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Analysis and Representation of Miscellaneous Electric Loads in NEMS

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Analysis and Representation of Miscellaneous Electric Loads in NEMS

Miscellaneous electric loads (MELs) account for a growing portion of delivered energy consumption in residential and commercial buildings. Recently, the growth of MELs has offset some of the efficiency gains made through technology improvements and standards in major end uses such as space conditioning, lighting, and water heating. Miscellaneous end uses—including televisions, personal computers, security systems, data center servers, and many other devices—have continued to penetrate into building-related market segments. Part of this proliferation of devices and equipment can be attributed to increased service demand for entertainment, computing, and convenience appliances.

Stock, usage, and consumption data can be difficult to obtain given the dispersed and increasingly varied nature of such equipment and appliances. EIA conducts two surveys of the building sectors, the *Residential Energy Consumption Survey* (RECS) and *Commercial Buildings Energy Consumption Survey* (CBECS), which provide information on the equipment stock and energy consumption of major end-use equipment within existing buildings. Although we capture some devices and appliances in this process, we cannot account for all MELs within buildings with these large-scale survey methods. These surveys also do not capture estimates of consumption for end uses outside of buildings, such as water treatment and distribution or telecommunications equipment.

The Residential Demand Module (RDM) and Commercial Demand Module (CDM) of the National Energy Modeling System (NEMS) generally project annual energy consumption of MELs by combining unit energy consumption (UEC) with total stock of equipment or devices by type. This method differs from what we use for major end-use equipment, which is modeled using a technology menu that accounts for equipment vintage, performance, and costs.

The contract reports in Appendix A and Appendix B characterize a number of residential and commercial MELs and provide the informational basis for modeling these projections with based on equipment stock and annual energy consumption across end uses. This focus enables more detailed and specific MEL projections and analysis. We will use Appendix A to help develop Reference case projections for the *Annual Energy Outlook 2022* (AEO2022) and future reports. We have been using Appendix B data since AEO2018.

The contract report in Appendix A should be cited as a report by Guidehouse, Inc. and Leidos, Inc., prepared for the U.S. Energy Information Administration. The contract report in Appendix B should be cited as a report by Guidehouse, Inc. (formerly Navigant Consulting, Inc.) and Leidos, Inc., prepared for the U.S. Energy Information Administration.

APPENDIX A

MISCELLANEOUS ELECTRIC LOAD CONSUMPTION CHARACTERIZATION 2021 UPDATE

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EXECUTIVE SUMMARY » OBJECTIVE, SCOPE, AND GOALS

Summary: This study characterizes energy consumption and installed base for 23 residential miscellaneous electric loads (RMELs) and 18 commercial MELs (CMELs). The evaluations include projections through 2050.*

Objective: Develop an updated and expanded list of the estimated unit and national energy consumption for RMELs and CMELs.

RMELs covered: Audio equipment, ceiling fans, coffee makers, dehumidifiers, desktop PCs, laptop PCs, microwaves, miscellaneous refrigeration products, monitors, network equipment, Non-PC rechargeable electronics, pool heaters, pool pumps, portable electric spas, residential security systems, set-top boxes, small kitchen appliances, smart speakers, smartphones, tablets, televisions, and video game consoles.

CMELs covered: Data center servers, desktop PCs, distribution transformers, elevators, IT equipment, kitchen ventilation, laboratory fume hoods, laboratory refrigerators/freezers, laptop PCs, medical imaging equipment, monitors, point-of-sale (POS) machines, security systems, televisions, video displays, warehouse robots, wastewater treatment, and water supply and purification.

Goals:

- Define each MEL and determine the scope of the technology to be analyzed.
- Characterize the base year installed stock and unit energy consumption (2015 for residential and 2012 for commercial).
- Develop scenario-based projections through 2050.

**** High-level analyses without projections were conducted for an additional 5 residential MELs (Air Purifiers, Blu-Ray/DVDs/VHS, Electric Scooters/Bikes, Residential Video Surveillance Systems, Video Doorbells) and 10 commercial MELs (Commercial Coffee Brewers, Commercial Laundry Equipment, Escalators, Slot Machines and Arcade Games, Treadmills, Large-Format Video Boards, Non-Road EVs, Building Management Systems, ATMs, Electronic Doors) (Appendix E and F).***

EXECUTIVE SUMMARY » PROCESS DESCRIPTION

The evaluation used the following procedure:

1. Define the scope of each selected MEL.
2. Estimate the U.S. installed base in number of units, devices, pieces of equipment, or systems, with the following exceptions:
   - Installed base estimates for wastewater treatment and for water supply and purification are in units of million gallons per year (Mgal/yr).
3. Approximate the unit energy consumption (UEC) by determining typical:
   - Usage hours for each mode of operation
   - Power consumption for each mode of operation (per unit or per user, as appropriate)
4. Characterize relevant market, economic, demographic, and technology trends.
5. Develop projections up to the year 2050 based on expected changes in:
   - Usage hours
   - Power consumption
   - UEC
   - Annual energy consumption (AEC)
   - Installed base

EXECUTIVE SUMMARY » RMEL DEFINITIONS

This analysis covered 23 residential MELs.

MEL	Definition
Set-top boxes	Set-top boxes are devices designed for the reception of television and related services from terrestrial, cable, satellite, broadband, or local networks, providing video output using at least one direct video connection. This analysis includes DVR, non-DVR, thin-client, and Digital Television Adapter (DTA) set-top boxes.
Pool pumps	The most energy intensive aspects of residential swimming pools are related to water circulation, filtration, and water heating. This analysis only includes pool pumps.
Televisions	Televisions include cathode ray tube, plasma, and LCD televisions. Light-emitting diode (LED) and organic light-emitting diode (OLED) TVs are included within LCD TVs.
Network equipment	Network equipment consists of routers, modems, hubs, and switches for residences. This technology includes three general categories: 1) broadband modems, 2) integrated access devices (modem + router in one device), and 3) local network equipment (hubs, routers, switches).
Home audio equipment	Audio equipment consists of audio video receiver based component audio systems (surround sound and stereo including sound bars), compact audio systems, and Home Theater in a Box (HTIB) systems.
Laptop PCs	Residential laptop PCs includes laptops and netbooks.
Desktop PCs	Residential desktop PCs includes desktop towers and all-in-one desktop PCs. This analysis does not account for the monitor unless it is included as part of an all-in-one desktop PC configuration.
Monitors	Residential monitors include external monitors for both desktops and laptops. This technology does not include laptop monitors or monitors that are integrated into the desktop PC.

EXECUTIVE SUMMARY » RMEL DEFINITIONS

This analysis covered 23 residential MELs.

MEL	Definition
Dehumidifiers	Dehumidifiers are portable, electrically operated, and mechanically refrigerated encased assembly consisting of (1) a refrigerated surface (evaporator) that condenses moisture from the atmosphere; (2) a refrigerating system, including an electric motor; (3) an air-circulating fan; and (4) means for collecting or disposing of the condensate.
Ceiling Fans	Non-portable device designed for home use that is suspended from the ceiling for circulating air via the rotation of fan blades.
Microwaves	Microwave ovens are cooking appliances consisting of a compartment designed to cook or heat food by means of microwave energy.
Smart speakers	Smart speakers are usually wireless speakers with built in virtual assistants and were first introduced by Amazon in 2014.
Non-PC rechargeables	Non-PC rechargeables include battery-operated products, not those directly powered by electrical outlets, electronics other than PCs, tablets, and smartphones. Typical examples include wireless headsets, wireless speakers, portable media players, cameras, and battery powered video game consoles (for example, PlayStation Portable, Nintendo Switch, Nintendo 3DS, and virtual reality (VR) headsets.)
Pool heaters	The most energy intensive aspects of residential swimming pools are related to water circulation, filtration, and water heating. The primary equipment used to provide these amenities are pool pumps and pool heaters. This analysis only includes electric pool heaters.
Smartphones	Smartphones use different operating systems to offer users a wide range of functions such as multimedia playbacks, internet browsing, and photography in addition to core phone functions. Smartphones make up the majority of shipments from portable electronics.
Tablets	Tablets offer a more portable solution to regular laptops, but they usually lack the extra input/output capabilities, typically with lower energy consumption than regular laptops as well.

EXECUTIVE SUMMARY » RMEL DEFINITIONS

This analysis covered 23 residential MELs.

MEL	Definition
Over-the-top streaming devices	Over-the-top (OTT) streaming devices are external devices that enable TVs to stream content via internet (for example, Roku stick, Apple TV, Amazon Fire stick.)
Coffee makers	Coffee makers are made up of automatic drip, single-serve, and espresso machines.
Miscellaneous refrigeration products	This device category includes coolers that are separate from standard residential refrigerators and freezers, such as: compact coolers, built-in coolers, freestanding coolers, coolers with freezers, and coolers with icemakers.
Small kitchen appliances	Small kitchen appliances include toasters, toaster ovens, pressure cookers, food processors, rice cookers, blenders.
Video game consoles	Video game consoles include PlayStation 2, PlayStation 3, PlayStation 4, PlayStation 5, Xbox 360, Xbox One, Xbox Series X/S (metrics are averaged across the two system types), Nintendo Wii, Nintendo Wii U, Nintendo Switch, and future generations of consoles.
Residential security systems	System of control panel(s), keypad(s), and sensors used to detect intruders, water, fire, and/or carbon monoxide (does not include security cameras or video doorbells.)
Portable electric spas	Pre-fabricated, self-contained electric spas or hot tubs. Excludes in-ground units (such as those attached to a pool), other permanently installed residential spas, public spas, or spas that are operated for medical treatment or physical therapy.

EXECUTIVE SUMMARY » CMEL DEFINITIONS

This analysis covered 18 commercial MELs.

MEL	Definition
Commercial laptop PCs	This product category consists of laptops in only commercial settings. This does not include netbooks or tablets or the additional, external monitors that may be attached to laptops in some cases.
Commercial desktop PCs	Desktop computers include computer tower units and integrated desktop/monitor units. This does not include computers associated with BMS.
Commercial PC monitors	This product category consists of external monitors connected to either desktops or laptops.This does not include desktop PCs with integrated monitors.
Data center servers	Data center servers are usually rack mounted equipment designed for large amounts of computing within data centers.
IT equipment	IT equipment includes network equipment infrastructure (i.e. router/WLAN, switches, security).
Medical imaging equipment	Medical imaging equipment includes magnetic resonance imaging (MRI), computed tomography scans (CT), X-rays, and ultrasounds.
Laboratory refrigerators and freezers	This product category consists of laboratory refrigerators, freezers, and ultra-low freezers.
Point-of-sale (POS) systems	Point-of-sale, or point-of-service, systems used to execute and manage retail transactions, including cash registers and POS terminals (computer-based and tablet-based.)

EXECUTIVE SUMMARY » CMEL DEFINITIONS

This analysis covered 18 commercial MELs.

MEL	Definition
Wastewater treatment	Also referred to as municipal wastewater treatment and publicly-owned treatment works (POTW). Includes wastewater collection systems treatment facilities. Excludes all septic, dedicated industrial effluent treatment, and other private on-site systems.
Water supply & purification	Also referred to as municipal water supply and public water systems (PWS). Includes treatment/purification plants, water storage systems, and distribution infrastructure. Excludes all self-supply of potable water (for example, private wells.)
Elevators	Elevators are vertical cable transportation machines that move people or freight between floors or levels.
Kitchen ventilation	Commercial kitchen ventilation (CKV) uses exhaust hoods with fans to remove smoke and grease from restaurant kitchens and food service prep rooms in supermarkets. Energy consumption is determined by three different factors: exhaust fans, makeup air fans, and conditioning (heating and cooling) of the makeup air.
Distribution transformers	This product category consists of building-based distribution transformers, including only those on the building-side of the meter (i.e., no transformers used by the utility for distribution or transmission of electricity).
Laboratory fume hoods	A fume hood is a ventilation device used to limit exposure while working with harmful chemicals and toxins.
Televisions	Commercial TVs include cathode ray tube, plasma, and LCD televisions. Light-emitting diode (LED) and organic light-emitting diode (OLED) TVs are included within LCD TVs.
Video displays	This product category includes electronic displays or screens (such as LCD or plasma) that deliver entertainment, information, and/or advertisement in public or private commercial spaces. This does not include large-format video displays, such as those used in arenas/stadiums, which are covered under *Large-Format Video Boards.*

EXECUTIVE SUMMARY » CMEL DEFINITIONS

This analysis covered 18 commercial MELs.

MEL	Definition
Commercial security systems	Video surveillance, access control, intrusion detection, fire detection, and electronic article surveillance (EAS) systems
Warehouse robots	A robot used within a logistics operation such as a warehouse, fulfillment center, or distribution center. There are many types of robots, but the dominant types are drives (motorized dollies) and palletizers (articulated arms).

EXECUTIVE SUMMARY » RMEL RESULTS SUMMARY

Televisions consumed 30 TWh of site electricity in 2015, the most of any RMEL in this analysis.

Total residential site electricity use was 1,404 TWh in 2015*

Appendix A contains a complete summary of Installed Base, UEC and AEC in 2015 for RMELs

*Total electricity retail sales in 2015 for residential sector from U.S. EIA, *Monthly Energy Review*, Table 2.2, January 2021

Residential MEL	AEC (TWh/yr)	Installed Base (000s)
Televisions	30	275,403
Pool Pump	25	8,319
Ceiling Fans	23	255,728
Set-Top Boxes	23	226,728
Desktop PCs	15	59,100
Microwave Ovens2	14	118,629
Network Equipment	13	139,000
Dehumidifiers	11	18,257
Portable Electric Spas	9.0	4,001
Home Audio Equipment	7.9	97,261
Miscellaneous Refrigeration Products	7.4	16,237
Coffee Makers	5.2	75,914
Laptop PCs	4.7	119,767
Video Game Consoles	4.1	65,536
Monitors	3.8	77,624
Small Kitchen Appliances	3.5	193,272
Non-PC Rechargables	2.2	832,184
Pool Heaters	1.5	688
Residential Security Systems	1.2	24,474
Smartphones	0.9	189,337
Tablets	0.7	113,568
OTT Streaming Devices	0.4	47,356
Smart Speakers	0.04	3,000

EXECUTIVE SUMMARY » CMEL RESULTS SUMMARY

Commercial kitchen ventilation consumed 53 TWh of site electricity in 2012, the most of any CMEL in this analysis.

Total commercial site electricity use was 1,327 TWh in 2012**

Appendix B contains a complete summary of Installed Base, UEC and AEC in 2012 for CMELs

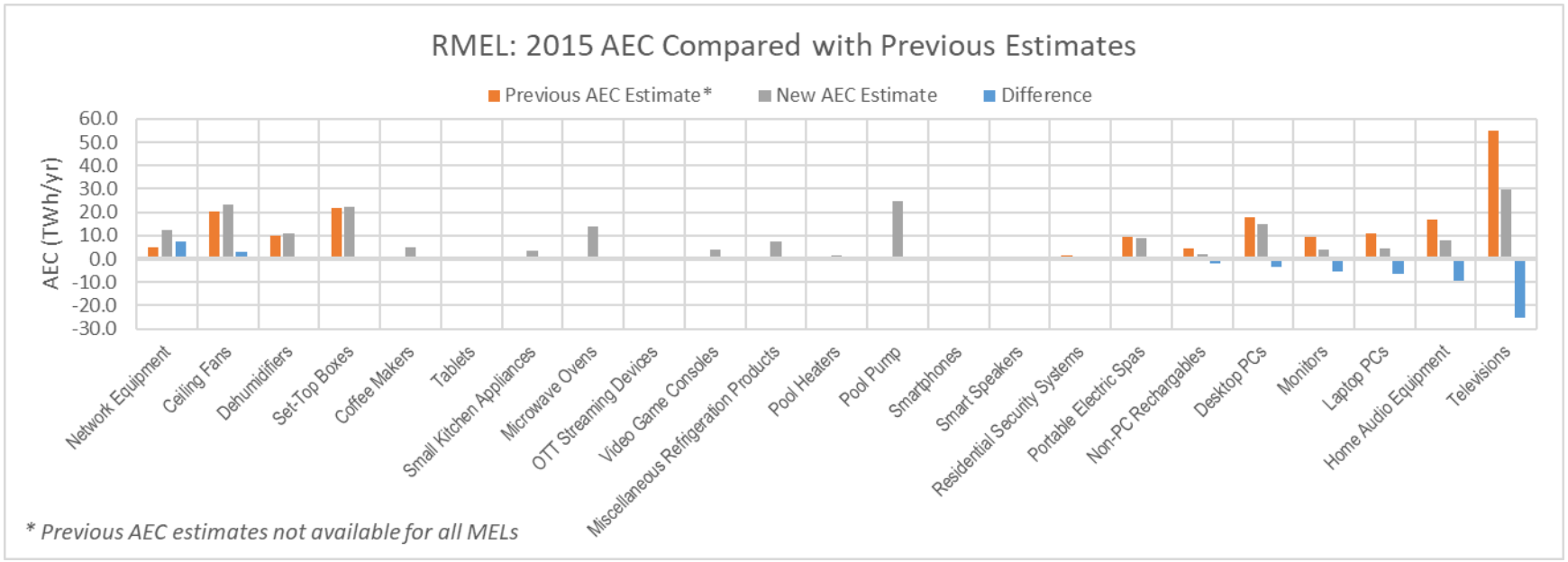
**Total electricity retail sales in 2012 for commercial sector from U.S. EIA, *Monthly Energy Review*, Table 2.3, January 2021

Commercial MEL	AEC (TWh/yr)	Installed Base (000s)*
Kitchen Ventilation	53	1,042
Distribution Transformers	46	5,824
Data Center Servers	46	13,500
Commercial Desktop PCs	31	75,757
Wastewater Treatment*	31	11,886,208
Water Supply & Purification*	29	14,666,269
IT Equipment	15	581,654
Lab Fume Hoods	14	872
Lab Refrigerator and Freezers	11	2,756
Commercial Security Systems	7.5	11,214
Commercial Monitors	7.5	70,746
Elevators	5.7	751
Medical Imaging Equipment	4.9	478
Commercial Televisions	3.9	19,194
Commercial Video Displays	3.6	9,028
POS Systems	1.6	5,430
Commercial Laptop PCs	0.8	30,358
Warehouse Robots	0.02	20

** Installed base units in million gallons per year (Mgal/yr) for wastewater treatment and water supply & purification*

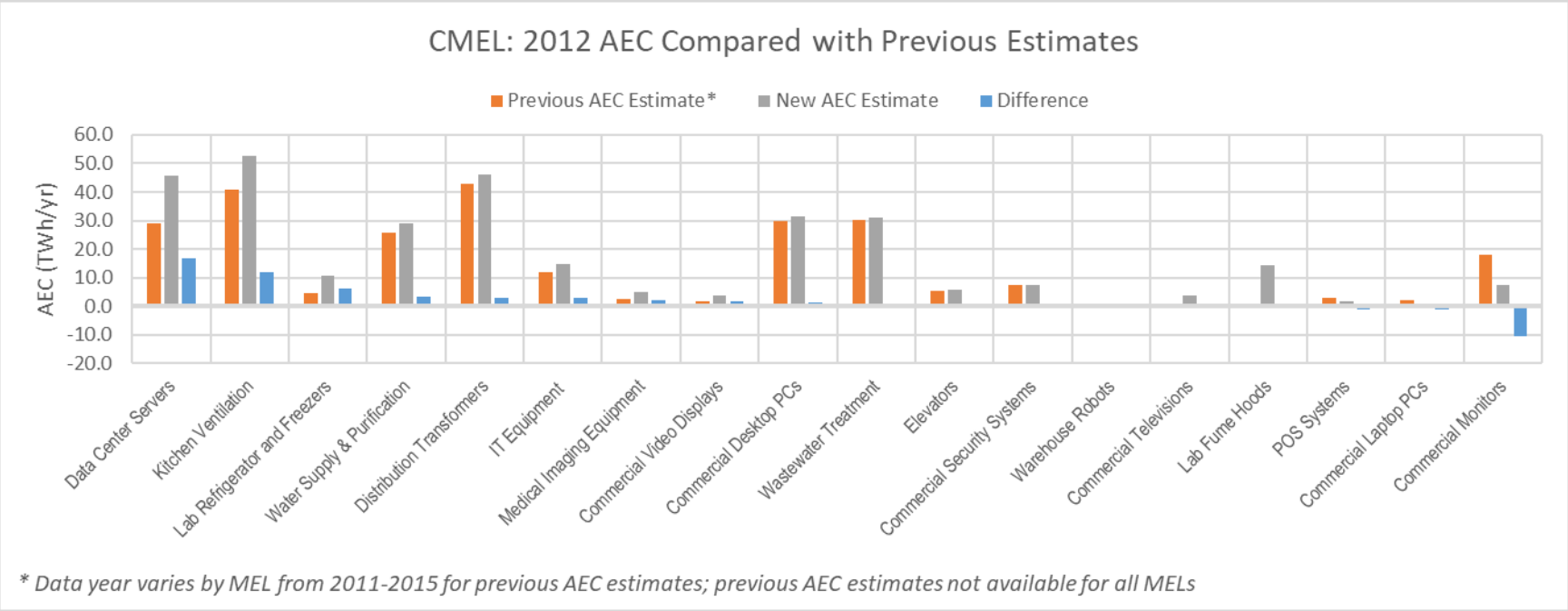
EXECUTIVE SUMMARY » RMEL COMPARISONS

Our estimates build on the best available past research but can, in some cases, differ substantially from other recent MELs studies.



- **Network equipment:** AEC is higher than previous results primarily due to increases in unit energy consumption as a result of higher energy consumption of integrated access devices (that is, modem plus router) from updated references.
- **Home audio equipment:** AEC was found to be lower than the 2013 report mostly due to the updated and revised methodology in calculating installed base of home audio equipment based on data from the 2015 Residential Energy Consumption Survey (2015 RECS), the Annual Energy Outlook 2021 (AEO2021), ENERGY STAR®, and industry reports.
- **Residential televisions:** AEC is significantly lower than previous results as a result of a much faster than anticipated phase-out of plasma and CRT televisions in favor of LCD televisions. This shift in television type installed base led to significant reductions in UEC.

EXECUTIVE SUMMARY » CMEL COMPARISONS

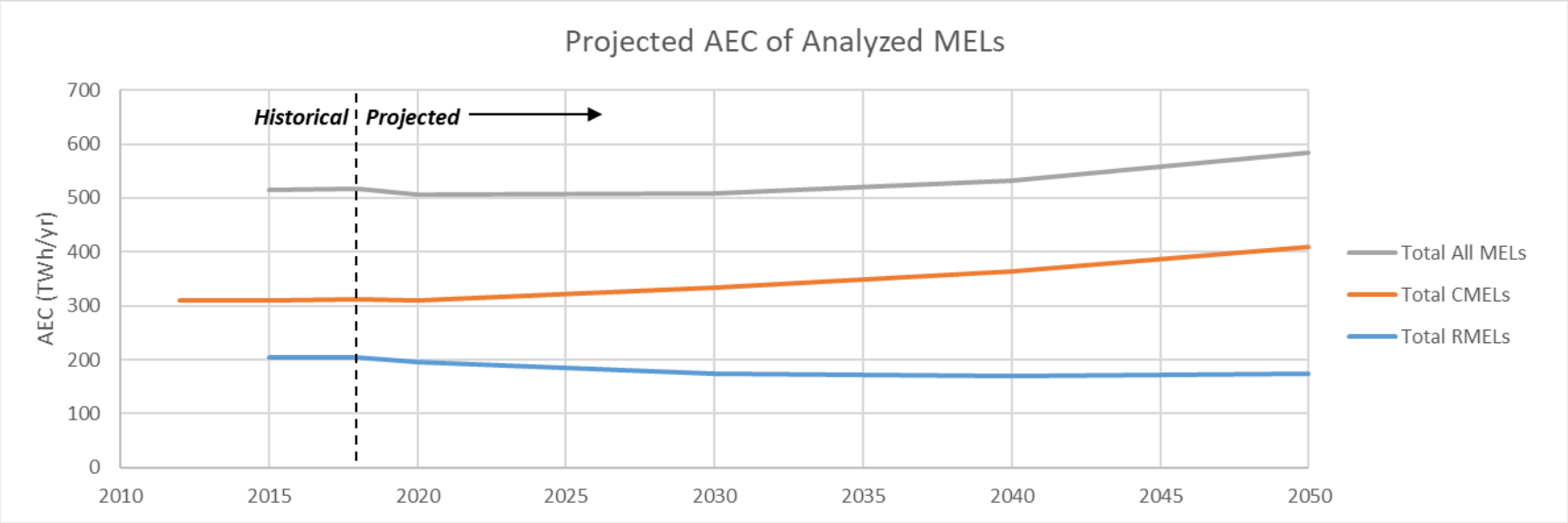


** Data year varies by MEL from 2011-2015 for previous AEC estimates; previous AEC estimates not available for all MELs*

- **Data center servers:** AEC is higher than the 2013 report primarily due to updated unit power draws across all data center server types. A 2016 report on data center server energy consumption indicated there was substantial increases in unit energy consumption compared with the 2013 report, which used estimates from 2007 and 2011 reports.
- **Kitchen ventilation:** AEC is higher due to a new and more rigorous method of calculating installed stock based on CBECS data.
- **Commercial monitors:** AEC is significantly lower than previous estimates primarily due to substantially lower unit energy consumption. The increase in efficiency was faster than expected due to a rapid phase-out of CRT monitors and decrease in LCD monitor power draw.

EXECUTIVE SUMMARY » PROJECTIONS

The analyzed MELs consumed 515 TWh in 2015, 310 TWh in commercial buildings and 205 TWh in residential buildings.*



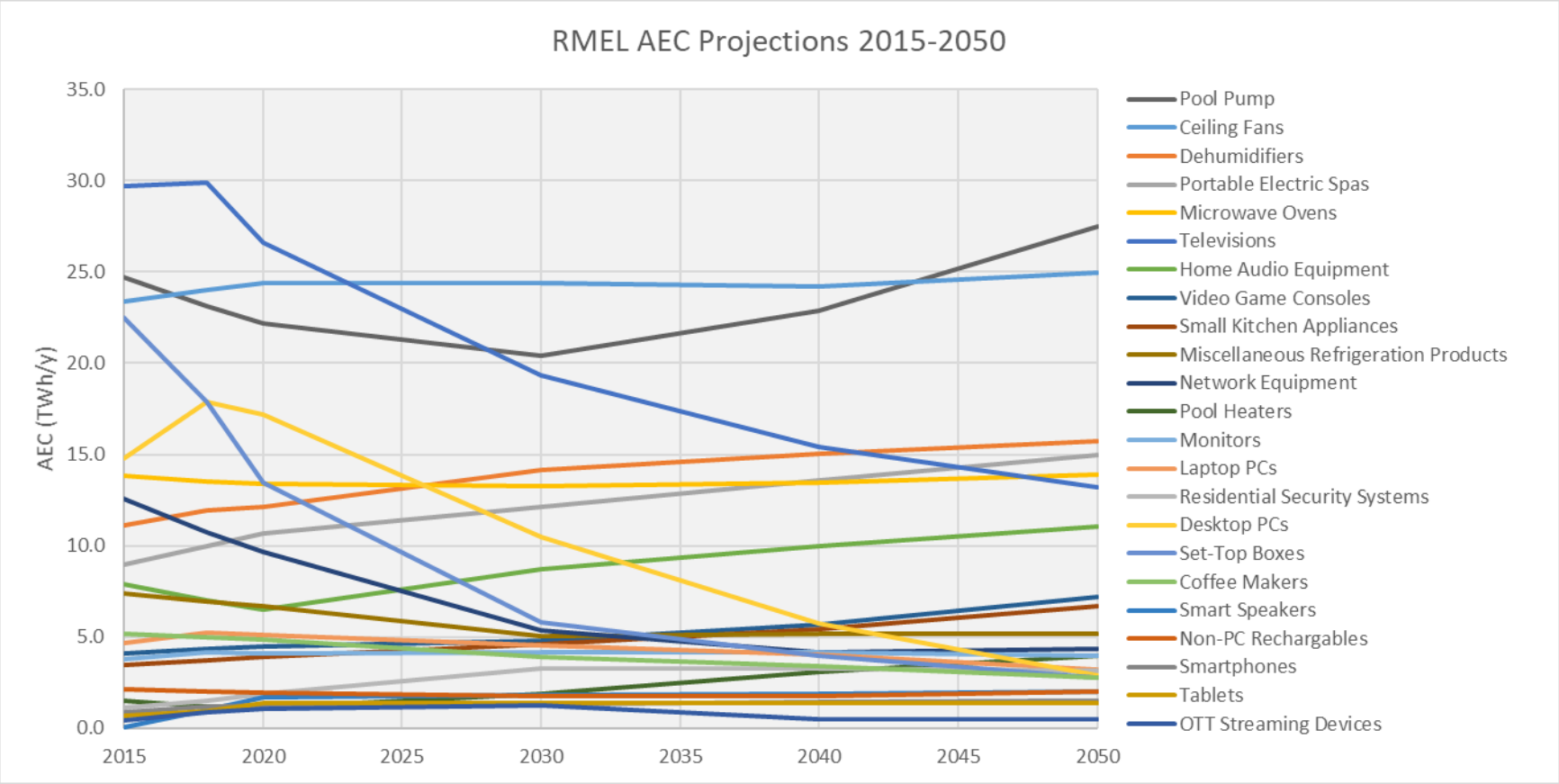
Between 2015 and 2050, we project the total AEC of analyzed MELs to increase due to a 31% increase in AEC for CMELs compared with a 15% drop in AEC for RMELs.**

** 2015 is the first year for which RMELs and CMELs were both analyzed. The analysis base years were 2012 for CMELs and 2015 for RMELs per the U.S. Energy Information Administration (EIA) requirements*

*** Data are projected to 2050 to align with projection timelines in the Annual Energy Outlook. Selected intervals for MEL projections were specified per EIA requirements.*

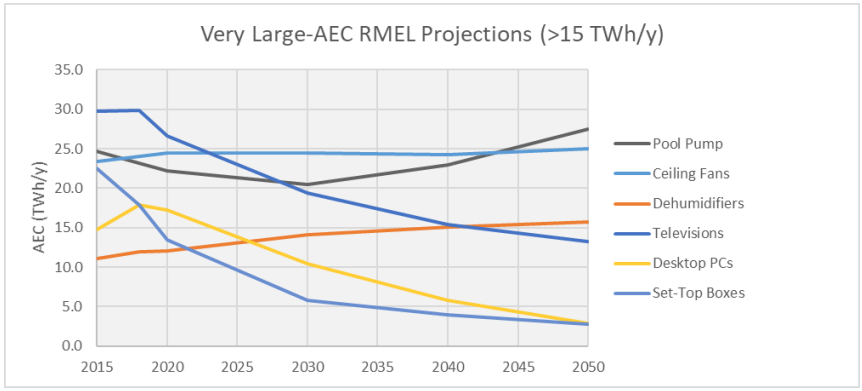
EXECUTIVE SUMMARY » RMEL PROJECTIONS

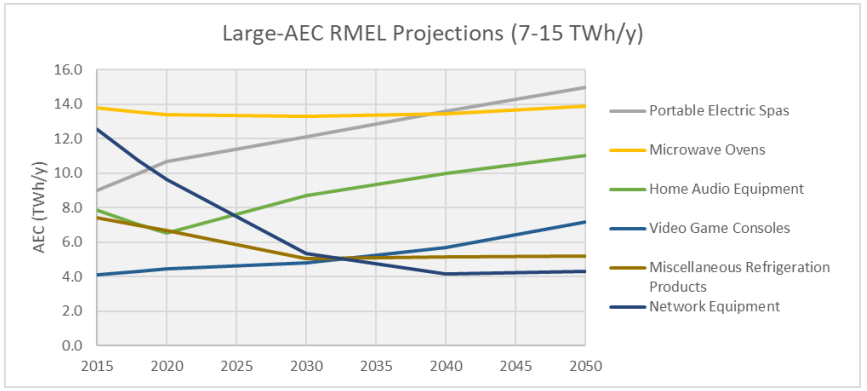
- AEC ranges from less than 1 TWh/y to nearly 30 TWh/y for individual RMELs over the study period, but AEC for most RMELs is less than 7 TWh/y.
- AEC is projected to decrease from 2015 to 2050 for 8 RMELs and increase for 15 RMELs.

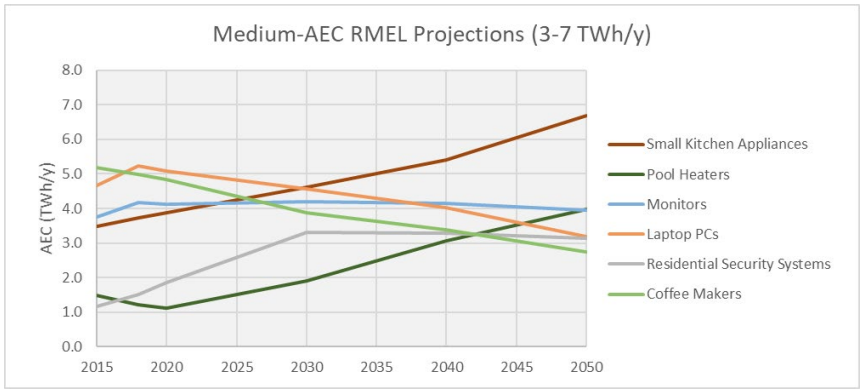


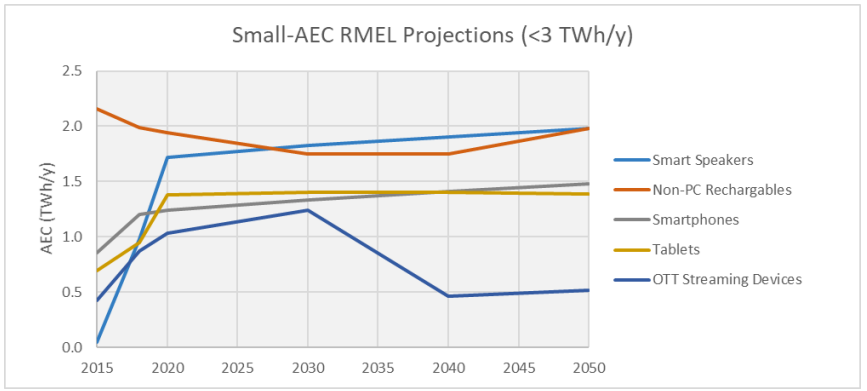
EXECUTIVE SUMMARY » RMEL PROJECTIONS BY SIZE CLASS

- AEC projections for individual RMELs are charted below according to four AEC size classifications for better viewing (y-axis range and interval varies by chart).
- AEC is projected to decrease by more than 5 TWh/yr for set-top boxes, televisions, network equipment, and desktop PCs and increase by more than 5 TWh/yr portable electric spas.



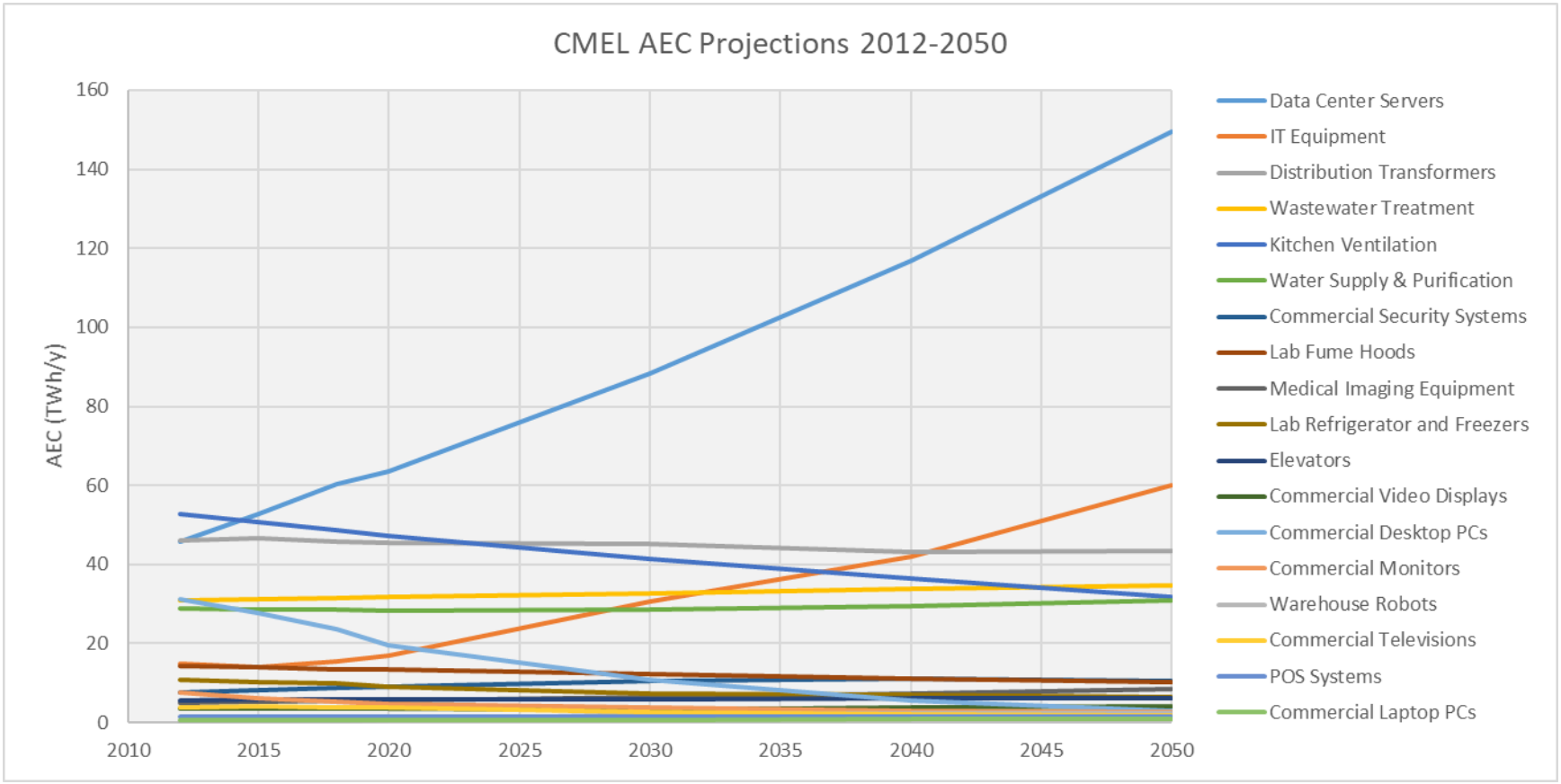






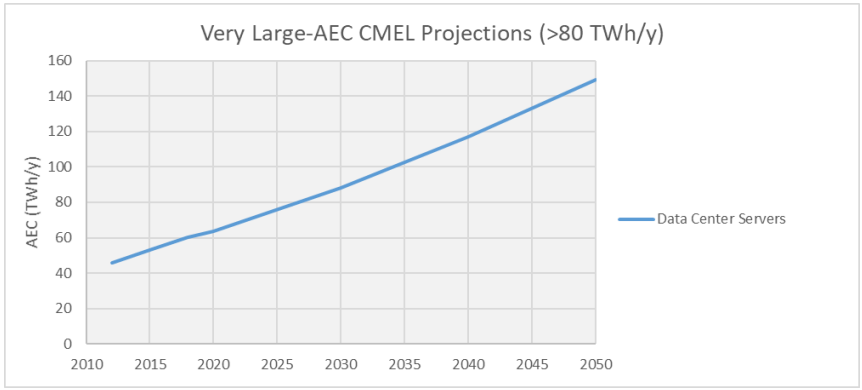
EXECUTIVE SUMMARY » CMEL PROJECTIONS

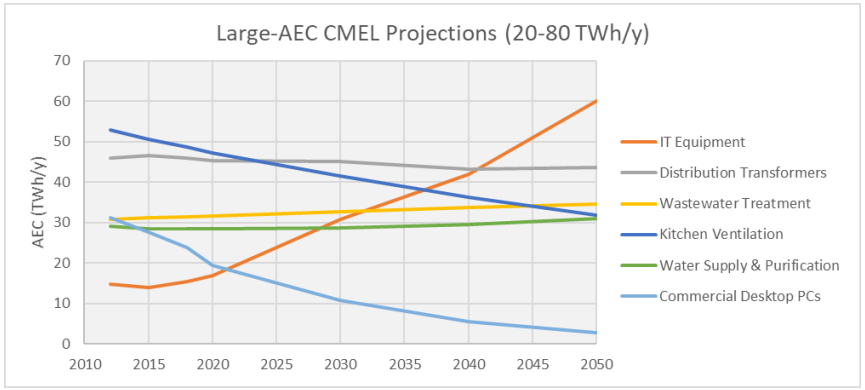
- AEC ranges from less than 1 TWh/y to nearly 150 TWh/y for individual CMELs over the study period, but AEC for most CMELs is less than 20 TWh/y.
- AEC is projected to decrease from 2012-2050 for 7 CMELs and increase for 11 CMELs.

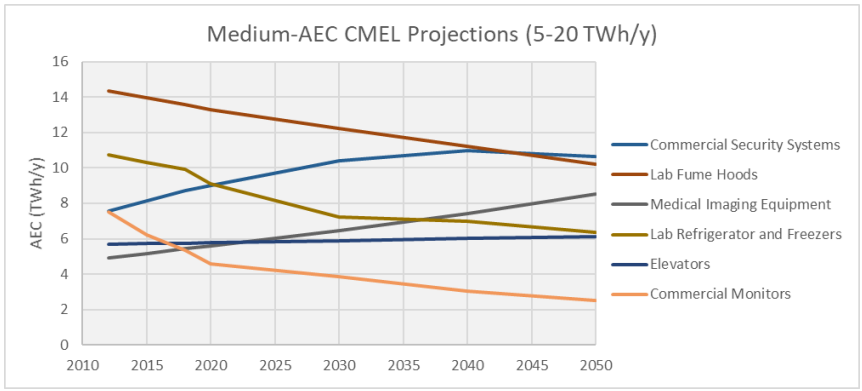


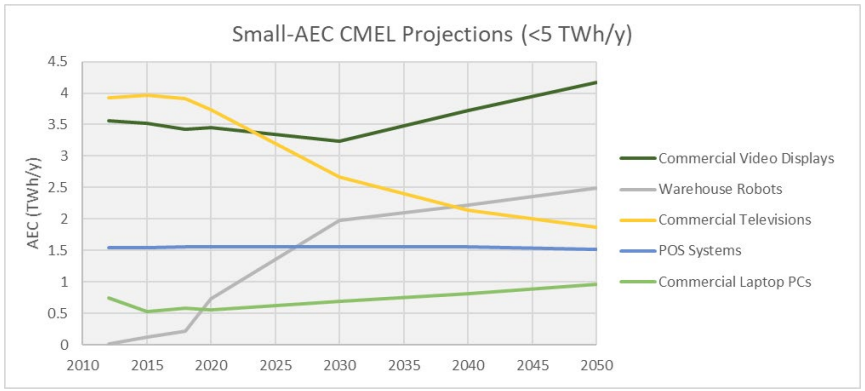
EXECUTIVE SUMMARY » CMEL PROJECTIONS BY SIZE CLASS

- AEC projections for individual CMELs are charted below according to four AEC size classifications for better viewing (y-axis range and interval varies by chart).
- AEC is projected to decrease by more than 21 TWh/yr for commercial desktop PCs and kitchen ventilation and increase by more than 45 TWh/yr for data center servers and IT equipment.
- AEC for data center servers is projected to increase by about 104 TWh/yr from 2012 to 2050.









EXECUTIVE SUMMARY » KEY FINDINGS

- For many MELs, decreasing energy consumption is offset in future years by growth in installed base. In many cases, in the near term, this leads to decreasing AEC but results in small overall increases in AEC over the longer term.
  - Population or housing stock growth drives increases in most residential MELs.
  - Commercial floorspace expansion leads to increases in several commercial MELs.
- Many electronics-related MELs exhibit downward AEC trends due to individual devices using less power overall. However, this is partially countered by large increases in AEC for servers and other IT equipment drawing more power for increased network connectivity and cloud computing. The trend shows a transfer of computer power away from individual devices and more towards cloud computing with major central data centers.
- Personal computing in both residential and commercial sectors is shifting away from high power draw desktop PCs to portable and significantly more energy efficient options such as laptop PCs, tablets, and smartphones.
- The increasing popularity of streaming services affects the energy consumption of televisions, video game consoles, and over-the-top streaming devices by driving the growth of devices with built-in network connected capabilities. This trend increases standby energy consumption but leads to the phase-out of redundant devices (for example, DVD/VCR players, traditional set-top boxes).

EXECUTIVE SUMMARY » KEY FINDINGS (CONTINUED)

- Many commercial MELs (for example, kitchen ventilation, lab fume hoods) are adopting advanced controls to increase energy efficiency by intelligently modulating throughput and power draw depending on operating conditions.
- The adoption of mandatory energy efficiency standards and voluntary ENERGY STAR specifications leads to substantial energy efficiency improvements over time. Computers, televisions, distribution transformers, and microwave ovens are examples of MELs with ENERGY STAR specifications that are expected to drive energy efficiency improvements over time.
- Projections are subject to heightened uncertainty from the ongoing effects of COVID-19.
  - It is possible that changes in social behavior resulting from COVID-19 will be reflected in the use of MELs. For example, the prevalence of teleworking will increase the use of home office equipment, and reduce demands on corresponding items in the traditional workplace. There is no question that these are real impacts, but quantifying the effect of behavioral changes is rife with uncertainty and likely to vary across sectors, regions, and building types.
  - Given a perturbation in a stable system, there is generally a short-term transitory effect, and a longer-term persistent effect that controls the rate of return to the original (unperturbed) trend. By referencing population, employment, household, and commercial floorspace projections from the recently-published AEO2021, at least a portion of the transitory effect is captured for many MELs in this study; however, a characterization of the long-term return to equilibrium is within the purview of the modelers and beyond the scope of this study.

Background & Methodology

EXECUTIVE SUMMARY » PROJECT SCOPE AND BACKGROUND

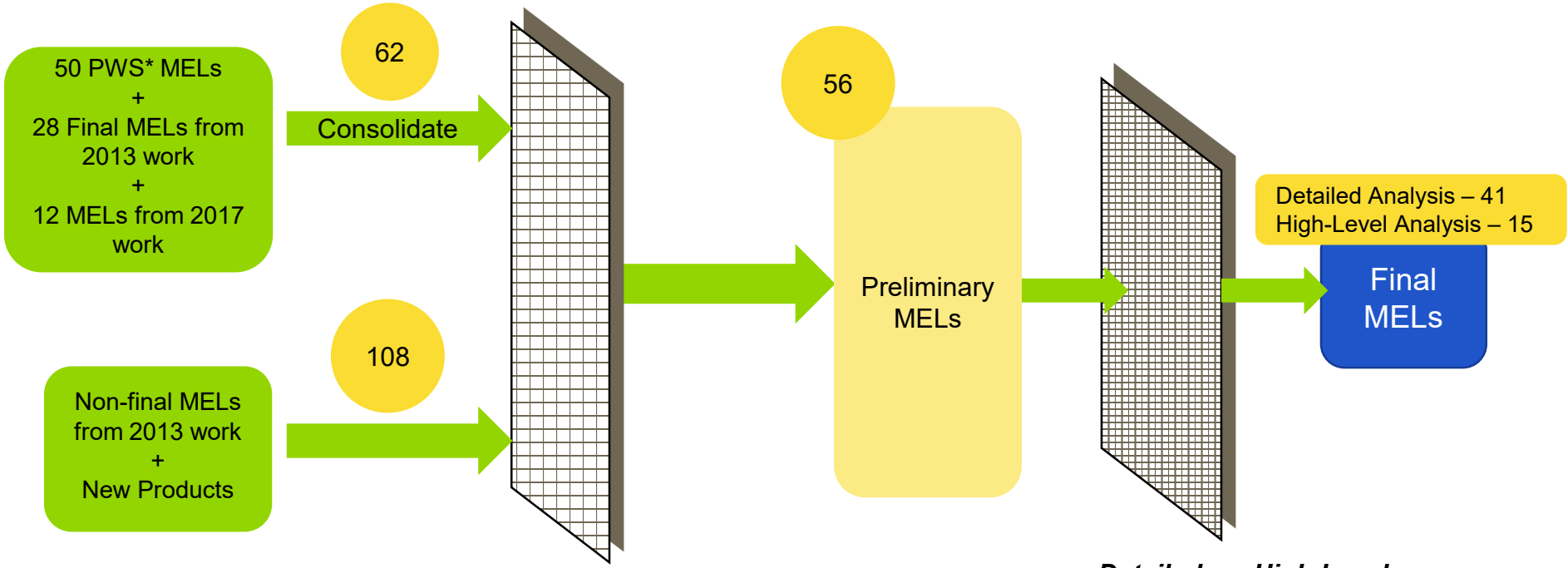
- Objective: Update MEL consumption data for use in NEMS. Evaluate current and projected stocks and energy.

- Task 1: Identify MELs and update energy consumption estimates
  - Screen and identify priority MELS
  - Recommend residential and commercial MELs for further analysis
  - Confirm MEL selection with EIA
  - Develop updated descriptions and revised base-year annual energy consumption, stock, and other characterization data for each selected MEL

- Task 2: Develop scenario-based projections through 2050
  - Investigate market, economic, technology, and demographic trends
  - Make projections for each priority MEL
  - Consider technology trends in MELs not included in the detailed analysis

SCREENING PROCESS

We consolidated and screened the lists of MELs and categorized them into detailed or high-level analysis.



Initial Screen by:

- Inconsequential energy consumptions
- Already well-characterized in AEO
- Already characterized in 2017
- Trend in adoption

Detailed vs. High Level Categorization by:

- Estimated AEC
- Installed base
- Well characterized
- Trend in adoption
- EIA priority

* PWS - project work statement

FINAL MELS FOR DETAILED ANALYSIS

We selected 23 residential and 18 commercial MELs for detailed analysis.

Residential MELs
Coffee Makers
Dehumidifiers
Desktop PCs
Home Audio
Home Network Equipment
Home Security Systems
Laptop PCs
Microwave Ovens
Misc Refrigeration Products
Monitors
Non-PC Rechargeables
OTT TV Services (Streaming)
Pool Heaters
Pool Pumps
Portable Electric Spas
Set-Top Boxes
Small Kitchen Appliances
Smart Speakers
Smartphones
Tablets
Televisions
Video Game Consoles
Ceiling Fans

Commercial MELs
Televisions
Commercial Desktop PCs
Commercial IT Equipment (non-data center)
Commercial Kitchen Ventilation
Commercial Laptop PCs
Commercial PC Monitors
Commercial Security Systems
Commercial Video Displays
Data Center Servers
Distribution Transformers
Elevators
Laboratory Fume Hoods
Laboratory Refrigerators/Freezers
Medical Imaging Equipment
Point-Of-Sale Machines
Warehouse Robots
Waste Water Treatment
Water Supply And Purification

FINAL MELS FOR HIGH LEVEL ANALYSIS

We selected 5 residential and 10 commercial MELs for high-level analysis.

Residential MELs
Air Purifiers
Blu-Ray/DVDs/VHS
Electric Scooters/Bikes
Residential Video Surveillance Systems
Video Doorbells

Commercial MELs
ATMs
Building Management Systems
Commercial Coffee Brewers
Commercial Laundry Equipment
Electronic Doors
Escalators
Large-Format Video Boards
Non-Road Electric Vehicles (EVs)
Slot Machines and Arcade Games
Treadmills

High-level analysis results are presented in Appendix E and F.

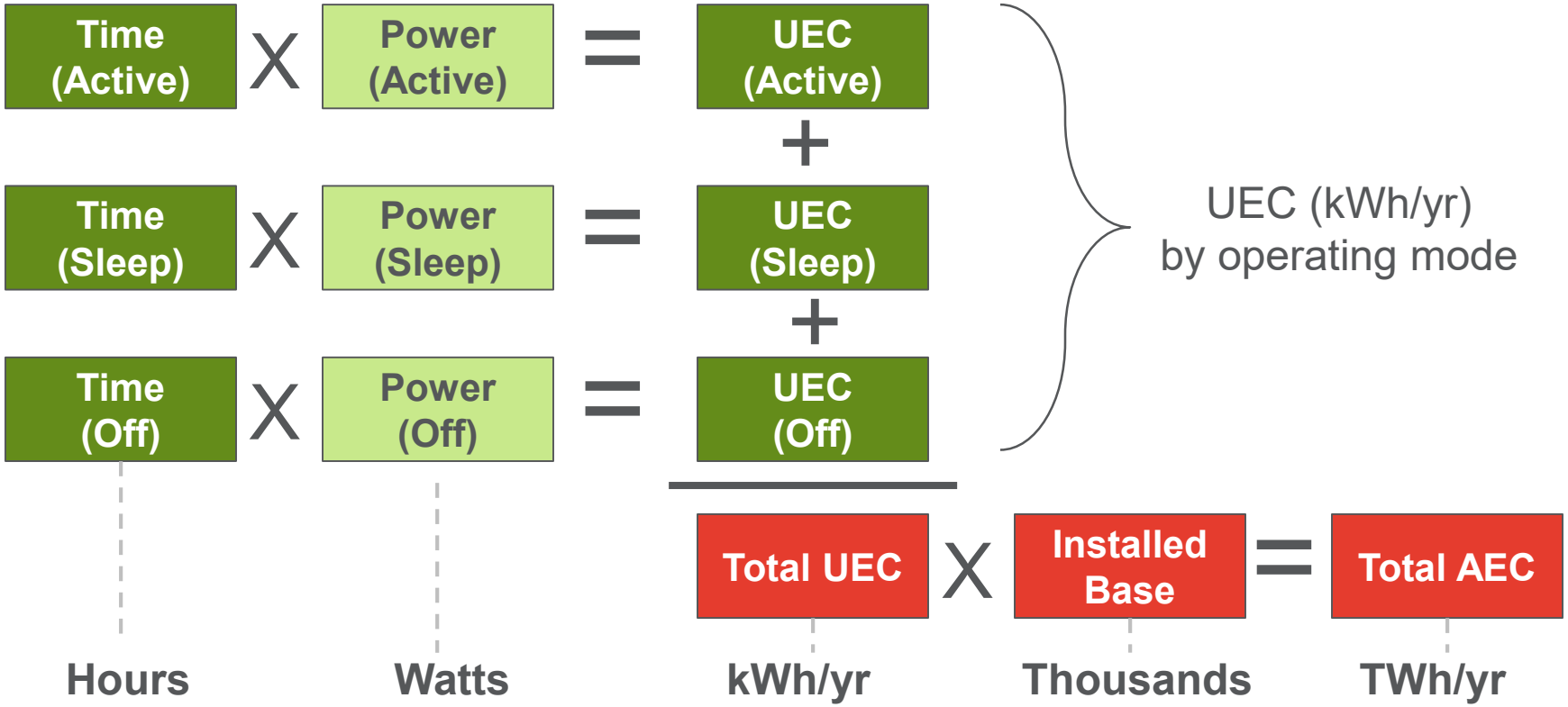
BACKGROUND » MEL DEFINITION

- **Miscellaneous electric loads (MELs)** are the loads outside of a building's core functions of heating, ventilating, air-cooling, lighting, water heating, and major appliances.*
- Wherever workable, we followed the same methodology, reporting framework, and outputs as we provided in the past to ensure consistency. The primary model leveraged was from *Analysis and Representation of Miscellaneous Electric Loads in NEMS* (2013).

*Source: Emily Rauch and Michael Baechler, Pacific Northwest National Laboratory, *Assessing and Reducing Miscellaneous Electric Loads (MELs) in Banks*, September 2011, http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-20973.pdf

METHODOLOGY » OVERVIEW

When sufficient data were available,* we followed a bottom-up methodology to calculate the three primary outputs for each MEL: unit energy consumption (UEC), installed base, and annual energy consumption (AEC).



* Based on the Contractor's judgment of whether available data were sufficient to formulate credible, bottom-up estimates.

METHODOLOGY » ENERGY USE

When sufficient data were not available for a complete bottom-up analysis of energy consumption,* we customized the approach to develop the best estimates possible.

Example: Pool Pumps

- Very little data were available on hours of operation and energy consumption in individual modes. Accordingly, we based UEC estimates from a study by the Consortium for Energy Efficiency.

* Based on the Contractor's judgment of whether available data were insufficient to formulate credible, bottom-up estimates.

METHODOLOGY » PROJECTIONS

We projected UEC, installed base, and AEC for each MEL out to 2050.

- Where data were available, we based energy projections on individual growth rates for annual hours of use and power consumption for each MEL.
- For MELs that did not have use and power data available, we projected UEC directly.
- In general, we developed projections based on a composite unit for each MEL, which is defined by an average that is weighted by the installed base of each product subtype.
  - For example, the composite medical imaging equipment, used for all medical imaging equipment projections, comprises of MRIs, CTs, X-Ray machines, and ultrasound machines.
- We based projections for each MEL on unique trends in:
  - Population
  - Building floorspace or stock
  - Gross domestic product (GDP)
  - Past sales data and effective useful life
  - Other market trends

METHODOLOGY » BREAKDOWN BY BUILDING TYPE AND CENSUS DIVISION

We split MEL estimates by building type and census division, using the National Energy Modeling System (NEMS) definitions, which are closely correlated to the 2012 CBECS and 2015 RECS definitions.

Residential Building Types
Mobile
Multifamily
Single-family

Commercial Building Types
Assembly
Education
Food Sales
Food Service
Health care
Lodging
Large Office
Small Office
Mercantile and Service
Warehouse
Other

Census Divisions
New England
Middle Atlantic
East North Central
West North Central
South Atlantic
East South Central
West South Central
Mountain
Pacific

Note: For buildings with multiple functions, the largest usage of floor area determines principal activity.

Results – Residential MELs

RESIDENTIAL MELS » SET-TOP BOXES

Scope: Set-top boxes are devices designed for the reception of television and related services from terrestrial, cable, satellite, broadband, or local networks, providing video output using at least one direct video connection. This analysis includes DVR, non-DVR, thin-client, and DTA set-top boxes.

		2015	2018	2020	2030	2040	2050
Installed Base	**(000s)**	226,728	198,332	179,183	128,145	91,644	65,541
UEC	**kWh/yr**	99	90	75	45	44	42
AEC	**TWh/yr**	22	18	13	6	4	3

- Voluntary industry agreements are driving energy efficiency improvements for set-top boxes.
- Thin clients and digital transport adapters (DTAs) will increase in installed base share through 2050.
- Non-DVR set-top boxes are decreasing in installed base share and will continue to decrease through 2050.
- Installed base share of DVR set-top boxes will remain relatively constant through 2050.

RESIDENTIAL MELS » SET-TOP BOXES

2015 Base Year Data	Installed Base (000s)	UEC (kWh/yr)	AEC (TWh/yr)
Single-family homes	174,250	99	17
Multifamily homes	40,795	99	4.0
Mobile homes	11,683	99	1.2

- Single-family homes make up most of the installed base as these households are typically larger than multifamily and mobile homes and sometimes include more than one TV per household.
- This analysis assumes that the UEC of a set-top box does not vary across housing types and census divisions.

RESIDENTIAL MELS » POOL PUMPS

Scope: The most energy intensive aspects of residential swimming pools are related to water circulation, filtration, and water heating. The primary equipment used to provide these amenities are pool pumps and pool heaters. This analysis only includes pool pumps.

		2015	2018	2020	2030	2040	2050
Installed Base	(000s)	8,319	8,770	9,085	10,836	12,924	15,415
UEC	kWh/yr	2,971	2,638	2,439	1,884	1,771	1,784
AEC	TWh/yr	24.7	23.0	22.0	20.1	22.4	26.8

- Based on RECS data, the compound annual growth rate of the installed base of pool pumps from 2001 to 2015 is approximately 1.78%. This analysis assumes a constant growth rate through 2050 for the installed base.
- By 2050, approximately 10% of U.S. households will have pool pumps.
- Increase in sales of variable-speed pool pumps will decrease the energy consumption through 2050.
- Additional pipe and fitting improvements will further decrease energy consumption.

RESIDENTIAL MELS » POOL PUMPS

2015 Base Year Data	Installed Base (000s)	UEC (kWh/yr)	AEC (TWh/yr)
Single-family homes	8,209,624	2,963	24
Multifamily homes	n/a	n/a	n/a
Mobile homes	109,794	3,569	0.4

- This analysis assumes that swimming pools are only in single-family and mobile homes due to data shown in 2015 RECS.
- This analysis assumes that the UEC of pool pumps does not vary across housing types. However, this analysis considers differences in UEC across census divisions.
- Federal pool pump standard will be effective in July 2021, resulting in less sales of low efficiency single speed pumps in favor of high efficiency ones and variable speed pumps.

RESIDENTIAL MELS » RESIDENTIAL TELEVISIONS

Scope: Televisions include cathode ray tube, plasma, and LCD TVs. Light-emitting diode (LED) and organic light-emitting diode (OLED) TVs are included within LCD TVs.

		2015	2018	2020	2030	2040	2050
Installed Base	(000s)	275,403	303,078	323,301	401,495	428,642	454,822
Power Draw (W)	Active	81	74	64	38	27	21
	Standby	1.1	0.9	0.6	0.1	0.1	0.1
	Active Standby	4.6	0.8	0.8	0.5	0.5	0.5
Annual Usage (hrs)	Active	1,195	1,195	1,195	1,195	1,195	1,195
	Standby/Active Standby	7,565	7,565	7,565	7,565	7,565	7,565
UEC	kWh/yr	108	99	82	48	36	29
AEC	TWh/yr	30	30	27	19	15	13

- Cathode ray and plasma TVs will decrease in installed base as LCDs continue to dominate the TV market. (Fraunhofer, 2017).
  - Major manufacturers such as LG and Samsung halted production of plasma TVs in 2014. (CNET, 2014) (PCMag, 2014).
- Active standby mode (standby mode when the TV is connected to the internet) can consume significantly more power than regular standby mode (when there is no internet connection) (Fraunhofer, 2017).
- Average TV screen size has increased significantly over the past decade and will continue to increase, partially offsetting energy savings of screen technologies that are more energy efficient (CTA, 2019).

RESIDENTIAL MELS » RESIDENTIAL TELEVISIONS

2015 Base Year Data	Installed Base (000s)	UEC (kWh/yr)	AEC (TWh/yr)
Single-family homes	207,804	108	22.4
Multifamily homes	52,235	108	5.6
Mobile homes	15,364	108	1.7

- Single-family homes make up most of the installed base as these households are typically larger than multifamily and mobile homes and sometimes include more than one TV per household.
- This analysis assumes that the UEC of a TV does not vary across housing types and census divisions.
- The estimated usage of TVs is based on data from the U.S. Bureau of Labor Statistics.
    - These data assume that half of the time spent playing video games uses a TV.

RESIDENTIAL MELS » NETWORK EQUIPMENT

Scope: Network equipment consists of routers, modems, hubs, and switches for residences. This technology includes three general categories: 1) broadband modems, 2) integrated access devices (modem + router in one device), and 3) local network equipment (hubs, routers, switches).

		2015	2018	2020	2030	2040	2050
Installed Base	**(000s)**	139,000	137,519	136,358	125,960	140,023	148,575
Power Draw (W)	**Active Mode**	11	9.9	8.9	5.2	3.6	4
	Standby/Off Mode	1.1	1.2	1.2	1.5	1.4	1
Annual Usage (hrs)	**Active Mode**	7,811	7,811	7,811	7,811	7,811	7,811
	Standby/Off Mode	949	949	949	949	949	949
UEC	**kWh/yr**	90	78	71	42	30	29
AEC	**TWh/yr**	13	11	9.7	5.3	4.2	4.3

- IADs are increasing in installed base share as they replace modems and local network equipment (Fraunhofer, 2017).
  - This trend causes a decrease in the installed base of network equipment from 2015 to 2030.
- In 2015, 85% of U.S. households have internet access according to 2015 RECS data.
- By 2040, we assume 98% of U.S. households will have internet access, driving the increase in the installed base of network equipment.
  - According to the Federal Communications Commission, internet access in rural areas of the United States is less prevalent than in urban/sub-urban areas (FCC, 2018). The growth in the household internet penetration rate will be driven by closing the gap of internet access between rural and urban areas.
  - This analysis does not make any specific assumptions on the availability of specific internet connection types (satellite, DSL, cable, or mobile broadband) in the future.

RESIDENTIAL MELS » NETWORK EQUIPMENT

2015 Base Year Data	Installed Base (000s)	UEC (kWh/yr)	AEC (TWh/yr)
Single-family homes	98,810	90	8.9
Multifamily homes	33,339	90	3.0
Mobile homes	6,852	90	0.6

- Households with internet access typically have one gateway (IAD or modem) but can have additional local network equipment (routers, switches, Wi-Fi extenders/repeaters, hubs).
- This analysis assumes that the UEC of network equipment does not vary across housing types or census divisions.

RESIDENTIAL MELS » AUDIO EQUIPMENT

Scope: Audio equipment consists of audio video receiver based component audio systems (surround sound and stereo including sound bars), compact audio systems, and Home Theater in a Box (HTIB) systems.

		2015	2018	2020	2030	2040	2050
Installed Base	**(000s)**	97,261	88,671	82,728	118,742	155,019	194,460
Power Draw (W)	**Active**	31	29	26	22	18	15
	Idle	16	17	18	17	14	12
	Standby/Off Mode	3.5	3.2	3.3	2.9	2.9	2.8
Annual Usage (hrs)	**Active**	1,324	1,374	1,414	1,466	1,451	1,441
	Idle	1,099	1,189	1,262	1,390	1,509	1,592
	Standby/Off Mode	6,340	6,203	6,090	5,913	5,810	5,739
UEC	**kWh/yr**	81	79	79	73	64	57
AEC	**TWh/yr**	7.9	7.0	6.5	8.7	10	11

- Compact audio systems are decreasing in installed base due to the advent of smart speakers (covered in a separate analysis).
- Sound bars make up an increasing majority of component audio systems. (Fraunhofer, 2017).
- This analysis assumes a linear growth of the installed base of component audio and HTIB systems through 2050.
- This analysis assumes a linear decline of the installed base of compact audio systems, reaching a 5% market share by 2030, at which point smart speakers will largely replace compact audio systems.

RESIDENTIAL MELS » AUDIO EQUIPMENT

2015 Base Year Data	Installed Base (000s)	UEC (kWh/yr)	AEC (TWh/yr)
Single-family homes	66,549	81	5.4
Multifamily homes	25,128	81	2.0
Mobile homes	5,584	81	0.5

- This analysis assumes that the UEC of home audio equipment does not vary across housing types.

RESIDENTIAL MELS » LAPTOP PCS

Scope: Residential laptop PCs include laptops and netbooks.

		2015	2018	2020	2030	2040	2050
Installed Base	**(000s)**	119,767	126,974	131,599	158,368	185,435	193,080
Power Draw (W)	**High-Active**	19	20	19	14	10	7.7
	Idle-Short	9.8	10	9.8	7.2	5.4	4.0
	Idle-Long	8.5	8.8	8.3	6.1	4.5	3.4
	Sleep	0.8	0.8	0.7	0.5	0.4	0.4
	Off	0.3	0.3	0.3	0.3	0.3	0.3
Annual Usage (hrs)	**High-Active**	785	785	785	785	785	785
	Idle-Short	1,387	1,387	1,387	1,387	1,387	1,387
	Idle-Long	876	876	876	876	876	876
	Sleep	2,701	2,701	2,701	2,701	2,701	2,701
	Off	3,011	3,011	3,011	3,011	3,011	3,011
UEC	**kWh/yr**	39	41	39	29	22	17
AEC	**TWh/yr**	4.7	5.2	5.1	4.6	4.0	3.2

- Laptop PCs saw significant growth from 2000 to 2010, but this growth has declined due to the proliferation of smartphones and tablets.
- According to 2015 RECS data, approximately 37 laptops existed per 100 people. This analysis assumes that by 2040, 50 laptops will exist per 100 people.

RESIDENTIAL MELS » LAPTOP PCS

2015 Base Year Data	Installed Base (000s)	UEC (kWh/yr)	AEC (TWh/yr)
Single-family homes	88,381	39	3.4
Multifamily homes	26,275	39	1.0
Mobile homes	5,111	39	0.2

- Data for the installed base for each housing type were taken from 2015 RECS data.
- This analysis assumes that the UEC of laptop PCs does not vary across housing types.

RESIDENTIAL MELS » DESKTOP PCS

Scope: Residential desktop PCs include desktop towers and all-in-one desktop PCs. This analysis does not account for the monitor unless it is included as part of an all-in-one desktop PC configuration.

		2015	2018	2020	2030	2040	2050
Installed Base	**(000s)**	59,100	79,470	82,681	74,775	61,097	45,054
Power Draw (W)	**High-Active**	82	74	68	46	31	21
	Idle-Short	57	52	48	32	22	15
	Idle-Long	53	48	44	30	20	14
	Sleep	2.2	2.7	2.3	1.1	0.5	0.5
	Off	1.0	0.3	0.3	0.3	0.3	0.3
Annual Usage (hrs)	**High-Active**	858	858	858	858	858	858
	Idle-Short	1,789	1,789	1,789	1,789	1,789	1,789
	Idle-Long	1,351	1,351	1,351	1,351	1,351	1,351
	Sleep	1,278	1,278	1,278	1,278	1,278	1,278
	Off	3,486	3,486	3,486	3,486	3,486	3,486
UEC	**kWh/yr**	250	225	208	140	94	64
AEC	**TWh/yr**	15	18	17	10	5.8	2.9

- The growth rate of desktop PCs is declining due to the proliferation of more portable options (laptops, tablets, smartphones).
- This analysis assumes that the installed base will peak in 2020 and decline linearly through 2050.

RESIDENTIAL MELS » DESKTOP PCS

2015 Base Year Data	Installed Base (000s)	UEC (kWh/yr)	AEC (TWh/yr)
Single-family homes	47,858	250	12
Multifamily homes	8,624	250	2.2
Mobile homes	2,618	250	0.7

- Data for the installed base for each housing type were taken from 2015 RECS data.
- This analysis assumes that the UEC of desktop PCs does not vary across housing types.

RESIDENTIAL MELS » MONITORS

Scope: Residential monitors include external monitors for both desktops and laptops. This technology does not include laptop monitors or monitors that are integrated into the desktop PC.

		2015	2018	2020	2030	2040	2050
Installed Base	**(000s)**	77,624	112,920	128,282	128,346	124,270	115,380
Power Draw (W)	**Active**	20	16	14	14	14	14
	Sleep	0.4	0.2	0.2	0.2	0.2	0.2
	Off	0.2	0.2	0.1	0.1	0.1	0.1
Annual Usage (hrs)	**Active**	2,288	2,261	2,256	2,294	2,349	2,410
	Sleep	3,345	3,398	3,408	3,333	3,223	3,101
	Off	3,127	3,101	3,096	3,133	3,188	3,249
UEC	**kWh/yr**	48	37	32	33	33	34
AEC	**TWh/yr**	3.8	4.2	4.1	4.2	4.1	3.9

- LCD monitors, which include LED and OLED display types, make up most of the installed base of monitors.
  - Cathode ray tubes make up an extremely small share (3% as of 2016), and the analysis assumes they will make up 0% of the installed base by 2017.
- Installed base of monitors is closely correlated with the installed base of laptop and desktop PCs.
  - The installed base of desktop PCs is expected to decrease after 2020, and the installed base of laptop PCs is expected to increase through 2050. Moreover, the number of monitors used with laptop PCs is expected to increase through 2050. These three competing forces result in a relatively constant installed base of residential monitors after 2020.
- Technological advancements in LCD technology will drive the decrease in energy consumption of this technology.

RESIDENTIAL MELS » MONITORS

2015 Base Year Data	Installed Base (000s)	UEC (kWh/yr)	AEC (TWh/yr)
Single-family homes	61,495	48	3.0
Multifamily homes	12,721	48	0.6
Mobile homes	3,408	48	0.2

- The installed base of monitors is correlated with the installed bases of desktop and laptop PCs.
- This analysis assumes that the UEC of monitors does not vary across housing types.

RESIDENTIAL MELS » DEHUMIDIFIERS

Scope: Dehumidifiers are portable, electrically operated, and mechanically refrigerated encased assembly consisting of (1) a refrigerated surface (evaporator) that condenses moisture from the atmosphere; (2) a refrigerating system, including an electric motor; (3) an air-circulating fan; and (4) means for collecting or disposing of the condensate.

		2015	2018	2020	2030	2040	2050
Installed Base	**(000s)**	18,257	19,819	20,228	24,877	27,817	30,728
Power Draw (W)	**Dehumidification Mode**	521	517	513	488	463	440
	Fan-only Mode	51	51	50	48	45	43
	Standby/Off-mode	1.0	1.0	1.0	0.9	0.9	0.8
	Unplugged	0	0	0	0	0	0
Annual Usage (hrs)	**Dehumidification Mode**	1,095	1,095	1,095	1,095	1,095	1,095
	Fan-only Mode	657	657	657	657	657	657
	Standby/Off-mode	3,001	3,001	3,001	3,001	3,001	3,001
	Unplugged	4,013	4,013	4,013	4,013	4,013	4,013
UEC	**kWh/yr**	607	602	598	568	540	513
AEC	**TWh/yr**	11	12	12	14	15	16

- This analysis assumes that the installed base of dehumidifiers will follow the same linear trend from the past 30 to 40 years.
  - Even though we expect an increase in the use of central heating and cooling systems, dehumidifiers are mainly used in areas of the home which are not accessible to these central systems, such as basements.

RESIDENTIAL MELS » DEHUMIDIFIERS

2015 Base Year Data	Installed Base (000s)	UEC (kWh/yr)	AEC (TWh/yr)
Single-family homes	16,770	591	9.9
Multifamily homes	1,141	416	0.5
Mobile homes	345	460	0.2

- This analysis assumes that the UEC of dehumidifiers varies by census division.

RESIDENTIAL MELS » CEILING FANS

Scope: Non-portable device designed for home use that is suspended from the ceiling for circulating air via the rotation of fan blades.

		2015	2018	2020	2030	2040	2050
Installed Base	**(000s)**	255,728	262,412	267,168	290,947	311,664	331,550
Power Draw (W)	**Low Speed**	15	15	15	14	13	12
	Medium Speed	33	33	33	30	28	27
	High Speed	61	61	61	56	52	50
	Off/Standby	0.7	0.7	0.7	0.6	0.6	0.6
Annual Usage (hrs)	**Low Speed**	683	683	683	683	683	683
	Medium Speed	895	895	895	895	895	895
	High Speed	777	777	777	777	777	777
	Off/Standby	6,406	6,406	6,406	6,406	6,406	6,406
UEC	**kWh/yr**	91	91	91	84	78	75
AEC	**TWh/yr**	23	24	24	24	24	25

- This category includes ceiling fans permanently installed in residential homes.
- This analysis excludes attic and whole-house fans and energy consumption of attached light fixtures.
- The installed base is assumed to grow with the number of households.
- Power consumption estimates are based on data from a National Impact Analysis (NIA) of potential standards for ceiling fans conducted in 2016 (EERE, 2017).

RESIDENTIAL MELS » CEILING FANS

2015 Base Year Data	Installed Base (000s)	UEC (kWh/yr)	AEC (TWh/yr)
Single-family homes	217,618	91	20
Multifamily homes	26,512	91	2.4
Mobile homes	11,599	91	1.1

- DOE recently finalized an updated energy efficiency standard for ceiling fans, which became effective in January 2020. The new standard is the first performance-based standard for ceiling fans (EERE, 2017).
- This analysis estimated reductions in UEC over the forecast period based on shipment data from the 2016 National Impact Assessment (NIA), which estimated the number of units shipped by efficiency level (EERE, 2017).
- The NIA shipment data accounts for shipments of higher efficiency ENERGY STAR fans over the forecast period (EERE, 2017).
- Annual operating hours by fan speed are based on a Lawrence Berkeley National Laboratory (LBNL) study that surveyed ceiling fan owners to estimate the total daily operating hours for each sampled RECS household (2015 RECS).

RESIDENTIAL MELS » MICROWAVE OVENS

Scope: Microwave ovens are cooking appliances consisting of a compartment designed to cook or heat food by means of microwave energy.

		2015	2018	2020	2030	2040	2050
Installed Base	**(000s)**	118,629	122,145	124,642	136,994	146,257	155,190
Power Draw (W)	**Active**	1,230	1,230	1,230	1,230	1,230	1,230
	Standby/Off	3.4	2.7	2.3	1.1	0.5	0.3
Annual Usage (hrs)	**Active**	71	71	71	71	71	71
	Standby/Off	8,689	8,689	8,689	8,689	8,689	8,689
UEC	**kWh/yr**	116	111	108	97	92	90
AEC	**TWh/yr**	14	14	13	13	13	14

- This analysis projects further increases in microwave oven adoption from 96% of households in 2015 to 98% of households in 2030.
- The most recent DOE energy efficiency standards for microwave ovens were published in 2013 and mandated maximum standby/off power draws of 1-2.2 W depending on product class.
- Projections of improvements in microwave oven UEC takes into consideration only the standby/off mode, since active mode power consumption is not regulated by DOE and is unlikely to see significant technological improvements.

RESIDENTIAL MELS » MICROWAVE OVENS

2015 Base Year Data	Installed Base (000s)	UEC (kWh/yr)	AEC (TWh/yr)
Single-family homes	83,655	116	9.7
Multifamily homes	28,185	116	3.3
Mobile homes	6,788	116	0.8

- This analysis assumes the UEC of microwave ovens does not vary across housing types and census divisions, although microwave oven usage patterns may be slightly different by housing types and census division in the real world.

RESIDENTIAL MELS » SMART SPEAKERS

Scope: Smart speakers are usually wireless speakers with built in virtual assistants and were first introduced by in 2014.

		2015	2018	2020	2030	2040	2050
Installed Base	**(000s)**	3,000	66,000	116,044	125,872	134,382	142,590
UEC	**kWh/yr**	15	15	15	14	14	14
AEC	**TWh/yr**	0.04	1.0	1.7	1.8	1.9	2.0

- Smart speakers have rapidly gained a large market share since their introduction, especially from 2018 to 2020.
- The smart speaker market share spiked in 2020 resulting from a combination of reasons such as the rapid acceptance and growth of smart home electronics, integration of smart speakers with different smart ecosystems, and more people staying at home because of the COVID-19 pandemic.
- Smart speakers come with a variety of form factors and features, with the market still adapting to consumer needs. The rapidly changing nature of this market makes it hard to forecast the real energy consumption for smart speakers in the future. However, improvements in the power delivery design may result in slightly lower UEC over time.

RESIDENTIAL MELS » SMART SPEAKERS

2015 Base Year Data	Installed Base (000s)	UEC (kWh/yr)	AEC (TWh/yr)
Single-family homes	2,189	15	0.03
Multifamily homes	682	15	0.01
Mobile homes	129	15	0.002

- This analysis assumes that the household penetration holds true for homes with wireless internet.
- This analysis assumes that the UEC of a smart speaker does not vary across housing types.

RESIDENTIAL MELS » NON-PC RECHARGEABLES

Scope: Non-PC rechargeables include battery-operated products, not those directly powered by electrical outlets, electronics other than PCs, tablets, and smartphones. Typical examples include wireless headsets, wireless speakers, portable media players, cameras, and battery powered video game consoles (for example, PlayStation Portable, Nintendo Switch, Nintendo 3DS, and virtual reality (VR) headsets.)

		2015	2018	2020	2030	2040	2050
Installed Base	**(000s)**	832,184	873,458	888,474	814,372	844,543	988,286
UEC	**kWh/yr**	2.6	2.3	2.2	2.1	2.1	2.0
AEC	**TWh/yr**	2.2	2.0	1.9	1.7	1.8	2.0

- This analysis includes the installed base and UEC for Bluetooth headsets, wireless speakers, portable DVD or Blu-Ray players, portable media players, e-readers, handheld GPSs, smart wearables, non-smartphones, camcorders, digital cameras, and portable rechargeable video game consoles.
  - Virtual reality (VR) headsets (which are primarily rechargeable) are included in the handheld video game console category.

Installed Base Examples (000s)	**2015**	**2018**	**2020**	**2030**	**2040**	**2050**
Bluetooth Headset	68,971	72,037	74,156	85,724	99,098	114,557
Wireless Speaker	81,976	182,957	235,690	253,364	268,580	280,910
DVD or Blu-Ray Player	80,000	80,000	72,727	36,364	0	0
Media Player, MP3 + CD	115,802	79,343	61,664	17,485	4,958	1,406
eReader	49,295	56,518	61,913	61,913	61,913	61,913
GPS, Handheld	73,294	65,498	60,767	41,771	28,713	19,737
Smart Watch + Wearable	32,000	80,000	87,380	135,836	211,164	328,264
Mobile Non-Smartphone	89,364	56,720	41,890	9,205	2,023	444
Camcorder	55,964	53,044	51,182	42,809	35,805	29,948
Digital Camera	129,198	97,375	80,645	31,421	12,243	4,770
Handheld Video Game Console	56,321	49,966	60,458	98,480	120,047	146,337
Total Installed Base	**832,184**	**873,458**	**888,474**	**814,372**	**844,543**	**988,286**

RESIDENTIAL MELS » NON-PC RECHARGEABLES

2015 Base Year Data	Installed Base (000s)	UEC (kWh/yr)	AEC (TWh/yr)
Single-family homes	584,591	2.6	1.5
Multifamily homes	184,607	2.6	0.5
Mobile homes	62,985	2.6	0.2

- This analysis assumes that the UEC of different non-PC rechargeables does not vary across housing types or census divisions.
- The previous MELs analysis underestimated the growth of some of the subcategories of non-PC rechargeable devices such as smart phones and tablets. These underestimated subcategories are further analyzed in their individual spreadsheets in this analysis.

RESIDENTIAL MELS » POOL HEATERS

Scope: The most energy intensive aspects of residential swimming pools are related to water circulation, filtration, and water heating. The primary equipment used to provide these amenities are pool pumps and pool heaters. This analysis only includes electric pool heaters.

		2015	2018	2020	2030	2040	2050
Installed Base	**(000s)**	688	805	895	1,515	2,434	3,166
UEC	**kWh/yr**	2,174	1,504	1,256	1,256	1,256	1,256
AEC	**TWh/yr**	1.4	1.1	0.9	1.3	1.5	2.0

- Based on RECS data, the compound annual growth rate of the installed base of pool heaters from 2005 to 2015 is approximately 2.7%. This analysis assumes a constant growth rate through 2050 for the installed base.
- By 2050, approximately 2.2% of U.S. households will have electric pool heaters.
- Switching from resistance heaters to heat pump heaters improves energy savings drastically. Additionally, the use of pool cover will further promote energy savings.

RESIDENTIAL MELS » POOL HEATERS

2015 Base Year Data	Installed Base (000s)	UEC (kWh/yr)	AEC (TWh/yr)
Single-family homes	688	2,174	1.4
Multifamily homes	n/a	n/a	n/a
Mobile homes	0	2,174	0

- This analysis assumes that pool heaters are only in single-family and mobile homes due to data shown in RECS.
- This analysis assumes that the UEC of pool heaters does not vary across these housing types.

RESIDENTIAL MELS » SMARTPHONES

Scope: Smartphones use different operating systems to offer users a wide range of functions such as multimedia playbacks, internet browsing, and photography in addition to core phone functions. Smartphones make up most shipments from portable electronics.

		2015	2018	2020	2030	2040	2050
Installed Base	**(000s)**	189,337	266,838	275,421	296,074	313,855	328,264
UEC	**kWh/yr**	4.5	4.7	4.7	4.8	4.9	4.9
AEC	**TWh/yr**	0.9	1.3	1.3	1.4	1.5	1.6

- The smartphone installed base grew rapidly starting in 2015 but market penetration will plateau around 2020.
- After 2020, installed base is based on the estimated 100% market penetration for people age 14 and above.
- Smartphone UEC has remained constant based on Fraunhofer reports. The energy savings by improved components is estimated to be offset by the growing energy consumption of bigger screens and longer screen time.

RESIDENTIAL MELS » SMARTPHONES

2015 Base Year Data	Installed Base (000s)	UEC (kWh/yr)	AEC (TWh/yr)
Single-family homes	138,719	4.5	0.6
Multifamily homes	41,897	4.5	0.2
Mobile homes	8,721	4.5	0.04

- RECS data for 2015 show that there are approximately 1.6 smartphones per household.
- This analysis assumes that the UEC of a smartphone does not vary across housing types.

RESIDENTIAL MELS » TABLETS

Scope: Tablets offer a more portable solution to regular laptops, but they usually lack the extra input/output capabilities. Because of the compactness and intuitive input methods, tablets offer versatile solutions for different applications.

		2015	2018	2020	2030	2040	2050
Installed Base	**(000s)**	113,568	155,440	226,078	241,261	253,763	264,225
UEC	**kWh/yr**	6.1	6.1	6.1	6.1	6.1	6.1
AEC	**TWh/yr**	0.7	0.9	1.4	1.5	1.5	1.6

- Tablet market penetration is estimated to plateau around 2020. Subsequently, the installed base will grow relative to the population growth.
- Coherent Market Insight estimated a 20.6% compound annual growth rate for tablet installed base.
- Similar to smartphones, tablet UEC has remained constant based on Fraunhofer reports. The energy savings by improved components is estimated to be offset by the growing energy consumption of bigger screens and longer screen time.

RESIDENTIAL MELS » TABLETS

2015 Base Year Data	Installed Base (000s)	UEC (kWh/yr)	AEC (TWh/yr)
Single-family homes	88,272	6.1	0.5
Multifamily homes	20,780	6.1	0.1
Mobile homes	4,516	6.1	0.03

- 2015 RECS data indicates a 57% household penetration rate for tablets.
- This analysis assumes that the UEC of a tablet does not vary across housing types.

RESIDENTIAL MELS » OVER-THE-TOP STREAMING DEVICES

Scope: Over-the-top (OTT) streaming devices are external devices that enable TVs to stream content via internet (for example, Roku stick, Apple TV, Amazon Fire stick).

		2015	2018	2020	2030	2040	2050
Installed Base	(000s)	47,356	96,762	114,668	116,703	41,217	43,536
Power Draw (W)	Active Mode	2.8	2.8	2.8	5.8	5.8	5.8
	Standby Mode	1.0	1.0	1.0	1.0	1.0	1.0
Annual Usage (hrs)	Active Mode	297	332	356	475	593	712
	Standby Mode	8,463	8,428	8,404	8,286	8,167	8,048
UEC	kWh/yr	8.9	9.0	9.0	11	11	12
AEC	TWh/yr	0.4	0.9	1.0	1.2	0.5	0.5

- Over the past decade, OTT streaming devices have become popular in U.S. households as video streaming services have grown in popularity.
    - The COVID-19 pandemic has accelerated the adoption of OTT streaming devices (Weinschenk, 2020). However, it is unclear whether this rapid acceleration will be sustained in the future.
- The increasing popularity of smart TVs, which include built-in streaming functionality, will hinder the adoption of OTT streaming devices (Fortune Business Insights, 2020).
- This analysis shows an increase in OTT streaming devices through 2030, followed by a decrease through 2050 as smart TVs accelerate the obsolescence of OTT streaming devices.

RESIDENTIAL MELS » OVER-THE-TOP STREAMING DEVICES

2015 Base Year Data	Installed Base (000s)	UEC (kWh/yr)	AEC (TWh/yr)
Single-family homes	35,746	8.9	0.3
Multifamily homes	9,429	8.9	0.1
Mobile homes	2,180	8.9	0.02

- The power consumption of OTT streaming devices is relatively low (usually less than 5W during active mode).
- As higher-definition content becomes more common, this analysis projects an increase in power consumption by 2030.
- This analysis assumes that increases in power consumption through 2050 would be offset by future improvements in energy efficiency performance, driven by the ENERGY STAR specification for set-top boxes, which cover OTT streaming devices. Thus, from 2030 to 2050, the power consumption of OTT streaming devices will likely remain constant.
- This analysis assumes that the UEC of OTT streaming devices does not vary across housing types and census divisions.

RESIDENTIAL MELS » COFFEE MAKERS

Scope: Coffee makers are made up of automatic-drip, single-serve, and espresso machines.

		2015	2018	2020	2030	2040	2050
Installed Base	(000s)	75,914	78,366	80,104	88,799	96,889	105,068
Power Draw (W)	Active Mode	634	630	625	586	503	420
	Standby Mode	1.8	1.7	1.6	1.1	0.6	0.1
	Off Mode	0	0	0	0	0	0
Annual Usage (hrs)	Active Mode	86	81	77	60	60	60
	Standby Mode	7,807	7,812	7,815	7,830	7,830	7,830
	Off Mode	867	868	868	870	870	870
UEC	kWh/yr	68	64	60	44	35	26
AEC	TWh/yr	5.2	5.0	4.8	3.9	3.4	2.7

- Automatic-drip coffee machines are decreasing in installed base as single-serve and espresso machines are increasing in popularity (ENERGY STAR, 2011).
  - The shift from automatic-drip coffee machines to single-serve machines may increase energy use in other sectors where the coffee is packaged and shipped.
- This analysis assumes that single-serve and espresso machines will make up 60% of the installed base of coffee makers by 2030.
- The household penetration rate of coffee makers increased slightly from 2009 to 2015 according to RECS data. This analysis assumes a modest growth rate in the household penetration rate of coffee makers through 2050.

RESIDENTIAL MELS » COFFEE MAKERS

2015 Base Year Data	Installed Base (000s)	UEC (kWh/yr)	AEC (TWh/yr)
Single-family homes	56,334	68	3.9
Multifamily homes	15,041	68	1.0
Mobile homes	4,539	68	0.3

- Opportunities for improvements in energy performance include improvements in insulation, water heating, and standby power consumption (ENERGY STAR, 2011).
  - These improvements, along with the increase of less energy-consumptive makers such as single-serve and espresso machines, will drive the decrease in UEC for coffee makers.
- This analysis assumes that the UEC for all types of coffee makers does not vary across census divisions or housing types.
- The annual usage for coffee makers may vary significantly by household due to differences in personal habits. This analysis derives an average annual usage for each coffee maker type based on survey data from ENERGY STAR and typical operation duration for each type of coffee maker.

RESIDENTIAL MELS » MISC. REFRIGERATION PRODUCTS

Scope: This device category includes coolers that are separate from standard residential refrigerators and freezers, such as: compact coolers, built-in coolers, freestanding coolers, coolers with freezers, and coolers with icemakers.

		2015	2018	2020	2030	2040	2050
Installed Base	**(000s)**	16,237	16,708	17,052	19,310	21,700	24,060
UEC	**kWh/yr**	456	417	391	260	238	216
AEC	**TWh/yr**	7.4	7.0	6.7	5.0	5.2	5.2

Source: https://www.wayfair.com/kitchen-tabletop/pdp/whynter-34-bottle-single-zone-freestanding-wine-refrigerator-ejh1138.html

- This analysis draws largely from DOE standards rulemaking data for miscellaneous refrigeration products. Granular data on typical power consumptions and annual usage were not available.
- This analysis assumes that future energy efficiency standards will drive the decrease of UECs.
- The increase in installed base is driven mostly by the increasing number of households in the United States.

RESIDENTIAL MELS » MISC. REFRIGERATION PRODUCTS

2015 Base Year Data	Installed Base (000s)	UEC (kWh/yr)	AEC (TWh/yr)
Single-family homes	14,754	456	6.7
Multifamily homes	910	456	0.4
Mobile homes	573	456	0.3

- This analysis assumes that the distribution of miscellaneous refrigeration products across housing types and census divisions correlates with the number of refrigeration products in each household according to 2015 RECS data.
- Miscellaneous refrigeration products are more commonly found in single-family homes.
- Freestanding compact coolers make up the vast majority of the installed base miscellaneous refrigeration products (92%).
- This analysis assumes that the UEC of miscellaneous refrigeration products does not vary across housing types and census divisions.

RESIDENTIAL MELS » SMALL KITCHEN APPLIANCES

Scope: Small kitchen appliances include toasters, toaster ovens, pressure cookers, food processors, rice cookers, blenders.

		2015	2018	2020	2030	2040	2050
Installed Base	**(000s)**	193,272	203,010	210,032	248,735	292,772	345,861
Power Draw (W)	**Active Mode**	840	837	835	767	701	693
	Standby Mode	0.6	0.6	0.6	0.6	0.6	0.6
	Off Mode	0.0	0.0	0.0	0.0	0.0	0.0
Annual Usage (hrs)	**Active Mode**	29	30	31	34	37	40
	Standby Mode	6,405	6,352	6,316	6,134	5,950	5,766
	Off Mode	2,326	2,378	2,413	2,592	2,774	2,954
Mkt Wtd. Avg. UEC	**kWh/yr**	18	18	19	19	18	19
AEC	**TWh/yr**	3.5	3.7	3.9	4.6	5.4	6.7

- Toasters, food processors, and blenders are mature technologies; thus, this analysis assumes the household penetration of these appliances will remain relatively constant through 2050.
- Toaster ovens, pressure cookers, and rice cookers are gaining popularity as consumer preference is shifting towards small appliances that can help prepare meals (Grand View Research, 2019). Thus, this analysis assumes the household penetration rate of these appliances will increase through 2050.
- None of the appliances examined in this analysis are subject to energy efficiency regulations or are covered by voluntary ENERGY STAR specifications. However, improvements in motor efficiency for food processors and blenders as well as improvements in product insulation and temperature control in toasters, toaster ovens, rice cookers, and pressure cookers can provide energy efficiency improvements (ENERGY STAR, 2011).

RESIDENTIAL MELS » SMALL KITCHEN APPLIANCES

2015 Base Year Data	Installed Base (000s)	Weighted Avg. UEC (kWh/yr)	AEC (TWh/yr)
Single-family homes	137,994	18	2.5
Multifamily homes	44,551	18	0.8
Mobile homes	10,726	18	0.2

- The UEC listed in these tables is the market weighted average of UECs for all small kitchen appliances analyzed. The UEC varies significantly by appliance as a result of differences in power consumption and usage. See accompanying spreadsheet for detailed energy consumption data for each appliance.
- The AEC was calculated as the sum of the AEC for each appliance, which is the product of its UEC and its installed base.
- This analysis assumes that UEC for each small kitchen appliance does not vary across housing types and census divisions.

RESIDENTIAL MELS » SMALL KITCHEN APPLIANCES

- The following slides present data for the individual appliances analyzed as part of the small kitchen appliances analysis.

			2015	2018	2020	2030	2040	2050
Installed Base (000s)		Toaster	73,964	75,856	77,202	83,740	89,402	94,862
		Toaster Oven	28,719	31,256	33,096	43,761	56,951	73,663
		Crockpot	33,347	36,293	38,429	50,812	66,128	85,532
		Food Processor	12,125	12,435	12,656	13,728	14,656	15,551
		Rice Cooker	14,339	15,606	16,524	21,849	28,434	36,778
		Blender	30,778	31,565	32,125	34,846	37,202	39,474
		Total	193,272	203,010	210,032	248,735	292,772	345,861
Power Draw (W)	Active Mode	Toaster	1,200	1,200	1,200	1,110	1,020	1,020
		Toaster Oven	1,300	1,300	1,300	1,203	1,105	1,105
		Crockpot	250	250	250	238	225	225
		Food Processor	600	600	600	570	540	540
		Rice Cooker	600	600	600	570	540	540
		Blender	390	390	390	371	351	351
	Standby Mode	Toaster	0.3	0.3	0.3	0.3	0.3	0.3
		Toaster Oven	0.2	0.2	0.2	0.2	0.2	0.2
		Crockpot	1.0	1.0	1.0	1.0	1.0	1.0
		Food Processor	1.0	1.0	1.0	1.0	1.0	1.0
		Rice Cooker	1.0	1.0	1.0	1.0	1.0	1.0
		Blender	1.0	1.0	1.0	1.0	1.0	1.0
	Off Mode	Toaster	0	0	0	0	0	0
		Toaster Oven	0	0	0	0	0	0
		Crockpot	0	0	0	0	0	0
		Food Processor	0	0	0	0	0	0
		Rice Cooker	0	0	0	0	0	0
		Blender	0	0	0	0	0	0

RESIDENTIAL MELS » SMALL KITCHEN APPLIANCES

			2015	2018	2020	2030	2040	2050
Annual Usage (hrs)	Active Mode	Toaster	6.9	6.9	6.9	6.9	6.9	6.9
		Toaster Oven	17	17	17	17	17	17
		Crockpot	104	104	104	104	104	104
		Food Processor	3.5	3.5	3.5	3.5	3.5	3.5
		Rice Cooker	78	78	78	78	78	78
		Blender	0.7	0.7	0.7	0.7	0.7	0.7
	Standby Mode	Toaster	7,878	7,878	7,878	7,878	7,878	7,878
		Toaster Oven	7,868	7,868	7,868	7,868	7,868	7,868
		Crockpot	866	866	866	866	866	866
		Food Processor	7,881	7,881	7,881	7,881	7,881	7,881
		Rice Cooker	4,341	4,341	4,341	4,341	4,341	4,341
		Blender	7,883	7,883	7,883	7,883	7,883	7,883
	Off Mode	Toaster	875	875	875	875	875	875
		Toaster Oven	874	874	874	874	874	874
		Crockpot	7,790	7,790	7,790	7,790	7,790	7,790
		Food Processor	876	876	876	876	876	876
		Rice Cooker	4,341	4,341	4,341	4,341	4,341	4,341
		Blender	876	876	876	876	876	876

RESIDENTIAL MELS » SMALL KITCHEN APPLIANCES

		2015	2018	2020	2030	2040	2050
UEC (kWh/yr)	Toaster	11	11	11	10	9.4	9.4
	Toaster Oven	24	24	24	22	21	21
	Crockpot	27	27	27	26	24	24
	Food Processor	10	10	10	9.9	9.8	9.8
	Rice Cooker	51	51	51	49	46	46
	Blender	8.1	8.1	8.1	8.1	8.1	8.1
	Market Weighted Avg	18	18	19	19	18	19
AEC (TWh/yr)	Toaster	0.8	0.8	0.8	0.8	0.8	0.9
	Toaster Oven	0.7	0.8	0.8	1.0	1.2	1.5
	Crockpot	0.9	1.0	1.0	1.3	1.6	2.1
	Food Processor	0.1	0.1	0.1	0.1	0.1	0.2
	Rice Cooker	0.7	0.8	0.8	1.1	1.3	1.7
	Blender	0.3	0.3	0.3	0.3	0.3	0.3
	Total	3.5	3.7	3.9	4.6	5.4	6.7

RESIDENTIAL MELS » VIDEO GAME CONSOLES

Scope: Video game consoles include PlayStation 2, PlayStation 3, PlayStation 4, PlayStation 5, Xbox 360, Xbox One, Xbox Series X/S (metrics are averaged across the two system types), Nintendo Wii, Nintendo Wii U, Nintendo Switch, and future generations of consoles.

		2015	2018	2020	2030	2040	2050
Installed Base	**(000s)**	65,536	66,630	67,212	68,405	74,198	79,215
Power Draw (W)	**Gaming**	74	77	81	89	165	239
	Video Streaming	49	51	52	54	49	45
	Video Playback	48	51	52	54	50	45
	Idle	52	53	52	49	26	3
	Standby/Off	1.0	0.9	0.9	0.8	0.6	0.8
	Connected Standby/Off	3.4	3.6	3.8	4.2	1.8	0.9
Annual Usage (hrs)	**Gaming**	300	300	300	300	300	300
	Video Streaming	168	168	168	168	168	168
	Video Playback	90	90	90	90	90	90
	Idle	198	198	198	198	198	198
	Standby/Off	4,002	4,002	4,002	4,002	4,002	4,002
	Connected Standby/Off	4,002	4,002	4,002	4,002	4,002	4,002
UEC	**kWh/yr**	63	65	67	70	77	90
AEC	**TWh/yr**	4.1	4.3	4.5	4.8	5.7	7.2

- This analysis examines video game consoles from the three most popular manufacturers in the United States: PlayStation, Xbox, and Nintendo.
- Rechargeable controllers are not included as part of this analysis.
- These manufacturers typically release new consoles every 5–7 years (Casey, 2020).
- PlayStation and Xbox consoles typically consume more power than Nintendo consoles.
- As gaming becomes more power-intensive as a result of higher quality graphics and more powerful processors, this analysis assumes that unit power consumption will increase through 2050.

RESIDENTIAL MELS » VIDEO GAME CONSOLES

2015 Base Year Data	Installed Base (000s)	UEC (kWh/yr)	AEC (TWh/yr)
Single-family homes	47,377	63	3.0
Multifamily homes	14,725	63	0.9
Mobile homes	3,434	63	0.2

- The increase in video game console installed base is primarily driven by the increase in households, as the video game console market is mature, and we do not expect significant increases in market penetration.
- There is little data available on console usage, and it likely varies significantly between households.
- This analysis considers various modes, including video streaming, playback, idle mode, and connected standby mode. These modes can vary significantly in power consumption.
- This analysis assumes that the UEC of video game consoles does not vary across housing types and census divisions.

RESIDENTIAL MELS » RESIDENTIAL SECURITY SYSTEMS

Scope: System of control panel(s), keypad(s), and sensors used to detect intruders, water, fire, and/or carbon monoxide (excludes security cameras and video doorbells)

		2015	2018	2020	2030	2040	2050
Installed Base	**(000s)**	24,474	32,677	41,282	81,208	89,704	94,291
Power Draw (W)	**On**	n/a	n/a	n/a	n/a	n/a	n/a
	Active Standby	5.4	5.2	5.1	4.6	4.2	3.8
	Passive Standby	5.4	5.2	5.1	4.6	4.2	3.8
Annual Usage (hrs)	**On**	n/a	n/a	n/a	n/a	n/a	n/a
	Active Standby	4,990	4,990	4,990	4,990	4,990	4,990
	Passive Standby	3,770	3,770	3,770	3,770	3,770	3,770
UEC	**kWh/yr**	47	46	45	41	37	33
AEC	**TWh/yr**	1.2	1.5	1.9	3.3	3.3	3.1

- After a decade of limited growth, U.S. household penetration of residential security systems increased from about 21% in 2015 to about 34% in 2020 (SDM Magazine, 2019).
- This analysis projects that household penetration will continue to grow dramatically in the near term but will begin to level off as penetration approaches a ceiling after 2030
- Drivers for growth include connected and interactive features and services, smart home capabilities, do-it-yourself (DIY) products, and products and services newly available from online and big-box retailers, telcos, and cablecos.

RESIDENTIAL MELS » RESIDENTIAL SECURITY SYSTEMS

2015 Base Year Data	Installed Base (000s)	UEC (kWh/yr)	AEC (TWh/yr)
Single-family homes	22,027	48	1.1
Multifamily homes	2,002	39	0.1
Mobile homes	445	39	0.02

- System operates almost entirely in active standby (system armed) and passive standby (system unarmed) modes. On mode (alarm sounding) is exceptionally rare.
- Power consumption in active standby and passive standby is approximately the same (Australian Government 2005).
- Excluding external power supplies, nearly 90% of power consumption is from the control unit and key pad, and the remaining 10% is from sensors (Australian Government 2005).
- This analysis assumes that 90% of systems are installed in single-family homes.
- UEC is higher in single-family homes where systems are more likely to include multiple keypads.

RESIDENTIAL MELS » PORTABLE ELECTRIC SPAS

Scope: Portable electric spas include pre-fabricated, self-contained electric spas and hot tubs.

		2015	2018	2020	2030	2040	2050
Installed Base	**(000s)**	4,001	4,497	4,844	5,626	6,320	6,981
Power Draw (W)	**Active**	5,524	5,479	5,450	5,314	5,191	5,079
	Standby	241	239	237	232	232	232
Annual Usage (hrs)	**Active**	25	25	25	25	25	25
	Standby	8,735	8,735	8,735	8,735	8,735	8,735
UEC	**kWh/yr**	2,244	2,224	2,204	2,153	2,150	2,147
AEC	**TWh/yr**	9.0	10	11	12	14	15

- The analysis does not include *in-ground* units (such as those attached to a pool), other permanently installed residential spas, public spas, or spas used for medical treatment or physical therapy.
- The analysis does not include spas that are heated using natural gas.
- Portable electric spas have two primary operating states: in-use and standby.
- The majority of energy use is from the standby mode (>90%) as the spa uses electric heating to maintain the water temperature when not in use.

RESIDENTIAL MELS » PORTABLE ELECTRIC SPAS

2015 Base Year Data	Installed Base (000s)	UEC (kWh/yr)	AEC (TWh/yr)
Single-family homes	3,673	2,244	8.2
Multifamily homes	210	2,244	0.5
Mobile homes	117	2,244	0.3

- Energy consumption is based on representative models as well as updated standards for standby power consumption.
- In 2014, the American National Standard Institute (ANSI) approved an industry standard for portable electric spa efficiency (ANSI/APSP/ICC 14-2014), which was developed by the Association of Pool and Spa Professionals (APSP) and other stakeholders.
- The 2014 ANSI Standard increased the maximum limit on standby power consumption based on the volume of water the spa holds.
- Installed base trajectory is based on residential household growth and the increasing share of households with spas.

Results – Commercial MELs

COMMERCIAL MELS » COMMERCIAL LAPTOP PCS

Scope: This product category consists of laptops in only commercial settings. This does not include netbooks or tablets or the additional, external monitors that may be attached to laptops in some cases.

		2012	2015	2018	2020	2030	2040	2050
Installed Base	**(000s)**	30,358	34,803	39,673	39,782	59,680	83,274	116,011
Power Draw (W)	**High-Active**	30	19	18	17	14	11	9.2
	Idle-Short	16	9.8	9.4	9.0	7.2	5.8	4.7
	Idle-Long	14	8.5	8.0	7.6	6.1	4.9	4.0
	Sleep	1.0	0.8	0.7	0.6	0.5	0.4	0.4
	Off	0.5	0.3	0.3	0.3	0.3	0.3	0.3
Annual Usage (hrs)	**High-Active**	278	278	278	278	278	278	278
	Idle-Short	491	491	491	491	491	491	491
	Idle-Long	310	310	310	310	310	310	310
	Sleep	828	828	828	828	828	828	828
	Off	6,854	6,854	6,854	6,854	6,854	6,854	6,854
UEC	**kWh/yr**	25	15	15	14	12	9.8	8.3
AEC	**TWh/yr**	0.8	0.5	0.6	0.6	0.7	0.8	1.0

- Commercial laptop PCs are expected to increase more than 350% in stock and overwhelmingly replace desktop PCs from 2012 to 2050.
- Growth in commercial PC installed stock projections (laptop and desktop) is expected to align with the growth of total number of employed persons in the United States.
- Laptop PC energy efficiency is projected to increase steadily until 2050 (Fraunhofer, 2019).

COMMERCIAL MELS » COMMERCIAL LAPTOP PCS

2012 Base Year Data	Installed Base (000s)	UEC (kWh/yr)	AEC (TWh/yr)
Assembly	1,363	25	0.03
Education	9,123	25	0.2
Food Sales	96	25	0.002
Food Service	249	25	0.01
Healthcare	782	25	0.02
Lodging	2,708	25	0.07
Large Office	6,839	25	0.2
Small Office	5,176	25	0.1
Mercantile & Service	2,053	25	0.05
Warehouse	1,097	25	0.03
Other	872	25	0.02

- Commercial laptop PC usage are concentrated in education and offices buildings, with significant contributions from lodging, mercantile and service, and assembly building types (CBECS, 2012).
- In this analysis, commercial laptop PC penetration is not expected to deviate significantly from population distribution within the nine census divisions.

COMMERCIAL MELS » COMMERCIAL DESKTOP PCS

Scope: Desktop computers include computer tower units and integrated desktop/monitor units.

		2012	2015	2018	2020	2030	2040	2050
Installed Base	**(000s)**	75,757	72,424	68,845	61,161	50,080	38,142	29,003
Power Draw (W)	**High-Active**	87	82	74	68	46	31	21
	Idle-Short	61	57	52	48	32	22	15
	Idle-Long	58	53	48	44	30	20	14
	Sleep	3.5	2.2	2.7	2.3	1.1	0.5	0.5
	Off	1.6	1.0	0.3	0.3	0.3	0.3	0.3
Annual Usage (hrs)	**High-Active**	1,335	1,335	1,335	1,335	1,335	1,335	1,335
	Idle-Short	2,784	2,784	2,784	2,784	2,784	2,784	2,784
	Idle-Long	2,102	2,102	2,102	2,102	2,102	2,102	2,102
	Sleep	346	346	346	346	346	346	346
	Off	2,193	2,193	2,193	2,193	2,193	2,193	2,193
UEC	**kWh/yr**	413	383	345	319	215	145	98
AEC	**TWh/yr**	31	28	24	20	11	5.5	2.8

- Commercial desktop PCs are expected to decrease more than 65% in stock as laptop PCs increase in installed base share from 2012 to 2050.
- Growth in commercial PC installed stock projections (laptop and desktop) is expected to align with the growth of total number of employed persons in the United States.
- Desktop PC unit energy consumption is projected to decrease gradually year over year until 2050 (Fraunhofer, 2019).

COMMERCIAL MELS » COMMERCIAL DESKTOP PCS

2012 Base Year Data	Installed Base (000)	UEC (kWh/yr)	AEC (TWh/yr)
Assembly	3,729	413	1.5
Education	19,834	413	8.2
Food Sales	367	413	0.2
Food Service	617	413	0.3
Health care	4,080	413	1.7
Lodging	1,390	413	0.6
Large Office	17,527	413	7.2
Small Office	15,411	413	6.4
Mercantile & Service	6,543	413	2.7
Warehouse	3,297	413	1.4
Other	2,963	413	1.2

- Like commercial laptop PCs, commercial desktop PC usage is concentrated in education and offices buildings (CBECS, 2012).
- Similarly, commercial desktop PC penetration is not expected to deviate significantly from population distribution within the nine census divisions.

COMMERCIAL MELS » COMMERCIAL PC MONITORS

Scope: This product category consists of external monitors connected to either desktops or laptops.

		2012	2015	2018	2020	2030	2040	2050
Installed Base	**(000s)**	70,746	79,058	87,875	86,662	78,330	71,095	71,790
Power Draw (W)	**Active**	27	20	16	14	14	14	14
	Sleep	0.6	0.4	0.2	0.2	0.2	0.2	0.2
	Off	0.4	0.2	0.2	0.1	0.1	0.1	0.1
Annual Usage (hrs)	**Active**	3,831	3,814	3,796	3,784	3,500	3,061	2,494
	Sleep	2,336	2,329	2,322	2,317	2,206	2,034	1,813
	Off	2,593	2,617	2,642	2,659	3,054	3,665	4,453
UEC	**kWh/yr**	106	79	61	53	49	43	35
AEC	**TWh/yr**	7.5	6.2	5.3	4.6	3.8	3.1	2.5

- Commercial PC monitor installed stock is projected to increase until its peak in 2020, at which point it will begin to decrease gradually. This trend is the result of two countervailing forces:
  1. The general increase in PCs and the average number of monitors per PC.
  2. The phaseout of desktop PCs, which are more likely to use an external monitor.
- Monitor energy efficiency is expected to increase significantly in part due to the complete phaseout of cathode ray tube monitors by 2018.

COMMERCIAL MELS » COMMERCIAL PC MONITORS

2012 Base Year Data	Installed Base (000)	UEC (kWh/yr)	AEC (TWh/yr)
Assembly	3,388	106	0.4
Education	18,300	106	1.9
Food Sales	328	106	0.04
Food Service	564	106	0.1
Health care	3,600	106	0.4
Lodging	1,593	106	0.2
Large Office	15,988	106	1.7
Small Office	13,933	106	1.5
Mercantile & Service	5,894	106	0.6
Warehouse	2,979	106	0.3
Other	2,660	106	0.3

- Aligning with the distribution of overall commercial PCs, commercial PC monitor usage is concentrated in education and offices buildings (CBECS, 2012).
- Similarly, commercial PC monitor penetration is not expected to deviate significantly from population distribution across the nine census divisions.

COMMERCIAL MELS » DATA CENTER SERVERS

Scope: Data center cervers are usually rack mounted equipment designed for large amounts of computing within data centers.

		2012	2015	2018	2020	2030	2040	2050
Installed Base	**(000s)**	13,500	15,060	16,370	16,732	20,421	24,109	27,798
Power Draw (W)	**Active**	386	400	420	434	493	553	614
	Idle/Standby/Off	0	0	0	0	0	0	0
Annual Usage (hrs)	**Active**	8,760	8,760	8,760	8,760	8,760	8,760	8,760
	Idle/Standby/Off	0	0	0	0	0	0	0
UEC	**kWh/yr**	3,381	3,508	3,678	3,803	4,319	4,847	5,376
AEC	**TWh/yr**	46	53	60	64	88	117	149

- The installed base of data center servers, especially volume servers, is expected to increase significantly over the next few decades (LBNL, 2016).
- The average power draw of these servers is projected to either remain constant or increase over time (LBNL, 2016). However, based on our analysis and other references, the most likely trend is an increase in power draw due to increasing sizes and processing capacities of servers.
- By 2050, data center server AEC is expected to make up to 20% of total commercial MELs annual energy consumption.

COMMERCIAL MELS » DATA CENTER SERVERS

	Installed Base (000)	UEC (kWh/yr)	AEC (TWh/yr)
Assembly	355	3,381	1.2
Education	3,629	3,381	12
Food Sales	67	3,381	0.2
Food Service	111	3,381	0.4
Health care	306	3,381	1.0
Lodging	92	3,381	0.3
Large Office	2,432	3,381	8.2
Small Office	1,446	3,381	4.9
Mercantile & Service	633	3,381	2.1
Warehouse	384	3,381	1.3
Other	4,135	3,381	14

- Data center servers are concentrated in the following building types: education, office, and others (for example, laboratories, server farms) (CBECS, 2012).

COMMERCIAL MELS » IT EQUIPMENT

Scope: IT equipment includes network equipment infrastructure (i.e. router/WLAN, switches, security).

		2012	2015	2018	2020	2030	2040	2050
Installed Base	**(000s)**	581,654	472,000	466,123	466,398	594,836	712,781	909,102
Power Draw (W)	**Active**	3.0	3.4	3.8	4.2	6.0	6.8	7.6
	Idle/Ready	2.8	3.2	3.7	4.0	5.7	6.5	7.3
	Off	0	0	0	0	0	0	0
Annual Usage (hrs)	**Active**	6,570	6,570	6,570	6,570	6,570	6,570	6,570
	Idle/Ready	2,190	2,190	2,190	2,190	2,190	2,190	2,190
	Off	0	0	0	0	0	0	0
UEC	**kWh/yr**	26	29	33	36	52	59	66
AEC	**TWh/yr**	15	14	15	17	31	42	60

- IT equipment is made up of router/WLAN, switches, and security systems. The product subcategories are expected to vary in installed stock and power consumption trends.
- Routers/WLAN systems are expected to grow significantly in the next few decades, security systems are expected to increase gradually, and the installed stock of switches is expected to decline slightly (DOE, 2016).
- The power consumption of these devices is expected to remain relatively constant except for router/WLAN, which will reduce its unit energy consumption significantly (DOE, 2016). The aggregate UEC will increase to 2050 due to increased market share of routers/WLAN devices.

COMMERCIAL MELS » IT EQUIPMENT

2012 Base Year Data	Installed Base (000)	UEC (kWh/yr)	AEC (TWh/yr)
Assembly	27,912	26	0.7
Education	158,718	26	4.1
Food Sales	2,539	26	0.1
Food Service	4,746	26	0.1
Health care	26,651	26	0.7
Lodging	22,462	26	0.6
Large Office	133,558	26	3.4
Small Office	112,848	26	2.9
Mercantile & Service	47,119	26	1.2
Warehouse	24,085	26	0.6
Other	21,017	26	0.5

- IT equipment installed base and energy consumption are concentrated in education and office buildings (CBECS, 2012).

COMMERCIAL MELS » MEDICAL IMAGING EQUIPMENT

Scope: Medical imaging equipment includes magnetic resonance imaging (MRI), computed tomography scans (CT), X-rays, and ultrasounds.

		2012	2015	2018	2020	2030	2040	2050
Installed Base	**(000s)**	478	504	531	549	653	776	922
Power Draw (W)	**Active**	5,579	5,569	5,560	5,553	5,386	5,225	5,069
	Idle/Ready	3,269	3,264	3,259	3,256	3,161	3,069	2,980
	Sleep/Standby	2,361	2,358	2,355	2,353	2,284	2,218	2,154
	Off	129	128	127	126	118	111	105
Annual Usage (hrs)	**Active**	284	284	284	283	282	281	280
	Idle/Ready	240	239	238	237	234	231	228
	Sleep/Standby	3,075	3,075	3,075	3,075	3,075	3,076	3,076
	Off	5,161	5,162	5,164	5,165	5,169	5,173	5,176
UEC	**kWh/yr**	10,298	10,271	10,246	10,228	9,894	9,574	9,267
AEC	**TWh/yr**	4.9	5.2	5.4	5.6	6.5	7.4	8.5

- The number of all medical imaging equipment is expected to increase gradually until 2050 (OECD, 2019) (DOE, 2015).
- Most medical imaging equipment is made up of X-ray machines (~80%), followed by ultrasound devices (~15%), and the remainder is made up of MRI and CT machines (CBECS, 2012).
- Energy efficiency of medical imaging equipment is not expected to increase significantly because there are no substantial incentives (for example, regulatory or voluntary standards.)

COMMERCIAL MELS » MEDICAL IMAGING EQUIPMENT

2012 Base Year Data	Installed Base (000)	UEC (kWh/yr)	AEC (TWh/yr)
Assembly	0	10,298	0
Education	0	10,298	0
Food Sales	0	10,298	0
Food Service	0	10,298	0
Health care	334	10,298	3.4
Lodging	0	10,298	0
Large Office	3	10,298	0.03
Small Office	10	10,298	0.1
Mercantile & Service	130	10,298	1.3
Warehouse	0	10,298	0
Other	0	10,298	0

- Essentially all medical imaging equipment are found in health care (hospitals and clinics, outpatient medical offices), and mercantile & services (diagnostic clinics in retail areas).

COMMERCIAL MELS » LABORATORY REFRIGERATORS AND FREEZERS

Scope: This product category consists of laboratory refrigerators, freezers, and ultra-low freezers.

		2012	2015	2018	2020	2030	2040	2050
Installed Base	**(000s)**	2,756	2,832	2,910	2,962	3,265	3,592	3,936
Power Draw (W)	**Compressor on**	888	832	780	700	507	444	368
	Compressor off	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Annual Usage (hrs)	**Compressor on**	4,380	4,380	4,380	4,380	4,380	4,380	4,380
	Compressor off	4,380	4,380	4,380	4,380	4,380	4,380	4,380
UEC	**kWh/yr**	3,888	3,645	3,417	3,068	2,221	1,943	1,612
AEC	**TWh/yr**	11	10	9.9	9.1	7.2	7.0	6.3

- Laboratory refrigerator and freezer installed stock is expected to increase gradually in accordance with the increase in commercial floorspace over the next few decades.
- Commercial floorspace is expected to grow 0.9%–1.0% annually from 2012 to 2050 (AEO2021).
- These appliances are projected to increase in efficiency with innovations in vapor compression systems, refrigerants, and non-vapor compression developments (ETCC, 2015).

COMMERCIAL MELS » LABORATORY REFRIGERATORS AND FREEZERS

2012 Base Year Data	Installed Base (000s)	UEC (kWh/yr)	AEC (TWh/yr)
Assembly	0	3,888	0
Education	586	3,888	2.3
Food Sales	0	3,888	0
Food Service	0	3,888	0
Healthcare	882	3,888	3.4
Lodging	0	3,888	0
Large Office	65	3,888	0
Small Office	213	3,888	1
Mercantile & Service	0	3,888	0
Warehouse	0	3,888	0
Other	1,011	3,888	3.9

- Virtually all laboratory refrigerators and freezers are located in the following buildings: health care (hospitals and clinics), education (university research facilities), large and small offices, and others (laboratories).

COMMERCIAL MELS » POS SYSTEMS

Scope: Point-of-sale (POS), or point-of-service, systems are used to execute and manage retail transactions. Modern POS systems have a wide range of applications that include processing payments, managing inventory, printing bills, and carrying out loyalty programs across various end-use verticals such as retail, hospitality, and entertainment. This analysis focuses only on the point-of-sale hardware.

		2012	2015	2018	2020	2030	2040	2050
Installed Base	**(000s)**	5,430	5,541	5,720	5,835	6,430	7,075	7,754
Power Draw (W)	**Active**	50	49	48	47	45	42	39
	Standby	41	39	38	37	31	26	21
	Off	0	0	0	0	0	0	0
Annual Usage (hrs)	**Active**	3,668	3,668	3,668	3,668	3,668	3,668	3,668
	Standby	2,546	2,546	2,546	2,546	2,546	2,546	2,546
	Off	2,546	2,546	2,546	2,546	2,546	2,546	2,546
UEC	**kWh/yr**	286	279	272	267	243	220	196
AEC	**TWh/yr**	1.6	1.5	1.6	1.6	1.6	1.6	1.5

- Point-of-sale (POS), or point-of-service, systems are devices used to execute and manage retail transactions.
- POS systems include traditional cash registers and more modern POS systems which are functionally similar to computers and tablets.
- Mobile systems, referred to as POS terminals in the analysis, make up a smaller fraction of systems, but they are expected to become more common.
- POS system UEC declines over time as more efficient hardware enters the market. Efficiency increases occur as a result of increased use of fanless systems, solid state drives (SSDs), and use of standby mode.

COMMERCIAL MELS » POS SYSTEMS

2012 Base Year Data	Installed Base (000s)	UEC (kWh/yr)	AEC (TWh/yr)
Assembly	297,934	286	0.1
Education	161,132	286	0.05
Food Sales	437,221	286	0.1
Food Service	860,520	286	0.2
Healthcare	24,371	286	0.007
Lodging	81,126	286	0.02
Large Office	91,509	286	0.03
Small Office	340,522	286	0.1
Mercantile & Service	2,915,139	286	0.8
Warehouse	156,680	286	0.04
Other	63,547	286	0.02

- Mercantile & service (54%) and food service (16%) account for about 70% of installed base.
- Installed base is assumed to grow with commercial floorspace.
- Commercial floorspace is expected to grow 0.6%–1.2% annually from 2012 to 2050 (AEO2021).
- POS systems are not currently covered under an ENERGY STAR dedicated product specification. However, a small number of POS systems are ENERGY STAR certified under the Desktop Computer product type.
- Modern and more efficient POS systems are expected to replace traditional cash registers over time resulting in reductions in energy use.

COMMERCIAL MELS » WASTEWATER TREATMENT

Scope: Also referred to as municipal wastewater treatment and publicly owned treatment works (POTW). Includes pumping in wastewater collection systems and pumping, treatment, solids handling, disposal and reuse, filtration and disinfection, bioreactors, and odor control systems in wastewater treatment facilities. Excludes all septic, dedicated industrial effluent treatment, and other private on-site systems.

		2012	2015	2018	2020	2030	2040	2050
Installed Base	Mgal/yr	11,886,208	11,852,014	11,817,821	11,795,025	11,681,046	11,567,068	11,453,089
UEC	kWh/Mgal	2,594	2,628	2,662	2,685	2,798	2,912	3,025
AEC	TWh/yr	31	31	31	32	33	34	35

- Wastewater treatment is considered a non-building service (akin to street lighting), thus, results are not assigned or apportioned to any commercial building types.
- Wastewater systems generally consist of collection systems (sewers and pumping stations), treatment plants, and effluent disposal.
- There are approximately 15,000 wastewater treatment plants in the United States with a total flow of over 32 billion gallons per day.
  - Most are publicly owned and serve more than 75% of the U.S. population.
  - Almost all wastewater is treated to secondary treatment levels or greater; more than half exceeds secondary standards.
- Installed base (in other words, influent flow in million gallons per year [Mgal/yr]) has held steady since 1996 as water efficiency gains have offset the demands of population growth.

COMMERCIAL MELS » WASTEWATER TREATMENT

- Most energy use is for secondary treatment systems (for example, aeration systems), pumping, and anaerobic digestion (if applicable).
- UEC primarily increases with degree of treatment, but aged infrastructure, smaller system capacities, and water reuse/recycling also tend to increase UEC.
- The industry has been trending toward more energy-intensive advanced treatment and non-discharging facilities since the federal Clean Water Act (CWA) of 1972, as a result of increasing stringency of water quality regulations and discharge standards; that trend is expected to continue.

Central Wastewater Treatment Plant, Nashville, Tennessee

Source: U.S. Geologic Survey, *Wastewater Treatment Water Use, The Central Wastewater Treatment Plant, Nashville, Tennessee (graphic)*, accessed February 2021.

- AEC is projected to increase by 12% from 2012 to 2050, driven primarily by a 17% projected increase in UEC (kWh/Mgal) during the same period.

COMMERCIAL MELS » WATER SUPPLY & PURIFICATION

Scope: Also known as municipal water supply and public water systems. Includes treatment/purification plants, water storage systems, and distribution infrastructure used for public supply of potable water. Public supply refers to water withdrawn by public and private water suppliers that provide water to at least 25 people or have a minimum of 15 connections. Public-supply water is delivered to users for domestic and commercial purposes; it also is used for public services and system losses. Public-supply excludes self-supplied water for domestic, thermoelectric, irrigation, and industrial purposes, but a small portion of public supply may be used for these purposes.

		2012	2015	2018	2020	2030	2040	2050
Installed Base	Mgal/yr	14,666,269	14,021,293	13,597,029	13,312,189	12,368,427	11,908,949	11,827,256
UEC	kWh/Mgal	1,977	2,037	2,096	2,136	2,322	2,484	2,615
AEC	TWh/yr	29	29	28	28	29	30	31

- Water supply & purification is considered a non-building service (akin to street lighting), thus, results are not assigned or apportioned to any commercial building types.
- After steady growth since the 1950s, U.S. water withdrawals for public supply have decreased sharply since 2005, primarily as a result of drought and water scarcity concerns.
  - California and Texas accounted for 76% of the national decrease from 2010-2015 through mandatory water restrictions and water conservation efforts.
  - Virtually all of the decrease was for surface water (rivers and lakes) withdrawals. Groundwater (wells) withdrawals have held steady.
- Aggressive reductions in water use are expected to continue in the near term, but the rate of reductions will likely decline over time as savings opportunities diminish.

COMMERCIAL MELS » WATER SUPPLY & PURIFICATION

- Installed base (in other words, water withdrawals for public supply in Mgal/yr) is projected to decrease 19% from 2012 to 2050 as per capita water use reductions outpace population growth.
- According to USGS (2015) estimates, about 63% of public supply withdrawals are from surface water and 37% are from ground water.
- Energy use for water is a function water source (surface water pumping typically requires less energy than groundwater pumping), raw water quality (high ambient quality raw water requires less treatment than brackish or seawater), distribution reach (pumping long distances requires more energy), and amount of water loss in the system through leakage and evaporation (CRS, 2017).
- Estimates of the share of population served by desalination range from 0.05% to nearly 3% (EPRI, 2013); this analysis assume growth in desalination from about 2% in 2012 to 6% by 2050.
- This analysis assumes 2,100 kWh/Mgal for groundwater-fed systems, 1,600 kWh/Mgal for surface water-fed systems, 12,000 kWh/Mgal for desalination (EPRI, 2013), and a weighted average UEC growth rate of about 0.8% per year for 2012 to 2050.
- The net effect of decreasing per capita water use and increasing UEC is a 7% increase in AEC from 2012 to 2050.

COMMERCIAL MELS » ELEVATORS

Scope: Elevators are vertical cable transportation machines that move people or freight between floors or levels.

		2012	2015	2018	2020	2030	2040	2050
Installed Base	**(000s)**	751	771	792	807	889	978	1,072
Power Draw (kW)	**Active**	1.5	1.5	1.5	1.4	1.3	1.2	1.2
	Idle	0.5	0.5	0.5	0.5	0.4	0.4	0.4
Annual Usage (hrs)	**Active**	3,468	3,468	3,468	3,468	3,468	3,468	3,468
	Idle	4,563	4,563	4,563	4,563	4,563	4,563	4,563
UEC	**kWh/yr**	7,600	7,429	7,263	7,153	6,632	6,148	5,700
AEC	**TWh/yr**	5.7	5.7	5.8	5.8	5.9	6.0	6.1

- The installed stock of elevators is projected to increase proportionally with the total commercial floorspace in the United States.
- Elevators have several energy efficiency improvement opportunities, and unit energy savings of up to 25% are expected. However, as a result of the longevity of elevator equipment, UEC improvements will occur over a long timeframe.
- Elevators are also a relatively minor part of total commercial MELs electricity consumption (<1%) and an even smaller proportion of total commercial energy consumption.

COMMERCIAL MELS » ELEVATORS

2012 Base Year Data	Installed Base (000s)	UEC (kWh/yr)	AEC (TWh/yr)
Assembly	79	7,600	0.6
Education	81	7,600	0.6
Food Sales	1	7,600	0.01
Food Service	5	7,600	0.04
Healthcare	52	7,600	0.4
Lodging	98	7,600	0.7
Large Office	186	7,600	1.4
Small Office	137	7,600	1.0
Mercantile & Service	32	7,600	0.2
Warehouse	29	7,600	0.2
Other	50	7,600	0.4

- The installed base of elevators varies significantly according to building category, as reflected in 2012 RECS and in the table above.
- The unit energy consumption of elevators varies for different building categories depending on different elevator types and equipment deployed. However, this analysis assumes the UEC of all elevators to be the same across building categories.

COMMERCIAL MELS » KITCHEN VENTILATION

Scope: Commercial kitchen ventilation (CKV) uses exhaust hoods with fans to remove smoke and grease from restaurant kitchens and food service prep rooms in supermarkets. Energy consumption is determined by three different factors: exhaust fans, makeup air fans, and conditioning (heating and cooling) of the makeup air.

		2012	2015	2018	2020	2030	2040	2050
Installed Base	**(000s)**	1,042	1,070	1,100	1,120	1,234	1,357	1,488
Power Draw (W)	**On**	7,980	7,456	6,967	6,660	5,317	4,249	3,400
	Off	0	0	0	0	0	0	0
Annual Usage (hrs)	**On**	5,971	5,971	5,971	5,971	5,971	5,971	5,971
	Off	2,789	2,789	2,789	2,789	2,789	2,789	2,789
UEC	**kWh/yr**	50,679	47,309	44,167	42,191	33,578	26,749	21,330
AEC	**TWh/yr**	53	51	49	47	41	36	32

- The installed stock of commercial kitchen ventilation is projected to increase proportionally with the total commercial floorspace in the United States.
- Commercial kitchen ventilation unit energy consumption is expected to decrease as demand control ventilation (DCV) systems are introduced (ENERGY STAR, 2015).

COMMERCIAL MELS » KITCHEN VENTILATION

2012 Base Year Data	Installed Base (000s)	UEC (kWh/yr)	AEC (TWh/yr)
Assembly	85	111,074	9.5
Education	69	51,729	3.6
Food Sales	18	111,074	2.0
Food Service	759	36,938	28
Health care	5	111,074	0.6
Lodging	46	111,074	5.1
Large Office	5	22,148	0.1
Small Office	8	22,148	0.2
Mercantile & Service	30	111,074	3.4
Warehouse	3	22,148	0.1
Other	13	22,148	0.3

- Commercial kitchen ventilation systems are installed in all building categories because kitchens are in all commercial building types. However, most commercial kitchen ventilation systems (>70%) exist in food service (that is, restaurants) buildings.
- The size and thus unit energy consumption of commercial kitchen ventilation systems also vary by building category.

COMMERCIAL MELS » DISTRIBUTION TRANSFORMERS

Scope: This product category consists of building-based distribution transformers, including only those on the building-side of the meter (that is, no transformers used by the utility for distribution or transmission of electricity).

		2012	2015	2018	2020	2030	2040	2050
Installed Base	**(000s)**	5,824	5,904	5,985	6,040	6,631	7,017	7,836
UEC	**kWh/yr**	7,900	7,900	7,665	7,513	6,794	6,145	5,557
AEC	**TWh/yr**	46	47	46	45	45	43	44

- Installed stock of distribution transformers is expected to increase proportionally with AEO2021 projections of delivered commercial electricity.
- The 2013 DOE Distribution Transformers Final Rule, which went into effect in 2016, requires certain low-voltage transformers to increase their baseline efficiency from 98.0% to 98.6%. This 30% improvement approximates to a 1% annual increase in energy efficiency due to the long product lifetimes and replacement schedules of transformers (DOE, 2013).
- In addition, current rulemaking activities may designate even more stringent efficiency requirements for transformers–thus continuing the trend (DOE, 2013).

COMMERCIAL MELS » DISTRIBUTION TRANSFORMERS

2012 Base Year Data	Installed Base (000s)	UEC (kWh/yr)	AEC (TWh/yr)
Assembly	473	7,900	3.7
Education	563	7,900	4.4
Food Sales	219	7,900	1.7
Food Service	637	7,900	5.0
Health care	228	7,900	1.8
Lodging	418	7,900	3.3
Large Office	490	7,900	3.9
Small Office	694	7,900	5.5
Mercantile & Service	1,284	7,900	10
Warehouse	394	7,900	3.1
Other	423	7,900	3.3

- Distribution transformer installed stock is proportional to the non-HVAC electricity consumption of the building categories. Typically, commercial HVAC electricity consumption and some refrigeration electricity consumption do not require voltage reduction via transformers.
- The electricity demand requirements of a commercial building determine the size of distribution transformers required. Accordingly, this affects the efficiency and energy consumption of transformers.

COMMERCIAL MELS » LAB FUME HOODS

Scope: A fume hood is a ventilation device used to limit exposure while working with harmful chemicals and toxins.

		2012	2015	2018	2020	2030	2040	2050
Installed Base	**(000s)**	872	896	921	938	1,033	1,137	1,246
Power Draw (W)	**On**	1,875	1,775	1,681	1,620	1,350	1,125	938
	Off	0	0	0	0	0	0	0
Annual Usage (hrs)	**On**	8,760	8,760	8,760	8,760	8,760	8,760	8,760
	Off	0	0	0	0	0	0	0
UEC	**kWh/yr**	16,425	15,550	14,722	14,195	11,828	9,856	8,213
AEC	**TWh/yr**	14	14	14	13	12	11	10

- The installed stock of lab fume hoods is projected to increase proportionally with the total commercial floorspace in the United States.
- Variable air volume (VAV) fume hoods are expected to reduce unit energy consumption of lab fume hoods up to 50%. However, as a result of the longevity of fume hoods, the UEC improvements will occur over a long timeframe.

COMMERCIAL MELS » LAB FUME HOODS

2012 Base Year Data	Installed Base (000s)	UEC (kWh/yr)	AEC (TWh/yr)
Assembly	0	16,425	0
Education	105	16,425	1.7
Food Sales	0	16,425	0
Food Service	0	16,425	0
Health care	12	16,425	0.2
Lodging	0	16,425	0
Large Office	22	16,425	0.4
Small Office	229	16,425	3.8
Mercantile & Service	0	16,425	0
Warehouse	0	16,425	0
Other	504	16,425	8.3

- Lab fume hoods are exclusively located in commercial buildings with laboratories. This includes building categories such as education (that is, universities and colleges), offices, health care facilities, and others (that is, whole building laboratory facilities).
- The unit energy consumption for lab fume hoods is expected to be relatively consistent across building types because of the ubiquity of fume hoods in labs and their near constant operation (TIAX, 2008).

COMMERCIAL MELS » COMMERCIAL TELEVISIONS

Scope: Commercial TVs include cathode ray tube, plasma, and LCD televisions. Light-emitting diode (LED) and organic light-emitting diode (OLED) TVs are included within LCD TVs.

		2012	2015	2018	2020	2030	2040	2050
Installed Base	**(000s)**	19,194	20,926	22,815	24,169	30,909	34,006	37,269
Power Draw (W)	**Active Mode**	87	81	74	67	38	27	21
	Standby	1.4	1.1	0.9	0.7	0.1	0.1	0.1
	Active Standby	6.9	4.6	0.8	0.8	0.5	0.5	0.5
Annual Usage (hrs)	**Active Mode**	2,221	2,221	2,221	2,221	2,221	2,221	2,221
	Standby/Active Standby	6,539	6,539	6,539	6,539	6,539	6,539	6,539
UEC	**kWh/yr**	204	190	171	155	86	63	50
AEC	**TWh/yr**	3.9	4.0	3.9	3.7	2.7	2.1	1.9

- The number of TVs in a building and annual usage varies significantly by principal building activity (TIAX, 2010).
  - Food service and hospitality building types have the greatest number of TVs per 100,000 square feet.
- Cathode ray and plasma TVs will decrease in installed base as LCDs continue to dominate the TV market (Fraunhofer, 2017).
  - Major manufacturers such as LG and Samsung halted production of plasma TVs in 2014 (CNET, 2014) (PC Magazine, 2014).
- Active standby mode (standby mode when the TV is connected to the internet) can consume significantly more power than regular standby mode (when there is no internet connection) (Fraunhofer, 2017).

COMMERCIAL MELS » COMMERCIAL TELEVISIONS

2012 Base Year Data	Installed Base (000s)	UEC (kWh/yr)	AEC (TWh/yr)
Assembly	1,675	76	0.1
Education	2,032	514	1.0
Food Sales	208	139	0.03
Food Service	1,532	514	0.8
Healthcare	402	264	0.1
Lodging	6,157	76	0.5
Large Office	1,516	139	0.2
Small Office	1,437	139	0.2
Mercantile & Service	943	514	0.5
Warehouse	2,180	139	0.3
Other	1,113	139	0.2

- Average TV screen size has increased significantly over the past decade and will continue to increase, partially offsetting energy savings of more efficient screen technologies (CTA, 2019).
- This analysis assumes that the UEC of TVs varies across principal building activities but not across census divisions.

COMMERCIAL MELS » VIDEO DISPLAYS

Scope: Commercial video displays include electronic displays or screens (such as LCD or plasma) that deliver entertainment, information and/or advertisement in public or private commercial spaces. This does not include large-format video displays, such as those used in arenas/stadiums, which are covered under *Large-Format Video Boards*.

		2012	2015	2018	2020	2030	2040	2050
Installed Base	**(000s)**	9,028	9,843	10,731	11,368	15,163	16,592	18,156
Power Draw (W)	**Active Mode**	125	113	100	95	67	71	74
	Standby Mode	1.9	2.0	2.2	2.2	1.6	0.9	0.6
Annual Usage (hrs)	**Active Mode**	3,066	3,066	3,066	3,066	3,066	3,066	3,066
	Standby Mode	5,694	5,694	5,694	5,694	5,694	5,694	5,694
UEC	**kWh/yr**	395	357	320	304	213	224	230
AEC	**TWh/yr**	3.6	3.5	3.4	3.5	3.2	3.7	4.2

- Similar to commercial TVs, the distribution and usage of commercial video displays varies by principal building activity.
  - Mercantile & service and food sales buildings account for the majority (55%) of commercial video displays.
- The size of commercial video displays varies by principal building activity. Office buildings typically use smaller displays, and warehouse and assembly buildings use larger displays (Grand View Research, 2019).
- This analysis assumes that, as displays become less expensive, they will also become larger and more common across all building types.

COMMERCIAL MELS » VIDEO DISPLAYS

2012 Base Year Data	Installed Base (000s)	UEC (kWh/yr)	AEC (TWh/yr)
Assembly	181	1,388	0.3
Education	903	653	0.6
Food Sales	1,354	258	0.3
Food Service	903	653	0.6
Health care	181	653	0.1
Lodging	181	653	0.1
Large Office	632	258	0.2
Small Office	632	258	0.2
Mercantile & Service	3,611	258	0.9
Warehouse	0	1,388	0
Other	451	653	0.3

- The ENERGY STAR specification for signage displays, which is a type of commercial video display, will contribute to energy efficiency improvements of commercial video displays through 2050.
- This analysis assumes that the proliferation of network functionality in commercial video displays will increase the standby power consumption of this technology through 2020, after which technological improvements and the ENERGY STAR program will drive the decrease of standby power consumption.
- This analysis assumes that the UEC of commercial video displays varies across principal building activities due to different equipment and usage patterns, but not census divisions.

COMMERCIAL MELS » COMMERCIAL SECURITY SYSTEMS

Scope: Includes video surveillance, physical access control, intruder and fire detection, and electronic article surveillance (EAS) systems. Does not include power supplies, computers, monitors, or IT/networking equipment captured under other MEL categories.

		2012	2015	2018	2020	2030	2040	2050
Installed Base	**(000s)**	11,214	12,023	12,833	13,493	17,041	19,961	21,735
Average Power Draw	**W**	77	77	77	76	70	63	56
Annual Usage	**hrs/yr**	8,760	8,760	8,760	8,760	8,760	8,760	8,760
UEC	**kWh/yr**	673	676	679	668	610	551	491
AEC	**TWh/yr**	7.5	8.1	8.7	9.0	10	11	11

- Security systems vary significantly from one system and building to another in terms of size, composition, configuration, complexity, and utilization.
- Video surveillance systems account for nearly 60% of AEC and are typically more energy-intensive than other system types.
- Strong growth is expected, especially for video surveillance because of security concerns, new wireless and DIY products, advanced analytics and smart features, decreasing costs, integration with building management and control systems, and cloud-hosted security as a service (SaaS) offering.

System Type	Installed Base (000s)	UEC (kWh/yr)	AEC (TWh/yr)
Video Surveillance	3,112	1,402	4.4
Access Control	2,723	500	1.4
Intrusion and Fire Detection	4,279	304	1.3
Electronic Article Surveillance	1,100	473	0.5

COMMERCIAL MELS » COMMERCIAL SECURITY SYSTEMS

2012 Base Year Data	Installed Base (000s)	UEC (kWh/yr)	AEC (TWh/yr)
Assembly	1,320	237	0.3
Education	1,203	604	0.7
Food Sales	320	219	0.1
Food Service	661	115	0.1
Healthcare	507	4,462	2.3
Lodging	325	595	0.2
Large Office	803	2,803	2.3
Small Office	1,857	144	0.3
Mercantile & Service	2,484	352	0.9
Warehouse	1,117	321	0.4
Other	616	240	0.1

- Security systems are found at all types of commercial buildings with the exception of EAS systems, which are typically only found at retail and some food sales stores.
- UEC is largely a function of floorspace and is dominated by hospitals and large office buildings.
- AEC is also dominated by health care and large offices where penetration rates are highest among building types and systems are large and complex.
- AEC is also relatively high for schools and universities where video surveillance is prevalent and for retail stores where EAS systems are common.

COMMERCIAL MELS » WAREHOUSE ROBOTS

Scope: This analysis defines a *warehouse robot* as a robot used within a logistics operation such as a warehouse, fulfillment center, or distribution center

		2012	2015	2018	2020	2030	2040	2050
Installed Base	**(000s)**	20	110	200	669	2,368	3,164	3,759
Power Draw (W)	**Active**	154	154	154	150	114	96	91
	Standby	1.9	1.9	1.9	1.5	1.1	1.0	0.9
	Off	0	0	0	0	0	0	0
Annual Usage (hrs)	**Active**	7,300	7,300	7,300	7,300	7,300	7,300	7,300
	Standby	1,460	1,460	1,460	1,460	1,460	1,460	1,460
	Off	0	0	0	0	0	0	0
UEC	**kWh/yr**	1,130	1,130	1,130	1,095	837	701	662
AEC	**TWh/yr**	0.02	0.1	0.2	0.7	2.0	2.2	2.5

- This analysis focuses on the two dominant types of warehouse robots: drive type robots (motorized dollies) and palletizers (articulated arms).
- Common drive type robots include automated guided vehicles (AGVs) which operate along a predefined pathway.
- Autonomous mobile robots (AMRs) are becoming more common in logistics settings.
- AMRs consume roughly the same amount of energy as a similar sized AGV; however, AMRs navigate dynamically to avoid obstacles and complete tasks more efficiently, thereby reducing energy consumption.

COMMERCIAL MELS » WAREHOUSE ROBOTS

2012 Base Year Data	Installed Base (000s)	UEC (kWh/yr)	AEC (TWh/yr)
Assembly	0	0	0
Education	0	0	0
Food Sales	0	0	0
Food Service	0	0	0
Healthcare	0	0	0
Lodging	0	0	0
Large Office	0	0	0
Small Office	0	0	0
Mercantile & Service	0	0	0
Warehouse	20	1,130	0.02
Other	0	0	0

- Growth in the e-commerce industry and the increased need for efficient warehousing and inventory management is driving market growth for warehouse robots.
- Warehouse robots are seeing a rapid rate of adoption driven by the need for flexible, efficient, and automated e-commerce fulfillment as same-day delivery becomes the norm.
- Energy consumption is based on representative model specification sheets.
- Installed base is approximated from industry estimates and is projected using industry forecasts of a warehouse's robot adoption rate.
- This analysis assumes a gradual increase in robot efficiency as hardware becomes more efficient and autonomous navigation capabilities increase.

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APPENDIX A » RMEL SUMMARY TABLES

- RMEL 2015 base year installed base by housing type

Residential MEL	Installed Base (000s)			
	SF	MF	MH	Total
Set-Top Boxes	174,250	40,795	11,683	226,728
Pool Pump	8,210	0	110	8,319
Televisions	207,804	52,235	15,364	275,403
Network Equipment	98,810	33,339	6,852	139,000
Home Audio Equipment	66,549	25,128	5,584	97,261
Laptop PCs	88,381	26,275	5,111	119,767
Desktop PCs	47,858	8,624	2,618	59,100
Monitors	61,495	12,721	3,408	77,624
Dehumidifiers	16,770	1,141	345	18,257
Ceiling Fans	217,618	26,512	11,599	255,728
Microwave Ovens	83,655	28,185	6,788	118,629
Smart Speakers	2,189	682	129	3,000
Non-PC Rechargables	584,591	184,607	62,985	832,184
Pool Heaters	688	0	0	688
Smartphones	138,719	41,897	8,721	189,337
Tablets	88,272	20,780	4,516	113,568
OTT Streaming Devices	35,746	9,429	2,180	47,356
Coffee Makers	56,334	15,041	4,539	75,914
Miscellaneous Refrigeration Products	14,754	910	573	16,237
Small Kitchen Appliances	137,994	44,551	10,726	193,272
Video Game Consoles	47,377	14,725	3,434	65,536
Residential Security Systems	22,027	2,002	445	24,474
Portable Electric Spas	3,673	210	117	4,001

APPENDIX A » RMEL SUMMARY TABLES

- RMEL 2015 base year UEC by housing type

Residential MEL	UEC (kWh/yr)			
	SF	MF	MH	Wtd Avg
Set-Top Boxes	99	99	99	99
Pool Pump	2,963	0	3,569	2,971
Televisions	108	108	108	108
Network Equipment	90	90	90	90
Home Audio Equipment	81	81	81	81
Laptop PCs	39	39	39	39
Desktop PCs	250	250	250	250
Monitors	48	48	48	48
Dehumidifiers	607	607	607	607
Ceiling Fans	91	89	100	91
Microwave Ovens	116	116	116	116
Smart Speakers	15	15	15	15
Non-PC Rechargables	2.6	2.6	2.6	2.6
Pool Heaters	2,174	0	0	2,174
Smartphones	4.5	4.5	4.5	4.5
Tablets	6.1	6.1	6.1	6.1
OTT Streaming Devices	8.9	8.9	8.9	8.9
Coffee Makers	68	68	68	68
Miscellaneous Refrigeration Products	456	456	456	456
Small Kitchen Appliances	18	18	18	18
Video Game Consoles	63	63	63	63
Residential Security Systems	48	39	39	47
Portable Electric Spas	2,244	2,244	2,244	2,244

APPENDIX A » RMEL SUMMARY TABLES

- RMEL 2015 base year AEC by housing type

Residential MEL	AEC (TWh/yr)			
	SF	MF	MH	Total
Set-Top Boxes	17.3	4.0	1.2	22.5
Pool Pump	24.3	0	0.4	24.7
Televisions	22.4	5.6	1.7	29.7
Network Equipment	8.9	3.0	0.6	12.6
Home Audio Equipment	5.4	2.0	0.5	7.9
Laptop PCs	3.4	1.0	0.2	4.7
Desktop PCs	12.0	2.2	0.7	14.8
Monitors	3.0	0.6	0.2	3.8
Dehumidifiers	10.2	0.7	0.2	11.1
Ceiling Fans	19.8	2.4	1.2	23.4
Microwave Ovens	9.7	3.3	0.8	13.8
Smart Speakers	0.03	0.01	0.002	0.04
Non-PC Rechargables	1.5	0.5	0.2	2.2
Pool Heaters	1.5	0	0	1.5
Smartphones	0.6	0.2	0.04	0.9
Tablets	0.5	0.1	0.03	0.7
OTT Streaming Devices	0.3	0.1	0.02	0.4
Coffee Makers	3.9	1.0	0.3	5.2
Miscellaneous Refrigeration Products	6.7	0.4	0.3	7.4
Small Kitchen Appliances	2.5	0.8	0.2	3.5
Video Game Consoles	3.0	0.9	0.2	4.1
Residential Security Systems	1.1	0.1	0.02	1.2
Portable Electric Spas	8.2	0.5	0.3	9.0

APPENDIX A » RMEL SUMMARY TABLES

- RMEL installed base projections 2015–2050

	Installed Base (000s)					
Residential MEL	**2015**	**2018**	**2020**	**2030**	**2040**	**2050**
Set-Top Boxes	226,728	198,332	179,183	128,145	91,644	65,541
Pool Pump	8,319	8,771	9,086	10,837	12,927	15,418
Televisions	275,403	303,078	323,301	401,495	428,642	454,822
Network Equipment	139,000	137,519	136,358	125,960	140,023	148,575
Home Audio Equipment	97,261	88,671	82,728	118,742	155,019	194,460
Laptop PCs	119,767	126,974	131,599	158,368	185,435	193,080
Desktop PCs	59,100	79,470	82,681	74,775	61,097	45,054
Monitors	77,624	112,920	128,282	128,346	124,270	115,380
Dehumidifiers	18,257	19,819	20,228	24,877	27,817	30,728
Ceiling Fans	255,728	262,412	267,168	290,947	311,664	331,550
Microwave Ovens	118,629	122,145	124,642	136,994	146,257	155,190
Smart Speakers	3,000	66,000	116,044	125,872	134,382	142,590
Non-PC Rechargables	832,184	873,458	888,474	814,372	844,543	988,286
Pool Heaters	688	805	895	1,515	2,434	3,166
Smartphones	189,337	266,838	275,421	296,074	313,855	328,264
Tablets	113,568	155,440	226,078	229,942	230,413	227,405
OTT Streaming Devices	47,356	96,762	114,668	116,703	41,217	43,536
Coffee Makers	75,914	78,366	80,104	88,799	96,889	105,068
Miscellaneous Refrigeration Products	16,237	16,708	17,052	19,310	21,700	24,060
Small Kitchen Appliances	193,272	203,010	210,032	248,735	292,772	345,861
Video Game Consoles	65,536	66,630	67,212	68,405	74,198	79,215
Residential Security Systems	24,474	32,677	41,282	81,208	89,704	94,291
Portable Electric Spas	4,001	4,497	4,844	5,626	6,320	6,981

APPENDIX A » RMEL SUMMARY TABLES

- RMEL UEC projections 2015–2050

	UEC (kWh/yr)					
Residential MEL	**2015**	**2018**	**2020**	**2030**	**2040**	**2050**
Set-Top Boxes	99	90	75	45	44	42
Pool Pump	2,971	2,638	2,439	1,884	1,772	1,785
Televisions	108	99	82	48	36	29
Network Equipment	90	78	71	42	30	29
Home Audio Equipment	81	79	79	73	64	57
Laptop PCs	39	41	39	29	22	17
Desktop PCs	250	225	208	140	94	64
Monitors	48	37	32	33	33	34
Dehumidifiers	607	602	598	568	540	513
Ceiling Fans	91	91	91	84	78	75
Microwave Ovens	116	111	108	97	92	90
Smart Speakers	15	15	15	14	14	14
Non-PC Rechargables	2.6	2.3	2.2	2.1	2.1	2.0
Pool Heaters	2,174	1,504	1,256	1,256	1,256	1,256
Smartphones	4.5	4.5	4.5	4.5	4.5	4.5
Tablets	6.1	6.1	6.1	6.1	6.1	6.1
OTT Streaming Devices	8.9	9.0	9.0	11	11	12
Coffee Makers	68	64	60	44	35	26
Miscellaneous Refrigeration Products	456	417	391	261	238	216
Small Kitchen Appliances	18	18	19	19	18	19
Video Game Consoles	63	65	67	70	77	90
Residential Security Systems	47	46	45	41	37	33
Portable Electric Spas	2,244	2,224	2,204	2,153	2,150	2,147

APPENDIX A » RMEL SUMMARY TABLES

- RMEL AEC projections 2015–2050

	Annual Energy Consumption (TWh/yr)					
Residential MEL	**2015**	**2018**	**2020**	**2030**	**2040**	**2050**
Set-Top Boxes	22.5	17.9	13.5	5.8	4.0	2.8
Pool Pump	24.7	23.1	22.2	20.4	22.9	27.5
Televisions	29.7	29.9	26.6	19.3	15.4	13.2
Network Equipment	12.6	10.7	9.7	5.3	4.2	4.3
Home Audio Equipment	7.9	7.0	6.5	8.7	10.0	11.0
Laptop PCs	4.7	5.2	5.1	4.6	4.0	3.2
Desktop PCs	14.8	17.9	17.2	10.5	5.8	2.9
Monitors	3.8	4.2	4.1	4.2	4.1	3.9
Dehumidifiers	11.1	11.9	12.1	14.1	15.0	15.8
Ceiling Fans	23.4	24.0	24.4	24.4	24.2	25.0
Microwave Ovens	13.8	13.5	13.4	13.3	13.5	13.9
Smart Speakers	0.0	1.0	1.7	1.8	1.9	2.0
Non-PC Rechargables	2.2	2.0	1.9	1.7	1.8	2.0
Pool Heaters	1.5	1.2	1.1	1.9	3.1	4.0
Smartphones	0.9	1.2	1.2	1.3	1.4	1.5
Tablets	0.7	0.9	1.4	1.4	1.4	1.4
OTT Streaming Devices	0.4	0.9	1.0	1.2	0.5	0.5
Coffee Makers	5.2	5.0	4.8	3.9	3.4	2.7
Miscellaneous Refrigeration Products	7.4	7.0	6.7	5.0	5.2	5.2
Small Kitchen Appliances	3.5	3.7	3.9	4.6	5.4	6.7
Video Game Consoles	4.1	4.3	4.5	4.8	5.7	7.2
Residential Security Systems	1.2	1.5	1.9	3.3	3.3	3.1
Portable Electric Spas	9.0	10.0	10.7	12.1	13.6	15.0

APPENDIX B » CMEL SUMMARY TABLES

- CMEL 2012 base year installed base by building type

Installed Base (000s)	Assembly	Education	Food Sales	Food Service	Healthcare	Lodging	Large Office	Small Office	Mercantile & Service	Warehouse	Other	Total	Non-Building Services (Mgal/y)
Commercial Laptop PCs	1,363	9,123	96	249	782	2,708	6,839	5,176	2,053	1,097	872	30,358	N/A
Commercial Desktop PCs	3,729	19,834	367	617	4,080	1,390	17,527	15,411	6,543	3,297	2,963	75,757	N/A
Commercial Monitors	3,462	18,702	335	577	3,679	1,628	16,339	14,239	6,023	3,045	2,718	70,746	N/A
Data Center Servers	353	3,605	66	110	304	92	2,416	1,437	629	381	4,107	13,500	N/A
IT Equipment	27,912	158,718	2,539	4,746	26,651	22,462	133,558	112,848	47,119	24,085	21,017	581,654	N/A
Medical Imaging Equipment	0	0	0	0	334	0	3	10	130	0	0	478	N/A
Lab Refrigerator and Freezers	0	586	0	0	882	0	65	213	0	0	1,011	2,756	N/A
POS Systems	298	161	437	861	24	81	92	341	2,915	157	64	5,430	N/A
Wastewater Treatment	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	11,886,208
Water Supply & Purification	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	14,666,269
Elevators	79	81	1	5	52	98	186	137	32	29	50	751	N/A
Kitchen Ventilation	85	69	18	759	5	46	5	8	30	3	13	1,042	N/A
Distribution Transformers	473	563	219	637	228	418	490	694	1,284	394	423	5,824	N/A
Lab Fume Hoods	0	105	0	0	12	0	22	229	0	0	504	872	N/A
Commercial Televisions	1,675	2,032	208	1,532	402	6,157	1,516	1,437	943	2,180	1,113	19,194	N/A
Commercial Video Displays	181	903	1,354	903	181	181	632	632	3,611	0	451	9,028	N/A
Commercial Security Systems	1,320	1,203	320	661	507	325	803	1,857	2,484	1,117	616	11,214	N/A
Warehouse Robots	0	0	0	0	0	0	0	0	0	20	0	20	N/A

APPENDIX B » CMEL SUMMARY TABLES

- CMEL 2012 base year UEC by building type

UEC (kWh/yr)	Assembly	Education	Food Sales	Food Service	Healthcare	Lodging	Large Office	Small Office	Mercantile & Service	Warehouse	Other	Wtd Avg	Non-Building Services (kWh/Mgal)
Commercial Laptop PCs	25	25	25	25	25	25	25	25	25	25	25	25	N/A
Commercial Desktop PCs	413	413	413	413	413	413	413	413	413	413	413	413	N/A
Commercial Monitors	106	106	106	106	106	106	106	106	106	106	106	106	N/A
Data Center Servers	3,381	3,381	3,381	3,381	3,381	3,381	3,381	3,381	3,381	3,381	3,381	3,381	N/A
IT Equipment	26	26	26	26	26	26	26	26	26	26	26	26	N/A
Medical Imaging Equipment	0	0	0	0	10,298	0	10,298	10,298	10,298	0	0	10,298	N/A
Lab Refrigerator and Freezers	0	3,888	0	0	3,888	0	3,888	3,888	0	0	3,888	3,888	N/A
POS Systems	286	286	286	286	286	286	286	286	286	286	286	286	N/A
Wastewater Treatment	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2,594
Water Supply & Purification	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1,977
Elevators	7,600	7,600	7,600	7,600	7,600	7,600	7,600	7,600	7,600	7,600	7,600	7,600	N/A
Kitchen Ventilation	111,074	51,729	111,074	36,938	111,074	111,074	22,148	22,148	111,074	22,148	22,148	50,679	N/A
Distribution Transformers	7,900	7,900	7,900	7,900	7,900	7,900	7,900	7,900	7,900	7,900	7,900	7,900	N/A
Lab Fume Hoods	0	16,425	0	0	16,425	0	16,425	16,425	0	0	16,425	16,425	N/A
Commercial Televisions	76	514	139	514	264	76	139	139	514	139	139	204	N/A
Commercial Video Displays	1,388	653	258	653	653	653	258	258	258	0	653	395	N/A
Commercial Security Systems	237	604	219	115	4,462	595	2,803	144	352	321	240	673	N/A
Warehouse Robots	0	0	0	0	0	0	0	0	0	1,130	0	1,130	N/A

APPENDIX B » CMEL SUMMARY TABLES

- CMEL 2012 base year AEC by building type

AEC (TWh/yr)	Assembly	Education	Food Sales	Food Service	Healthcare	Lodging	Large Office	Small Office	Mercantile & Service	Warehouse	Other	Total	Non-Building Services
Commercial Laptop PCs	0.03	0.2	0.002	0.01	0.02	0.1	0.2	0.1	0.1	0.03	0.02	0.8	N/A
Commercial Desktop PCs	1.5	8.2	0.2	0.3	1.7	0.6	7.2	6.4	2.7	1.4	1.2	31	N/A
Commercial Monitors	0.4	2.0	0.04	0.1	0.4	0.2	1.7	1.5	0.6	0.3	0.3	7.5	N/A
Data Center Servers	1.2	12	0.2	0.4	1.0	0.3	8.2	4.9	2.1	1.3	13.9	46	N/A
IT Equipment	0.7	4.1	0.1	0.1	0.7	0.6	3.4	2.9	1.2	0.6	0.5	15	N/A
Medical Imaging Equipment	0	0	0	0	3.4	0	0.03	0.1	1.3	0	0	4.9	N/A
Lab Refrigerator and Freezers	0	2.3	0	0	3.4	0	0	1	0	0	3.9	11	N/A
POS Systems	0.1	0.05	0.1	0.2	0.007	0.02	0.03	0.1	0.8	0.04	0.02	1.6	N/A
Wastewater Treatment	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	31
Water Supply & Purification	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	29
Elevators	0.6	0.6	0.01	0.04	0.4	0.7	1.4	1.0	0.2	0.2	0.4	5.7	N/A
Kitchen Ventilation	9.5	3.6	2.0	28.1	0.6	5.1	0.1	0.2	3.4	0.1	0.3	53	N/A
Distribution Transformers	3.7	4.4	1.7	5.0	1.8	3.3	3.9	5.5	10	3.1	3.3	46	N/A
Lab Fume Hoods	0	1.7	0	0	0.2	0	0.4	3.8	0	0	8.3	14	N/A
Commercial Televisions	0.1	1.0	0.03	0.8	0.1	0.5	0.2	0.2	0.5	0.3	0.2	3.9	N/A
Commercial Video Displays	0.3	0.6	0.3	0.6	0.1	0.1	0.2	0.2	0.9	0	0.3	3.6	N/A
Commercial Security Systems	0.3	0.7	0.1	0.1	2.3	0.2	2.3	0.3	0.9	0.4	0.1	7.5	N/A
Warehouse Robots	0	0	0	0	0	0	0	0	0	0.02	0	0	N/A

APPENDIX B » CMEL SUMMARY TABLES

- CMEL installed base projections 2012–2050

	Installed Base (000s, except where otherwise noted)						
Commercial MEL	**2012**	**2015**	**2018**	**2020**	**2030**	**2040**	**2050**
Commercial Laptop PCs	30,358	34,803	39,673	39,782	59,680	83,274	116,011
Commercial Desktop PCs	75,757	72,424	68,845	61,161	50,080	38,142	29,003
Commercial Monitors	70,746	79,058	87,875	86,662	78,330	71,095	71,790
Data Center Servers	13,500	15,060	16,370	16,732	20,421	24,109	27,798
IT Equipment	581,654	472,000	466,123	466,398	594,836	712,781	909,102
Medical Imaging Equipment	478	504	531	549	653	776	922
Lab Refrigerator and Freezers	2,756	2,832	2,910	2,962	3,265	3,592	3,936
POS Systems	5,430	5,541	5,720	5,835	6,430	7,075	7,754
Wastewater Treatment (Mgal/y)	11,886,208	11,852,014	11,817,821	11,795,025	11,681,046	11,567,068	11,453,089
Water Supply & Purification (Mgal/y)	14,666,269	14,021,293	13,597,029	13,312,189	12,368,427	11,908,949	11,827,256
Elevators	751	771	792	807	889	978	1,072
Kitchen Ventilation	1,042	1,070	1,100	1,120	1,234	1,357	1,488
Distribution Transformers	5,824	5,904	5,985	6,040	6,631	7,017	7,836
Lab Fume Hoods	872	896	921	938	1,033	1,137	1,246
Commercial Televisions	19,194	20,926	22,815	24,169	30,909	34,006	37,269
Commercial Video Displays	9,028	9,843	10,731	11,368	15,163	16,592	18,156
Commercial Security Systems	11,214	12,023	12,833	13,493	17,041	19,961	21,735
Warehouse Robots	20	110	200	669	2,368	3,164	3,759

APPENDIX B » CMEL SUMMARY TABLES

- CMEL UEC projections 2012–2050

	UEC (kWh/yr, except where otherwise noted)						
Commercial MEL	**2012**	**2015**	**2018**	**2020**	**2030**	**2040**	**2050**
Commercial Laptop PCs	25	15	15	14	12	10	8
Commercial Desktop PCs	413	383	345	319	215	145	98
Commercial Monitors	106	79	61	53	49	43	35
Data Center Servers	3,381	3,508	3,678	3,803	4,319	4,847	5,376
IT Equipment	26	29	33	36	52	59	66
Medical Imaging Equipment	10,298	10,271	10,246	10,228	9,894	9,574	9,267
Lab Refrigerator and Freezers	3,888	3,645	3,417	3,068	2,221	1,943	1,612
POS Systems	286	279	272	267	243	220	196
Wastewater Treatment (kWh/Mgal)	2,594	2,628	2,662	2,685	2,798	2,912	3,025
Water Supply & Purification (kWh/Mgal)	1,977	2,037	2,096	2,136	2,322	2,484	2,615
Elevators	7,600	7,429	7,263	7,153	6,632	6,148	5,700
Kitchen Ventilation	50,679	47,309	44,167	42,191	33,578	26,749	21,330
Distribution Transformers	7,900	7,900	7,665	7,513	6,794	6,145	5,557
Lab Fume Hoods	16,425	15,550	14,722	14,195	11,828	9,856	8,213
Commercial Televisions	204	190	171	155	86	63	50
Commercial Video Displays	395	357	320	304	213	224	230
Commercial Security Systems	673	676	679	668	610	551	491
Warehouse Robots	1,130	1,130	1,130	1,095	837	701	662

APPENDIX B » CMEL SUMMARY TABLES

- CMEL AEC projections 2012–2050

	Annual Energy Consumption (TWh/yr)						
Commercial MEL	**2012**	**2015**	**2018**	**2020**	**2030**	**2040**	**2050**
Commercial Laptop PCs	0.8	0.5	0.6	0.6	0.7	0.8	1.0
Commercial Desktop PCs	31	28	24	20	11	5.5	2.8
Commercial Monitors	7.5	6.2	5.3	4.6	3.8	3.1	2.5
Data Center Servers	46	53	60	64	88	117	149
IT Equipment	15	14	15	17	31	42	60
Medical Imaging Equipment	4.9	5.2	5.4	5.6	6.5	7.4	8.5
Lab Refrigerator and Freezers	11	10	9.9	9.1	7.2	7.0	6.3
POS Systems	1.6	1.5	1.6	1.6	1.6	1.6	1.5
Wastewater Treatment	31	31	31	32	33	34	35
Water Supply & Purification	29	29	28	28	29	30	31
Elevators	5.7	5.7	5.8	5.8	5.9	6.0	6.1
Kitchen Ventilation	53	51	49	47	41	36	32
Distribution Transformers	46	47	46	45	45	43	44
Lab Fume Hoods	14	14	14	13	12	11	10
Commercial Televisions	3.9	4.0	3.9	3.7	2.7	2.1	1.9
Commercial Video Displays	3.6	3.5	3.4	3.5	3.2	3.7	4.2
Commercial Security Systems	7.5	8.1	8.7	9.0	10	11	11
Warehouse Robots	0.02	0.1	0.2	0.7	2.0	2.2	2.5

APPENDIX C » RESIDENTIAL PROJECTION RESOURCES

Number of Households
AEO2021 Reference case (d113020a)

Census Division	Housing Type	2015	2018	2020	2030	2040	2050
1 New England	Single Family	3,496,102	3,565,621	3,614,057	3,846,841	4,031,796	4,190,386
	Multi-Family	2,004,141	2,043,938	2,071,512	2,175,361	2,250,437	2,314,653
	Mobile	128,601	128,043	127,701	127,651	125,261	122,521
1 New England Total		5,628,844	5,737,602	5,813,270	6,149,853	6,407,494	6,627,560
2 Middle Atlantic	Single Family	9,174,731	9,302,996	9,392,540	9,822,540	10,162,784	10,442,598
	Multi-Family	5,841,457	5,901,905	5,944,308	6,090,903	6,184,797	6,256,009
	Mobile	361,506	354,789	350,525	334,229	316,221	298,378
2 Middle Atlantic Total		15,377,694	15,559,690	15,687,373	16,247,672	16,663,802	16,996,985
3 East North Central	Single Family	13,175,099	13,374,119	13,512,957	14,180,864	14,711,100	15,163,773
	Multi-Family	4,289,665	4,343,476	4,381,039	4,515,471	4,606,368	4,675,981
	Mobile	629,627	615,298	606,187	569,608	532,310	498,820
3 East North Central Total		18,094,391	18,332,893	18,500,183	19,265,943	19,849,778	20,338,574
4 West North Central	Single Family	6,263,921	6,412,717	6,516,957	7,027,401	7,452,102	7,841,695
	Multi-Family	1,662,715	1,713,683	1,749,087	1,889,930	2,002,517	2,106,585
	Mobile	350,708	345,457	342,183	331,285	318,450	308,661
4 West North Central Total		8,277,344	8,471,857	8,608,227	9,248,616	9,773,069	10,256,941
5 South Atlantic	Single Family	16,122,720	16,717,099	17,141,638	19,324,052	21,295,844	23,223,116
	Multi-Family	5,356,013	5,558,967	5,703,200	6,317,878	6,864,836	7,414,055
	Mobile	1,996,118	1,983,844	1,977,748	1,993,187	1,999,464	2,031,407
5 South Atlantic Total		23,474,851	24,259,910	24,822,586	27,635,117	30,160,144	32,668,578
6 East South Central	Single Family	5,195,207	5,353,654	5,465,132	6,017,465	6,484,701	6,916,625
	Multi-Family	1,202,266	1,259,148	1,298,748	1,461,297	1,595,803	1,721,659
	Mobile	799,716	783,261	772,989	735,038	696,761	667,570
6 East South Central Total		7,197,189	7,396,063	7,536,869	8,213,800	8,777,265	9,305,854
7 West South Central	Single Family	9,657,193	10,120,542	10,450,366	12,136,798	13,651,425	15,132,246
	Multi-Family	3,026,633	3,190,794	3,306,694	3,801,999	4,241,339	4,681,825
	Mobile	1,086,108	1,099,130	1,108,678	1,183,357	1,239,358	1,306,475
7 West South Central Total		13,769,934	14,410,466	14,865,738	17,122,154	19,132,122	21,120,546
8 Mountain	Single Family	6,045,482	6,288,454	6,463,778	7,388,851	8,263,025	9,146,826
	Multi-Family	1,817,089	1,929,357	2,009,644	2,365,776	2,701,423	3,048,523
	Mobile	651,176	635,749	626,365	594,317	568,768	556,540
8 Mountain Total		8,513,747	8,853,560	9,099,787	10,348,944	11,533,216	12,751,889
9 Pacific	Single Family	11,750,718	12,009,400	12,193,014	13,118,373	13,921,243	14,689,222
	Multi-Family	5,340,055	5,436,091	5,504,471	5,778,299	6,003,705	6,224,451
	Mobile	783,483	763,541	751,083	702,931	658,862	626,705
9 Pacific Total		17,874,256	18,209,032	18,448,568	19,599,603	20,583,810	21,540,378
Grand Total		118,208,250	121,231,073	123,382,601	133,831,702	142,880,700	151,607,305

APPENDIX C » RESIDENTIAL PROJECTION RESOURCES

Million Square Feet
AEO2021 Reference case (d113020a)

Census Division	Housing Type	2015	2018	2020	2030	2040	2050
1 New England	Single Family	8,362	8,603	8,765	9,569	10,274	10,928
	Multi-Family	1,940	2,022	2,078	2,318	2,520	2,702
	Mobile	169	171	173	180	182	181
1 New England Total		10,471	10,796	11,016	12,067	12,976	13,811
2 Middle Atlantic	Single Family	21,303	21,796	22,129	23,775	25,239	26,580
	Multi-Family	5,455	5,640	5,763	6,302	6,764	7,180
	Mobile	385	386	386	388	382	371
2 Middle Atlantic Total		27,143	27,822	28,278	30,465	32,385	34,131
3 East North Central	Single Family	32,397	33,151	33,648	36,143	38,405	40,553
	Multi-Family	4,002	4,145	4,238	4,650	5,009	5,336
	Mobile	705	702	700	693	673	651
3 East North Central Total		37,104	37,998	38,586	41,486	44,087	46,540
4 West North Central	Single Family	14,889	15,364	15,679	17,282	18,759	20,217
	Multi-Family	1,469	1,551	1,604	1,839	2,046	2,242
	Mobile	396	397	398	405	404	401
4 West North Central Total		16,754	17,312	17,681	19,526	21,209	22,860
5 South Atlantic	Single Family	32,680	34,180	35,193	40,564	45,823	51,289
	Multi-Family	4,707	5,010	5,216	6,130	6,957	7,760
	Mobile	2,151	2,180	2,201	2,329	2,413	2,500
5 South Atlantic Total		39,538	41,370	42,610	49,023	55,193	61,549
6 East South Central	Single Family	9,460	9,848	10,106	11,434	12,675	13,911
	Multi-Family	1,197	1,282	1,340	1,587	1,799	1,996
	Mobile	1,038	1,033	1,030	1,025	1,005	986
6 East South Central Total		11,695	12,163	12,476	14,046	15,479	16,893
7 West South Central	Single Family	19,797	20,914	21,668	25,661	29,546	33,592
	Multi-Family	2,590	2,803	2,948	3,586	4,159	4,718
	Mobile	1,360	1,400	1,428	1,586	1,701	1,818
7 West South Central Total		23,747	25,117	26,044	30,833	35,406	40,128
8 Mountain	Single Family	13,922	14,596	15,063	17,561	20,031	22,616
	Multi-Family	1,446	1,578	1,668	2,075	2,453	2,828
	Mobile	769	764	761	759	753	755
8 Mountain Total		16,137	16,938	17,492	20,395	23,237	26,199
9 Pacific	Single Family	21,139	21,843	22,321	24,764	27,049	29,328
	Multi-Family	3,171	3,346	3,462	3,986	4,454	4,896
	Mobile	795	791	788	781	765	750
9 Pacific Total		25,105	25,980	26,571	29,531	32,268	34,974
Grand Total		207,694	215,496	220,754	247,372	272,240	297,085

APPENDIX D » COMMERCIAL PROJECTION RESOURCES

Millions of Square Feet
AEO2021 Reference case (d113020a)

Census Division	Building Type	2012	2015	2018	2020	2030	2040	2050
1 New England	1 Assembly	633.46	632.07	633.79	633.78	633.37	634.03	635.17
	2 Education	642.12	656.54	674.06	685.20	742.82	806.05	870.26
	3 Food Sales	109.67	110.59	112.39	113.61	121.05	129.10	137.28
	4 Food Service	129.74	130.83	132.96	134.40	143.20	152.73	162.41
	5 Health Care	169.06	174.62	180.45	185.09	206.77	228.44	250.13
	6 Lodging	207.10	213.51	224.94	228.72	252.36	278.15	304.51
	7 Office -Large	398.67	398.95	403.22	406.36	426.64	449.06	471.86
	8 Office -Small	444.99	446.52	452.17	456.38	481.74	509.18	536.93
	9 Merc/Service	716.98	729.42	748.08	758.03	812.33	871.32	931.51
	10 Warehouse	520.63	525.93	543.93	550.59	605.49	662.77	721.74
	11 Other	332.83	339.69	348.85	355.46	398.33	451.19	509.36
1 New England Total		4,305.25	4,358.67	4,454.83	4,507.60	4,824.10	5,172.01	5,531.15
2 Middle Atlantic	1 Assembly	1,211.53	1,201.16	1,195.09	1,192.13	1,170.61	1,152.64	1,134.81
	2 Education	1,415.44	1,426.29	1,445.65	1,464.88	1,548.47	1,634.64	1,720.29
	3 Food Sales	206.52	207.39	209.83	211.87	224.59	238.13	251.83
	4 Food Service	162.37	163.05	164.97	166.57	176.58	187.23	197.99
	5 Health Care	367.20	374.25	384.43	389.85	424.56	462.13	500.89
	6 Lodging	793.77	833.88	890.60	916.94	1,016.12	1,118.86	1,223.27
	7 Office -Large	2,675.07	2,671.43	2,683.97	2,697.68	2,801.37	2,922.43	3,037.17
	8 Office -Small	762.35	762.66	767.70	772.22	805.20	843.08	879.36
	9 Merc/Service	1,718.83	1,736.17	1,769.10	1,792.53	1,910.91	2,035.52	2,161.22
	10 Warehouse	1,254.98	1,276.11	1,321.94	1,346.00	1,465.87	1,585.75	1,705.68
	11 Other	674.12	691.98	707.08	722.04	832.41	946.20	1,058.30
2 Middle Atlantic Total		11,242.18	11,344.37	11,540.37	11,672.70	12,376.69	13,126.60	13,870.81
3 East North Central	1 Assembly	1,761.84	1,764.11	1,776.27	1,787.42	1,869.13	1,960.84	2,056.15
	2 Education	2,207.50	2,241.42	2,287.57	2,331.26	2,561.92	2,794.79	3,028.42
	3 Food Sales	99.23	99.72	101.04	101.69	106.12	114.28	122.54
	4 Food Service	216.61	217.69	220.55	221.98	231.64	249.46	267.49
	5 Health Care	349.96	366.17	380.28	388.97	435.22	485.94	537.97
	6 Lodging	663.37	688.15	718.91	728.67	810.08	897.07	988.38
	7 Office -Large	1,333.03	1,330.80	1,345.07	1,352.67	1,423.84	1,507.51	1,593.40
	8 Office -Small	1,272.83	1,275.89	1,292.59	1,301.81	1,377.55	1,465.20	1,554.87
	9 Merc/Service	2,342.74	2,367.38	2,411.82	2,435.72	2,568.50	2,775.00	2,984.03
	10 Warehouse	1,583.61	1,624.22	1,697.96	1,739.38	1,960.55	2,192.01	2,431.96
	11 Other	920.27	941.17	970.76	994.57	1,156.60	1,325.21	1,496.19
3 East North Central Total		12,750.99	12,916.73	13,202.80	13,384.13	14,501.14	15,767.28	17,061.39

APPENDIX D » COMMERCIAL PROJECTION RESOURCES

Millions of Square Feet
AEO2021 Reference case (d113020a)

Census Division	Building Type	2012	2015	2018	2020	2030	2040	2050
4 West North Central	1 Assembly	760.95	768.96	781.00	789.19	834.65	881.37	928.75
	2 Education	968.65	1,000.08	1,042.11	1,069.13	1,180.61	1,296.10	1,413.55
	3 Food Sales	74.77	76.23	78.25	79.47	85.40	92.21	99.22
	4 Food Service	152.83	155.81	159.93	162.43	174.56	188.47	202.80
	5 Health Care	134.30	141.95	148.66	152.77	173.37	194.33	215.40
	6 Lodging	384.72	403.72	428.87	440.46	492.17	545.42	599.41
	7 Office -Large	464.37	466.87	476.29	482.69	509.69	544.94	583.38
	8 Office -Small	612.68	618.65	632.57	641.85	681.98	732.12	786.12
	9 Merc/Service	1,268.55	1,301.23	1,341.66	1,366.02	1,478.72	1,603.99	1,732.28
	10 Warehouse	958.70	972.76	993.13	1,007.20	1,086.11	1,164.84	1,242.29
	11 Other	384.47	403.01	422.07	433.68	485.77	548.71	628.47
4 West North Central Total		6,164.99	6,309.26	6,504.53	6,624.88	7,183.02	7,792.48	8,431.67
5 South Atlantic	1 Assembly	1,728.32	1,747.74	1,784.68	1,814.76	1,992.19	2,180.17	2,372.20
	2 Education	2,838.53	2,932.71	3,052.59	3,155.34	3,455.07	3,742.44	4,194.00
	3 Food Sales	187.74	191.62	198.05	201.34	220.88	247.26	274.76
	4 Food Service	396.14	404.32	417.90	424.85	466.07	521.72	579.76
	5 Health Care	390.98	408.10	427.09	439.45	501.05	568.17	636.48
	6 Lodging	1,219.59	1,265.18	1,337.17	1,357.38	1,530.48	1,717.77	1,918.82
	7 Office -Large	1,549.24	1,562.68	1,597.99	1,627.83	1,825.47	2,034.23	2,246.05
	8 Office -Small	1,882.23	1,904.19	1,951.11	1,989.28	2,233.98	2,493.21	2,756.26
	9 Merc/Service	3,497.60	3,600.69	3,751.28	3,819.51	4,171.93	4,636.96	5,121.48
	10 Warehouse	2,842.48	2,904.59	3,045.95	3,147.24	3,670.75	4,197.40	4,726.85
	11 Other	1,423.96	1,472.67	1,508.27	1,541.64	1,734.35	1,957.50	2,266.58
5 South Atlantic Total		17,956.81	18,394.45	19,072.09	19,518.61	21,802.22	24,296.82	27,093.25
6 East South Central	1 Assembly	944.82	954.60	967.62	977.82	1,034.74	1,101.77	1,178.54
	2 Education	469.33	482.57	498.24	510.70	570.35	632.07	694.32
	3 Food Sales	73.57	74.69	76.37	77.55	86.07	95.31	104.71
	4 Food Service	150.11	152.40	155.81	158.22	175.62	194.47	213.64
	5 Health Care	184.78	191.82	197.25	202.48	231.63	260.89	290.26
	6 Lodging	461.55	485.05	513.61	523.21	591.95	662.20	734.19
	7 Office -Large	302.35	304.47	308.90	312.42	337.31	363.69	389.39
	8 Office -Small	477.18	481.79	489.37	495.58	537.75	581.98	625.17
	9 Merc/Service	1,055.40	1,076.91	1,114.16	1,135.42	1,259.22	1,393.30	1,530.35
	10 Warehouse	520.90	541.93	569.37	583.11	662.06	743.44	826.47
	11 Other	256.25	265.59	273.60	279.87	327.07	376.22	425.33
6 East South Central Total		4,896.24	5,011.84	5,164.29	5,256.36	5,813.77	6,405.34	7,012.36

APPENDIX D » COMMERCIAL PROJECTION RESOURCES

Millions of Square Feet
AEO2021 Reference case (d113020a)

Census Division	Building Type	2012	2015	2018	2020	2030	2040	2050
7 West South Central	1 Assembly	1,314.16	1,338.54	1,371.34	1,393.78	1,516.96	1,647.47	1,780.39
	2 Education	1,849.36	1,934.93	2,068.48	2,153.20	2,460.22	2,769.18	3,078.73
	3 Food Sales	137.41	141.08	146.97	150.09	168.46	187.55	207.45
	4 Food Service	224.98	230.99	240.63	245.75	275.82	307.07	339.66
	5 Health Care	302.37	325.31	344.79	358.51	415.55	472.64	529.76
	6 Lodging	600.35	637.84	685.09	708.67	801.18	900.85	1,006.10
	7 Office -Large	795.15	817.47	858.95	882.73	985.54	1,093.34	1,199.31
	8 Office -Small	1,037.31	1,070.64	1,125.80	1,158.14	1,297.22	1,442.21	1,584.94
	9 Merc/Service	1,842.47	1,920.59	2,030.18	2,082.69	2,341.64	2,618.99	2,904.03
	10 Warehouse	1,915.86	1,981.39	2,128.98	2,200.76	2,505.15	2,821.51	3,143.53
	11 Other	1,389.72	1,440.11	1,495.93	1,538.09	1,746.25	1,997.43	2,293.94
7 West South Central Total		11,409.14	11,838.88	12,497.13	12,872.42	14,513.98	16,258.22	18,067.84
8 Mountain	1 Assembly	525.80	536.25	551.25	561.83	634.02	707.34	781.05
	2 Education	782.30	808.91	837.49	861.60	981.93	1,112.22	1,241.43
	3 Food Sales	58.61	59.50	60.85	61.91	69.72	78.64	87.74
	4 Food Service	104.14	105.72	108.12	110.01	123.88	139.74	155.89
	5 Health Care	137.05	146.24	155.34	160.84	184.10	206.71	228.66
	6 Lodging	449.35	465.02	485.01	498.22	562.30	637.68	717.79
	7 Office -Large	409.36	416.81	434.61	446.98	509.18	573.93	639.26
	8 Office -Small	593.11	606.37	633.26	651.68	742.67	836.83	931.54
	9 Merc/Service	841.65	862.58	894.64	914.41	1,032.91	1,164.89	1,298.93
	10 Warehouse	591.73	614.82	659.20	685.83	773.80	880.86	999.80
	11 Other	406.69	423.84	438.12	449.07	512.08	583.74	664.76
8 Mountain Total		4,899.79	5,046.07	5,257.88	5,402.38	6,126.60	6,922.57	7,746.85
9 Pacific	1 Assembly	1,208.58	1,208.27	1,232.57	1,250.33	1,344.20	1,440.39	1,537.33
	2 Education	1,065.79	1,082.16	1,111.91	1,133.24	1,228.62	1,336.00	1,447.01
	3 Food Sales	304.03	306.00	310.70	315.36	348.30	383.01	418.24
	4 Food Service	282.56	284.39	288.76	293.09	323.71	355.96	388.71
	5 Health Care	316.69	326.63	336.78	345.34	394.43	443.30	492.10
	6 Lodging	942.09	964.94	1,005.68	1,028.30	1,141.08	1,253.44	1,378.29
	7 Office -Large	1,279.72	1,285.54	1,313.68	1,338.60	1,460.95	1,603.92	1,765.12
	8 Office -Small	1,497.85	1,508.10	1,542.30	1,572.41	1,722.88	1,895.30	2,087.35
	9 Merc/Service	2,694.05	2,740.61	2,813.52	2,866.24	3,182.72	3,516.23	3,855.17
	10 Warehouse	2,941.24	2,982.02	3,089.38	3,185.83	3,696.06	4,208.58	4,722.71
	11 Other	918.30	950.45	988.26	1,014.59	1,140.35	1,280.12	1,436.88
9 Pacific Total		13,450.90	13,639.12	14,033.56	14,343.33	15,983.29	17,716.23	19,528.90
Grand Total		87,076.29	88,859.38	91,727.48	93,582.40	103,124.81	113,457.55	124,344.22

APPENDIX D » COMMERCIAL PROJECTION RESOURCES

Energy Consumption by Sector and Source
(quadrillion Btu, unless otherwise noted)
AEO2021 Reference case (d113020a)

Sector and Source	2012	2015	2018	2020	2030	2040	2050
Commercial							
Purchased Electricity	4.53	4.64	4.71	4.34	4.76	5.04	5.62

APPENDIX D » MACROECONOMIC PROJECTION RESOURCES

Macroeconomic Indicators

AEO2021 Reference case (d113020a)

Indicators	2012	2015	2018	2020	2030	2040	2050
Population and Employment (millions)							
Population, with Armed Forces Overseas	314.5	321.2	327.2	330.4	352.6	370.9	386.2
Employment, Nonfarm	134.1	141.8	149.0	141.5	162.0	172.4	183.3
Population, with Armed Forces Overseas (millions)							
1 New England	14.6	14.7	14.8	14.8	15.1	15.1	15.0
2 Middle Atlantic	41.3	41.5	41.5	41.4	41.6	41.2	40.3
3 East North Central	46.6	46.7	46.7	46.7	47.5	47.6	46.9
4 West North Central	20.8	21.1	21.3	21.5	22.4	23.1	23.5
5 South Atlantic	61.3	63.3	65.1	66.2	72.8	78.8	84.2
6 East South Central	18.7	18.9	19.0	19.1	20.0	20.5	20.9
7 West South Central	37.5	39.0	40.4	41.2	46.0	50.5	54.6
8 Mountain	22.7	23.5	24.4	25.0	28.4	31.8	35.1
9 Pacific	51.1	52.5	53.8	54.5	58.8	62.3	65.5
U.S. Total	314.5	321.2	327.2	330.4	352.6	370.9	386.2

APPENDIX E » RMEL HIGH-LEVEL ANALYSIS

This high-level analysis covered 5 residential MELs.

MEL	Definition
Air purifiers	An air purifier is an electric appliance that can remove particulate matter from the air and that can be moved from room to room.
Blu-ray/DVD/VHS players	This MEL consists of Blu-ray, DVD, VHS players.
Electric scooters/bikes	This MEL includes public (docked and dockless) and personal electric scooters and bikes.
Residential video surveillance systems	A residential video surveillance system is a system of one or more indoor and/or outdoor security cameras and associated recording equipment (for example, digital video recorder (DVR), network video recorder (NVR)), if applicable. This MEL excludes video doorbells.
Video doorbells	Video doorbells include doorbells with integrated network camera powered by doorbell transformer. Excludes all other types of residential security cameras and video surveillance systems.

APPENDIX E » RMEL HIGH-LEVEL ANALYSIS

Technology	Installed Base (000s)	UEC (kWh/yr)	AEC (TWh/yr)	Data Year	Technology trends likely to impact future energy consumption
Air Purifiers	23,000	340	7.8	2018/2020	Rising air pollution levels, increasing disposable income, and growing health awareness regarding the harmful effects of air pollution on human health are expected to boost air purifier adoption (Grand View Research, 2020). Improvements in energy efficiency over the last 20 years driven mostly by more efficient motor designs (ENERGY STAR, 2018). We are assuming this trend will continue into the future. We project that these two trends will partially offset each other and thus the AEC of air purifiers will remain constant through 2050.
Blu-Ray/DVDs/VHS	159,122	23	3.7	2015/2017	The installed stock of DVD, Blu-ray, and VHS players is being phased out by the increasing popularity of internet streaming devices such as over-the-top (OTT) streaming devices, smart TVs, and video game consoles. Therefore, we expect the annual energy consumption of these devices to decrease over time.
Electric Scooters/Bikes	962	86	0.1	2020	Electric scooters and bikes are generally expected to increase in adoption. In some US cities, regulators are beginning to limit the number of dockless e-scooters and e-bikes, which could reduce the rate of increase for these devices (Zipper, 2020). However, it is likely that personal ownership of these devices will increase over time (Hawkins, 2019). However improvements in lithium-ion batteries could reduce the UEC of these devices. Overall, we expect an increase in the total AEC of these devices.

APPENDIX E » RMEL HIGH-LEVEL ANALYSIS CONT'D

Technology	Installed Base (000s)	UEC (kWh/yr)	AEC (TWh/yr)	Data Year	Technology trends likely to impact future energy consumption
Residential Video Surveillance Systems	18,300	307	5.6	2020	Despite a decline in property crimes over 16 consecutive years the residential video surveillance market has grown dramatically in recent years due to the convergence and integration of security and smart home devices, do-it-yourself (DIY) products, and the conversion from legacy to interactive services (i.e., the ability to remotely control/monitor a system). Consumer data privacy concerns present a challenge for continued growth.
Video Doorbells	12,000	25	0.3	2020	Since entering the market in 2012, adoption of video doorbells has grown dramatically due to consumer home security concerns including prevention of package theft and demands for interactive smart home products. The share of video doorbells that are self-powered using solar chargers is currently small but is expected to grow.

APPENDIX F » CMEL HIGH-LEVEL ANALYSIS

This high-level analysis covered 10 commercial MELs

MEL	Definition
Automated teller machines (ATMs)	An ATM is an electronic banking machine that enables consumers to perform basic transactions using credit or debit cards.
Building management systems	A building management systems is a system of sensors, controllers, actuators and relays, communication protocols, software, and terminal interfaces (for example, computers) used to monitor and control heating, cooling, ventilation, lighting, and other building systems.
Coffee brewers	There are three major types of commercial-style coffee brewers: 1) decanter, 2) thermal, 3) satellite. Coffee makers consume most of their energy via heating the water through a resistive heating element.
Electronic doors	Electronic doors are electrically-powered doors designed to open using an electric motor when a pedestrian is present, hold the door open until no pedestrian is detected, then close.
Escalators	An escalator is a moving staircases that move people between vertical levels. The majority of escalators are installed in retail shopping buildings and office buildings.
Large-format video boards	A large-format video boards is an extremely large video display typically installed at sports stadiums and arenas and as billboards. Other video displays used at stadiums, for example the television-sized displays used for spectator viewing in concessions areas, are covered under Commercial Video Displays.
Laundry equipment	Commercial laundry equipment consists of washing machines, dryers, and dry cleaning equipment.
Treadmills	A treadmill is an exercise machine, typically with a continuous belt, that allows one to walk or run in place.
Non-road EVs	Non-road EVs primarily consist of electric forklifts, golf carts, and electric burnishers.
Slot machiness and arcade games	Slot machines are one of the most popular gambling methods in casinos and are almost completely computerized. Arcade games are coin or token-operated, electronic entertainment machines installed with various types of video games.

APPENDIX F » CMEL HIGH-LEVEL ANALYSIS CONT'D

Technology	Installed Base (000s)	UEC (kWh/yr)	AEC (TWh/yr)	Data Year	Technology trends likely to impact future energy consumption
Commercial Coffee Brewers	3,565	905	3.2	2015	The most recent ENERGY STAR voluntary energy efficiency standards for commercial coffee makers was published in 2018. ENERGY STAR certified commercial coffee makers are approximately 35% more efficient than standard models. Consequently, the UEC of commercial coffee makers is expected to gradually decline while the installed stock and AEC is projected to grow with commercial floorspace.
Commercial Laundry Equipment	4,100	341	1.4	2008	Federal energy efficiency standards have been instituted for residential-style washers. In addition, ENERGY STAR commercial washers consume approximately 25% less electric energy than conventional equipment. Long-term trends for commercial laundry equipment is an expectation for higher efficiency equipment and a move away from gas-powered dryers.
Escalators	35	22,950	0.7	2013	The installed stock of escalators is expected to follow the slow and stable growth of commercial floorspace. Energy efficient escalator models and modes of operation may decrease unit energy consumption by 30% through the use of high-efficiency, brushless motors and sensors and automation.
Slot Machines and Arcade Games	1,100	3,558	3.9	2008	Advanced controls such as automatic power on/off, timer plugs, and standby modes can be implemented to reduce total energy consumption for slot machines and arcade games. Automatic power on/off of slot machines can save up to 40% of energy. On the other hand, the use of timer plugs and standby modes can reduce arcade machine energy consumption by 50%.
Treadmills	403	2,400	1.0	2008	New treadmill technology can provide near-frictionless drive systems which can saving up to 50% of energy consumption.
Large-Format Video Boards	3	162,902	0.5	2010	The number of digital billboards is expected to increase over the next two decades. In addition, the size of large format video boards is expected to increase. Due to new display technologies and energy efficiency programming, digital displays may see up to 50% reduction in energy consumption per screen area.
Non-Road EVs	2,400	4,750	4.3	2008	Improvements of up to 33% in energy efficiency for non-road EVs may be achieved by improving the battery efficiency.

APPENDIX F » CMEL HIGH-LEVEL ANALYSIS

Technology	Installed Base (000s, except where otherwise noted)	UEC (kWh/yr, except where otherwise noted)	AEC (TWh/yr)	Data Year	Technology trends likely to impact future energy consumption	Notes
Building Management Systems	37,000	0.13	4.9	2012	BMS technologies are transitioning toward open frameworks that allow contractors to mix and match equipment and software from different suppliers. Since the large building market is relative mature, many new BMS solutions are being designed for retrofit of small and medium-sized buildings. Other technology trends that may lead to growth include wireless sensors and use of big data and analytics enhanced by artificial intelligence (AI) and machine learning (ML).	Installed base in units of million ft2 UEC in units of kWh/ft2/yr
ATMs	470	2,900	1.4	2018	The United States has seen a decline in the number of ATMs in recent years. Key drivers for the decline in ATMs are bank branch closures and consolidation among independent ATM deployers (IADs), as well as the expansion of digital banking and non-cash payments. Although the number of ATMs is expected to continue to decline, the rate of decline will be slowed as customers show interest ATMs with more functionality. The ATM Industry Association (ATMIA) says “tens of thousands” of independent ATMs now offer person-to-person (P2P) money transfer capabilities, and many financial institutions are deploying ATMs that use contactless technology so that customers can pre-stage their cash withdrawals (set up a withdrawal on a mobile device beforehand) and perform other transactions.	
Electronic Doors	2,550	99	0.3	2012	Electronic door count is expected to grow approximately in proportion to new commercial building construction. There will be continued demand for older building to install electronic door to improve accessibility and demand may increase in the near term due to health concerns related to the COVID-19 global pandemic. Increasing energy consumption associated with the increasing installed base will be partially offset by improving door motor efficiency.	

APPENDIX B

ANALYSIS OF COMMERCIAL MISCELLANEOUS ELECTRIC LOADS – 2017 UPDATE

PREPARED FOR:

U.S. ENERGY INFORMATION ADMINISTRATION

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FINAL

April 28, 2017

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Executive Summary

EXECUTIVE SUMMARY » OBJECTIVE, SCOPE, AND GOALS

Summary: We characterized energy consumption and installed base for four commercial miscellaneous electric loads (MELs) associated with telecommunication networks and seven MELs associated with commercial office equipment. The evaluation includes projections through 2050.

Objective: Develop an updated and expanded list of the estimated unit and national energy consumption for selected MELs.

MELs covered:

- **Telecommunications:** Traditional PBX, voice-over-IP (VoIP), cellular and PCS networks, ICT Long Haul networks, ICT Access Networks.
- **Office Equipment**: Copiers, scanners, multifunction devices (MFDs), fax machines, printers, shredders, and uninterruptible power supplies (UPS's).

Goals:

- Define each MEL and determine the scope of the technology to be analyzed.
- Characterize the 2012 installed base and unit energy consumption.
- Develop scenario-based projections through 2050.

EXECUTIVE SUMMARY » PROCESS DESCRIPTION

The evaluation used the following procedure:

1. Define the scope of each selected MEL (listed in table below).
2. Estimate the U.S. installed base in number of units or users.
3. Approximate the unit energy consumption (UEC) by determining typical:
   - Usage hours
   - Power consumption (per unit or per user, as appropriate)
4. Characterize relevant market, economic, demographic, and technology trends.
5. Develop projections up to the year 2050 based on expected changes in:
   - Usage hours
   - Power consumption
   - UEC
   - AEC
   - Installed base

Telecommunications	Office Equipment
• Traditional PBX	• Copier
• Voice-over-IP (VoIP)	• Scanner
• Cellular and PCS networks	• Multifunction device
• ICT long-haul networks	• Fax machine
• ICT access networks	• Printer
	• Shredder
	• Uninterruptible power supply (UPS)

EXECUTIVE SUMMARY » TELECOMMUNICATIONS EQUIPMENT

This analysis covered five separate types of telecommunications equipment.

MEL	Definition
Traditional PBX	Standalone on-premise equipment used to route calls over telephone lines (a.k.a. legacy PBX).
VoIP (IP PBX)	Standalone on-premise equipment used to route calls over the Internet (a.k.a. IP PBX and Media Gateway).
Cellular and PCS Networks	Central radio transmitter/receiver, including base station equipment.
ICT Long-haul Networks	System of routers and Ethernet switches interconnected by an optical transport network (OTN) of optical transceivers and amplifiers/repeaters used to transmit data packets over long distances (e.g., between regions or metropolitan areas).
ICT Access Networks	“The last mile" of telecom operator networks. Connect carrier/service provider central offices to end consumers, providing telephone and internet services.

EXECUTIVE SUMMARY » OFFICE EQUIPMENT

This analysis covers seven types of office equipment.

MEL	Definition
Copiers	A photocopier, or copier, is an office machine that duplicates physical documents on paper in a two dimensional format. It is used for reproducing text, images, charts, and graphs.
Scanners	A scanner converts physical documents into two-dimensional digital representations that can be either stored electronically, transmitted to a computer, or both.
Multifunction Devices (MFDs)	An MFD incorporates several, or all, of the operational capabilities of a copier, scanner, fax machine, printer, and the ability to send emails.
Fax Machines	A fax machine is a device that copies documents and transmits this copy via telephonic transmission to a telephone number connected to a printer or an output device.
Printers	A printer transcribes digital documents to two-dimensional representations on paper or an equivalent physical medium.
Shredders	A shredder uses a power source to mechanically cut paper into either strips or fine particles, typically with the aim of destroying documents containing sensitive information.
Uninterruptible Power Supplies (UPS's)	UPS's consists of a combination of convertors, switches and energy storage devices, constituting a power system for maintaining continuity of load power in case of input power failure.

EXECUTIVE SUMMARY » TELECOM TECH TRENDS

- The largest change in the telephone and telecommunications industry over the past ten years is the surfacing and widespread use of converged networks and Unified Communications (UC) – that is, a single network for all data, voice, and video.
- Due to UC, the same network equipment is often used to provide video, voice, and data services, and some parts of telephone networks are no longer separately distinguishable.
- A current trend indicates moving away from even these recent topologies to a cloud-services based concept, where the telephony head-end equipment is located off the private network and managed independently of the actual Local Area Network.
- Energy efficiency will likely improve in the “cloud” model; however, any savings realized through the efficient location and “sharing” of hardware will most likely be offset by an effort to increase available bandwidth and network speeds.
- Wired technologies offer higher bandwidths and energy efficiency per bit of data transfer; however, wireless technologies are growing faster due to consumer demand for mobility.

EXECUTIVE SUMMARY » OFFICE EQUIPMENT TRENDS

- The most significant trend in office-related commercial MELs is the replacement of single-function devices with MFDs.
- Because of combined functionalities, the total installed base of commercial imaging equipment MELs is expected to *decrease* by 9% from 2012 to 2050, even though commercial building floorspace will *grow* by 45%. Spaces that previously required a separate copier, scanner, fax, and printer will simply require one MFD.
- Fax machines are seeing dramatic decreases in installed base. By 2050, these devices are expected to be generally obsolete. This change is the result of the transition from paper to digital document storage, the MFD takeover, and the diminishing use of fax technology as other methods for secure transmission have become available.
- In data centers and other commercial spaces, reliable power supplies are essential to business operations. Growth in data center space will increase quicker than general commercial space because of increased demand for data storage and computing requirements. The installed base of UPS's will grow by 260%. Despite projected efficiency improvements, the AEC will grow by 230%.

EXECUTIVE SUMMARY » RESULTS SUMMARY

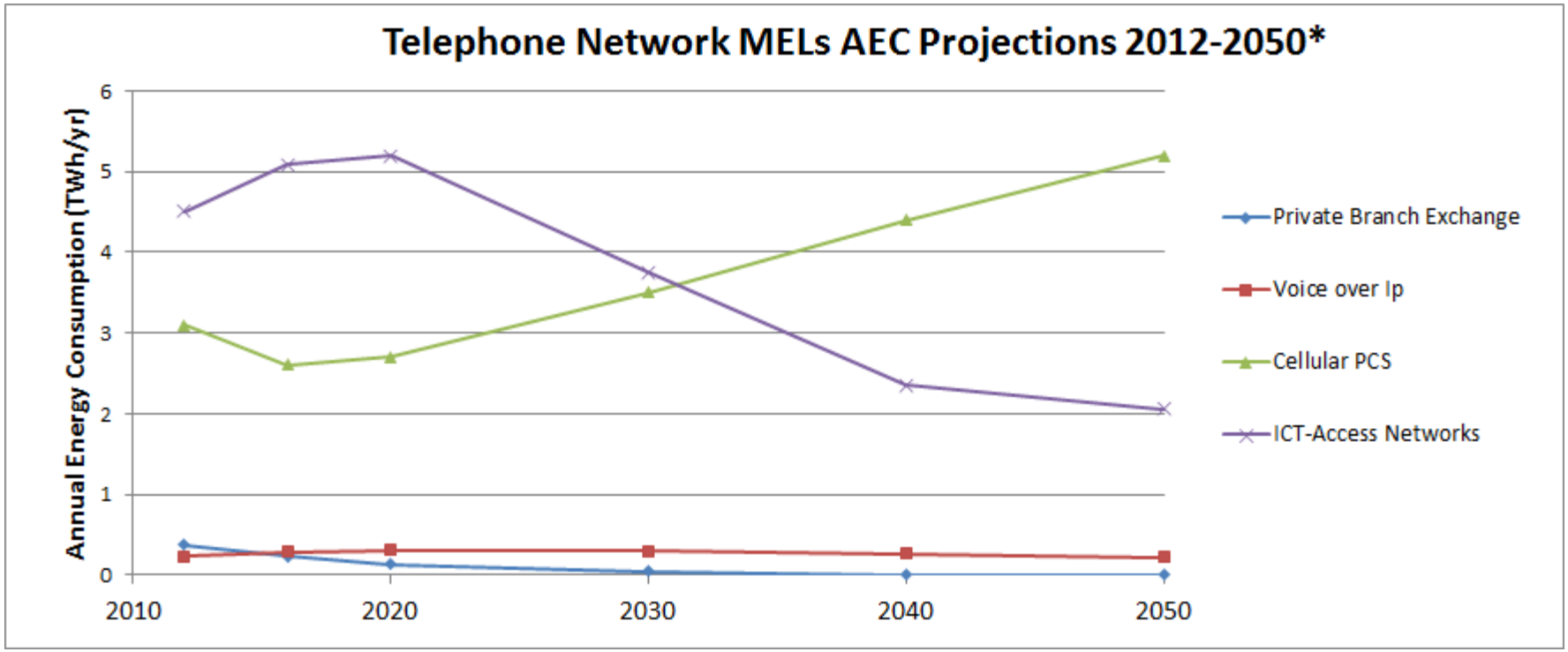
- The selected telecommunications MELs consumed an estimated 13 TWh in 2012.
- The selected office equipment MELs consumed 11 TWh in 2012.
- The MEL with the most significant AEC in 2012 was printers at 4.8 TWh.

Annual Energy Consumption by Building Type (TWh/yr)

AEC (TWh/yr)	Assembly	Education	Food Sales	Food Service	Healthcare	Lodging	Large Office	Small Office	Mercantile & Service	Warehouse	Other	Total
Office MELs												
Copiers	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	<0.01	<0.01	<0.01	0.05
Scanners	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	0.02	0.02	0.01	<0.01	<0.01	0.09
Multifunction Devices	0.10	0.11	0.02	0.03	0.06	0.03	0.17	0.34	0.19	0.09	0.05	1.20
Faxes	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01
Printers	0.27	0.73	0.05	0.10	0.24	0.17	0.80	1.22	0.68	0.34	0.17	4.80
Shredders	<0.01	0.03	<0.01	<0.01	0.02	<0.01	0.06	0.04	0.02	0.02	<0.01	0.23
Uninterruptible Power Supplies	0.30	0.80	0.10	0.10	0.20	0.10	4.50	1.40	0.60	0.40	0.50	4.60
Telephone MELs												
Private Branch Exchange	0.02	0.05	0.00	0.01	0.02	0.01	0.07	0.08	0.05	0.03	0.02	0.4
Voice over IP	0.01	0.03	0.00	0.01	0.01	0.01	0.05	0.05	0.03	0.02	0.01	0.2
Cellular-Personal Comm Service	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.1	3.1
ICT-Long Haul Networks	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.5	4.5
ICT-Access Networks	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.5	4.5

EXECUTIVE SUMMARY » PROJECTIONS

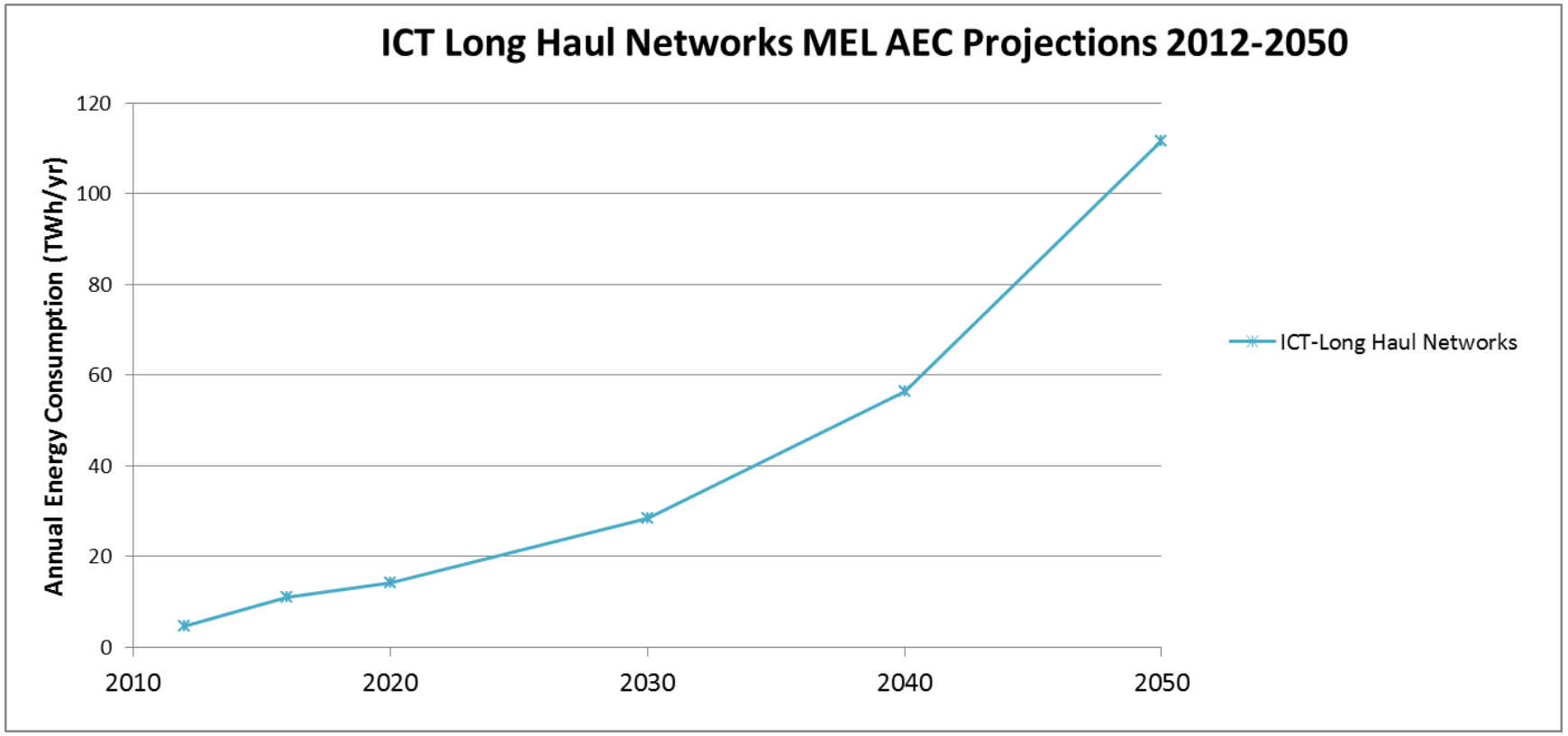
- Traditional PBX are quickly being replaced by IP PBX used for VoIP systems.
- Cellular and PCS network AEC shows steady growth after 2016 as subscribership and demand for wireless data increases.



* Does not include ICT Long Haul Networks

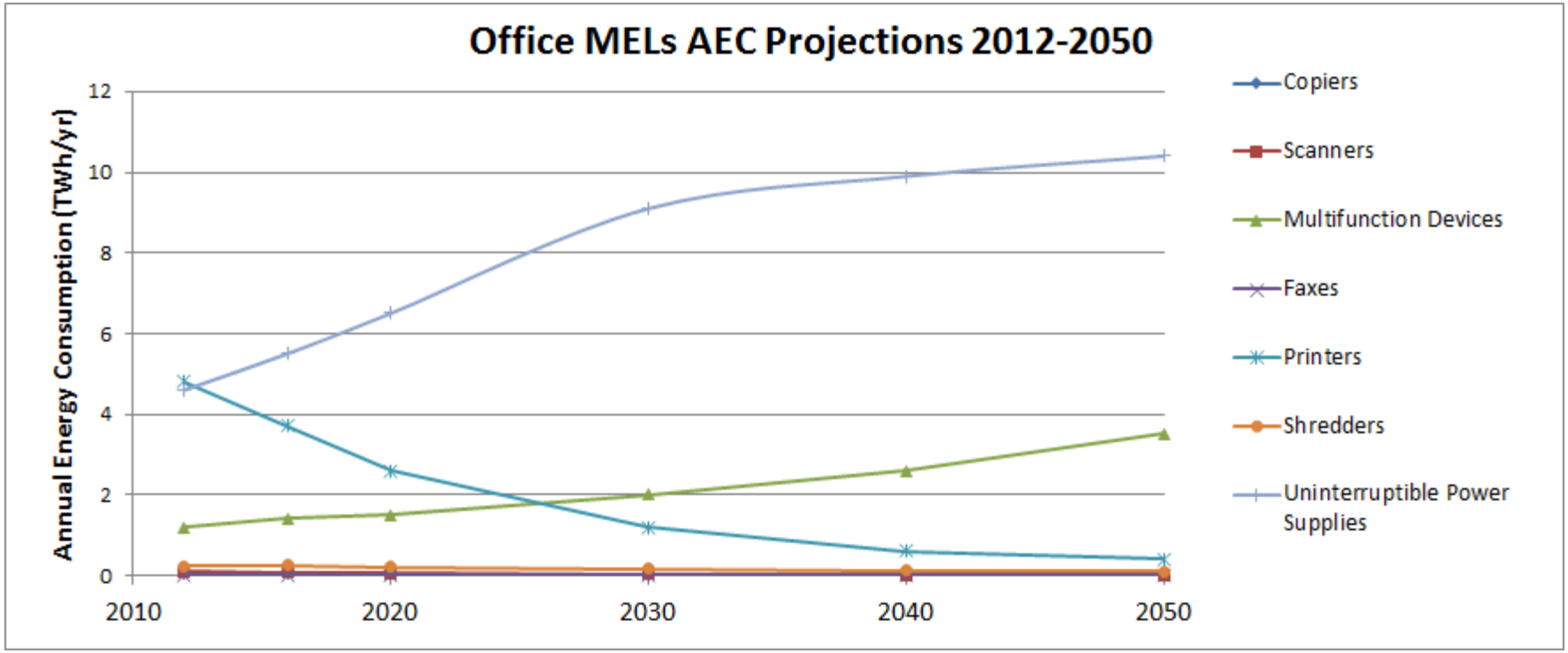
EXECUTIVE SUMMARY » PROJECTIONS CONT.

- ICT long-haul network AEC expected to grow at a CAGR of 9% through 2050 due to increasing data traffic volume



EXECUTIVE SUMMARY » PROJECTIONS CONT.

- The total AEC of the office-related MELs is expected to grow by 30% over the forecast period.
- MFDs will see the largest device-specific AEC growth—an increase of 290% between 2012 and 2050.



Background & Methodology

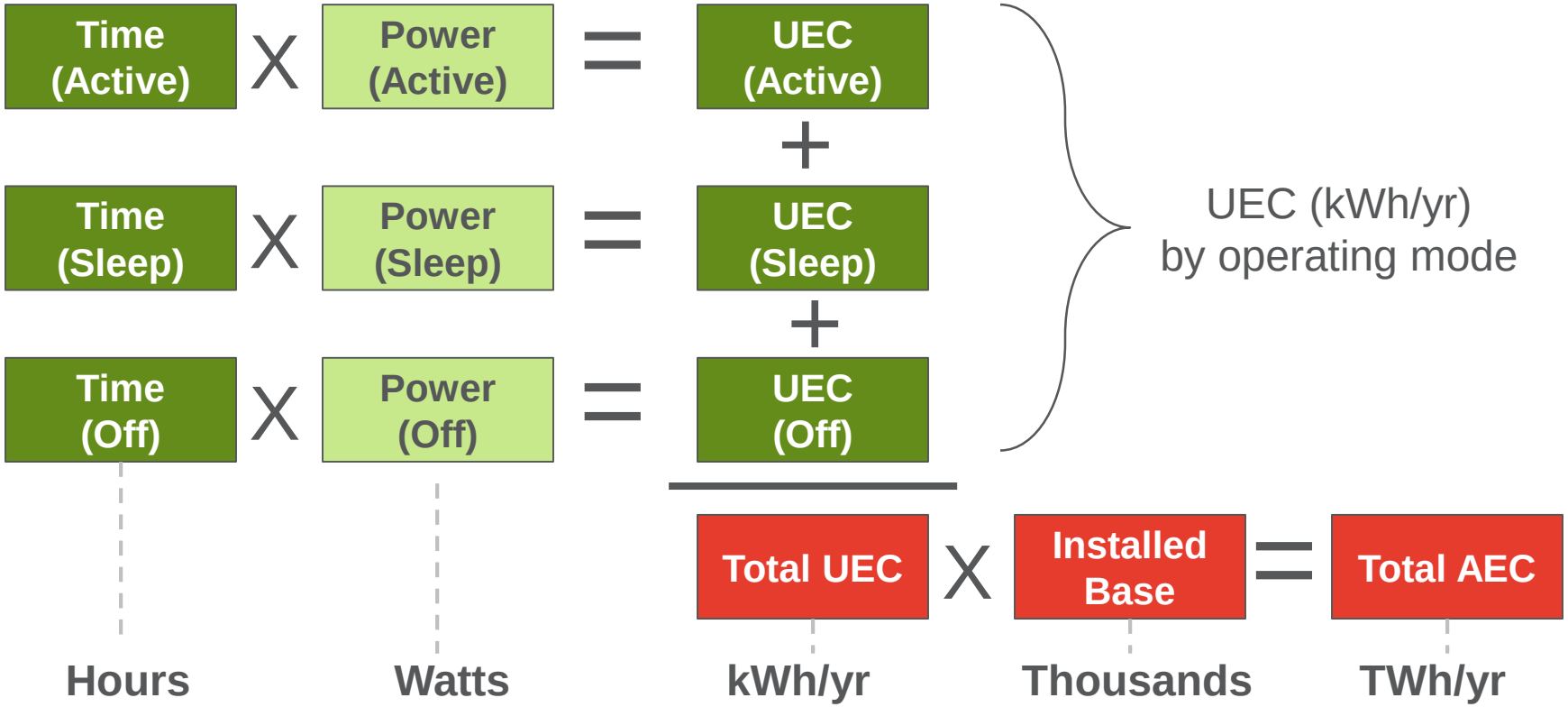
BACKGROUND » MEL DEFINITION

- **Miscellaneous electric loads (MELs)** are the loads outside of a building's core functions of heating, ventilating, air-cooling, lighting, and water heating.*
- This study focuses on a subset of MELs for:
  - Telecommunication networks.
  - Office equipment.
- Wherever workable, we followed the same methodology, reporting framework, and outputs as we provided in the past to ensure consistency. The primary model leveraged was from "Analysis and Representation of Miscellaneous Electric Loads in NEMS," Dec, 2013.**

*Source: Emily Rauch and Michael Baechler, Pacific Northwest National Laboratory, Sept 2011, "Assessing and Reducing Miscellaneous Electric Loads (MELs) in Banks" Available at: http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-20973.pdf
**Available: https://www.eia.gov/analysis/studies/demand/miscelectric/pdf/miscelectric.pdf

METHODOLOGY » OVERVIEW

When sufficient data were available*, we followed a bottom-up methodology to calculate the three primary outputs for each MEL: unit energy consumption (UEC), installed base, and annual energy consumption (AEC).



* Based on the Contractor's judgment of whether available data were sufficient to formulate credible, bottom-up estimates.

METHODOLOGY » ENERGY USE

When sufficient data were not available for a complete bottom-up analysis of energy consumption*, we customized the approach to develop the best estimates possible.

Example: Fax Machines

- Very little data were available on hours of operation and energy consumption in individual modes. Accordingly, we based UEC estimates directly on a study by the California Energy Commission.

* Based on the Contractor's judgment of whether available data were insufficient to formulate credible, bottom-up estimates.

METHODOLOGY » INSTALLED BASE

Installed base estimates were developed using one or more of the following available resources:

- Field surveys (e.g., Commercial Building Energy Consumption Survey [CBECS])
- Useful life and annual sales data
- Other recent studies that developed estimates

Unique case: MFDs

- While the installed base of copiers, scanners, and printers was gathered from CBECS 2012, the installed base for MFDs was not available.
- CBECS questions did not necessarily elicit distinctions from respondents regarding whether a device serves multiple functions, thus introducing a challenge to distinguish between single-function devices and MFDs. To overcome this challenge, we:
    1. Determined if multiple imaging devices were in each building.
    2. Assumed that the MEL with the smallest number of units represented the MFD count for each building.
    3. Subtracted the MFD count from the CBECS counts, with the remainder representing the numbers of copiers, printers, and scanners. E.g., if CBECS data indicated 3 copiers, 5 scanners, and 7 printers in a building, then our count was 3 MFDs, 2 scanners, and 4 printers.

METHODOLOGY » PRODUCT TYPES

Consideration was made for varying product sizes/capacities and product subtypes.

- In general, we developed projections based on a “typical” unit for each MEL, in terms of size/capacity and usage.
  - Such a composite unit may not exist in the real world; it represents the average unit in the U.S.
- Exceptions were made where product subtypes have markedly different power and usage hours.
  - For Cellular and PCS Networks, we projected each subtype separately and calculated the weighted average at the end.
- We developed a unique projection approach for each MEL, generally based on observed trends in:
  - Past sales data and effective useful life.
  - Reported installed base data.
  - Product specifications from manufacturer datasheets.

METHODOLOGY » PROJECTIONS

We projected UEC, installed base, and AEC for each MEL out to 2050.

- Where data were available, we based energy projections on individual growth rates for annual hours of use and power consumption for each MEL.
- For MELs that did not have use and power data available, we projected UEC directly.
- In general, we developed projections based on a composite unit for each MEL, which is defined by an average that is weighted by the installed base of each product subtype.
  - E.g., the composite shredder, used for all shredder projections, comprises models of all sizes.
- We based projections for each MEL on unique trends in:
  - Population
  - Building floor space or stock
  - Gross Domestic Product (GDP)
  - Past sales data and effective useful life
  - Other market trends, such as the decline in paper use in the U.S.

METHODOLOGY » BREAKDOWN BY BUILDING TYPE

We split MEL estimates by building type, using the National Energy Modeling System (NEMS) definitions, which are closely correlated to the CBECS 2012 definitions.

Building Type	Description
Assembly	Public assembly (stadium, gym, library), religious
Education	College, K-12 schools (elementary, middle, high)
Food Sales	Grocery stores and convenience stores
Food Service	Restaurant, fast food, cafeteria
Healthcare	Hospitals providing inpatient health services
Lodging	Hotel, motel, dormitory, nursing home
Large Office	Offices > 50k sq ft of floor space
Small Office	Offices < 50k sq ft, including outpatient healthcare
Mercantile and Service	Retail, service shops, strip malls, enclosed malls
Warehouse	Refrigerated and non-refrigerated storage
Other	Public order (police, fire), vacant, other

For buildings with multiple functions, the largest usage of floor area determines principal activity.

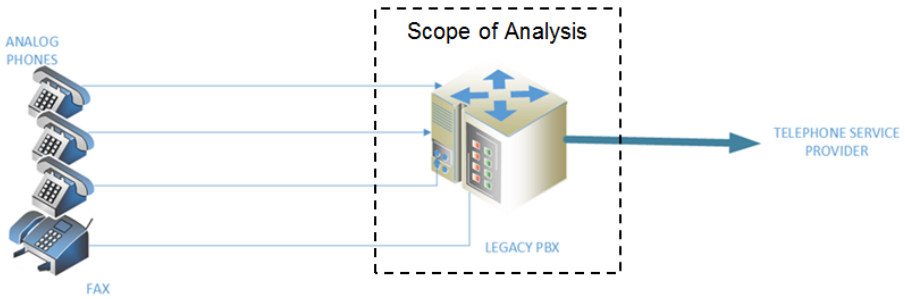
Results – Telecommunications Equipment

TELECOM MELS » TRADITIONAL PBX

Scope: Traditional or legacy Private Branch Exchanges (PBX) used by commercial enterprises to route and switch calls in a building over Plain Old Telephone Service (POTS) lines. Does not include IP PBX systems used to support VoIP networks.

		2012	2016	2020	2030	2040	2050
Installed Base	**(000s)**	21,400	13,100	7,900	2,200	0	0
Average Power Draw	**watts**	1.96	1.96	1.96	1.96	1.96	1.96
Annual Usage	**hours**	8,760	8,760	8,760	8,760	8,760	8,760
UEC	**kWh/yr**	17	17	17	17	17	17
AEC	**TWh/yr**	0.4	0.2	0.1	0.04	0.0	0.0

- Traditional PBX systems are rapidly being upgraded or replaced with Voice over Internet Protocol (VoIP) and unified communications (UC) technologies such as IP PBX systems and hosted/cloud-based services.
- Traditional PBX units come in a variety of user capacities from tens of users to thousands of users.
- Market data indicate that sales of new PBX units virtually stopped by 2012.
- Installed base data were only available in terms of PBX-connected phone lines (i.e., end users).*



* The terms lines and end users refer to individual people, rather than buildings

TELECOM MELS » TRADITIONAL PBX CONT.

2012 Base Year Data	Installed Base (000s)	UEC (kWh/yr)	AEC (TWh/yr)
Assembly	1,225	17	0.02
Education	2,642	17	0.05
Food Sales	284	17	0.00
Food Service	833	17	0.01
Healthcare	1,039	17	0.02
Lodging	744	17	0.01
Large Office	4,326	17	0.07
Small Office	4,675	17	0.08
Mercantile & Service	3,191	17	0.05
Warehouse	1,544	17	0.03
Other	898	17	0.02

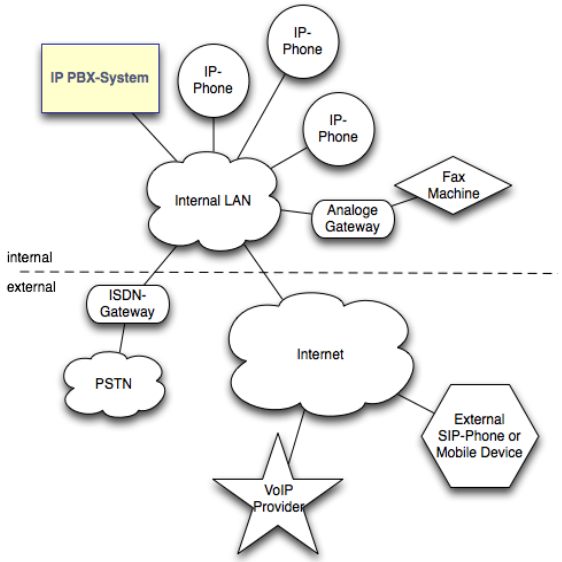
- This analysis allocates the installed base across building types based on total workers by building type from CBECS 2012.
- Power draw varies little by operating mode or call activity.
- This analysis assumes 24x7x365 operation with an average power draw of 1.96 watts per user.
- Efficiency is constant through 2050 since new units are not being installed after 2012.

TELECOM MELS » VoIP

Scope: Onsite equipment used to route voice calls on a VoIP network, often referred to as an IP PBX. Does not include connected communication devices (e.g., VoIP phones), analog gateways, computers, servers, or other networking or IT equipment, or hosted VoIP networks where the equipment resides on the host IT servers.

		2012	2016	2020	2030	2040	2050
Installed Base	**(000s)**	89,200	112,700	123,600	130,400	131,000	131,100
Average Power Draw	**watts**	0.29	0.28	0.28	0.26	0.23	0.19
Annual Usage	**hours**	8,760	8,760	8,760	8,760	8,760	8,760
UEC	**kWh/yr**	2.5	2.5	2.4	2.3	2.0	1.7
AEC	**TWh/yr**	0.2	0.3	0.3	0.3	0.3	0.2

- VoIP technology for business applications began in the mid 1990's and is currently growing rapidly.
- While on-premise VoIP systems continue to grow, businesses are increasingly moving to hosted VoIP solutions to cut costs and increase flexibility.
- Installed base data for on-premise systems was only available in terms of IP PBX-connected lines (i.e., end users).*



* The terms lines and end users refer to individual people, rather than buildings

TELECOM MELS » VoIP CONT.

2012 Base Year Data	Installed Base (000s)	UEC (kWh/yr)	AEC (TWh/yr)
Assembly	5,106	2.5	0.01
Education	11,011	2.5	0.03
Food Sales	1,186	2.5	0.00
Food Service	3,471	2.5	0.01
Healthcare	4,330	2.5	0.01
Lodging	3,101	2.5	0.01
Large Office	18,032	2.5	0.05
Small Office	19,485	2.5	0.05
Mercantile & Service	13,300	2.5	0.03
Warehouse	6,435	2.5	0.02
Other	3,744	2.5	0.01

- Average power draw per line determined by dividing total power draw by the number of connected users at 75% of user capacity for a representative sample of equipment.
- Rate of energy efficiency improvement assumed to match that of IT Equipment from.

TELECOM MELS » CELLULAR AND PCS NETWORKS

Scope: Equipment associated with the central radio transmitter/receiver and associated equipment, together known as a base station, that communicates with mobile telephones and other devices in order to provide wireless service in a geographic area. Both macro and micro/small base stations are included. Does not include connected communication devices (phones, tablets, computers, etc.), mobile switching, core transmission, data centers.

		2012	2016	2020	2030	2040	2050
Installed Base	**(000s)**	360	420	520	780	1,040	1,300
Average Power Draw	**watts**	980	720	580	510	470	450
Annual Usage	**hours**	8,760	8,760	8,760	8,760	8,760	8,760
UEC	**kWh/yr**	8,600	6,300	5,100	4,500	4,200	4,000
AEC	**TWh/yr**	3.1	2.6	2.7	3.5	4.4	5.2

- Base stations typically include several pieces of equipment that consume power, such as amplifiers, transceivers, power conversion modules, equipment air conditioning units, and signal processors. For the purpose of this analysis the entire base station is considered a single piece of end-use equipment.
- This analysis includes both large and small base stations. Large, or macro, base stations typically include large towers and have a range of 10 miles or more. Small, or micro, base stations are often located on top of buildings and a range of about 1 mile.
- Very small (Femto) cells are not included as they are typically behind the meter

leidos NAVIGANT

TELECOM MELS » CELLULAR AND PCS NETWORKS CONT.

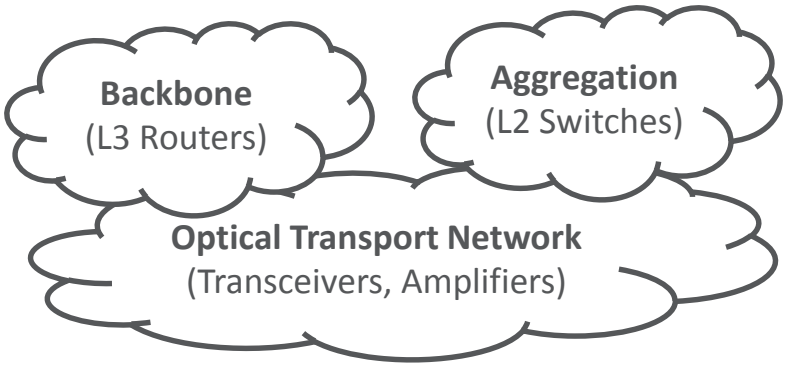
- The Wireless Industry Association (CTIA) tracks the number of macro base stations in service.
- Micro base station installed base data was not available, however, an estimate was obtained through personal communication with cell tower leasing company Steel in the Air.
- Although power draw varies depending on data traffic, the traffic often comes in bursts and varies widely among cell sites.
- This analysis assumes “always on” operation and uses an average power draw for macro and micro base stations.

TELECOM MELS » ICT LONG-HAUL NETWORKS

Scope: This analysis includes equipment in 3 network segments: (1) backbone, (2) aggregation, and (3) optical transport. The backbone segment includes layer 3 (L3) internet protocol/multiprotocol label switching (IP/MPLS) routers interconnected via an Optical Transport Network (OTN) platform. The aggregation segment includes layer 2 (L2) carrier-grade Ethernet switches interconnected via metro/regional OTN rings (Lange, 2011). OTNs are composed mainly of optical transceivers and amplifiers. Data centers, mobile radio networks, and access networks are not included. Overhead energy user for equipment cooling and power conditioning is also not included.

		2012	2016	2020	2030	2040	2050
AEC - Backbone	**TWh/yr**	1.3	5.1	6.7	13	27	53
AEC - Optical Transport	**TWh/yr**	0.8	1.2	1.6	3.1	6	12
AEC - Aggregation	**TWh/yr**	2.4	4.5	5.9	12	23	47
AEC - Total	**TWh/yr**	4.5	11	14	28	56	112

- Due to network complexity and data availability, this analysis utilizes an alternative, top-down estimation method. As a result, installed base, power draw, usage, and UEC data were not quantified.
- The consumption in network segments with aggregated traffic (aggregation and core networks) is proportional to the traffic volume. (Lange, 2011)



TELECOM MELS » ICT LONG-HAUL NETWORKS CONT.

- Annual Energy Consumption (AEC) was calculated for each network segment by multiplying worldwide telecom operator network energy consumption by the relative share of each network segment and by the U.S. share of worldwide broadband subscriptions, then dividing by an overhead factor.
- The backbone, aggregation, and optical transport network segments accounted for about 6%, 11%, and 3.5% of energy consumption in telecom operator networks in 2012 (Lange, 2011).
- The U.S. share of worldwide fixed telephone and broadband subscriptions was about 12.7% in 2012 and 11.8% in 2016 (ITU, 2016).*
- To avoid double-counting, overhead energy consumption for supplemental cooling and power conditioning requirements of long-haul network equipment was removed by dividing by an overhead factor of 1.5 per (Baliga, 2011).
- Projections for 2016-2050 assume equipment efficiency will improve 10% per year (Baliga, 2011 and Ishii, 2015) and internet traffic volume will increase 19% per year (Cisco, 2016).

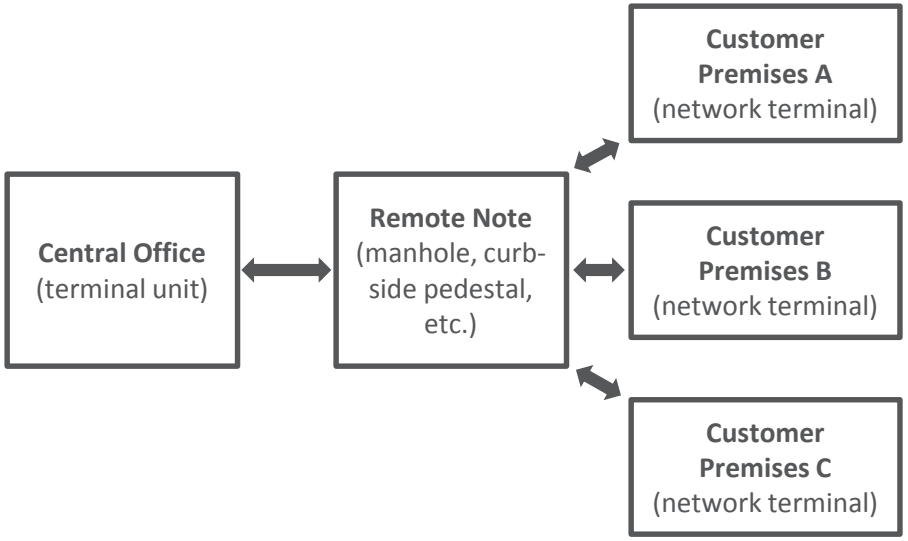
* Note that a single subscription is often shared by multiple or many individual end users, especially in commercial spaces.

TELECOM MELS » ICT ACCESS NETWORKS

Scope: This end-use includes terminal units in central offices and equipment in remote nodes (manholes, curbside pedestals, etc.). Customer premise equipment such as modems, routers, and network terminals located behind-the-meter are not included in this analysis to avoid double-counting. Overhead energy for equipment cooling and power conditioning in central offices is also not included.

		2012	2016	2020	2030	2040	2050
Installed Base	**(000s)**	93,000	102,000	110,000	123,000	133,000	141,000
Average Power Draw	**watts**	5.5	5.7	5.4	3.5	2.0	1.7
Annual Usage	**hours**	8,760	8,760	8,760	8,760	8,760	8,760
UEC	**kWh/yr**	48.5	49.9	47.2	30.5	17.7	14.6
AEC	**TWh/yr**	4.5	5.1	5.2	3.8	2.4	2.1

- Common types of access networks include cable, DSL, fiber-to-the-node (FTTN), and fiber-to-the-premise (FTTP).
- Depending on the connection type, signals may be sent over optical fiber, copper wires, or a combination of both.
- For many connection types, a remote node (e.g., manhole, curbside pedestal) located between the consumer and central office to split, aggregate, and/or amplify signals.



TELECOM MELS » ICT ACCESS NETWORKS CONT.

- In 2012, cable, DSL (including FTTN), and FTTP accounted for 56%, 34%, and 7% of broadband subscriptions in the U.S.*
- FTTP subscribership is increasing faster than any other access network type due to higher available access rates (i.e., internet speeds). The eventual replacement of DSL and cable with FTTP will also yield energy savings due to higher efficiency of FTTP networks.
- Terminal units and equipment at remote nodes are assumed to be loaded to 80% of max capacity per (Baliga, 2011). Since power does not scale with utilization, this results in a 25% increase in power draw per user compared to fully loaded conditions.
- Data was not available on the share of DSL connections supported by fiber-to-the-node (FTTN). The analysis assume a 50/50 split of all copper DSL and FTTN DSL.
- This analysis does not distinguish between residential and commercial subscribers due to a lack of available data on commercial access networks. All subscribers are treated as residential in terms of power draw and subscriber capacity of equipment. This may underestimate UEC and AEC since commercial subscribers are likely more energy intensive than residential subscribers due to higher access rates and connected users/devices per subscription. Commercial subscriptions represent about 9% of subscriptions.
- This analysis assumes increasing power demands from increasing access rates are approximately equivalent to power reductions from energy efficiency improvements on a watts per user basis.

* Note that a single subscription is often shared by multiple or many individual end users, especially in commercial spaces.

Results –
Office Equipment

OFFICE MELS » COPIER

Scope: This end-use includes single-function copiers only, i.e., those with the single function of copying and not those built into multifunction devices or having multiple functions, (e.g., copying and scanning).

		2012	2016	2020	2030	2040	2050
Installed Base	(000s)	270	240	190	100	50	30
UEC	kWh/yr	180	170	160	140	120	110
AEC	TWh/yr	0.049	0.041	0.030	0.014	0.006	0.003

- Copiers have the lowest installed base of all imaging equipment in this study.
- Formerly commonplace in every office, standalone copiers are becoming less common as:
  - Multifunction devices often take their place.
  - Paper-based documents are increasingly being used only in electronic formats.

Photo Source: http://www.amazon.com

OFFICE MELS » COPIER CONT.

2012 Base Year Data	Installed Base (000s)	UEC (kWh/yr)	AEC (TWh/yr)
Assembly	24	180	0.0042
Education	26	180	0.0046
Food Sales	2	180	0.0004
Food Service	3	180	0.0005
Healthcare	16	180	0.0029
Lodging	6	180	0.0011
Large Office	46	180	0.0083
Small Office	82	180	0.0150
Mercantile & Service	33	180	0.0060
Warehouse	18	180	0.0030
Other	11	180	0.0020

- Most standalone copiers utilize analog copying methods, which are correlated with a high UEC.
- Digital copiers are typically more efficient than their analog counterparts.
- However, since digital copiers use scanning technology, they often incorporate the functionality of a stand-alone scanner, and those that do are thus classified as MFDs.

OFFICE MELS » SCANNER

Scope: This end-use includes document scanners used to convert physical documents into digital form. Excluded are film scanners, hand-held scanners for 3-D printing, and large-scale industrial drum scanners used in publishing.

		2012	2016	2020	2030	2040	2050
Installed Base	(000s)	2,400	2,000	1,500	800	600	500
UEC	kWh/yr	37	35	33	30	29	28
AEC	TWh/yr	0.09	0.07	0.05	0.02	0.02	0.01

- Stand-alone scanners are most common in small offices (as well as in homes, which are outside the scope of this study).
- Large offices are more likely to use MFDs for all document imaging and printing needs due to higher volume requirements, which help justify the purchase of larger, more robust equipment.

Photo Source: http://pngimg.com/

OFFICE MELS » SCANNER CONT.

2012 Base Year Data	Installed Base (000s)	UEC (kWh/yr)	AEC (TWh/yr)
Assembly	140	37	0.005
Education	370	37	0.014
Food Sales	26	37	0.001
Food Service	46	37	0.002
Healthcare	120	37	0.004
Lodging	91	37	0.003
Large Office	410	37	0.015
Small Office	620	37	0.023
Mercantile & Service	350	37	0.013
Warehouse	180	37	0.007
Other	89	37	0.003

- Scanners have the lowest UEC of the characterized MELs.
- 87% of scanners sold in 2008 were ENERGY STAR qualified. This number reached 99% in 2010.
- After 2010, ENERGY STAR stopped releasing data for standalone scanners, which is believed to be a result of scanners commonly being incorporated into MFDs.
- ENERGY STAR imaging products are roughly 30% more efficient than non-ENERGY STAR products, according to the EPA.

OFFICE MELS » MFD

Scope: This end-use includes all-in-one small desktop units; multifunction devices for small office/home office use (i.e., desktop products); and full-size office multifunction devices (i.e., floor-standing products).

		2012	2016	2020	2030	2040	2050
Installed Base	(000s)	6,300	8,500	9,400	13,000	17,000	23,000
UEC	kWh/yr	190	170	160	150	150	150
AEC	TWh/yr	1.2	1.4	1.5	2.0	2.6	3.5

- MFDs combine multiple imaging equipment functions into one package, including printing, scanning, copying, and faxing.
- The MFD market has been growing steadily as improved imaging technology makes it possible for devices to perform multiple functions.
- Laser MFDs constitute the majority of the market. These units have high energy use due to the heat intensive process of fusing ink to paper.

Photo Source: https://www.energystar.gov/

OFFICE MELS » MFD CONT.

2012 Base Year Data	Installed Base (000s)	UEC (kWh/yr)	AEC (TWh/yr)
Assembly	540	190	0.10
Education	560	190	0.11
Food Sales	100	190	0.02
Food Service	180	190	0.03
Healthcare	290	190	0.06
Lodging	150	190	0.03
Large Office	900	190	0.17
Small Office	1,800	190	0.34
Mercantile & Service	1,000	190	0.19
Warehouse	470	190	0.09
Other	250	190	0.05

- In 2010, 99% of MFD shipments were ENERGY STAR qualified.
- After 2010, ENERGY STAR reports combined MFD and printing shipments, highlighting the takeover of printer market by MFDs.

- Power consumption is expected to decrease by 30% over the forecast period. This change is primarily because of changes in idle-state power consumption.

OFFICE MELS » FAX MACHINE

Scope: This includes all standalone fax machines, including inkjet, laser, and thermal technologies.

		2012	2016	2020	2030	2040	2050
Installed Base	(000s)	90	61	31	6	2	1
UEC	kWh/yr	57	52	47	40	34	31
AEC	TWh/yr	0.0051	0.0032	0.0015	0.0002	0.00007	0.00003

- The use of stand-alone fax machines is on the decline due to:
  - Proliferation of electronic document transmission as pdf files via email and, to a smaller extent, by fax-over-IP (FoIP).
  - Documents are being increasingly used in only electronic formats.
  - Multifunction devices are taking their place.
  - The acceptance of electronic signatures for sensitive documents
  - Multiple advances in secure data transmission reduce the value of faxes
- By 2050, only very few units will still be in use in niche applications; but will be obsolete for most intents and purposes.

Photo Source: https://www.cpsc.gov/

OFFICE MELS » FAX MACHINE CONT.

2012 Base Year Data	Installed Base (000s)	UEC (kWh/yr)	AEC (TWh/yr)
Assembly	8.9	57	0.00051
Education	6.2	57	0.00035
Food Sales	3.0	57	0.00017
Food Service	5.2	57	0.00030
Healthcare	0.2	57	0.00001
Lodging	2.4	57	0.00014
Large Office	1.5	57	0.00009
Small Office	27	57	0.0015
Mercantile & Service	23	57	0.0013
Warehouse	9.3	57	0.00053
Other	3.6	57	0.00021

- As of 2008 only 4% of fax shipments were Energy Star certified.
- This number rose to just 7% in 2013, when EPA stopped tracking shipments volumes.
- ENERGY STAR imaging products are about 30% more efficient than non-certified products.

- Due to decreasing demand for faxes, there is little incentive for the development and introduction of new, power-saving idle modes.

OFFICE MELS » PRINTER

Scope: This includes standalone ink-jet printers and standalone laser printers. Not covered are 3-D printers, plotters, thermal printers (e.g., cash registers), dye-sublimation printers, dot-matrix printers, line printers, liquid ink electrostatic printers, and photo printers.

		2012	2016	2020	2030	2040	2050
Installed Base	(000s)	20,000	17,000	13,000	7,000	4,000	3,000
UEC	kWh/yr	240	220	200	170	150	140
AEC	TWh/yr	4.8	3.7	2.6	1.2	0.6	0.4

- Printers currently have the largest installed base of all the imaging equipment MELs in this study.
- However, the growth of the MFD market will continue to erode the printer market as manufacturers are able to cheaply introduce other functionalities into single-function devices.
- Between the years 2020 and 2030, the total MFD installed base will surpass that of printers.

Photo Source: https://www.cpsc.gov/

OFFICE MELS » PRINTER CONT.

- Like MFDs, laser printers consume significantly more power than similar inkjet models.
- The technologies used for decreased idle-state power consumption in printers are identical to those used in MFDs. Together, the large installed bases and industry size will drive improvements in technology, including idle-state power.

2012 Base Year Data	Installed Base (000s)	UEC (kWh/yr)	AEC (TWh/yr)
Assembly	1,100	243	0.3
Education	3,000	243	0.7
Food Sales	200	243	0.05
Food Service	400	243	0.1
Healthcare	1,000	243	0.2
Lodging	700	243	0.2
Large Office	3,300	243	0.8
Small Office	5,000	243	1.2
Mercantile & Service	2,800	243	0.7
Warehouse	1,400	243	0.3
Other	700	243	0.2

OFFICE MELS » SHREDDER

Scope: This end-use includes paper shredders connected to an electric power source in a commercial space. Excluded are mobile paper-shredding box trucks.

		2012	2016	2020	2030	2040	2050
Installed Base	(000s)	5,700	5,900	5,600	5,100	4,800	4,800
Power Draw (W)	Active	550	550	550	550	550	550
	Idle/Ready	2.8	2.7	2.4	1.7	1.0	0.4
	Off	0	0	0	0	0	0
Annual Usage (hrs)	Active	30	30	30	30	30	30
	Idle/Ready	8,730	8,730	8,730	8,730	8,730	8,730
	Off	0	0	0	0	0	0
UEC	kWh/yr	41	40	37	31	25	20
AEC	TWh/yr	0.23	0.24	0.21	0.16	0.12	0.10

- Paper shredders preserve confidentiality by destroying sensitive documents.
- Approximately 60% of total power consumption occurs in idle mode since shredders are estimated to operate an average of only five minutes per day.
- With the emerging trend of power-saving idle modes, the idle power consumption will decrease significantly by 2050.

Photo Sources: http://www.abe-online.com/, http://rilane.com/

OFFICE MELS » SHREDDER CONT.

2012 Base Year Data	Installed Base (000s)	UEC (kWh/yr)	AEC (TWh/yr)
Assembly	220	40	0.009
Education	770	40	0.031
Food Sales	80	40	0.003
Food Service	240	40	0.010
Healthcare	540	40	0.021
Lodging	220	40	0.009
Large Office	1,200	50	0.060
Small Office	1,200	33	0.039
Mercantile & Service	570	40	0.023
Warehouse	450	40	0.018
Other	250	40	0.010

- With the continued transition from physical to digital information sharing, the decrease in paper use will diminish the need for shredders in commercial spaces.
- In the last decade, the market for outsourced shredding has grown significantly, further eroding the market for in-office shredders. Third-party outsourcing companies pick up documents from the client and shred them securely with their own equipment, typically built into a truck.

OFFICE MELS » UPS

Scope: This end-use includes those that support electronic equipment in an office, including in server closets and server rooms, and data centers.

		2012	2016	2020	2030	2040	2050
Installed Base	(000s)	9,000	11,000	13,000	19,000	21,000	23,000
Power Draw (W)	25% Load	90	90	89	88	86	86
	50% Load	61	61	61	59	58	58
	75% Load	55	55	55	53	52	52
	100% Load	53	53	53	52	51	50
Annual Usage (hrs)	25% Load	430	430	430	217	217	0
	50% Load	2,410	2,410	2,410	1,752	1,220	217
	75% Load	3,290	3,290	3,290	4,163	4,065	2,874
	100% Load	2,630	2,630	2,630	2,628	3,258	5,669
UEC	kWh/yr	510	500	500	480	470	450
AEC	TWh/yr	4.6	5.5	6.5	9.1	9.9	10.4

- There are 3 kinds of UPS:
  - Voltage and Frequency Dependent (VFD) - lower power ratings; used for equipment not sensitive to voltage and frequency fluctuations.
  - Voltage Independent(VI) - low to medium power ratings and can be a cheap alternative to VFIs for sensitive equipment.
  - Voltage and Frequency Independent(VFI) – medium to high power ratings and are used for sensitive equipment, like data center servers.

Photo Source: https://www.energystar.gov/

OFFICE MELS » UPS CONT.

2012 Base Year Data	Installed Base (000s)	UEC (kWh/yr)	AEC (TWh/yr)
Assembly	300	1,000	0.3
Education	800	1,000	0.8
Food Sales	100	1,000	0.1
Food Service	100	1,000	0.1
Healthcare	200	1,000	0.2
Lodging	100	1,000	0.1
Large Office	4,500	1,000	4.5
Small Office	1,400	1,000	1.4
Mercantile & Service	600	1,000	0.6
Warehouse	400	1,000	0.4
Other	500	1,000	0.5

- ~50% of the UPS installed base is in data center applications (included in the large office NEMS category). Splits across other building types is assumed to be equal to split of servers from CBECS.
- Data centers use larger-than-average UPSs in the range of ~5 to ~50 kVA.
- VFI UPS's are often used in data centers. They convert incoming AC current to DC current and then convert the DC back to AC before delivering it to the load. This double conversion makes them ideal for sensitive equipment (better protections) but also makes them the least efficient type of UPS.

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