales price to distributor. The number used in this graph is the median of that range.

The disparity between sales volume and unit volume for domestic versus imported products exists because the average per unit wholesale cost from manufacturer to distributor for imports (\$8.99) is significantly less than for domestic products (\$20.37)^{ix}. Figures 2.4 and 2.5 show average unit cost for domestic hardwire fixtures, including those for export (separate data for fixtures sold domestically were not available). Fixture category headings presented in these graphs reflect the actual accountings maintained by the Census Bureau. Over nine million hardwire fixtures were exported in 1993, and were valued at over \$30 million dollars^x. Less than

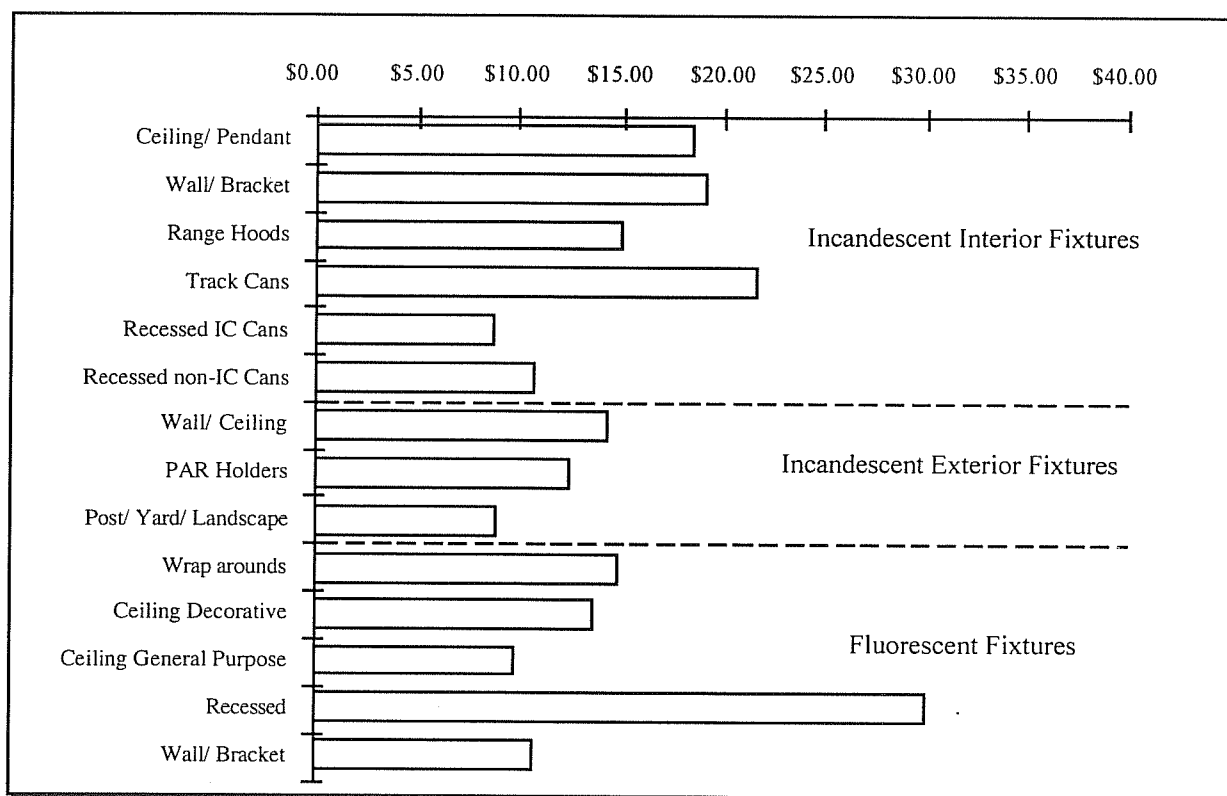
^{ix} These prices were calculated by dividing the total import and domestic values by the corresponding import and domestic unit shipments; such an average is not necessarily appropriate because it gives us no information about the distribution of prices, but is used here for lack of more complete data.

^x personal communication with Reba at Foreign Trade Division, U. S. Department of Commerce 3/20/95.

half a million portable fixtures, valued at \$15 million, were exported. Note that exports account for only 2% of the value of all domestic shipments and 5% of all units shipped.

Figure 2.4: Residential Hardwire Lighting Fixtures—1993 Average Per Unit Cost (Wholesale)

Includes exports but not imports. Does not include portable fixtures.

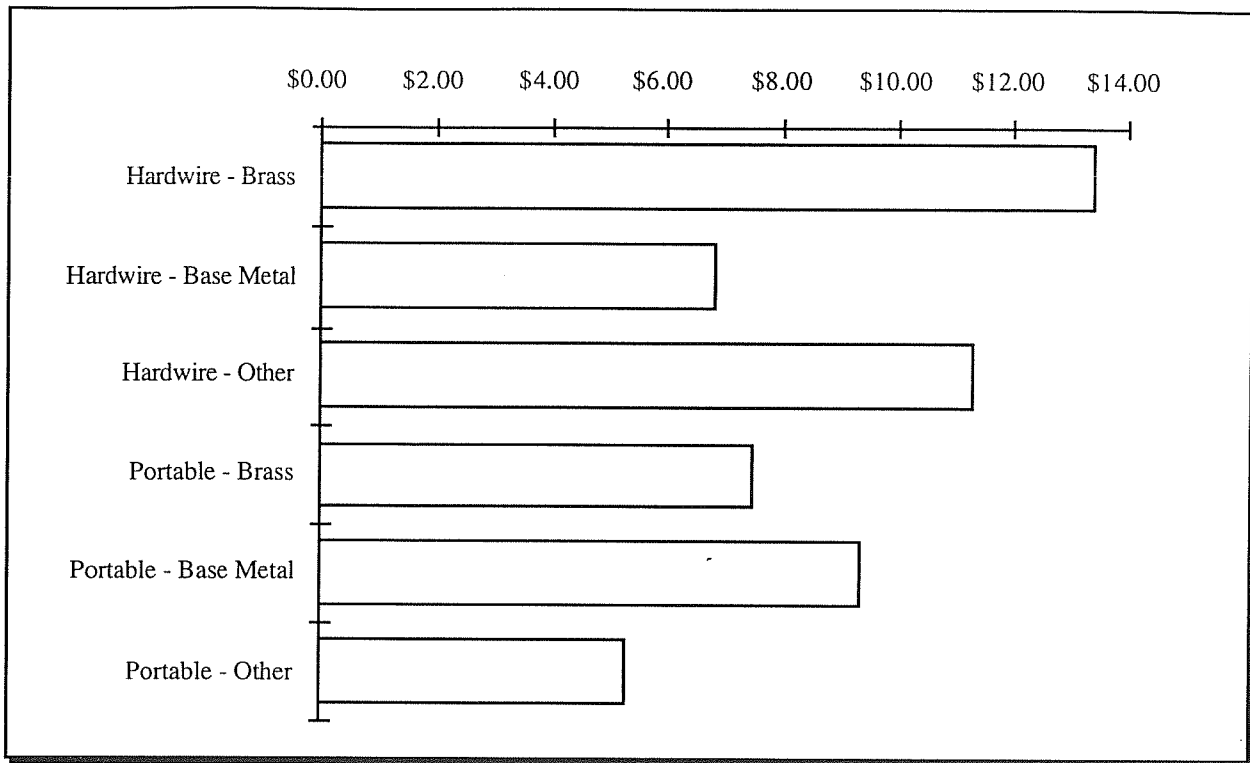


Source: U.S. Census Bureau Report # MA36L935, Table 2. Quantity and Value of Shipments of Electric Lighting Fixtures: 1992 - 1993

Number of PAR Holders is estimated from total number of PAR holders for all sectors in Report # MA36L935. Number of Range Hood Fixtures is estimated as one per family based on the U.S. Bureau of the Census, Current Construction Reports, Series C25, Characteristics of New Housing, 1993, U.S. Department of Commerce, Washington, Dc, 1994.

Per unit cost calculated by dividing total cost by total units for each category.

Figure 2.5: Electric Lighting Fixtures: Average Per-Unit Cost of Imports by Type - 1993



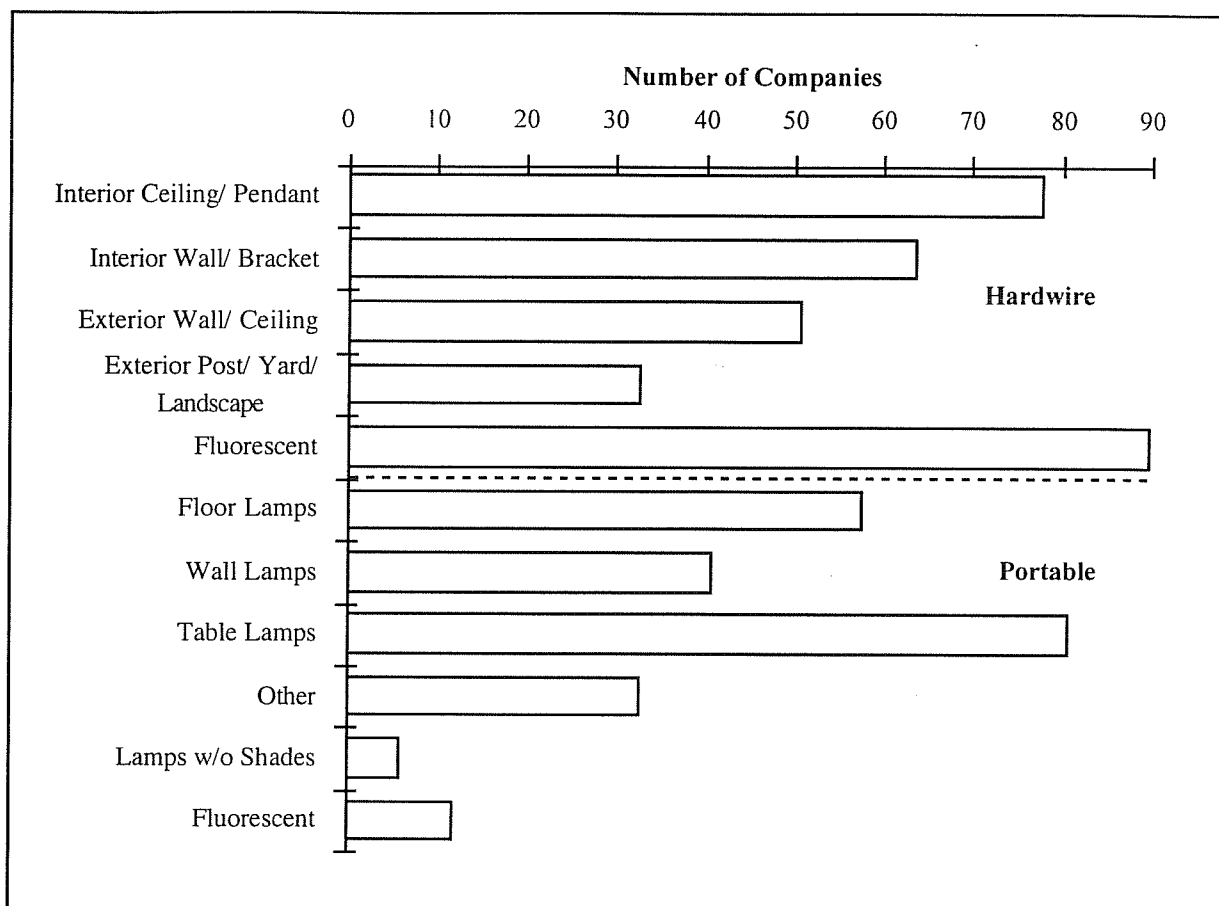
Source: Total import value and unit numbers from personal communication with Foreign Trade Division, U.S. Department of Commerce, Reba, 301/457-2242, 3/20/95

Per unit cost calculated by dividing total value for each category by total units for that category.

Several hundred domestic manufacturers produce residential lighting fixtures. Census Bureau data indicate that there were 120 manufacturers of hardwire fixtures in 1993 who had sales in excess of \$100,000 annually. No data are given for smaller companies. No total number is given for manufacturers of portable lighting fixtures; however, one can deduce from Census breakouts that there are more than 80 of these manufacturers. Likewise, no data are available for the number of foreign residential lighting fixture manufacturers who sell to the U.S., though one can reasonably assume that the number at least equals that of domestic manufacturers. In all, an estimated 500+ manufacturers, both domestic and foreign, supply the residential marketplace.⁴

Figure 2.6 breaks out the number of domestic manufacturers who make each fixture type. Because most manufacturers make a number of different fixture types, the same company is likely to be referenced in multiple categories. Though 30 to 90 manufacturers are shown for each fixture type, only a fraction of these account for the majority of sales. Market shipments by the largest 50 companies captured an estimated 70% of the residential marketplace in 1991¹³. This represents an increase from 65% in 1987, when 24% of market share was held by the 4 largest companies, 32% was held by the 8 largest companies, and 45% was held by the 20 largest companies.

Figure 2.6: Number of Manufacturers by Lighting Fixture Type Manufactured
Hardwire Data - 1993; Portable Data - 1992



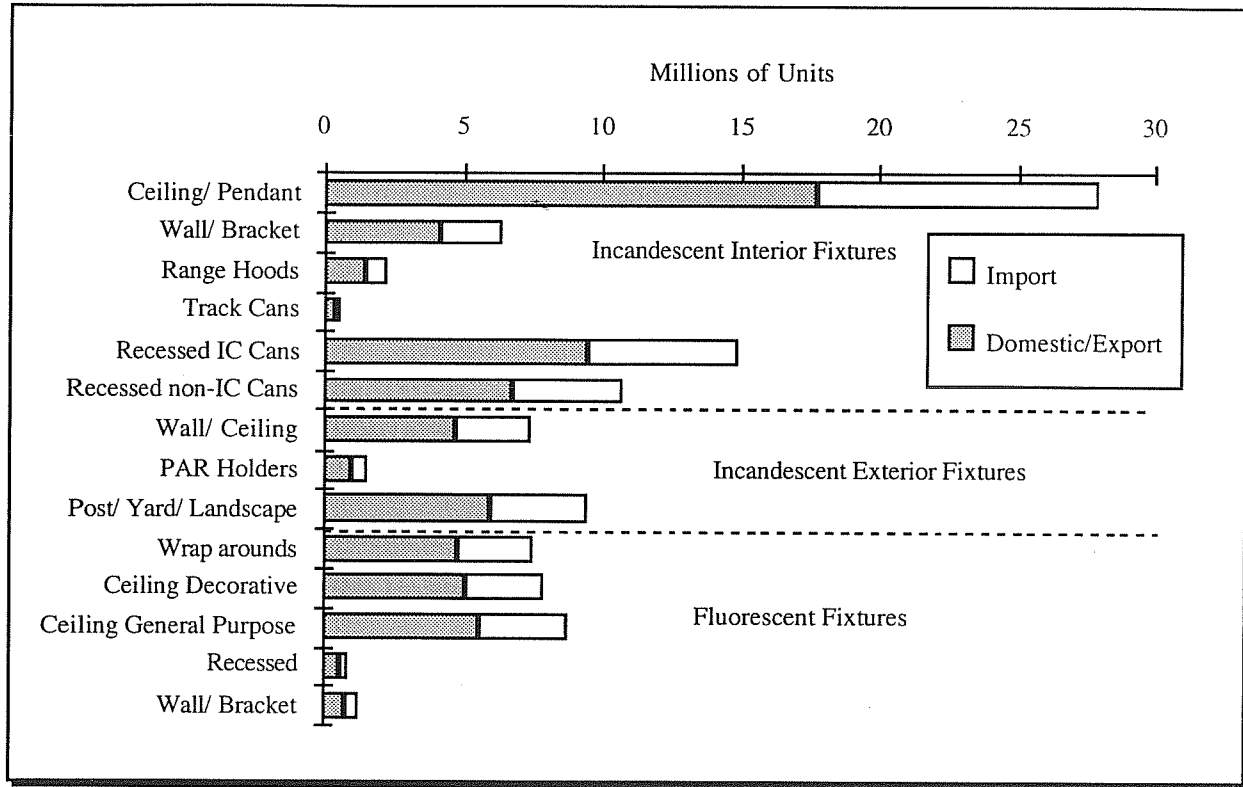
Source: U.S. Census Bureau Report # MA36L935, Table 2. Quantity and Value of Shipments of Electric Lighting Fixtures: 1992 - 1993

U.S. Department of Commerce, Bureau of the Census, 1002 Census of Manufacturers, MC92-I-36C(P), issued October 1994.

2.4 Product Mix

Lighting fixtures may be classified in any number of different ways. The U.S. Census breaks out lighting fixtures by light source, type, mounting and/or construction material. Figures 2.7 and 2.8 show data for hardwire fixtures by annual shipments and sales; Figures 2.9 and 2.10 do the same for domestically manufactured portable fixtures. The analysis presented in Figure 2.11 assumes that the allocation of imported fixture types is proportionate to that for domestic shipments, for lack of better information. The statistics for imported fixture shipments are shown in Figures 2.12 and 2.14.

Figure 2.7: Estimated U.S. Hardwire Lighting Market Breakdown - 1993
Includes Domestic, Import, and Export Shipments



Source: Domestic and export numbers are from U.S. Census Bureau Report # MA36L935, Table 2. Quantity and Value of Shipments of Electric Lighting Fixtures: 1992 - 1993

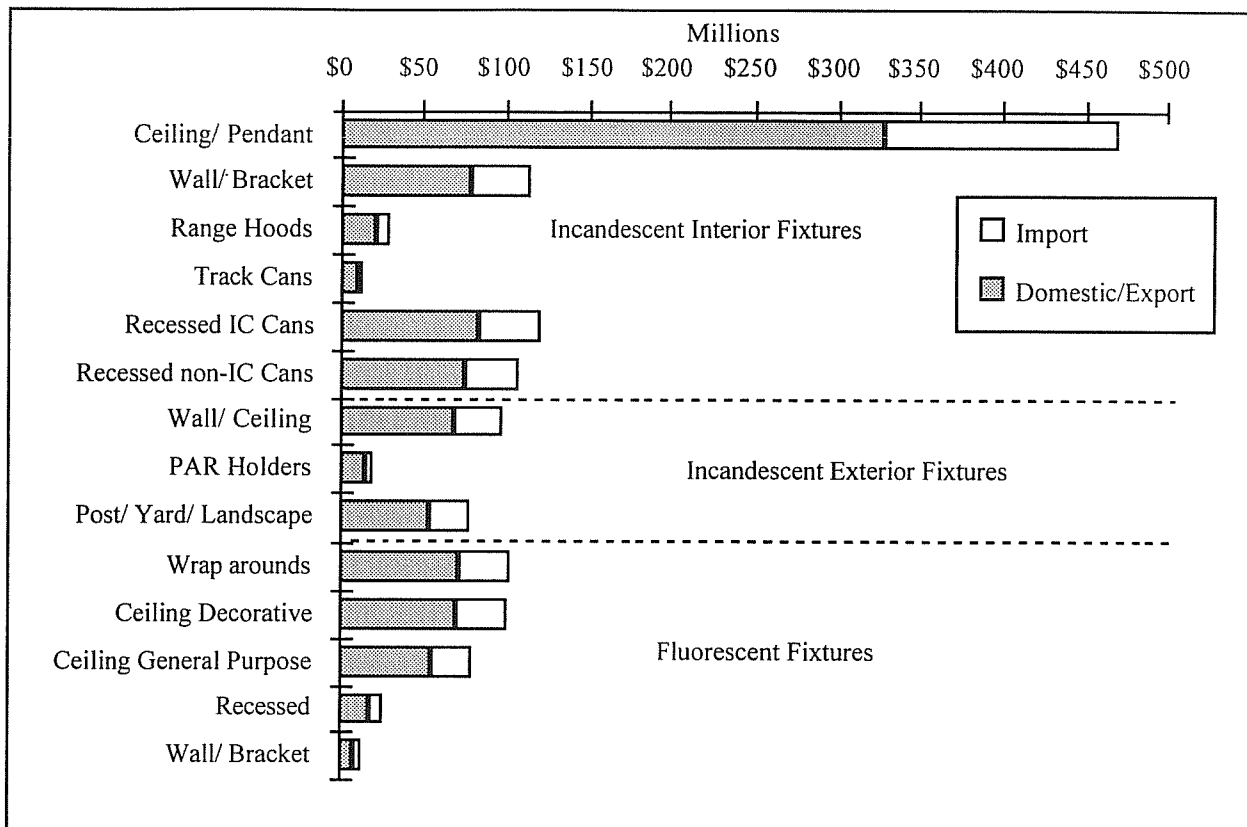
Number of PAR Holders is estimated as one per new housing start based on the U.S. Bureau of the Census, Current Construction Reports, Series C25 Characteristics of New Housing: 1993, U.S. Department of Commerce, Washington, DC 1994

Number of Range Hood Fixtures is estimated as one per family based on the U.S. Bureau of the Census, Current Construction Reports, Series C25 Characteristics of New Housing: 1993, U.S. Department of Commerce, Washington, DC 1994

Total Import Numbers from personal communication with Foreign Trade Division, U.S. Department of Commerce, Reba, 301/457-2242, 3/20/95

Breakdown of import numbers calculated based on same percentage breakdown as domestic numbers.

Figure 2.8: Value Of Residential Hardwire Lighting Fixture Shipments - 1993
Includes Domestic, Import, and Export Shipments



Source: Domestic and export numbers are from U.S. Census Bureau Report # MA36L935, Table 2. Quantity and Value of Shipments of Electric Lighting Fixtures: 1992 - 1993

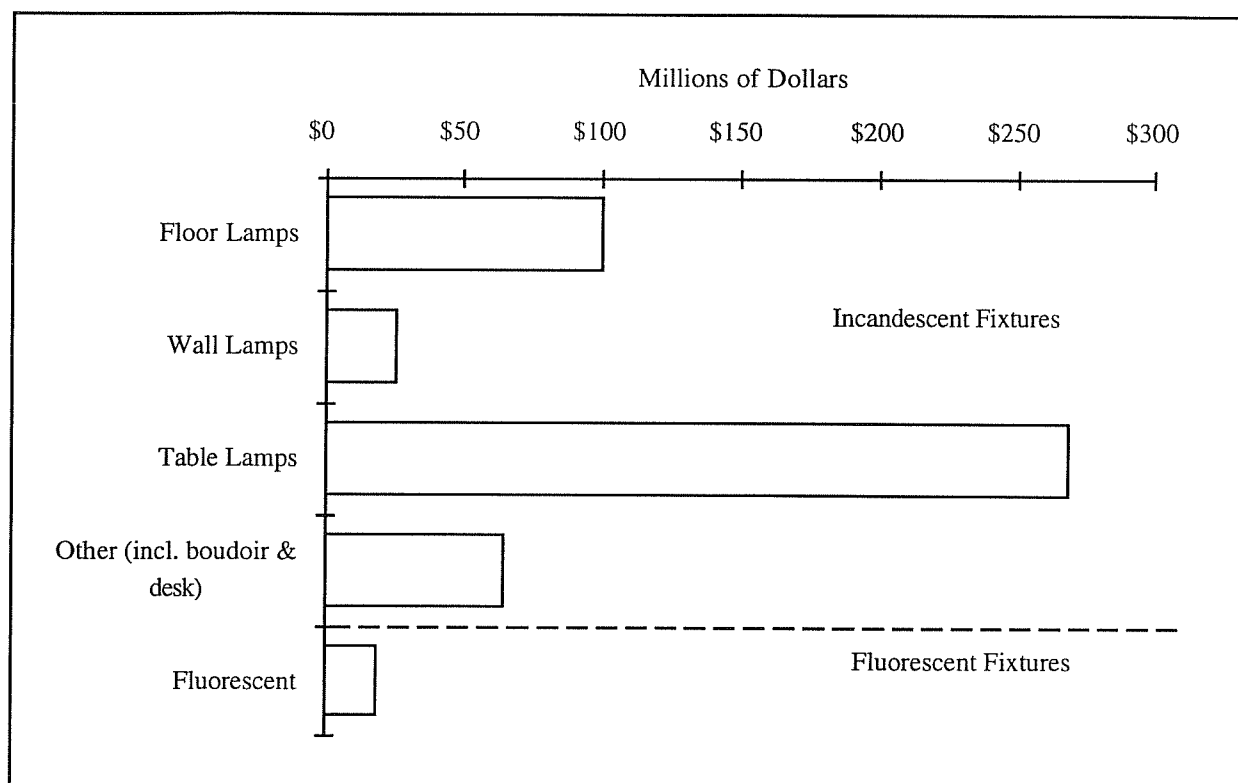
Number of PAR Holders is estimated as one per new housing start based on the U.S. Bureau of the Census, Current Construction Reports, Series C25 Characteristics of New Housing: 1993, U.S. Department of Commerce, Washington, DC 1994

Number of Range Hood Fixtures is estimated as one per family based on the U.S. Bureau of the Census, Current Construction Reports, Series C25 Characteristics of New Housing: 1993, U.S. Department of Commerce, Washington, DC 1994, with an average value of \$15 per unit.

Total Import Numbers from personal communication with Foreign Trade Division, U.S. Department of Commerce, Reba, 301/457-2242, 3/20/95

Breakdown of import numbers calculated based on same percentage breakdown as domestic numbers.

**Figure 2.9: Residential Portable Lighting Fixtures—
Value of Shipments by Fixture Type - 1992**
Includes Exports but not Imports



These values represent the manufacturer's sale price to the distributor.

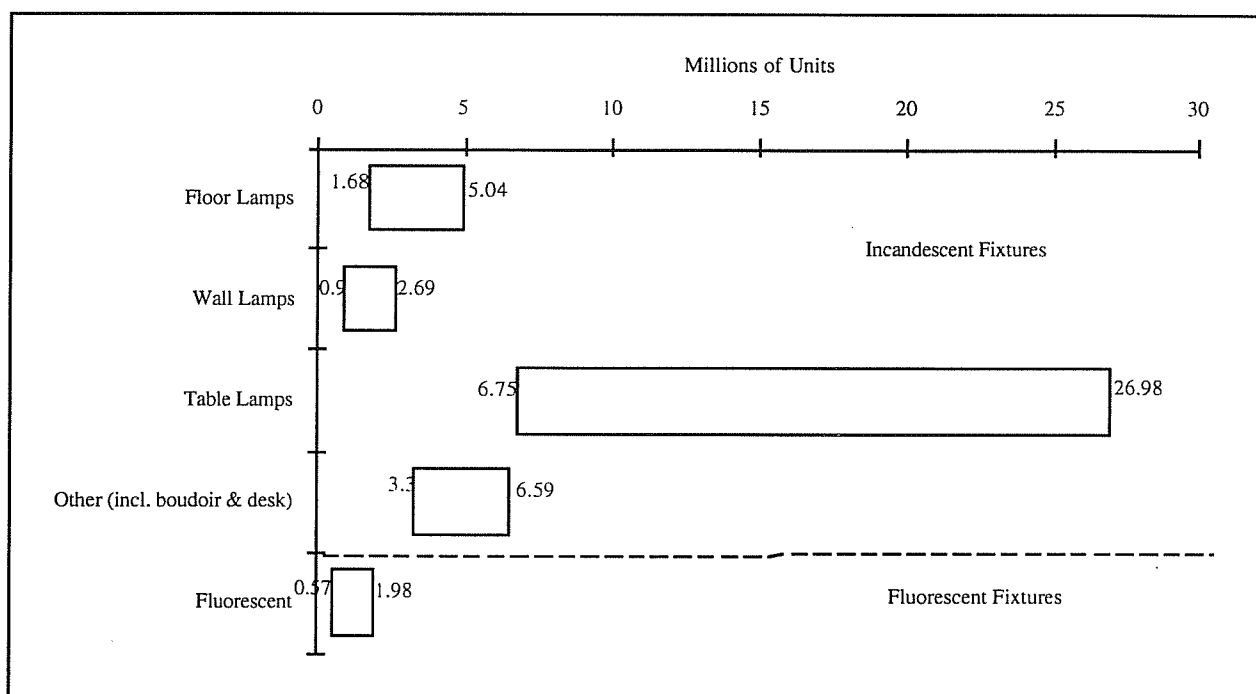
Source: U.S. Department of Commerce, Bureau of the Census, 1002 Census of Manufacturers, MC92-I-36C(P), issued October 1994

Figures 2.7 and 2.8 permit a number of interesting observations about product mix: Incandescent fixtures account for 76% of all new sales; ceiling/pendant fixtures and recessed can type fixtures (including both insulated can (IC) and non-IC types) are the most popular fixture types, accounting for 26% and 24% of all lighting fixtures sold respectively; and exterior fixtures account for 17% of all sales. Though fluorescent fixtures have a 15% actual penetration, their market share (new fixture sales) is 23%. Building standards clearly affect these numbers: for example, California's Title 24 requires that the primary light source in residential kitchens and bathrooms be fluorescent. Fluorescent fixtures are also common in garages, workshops, and utility rooms.

This report adds breakouts to these analyses for range hoods and PAR lamp holders because, though their numbers are not great (estimated at 2 million for range hoods and over a million for PAR lamp holders) each fixture type may represent a significant energy consumer. The lights built into kitchen range hoods are often lamped with 60–75 Watt incandescents. In some situations, these range hood lights are used as a night light, or in kitchens which are daylight the lights may be inadvertently left on during the day. PAR lamp holders are commonly installed to provide security lighting, operated from dusk to dawn, and are lamped with higher wattage (120–150 Watt) standard incandescent PAR floodlights.

Because the census only addresses the gross value of portable lighting fixture shipments as presented in Figure 2.9, we estimate a range of average wholesale costs for each fixture type to calculate the total quantity of each fixture type actually sold. Figure 2.10 shows the range of estimated domestic shipments by portable fixture type. Figure 2.11 shows the portable lighting market breakdown for all domestic and import shipments combined (the median of the range for the domestic shipments shown in Figure 2.10 is used as the base). With an estimated 46% of total portable fixture sales, table lamps stand out as the most significant portable fixture type, distantly trailed by floor lamps and "other" (boudoir, desk, etc.) portables. The fluorescent portables shown represent under-shelf fluorescent type plug-in fixtures and desktop task lights.

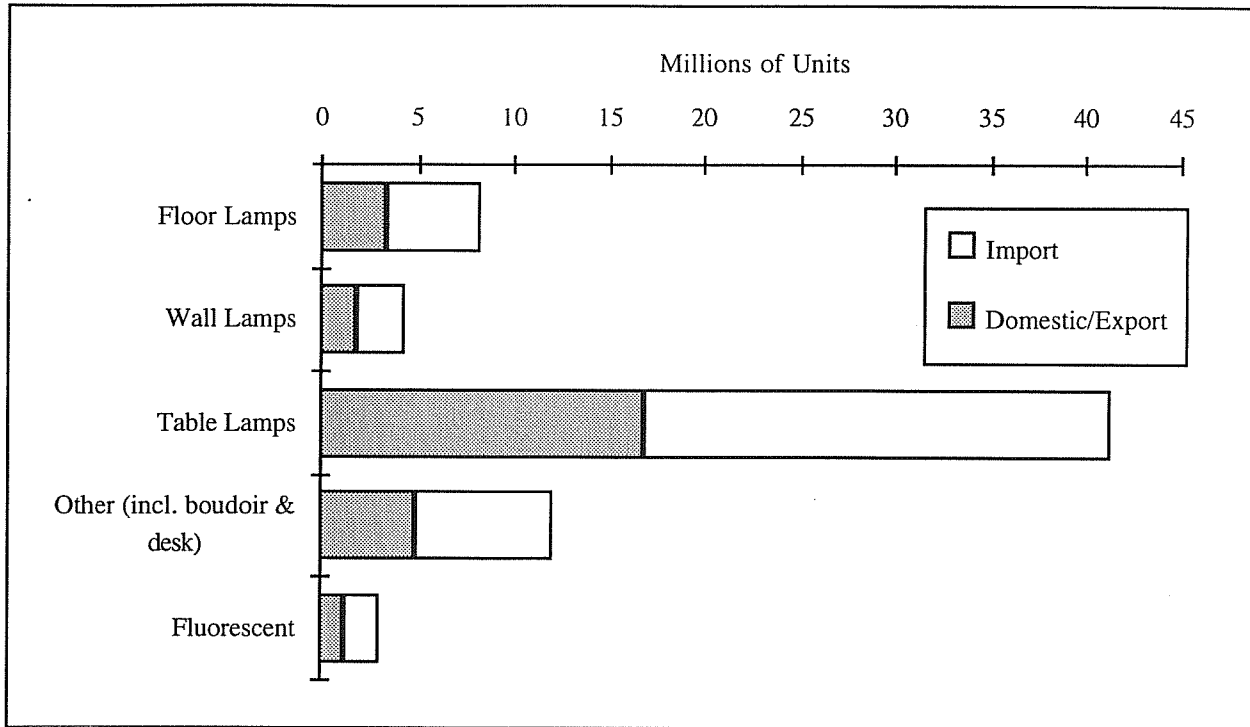
**Figure 2.10: Residential Portable Lighting Fixtures—
Estimated Number of Units by Fixture Type - 1992**
Includes Exports but not Imports



These values are based on the dollar values from the U.S. Department of Commerce, Bureau of the Census, 1002 Census of Manufacturers, MC92-I-36C(P), issued October 1994 and Rising Sun estimates of average manufacturer sales price to distributor as follows:

Floor Lamps - \$20 - \$60; Wall Lamps - \$10 - \$30; Table Lamps - \$15 - \$40; Other - \$10 - \$20; Fluorescent - \$10 - \$35

Figure 2.11: Estimated U.S. Portable Lighting Fixture Market Breakdown - 1993
Includes Domestic, Import, and Export Shipments



Source: Domestic and export numbers are from U.S. Census Bureau Report # MA36L935, Table 2. Quantity and Value of Shipments of Electric Lighting Fixtures: 1992 - 1993

Total Import Numbers from personal communication with Foreign Trade Division, U.S. Department of Commerce, Reba, 301/457-2242, 3/20/95

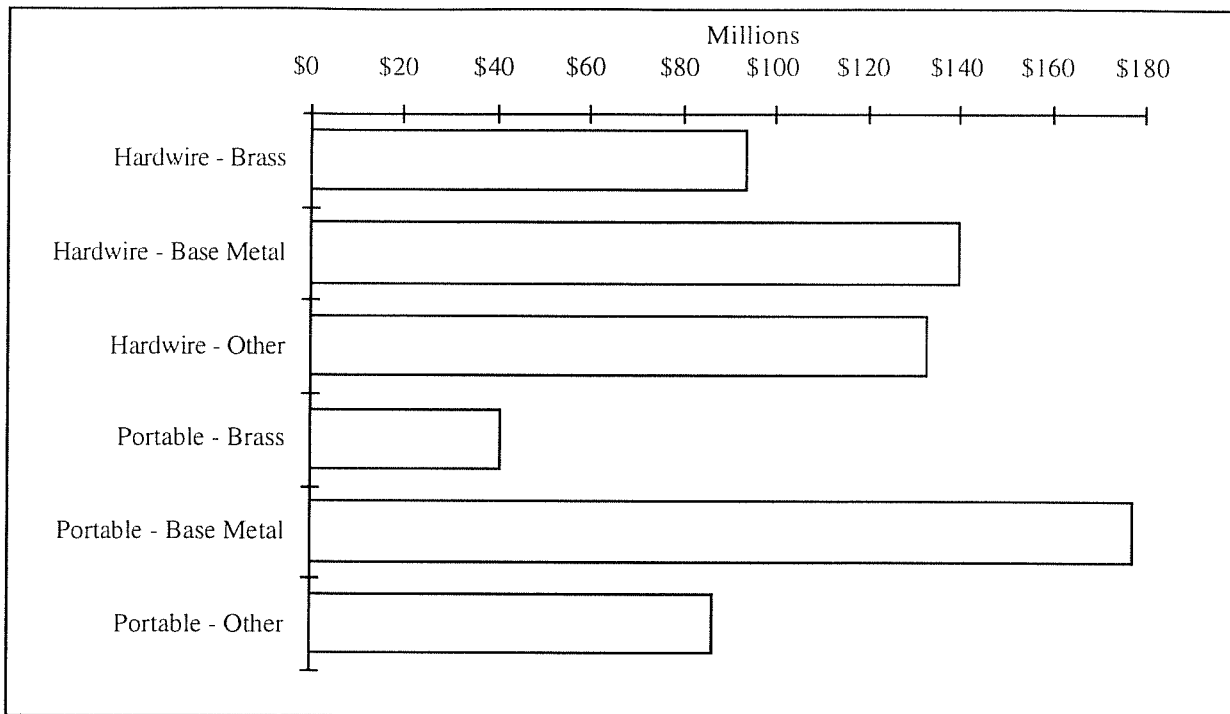
Domestic numbers used are median of ranges from Figure 11.

Breakdown of import numbers calculated based on same percentage breakdown as domestic numbers.

2.5 Turnover

In order to assess the amount of time it might take to infuse energy-efficient lighting into the residential marketplace, it is important to know where new lighting stock goes and how rapidly the stock naturally turns over. While Figures 2.7 - 2.13 document new fixture sales and volume, they do not tell us whether new construction, improvement/renovation, or replacement is driving these sales.

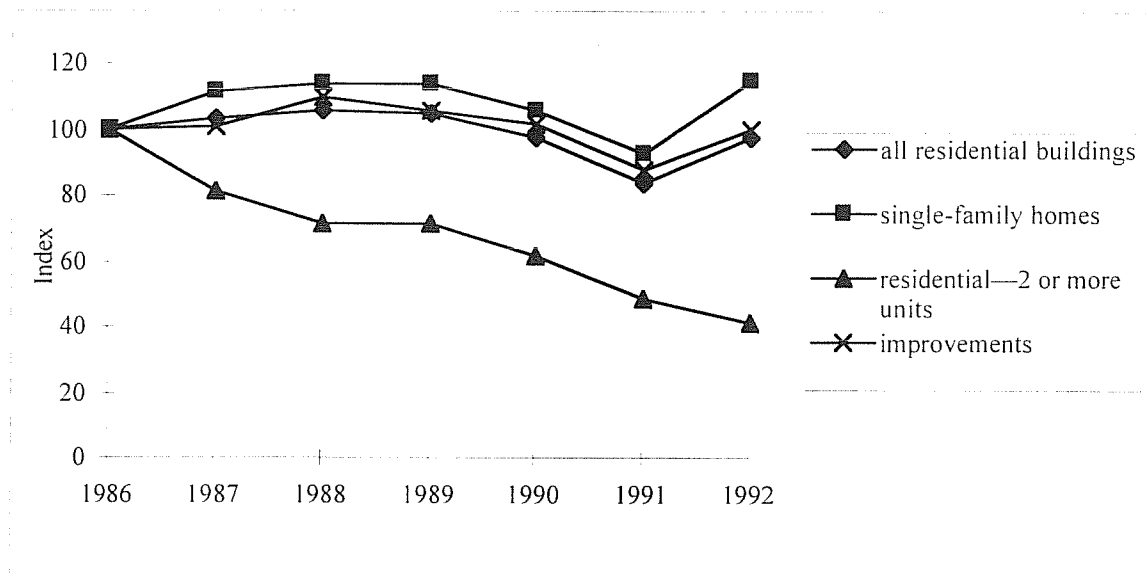
Figure 2.13: Electric Light Fixtures—Value of Imports by Type - 1993



Source: Personal communication with Foreign Trade Division, U.S. Department of Commerce, Reba, 301/457-2242, 3/20/95

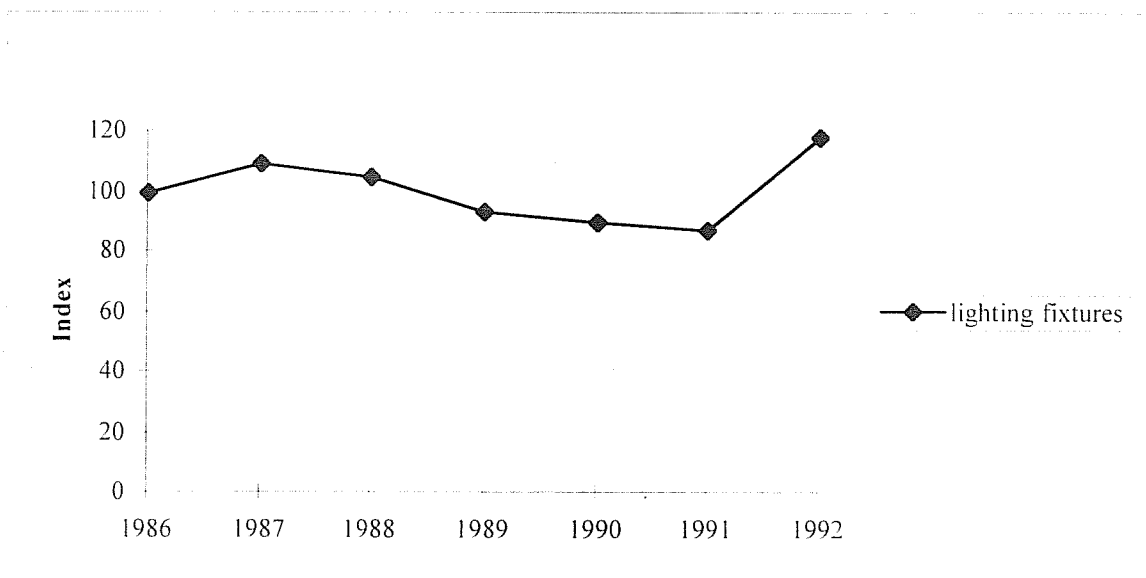
Figure 2.14 plots the annual historical value of new residential construction—including home improvements but not simple replacements—while Figure 2.15 plots the historical value of hardwire electric lighting fixture shipments. Note that the value of lighting fixture shipments closely tracks the value of new construction for "All Residential Buildings" and "Improvements." Between 1986 to 1992, value of all new home construction (including multifamily) was \$920 billion, and the value of home improvement construction was \$380 billion. Lacking better data, if we make the (rather tenuous) assumption that a correlation exists between the two, then we can propose that that about 70% of hardwire fixtures sold *for new construction* go into new homes and 30% are used in home improvements.

Figure 2.14: Annual Value of New Construction - Residential Buildings



Source: "The U.S. Lighting Fixtures Industry; An Economic & Market Study", Economic Industry Reports, 1993-94 Edition

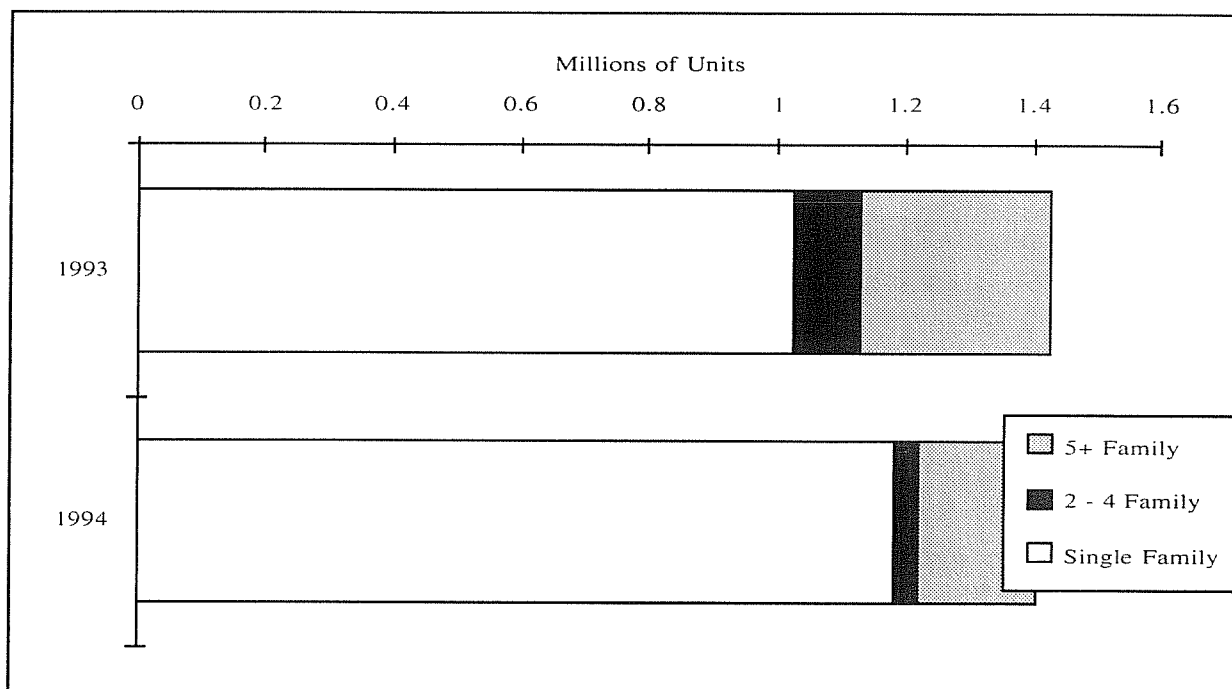
Figure 2.15: Annual Value of Hardwire Electric Lighting Fixture Shipments—Residential Buildings



Source: U.S. Census Bureau Report # MA36L935, Table 2. Quantity and Value of Shipments of Electric Lighting Fixtures: 1992 - 1993

Though new residential construction amounts to over 1.5 million homes per year including multi family units (see Figure 2.16). This is equal to only 1.6% of the entire U.S. housing stock. The existing 96 million households represent a much larger potential market for the replacement of existing lighting fixtures and for home improvement. Nevertheless the cost and effort required to replace existing fixtures are major disincentives for homeowners and particularly for tenants.

Figure 2.16: National Association of Home Builders Forecast of Housing Starts



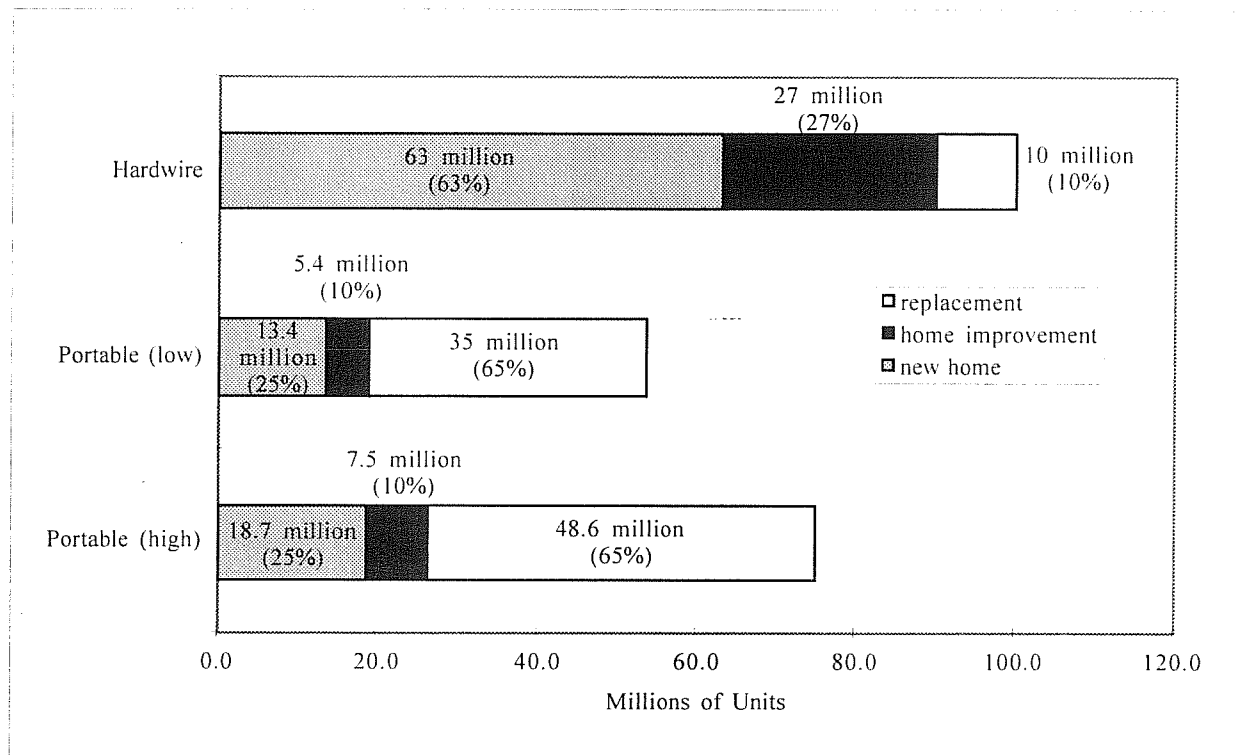
Source: 1993 data from U.S. Bureau of the Census, Current Construction Reports, Series C25 Characteristics of New Housing: 1993, U.S. Department of Commerce, Washington, DC, 1994.

1994 data from the National Association of Home Builders, Washington D.C., February 19, 1993 forecast

Portable fixtures, in contrast, account for the majority of sales in the replacement market. Portable fixtures are much more easily installed and moved, and are sold in a wider variety of retail locations. With the average household moving every 3-7 years, it is probable that most of new portable fixture purchases take place at around the time of moving.

Taking our assumption of a correlation between lighting fixture sales and new construction one step further, we propose that that 10% of *all new* hardwire fixture sales go to the replacement market. Then 63% of *all new* hardwire fixture sales can be assigned to construction of new homes ($.7 \times .9 = .63$), and 27% of *all new* hardwire fixture sales can be assigned to home improvement construction ($.3 \times .9 = .27$). These extrapolations are reflected in Figure 2.17. Again lacking better data, Figure 2.17 also contains the arbitrarily assumption that 25% of portable fixtures are purchased for new homes, 10% are purchased for home improvement and 65% are purchased as replacements. The low and high ranges are derived from the range of price estimates.

Figure 2.17: Estimated Hardwire and Portable Fixtures by New Construction vs. Renovation/Replacement Markets - 1993
Includes Domestic and Import Shipments only



Source: Hardwire fixture numbers from U.S. Census Bureau Report # MA36L935, Table 2. Quantity and Value of Shipments of Electric Lighting Fixtures: 1992 - 1993

Portable fixture numbers are based on the dollar values from the U.S. Department of Commerce, Bureau of the Census, 1002 Census of Manufacturers, MC92-I-36C(P), issued October 1994, and Rising Sun estimates of average manufacturer sales price to distributor as follows:

Floor Lamps - \$20 - \$60; Wall Lamps - \$10 - \$30; Table Lamps - \$15 - \$40; Other - \$10 - \$20; Fluorescent - \$10 - \$35

New construction / renovation split for hardwire units based on average percentage of total construction value in residential buildings attributed to renovation for the years 1986 - 1992.

Split = 60% New Construction; 30% Renovation; 10% Replacement

2.6 Decision Makers/Distribution Channels

In order to penetrate the residential marketplace with energy-efficient lighting, one must understand how conventional lighting products find their way into the home. In addition to the homeowner or tenant, a number of other players may be involved. While portable lighting is typically selected by the homeowner, hardwire fixtures are most commonly specified by a design professional, builder, electrical contractor, or lighting showroom. Figure 2.20 shows which parties most commonly specify residential lighting, particularly hardwire fixtures, by house type.

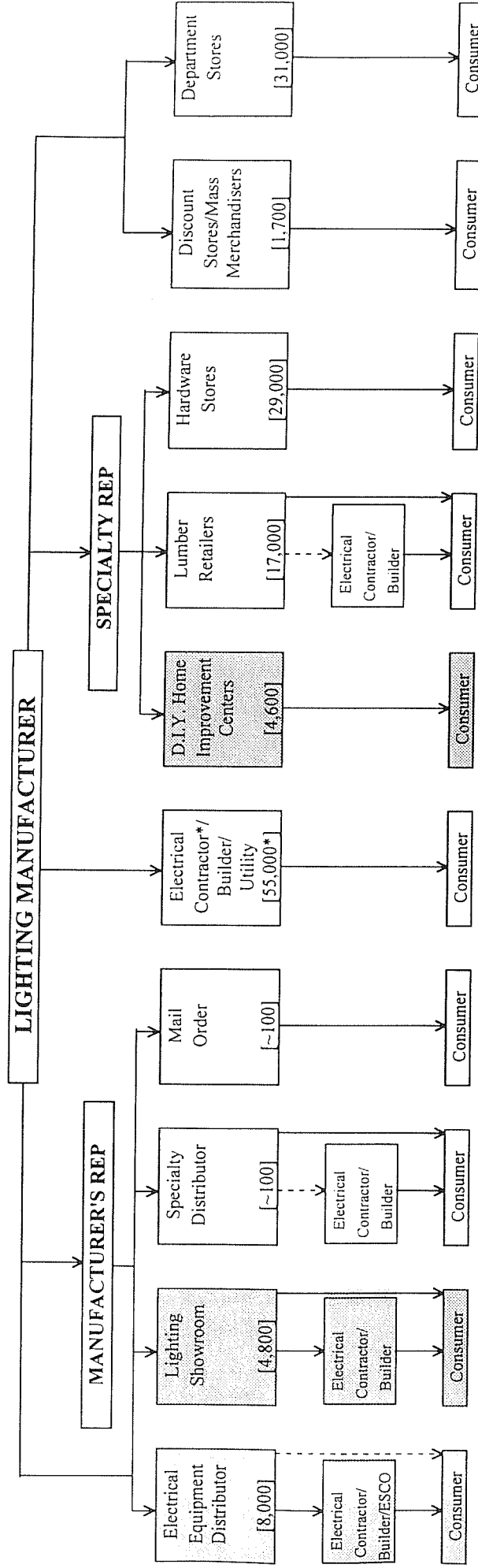
Figure 2.18: Who Specifies Residential Lighting?

Specifier	Tract Home	Semi- Custom Tract Home	Custom Home	Multi-Family Housing
Architect			X	X
Homeowner		X	X	
Builder	X	X		X
Electrical Contractor		X		X
Lighting Showroom		X	X	X
Lighting Designer			X	X
Interior Decorator		X	X	X
Electrical Engineer				X

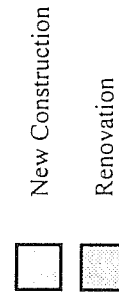
Figures 2.19 and 2.20 chart the primary distribution channels for hardwire and portable fixture sales. The bracketed numbers shown in each flow chart approximate the number of outlets known for each distribution channel. Figure 2.19 highlights that electrical contractors are the most common source for hardwire fixtures in new construction while lighting showrooms and do-it-yourself (DIY) home improvement centers are the most popular sources for renovation/replacement. For portable fixtures, Figure 2.20 highlights that lighting showrooms are the most common source for consumers shopping for higher quality or specialized designer lighting while furniture/home decor, discount stores/mass merchandisers, and department stores are the primary sources for commodity portables.

Figure 2.19:

RESIDENTIAL LIGHTING DISTRIBUTION CHANNELS HARDWARE FIXTURES



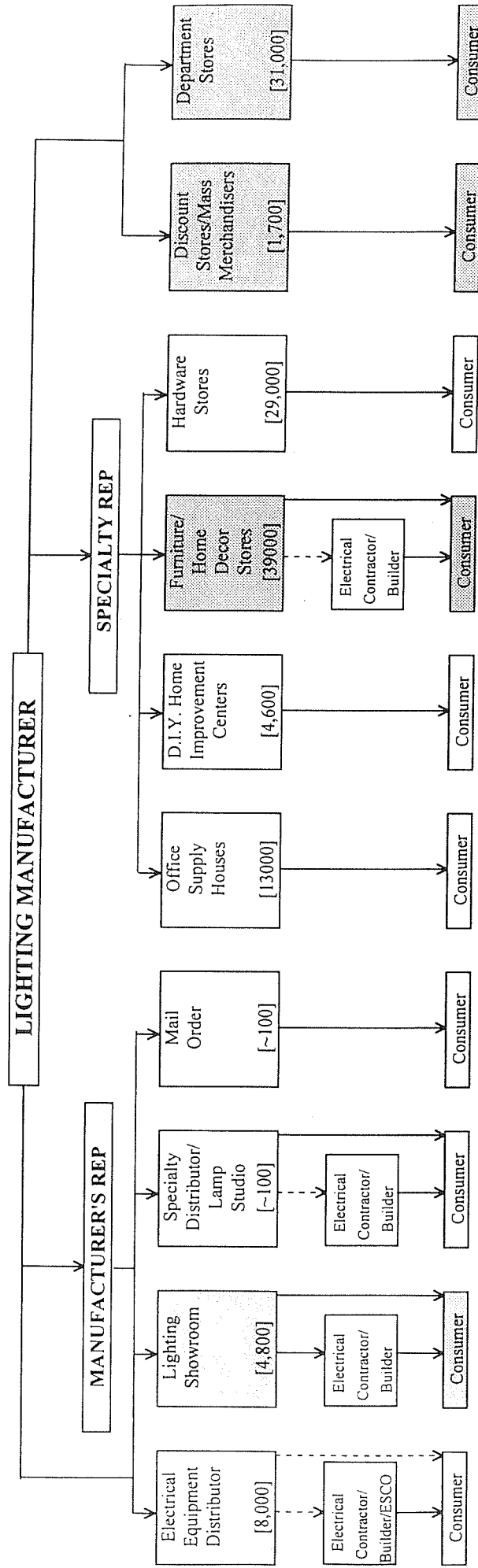
Primary Distribution Channels



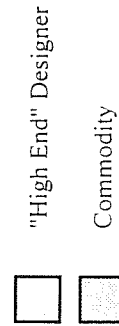
Source: Number of outlets obtained from personal conversation with American Business Lists, Omaha Nebraska, 402/593-4500

Figure 2.20:

RESIDENTIAL LIGHTING DISTRIBUTION CHANNELS PORTABLE FIXTURES



Primary Distribution Channels



Source: Number of outlets obtained from personal conversation with American Business Lists, Omaha Nebraska, 402/593-4500

2.7 Conclusions

Lighting studies undertaken by utilities to date have been limited, but those that are available show enough consistency to allow an initial description of the lighting in a “typical” U. S. residence. We believe that the TPU data, though from a small sample of single-family residences, brings us within hailing distance of such an approximation. Based on the PG&E and SCE data, the actual average house is likely to be smaller than the TPU average.

The available data confirm that the greatest opportunity for savings resides in the major luminaire types (ceiling, wall, table, and outdoor). The best value can be obtained by replacing fixtures with the longest operating hours in these categories with energy-efficient fixtures.

To have a substantial effect on residential lighting energy use, the implications of the large fraction of imported portable fixtures must be considered. It seems clear that the market for these fixtures is largely driven by first cost; the average price of an imported fixture is less than half the average price of a domestic fixture.

The characterization of residential lighting in the U. S. market permits attention to be focused on specific targeted programs with the greatest chance of success, and lays the groundwork for the implementation and analysis of these programs.

By installing energy-efficient lighting in place of all new and existing incandescent residential sockets that are turned on for significant operating hours, the technical potential exists to reduce the national electric bill by as much as \$5 billion annually, displace the need for the equivalent of 20 large power plants, and eliminate the emission of 94 million tons of CO₂ greenhouse gases. Accomplishing these savings though, represents an immense challenge. Little forethought is given to energy savings in the specification of most residential lighting, yet \$3.4 - \$4 billion is spent annually on new fixtures. Lack of product availability, lack of application knowledge, and the significant first-cost premium for energy-efficient lighting are substantial barriers to the penetration of energy-efficient lighting into the residential sector. Overcoming these barriers will require a concerted effort by a broad spectrum of vested parties, including legislators, regulators, utilities, manufacturers, distributors, retailers, designers, builders, electrical contractors, educators, and consumers.

References

- ¹ Hanford, J.W., J. G. Koomey, L.E. Stewart, M.E. Lecar, R.E. Brown, and L.K. Price, *Baseline Data for the Residential Sector and Development of a Residential Forecasting Database*. Lawrence Berkeley Laboratory report LBL-33717, May 1994.
- ² Mills, Evan, Michael Siminovitch, Erik Page, and Robert Sardinsky, "Dedicated Compact Fluorescent Fixtures: The Next Generation for Residential Lighting." Proceedings of Right Light Three Conference, Newcastle-upon-Tyne, England, June 1995.
- ³ Sardinsky, Robert, "U.S. Residential Lighting Fixture Marketplace". Prepared by Rising Sun Enterprises for Lawrence Berkeley Laboratory, June 1995.
- ⁴ David Lerman, "Baseline Residential Lighting Study". Tacoma Public Utilities, 1994. Presented at an informal session on residential lighting at the 1994 ACEEE Summer Study.
- ⁵ Tacoma Public Utilities, "Second Six-Month Data Summary," Tacoma Public Utilities, 28 October 1994.
- ⁶ Robinson, Donna M., "Comprehensive Residential Lighting Retrofits: A Case Study". Presented at ACEEE 1992 Summer Study on Energy Efficiency in Buildings in Asilomar, CA. American Council for an Energy-Efficient Economy, Washington DC, 1992.
- ⁷ Grays Harbor PUD, The Grays Harbor PUD Compact Fluorescent Maximization Study. Grays Harbor, Washington, 1992.
- ⁸ Kelsey, Jim and Valarie Richardson. "1991 Residential Appliance Saturation Survey -- A Profile of the Residential Lighting Load in Northern California". ACEEE 1992 Summer Study on Energy Efficiency in Buildings Proceedings, American Council for an Energy-Efficient Economy, Washington DC, 1992.
- ⁹ Southern California Edison, *Final Report: Residential Lighting Study (Inventory Results)*. Submitted to Southern California Edison by Lorna Stucky, HBRS, Inc. with Scott Dimetrosky, Barakat and Chamberlin, Inc., July 23, 1993.
- ¹⁰ Hanford et al., 1994, op. cit.
- ¹¹ Mills et al, 1995, op. cit.
- ¹² U.S. Department of Commerce, Bureau of the Census, 1992 Census of Manufactures, MC92-1-36C(P), October 1994.
- ¹³ *The U.S. Lighting Fixtures Industry; An Economic & Market Study 1993-94 Edition, Volume II*, Economic Industry Reports, Inc. p. 210.