U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy
BUILDING TECHNOLOGIES OFFICE

Energy Savings Potential and RD&D Opportunities for Commercial Building Appliances (2015 Update) – Executive Summary

W. Goetzler, M. Guernsey, K. Foley, J. Young, G. Chung

June 2016

(This page intentionally left blank)

Executive Summary

The U.S. Department of Energy (DOE), Office of Energy Efficiency and Renewable Energy's (EERE's), Building Technologies Office (BTO) commissioned this characterization and technology assessment of appliances used in commercial buildings. The primary objectives of this study were to document the energy consumed by commercial appliances and identify research, development, and demonstration (RD&D) opportunities to improve energy efficiency in each appliance category. For the purposes of this analysis, "commercial appliances" are defined as energy-consuming appliances and equipment used in commercial buildings, excluding heating, ventilation, and air conditioning (HVAC) for space conditioning, building lighting (interior or exterior), commercial refrigeration equipment, and distributed generation systems (including combined heat and power systems).

This report is an update to a 2009 report of the same name, hereafter the "2009 Commercial Appliances Report."[1] As such, this report aims to update the data where possible using newer sources and update the technology options that provide opportunities for efficiency improvements.

ES-1 Energy Consumption

Figure ES-1 provides a breakdown of commercial building primary energy consumption in the U.S. by major end-use categories.[2] According to the 2015 Annual Energy Outlook (AEO), commercial appliances consume 8.94 Quadrillion Btu (10^{15} Btu or Quad), which is nearly 50 percent of annual commercial building energy consumption in the U.S.[3]

[1] Zogg et al. 2009. "Energy Savings Potential and RD&D Opportunities for Commercial Building Appliances." Report by Navigant Consulting, Inc., for U.S. Department of Energy. December 2009. Available: http://apps1.eere.energy.gov/buildings/publications/pdfs/corporate/commercial_appliances_report_12-09.pdf

[2] Primary energy accounts for the losses in generation, transmission and distribution. We generally only account for these losses for electricity, as the transmission and distribution losses for natural gas and other fossil fuels tend to be small. Primary energy does not account for the losses associated with extraction.

[3] EIA. 2015. "2015 Annual Energy Outlook." U.S. Energy Information Administration. DOE/EIA-0383(2015). April 2015. Available at: http://www.eia.gov/forecasts/aeo/

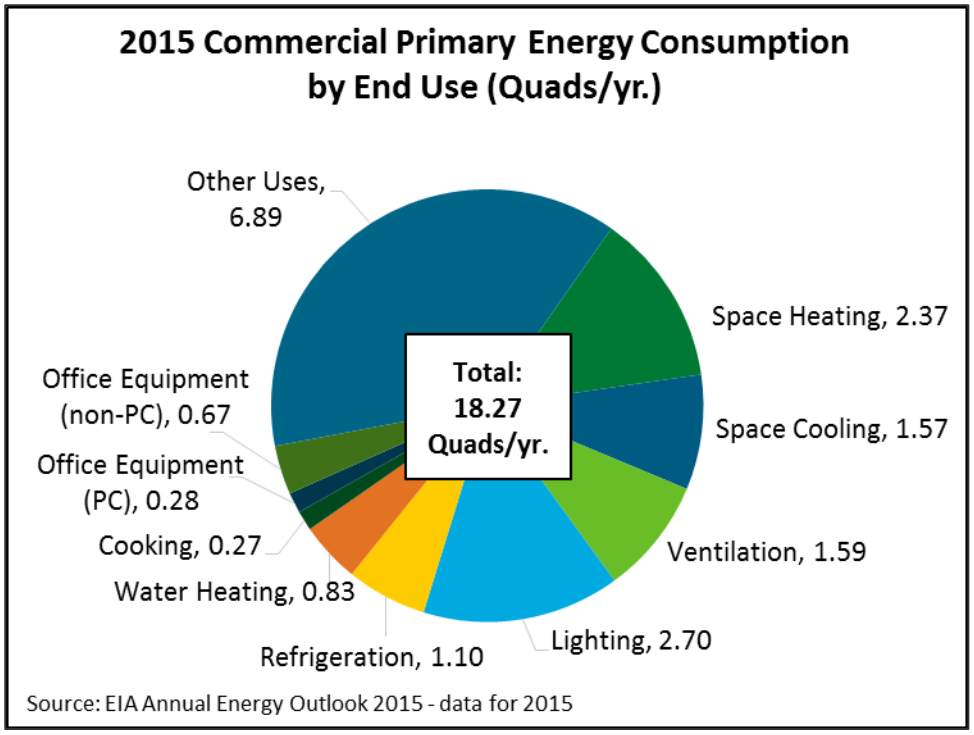
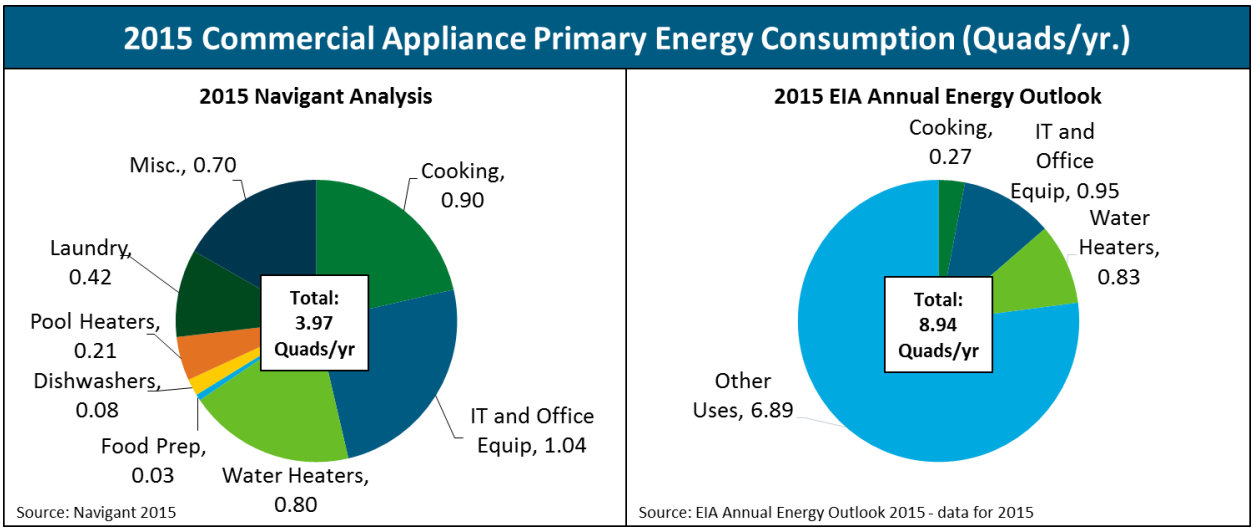


Figure ES-1: 2015 U.S. commercial sector energy consumption

This report analyzes the energy consumption and potential savings for specific end-use technologies within each appliance category, including specific breakdowns for gas-fired and electric equipment where applicable. This analysis includes eight commercial appliance categories:

- **Cooking appliances** – broilers, fryers, griddles, ovens, ranges, steamers, microwave ovens
- **Food preparation appliances** – a variety of electric appliances that aid in the preparation, storage, and serving of cooked food
- **Dishwashers** – undercounter, door-type, conveyor, flight-type
- **Information technology (IT) and office equipment** – personal computers (PCs), desktop monitors, imaging equipment, server computers, network equipment, uninterruptable power supply (UPS)
- **Water heaters** – storage water heaters, instantaneous water heaters, booster heaters, stand-alone water heaters
- **Pool heaters** – for both indoor and outdoor pools
- **Commercial laundry** – single-load, multi-load, and industrial washers and dryers, as well as dry-cleaning equipment
- **Miscellaneous appliances** – medical imaging equipment, vertical-lift technologies, coffee makers, non-refrigerated vending machines, automated teller machines (ATMs), point-of-service (POS) terminals, and distribution transformers.

Figure ES-2 (left side) shows that we estimate 3.97 quads of annual primary annual energy consumption (AEC) in the U.S. from these eight categories of commercial appliances. This value excludes any overlap of hot water energy consumption associated with water heaters, laundry, and dishwashers. Figure ES-2 (right side) shows the Energy Information Administration's (EIA) estimates in related categories in the AEO. In two of the categories characterized in both studies, including water heaters and IT and office equipment, we see good alignment of the data, with minimal variation in estimates between the two sources. Our estimate for cooking is significantly higher than the AEO estimate because of a difference in the estimated installed base of buildings that have food preparation and serving areas. The AEO estimate only includes those buildings in EIA's 2003 Commercial Building Energy Consumption Survey (CBECS) where food service is the principal building activity,[4] whereas we also include buildings in CBECS 2012 that have food preparation and serving areas, but are not primary food service buildings.



Note – 2015 Navigant analysis values for individual appliance categories do not sum due to overlap of hot water heating in both dishwasher and clothes washer operation, which is covered in the energy consumption for water heaters.

Figure ES-2: 2015 commercial appliance primary energy consumption estimates

Overall, AEO estimates a total of 8.94 Quads of primary energy consumption in commercial appliances, which is more than double the consumption documented in this report. While we do not have direct insights into the AEO's "Other Uses" category, we surmise that it includes numerous additional equipment types, such as audio/visual equipment, telecommunications equipment, water distribution equipment, security systems, and other miscellaneous building loads that this study does not address.

Table ES-1 compares the Navigant 2015 estimates and preliminary CBECS estimates for 2012.[5] Since the CBECS data are preliminary at the time of this report's publication, we do not have detailed insights on the underlying CBECS data, so the source of any differences is unclear.[6]

[4] See AEO assumptions, available: https://www.eia.gov/forecasts/aeo/assumptions/pdf/commercial.pdf
[5] During the writing of this report, EIA was analyzing the CBECS 2012 data and released preliminary energy consumption estimates in March 18, 2016.
[6] More detailed energy consumption tables and microdata tables will be available later in 2016.

This comparison provides another example for how different assumptions and end-use groupings can affect commercial appliance estimates.

Table ES-2: Source Energy Consumption by Data Source (Quads/yr.)

Building End-Use	Navigant 2015	CBECS 2012
Water Heating	0.80	0.53
Cooking	0.90	0.72
IT & Office Equipment	1.04	1.82
Other	1.23	2.52

Site kWh to Site Btu conversion of 3,412 Btu-to-kWh; site-to-source conversion factors: Electricity: 3.15 and natural gas: 1.09.

Figure ES-3 shows the estimates of primary energy consumption for cooking and food preparation equipment (0.93 Quads total) by the individual appliances types. Fryers consume the greatest amount of energy at 0.33 Quads. Of these appliances, natural gas accounts for 55% (0.51 Quads) of primary energy. Even with a large number of individual products, food preparation equipment has limited national energy consumption due to the low operating times for most appliance types.

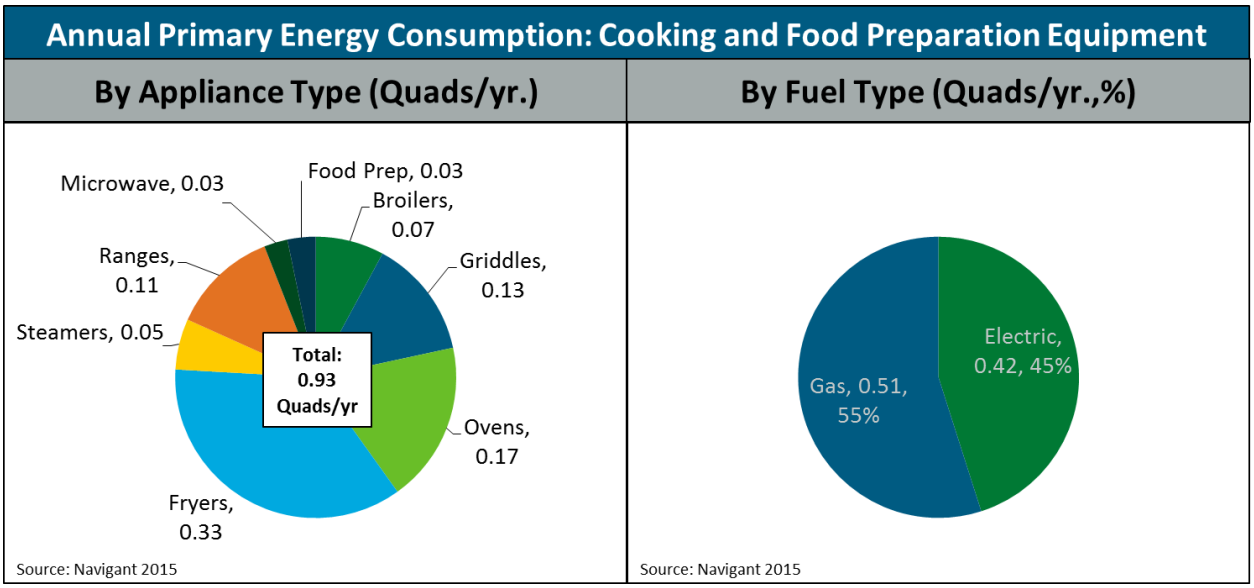


Figure ES-3: 2015 energy consumption estimates for cooking and food preparation equipment

Figure ES-4 shows the estimates of primary energy consumption for water heaters and pool heaters (1.01 Quads total). Gas-fired equipment constitutes over 60% of the primary energy consumption in this category. Gas-fired products constitute nearly 100% of the pool heater market.

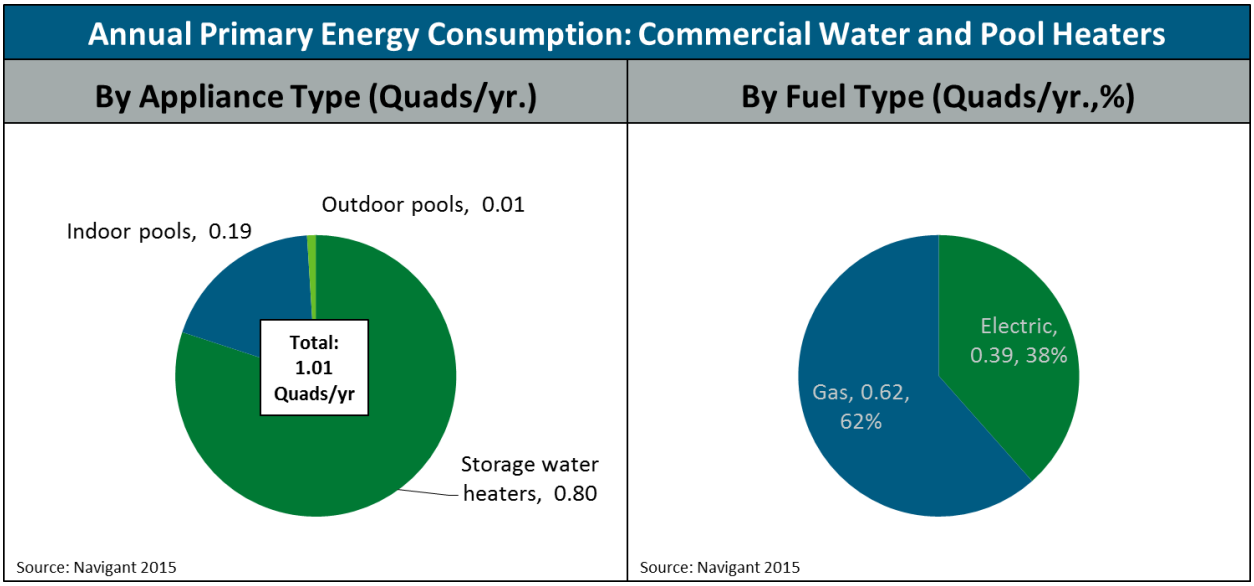


Figure ES-4: 2015 energy consumption estimates for commercial water and pool heaters

Figure ES-5 shows the estimates of primary energy consumption for the four types of common commercial dishwashers, as well as the split of this energy use associated with the building water heater versus the appliance itself (i.e., booster heater and machine energy consumption). In total, commercial dishwashers consume 0.18 Quads of primary energy annually. When excluding building water heater usage, dishwashers consume 0.08 Quads per year. More than 75% of the energy used for dishwashing is electric energy because all dishwashers require electricity to operate their controls, pumps, and motors, and because approximately 95% high-temperature dishwashers use electric booster heaters to bring the building's service water temperature up to 180°F.

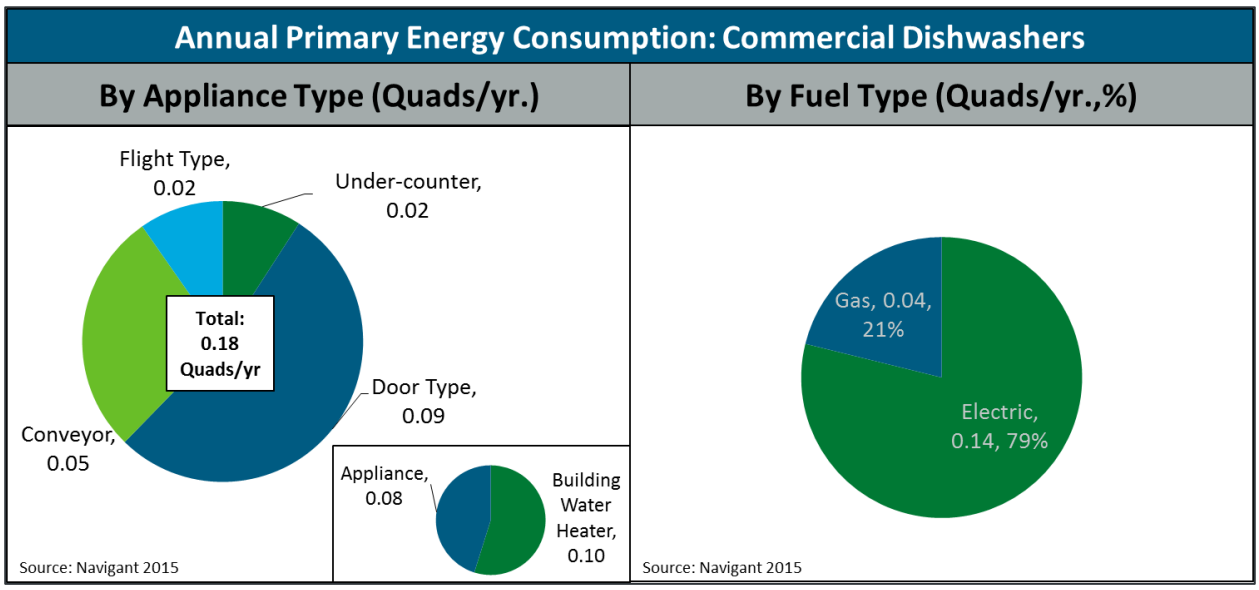


Figure ES-5: 2015 energy consumption estimates for commercial dishwashers

Figure ES-6 shows the estimates of primary energy consumption for commercial laundry equipment, including clothes washers, clothes dryers, and dry-cleaning. In total, commercial laundry equipment consumes a total of 0.42 Quads of primary energy annually. Approximately 50% of this energy is for the building water heater; therefore, the laundry equipment itself consumes 0.21 Quads per year. The largest end-use segments are multi-load washers and dryers (0.32 Quads combined, including building water heating); multi-load dryers have the largest energy consumption when excluding building water heater energy use. Natural gas accounts for approximately 88% of energy consumption in this category to supply hot water for washing, and hot air for drying.

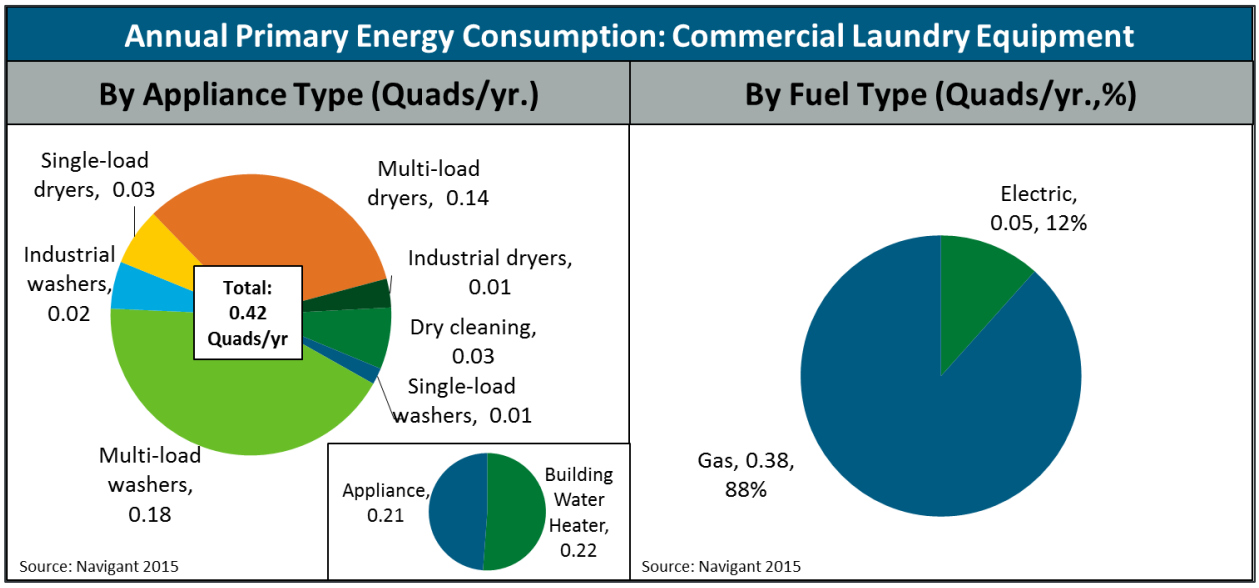


Figure ES-6: 2015 energy consumption estimates for commercial laundry equipment

Figure ES-7 shows the estimates of primary energy consumption for IT and office equipment, which together consume 1.04 Quads of primary energy annually. While computers and monitors and other equipment have become more energy efficient in recent years, the increase in installed base of server computers and network equipment has generated an increase in the total primary energy consumption for this category.

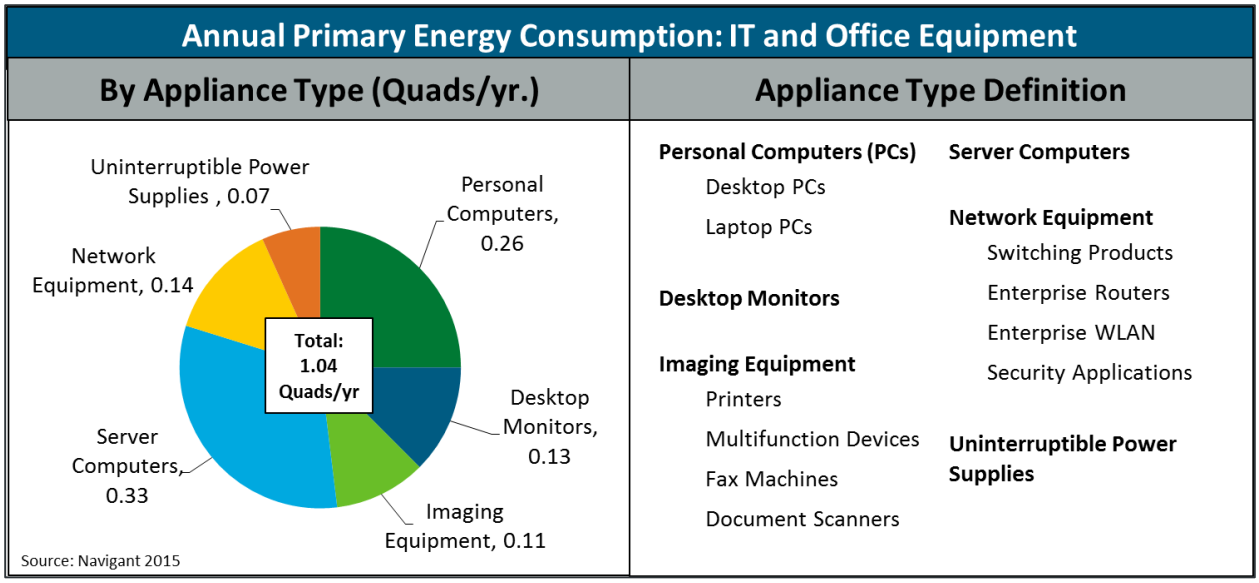


Figure ES-7: 2015 energy consumption estimates for IT and office equipment

Figure ES-8 shows the estimates of primary energy consumption for the miscellaneous commercial appliances evaluated in this report, including distribution transformers, medical imaging equipment, vertical-lift technologies and other "plug-loads." Together these appliances consume a total of 0.70 Quads of primary energy per year with distribution transformers within commercial buildings constituting over 65% (0.48 Quads) of the category total. This report documents many of the largest miscellaneous loads in commercial buildings, but does not cover all, or even all the largest, miscellaneous commercial appliances. As a comparison, our estimate makes up 23% of the miscellaneous equipment estimate from the 2008 BEDB.[7] This more-than 2 Quad difference suggests miscellaneous building loads could be one of the key differences between our total commercial appliance estimates and the AEO total estimates.

[7] DOE. 2008. "2008 Buildings Energy Data Book." U.S. Department of Energy. November 2008.

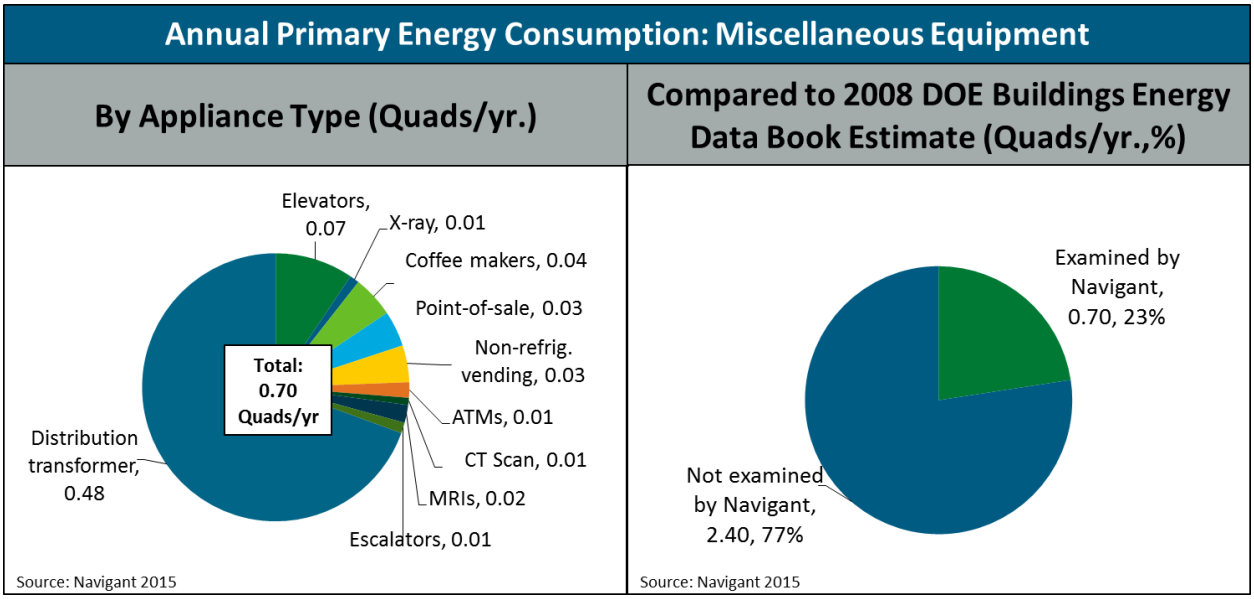


Figure ES-8: 2015 energy consumption estimates for miscellaneous commercial appliances

ES-2 Comparison to 2009 Commercial Appliances Report

Figure ES-9 compares the annual primary energy consumption estimates from this study to that of the 2009 Commercial Appliances Report, for which this report is an update. The 2009 Commercial Appliances Report documented 2.92 Quads of primary energy consumption; this report documents 3.97 Quads or 36% more, which reflects increases in consumption as well as coverage of additional end-uses. Each category, except laundry, shows an increase since 2009, with notably large increases in cooking, pool heaters, and miscellaneous loads:

- Cooking has a significant increase of 0.38 Quads (73%), due primarily to a change in calculation methodology that we believe better reflects actual consumption. As previously discussed, we expanded the installed base to include buildings with food preparation and serving areas but do not list food service as their principal building activity (e.g., a hospital with a cafeteria).
- Pool heater energy consumption nearly doubled since 2009 with a 0.11 Quad (110%) increase because newly available market data for swimming pool penetration in lodging facilities showed a significantly higher installed base.
- Laundry equipment decreased by 0.05 Quads (19%, which excludes overlap with hot water loads) based on changes in the calculation methodology to use newly available information sources.
- Miscellaneous building loads increased by 0.50 Quads (250%) primarily due to the inclusion of building distribution transformers (0.48 Quads).

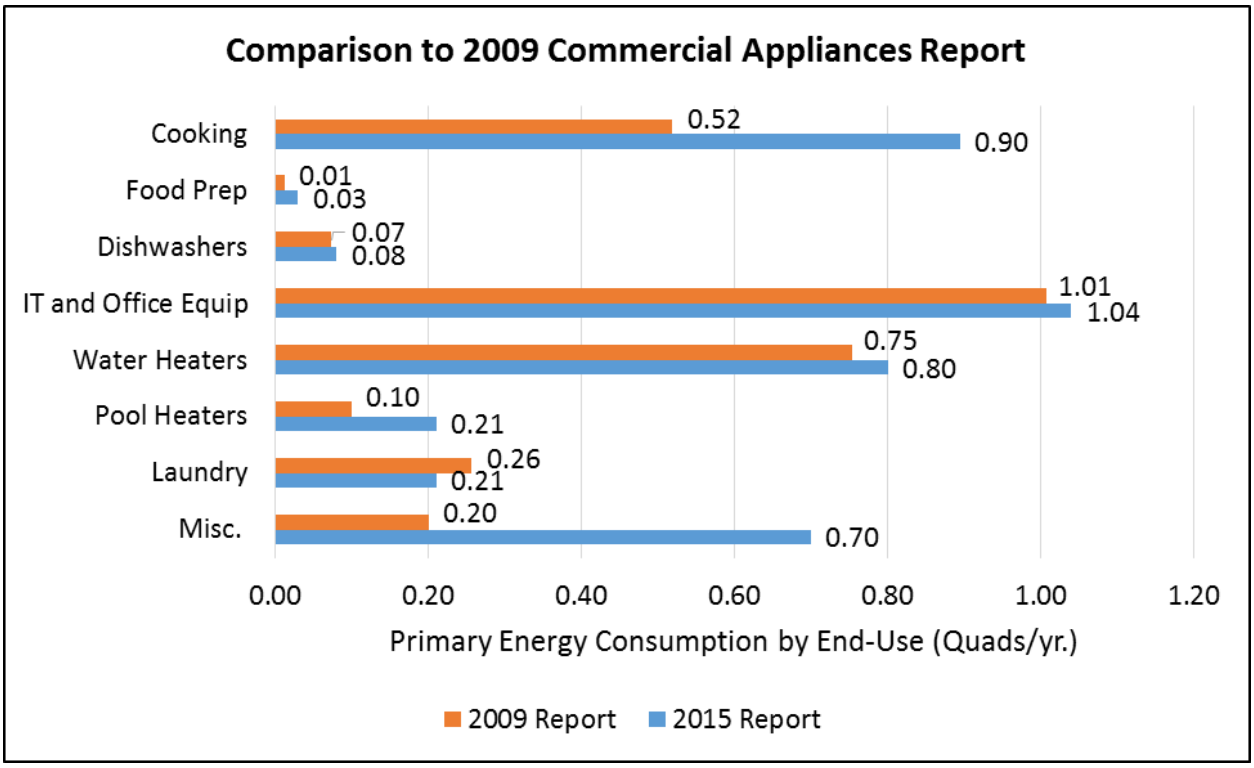


Figure ES-9: Comparison to 2009 Commercial Appliance Report

ES-3 Energy Savings Opportunities

This analysis also identified commercially available and emerging technologies that could offer energy savings for each appliance category. Figure ES-10 shows the technical potential[8] for each profiled technology, grouped by appliance category. These technologies offer energy savings over products meeting today's minimum efficiency standards or other specifications.

[8] Technical potential is the theoretical national primary energy savings that could be achieved if all technically suitable appliance/equipment installations are replaced with a particular energy-saving technology (i.e., 100% adoption). In this report, we calculate technical potential relative to the efficiency of typical new equipment, so that we do not double count the savings that will be achieved anyway, through normal equipment replacement cycles.

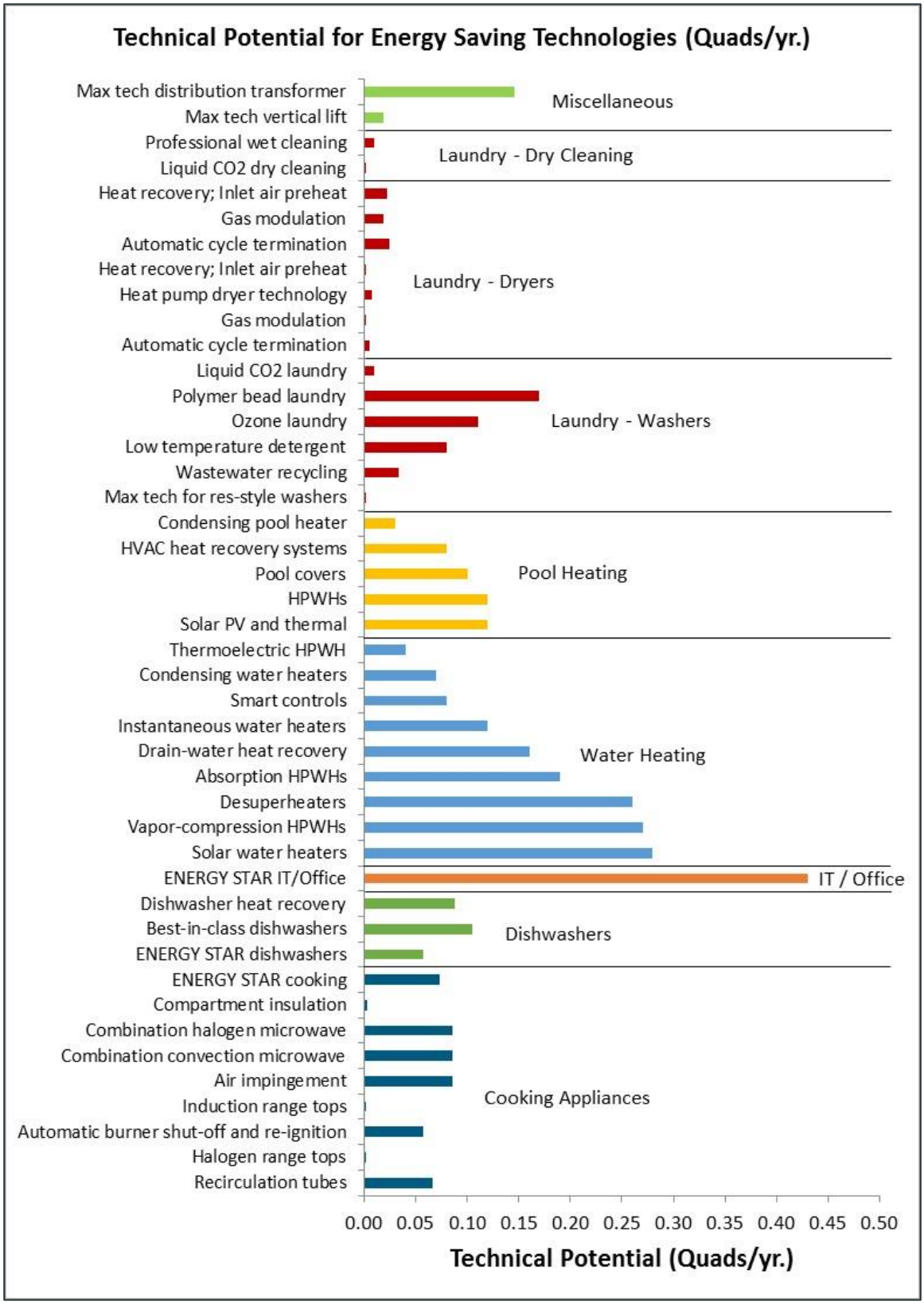
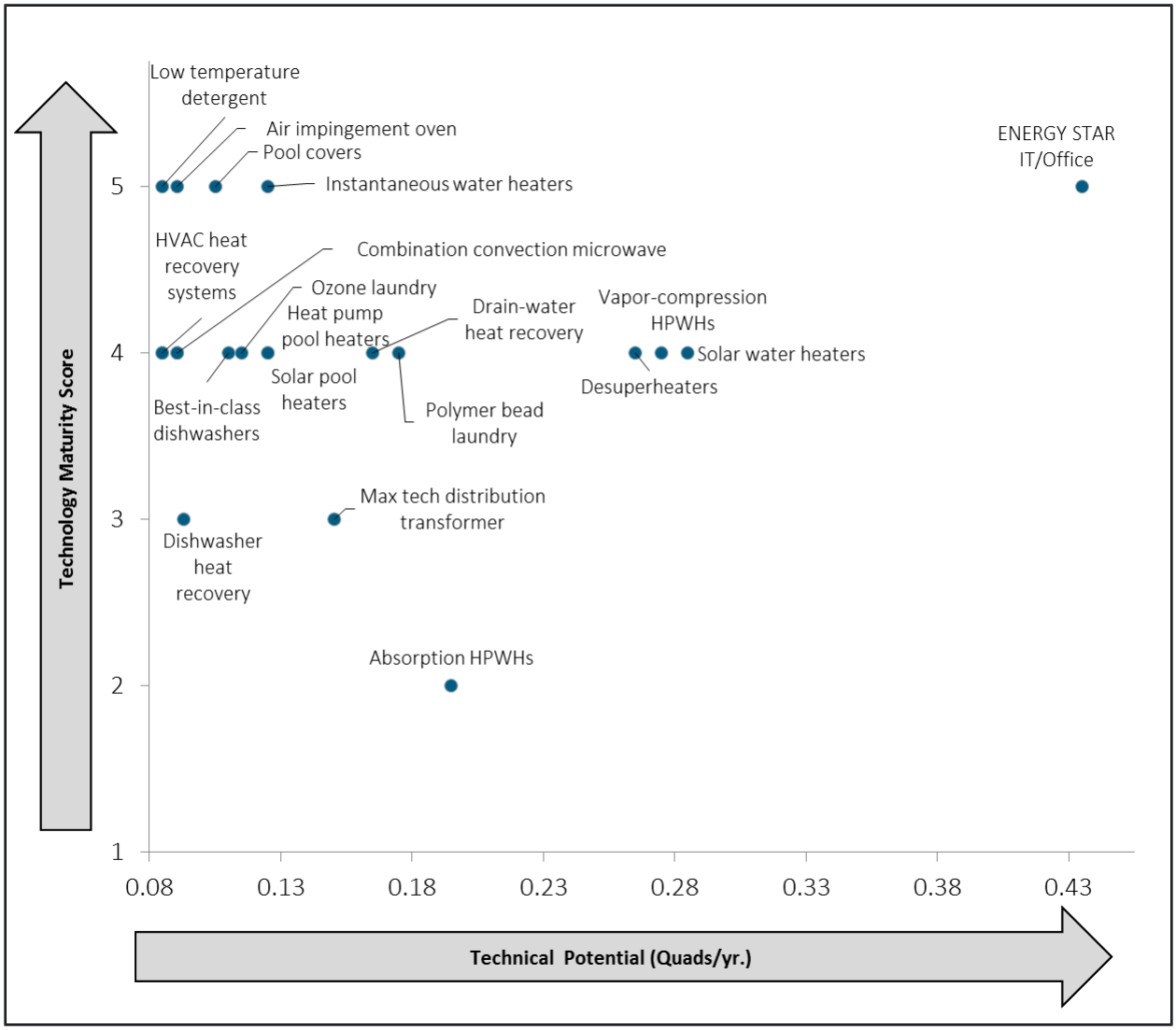


Figure ES-10: Technical potential for energy-saving technologies

Figure ES-11 plots each technology according to technology maturity and technical potential. Technology maturity ratings are based on the authors' judgement through a review of available products on the market, current RD&D efforts, and other resources.



Maturity ranking guidelines:

5 - Commercially available technology; high-efficiency models are competitive with typical models.

4 - Commercial available though only available from 1-2 manufacturers; low market penetration, high costs.

3 - Near Term technology: Proven technology though not in application, possibly in pilot stage or development

2 - Long Term: Proven technology though only in a lab setting or based on engineering fundamentals

1 - R&D: Unproven technology for application, energy savings is a preliminary estimate, costs are uncertain.

Note: Only selected technology labels are displayed for figure clarity.

Figure ES-11: Technology maturity and technical potential for energy-saving technologies

As Figure ES-11 shows, most of the energy savings potential resides in technologies that are already on the market today (represented by a 4 or 5 score, e.g., ENERGY STAR IT and office products, solar water heaters, instantaneous water heaters). However, in some of these cases, the technologies may not be widely used in the targeted application, and some design,

demonstration, and marketing work may be needed to increase the technology's adoption. For example, low-temperature detergents for commercial laundry facilities, ENERGY STAR dishwashers for leasing agents to food service buildings, or indoor pool covers are all available energy-saving technologies, but still are underutilized in the marketplace. In these cases, RD&D activities would focus on reducing installation, operation, and maintenance complexity, performing field demonstrations at commercial buildings, and marketing the benefits to key stakeholders such as utility energy efficiency programs and regional efficiency organizations.

Emerging technologies (represented by a technological maturity score of 2 or 3) such as absorption heat pump water heaters, desuperheaters coupled with packaged HVAC equipment, and polymer bead laundry show large technical potentials, but require further RD&D before product introduction and/or wide adoption. In these cases, RD&D activities would focus on proving technical performance relative to baseline technologies, reducing technology cost to decrease cost premiums and payback times, and facilitating connections between researchers, manufacturers, retailers, and system designers for successful product launch.

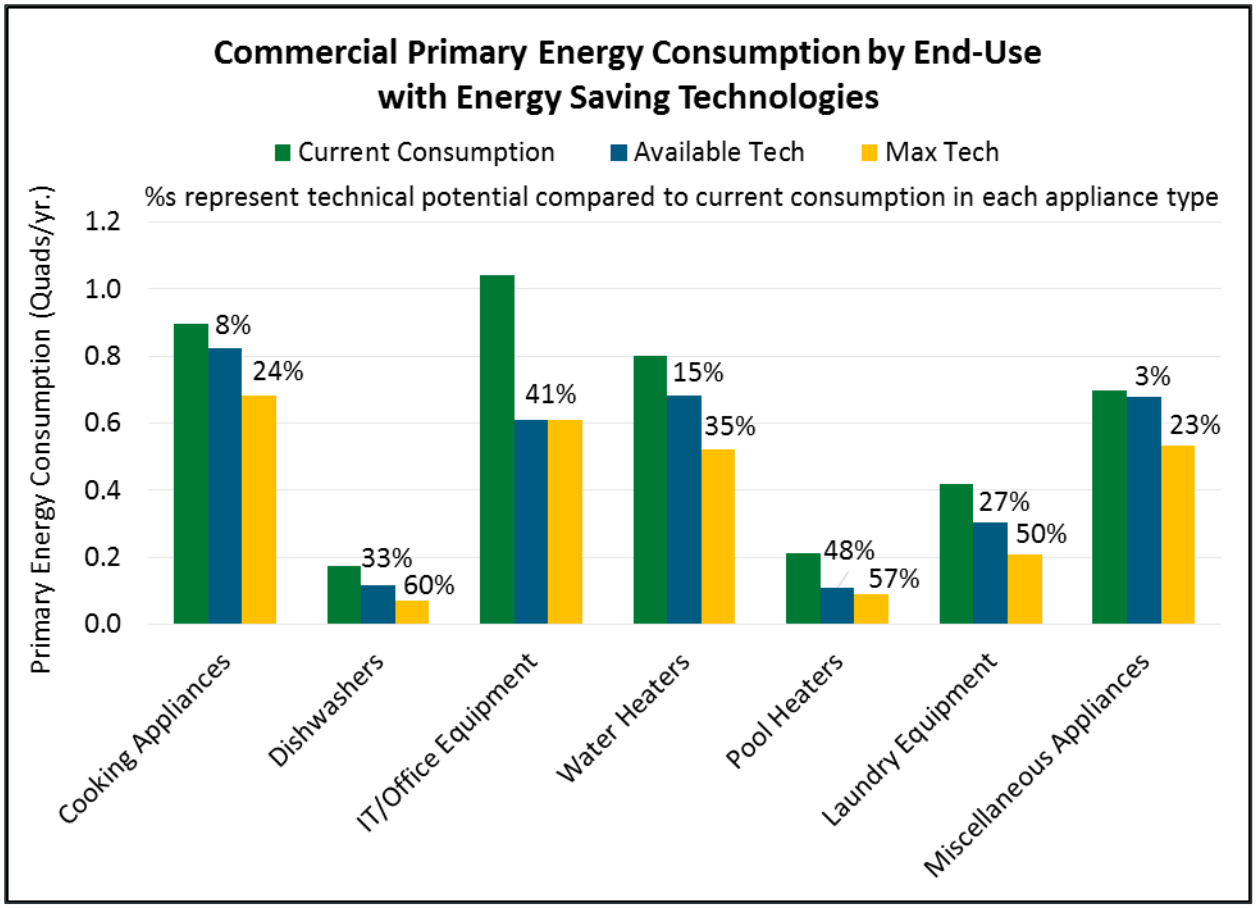
Table ES-3 and Figure ES-12 outline the technical savings potential (i.e., assuming 100% adoption) for the most promising available technologies and separately, emerging (i.e., max tech) technologies. In most commercial appliance categories, technologies exist today that can significantly improve the energy efficiency of commercial buildings. As shown in Figure ES-12, energy-saving technologies available today could reduce commercial appliance consumption by 22% overall (with a range of 3-48% among the categories) compared to technologies on the market today meeting minimum efficiency standards. Programs such as EPA's ENERGY STAR, DOE's Federal Energy Management Program (FEMP), and utility incentive programs help commercial building operators and designers identify energy-saving opportunities and reduce project cost and complexity.

Max tech technologies represent the additional energy savings that products currently in the research and development (R&D) stage or those waiting for a breakthrough could provide to commercial buildings. As shown in Figure ES-12, emerging technologies could surpass the energy saving of today's efficient products and save 36% (with a range of 23-60%) compared to baseline technologies on the market today. These opportunities require additional RD&D effort to reach the marketplace with acceptable costs, payback, and complexity.

Table ES-3: Technical Potential for Energy Savings Technologies by Commercial End-Use

End-Use	Current Consumption (Quads/yr.)	Available		Max Tech	
		Technology Name(s)	Energy Savings (Quads/yr.)	Technology Name(s)	Energy Savings (Quads/yr.)
Cooking Appliances	0.90	ENERGY STAR cooking equipment	0.07	Fryer recirculation tubes, automatic range burner control, air impingement ovens, steamer compartment insulation	0.21
Dishwashers	0.18	ENERGY STAR dishwashers	0.06	Best-in-class dishwashers	0.11
IT/Office Equipment	1.04	ENERGY STAR IT/Office equipment	0.43	ENERGY STAR IT/Office equipment	0.43
Water Heaters	0.80	Instantaneous water heaters	0.12	Solar water heaters	0.28
Pool Heaters	0.21	Pool covers	0.10	Heat pump pool heaters	0.12
Laundry Equipment	0.42	Max tech for residential washers, low-temperature detergent, automatic dryer cycle termination, gas dryer modulation, professional wet cleaning	0.11	Max tech for residential washers, polymer bead laundry, heat pump dryer, heat recovery, professional wet cleaning	0.21
Misc. Appliances	0.70	Max tech vertical-lift technologies	0.02	Max tech vertical-lift technologies, max tech distribution transformer	0.16

Note - dishwasher and clothes washer consumption and savings includes the energy associated with building's water heater



Note – energy savings estimates reflect energy efficiency improvements over today's baseline products meeting minimum efficiency standards rather than the typical installed base. Actual savings may be higher as today's standards are higher efficiency than typical installed base.

Figure ES-12: Commercial primary energy consumption by end-use with energy-saving technologies

This report provides a detailed look at each of these technology categories, including the basis for our energy consumption and installed base estimates, as well as discussion of the energy savings opportunities for each technology.

For more information, please see the full report available at: eere.energy.gov/buildings

(This page intentionally left blank)

U.S. DEPARTMENT OF
ENERGY
Energy Efficiency &
Renewable Energy

For more information, visit: eere.energy.gov/buildings

DOE/EE-1393 • June 2016