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Residential Lighting: The Data to Date

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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 27% of incandescent residential fixtures are responsible for over 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[i] ceiling fixtures in kitchens, portable fixtures in living/family rooms, hardwired fixtures in dining rooms, and hardwired fixtures outdoors. An assessment of the market for residential fixtures shows that nearly half of new residential fixtures are imported, about 60% of new fixtures sold are hardwired, and about half of all new fixtures sold are for ceiling installation.

[i] "Hardwired" fixtures are those that are wired permanently in place, typically in a wall or ceiling. "Portable" fixtures consist of table, floor, and desk lamps and others that are simply plugged into an ordinary socket and can thus be easily moved.

Introduction

About 2.9 billion light fixtures illuminate the nation's 96 million households[ii]. Eighty-five percent of these are equipped with incandescent lamps, while the remainder are primarily fluorescent. 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 use[1]. 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 gas[2]. This translates to an average of about 1440 kWh and $115 per year for each U. S. home (at 8 cents per kWh). In this paper, we attempt to describe actual U.S. residential lighting usage and provide information about the residential lighting marketplace, to help residential lighting program designers and researchers target their efforts most effectively.

Residential lighting is difficult to describe simply because of its 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 aesthetics of lighting products and the light they produce strongly influence consumer selection. Utilities have learned from experience that programs that promote screw-in compact fluorescent lamps are prone to misapplication, resulting in poor lighting quality and customer dissatisfaction. Successful program designs must carefully consider the interaction between occupants and their lighting products, focusing on attractive fixtures designed for efficient light sources rather than on lamps alone. As a basis for program design, this analysis presents detailed new residential lighting use data gathered by Tacoma Public Utilities and draws on the best data available from four other recent residential lighting studies to provide important insight into U.S. residential lighting use patterns.

The data tabulations and comparisons presented in this paper are based on the most detailed and comprehensive residential lighting monitoring study undertaken to date. However, a key issue in applying the results of this study is the degree to which the subjects of the cited studies can be considered representative of the United States as a whole, or to any specific subpopulation within. While we cannot answer this question precisely, the consistency of the results between the five studies implies that the data provide a reasonable estimate of current U.S. residential lighting conditions, at least on a room-by-room basis.

Section 1 of this paper contains a description and analysis of the current stock of lighting products (lamps and fixtures) installed in U.S. residences, with insight into which lighting applications (fixture types, room types, lamp types, etc.) are responsible for the most significant energy use and have the greatest potential for pollution prevention. Section 2 provides a description of the current market processes affecting residential lighting products.

[ii] Assumes 30 fixtures per household.

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

Several studies of residential lighting have been conducted by utilities and energy services companies (ESCOs) around the United States in recent years. Most have 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 to 7,700 homes. In all but two of the studies, energy use was estimated from residents' self-reported hours of use, while in the most recent (and most detailed) study every accessible fixture in the home was equipped with a data logger that recorded 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 two more whose results were presented either in published or internal reports. In this section we discuss those studies, comparing and analyzing their results.

1.1 New Data

Tacoma Study (Tacoma)[3,4,5]

The most comprehensive monitoring study for which we have been able to obtain data was carried out by Tacoma Public Utilities (WA), Eugene Water and Electric Board (OR), Pacific County PUD #2 (WA), City of Port Angeles (WA), Portland General Electric (OR), Peninsula Light Company (WA), and Snohomish County PUD (WA), and funded by Bonneville Power Administration. The importance of this study lies in its use of light loggers to record the hours of use for 82% of the lighting fixtures in every home in the study. All remaining fixtures were included in the database unless mounted above 12 feet[iii]. All but one (Grays Harbor, whose sample size was very small) of the previous studies were able to monitor at best a few fixtures in every home. Data were collected in four six-month periods over two years, from 1994 to 1996.

The Tacoma study set out to answer four primary research questions:

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

In each of the four six-month periods 50 houses were fully monitored, using one light logger per fixture or group of fixtures. By the end of the study a total of 161 homes had been monitored for periods ranging from four months to a year, as there was some carryover from one period to the next.

Participants in the study were recruited by various means[iv]. The homes had from one to eight occupants, an average of 13.3 rooms, and a range of floor areas (data were collected in bins of

[iii] The average wattage of fixtures with loggers was 108. The average wattage of fixtures with no loggers is 90.

[iv] Each utility attempted to obtain a group of single family homes representative of their service territory: Two matched their samples to recent customer characteristics surveys; one used a "stratified random" sample based on the number of people home during the day and the square footage of the home; another used utility employees and satisfied themselves that their sample was representative of their service territory; a rural utility selected participants from a

1000 square feet; the resultant average floor area is approximately 1730 square feet). There appears to be only a small correlation between energy use for lighting and either number of occupants or house size.

1.2 Recent Lighting Breakdowns

Free Lighting Corporation[6]

The Free Lighting Corporation (FLC) conducted a study of 7,700 homes in two distinct service areas of Orange & Rockland Utilities, Inc. The target areas were in New York and New Jersey, and only "basic service" customers (without either electric heat or electric water heat) were included in the study.

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.

During the survey, a trained lighting installer conducted a direct inspection of the number of incandescent lamps in each home. Together the homes contained 287,000 lamps, an average of 37 lamps per home. 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 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) were monitored using light loggers on all possible fixtures.

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 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 .115 W/m2 (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. Conversion to CF was possible in 421 sockets:

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list of customers that met certain criteria; another drew a "random" sample from the complete list of utility customers. A description of survey methods is available on request.The home in this study are larger than the average based on Table 1.1.

49.8% of all sockets or 58% of all incandescent sockets; 118 (14%) of the original sockets were fluorescent.

Pacific Gas & Electric (PG&E)[8]

PG&E conducted a detailed inventory of existing lighting equipment in 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 randomly chosen along each route by telemarketing. Efforts were made to minimize selection bias. The house sizes ranged from 500 to 3000 square feet, with an average of 1400.

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 interviews.

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 (portable) fixtures each accounted for 20% of lamps in high-use areas, and task lighting accounted for another 6%. The remaining 20 % were distributed among smaller categories. In kitchens and garages .37 m (4-ft) fluorescent lamps were common, but they were not widely found in other rooms.

Southern California Edison (SCE)[9]

In 1993, SCE carried out a study of residential lighting to determine typical lighting equipment and hours of operation. The study also addressed time-of-use metering. 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. With only one logger per home we believe that the usefulness of the time-of-use data gathered is limited.

The average number of lighting fixtures per dwelling varied 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 homes 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 2.9 lamps per room and 1.8 fixtures per room from the data in the SCE report.

Self-reported hours of operation may tend to overestimate actual use: For the single metered fixture occupants reported an average of 3.8 hours per day, while the meter only measured an average of 2.6 hours per day. An average of 2.8 hours of operation per day was reported by the occupants for all the remaining fixtures.

As in other studies, ceiling fixtures were found to be the most common fixture type, representing about half of all fixtures. Wall and table fixtures made up most of the remainder. Hardwired (wall

and ceiling) fixtures accounted 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).

1.3 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 161 homes over a two-year period in a limited geographical area, so it must be used with care. The Tacoma study is far more comprehensive than the Free Lighting and SCE studies (for which we have not been able to obtain actual data) or the PG&E study, and much larger than the Grays Harbor study. Its main advantages are the monitoring of lighting hours of use for all possible fixtures and the collection of data over a long period of time, making it the most meaningful of the studies we reviewed.

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 were similar in the Grays Harbor, PG&E, Tacoma, 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 Tacoma, PG&E, SCE, and Grays Harbor data yields a similar number of lamps per unit area.

The *mean* lamp daily usage for the Tacoma data set is about 2 hours per day; this is substantially lower than reported in either the SCE or Grays Harbor studies. While mean daily usage estimates range from 2 to 2.8 hours per day among these three studies, analysis of the Tacoma data indicates that "typical" (*median*) lamp usage is less than 1 hour per day. See Figure 1.1 for another perspective on concentration of lighting usage.

We also broke down the mean usage hours by lamp type, yielding 1.82 for non-fluorescent (primarily incandescent), 4.39 for compact fluorescent, and 2.83 for standard fluorescent. Evidently these subjects chose appropriate (high-use) places to install their high-efficacy lamps.

Table 1.1: Comparison of Studies

Mean values except where noted:	# of fixtures with loggers installed (total)	# of homes (total sites)	total fixtures per home	lamps per home	lamp wattage (1)	rooms per home	lamps per room	fixtures per room	calcu-lated wattage per room	whole house area(2) m2 (ft2)	whole house area without garage m2 (ft2)	watts per unit area W/m2 (W/ft2)	annual lighting energy use (mean kWh/year)	usage reporting (3) (method)	lamp daily usage (4) (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	183 (1976)	148 (1594)	15.0 (1.39)	2520	loggers on all possible	2.52
PG&E		1009		29.7	71.6					130 (1400)		16.2 (1.50)		self-reported	
Tacoma	3955	161	29.6	48.0	67.3	13.3	3.6	2.2	242	161 (1730)		19.1 (1.77)	1855(5)	loggers on 82%	1.99
SCE	477 total	692	21	34.9	60.4	11.9	2.9	1.8	177		139 (1496)	15.2 (1.41)	2150	self-reported	2.8

(1) 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 thus this number should be viewed as approximate.

(2) The Grays Harbor study reported floor area both with and without garage. The PG&E study did not specify whether or not a garage was included. The SCE study did not include the garage. The Tacoma study reported area in usage bins of 92 m2 (1000 ft2) increments with an average between 184 and 276 m2 (2000 and 2999 ft2). The number reported is calculated by assuming the average size in each of the lower three size categories is equal to its midpoint, and using 323 m2 (3500 ft2) for the >=277 m2 (3000 ft2) category.

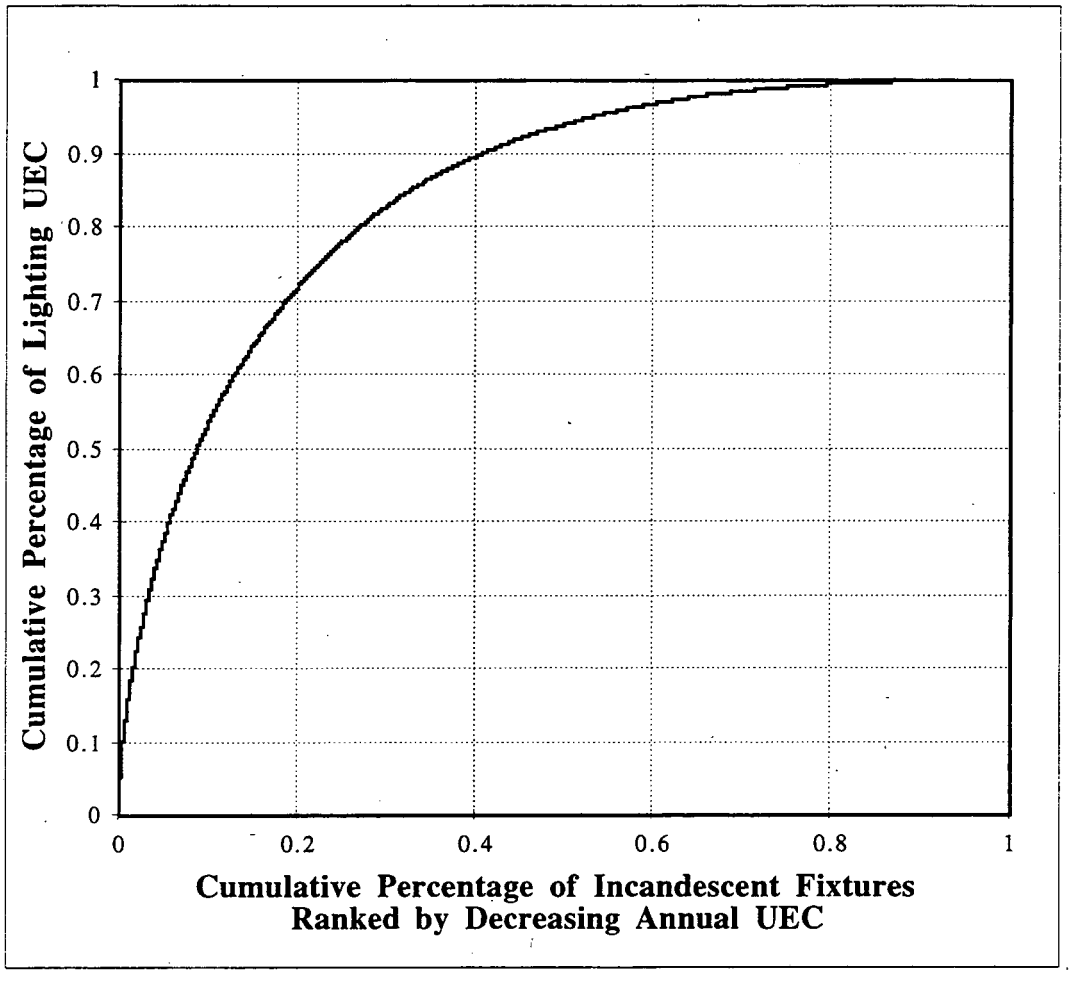
(3) PG&E usage data was self-reported on "high-use" fixtures; for all others 2.00 hours was assumed. Gray's Harbor and Tacoma installed loggers everywhere possible. SCE installed loggers on one lamp in each of 477 homes "randomly" chosen from among their larger sample.

(4) For Tacoma, this is the average of all unique logged fixtures. Some logged fixtures were never turned on during the study.

(5) The Tacoma average annual lighting energy use is based only upon the 80% of fixtures that were logged. The actual number is likely to be higher, due to energy used by the unlogged fixtures.

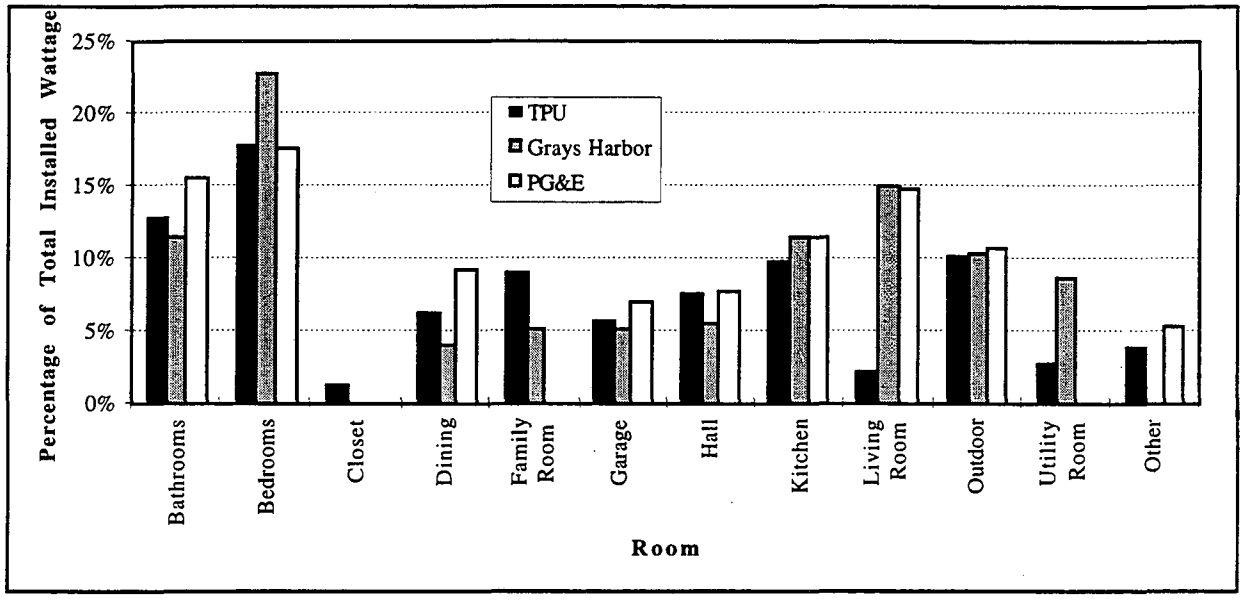
Using the Tacoma sample, we ranked incandescent fixtures in order of decreasing UEC and compared their cumulative percentage with their cumulative percentage of unit energy consumption. Figure 1.1 shows that the highest-use 27% of incandescent fixtures are responsible for over 80% of incandescent lighting energy.

Figure 1.1: Cumulative Incandescent Lighting UEC, by Household—Tacoma Data



We compared the survey results by room and fixture type for the three available data sets. Figures 1.2 and 1.3 show the results of these comparisons. The percentage of installed wattage by room (Figure 1.2) appears to be very consistent for all three studies, though differences in room definitions create bias errors and complicate comparisons. For example, the Grays Harbor study grouped closets with the nearest adjacent room, while the Tacoma study collected data on closet fixtures separately. PG&E did not include utility rooms or closets, and Grays Harbor did not include "other" rooms.

Figure 1.2: Percentage of Installed Wattage, by Room Type



Installed wattage by fixture type (Figure 1.3) also indicates a fair correlation for the two studies for which such data were available. There is less agreement here because it is more difficult to characterize fixtures than rooms. Fluorescent fixtures were included in the "Other" category in the Grays Harbor study.

Figure 1.3: Percentage of Installed Wattage, by Fixture Type

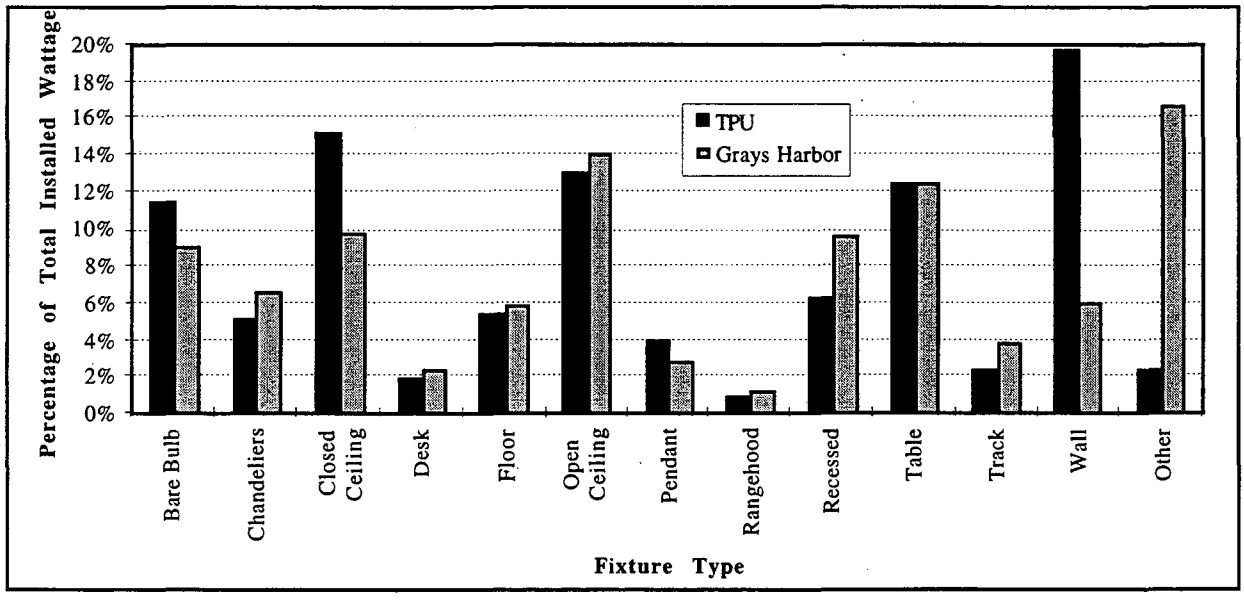


Figure 1.4 compares installed wattage with total annual lighting unit energy consumption (UEC)[v] for the entire Tacoma sample set, illustrating that installed wattage is not an accurate indicator of energy use. Though they have the highest total installed wattage, bedrooms are in the midrange of energy users. (Note that the values for bedrooms and bathrooms are for multiple rooms). The UEC is relatively low compared with the installed wattage in bathrooms, halls, and garage also. In these rooms the lights are used for shorter periods of time. In the kitchen, living room, and other high-use areas the converse is true. Most residential lighting energy is used in the kitchen, living room, bathrooms, bedrooms, and outdoors.

Figure 1.4: Tacoma Comparison of Installed Wattage and Annual Lighting UEC by Room Type

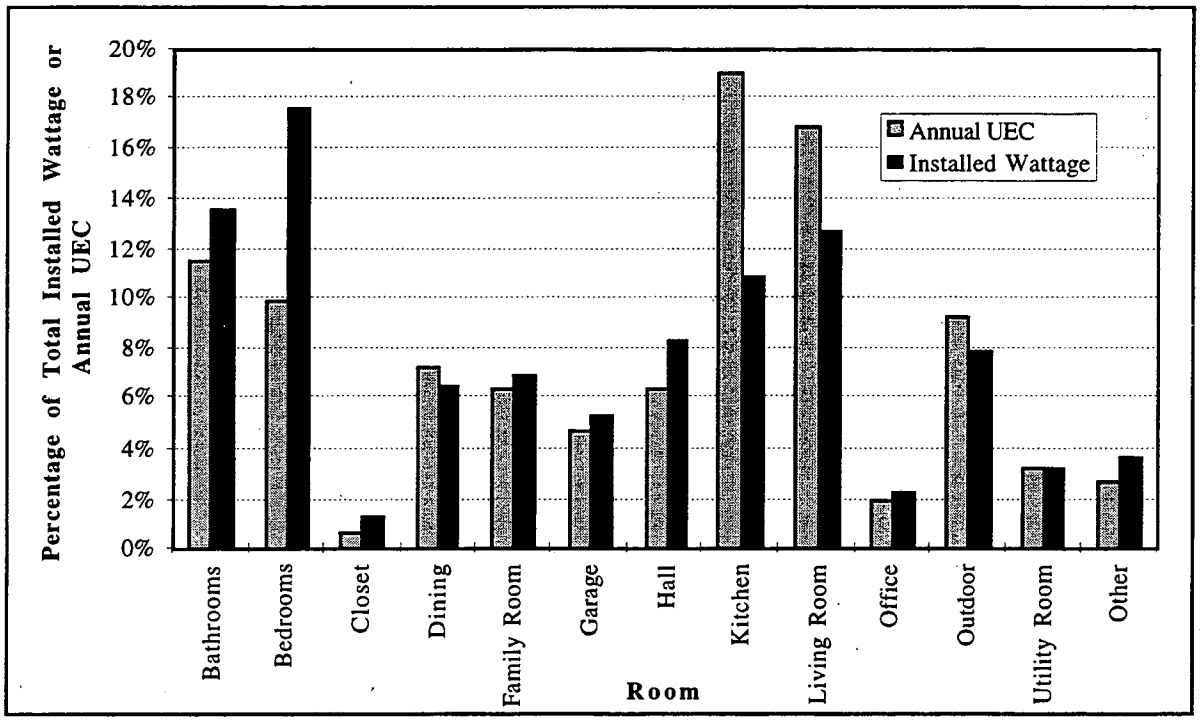


Figure 1.5 makes a similar comparison of installed wattage and annual UEC by fixture type. Ceiling (open, closed, recessed, pendant, and chandelier) fixtures as a group account for about 45% of all lighting energy use, followed by wall fixtures at 19%. Portable (table, floor, and desk) fixtures make up another 19%, leaving 17% among all other fixture types. The highest use fixtures are hardwired[vi] ceiling fixtures in kitchens, portable fixtures in living/family rooms, hardwired fixtures in dining rooms, and hardwired fixtures outdoors.

[v] 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.

[vi] "Hardwired" fixtures are those that are wired permanently in place, typically in a wall or ceiling. "Portable" fixtures consist of table, floor, and desk lamps and others that are simply plugged into an ordinary socket and can thus be easily moved.

Figure 1.5: Tacoma Comparison of Installed Wattage and Annual Lighting UEC, by Fixture Type

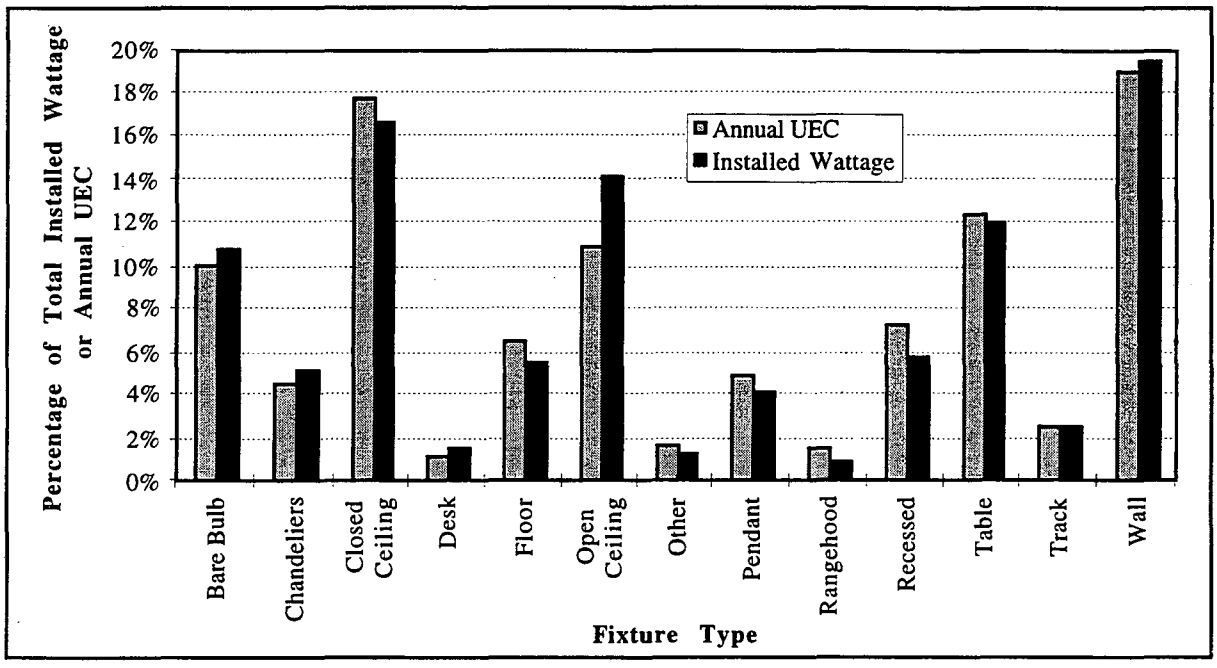


Figure 1.6 breaks down the annual UEC even further by lamp type, comparing lighting UEC by the relative percentages of fluorescent vs. non-fluorescent lamps by room. Figure 1.7 does the same by fixture type. Energy consumption by standard fluorescent lamps is highest in kitchens and garages, and in bare bulb and ceiling fixtures. Track lights, wall-mounted fixtures, and portable fixtures show little fluorescent energy use, though these applications would make good targets for efforts to improve efficiency.

Figure 1.6: Tacoma Comparison of Annual Lighting UEC by Lamp Type and Room Type

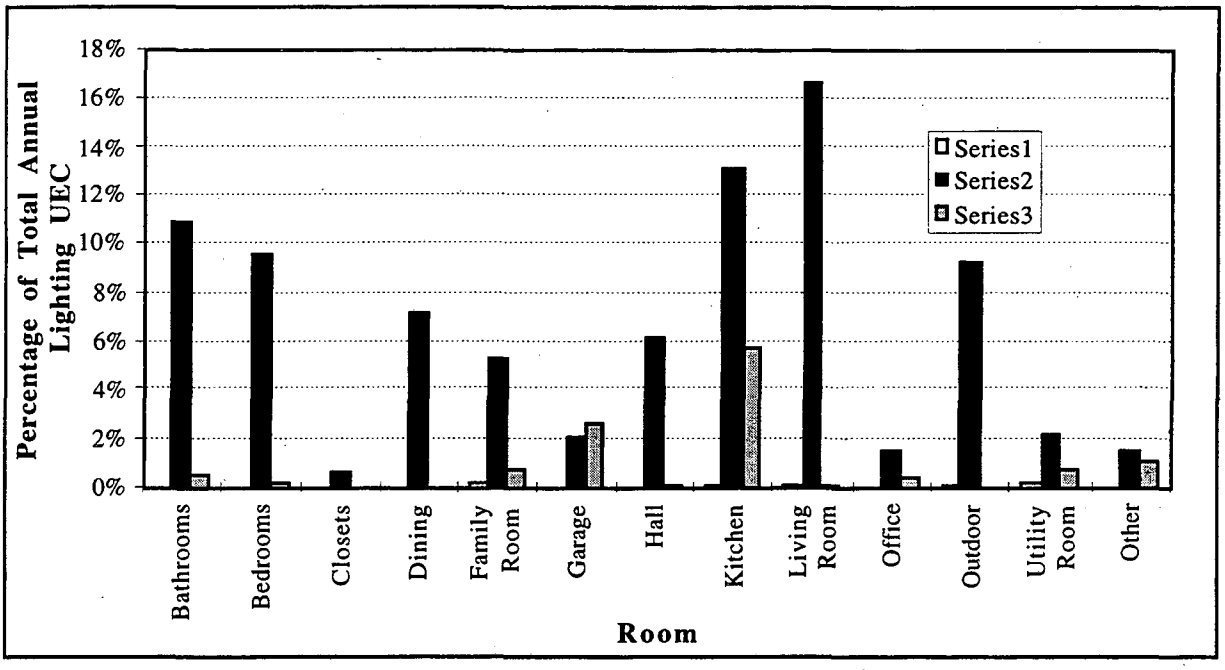


Figure 1.7: Tacoma Comparison of Annual Lighting UEC by Lamp Type and Fixture Type

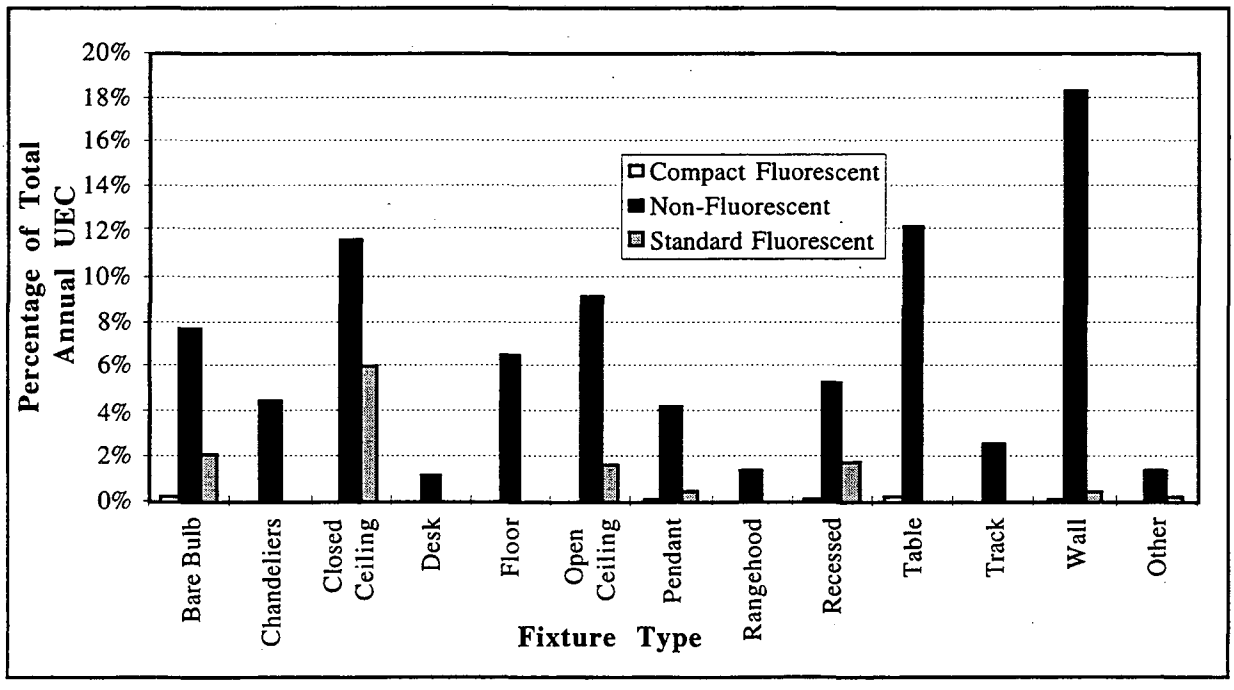


Figure 1.8 breaks down the fluorescent percentage (saturation) of total installed lamps in the PG&E service territory. As figure 1.6 also implies, standard fluorescent lamps are common in the kitchen and garage. CF lamps are distributed more evenly throughout the house where they can substitute more readily for incandescent lamps. Note that the saturations are higher than the percentage of UEC, because the efficacy of fluorescent lamps is higher than that of incandescents.

Figure 1.8: Fluorescent Lamp Saturation—PG&E Service Territory

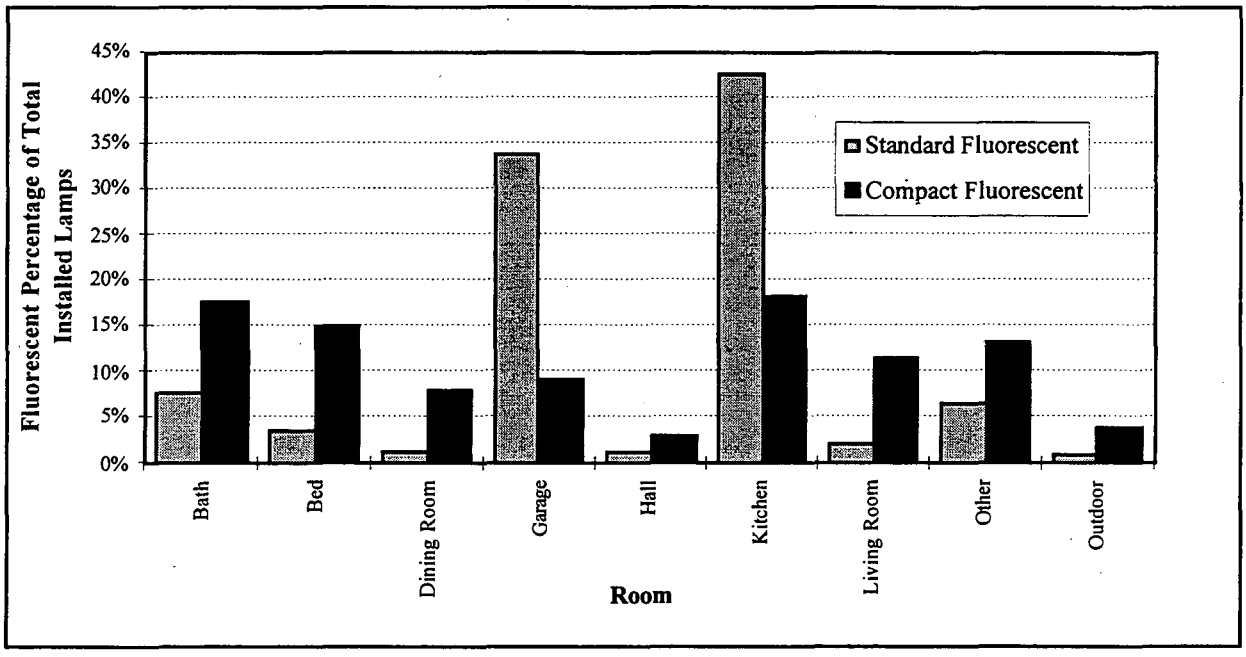
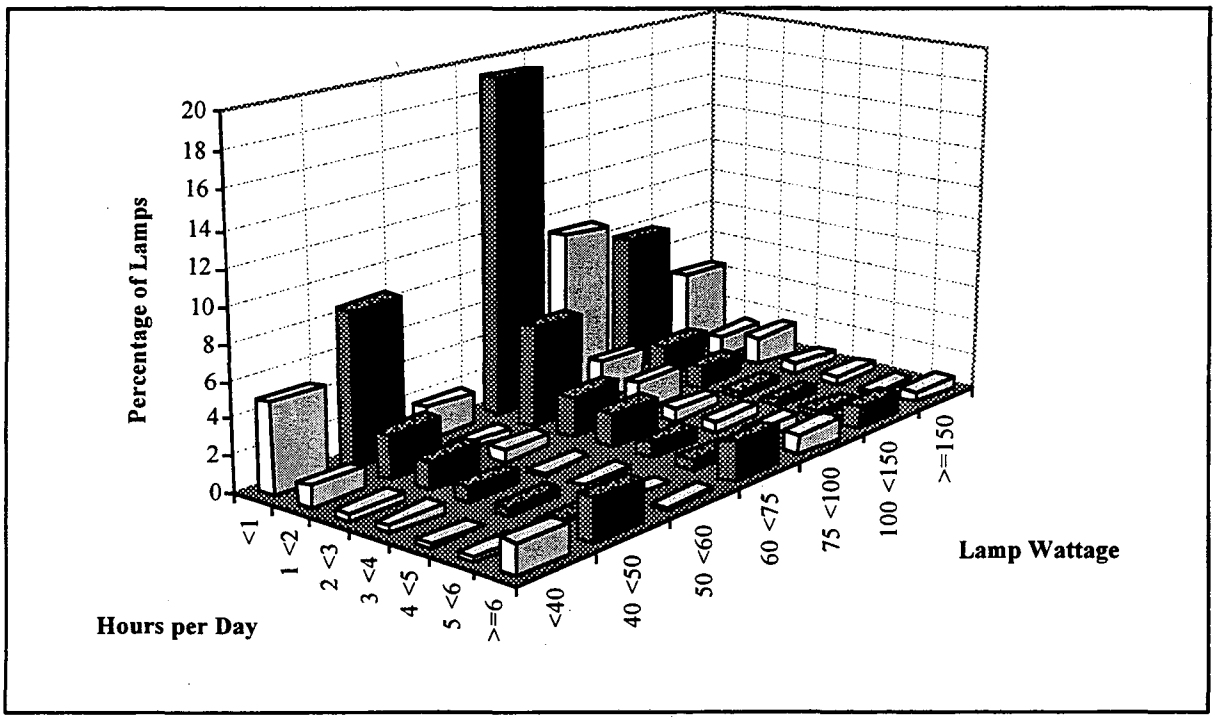


Figure 1.9 shows percentage of lamps by wattage and hours of use per day for the Tacoma study. All types of lamps are included, accounting for the two peaks that appear around 40 Watts (full-sized fluorescents and 40-W incandescents) and between 60 and 75 Watts (average incandescent lamp sizes). Most lamps of all wattages are in use less than one hour per day, and the fraction drops off quickly with longer operating hours. Above 6 hours per day, the number of lamps increases again, probably due to outdoor security lighting at night.

Figure 1.9: Lamp Wattage and Daily Hours of Use



SECTION 2: U.S. Residential Lighting Fixture Marketplace[10]

When estimating the energy savings potential from upgrading to efficient fixtures, we must also consider market forces affecting fixture performance. Residential light fixtures are unlikely to be purchased solely for their energy-conservation benefits. Though significant in terms of national energy consumption, the cost of residential lighting energy is not usually considered by the purchaser. Fixture cost, availability, and aesthetics are more likely to affect purchase decisions.

From Figure 1.1 it is clear that energy conservation efforts should concentrate primarily on the 20% of fixtures that are responsible for 75% of residential lighting energy use. In the remainder of this paper we seek to provide data on which decisions can be made in support of these efforts.

Each year, it is estimated that more than 500 domestic and foreign manufacturers collectively sell approximately 165 million light fixtures in the residential marketplace, with a retail value totaling approximately $3.4–$4 billion. Annual wholesale sales of about $2.5 billion were reported in 1993-1994[11].

New fixture design strategies are evolving rapidly. A growing handful of manufacturers now offer dedicated CF fixtures in a variety of aesthetic as well as utilitarian packages that integrate optimized optical, thermal, and ballast systems. With these fixtures, consumers can have energy efficiency without compromising lighting quality.

2.1 Fixture Marketplace

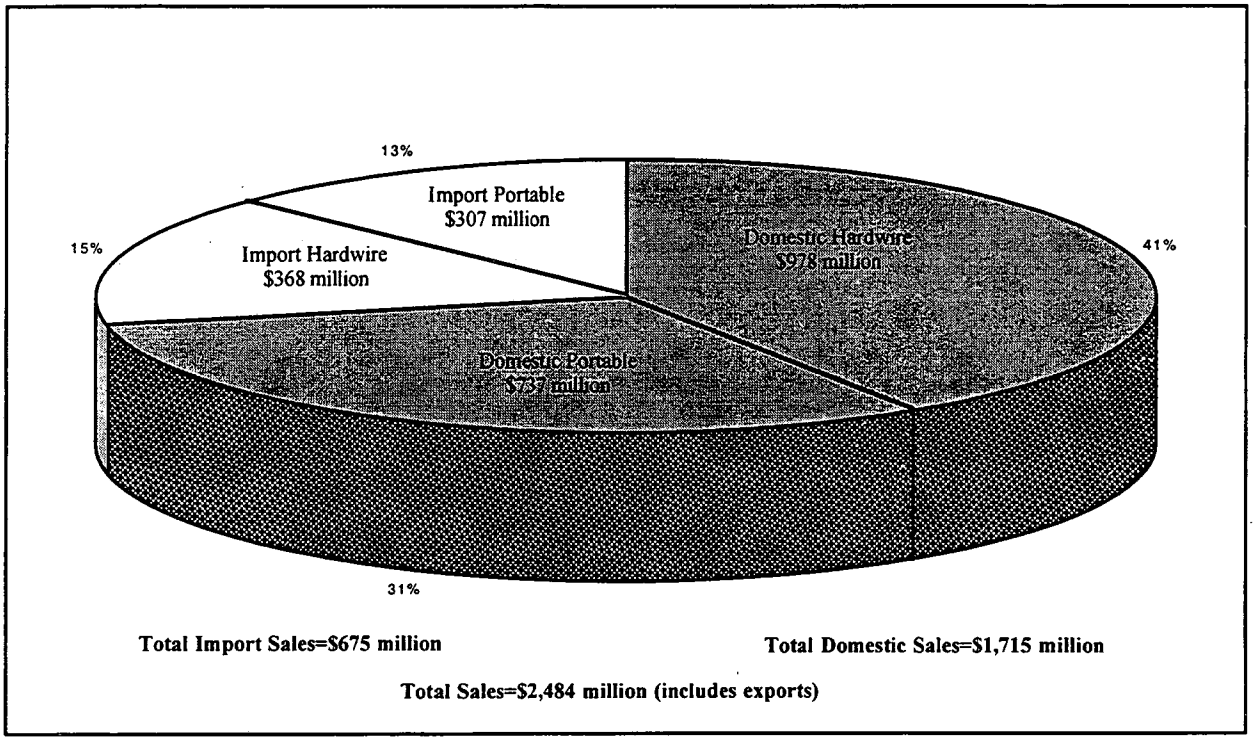
In describing the fixture market, we find it useful to categorize fixtures by their location of manufacture (import vs. domestic) and their design (hardwired vs. portable). The location of manufacture is important because it influences the design of a program targeting fixture manufacturers. The fixture design is important because different fixture types tend to enter the home through different specification and distribution channels.

2.2 Residential Fixture Sales

Figure 2.1 shows the breakout of 1993 residential sales by domestic shipments, imports, and exports. Factoring in the markups by distributors, contractors, and/or retailers, which may range from 15% to more than 100%, we estimate the annual retail value of residential sales is $3.4-4 billion.

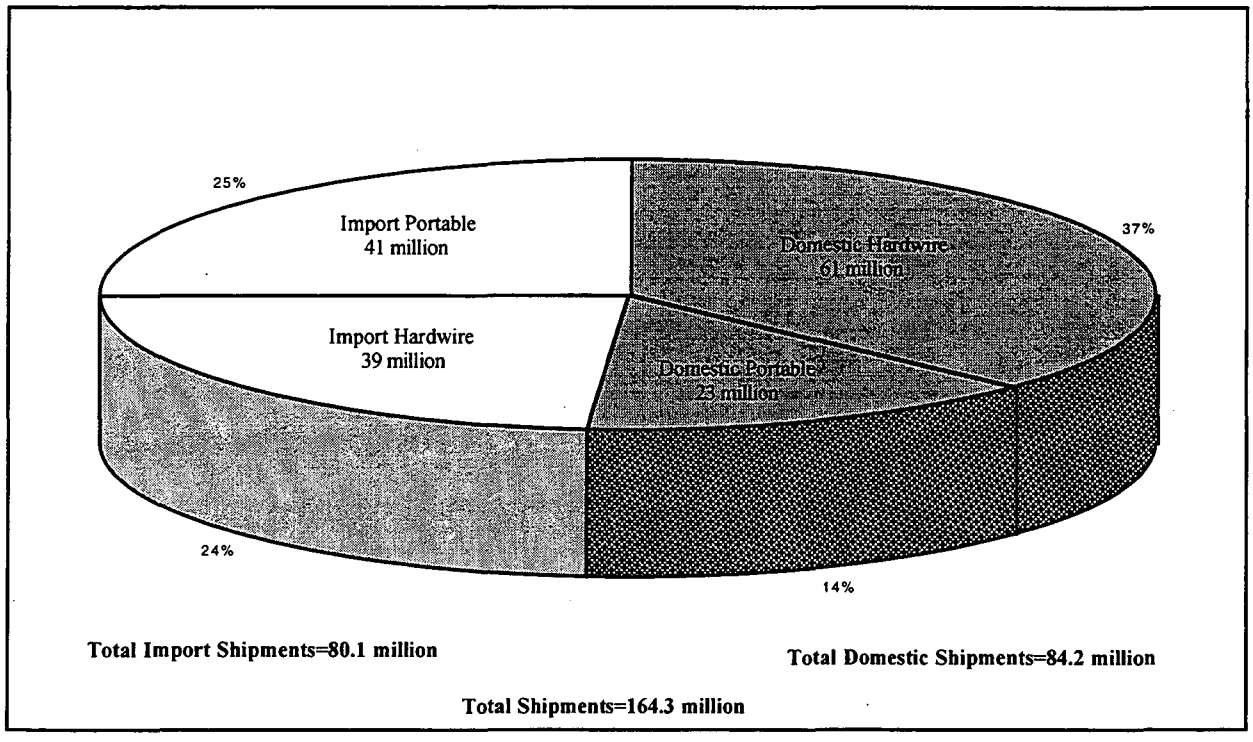
We have classified lighting fixtures generally as hardwired and portable. In new construction, hardwired fixtures are most often specified and supplied by the developer, builder or electrical contractor. In renovation/replacement construction, they are specified by the contractor or homeowner. In contrast, portable lighting is almost exclusively purchased directly by the homeowner/tenant. When existing homes are sold, the hardwired fixtures are generally left in place, while portable ones are moved to the new home or discarded. Figure 2.1 shows the breakdown of domestic and import shipments for these two types of fixtures for 1993.

Figure 2.1: Value of Residential Hardwired and Portable Lighting Fixture Shipments - 1993 [11, 12, 13]



While Figure 2.1 shows that imported products account for about one third of the dollar value of all U.S. residential lighting sales, Figure 2.2 shows that these same imports account for about one half of unit shipments of lighting fixtures. Of the 165 million light fixtures sold in 1993, imports accounted for 39% of all hardwired fixtures and 64% of all portable lighting fixtures. About 60% of all lighting fixtures sold in the U.S are hardwired and 40% are portable.

Figure 2.2: Quantity of Residential Hardwired and Portable Lighting Fixture Shipments - 1993 [11, 12, 13,]



Note: A range of domestic portable units was calculated based on U. S. Census data and 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)[10]. Over nine million hardwired fixtures were exported in 1993, and were valued at over $30 million dollars[12], implying that many exported fixtures are very inexpensive. Less than half a million portable fixtures, valued at $15 million, were exported. Exports account for only 2% of the value of all domestic shipments and 5% of all units shipped.

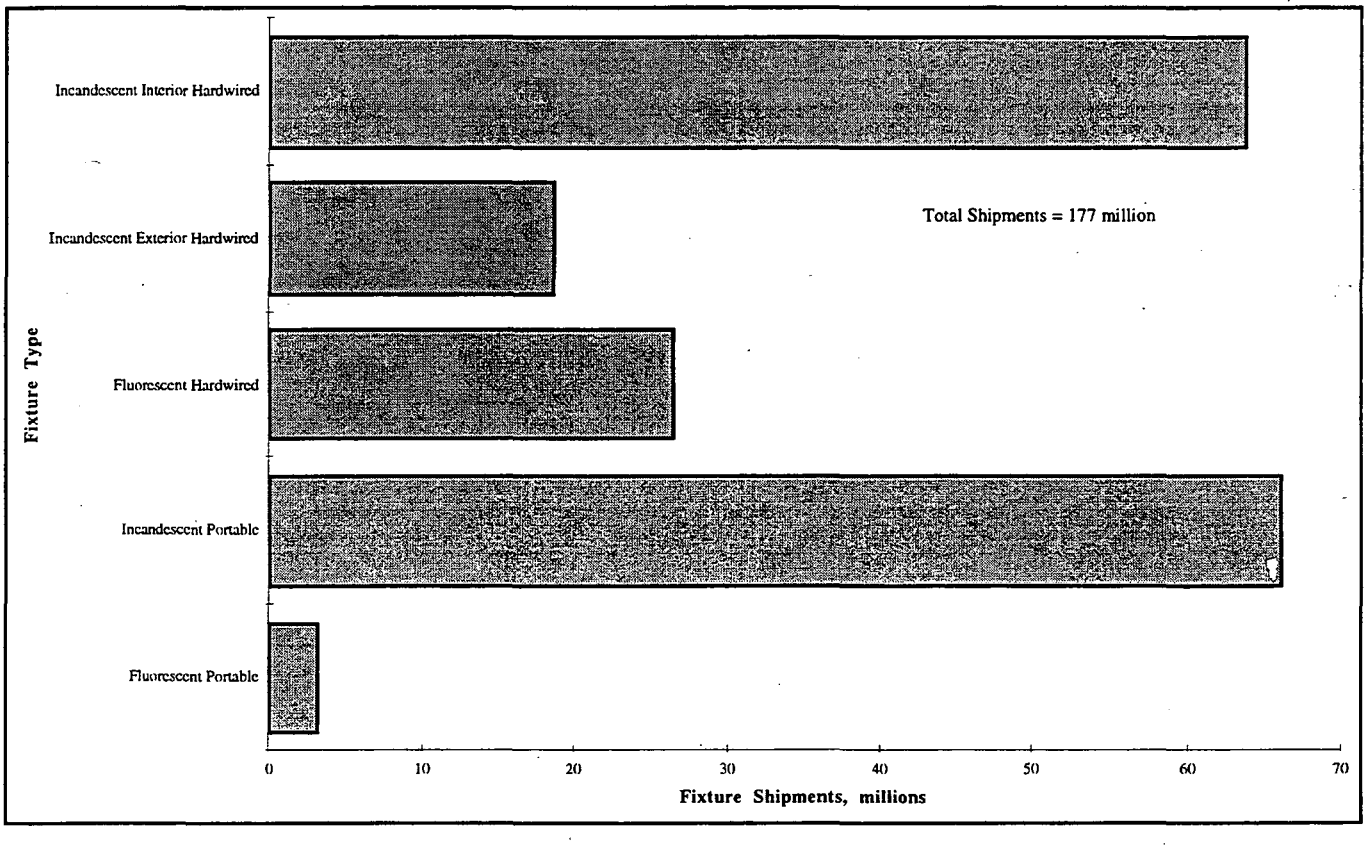
More than 500 manufacturers, both domestic and foreign, supply the residential marketplace[13]. The industry is very competitive. Each major fixture type is produced by 10 to 80 domestic manufacturers (most manufacturers make more than one fixture type). Within each fixture type, the majority of sales are concentrated among only a few manufacturers. Market shipments by the largest 50 companies captured an estimated 70% of the residential marketplace in 1991[14]. This

represents an increase from 65% in 1987, when 24% of market share was held by the four largest companies, 32% was held by the 8 largest companies, and 45% was held by the 20 largest companies. This concentration of the fixture manufacturing industry could permit program designers to influence the market by working with a relatively small number of manufacturers.

2.4 Product Mix

The U.S. Census breaks out lighting fixtures by light source, type, mounting and/or construction material. Figure 2.3 shows data for hardwired fixture annual shipments. The analysis presented in Figure 2.3 assumes that the allocation of imported fixture types is proportional to that for domestic shipments.

Figure 2.3: Estimated U.S. Lighting Market Breakdown - 1993 [11, 12, 15]
Includes Domestic, Import, and Export Shipments



Note: Shipments of imported fixtures by fixture type were estimated by applying the domestic fixture type market shares to the total import fixture shipments. Shipments of domestic fixtures were estimated assuming average fixture price for each fixture type[11].

Figure 2.3 illustrates that Edison-based (primarily incandescent) fixtures account for about three-quarters of all new sales. Ceiling/pendant fixtures and recessed cans are the most popular fixture types, each accounting for about one quarter of all sales. Exterior fixtures account for about one-fifth of all sales, but are 5 to 10% of stock in existing homes, indicating that this is a growth

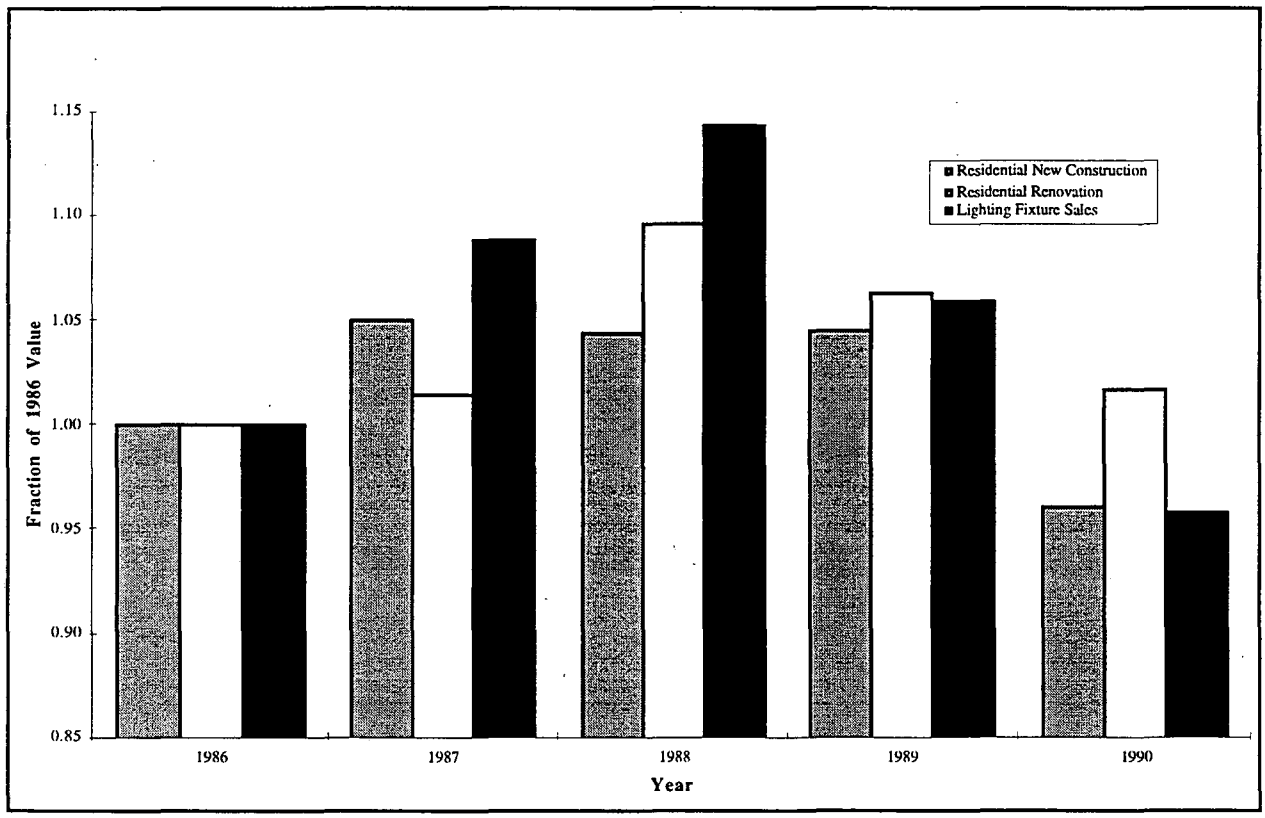
sector. Though fluorescent fixtures have a 15% actual penetration, their market share (new fixture sales) is 23%, probably affected by building standards. For example, California's Title 24 requires that the primary light source in residential kitchens and bathrooms be fluorescent. Fluorescent fixtures are also common in garages, workshops, and utility rooms.

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" portables.

2.5 Turnover

The rate of natural fixture turnover is a key driver of the rate of penetration of CF fixtures. In general, hardwired fixtures are installed at the time of construction or major renovation of a home. We estimate that at least half of hardwired fixture sales are for new homes, about one-quarter are for home renovations, and a small fraction (on the order of 10%) are to replace individual outmoded or failed fixtures. This correlation between hardwired fixture sales and residential building construction is illustrated by Figure 2.4.

Figure 2.4 Comparison of Construction Expenditures to Lighting Fixture Sales[10,11,12]



New residential construction amounts to over 1.5 million homes per year including multi-family units. 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.

Portable fixtures account for the majority of sales in the replacement market. They are much more easily installed and moved than hardwired fixtures, 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.

2.6 Decision Makers/Distribution Channels

The intended purpose of a fixture largely determines who selects the fixture and the factors they consider in the purchase. In addition to the homeowner or tenant, a number of other players are involved in the distribution of residential fixtures. While portable lighting is typically selected by the homeowner, hardwired fixtures are most commonly specified by a design professional, builder, electrical contractor, or lighting showroom. Table 2.1 shows which parties most commonly specify residential lighting, particularly hardwired fixtures, by house type.

Table 2.1: 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

Electrical contractors and builders are the most common source for hardwired 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, 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.

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. Although from a small sample of single-family residences, because of consistency with other studies we believe that the Tacoma data bring us within hailing distance of such an approximation.

The available data confirm that a small percentage of fixtures in each home are responsible for the vast majority of residential lighting energy consumption. (Figure 1). The greatest opportunity for savings reside in ceiling, portable, and wall fixtures in the kitchen, living room, bathrooms,

bedrooms, and outdoors. The highest-UEC fixtures are generally ceiling fixtures (of all types). Wall fixtures and portable fixtures also use a significant fraction of lighting energy. The best value can be obtained by replacing incandescent fixtures in these high-use categories with well-designed, energy-efficient fixtures (including dedicated pin-based CF fixtures).

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

This characterization of residential lighting in the U. S. market will help program designers focus their efforts on the specific residential fixtures with the greatest potential energy savings and best payback. Market analysis, as presented in this paper, also lays the groundwork for the effective implementation of these programs.

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