

U.S. Lighting Market Characterization

Volume I: National Lighting Inventory and Energy Consumption Estimate

Final Report

Prepared by
Navigant Consulting, Inc.

for
U.S. Department of Energy

Office of Energy Efficiency and Renewable Energy
Building Technologies Program

September 2002



U.S. Lighting Market Characterization

Volume I: National Lighting Inventory and Energy Consumption Estimate

Prepared for:

Building Technologies Program
Office of Energy Efficiency and Renewable Energy
U.S. Department of Energy

Prepared by:

Navigant Consulting Inc.
1801 K Street, NW Suite 500
Washington DC, 20006

with XENERGY, Inc.
Burlington, MA

September 2002

Disclaimer

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government, nor any agency thereof, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency, contractor or subcontractor thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Copies of this Report

Electronic (PDF) copies of this report are available to the public from:

National Technical Information Service (NTIS)
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161
Tel: 1-800-553-6847
Web: www.ntis.gov

Building Technologies Program
U.S. Department of Energy
Web: www.eren.doe.gov/buildings/documents/

Comments

The Department is interested in receiving input on the material presented in this report. If you have suggestions of better data sources and/or comments on the findings presented in this report, please submit your feedback to Jim Brodrick by September 30, 2003 at the following address:

James R. Brodrick, Ph.D.
Program Manager – Lighting Market Characterization Report
EE-2J / **Forrestal Building**
U.S. Department of Energy
1000 Independence Avenue SW
Washington D.C. 20585-0121

Acknowledgments

The authors would like to acknowledge the valuable support, guidance and input provided by others in the preparation of this report. Dr. James R. Brodrick of the U.S. Department of Energy, Building Technologies Program provided day-to-day oversight of this assignment, helping to shape the approach, execution and documentation. John D. Ryan, also of the Building Technologies Program provided valuable review and input to the study. Robert Adler, Erin Boedecker, John Cymbalsky, Robert Latta, Alan Swenson, Steven Wade and Michael Laurence all of the U.S. Department of Energy's Energy Information Agency provided very helpful comments and input, which contributed to the integrity of the 2001 estimate of the lighting inventory. Ted Collins of the Federal Energy Management Program also provided review and constructive comments to the report. Seth Couslar, Tod Lewis and Lansine Toure of the Federal Aviation Administration provided valuable input concerning airport runway lighting systems. Raj Ghaman of the Federal Highway Administration provided helpful input on highway lighting. Edward D. Petrow of Lincoln Technical Services reviewed drafts and provided constructive criticism.

The authors are also grateful to the following industry representatives and research experts who reviewed drafts of the report circulated for comment:

Barbara Atkinson	Lawrence Berkeley National Laboratory
Peter Bleasby	Osram Sylvania
Mike Borgos	Osram Sylvania
Haina Cohen	Philips Lighting Company
Steve Denny	Airport Lighting Systems
Andrea Denver	Lawrence Berkeley National Laboratory
Diane Fisher	Lawrence Berkeley National Laboratory
Tom Harding	ADLT/Venture Lighting
Rita Harrold	Illuminating Engineering Society of North America
Lisa Heschong	Heschong-Mahone Group
Noah Horowitz	Natural Resources Defense Council
Joe Howley	GE Lighting
James George	Permlight Products
Judy Jennings	Lawrence Berkeley National Laboratory
Steve Johnson	Lawrence Berkeley National Laboratory
Kent Kipling	Fusion Lighting
Jon Koomey	Lawrence Berkeley National Laboratory
Myron Laible	Outdoor Advertising Association of America
William Leaman	Fiberstars, Inc.
Terry McGowen	Lighting Ideas, Inc.
Jim McMahan	Lawrence Berkeley National Laboratory
Kyle Pitsor	National Electrical Manufacturers Association
Mark S. Rea	Lighting Research Center, RPI
Al Rousseau	Philips Lighting Company
Francis Rubinstein	Lawrence Berkeley National Laboratory
Michael Stein	Universal Lighting Technologies
Marsha Walton	New York State Energy Research and Development Authority
Terry Winer	Corning Company
Robert Zeimer	Xenergy, Inc.

The authors thank all the reviewers for their extremely helpful comments and feedback provided throughout the development of this report.

TABLE OF CONTENTS

1. INTRODUCTION.....	1
1.1. U.S. DEPARTMENT OF ENERGY’S LIGHTING RESEARCH AND DEVELOPMENT PROGRAM.....	1
1.2. EXISTING SOURCES OF INFORMATION ON THE LIGHTING MARKET.....	1
1.3. ROLE OF THE LIGHTING MARKET CHARACTERIZATION — INVENTORY PHASE	2
1.3.1. <i>New Data Sources</i>	2
1.3.2. <i>Results by Lighting Application</i>	3
2. CLASSIFICATION NOMENCLATURE.....	4
2.1. BUILDING CLASSIFICATION.....	4
2.2. LIGHT SOURCES	5
3. DATA SOURCES	7
3.1. EIA SURVEYS.....	8
3.1.1. <i>Residential Energy Consumption Survey (RECS)</i>	8
3.1.2. <i>Commercial Building Energy Consumption Survey (CBECS)</i>	8
3.1.3. <i>Manufacturing Energy Consumption Survey (MECS)</i>	9
3.2. XENCAP™.....	9
3.3. TACOMA PUBLIC UTILITIES, BASELINE RESIDENTIAL LIGHTING ENERGY USE STUDY	15
3.4. AMERICAN HOUSING SURVEY (AHS).....	16
4. ENERGY USE ESTIMATE METHODOLOGY	17
4.1. BUILDING SECTORS.....	18
4.1.1. <i>Introduction</i>	18
4.1.2. <i>Allocating Floorspace To Space Types</i>	18
4.1.3. <i>Estimating The Models</i>	19
4.1.3.1. <i>Dependent Variable</i>	19
4.1.3.2. <i>Independent Variables</i>	20
4.1.3.3. <i>Results</i>	21
4.1.4. <i>Applying The Models</i>	21
4.1.4.1. <i>Commercial and Industrial Buildings</i>	21
4.1.4.2. <i>Residential Buildings</i>	22
4.1.5. <i>National Results Provided</i>	23
4.1.5.1. <i>Prepare the Results for Each Building</i>	24
4.1.5.2. <i>Calculate kW and kWh</i>	25
4.1.5.3. <i>National Results</i>	26
4.1.5.4. <i>Spreadsheet Matrices</i>	27
4.2. OUTDOOR STATIONARY LIGHTING SECTOR	27
4.2.1. <i>Billboard Lighting</i>	28
4.2.2. <i>Traffic Signals</i>	28
4.2.3. <i>Roadway Lighting</i>	28
4.2.4. <i>Aviation Lighting</i>	29
4.2.5. <i>Parking</i>	29
4.2.6. <i>Sports Facilities</i>	30
4.3. SUPPLEMENTS TO THE LIGHTING ESTIMATES.....	30
4.3.1. <i>Electric Signs</i>	30
4.3.2. <i>Common Spaces in Multifamily Buildings</i>	30

5.	NATIONAL LIGHTING INVENTORY AND ENERGY CONSUMPTION ESTIMATES ...	31
5.1.	RESULTS FOR LAMP TECHNOLOGIES	32
5.2.	RESULTS BY SECTOR, SUBSECTOR, AND APPLICATION	40
5.2.1.	<i>Residential Sector</i>	40
5.2.2.	<i>Commercial Sector</i>	41
5.2.3.	<i>Industrial Sector</i>	44
5.2.4.	<i>Outdoor Stationary Lighting</i>	46
5.2.5.	<i>National Lighting Summary</i>	50
6.	XENCAP DATABASE AND LIGHTING ESTIMATE	53
6.1.	SPACE FUNCTIONS	53
7.	LIGHTING MARKET CHARACTERIZATION COMPARISON.....	56
7.1.	COMPARISON TO OTHER STUDIES.....	56
7.2.	STATISTICAL VALIDITY.....	57
7.2.1.	<i>TPU Data</i>	57
7.3.	XENCAP™ DATA	58
8.	SUMMARY RESULTS	59
8.1.	LIGHTING MARKET CHARACTERISTICS	59
8.2.	LIGHTING TECHNOLOGY OBSERVATIONS.....	66
9.	REFERENCES.....	68
10.	APPENDICES	73
	APPENDIX A. TECHNOLOGY TABLES AND ASSUMPTIONS	
	APPENDIX B. TPU RESIDENTIAL DATASET DISTRIBUTIONS	
	APPENDIX C. EXAMPLES XENCAP™ TABLES OF FACILITY AND LIGHTING GROUPS	
	APPENDIX D. INVENTORY MATRICES FOR THE RESIDENTIAL SECTOR	
	APPENDIX E. INVENTORY MATRICES FOR THE COMMERCIAL SECTOR	
	APPENDIX F. INVENTORY MATRICES FOR THE INDUSTRIAL SECTOR	
	APPENDIX G. INVENTORY MATRICES FOR THE OUTDOOR STATIONARY SECTOR	
	APPENDIX H. XENCAP™ STATISTICAL ANALYSIS OF RESIDENTIAL SECTOR UPDATE	*
	APPENDIX I. XENCAP™ STATISTICAL ANALYSIS OF COMMERCIAL SECTOR UPDATE	*
	APPENDIX J. XENCAP™ STATISTICAL ANALYSIS OF INDUSTRIAL SECTOR UPDATE	*

* Appendices H, I and J appear in a separate report, U.S. Lighting Market Characterization Volume I — National Lighting Inventory and Energy Consumption Estimate, Appendices H, I and J.

LIST OF TABLES

TABLE 2-1: SECTOR AND SUBSECTOR CLASSIFICATION.....	4
TABLE 2-2: SPACE FUNCTIONS IN XENCAP DATABASE.....	5
TABLE 2-3: LAMP AND BALLAST CLASSIFICATION.....	6
TABLE 3-1: DATA SOURCES USED IN PREPARING THE INVENTORY.....	7
TABLE 3-2: CHARACTERISTICS OF EIA BUILDING ENERGY USE SURVEYS.....	8
TABLE 3-3: XENCAP™ DATABASES.....	10
TABLE 3-4: RELATIONSHIP BETWEEN XENCAP™ AND THE POPULATION OF COMMERCIAL BUILDINGS	11
TABLE 3-5: MAPPING OF CBECS FLOORSPACE TO XENCAP™ BUILDING TYPES.....	12
TABLE 3-6: MAPPING XENCAP™ INDUSTRIAL BUILDINGS TO CBECS BASED ON SIC.....	13
TABLE 3-7: RELATIONSHIP BETWEEN XENCAP™ AND THE POPULATION OF INDUSTRIAL BUILDINGS..	14
TABLE 3-8: XENCAP™ LAMP TYPES.....	15
TABLE 4-1: ILLUMINANCE LEVELS ASSIGNED TO EACH SPACE TYPE.....	19
TABLE 5-1: AVERAGE LAMP WATTAGE BY BUILDING SECTOR (W), 2001.....	32
TABLE 5-2: AVERAGE NUMBER OF LAMPS PER BUILDING, 2001.....	33
TABLE 5-3: DISTRIBUTION OF LAMPS IN EACH BUILDING SECTOR (%).....	34
TABLE 5-4: ESTIMATED INVENTORY OF LAMPS IN THE U.S. BY END-USE SECTOR.....	35
TABLE 5-5: DISTRIBUTION OF INSTALLED WATTAGE PER BUILDING BY LAMP TYPE (%).....	36
TABLE 5-6: OPERATING HOURS PER DAY BY LIGHT SOURCE.....	37
TABLE 5-7: DISTRIBUTION OF LIGHTING ELECTRICITY CONSUMED PER SECTOR BY LAMP TYPE (%)....	38
TABLE 5-8: DISTRIBUTION OF LAMP OUTPUT (TLM-HR) PER YEAR BY LAMP TYPE.....	39
TABLE 5-9: LIGHTING ELECTRICITY USAGE -- TYPICAL RESIDENTIAL UNIT.....	40
TABLE 5-10: LIGHTING ELECTRICITY USAGE -- TYPICAL RESIDENTIAL BUILDINGS.....	40
TABLE 5-11: LIGHTING ELECTRICITY USAGE -- TYPICAL COMMERCIAL BUILDINGS.....	41
TABLE 5-12: LIGHTING ELECTRICITY USE IN COMMERCIAL BUILDINGS -- ESTIMATE BY SUBSECTOR..	42
TABLE 5-13: LIGHTING ELECTRICITY USE IN COMMERCIAL BUILDINGS BY LAMP TECHNOLOGY.....	43
TABLE 5-14: LIGHTING ELECTRICITY USAGE -- TYPICAL INDUSTRIAL BUILDINGS.....	44
TABLE 5-15: LIGHTING ELECTRICITY USE IN INDUSTRIAL BUILDINGS -- ESTIMATE BY SUBSECTOR....	45
TABLE 5-16: SHARE OF LIGHTING ELECTRICITY USE IN INDUSTRIAL BUILDINGS BY LAMP.....	46
TABLE 5-17: LAMPS PER OUTDOOR STATIONARY INSTALLATION.....	47
TABLE 5-18: LAMP WATTAGE ASSUMED FOR OUTDOOR STATIONARY INSTALLATIONS.....	48
TABLE 5-19: FRACTION OF OUTDOOR STATIONARY LIGHTING ENERGY BY LAMP TECHNOLOGY (%)...	49
TABLE 5-20: LIGHTING ENERGY USE IN OUTDOOR STATIONARY SOURCES.....	50
TABLE 5-21: NATIONAL LIGHTING ENERGY USE SUMMARY.....	51
TABLE 5-22: NATIONAL LIGHTING ENERGY USE BY SECTOR AND SOURCE.....	51
TABLE 5-23: LIGHTING USE ON A FLOORSPACE BASIS.....	52
TABLE 6-1: DESCRIPTION OF SPACE FUNCTIONS.....	54
TABLE 6-2: LIGHTING ENERGY CONSUMED IN EACH SECTOR BY SPACE FUNCTION (TWh/YR).....	55
TABLE 7-1: ANNUAL LIGHTING ELECTRICITY CONSUMPTION ESTIMATES.....	56
TABLE 7-2: COMPARISON OF AHS AND TPU ROOMS PER HOUSING UNIT.....	58
TABLE 8-1. U.S. NATIONAL LIGHTING ENERGY USE ESTIMATES FOR 2001.....	63
TABLE 8-2: NATIONAL LIGHTING ENERGY USE BY SECTOR AND SOURCE.....	63
TABLE 8-3. AVERAGE INSTALLED WATTAGES BY SECTOR AND LAMP TYPE, 2001.....	64
TABLE 8-4. PERCENTAGE OF INSTALLED LAMPS IN AVERAGE BUILDINGS BY SECTOR, 2001.....	64
TABLE 8-5. PERCENTAGE OF INSTALLED WATTAGES IN AVERAGE BUILDINGS BY SECTOR, 2001.....	65
TABLE 8-6. AVERAGE OPERATING HOURS PER DAY BY SECTOR AND SOURCE, 2001.....	65
TABLE 8-7. PERCENTAGE OF ELECTRICITY CONSUMPTION BY SECTOR AND SOURCE, 2001.....	66
TABLE 8-8. PERCENTAGE OF SOURCE LUMEN OUTPUT BY SECTOR AND SOURCE, 2001.....	66

TABLE OF FIGURES

FIGURE 4-1 ELECTRICITY CONSUMPTION CALCULATION METHODOLOGY.....	17
FIGURE 8-1. TOTAL U.S. PRIMARY ENERGY CONSUMPTION FOR ELECTRICITY PRODUCTION 2001	59
FIGURE 8-2. TOTAL U.S. PRIMARY ENERGY CONSUMPTION FOR ELECTRICITY FOR LIGHTING BY SECTOR 2001, PEC	60
FIGURE 8-3. LIGHTING ENERGY CONSUMPTION BY SECTOR & SOURCE.....	61
FIGURE 8-4. SOURCE LIGHT PRODUCTION BY SECTOR & SOURCE	62

List of Acronyms and Abbreviations

ACEEE	American Council for an Energy Efficiency Economy
AHS	American Housing Survey
BT	DOE Building Technologies Program
CBECS	Commercial Building Energy Consumption Survey
CFL	Compact Fluorescent Lamp
CRI	Color Rendering Index
CU	Coefficient of Utilization
DOE	United States Department of Energy
EIA	Energy Information Administration
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
HID	High Intensity Discharge
HPS	High Pressure Sodium
IESNA	Illuminating Engineering Society of North America (also “IES”)
LBL	Lawrence Berkeley National Laboratory
LED	Light Emitting Diode
LPS	Low Pressure Sodium
LR&D	Lighting Research and Development
MECS	Manufacturing Energy Consumption Survey
NAICS	North American Industrial Classification System
NEEP	Northeast Energy Efficiency Partnerships
NWEEA	Northwest Energy Efficiency Alliance
PNNL	Pacific Northwest National Laboratory
RECS	Residential Energy Consumption Survey
SIC	Standard Industrial Classification
TPU	Tacoma Public Utilities
h	Hour
kWh	Kilowatt-hour
lm	Lumen
quad	Quadrillion (10^{15}) British Thermal Units
TWh	Terawatt-hour
W	Watt
yr	Year

Useful Conversions

1 TWh = 1 billion (10^9) kWh
1000 TWh electricity = 3.412 quads delivered electricity
1 quad delivered electricity = 3.211 quads primary energy

Executive Summary

The *Lighting Market Characterization* study is a multiyear program to evaluate light sources in the United States, and identify opportunities for saving energy. Sponsored by the United States Department of Energy's (DOE's) Building Technologies Program (BT), the *Lighting Market Characterization* consists of two phases. This report, Phase I, provides an estimated inventory of installed lighting technologies for 2001 and their associated energy consumption. Phase II will evaluate this inventory and research lighting technologies to identify energy saving opportunities.

The objective of Phase I is to collect and present in one document the fundamental energy consumption information that DOE needs to plan an effective lighting research and development (LR&D) program. This report answers three main questions:

- How much energy is consumed by light sources in the United States?
- How many lighting technologies are installed, where are they installed, and what area do they illuminate?
- What are the performance attributes of the installed stock of lighting technologies?

This report attempts to answer these questions at the right level of aggregation and as uniformly as possible across end-use sectors. This study draws data from existing sources such as the Commercial Building Energy Consumption Survey (CBECS) and the Manufacturing Energy Consumption Survey (MECS), as well as previously untapped data sources such as end-use metering studies and building audits. Two important features that distinguish this study from prior efforts are its use of new data sources, and its analysis by applications that cut across building sectors.

One of the new sources of data on lighting use in buildings was the XenCAP™ energy auditing system. XenCAP™ is based on a database of nearly twenty-five thousand detailed audits of commercial and industrial facilities conducted throughout the U.S. in the 1990's. A statistical correction was applied to these audits to establish 2001 as the inventory estimate year. The report was circulated to more than 35 reviewers from government, industry, and academia. This final report incorporates their valuable input and additional insights.

End-use lighting installations in the U.S. were classified into four general sectors made up of three building categories (residential, commercial and industrial) and one category called 'outdoor stationary' which incorporates lighting installations such as street lighting, airport runway systems, traffic signals, and billboard lighting. The term 'stationary' is used in the category to differentiate it from automobile and other mobile lights that are beyond the scope of this study. To evaluate the available data on installed lighting technologies, these general sectors were broken down into further sub-groups (e.g., office, education, retail, etc.), which correspond to those used by the Energy Information Administration in CBECS and MECS. In total, more than fifty separate building types across the sectors were evaluated in this analysis.

Light sources in this study were grouped into four broad categories: incandescent, fluorescent, high intensity discharge and solid state. Within each of these, the market analysis evaluated subgroups of commonly available lighting products (e.g., reflector lamps, T8 fluorescent tubes, metal halide lamps). In total, thirty-one lamp subgroups were carried through the analysis, extracting information like average wattage and number of sockets from the data set. A complete list of the light source subgroups can be found in Table 2-3 of the main report.

Table ES-1 summarizes the lighting energy consumption estimate for the four general lighting market sectors in terms of both delivered (end-use site energy) and primary (source) energy. Primary energy refers to the total energy required to generate and supply electricity to the customer site.¹

Table ES-1 U.S. National Energy Use for Lighting Disaggregated by Sector

Sector	Electricity Use per Building (kWh/yr)	Number of Buildings	Site Energy (TWh/yr)	Primary Energy (quads)	Percent of Total
Residential	1,946	106,989,000	208	2.2	27%
Commercial	83,933	4,657,000	391	4.2	51%
Industrial	475,063	227,000	108	1.2	14%
Outdoor stationary	n/a	n/a	58	0.6	8%
Totals			765	8.2	100%

Table ES-1 shows the estimate of total lighting electricity consumption as 765 Terawatt-hours (TWh) at the building site, or 8.2 quadrillion british thermal units (quads) of primary energy. Putting this level of consumption into a broader context, the United States used approximately 98.3 quads in 2001, more than a third of which, about 37 quads, to generate electricity (EIA, 2002a). Thus, lighting was approximately 8.3% of national primary energy consumption, or about 22% of the total electricity generated in the U.S.

From a buildings perspective, the percentages are even higher. Nationally, total energy use in commercial and residential buildings was approximately 36.4 quads, of which electricity use in buildings was approximately 21.3 quads (BTS, 2002). Summing together the energy use for lighting from Table ES-1, the residential and commercial sectors consume approximately 6.4 quads. Thus, in these two building types, lighting constituted approximately 17.6% of total building energy consumption, or approximately 30.3% of total building electricity use.

Looking across the sectors shown in Table ES-1, commercial buildings were found to use the largest share of lighting energy use (51 percent), followed by residential (27 percent), industrial (14 percent) and outdoor stationary (8 percent). The estimates presented in this table for lighting energy use are compared with other studies on lighting energy consumption in Table 7-1 of this report.

Providing further breakdown of the study findings, Figure ES-1 shows the total lighting energy consumption for each of these four general sectors, and illustrates the amounts of energy used by the various light source technologies. The numerical values presented in this figure appear in Table 5-22 of this report.

¹ The factor used to convert the site-use electrical energy to primary energy consumed at the generating power plant is 10,768 BTU/kWh (DOE, 2002) for the year 2000. This conversion factor incorporates generation, transmission and distribution losses on an average basis for the U.S. Note that the conversion efficiency varies from year to year, depending on the mix of electrical generating power plants used in a given year.

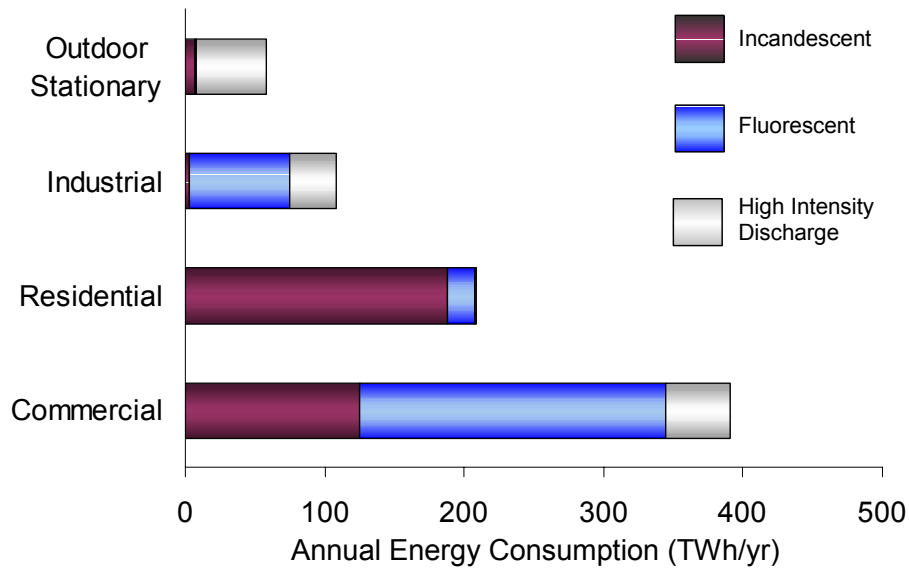


Figure ES-1 Shares of Sectoral Energy Use by Lighting Technology

Figure ES-1 shows that the outdoor stationary energy consumption is primarily HID sources, which account for 87% of the outdoor stationary’s 56 TWh/year electricity use. The industrial sector has sizable energy shares of both fluorescent and HID sources, 67% and 31%, respectively, of this sector’s 108 TWh/year consumption. The commercial sector is the largest energy user overall, having large quantities of energy used by all three light sources. Fluorescent and incandescent are the two largest commercial lighting energy users, accounting for 56% and 32% of its annual 391 TWh/year of electricity use. In the residential sector, energy use is primarily driven by incandescent technologies, where 90% of the energy is consumed by this light source.

It is helpful to have an estimate of the lighting energy budget in the United States, by sectors and light sources. Additionally, it is also helpful to understand the technologies and sectors where the estimated energy consumption levels are found. Electricity is a means to provide a service – visible light – in our workspaces, homes and other installations. Using manufacturer catalogues, lamp efficacies² were gathered for all 31-lamp types, differing by general building sector and average wattage.³ Figure ES-2 provides an estimate of the resulting calculated source lumen⁴ production in the United States. The numerical values shown in this figure appear in Table 5-8 of this report.

² Efficacy is a lighting measure of efficiency, based on number of lumens of light produced per watt of energy consumed (lm/W). It is a metric similar to miles per gallon (MPG) in an automobile. MPG tells you how far you can travel on a gallon of gas, while efficacy tells you how much light you will get per watt of energy.

³ A table of efficacies used can be found in Appendix D, E and F of this report.

⁴ A lumen is a measure of light production, specifically it is the SI unit of luminous flux, defined as the quantity of light emitted in a unit solid angle (1 steradian) by a point source with uniform intensity of 1 candela. A lumen-hour (lm-hr), the metric used in Figure ES-2, is a measure of lighting service over a period of time (one hour). Tera is a unit modifier referring to a trillion units, or 10¹².

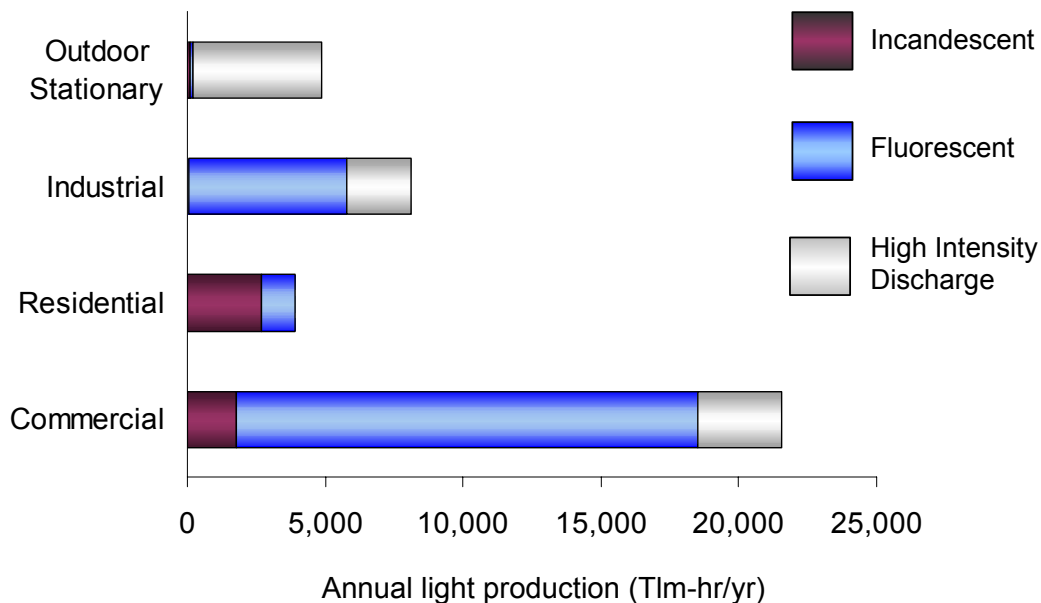


Figure ES-2 Estimated Source Light Production by Sector and Lamp Type, 2001

According to Figure ES-2, the greatest source lumen production in the United States is for the commercial sector. This sector, comprising retail establishments, office buildings, and many other commercial space-types, is generally lit throughout the day and into the evening hours – contributing to the large demand for lighting services. The high prevalence of fluorescent lighting in this sector (see Table ES-2), the high occupancy rates of many commercial space-types and fluorescent’s relatively high efficacy all contribute to this considerable source lumen output.

When compared with Figure ES-1, Figure ES-2 shows the relative efficiencies – or lamp efficacies – associated with each of the light sources. For example, within the commercial sector, 32% of its energy use was for incandescent lighting – but only 8% of the commercial lumens were generated by this source. Conversely, 56% of energy use in the commercial sector was for fluorescent sources, which provide 78% of its lumen output.

Looking across all four sectors in Figure ES-2, it becomes clear that fluorescent is the most important light source in the U.S. in terms of lighting service. On a national basis, 62% of the source lumens are produced by this source. HID sources are the second most important, generating 26% of the lumens in 2001, followed by incandescent which delivered 12%. Figure ES-1 reports the energy consumed by each of these sources. Contrasting with their lumen output, incandescent is the highest energy user, accounting for 42% of the nation’s electricity use for lighting. This is followed by fluorescent with 41% and HID with 17%. Thus, incandescent lighting, the light source developed more than 100 years ago and still in use today, consumes the most energy and provides the least amount of light nationally.

Table ES-2 provides a summary estimate of the number of lamps installed for a typical building in the United States. Further detail on this table can be found in Table 5-2 of the main report. A estimate of the total installed lamps by technology category is also provided in Table ES-2. Note that this column includes the lamps from the outdoor stationary sector, however outdoor stationary is not shown in the table because they cannot be presented on a per-building basis.

Table ES-2. Average Number of Lamps per Building and Total Lamps, 2001

Technologies	Residential	Commercial	Industrial	Total Lamps in US	Percent of Lamps
Incandescent	39	91	33	4,397,000,000	63%
Fluorescent	6	324	1,340	2,473,000,000	35%
HID	0.04	7	67	105,357,000	2%
Solid State	-	0.4	0.3	1,840,000	0.03%
Total	45	422	1,440	6,977,197,000	100%
Number of Buildings	106,989,000	4,657,000	227,000	n/a	n/a

Note the dominance of incandescent lighting in the residential sector, and fluorescent in the commercial and industrial sectors. Of the 7 billion lamps in the United States, incandescent constitutes the most common light source (63%) by sheer number of installations, however as was shown in Figure ES-2, incandescent contributes the least amount of light to the national annual lumen demand.

Table ES-3 presents an estimate of the daily operating hours by light source. Although incandescent outnumber other lamp types (particularly in the residential sector), the majority of them generally operate for less than three hours per day – contrasting with fluorescent and HID, that operate three times as long.

Table ES-3. Average Operating Hours per Day by Light Source, 2001

Lamp Type	Residential (hours/day)	Commercial (hours/day)	Industrial (hours/day)	Outdoor (hours/day)	National Avg. (hours/day)
Incandescent	1.9	10.2	16.7	7.9	2.8
Fluorescent	2.2	9.7	13.4	10.8	8.2
HID	2.8	10.1	13.9	11.3	11.0
Solid State	-	23.0	23.4	7.0	22.2
Total	2.0	9.9	13.5	10.5	4.8

In addition to this type of summary information on the installed base of lighting (both number and type of lamps) and the typical use profile, more detailed information is provided in the body of the main report where lamp type subgroups and other disaggregated information is presented. For example, the following observations about light sources can be made from information presented in Chapter 5:

- General service lamps account for 73% of the electricity consumed by incandescent sources across all building sectors. The second highest incandescent energy user is the standard-reflector lamp, estimated at 17% of the electricity consumed by incandescent sources.
- Four-foot linear lamps account for 61% (T-8 and T-12 together) of electricity for fluorescent

sources in all sectors. The second highest energy consumer in the fluorescent category includes the greater than four foot tubes, accounting for 23%. Of these, most are used in industrial building installations.

- For high intensity discharge lamps, metal halide is the primary consumer, constituting 49% of energy consumed by HID sources in all sectors. This is followed by high pressure sodium at 32% and mercury vapor at 17%. HID sources, while both used in commercial and industrial applications, consume 87% of the energy for the Outdoor stationary sources, and deliver 96% of the lumens for that sector.

In addition to the results presented in Chapter 5, the Appendices to this report contain the tables of data used to calculate and generate this 2001 US Lighting Market Inventory. Providing this level of transparency is intended to provide researchers and interested parties with a useful resource.

Observations such as these about the installed base of lighting technologies in the United States give the DOE a baseline from which to make decisions on the allocation of lighting research and development. This study helps to identify areas where new technologies could be developed, where incremental improvements in existing technologies may be targeted and the magnitude of energy savings that would result.