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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) comprise 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.

Given the dispersed and increasingly varied nature of these equipment and appliances, stock, usage, and consumption data can be difficult to obtain. 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. While some devices and appliances are captured in this process, it is impossible to account for all MELs within buildings using these large-scale survey methods.

The Residential Demand Module (RDM) and Commercial Demand Module (CDM) of the National Energy Modeling System (NEMS) project annual energy consumption of MELs by combining unit energy consumption (UEC) with total stock of equipment or devices by type.[1] This differs from major end-use equipment, which is modeled using a technology menu accounting for equipment vintage, performance, and costs.

The contract report in Appendix A characterizes a number of residential and commercial MELs and provides the informational basis for modeling these projections with a consistent perspective on equipment stock and annual energy consumption across end uses. This enables more detailed and specific MEL projections and analysis. Appendix A was used in developing Reference case projections implemented during the *AEO2014* cycle.

When referencing the contract report in Appendix A it should be cited as a report by Navigant Consulting, Inc. and SAIC (now Leidos) prepared for the U.S. Energy Information Administration.

[1] Additional information on the modeling of MELs can be found in the RDM and CDM model documentations, located at http://www.eia.gov/reports/index.cfm?t=Model%20Documentation.

APPENDIX A

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Analysis and Representation of Miscellaneous Electric Loads in NEMS

Prepared for: U.S. Energy Information Administration

Prepared By: Navigant Consulting, Inc.

and SAIC

Final Report: May 22, 2013 ***(Appendix A Amended Sept 2013)***

Navigant Reference: 160750

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May 2013

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Executive Summary

We updated energy consumption data for 28 residential (R) & commercial (C) miscellaneous electric loads (MELs), including projections to 2040.

Activity steps:

1. Select MELs for evaluation, including new loads and previously analyzed loads
2. Estimate U.S. installed base in number of units
3. Characterize usage to estimate unit energy consumption (UEC) in kWh/yr:
   - Usage hours
   - Power consumption
4. Calculate total annual energy consumption (AEC) in TWh/yr in the United States
5. Characterize market, economic, demographic and technology trends
6. Develop Projections to 2040 based on typical operating parameters for:
   - Usage hours
   - Power consumption
   - UEC
   - AEC
   - Installed base

Selected MELs	Sector(s)
TV, Set-Top-Boxes, DVD players	R
Computers, Laptops, Monitors	C & R
Ceiling Fans	R
Audio Equipment	R
Portable Electric Spas	R
Modems & Routers	R
Rechargeable Electronics and Power Supplies	R
Pools/Pool Pumps	R
Dehumidifiers	R
Security Systems	C & R
Medical Imaging Equipment	C
Kitchen Ventilation (Exhaust Hoods)	C
Laboratory Refrigerators and Freezers	C
Water Distribution*	C
Distribution Transformers	C
IT Equip. & Data Center Servers	C
Video Displays & Video Boards	C

*See Appendix A for supplemental discussion of wastewater treatment trends

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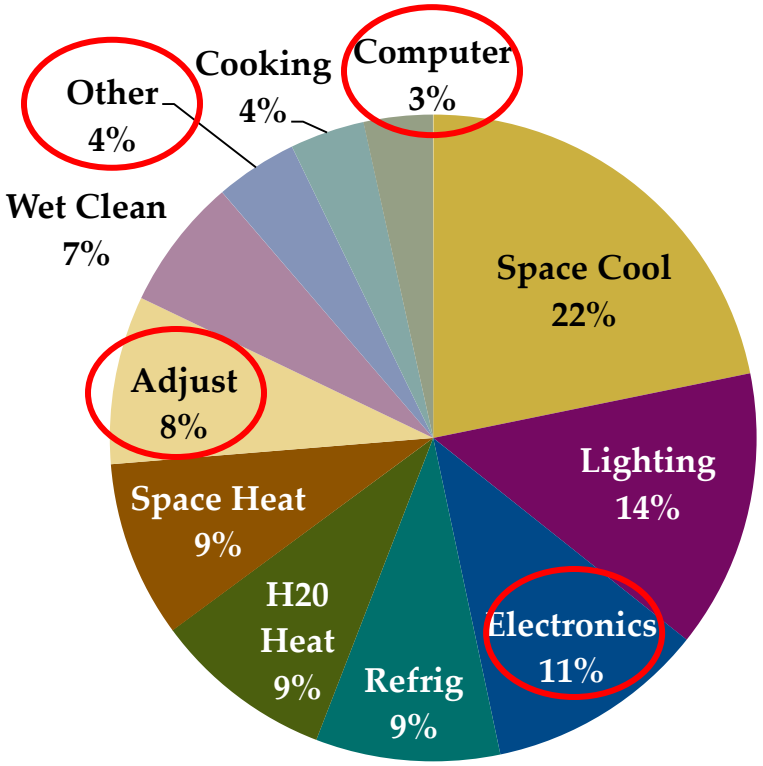
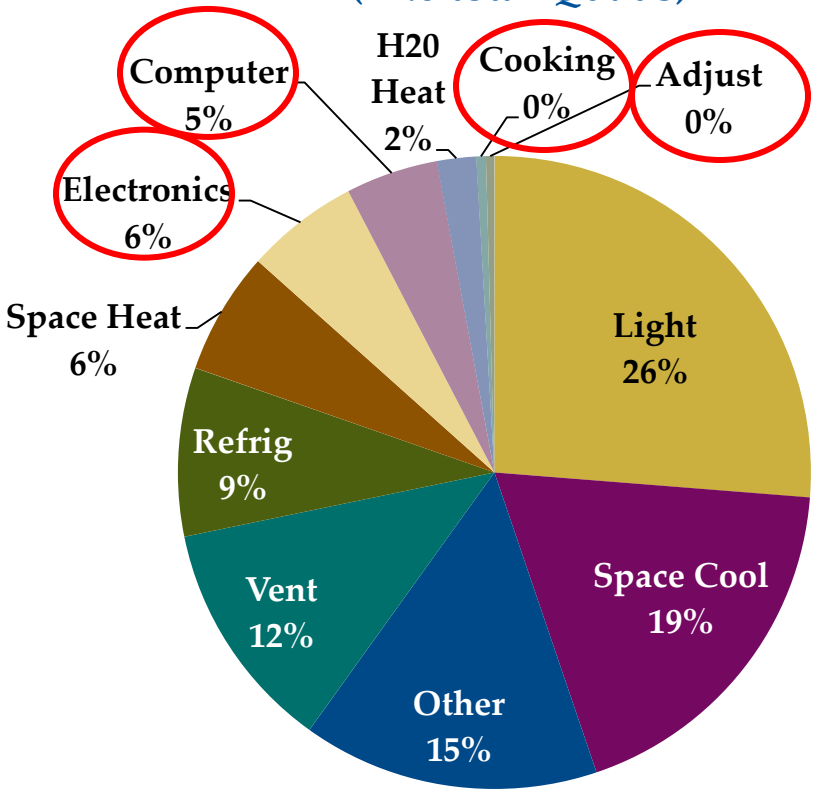
MELs characterization research helps to define the numerous, poorly understood loads that, in aggregate, constitute substantial energy use.

Residential Primary Electricity Consumption (2010) (15.3 total Quads)



Commercial Primary Electricity Consumption (2010) (14.0 total Quads)



Buildings consume 29 quads of primary electric energy in the US; 15 in residential and 14 in commercial buildings.

Source: EIA data from Buildings Energy Data Book: http://buildingsdatabook.eren.doe.gov/

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The largest analyzed MEL by AEC, Televisions, used 70 TWh/yr of site electricity in 2011.

Site-electricity use in 2011**:

Commercial: 1,319 TWh
Residential: 1,424 TWh

Total: 2,743 TWh

Appendices B and C contain complete summaries for CMELs and RMELs, respectively, of Installed Base, UEC and AEC in 2011

Sector	MEL	AEC (TWh/yr)	Installed Base (000s)
R	Televisions	70	355,000
C	Distribution Transformers	43	5,470
C	Kitchen Ventilation	41	790
C	DesktopPC	30	74,000
C	Data Center Servers	29	12,200
R	Pool Heaters & Pumps	26	10,400
R	Desktop PCs	22	102,000
R	Set Top Boxes	22	176,000
R	Ceiling Fans	20	263,000
C	MonitorsPC	18	93,000
R	Audio Equipment	16	193,000
R	Monitors	13	130,000
C	IT Equipment	12	487,000
R	Dehumidifiers	11	15,600
R	Laptop PCs	10	165,000
R	Portable Electric Spas	9	4,630
C	Security Systems	7	11,000
R	Modems & Routers	7	138,000
R	External Power Supplies	7	1,077,000
C	Water Distribution*	7	5,115,000
R	DVD Players	6	227,000
C	Lab R-Fs	5	1,000
R	Non PC Rechargeable Electronics	4	1,200,000
C	Medical Imaging Equipment	3	178
C	LaptopPC	2	63,000
C	Video Displays	2	1,600
R	Home Security Systems	1	28,000
C	Large Format Video Boards	0	1

Note: *Water distribution Installed base is in Million of Gallons per year (Mgal/yr), not thousands

**Site Electricity data from AEO 2013, Table A8, page 138

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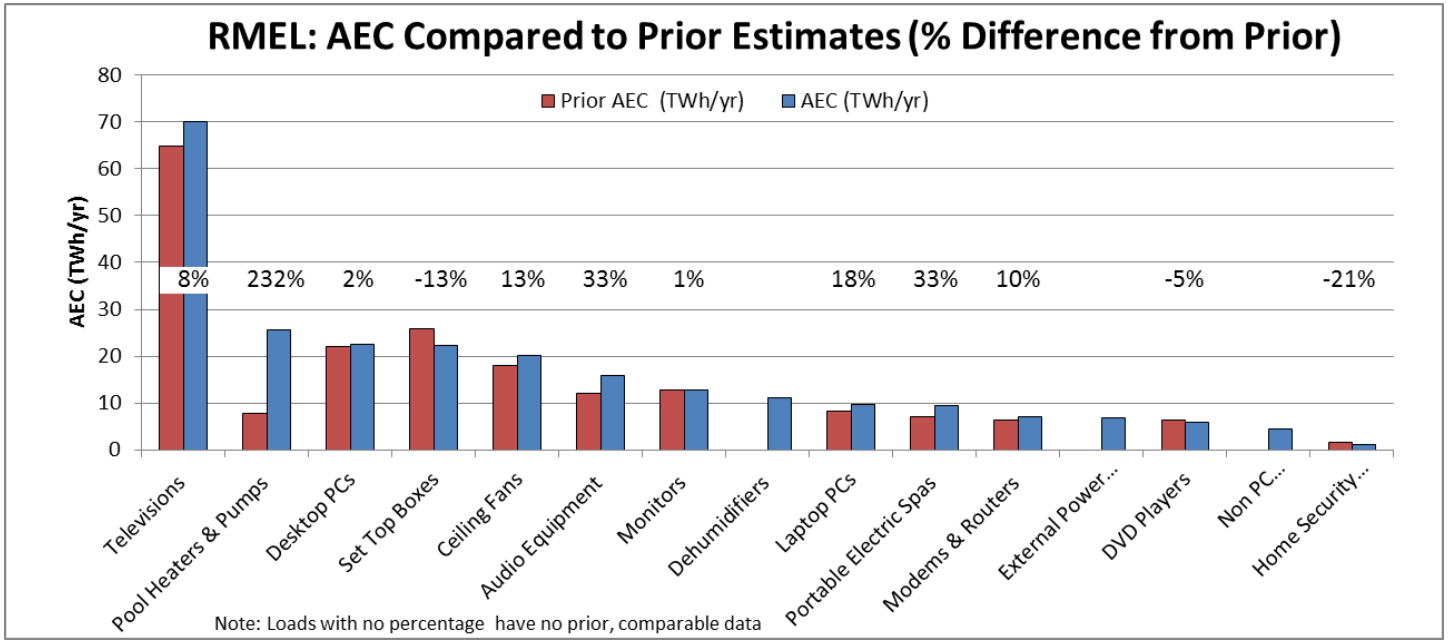
Our estimates build on the best available past research, but can, in some cases, differ substantially from other recent MELs studies.



» **Set-Top-Boxes:** New estimates are 13% lower than the Fraunhofer 2010 study, but are based on newly published data from the DOE standard rulemaking process.

» **Ceiling Fans:** New estimates are 13% higher than TIAX 2008 based on higher average household penetration of ceiling fans and a different methodology of calculating annual usage hours, which we believe to be more accurate.

» **Pools**: New estimates are 230% higher than TIAX 2008 based on significantly higher installed base from a different sources which we believe to be more accurate. Also, TIAX assumes a much shorter pool season of less than 6 months even in the warmest regions of the U.S. We assumed pools in the warmest regions are open year-round and about 4 months in cooler regions such as the northeast.

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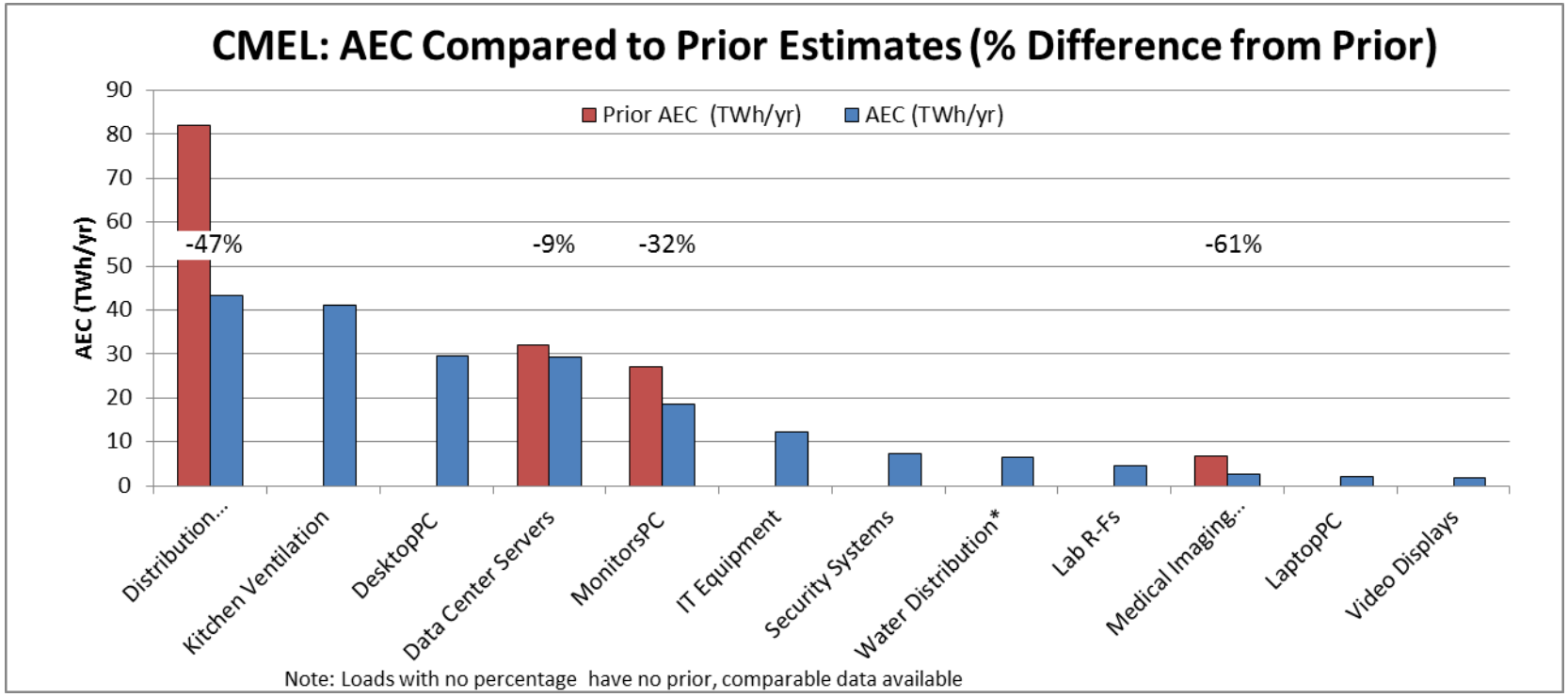
Differences from prior estimates in the commercial sector are more common, but due often to distinctions in MEL definitions.



» **Distribution Transformers:** TIAX 2010 included non-building transformers and assumed all building loads require a transformer; our estimates are based on the DOE rulemaking.

» **Monitors**: Prior installed base data vary by up to 50 million (110 M vs. 160 M); using underlying data, we developed new estimates based on the computer installed base.

» **Medical Imaging:** TIAX shows 3 times larger UEC and 2 times larger installed base for X-ray; we suspect TIAX included non-medical and/or portable x-rays in their estimates.

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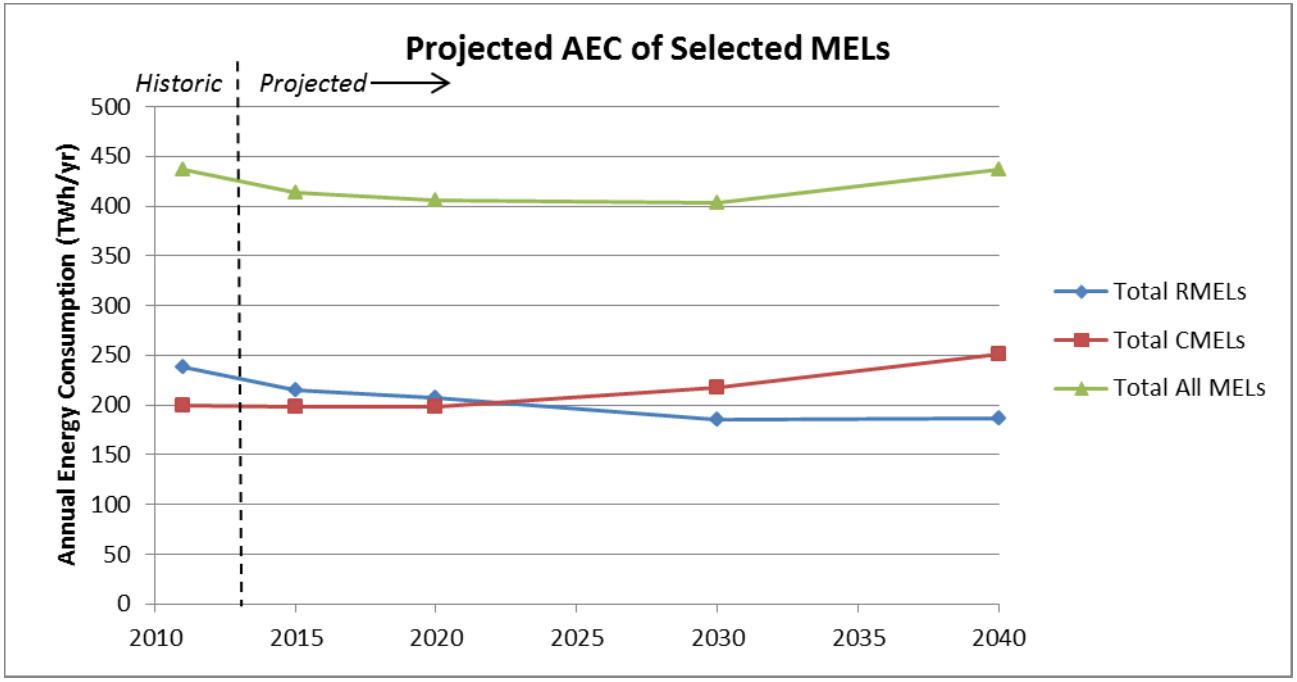
The selected MELs consumed 437 TWh in 2011, 199 TWh in commercial buildings and 238 TWh in residential buildings.*



By 2040, the total AEC of selected MELs will not increase, due to a 26% increase in AEC for CMELs compared to an 22% drop in AEC for RMELs.**

*2011 data are a sum of the best historical estimates available for each MEL.
**Data are projected to 2040 to match other projection timelines within the Annual Energy Outlook. Selected intervals for MEL projections were specified per EIA requirements..

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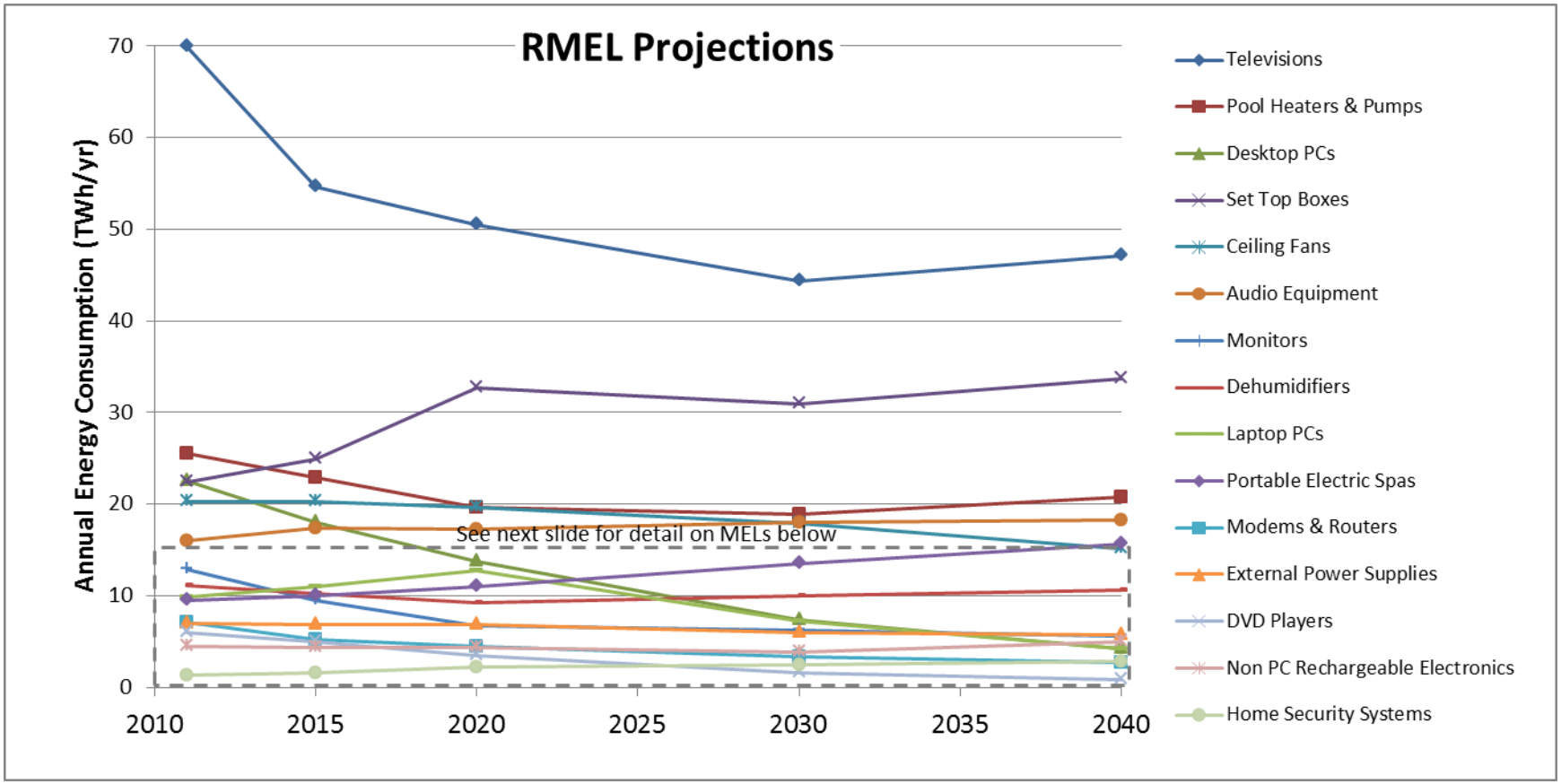
RMEL projections show decreases in AEC for all but five MELs – Set-Top-Boxes, Rechargeable Electronics, Security Systems, and Portable Electric Spas, and Audio Equipment.



Appendix D contains complete data tables for RMEL projections of Installed Base, UEC and AEC.

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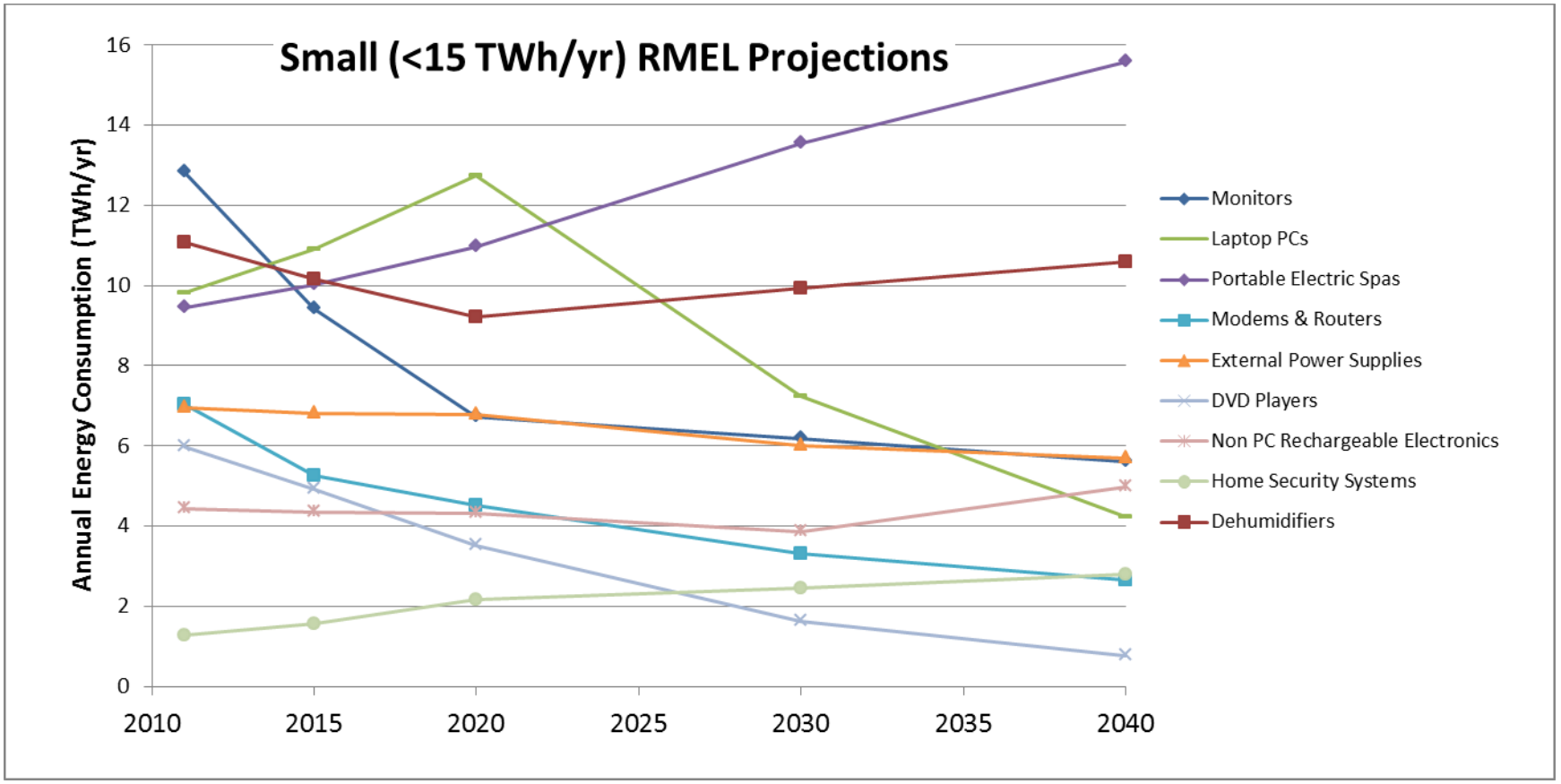
Of the smaller RMELs, Portable Electric Spas exhibit the greatest growth due primarily to a large increase in the installed base, in addition to a slight increase in UEC (trend toward larger spas with more jets).



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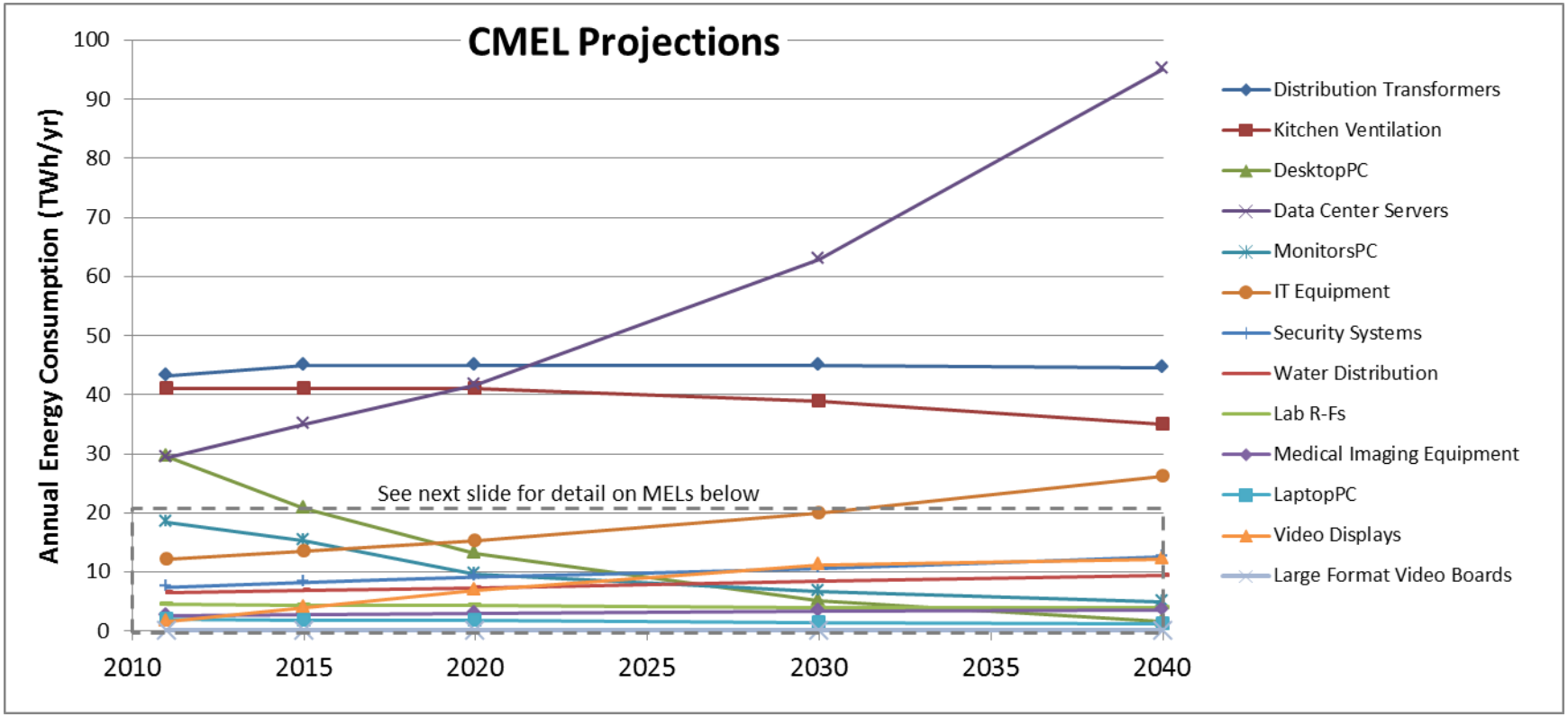
Unlike RMEL projections, the CMEL AEC projections exhibit greater upward trends, particularly for Data Center Servers and IT Equipment.



Appendix E contains complete data tables for CMEL projections of Installed Base, UEC and AEC.

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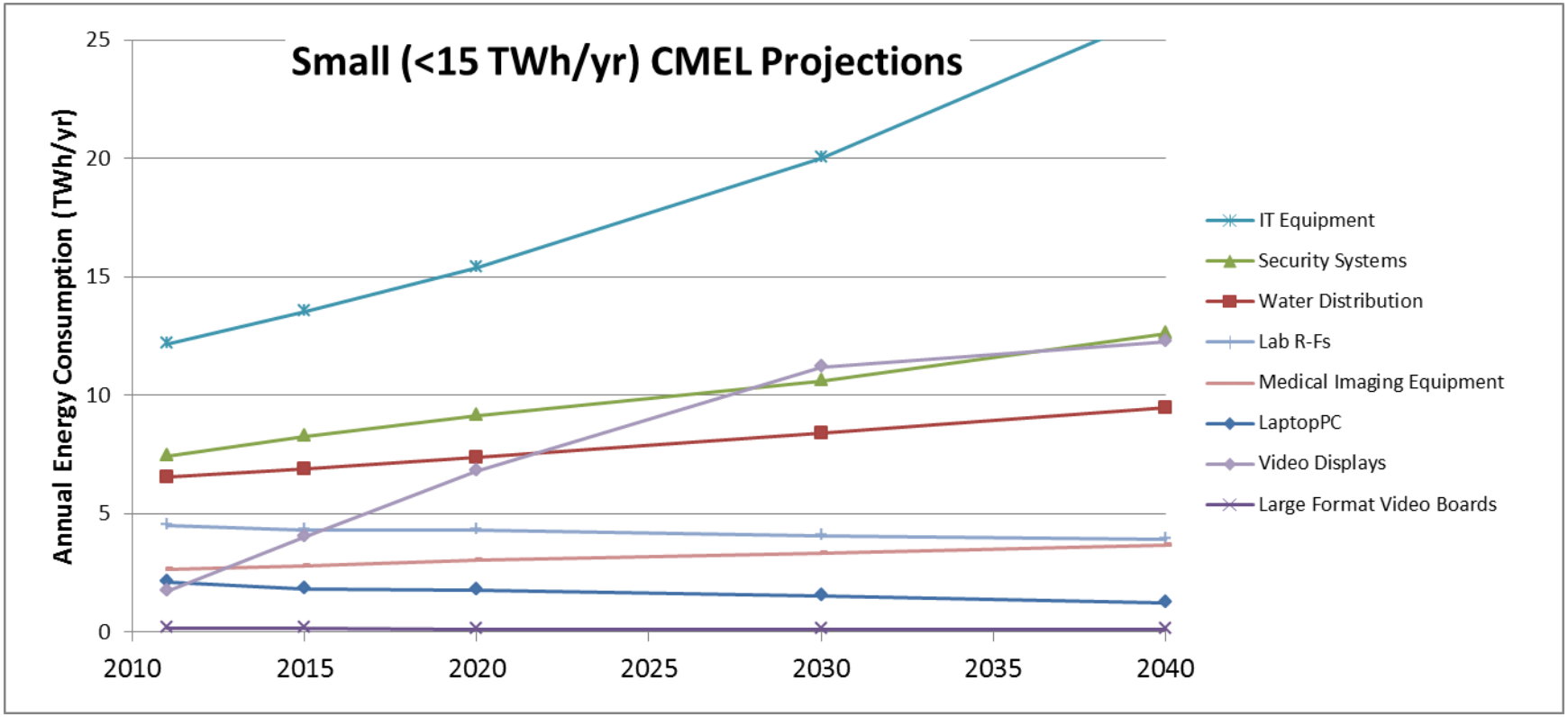
IT equipment growth, in which we expect to see a doubling in AEC by 2040, supports the transition to cloud computing and reductions in AEC for all computers.



Of the CMELs with smaller AECs, video displays also show very rapid growth, increasing by 700% by 2040.

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Across all of the MELS analysis, we identified some key recurring findings.

- In 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 minimal additional gains in the longer term.
  - Population growth drives increases in most residential and many commercial MELs, even if per capita energy consumption growth is tempered (such as seen in California in recent decades).
- Many electronics-related MELs exhibit downward AEC trends. However, some of this is countered by large increases in AEC for servers and other IT equipment. The trend shows a transfer of computer power away from individual devices and more towards cloud computing with major central data centers.
- This same centralization of computing power trend is also evident in televisions and set-top-boxes (STB), which are relying more and more on streaming internet content with less hardware in the customer's home. New Over-the-Top (OTT) STBs stream internet content from services such as Netflix and Hulu directly to your TV, and most new TVs have this capability built in – this trend has rapidly progressed in only the last 3 to 5 years.
- DVD players and desktop computers (both residential and commercial) are the only loads which we expect to exhibit a drop in AEC due primarily to a drop in installed base. As new technologies stop the growth of desktops, and accelerate the disposal of DVD players, these MELs will have a slow, but steady decline.

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Miscellaneous electric loads (MELs) are the loads outside of a building's core functions of heating, ventilating, air conditioning, lighting, and water heating.*

*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

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

Task 1: Identify MELs and update energy consumption estimates

- Screen and identify priority MELS
- Recommend 15 residential and 10 commercial MELs for further analysis
- Confirm MEL selection with EIA
- Develop updated descriptions and revised energy-consumption estimates

Task 2: Develop scenario-based projections through 2040

- Investigate market, economic, technology, and demographic trends
- Make projections for each priority MEL
- Consider technology trends in commercial MELs not included in the detailed analysis

We split CMEL estimates by building type, using the 11 NEMs definitions, which are closely correlated to the CBECS 2003 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.

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Navigant started with the EIA's list of MELs from the SOW and added MELs from other resources to create a comprehensive list of 173 MELs.

EIA RFP – Residential MELs
Audio Equipment
Ceiling Fans
Coffee Machines
Microwave Ovens
Portable Electric Spas
Rechargeable Electronics
Security Systems
Set-Top Boxes
Televisions
DVD Players and VCRs
Video Game Consoles
Dehumidifiers
External Power Supplies
Room Air Cleaners & Purifiers
Pool Pumps

EIA RFP – Commercial MELs
Coffee Makers
Distribution Transformers
Non-Road Electric Vehicles
Elevators
Escalators
Water Distribution
Water Purification/Treatment
Arcades
Automated Teller Machines (ATMs)
Fitness Equipment
Fume Hoods
Laundry Equipment
Medical Imaging Equipment
Other Medical Equipment
Servers in Data Centers
Office Equipment

Appendix F includes a list of all candidate MELs.

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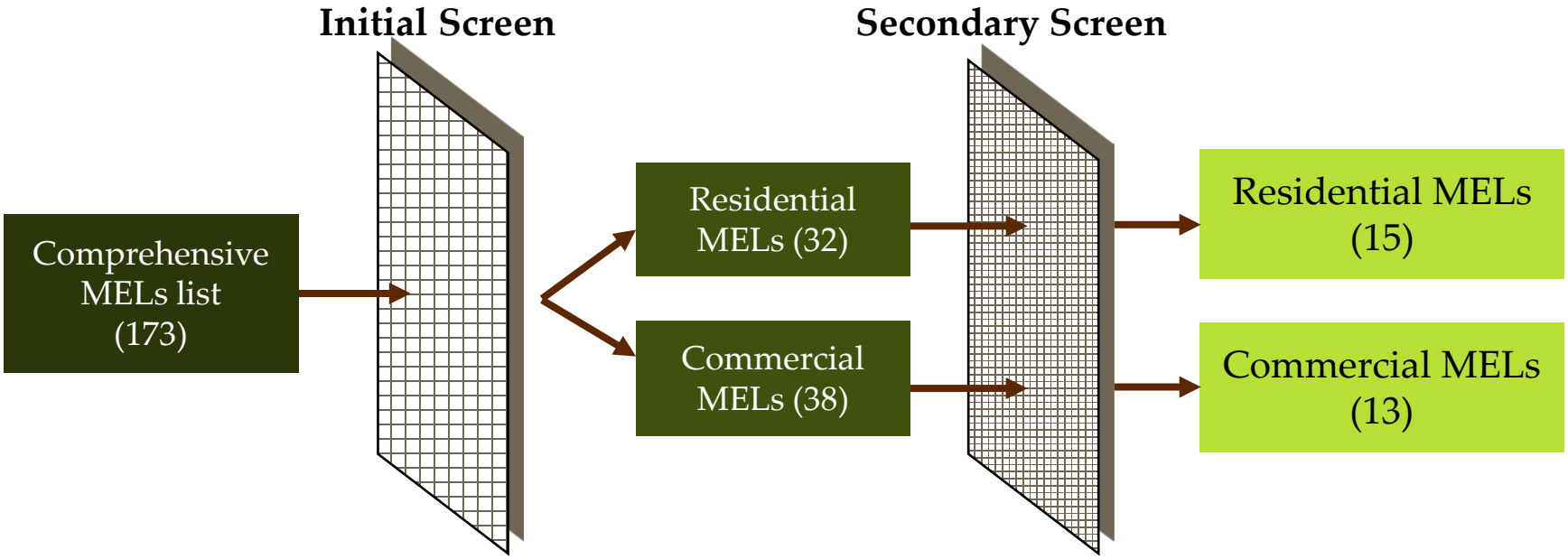
To identify key residential and commercial MELs, we employed two distinct screening phases.



Initial Screen Criteria (based on Navigant judgment):

- Inconsequential energy consumptions
- Already well-characterized

Secondary Screen Criteria:

Evaluated based on the following characteristics:

- Annual Energy Consumption for the entire installed base in the U.S. (AEC - TWh/yr)
- Installed base (number of units in the U.S.)
- Unit Energy Consumption (UEC - kWh/yr)
- Trend in installed base
- Date of most recent analysis

Appendix G includes a list of all MELs removed during the secondary screening.

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Through discussions with EIA, we identified 15 residential and 13 commercial MEL categories for analysis.*

Selected Residential MELs
Televisions
PCs, Desktop
PCs, Laptop
Set-top Boxes, All
Ceiling Fans
DVD/Media Players
Audio Equipment
Portable Electric Spas
Modems & Routers
Non-Computer Rechargeable Electronics
External Power Supplies
Pools/Pool Pumps
Monitors (i.e. desktop PC monitors)
Dehumidifiers
Security Systems, Home

Selected Commercial MELs
Distribution Transformers
Data Center Servers
IT Equipment (non-data center)
Video Displays
Large-Format Video Boards
PCs, Desktop
PCs, Laptop
Water Treatment/Distribution
Monitors (i.e. desktop PC monitors)
Kitchen Ventilation (Exhaust Hoods)
Lab Refrigerators/Freezers
Security Systems, Commercial
Medical Imaging Equipment

* The Contractor's work scope called for minimums of 10 commercial and 15 residential MELs. Some categories represent groupings of MELs, so the total number of categories included is subject to interpretation.

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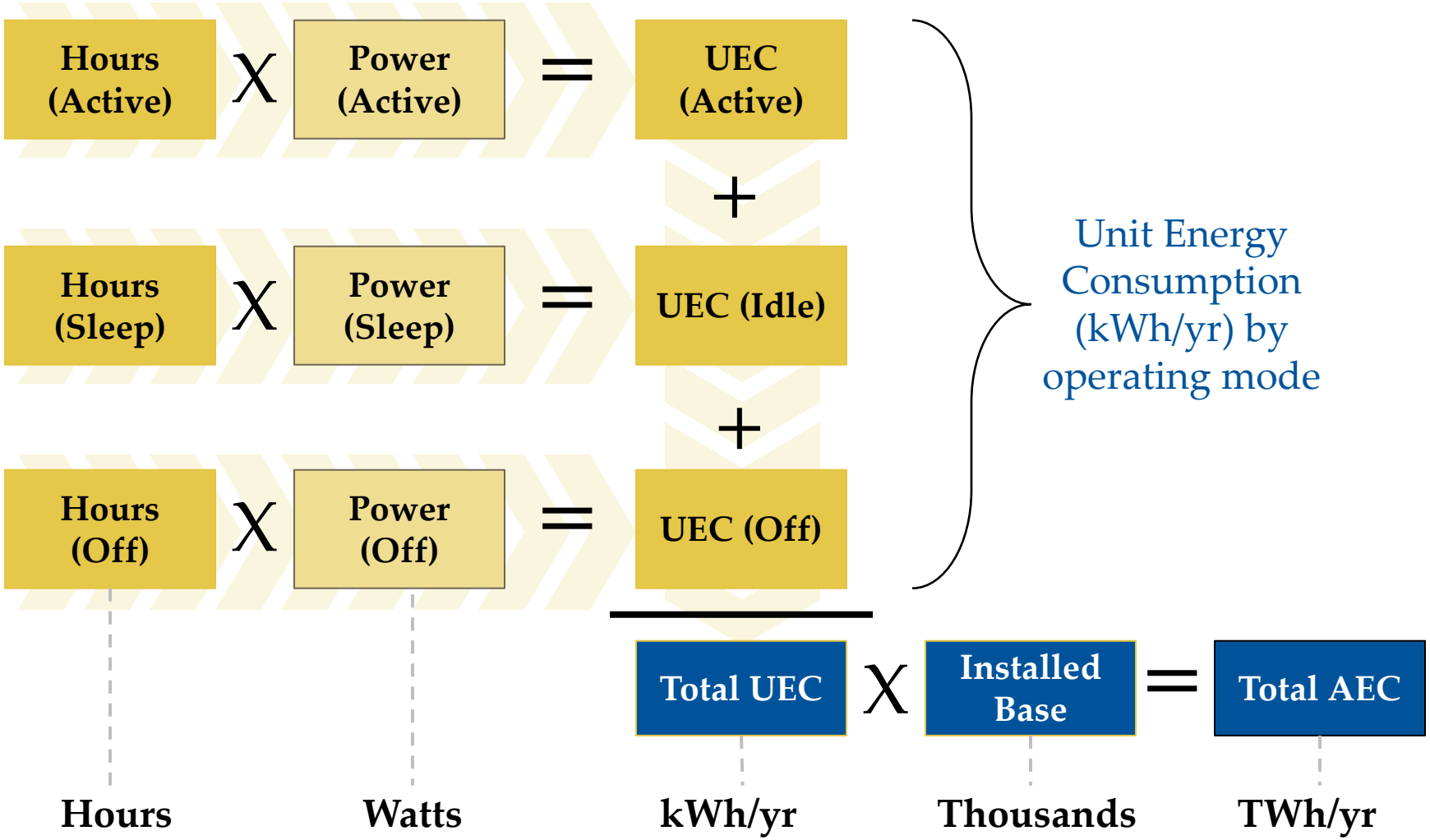
When sufficient data were available*, we followed a bottom-up methodology to calculate the UEC, Installed Base, and AEC for each MEL.



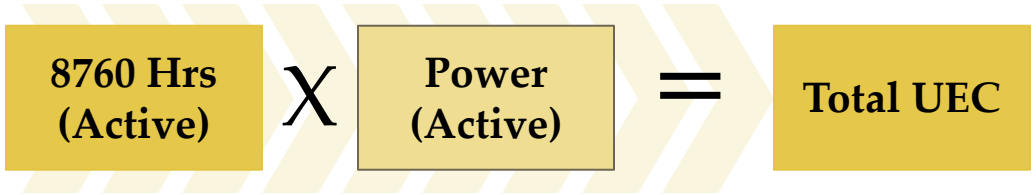
* Based on the Contractor's judgment of whether available data were sufficient to formulate credible, bottom-up estimates.

NAVIGANT ENERGY

When sufficient data were not available to do a complete bottom-up analysis*, we customized the approach to develop the best estimates.

Example 1: Data Center Servers

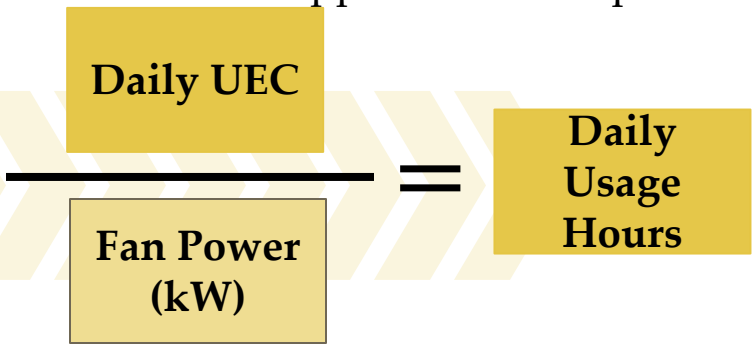
» Servers run continuously and are never in idle state, so the team assumed a single value for active-mode wattage for the entire year.



» With additional data on usage profiles, it would be possible to more closely model the usage hours and wattage according to the actual throughput of the server.

Example 2: Commercial Kitchen Ventilation

» Very little data were available on energy consumption, so we based UEC estimates on select case studies for energy efficient upgrades (FisherNickel) – The team back-calculated the hours of use based on the approximate fan power and qualitatively validated the output.



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

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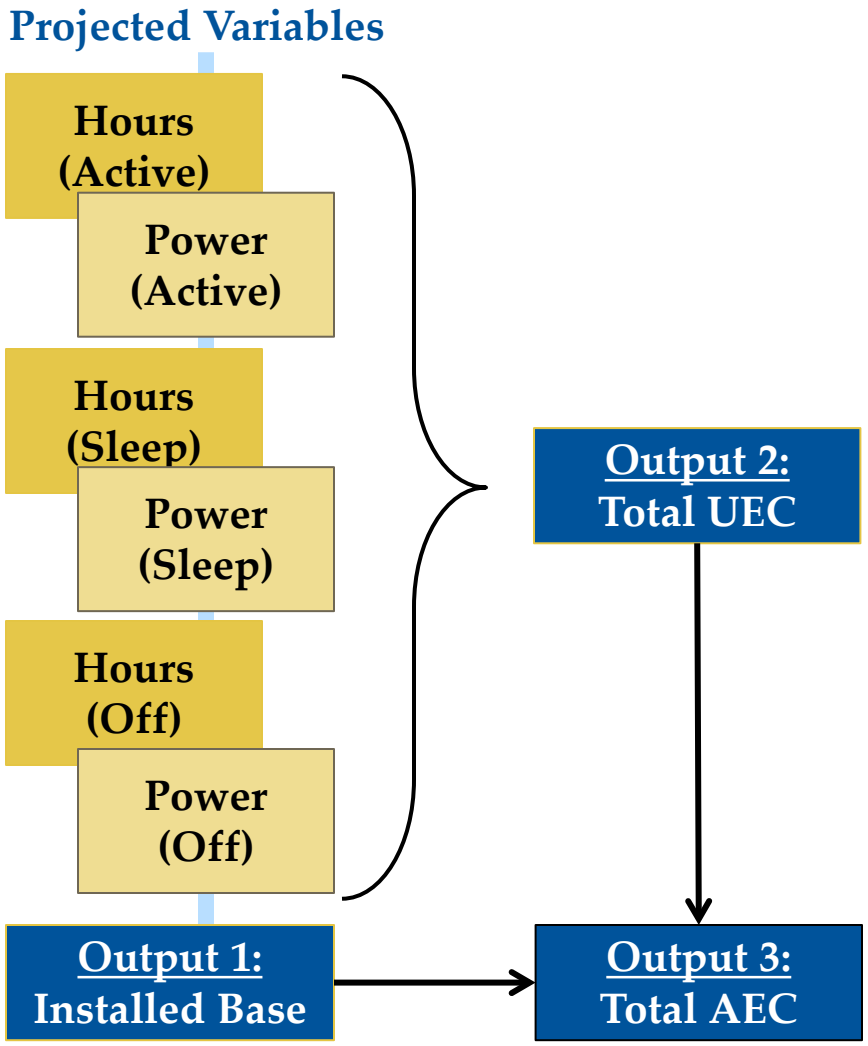
Where data are available, we based projections on individual growth rates for annual hours of use and power use (Watts) for each MEL.



- We project two variables independently for each relevant mode of operation:
  - Primary modes: Active, Sleep, Off
  - Additional modes used for select MELS included: Standby, Idle, Unplugged, Low/Med/High
- There are three primary outputs associated with each MEL:
  - Installed Base – projected independently
  - UEC – calculated as a sum product of hours and Watts (by mode)
  - AEC – calculated as product of Installed Base and UEC

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We customized the projection methodology as necessary based on the unique characteristics of each individual MEL.

» In general, we developed projections based on a composite unit for each MEL, which is defined by a weighted average of each projection variable (see previous slide), weighted by the installed base of each sub-product type.
  – Such a composite unit may not exist in the real world; it represents the average unit in the U.S.
  – E.g. the composite computer monitor, used for all projections, comprises both LCD and CRT models of all sizes.

» Exceptions made where sub-product types have markedly different power & usage hours; for the following MELs, we projected each sub-product separately and calculated the weighted average at the end:
  – Medical Imaging
  – Commercial Kitchen Ventilation
  – External Power Supplies

» We developed a unique projection approach for each MEL, generally based on trends in:
  – Population
  – Building floor space or stock
  – Gross Domestic Product (GDP)
  – Past sales data and effective useful life
  – Number of households (HH) and size
  – Scheduled efficiency standard updates

» See Appendix H for Projection Resources

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The team analyzed 13 commercial MELs.

Commercial MELs	Description/Examples
Distribution Transformers	Dry-Type distribution transformers directly serving buildings
Data Center Servers	Servers which are used in data centers
IT Equipment (non-data center)	Hubs, switches, routers, and security equipment
Water Treatment/Distribution	Pumping and filtration systems to deliver water to buildings
PC – Laptops	Laptop Computers, including netbooks
PC – Desktops	Desktop Computers, including those with integral monitors
PC – Monitors	Monitors, used with either desktops of laptops
Kitchen Ventilation	Kitchen ventilation systems, including exhaust hoods
Lab Refrigerators/Freezers	Lab-grade refrigerators, freezers, and ultra-low temp freezers
Medical Imaging Equipment	MRI, CT scan, X-Ray, Ultrasound
Video Displays	Large public displays, used for advertising/branding
Video Boards	Large screens used in stadiums and arenas
Security Systems	Commercial security systems

Distribution transformers (DT) used 43 TWh of site electricity in 2011, but upcoming efficiency standards limit AEC growth.

		2011	2015	2020	2030	2040
Installed Base	(000s)	5,470	5,700	6,000	6,600	7,300
UEC	kWh/yr	7,900	7,900	7,500	6,800	6,100
AEC	TWh/yr	43	45	45	45	45

- Includes only dry-type, low voltage distribution transformers (LVDT) on the customer-side of the meter, i.e., where the customer pays for any electrical losses.
- Excludes utility distribution and transmission DTs.
- Medium voltage dry-type DTs are only applicable for industrial processes, and liquid filled DTs are all medium voltage with well over 90% of shipments serving utilities and the remainder serving industrial processes.
- Analysis is based primarily on DOE rulemaking engineering analysis for the energy efficiency codes and standards program, which uses three representative models:

2011 Base Year Data	Installed Base (000s)	UEC (kWh/yr)	AEC (TWh/yr)
25kVA - 1 Phase	600	2,200	1.3
75kVA - 3 Phase	4,100	6,600	27
300 kVA - 3 Phase	800	19,200	15

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Distribution transformer usage is proportional to the energy consumption in each building type.

2011 Base Year Data	Installed Base (000s)	UEC (kWh/yr)	AEC (TWh/yr)
Assembly	380	7,400	2.8
Education	390	8,500	3.3
Food Sales	440	6,400	2.8
Food Service	460	6,100	2.8
Healthcare	210	10,800	2.3
Lodging	400	8,500	3.4
Large Office	450	10,900	4.9
Small Office	600	6,000	3.6
Mercantile & Service	1,500	7,900	12
Warehouse	360	8,800	3.2
Other	280	8,900	2.5

- Installed base calculated for each building based on the total electricity use (from CBECS) that DTs serve, i.e., all loads except HVAC and large refrigeration, and on the market share and losses for each of the three representative sizes. We determined:
  - Energy use by multiplying the total applicable electricity use by the weighted losses
  - Total DT installed base by dividing DT energy consumption by the weighted UEC
  - Installed base of each size by multiplying the total number by the distribution of each DL
- Some buildings receive low voltage power directly from the utility (similar to residential buildings) and do not need a Dry-LVDT. The analysis assumes the quantity of such buildings is offset by the quantity with a greater portion of Dry-LVDTs.

 Photo source: http://www.southlandelectric.com/

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Distribution transformers (cont.)

Data Sources:

» This analysis builds on two industry-accepted reports: DOE rulemaking engineering analysis (DOE-TSD) and a study by the Cadmus Group.*

Projections:

» UEC projections based on the proposed efficiency levels in the Feb 2012 DOE notice of public rulemaking (NOPR). We expect approval of these levels based on the National Electrical Manufacturers Association (NEMA) letter of support from June 2012.**
  – Selected efficiency level reduces UEC by 24% (see DOE rulemaking summary table)
  – Annual shipments represent 4% of installed base, resulting in -1% annual UEC growth rate

» Installed base projections based on DOE-TSD growth of commercial building energy use.

Design Line (DOE Rule)	kVA	Baseline Efficiency	Proposed CSL	Proposed Efficiency	UEC Reduction (Baseline to Proposed)	% of National Shipments	Weighted UEC Reduction
6	25	98.0%	Base	98.00%	0%	8%	24%
7	75	98.0%	2	98.47%	24%	55%	
8	300	98.6%	2	99.02%	30%	37%	

Key Data Variability:

» LVDT energy use is due entirely to losses, which are highly dependent on site-specific sizing and site-specific loading profiles.

Sources: *Cadmus Group, 1999, "Metered Load Factors for Low-Voltage, Dry-Type Transformers in Commercial, Industrial, and Public Buildings."
**NEMA 2012 (http://www.nema.org/Policy/Documents/EERE2010BTSTD0048%20NEMA%20comments%20DOE%20Transformer%20SupplAn%20June%202012.pdf)
DOE NOPR 2012 (http://www1.eere.energy.gov/buildings/appliance_standards/pdfs/distribution_transformers_nopr_notice.pdf)

Data center servers consumed 29 TWh in 2011.

		2011	2015	2020	2030	2040
Installed Base	(000s)	12,200	14,000	16,000	21,000	28,000
Power Draw (W)	Active	269	282	300	339	382
	Idle/Standy/Off	0	0	0	0	0
Annual Usage (hrs)	Active	8,760	8,760	8,760	8,760	8,760
	Idle/Standy/Off	0	0	0	0	0
UEC	kWh/yr	2,400	2,500	2,600	3,000	3,400
AEC	TWh/yr	29	35	42	63	95

- Data Center Servers are only installed in dedicated data centers, so there is no breakdown of this equipment by building type – all units are in the 'other' building type category.
- While businesses do use some servers within offices or other buildings, we exclude those products from this analysis.
- Analysis does NOT include the energy consumption associated with the extensive space cooling load imposed by this equipment.
- We divided data into volume servers, mid-range servers, and high-end servers.

2011 Base Year Data	Installed Base (000s)	UEC (kWh/yr)	AEC (TWh/yr)
Volume Servers	11,800	2,000	24
Mid-range Servers	340	8,000	2.7
High-end Servers	38	50,500	1.9

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Data center servers (cont.)

Utilization Assumptions:

» All servers assumed to be active 100% of the time; however, load is dynamically shared evenly across servers to promote rapid throughput – typical utilization is >80% and increasing.*

» Data centers push for high utilization to minimize capital expenditures for "peaking" capacity. Data centers minimize the number of extra, idle machines held in reserve.

» Active-mode power is based on the average workload, which is proportional to power.

Projections:

» Shipment growth reached >10% annually in the early 2000s, but slowed in the recession.*

» Demand for computing resources is not expected to saturate in the future; We assume 2.8% annual installed base growth (slightly above expected annual GDP growth).**

» Based on historical power draw trends, we expect consistent, 1.2% annual power draw growth in the future.* Due to faster increases in computing power, this represents an improvement in efficiency.

- Performance per server increases each generation, the associated power consumption for which is partially offset by Moore's law (i.e., greater performance increase than power increase).
- Increased power also pressured by needs to cram more computing into smaller areas to take up less floor space. (e.g. more cores, memory, and storage in a single server)

*Source: Koomey, Jonathan. 2011. Growth in data center electricity use 2005 to 2010. Oakland, CA: Analytics Press. July.
**GDP growth is 2.5% annually in EIA's AEO 2013 early release from 2011 to 2040.

IT equipment consumed 12 TWh in 2011.

		2011	2015	2020	2030	2040
Installed Base	(000s)	487,000	551,000	642,000	873,000	1,190,000
Power Draw (W)	Active	3.0	2.9	2.8	2.7	2.6
	Idle/Ready	2.8	2.8	2.7	2.6	2.5
	Off/Standby	0.0	0.0	0.0	0.0	0.0
Annual Usage (hrs)	Active	2190	2190	2190	2190	2190
	Idle/Ready	6570	6570	6570	6570	6570
	Off/Standby	0	0	0	0	0
UEC	kWh/yr	25	25	24	23	22
AEC	(TWh/yr)	12	14	15	20	26

This technology includes:

- Routers and wireless LANs (WLAN) – manage traffic to multiple networking devices
- Switches – provide point-to-point connection between networking devices
- Security Equipment – includes firewalls and website blockers that filter and protect traffic to the Internet
- Some offices may have servers and data storage in the building (not included here), but the trend is to locate this infrastructure in data centers

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

NAVIGANT ENERGY

IT equipment is used in all buildings, but 70% of the installed base is concentrated in office and education buildings

2011 Base Year Data	Installed Base (000s)	UEC (kWh/yr)	AEC (TWh/yr)
Assembly	12,200	25	0.3
Education	101,000	25	2.5
Food Sales	5,800	25	0.1
Food Service	5,400	25	0.1
Healthcare	21,400	25	0.5
Lodging	19,000	25	0.5
Large Office	148,000	25	3.7
Small Office	94,000	25	2.4
Mercantile & Service	45,300	25	1.1
Warehouse	14,100	25	0.4
Other	21,400	25	0.5

- IT Equipment is dominated by network equipment infrastructure, and is used primarily in office spaces.
- The IT equipment split above is based on the total percentage of AEC associated with computers in each building type from CBECS 2003.

NAVIGANT ENERGY

IT equipment (cont.)

- For this study, we assume that network equipment spends 25% of the time with high traffic (active state) and 75% of the time with low traffic (idle state). This may be a conservative estimate compared to other studies which assume 100% idle time.*
- Traffic does not significantly impact power – we assume active power is 5% higher than idle power.
- Power used in network equipment has not changed significantly in the past.
- Growth in installed base drives most of the increase in energy consumption.
  - Switches/WLANs recently grew faster than routers/security due to growth in the number of connected devices.
  - Routers and security appliances allow more users on a single device, so growth in this area is expected to remain low.
- Installed base growth assumed to be equal to rate between 2008 and 2011
- Main growth driver is the number of devices connected, (not the amount of floors pace).
- There is nothing to suggest that there will be more device consolidation. Even if there is, the power needed per port or device will likely not change.
- The number of devices connected has probably been increasing faster than commercial floor space; however, at some point the market may reach saturation, but when that time will occur is highly unpredictable at the present.

*Source: Lanzisera, S., B. Nordman, and R. E. Brown, 2011. ``Data Network Equipment Energy Use and Savings Potential in Buildings."

New IT equipment technologies have the potential to achieve high levels of savings, but adoption of these technologies is not certain.

- Substantial energy savings could be achieved through EEE (energy efficient Ethernet)
  - Most network equipment does not fully utilize all ports, e.g., switches on avg. utilize 50% of ports.
  - EEE shuts off power to ports that are not connected - savings is not in time spent in idle, but idle/active power itself as it saves power on unused ports. Savings is approximately 50%.
  - Minimal adoption to date - partially due to the fact that it requires both the endpoint device and the network equipment to support EEE.
- Many endpoint devices are powered by Ethernet (PoE) instead of AC wall power (e.g., VOIP phones).
  - Efficiency of power supplies in network equipment will be more relevant as more and more devices are powered over Ethernet.
  - PoE energy is not included here so as to avoid double counting with the actual end use.
- Network equipment power itself has not been changing significantly, but shipments drive most of the changes in energy consumption.

Water distribution (external to the building) consumed 6.5 TWh in 2011 to supply water to buildings.

All Commercial Supply		2011	2015	2020	2030	2040
Installed Base	Mgal/yr	5,115,000	5,250,000	5,514,000	5,956,000	6,402,000
UEC	kWh/Mgal	1,284	1,310	1,340	1,410	1,480
AEC	TWh/yr	6.6	6.9	7.4	8.4	9.5
Commercial Self Supply						
Comm Self Supply Installed	Mgal/yr	1,192,000	1,223,480	1,285,094	1,388,033	1,492,042
Comm Self Supply UEC	kWh/Mgal	430	439	450	473	497
Comm Self Supply AEC	TWh/yr	0.51	0.54	0.58	0.66	0.74
All Public Supply (All sectors)						
All Public Installed Base	Mgal/yr	16,582,000	17,019,921	17,877,032	19,309,035	20,755,906
All Public UEC	kWh/Mgal	1,544	1,575	1,615	1,698	1,784
All Public AEC	TWh/yr	25.6	26.8	28.9	32.8	37.0

- Commercial water supply is generally served by public distribution systems (75% of all commercial supply).
- Surface-water supplies consume 22% less energy than ground-water supplies (both of which are included in these data).
- Wastewater treatment is not included in this analysis.
- Water distribution within buildings (e.g., hot water circulation pumps) is not considered here.
- We include estimates for private wells as "self supply".

Note: Bgal = Billions of gallons

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

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The water distribution split by building type is based on an EPA study from 1995; we assume this trend has generally held over that time.*

2011 Base Year Data	All Comm'l (Self & Public) - Mgal/yr	Avg UEC - kWh/MGal/yr	AEC TWh/yr
Assembly	256,000	1,284	0.3
Education	512,000	1,284	0.7
Food Sales	213,000	1,284	0.3
Food Service	639,000	1,284	0.8
Healthcare	597,000	1,284	0.8
Lodging	639,000	1,284	0.8
Large Office	384,000	1,284	0.5
Small Office	384,000	1,284	0.5
Mercantile & Service	213,000	1,284	0.3
Warehouse	1,023,000	1,284	1.3
Other	256,000	1,284	0.3

- Unlike other commercial MELs, water distribution (except private wells for self-supply) is not typically associated with the building – it is usually considered a utility service.
- These data represent the nationwide energy consumption required to deliver the water to the stock of each building type; the actual pumps are located outside of the building, at central pumping stations and at various locations in the pumping distribution infrastructure.

*Source: http://www.epa.gov/WaterSense/docs/ci_whitepaper.pdf, figure 2 (secondary source).

Water distribution (cont.)

- According the USGS (2005), 67% of all commercial water is from surface sources - this is also true of all public water supply (including residential).*
- Commercial-use constitutes 24% of all public water supply.*
- On average, ground water requires 36% greater energy than surface water due to the additional pumping to extract water from deep wells.*
- 75% of commercial supply comes from the public supply system - self supply generally occurs in rural areas where public distribution is not available.*
- The installed base (Mgal/yr) will increase proportionally to the growth of commercial floor space, but the growth will slow over time as water-use becomes more efficient.
- Energy use is expected to grow due to heavily taxed water resources and the need to draw water from greater depths (ground water) or farther distances (surface water).
- Regionally, the data vary dramatically, mostly due to availability of water, which heavily impacts the UEC.
- Findings differ slightly from TIAX 2010 - one main driver is public supply UEC - TIAX shows greater energy use for surface supplies than for ground supplies (counter-intuitive), which no clear justification.

Refer to Appendix A for supplemental discussion of wastewater treatment

Source: USGS, (2005) "Estimated Use of Water in the United States in 2005" http://pubs.usgs.gov/circ/1344/

Desktop computers consumed 30 TWh in 2011, but are slowly losing market share to laptops and tablets.

		2011	2015	2020	2030	2040
Installed Base	(000s)	74,000	69,000	61,000	47,000	36,000
Power Draw (W)	Active	64	51	39	23	11
	Idle/Ready	0.0	0.0	0.0	0.0	0.0
	Sleep/Standby	3.4	2.8	2.1	1.3	0.5
	Off	1.8	1.6	1.2	0.6	0.3
Annual Usage (hrs)	Active	6,060	5,751	5,387	4,727	4,147
	Idle/Ready	0	0	0	0	0
	Sleep/Standby	507	816	1,180	1,840	2,420
	Off	2,193	2,193	2,193	2,193	2,193
UEC	kWh/yr	400	301	216	111	47
AEC	TWh/yr	30	21	13	5	2

- Desktops include only the actual computer itself, not the external monitor. However, the category does include all-in-one desktop computers in which the monitor is integrated with the CPU.
- There is conflicting information on desktop installed base with NCI (2009) listing 60,381,000 desktops and 47,619,000 laptops (108 million total PCs) and TIAX (2010) listing a 2008 installed base of 150,000,000 PCs.

Photo Source: www.askthecomputertech.com

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As with other computing equipment, desktop computers are found in all building types, but are concentrated in offices and education.

- The installed base of desktops will decrease as they are supplanted by laptops.
- Sleep Mode time will increase as power management (PM) becomes more widespread, particularly when pushed by corporate IT departments.
- The breakdown by building type is based on the energy consumption breakdown for computers in CBECS (2003).

2011 Base Year Data	Installed Base (000s)	UEC (kWh/yr)	AEC (TWh/yr)
Assembly	2,000	402	0.8
Education	16,000	402	6.4
Food Sales	950	402	0.4
Food Service	870	402	0.3
Healthcare	3,500	402	1.4
Lodging	3,100	402	1.2
Large Office	24,000	402	9.6
Small Office	15,000	402	6.0
Mercantile & Service	7,300	402	2.9
Warehouse	2,300	402	0.9
Other	3,500	402	1.4

Desktop computers (cont.)

Installed Base:

» Differences in prior installed base estimates could result from difficulties distinguishing desktop PCs from laptop PCs in the commercial sector.

» To obtain what we view as a more accurate representation, we used TIAX's (2010) report data, which shows ~0.98 computers per employed person.

» With a nearly1-to-1 ratio between employed persons and computers, it is likely that the market is nearing saturation.

– Based on common economic assumptions, we assumed that the employment rates would return to "full employment" levels within 5 years.

» According to NCI (2009), desktops comprised 56% of commercial PCs, and exhibit a downward trend due to the increasing capabilities and portability of laptops.

– Therefore, we assumed desktop installed base decrease at a constant rate through 2040, when they constitute 20% of the PC installed base.

o We believe 20% is appropriate because certain applications, such as architecture and engineering design, will require the power and memory found only in a desktop.

Power Consumption:

» Based on a typical 4 year lifespan, we assumed that by 2017, the average power consumption for commercial desktops would be that of the current ENERGYSTAR specification.

Laptop computers consumed 2.1 TWh in 2011.

		2011	2015	2020	2030	2040
Installed Base	(000s)	63,000	77,000	92,000	120,000	150,000
Power Draw (W)	Active	21	16	12	8.3	5.6
	Idle/Ready	0	0	0	0	0
	Sleep/Standby	1.8	1.4	1.2	0.7	0.4
	Off	1.5	0.8	0.7	0.5	0.3
Annual Usage (hrs)	Active	1,078	1,078	1,078	1,078	1,078
	Idle/Ready	0	0	0	0	0
	Sleep/Standby	828	828	828	828	828
	Off	6,854	6,854	6,854	6,854	6,854
UEC	kWh/yr	34	24	19	13	8
AEC	TWh/yr	2.1	1.8	1.8	1.5	1.3

- Commercial laptops includes laptops, but not any additional external monitors or other peripheral devices.
- Commercial and residential laptops show some similarities in power consumption. Specifically, they exhibit very similar Sleep and Off Mode power consumptions, but their usage patterns are dissimilar. We used NCI (2009) data for the usage pattern of commercial laptops, as it was the best available; however, it appears low relative to Fraunhofer estimates for residential computing usage.

Photo Source: www.cpsc.gov

NAVIGANT ENERGY

Laptop computers by building type

2011 Base Year Data	Installed Base (000s)	UEC (kWh/yr)	AEC (TWh/yr)
Assembly	1,500	34	0.1
Education	13,000	34	0.4
Food Sales	740	34	0.0
Food Service	680	34	0.0
Healthcare	2,700	34	0.1
Lodging	2,400	34	0.1
Large Office	19,000	34	0.6
Small Office	12,000	34	0.4
Mercantile & Service	5,700	34	0.2
Warehouse	1,800	34	0.1
Other	2,700	34	0.1

- The installed base of laptops will increase as they supplant desktops.
- We calculated the installed base for laptops using the same methodology as we used for commercial desktops.
- Sleep mode time will increase as power management (PM) becomes more widespread, particularly when pushed by corporate IT departments.
- The breakdown by building type is based on the energy consumption breakdown for computers in CBECS (2003).

Laptop computers (cont.)

Installed Base:

» The 2011 installed base for both commercial and residential laptops is in line with shipment data from ENERGY STAR (75% of shipments are ENERGY STAR).*

» We expect the laptop installed base to increase relative to desktops at a constant rate through 2040, when they will constitute 80% of the PC installed base.

Power Consumption:

» As the commercial sector's analysis does not include tablets or netbooks like the residential sector's, commercial laptops exhibit a slightly higher Active Mode power consumption.

» Tablet use in commercial settings (excluded here) is in its early stages and is difficult to characterize; however, it is likely that UEC will be greater than in the residential sector due to more usage hours (e.g., doctor using tablet with patients steadily for a full day).

Hourly Usage:

» As the usage patterns of commercial laptops will likely remain similar in the future, we assumed they would stay the same through 2040.

*Source: Energy Star Market Penetration Data: http://www.energystar.gov/index.cfm?c=partners.unit_shipment_data

Computer monitors in commercial buildings consumed 18 TWh in 2011.

		2011	2015	2020	2030	2040
Installed Base	(000s)	93,000	91,000	86,000	77,000	71,000
Power Draw (W)	Active	38	34	25	25	25
	Idle/Ready	0	0	0	0	0
	Sleep/Standby	1.3	1.2	0.7	0.0	0.0
	Off	0.8	0.7	0.6	0.0	0.0
Annual Usage (hrs)	Active	5,323	4,879	4,365	3,475	2,764
	Idle/Ready	0	0	0	0	0
	Sleep/Standby	554	818	1,096	1,493	1,702
	Off	2,883	3,063	3,298	3,792	4,293
UEC	kWh/yr	198	168	112	87	69
AEC	TWh/yr	18	15	10	7	5

» Computer monitors include only those that are independent of (i.e., not integral to) the computer's CPU – this may include those connected to desktops and laptops

Photo Source: www.publicdomainpictures.net

NAVIGANT ENERGY

Computer monitors are primarily located in office and education buildings, but are found in lesser numbers in all building types.

2011 Base Year Data	Installed Base (000s)	UEC (kWh/yr)	AEC (TWh/yr)
Assembly	2,400	200	0.5
Education	20,000	200	4.0
Food Sales	1,200	200	0.2
Food Service	1,100	200	0.2
Healthcare	4,300	200	0.9
Lodging	3,800	200	0.8
Large Office	30,000	200	6.0
Small Office	19,000	200	3.8
Mercantile & Service	9,100	200	1.8
Warehouse	2,800	200	0.6
Other	4,300	200	0.9

- Hourly usage is based on the weighted average of commercial desktop and laptop usage.
- Active Mode power will likely taper to a plateau of 25 W (based on NCI expert opinion).
- The split building type is based on the representative split in CBECs (2003) for computer energy consumption.

We encountered many challenges while analyzing computer monitor installed base and energy consumption.

Installed Base:

» As there was conflicting data between NCI (2009) that said the installed base of just desktop-associated monitors was 110,000,000 and TIAX (2010) that said the 2008 total installed base of commercial monitors was 160,000,000, we determined the number of commercial monitors based on the number of desktops and laptops.

» According to NCI (2009), there are 1.073 monitors per desktop; and we assumed that 22% of laptops have one.

– 22% accounts for 1/3 of office laptops having an external monitor as well as 5% of the remaining commercial laptops.

» To break the installed base into CRT and LCD, we took the percentages given in NCI (2009) 21% and 79%, respectively. LCDs are increasing in market share, so we projected that within two 4-year lifecycles from 2009, CRTs will constitute 0% of the installed base.

Power Consumption and Usage:

» Power consumption values are weighted averages of the number of CRTs and LCDs.

» We assumed that the power consumption of CRTs in each mode will remain the same through 2017.

» Hourly usage values are weighted averages of the amount of time commercial desktops and laptops are in each of the modes.

Commercial kitchen ventilation (CKV) consumed 41 TWh in 2011, but demand-based controls will reduce the AEC in future years.

		2011	2015	2020	2030	2040
Installed Base	(000s)	790	810	860	950	1,050
Power Draw (W)	On	8,071	7,911	7,335	6,306	5,153
	Off	0	0	0	0	0
Annual Usage (hrs)	On	6,100	6,100	6,100	6,100	6,100
	Off	2,660	2,660	2,660	2,660	2,660
UEC	kWh/yr	52,000	51,000	48,000	41,000	33,000
AEC	TWh/yr	41	41	41	39	35

- Commercial Kitchen Ventilation systems are comprised of:
  - Exhaust hood(s)
  - Exhaust fan(s)
  - Make-up air (MUA) fan(s)
  - Space conditioning system to heat/cool MUA
  - Ducting
- Our analysis covers the energy consumption due to exhaust and MUA fans, but excludes the conditioning loads because very little primary data are available and NEMS data are based solely on fan power.

Building codes require all commercial kitchens to install a CKV; however, little data is available on the installed base, so our assumptions are based on 7 targeted building types.

» Split by building type is based on CBECS (projected to 2011 using AEO floor space growth rates)

» We assume one CKV system per facility for:

- Food Sales (grocery stores, other food sales)
- Food Service (fast food, restaurant, other food service)
- Public Assembly (entertainment/culture)
- Education (college/university, elementary or middle school, high school)
- Healthcare (inpatient healthcare)
- Lodging (hotel)
- Retail (Malls)

2011 Base Year Data	Installed Base (000s)	UEC (kWh/yr)	AEC (TWh/yr)
Assembly	30	109,000	3.3
Education	300	51,500	16
Food Sales	100	111,000	12
Food Service	320	22,900	7.4
Healthcare	9	105,000	0.9
Lodging	21	112,000	2.4
Large Office	0	0	0
Small Office	0	0	0
Mercantile & Service	4	119,000	0.5
Warehouse	0	0	0
Other	0	0	0

Commercial kitchen ventilation (cont.)

- There are currently no mandatory energy efficiency standards for CKV.
- We estimated UEC by taking the average from 14 different case studies.*
- To calculate the installed base of Commercial Kitchen Ventilation systems, we separated CKV system into 3 main subgroups by exhaust fan capacity:

	Installed Base (000s)	UEC (kWh/yr)	AEC (TWh/yr)	Size Category (Exhaust Fan CFM Capacity)
Small	320	23,000	7	<=9000
Medium	300	51,000	16	>9000 and <=20,000
Large	170	111,000	19	>20,000

- Data for the number of installed commercial kitchen ventilation unit are unavailable.
- We assumed that growth in the installed base would follow the growth trend in commercial floor space
- Multiple case studies show up to 65% savings in UEC by using a Demand Control Ventilation (DCV). DCV uses a Variable Frequency Drive (VFD) to modulate the speed of the exhaust and MUA fan motor based on outdoor temperature and kitchen demand.*

Case study sources: http://www.etcc-ca.com/images/stories/et_07_10_dcv_com_kitch_hoods_final_report.pdf, http://partnershipdemonstrations.org/file_browser/db/Kitchen_DVC_Case_Study_CCCs_draft_D.pdf, http://www.fishnick.com/publications/appliancereports/hoods/mark_hopkins_melink_report.pdf, http://www.fishnick.com/publications/appliancereports/hoods/Supermarket_Melink_Report.pdf

Lab refrigerators and freezers consumed 4.5 TWh in 2011 with a slow decline expected in the future.

		2011	2015	2020	2030	2040
Installed Base	(000s)	1,000	1,030	1,100	1,200	1,300
Power Draw (W)	Compressor On Cycle	975	920	857	742	642
	Compressor Off Cycle	50	47	44	38	33
	Off	0	0	0	0	0
Annual Usage (hrs)	Compressor On Cycle	4,380	4,380	4,380	4,380	4,380
	Compressor Off Cycle	4,380	4,380	4,380	4,380	4,380
	Off	0	0	0	0	0
UEC	kWh/yr	4,500	4,200	3,900	3,400	3,000
AEC	TWh/yr	4.5	4.3	4.3	4.1	3.9

Technology includes three sub groups:

- **Refrigerators:** 4°C – Blood, some medications/vaccines, non-volatile reagents and biological specimens (e.g., mice)
- **Freezers:** -20°C – Volatile reagents, biological specimens, certain medications/vaccines
- **Ultra-low Freezers (ULF):** -70 to -80°C – Long-term sample storage, proteins, cells & small biological samples
- **Excluded:** Cryogenic (-150 C) and liquid nitrogen freezers

Lab refrigerators and freezers are used in labs at universities, pharmaceutical companies and government agencies.

	Installed Base (000s)	UEC (kWh/yr)	AEC (TWh/yr)
Assembly	0	0	0
Education	200	5,000	1.0
Food Sales	0	0	0
Food Service	0	0	0
Healthcare	300	4,100	1.2
Lodging	0	0	0
Large Office	0	0	0
Small Office	0	0	0
Mercantile & Service	0	0	0
Warehouse	0	0	0
Other	400	5,700	2.3

» Three types of establishments dominate the market for lab-grade refrigeration and there are relatively few discrete entities.
  – Research universities
  – Pharmaceutical companies
  – Large government agencies (CDC, NIH)

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

Lab refrigerators and freezers (cont.)

Growth Rates:

» Growth in the installed base assumed to be the same as growth in commercial floor space.

» Increases in efficiency over time assume that after two turnovers of the installed base, annual equipment energy use decreases by approximately 25%.

» No efficiency standards currently exist, but efficiency is expected to increase due to:

- Future ENERGY STAR specifications: ESTAR is currently developing a test procedure
- Use of hydrocarbon refrigerants: not currently allowed in the US, but is in Europe, where it contributes to higher efficiency of equipment (subject to EPA approval)
- New technologies: most products use one or more (cascaded) vapor compression cycle(s). However, one ULF manufacturer has introduced a Stirling-cycle freezer that shows dramatic energy savings.

Energy Use:

» Average equipment size and energy use came from manufacturer-supplied data for the Lab R/F ENERGY STAR test method development.

» No ENERGY STAR, DOE, industry, or other energy specification for these products exists.

» Our analysis broke out the three different temperatures of equipment:

	Installed Base (000s)	UEC (kWh/yr)	AEC (TWh/yr)
Refrigerator	400	3,300	1.3
Freezer	350	4,400	1.5
Ultra-low Freezer	250	6,600	1.6

Medical imaging equipment consumed 2.7 TWh in 2011, with slow growth expected; however ,this may be a rapidly evolving end use.

		2011	2015	2020	2030	2040
Installed Base	(000s)	178	186	195	215	238
Power Draw (W)	Active	27,774	27,774	27,774	26,416	25,124
	Idle/Ready	2,849	2,849	2,849	2,710	2,577
	Sleep/Standby	2,108	2,108	2,108	2,005	1,907
	Off	346	346	346	329	313
Annual Usage (hrs)	Active	762	762	801	885	977
	Idle/Ready	292	292	307	339	375
	Sleep/Standby	2,512	2,512	2,610	2,822	3,055
	Off	5,193	5,193	5,041	4,714	4,352
UEC	kWh/yr	15,000	15,000	15,500	15,400	15,400
AEC	TWh/yr	2.7	2.8	3.0	3.3	3.7

» Medical Imaging includes MRI, CT, X-ray, Ultrasound

» MRI constitutes 50% of the total AEC

	Installed Base (000s)	UEC (kWh/yr)	AEC (TWh/yr)
MRI	12	111,000	1.3
CT Scan	13	42,000	0.56
X-Ray	78	9,500	0.74
Ultrasound	75	760	0.06

Photo Source: www.teslasociety.com

NAVIGANT ENERGY

Medical imaging equipment is used in hospitals (healthcare category), and outpatient healthcare (small office category) buildings.

2011 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	59	32,500	1.9
Lodging	0	0	0
Large Office	0	0	0
Small Office	120	6,500	0.77
Mercantile & Service	0	0	0
Warehouse	0	0	0
Other	0	0	0

- Medical imaging equipment is used in large, inpatient healthcare facilities as well as outpatient healthcare offices, which are classified as small offices.
- Some are used at universities, but the quantities are limited, particularly for MRI and CT.
- Does NOT include dental X-ray machines, which have a much higher installed base, but are powered off more than 75% of the time. Based on a population of 5700 dental X-rays in PA, we expect that the US has an entire population of approximately 140,000.

Medical imaging equipment (cont.)

Installed Base:

» $2.5 Billion market for X-ray machines in 2015 (a slight increase from today) due mostly to growth of more expensive, but much better digital equipment.

» TIAX estimates 48k mammography machines, 17k fluoroscopy machines, and 21k non-medical x-rays, all of which have smaller AECs and are not included here.*

» Markets contracted significantly during recession, and will rebound in the coming years, but are not expected to return to the growth seen in the mid 2000s (10-30% annually).

» Estimates of X-ray units in the US varies widely, but the total variation may only impact the AEC by up to approximately 0.2 TWh/yr.

Energy Use:

» Unclear whether imaging is consistently used 7 days per week. In many locations, it may only be used 5 days per week, which would reduce the UEC proportionately.

» TIAX (2006) reports an x-ray UEC that is more than double our estimate due to a 50% utilization rate, which we believe to be unrealistic; typical x-rays are off for 14 hrs/day, idle for 9 hours, and are only exposing for as little as a few minutes per day ("partial power" mode to move bed, rotate gantry, etc., for the remaining time).**

» Estimated MRI/CT building-type split is 90% in hospitals, 10% in outpatient healthcare

*Source: TIAX (2006) "Commercial and Residential Sector Miscellaneous Electricity consumption: Y2005 and Projections to 2030"
**Calculated based on power by mode from From
http://emse.mst.edu/media/academic/emse/documents/EMSEGraduateSeminar-DrJanetTwomey.pdf

Commercial video displays consumed 2 TWh in 2011, with dynamic growth expected.

		2011	2015	2020	2030	2040
Installed Base	(000s)	1,600	3,200	5,200	9,200	13,200
Power Draw (w)	Active/On	246	285	299	277	212
	Idle/Ready	0	0	0	0	0
	Sleep/Standby	2.0	1.0	0.5	0.5	0.5
	Off	0	0	0	0	0
Annual Usage (hrs)	Active/On	4,380	4,380	4,380	4,380	4,380
	Idle/Ready	0	0	0	0	0
	Sleep/Standby	4,380	4,380	4,380	4,380	4,380
	Off	0	0	0	0	0
UEC	kWh/yr	1,084	1,252	1,311	1,216	929
AEC	TWh/yr	2	4	7	11	12

- Includes electronic displays or screens (typically LCD or plasma) used to deliver entertainment, information and/or advertisement in public or private commercial spaces.
- Does not include displays less than 30 inches
- Does not include large arena/stadium displays (see "Large-Format Video Displays" on page 62)
- The market for commercial video displays is relatively new and very dynamic with a recent compound annual growth rate of 20-25%.

NAVIGANT ENERGY

Commercial video displays are most commonly found in retail environments where they are primarily use for advertising and branding.

2011 Base Year Data	Installed Base (000s)	UEC (kWh/yr)	AEC (TWh/yr)
Assembly	32	1,084	0.0
Education	160	1,084	0.2
Food Sales	240	1,084	0.3
Food Service	160	1,084	0.2
Healthcare	32	1,084	0.0
Lodging	32	1,084	0.0
Large Office	112	1,084	0.1
Small Office	112	1,084	0.1
Mercantile & Service	640	1,084	0.7
Warehouse	0	1,084	0.0
Other	80	1,084	0.1

- Retail stores represent about 40% of commercial video display AEC.
- Current high growth markets include; university campuses where they are being used to convey news, public safety information, coming events, and general way-finding; fast food restaurant for dynamic menus and nutrition information; and food sales such as grocery stores and gas stations primarily for advertising.
- As consumer TVs reach market saturation, manufacturer focus may shift to commercial video displays.

Commercial video displays (cont.)

Installed Base:

» Professional displays and signage is a new and dynamic market with extremely high uncertainty.

» Recent dramatic growth is expected to be sustained beyond 2016 according to worldwide shipping forecasts.

» This analysis assumes the current U.S. installation rate of about 400,000 displays per year will continue through 2040.

Power Consumption:

» Power consumption is similar to commercial TVs and is largely a function of screen size which increase from 41.3 inches in 2011 to 46.5 inches in 2013 and is expected to continue to grow toward 60 inches on average.

» Organic LED (OLED) and Laser Phosphor Display (LPD) technologies have the potential to reduce energy consumption by 40-75% but will be prohibitively expensive for several more years.

Hourly Usage:

» Hours of operation are assumed to coincide with typical retail store hours of about 12 hours per day

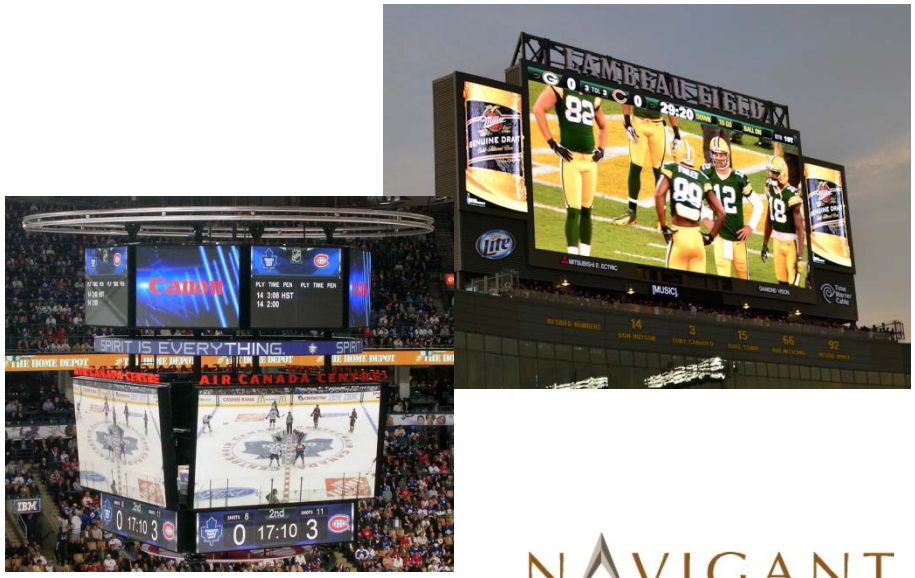
» As the usage patterns of commercial video displays will likely remain similar in the future, we assumed they would stay the same through 2040.

Large Format Video Displays, i.e., stadium video boards, consumed 0.15 TWh in 2011; we expect this to decrease gradually in the future.

		2011	2015	2020	2030	2040
Installed Base	(000s)*	1.0	1.0	1.0	1.0	1.0
Power Draw (W)	Active	190,000	180,000	171,000	161,000	152,000
	Off	0	0	0	0	0
Annual Usage (hrs)	Active	800	800	800	800	800
	Off	7,960	7,960	7,960	7,960	7,960
UEC	kWh/yr	152,000	144,000	137,000	129,000	121,000
AEC	TWh/yr	0.15	0.14	0.14	0.13	0.12

** Note that installed base is the number of venues with installed video boards, not the number of individual video boards.*

- Includes large-format video screens (typically LED) used to deliver live feed and video replay, game and player stats, advertisements, and other information and entertainment directed at sports fans in stadiums and arenas.
- Does not include digital billboards.
- Does not include standard television-sized displays at arenas, such as those for spectator viewing in concession areas (see "Video Displays" on page 59)



NAVIGANT ENERGY

For the purposes of this analysis, we considered only video boards installed at sporting venues such as stadiums and arenas.

2011 Base Year Data	Installed Base (000s)	UEC (kWh/yr)	AEC (TWh/yr)
Assembly	1.0	151,805	0.2
Education	0	151,805	0
Food Sales	0	151,805	0
Food Service	0	151,805	0
Healthcare	0	151,805	0
Lodging	0	151,805	0
Large Office	0	151,805	0
Small Office	0	151,805	0
Mercantile & Service	0	151,805	0
Warehouse	0	151,805	0
Other	0	151,805	0

Installed Base:

» The number of sporting venues in the U.S. is fairly static, however, the quantity and average size of individual video boards per venues is increasing.

Unit Power Consumption:

» Power consumption per unit of display area is expected to decrease through 2040 as a result of efficiency gains, which will be partially offset by increasing average screen size.

Hourly Usage:

» Hours of operation based on 100 events per year and 8 hours of operation per event

» As the usage patterns of commercial video boards will likely remain similar in the future, we assumed they would stay the same through 2040.

NAVIGANT ENERGY

Commercial security systems consumed 7 TWh in 2011 with strong growth expected, especially for video surveillance.

		2011	2015	2020	2030	2040
Installed Base	(000s)	11,000	12,000	14,000	18,000	22,000
Power Draw (W)	Active	290	270	260	240	230
	Off/Standby	0.0	0.0	0.0	0.0	0.0
Annual Usage (hrs)	Active	8760	8760	8760	8760	8760
	Off/Standby	0	0	0	0	0
UEC	kWh/yr	2,500	2,400	2,300	2,100	2,000
AEC	(TWh/yr)	7	8	9	11	13

- Includes video surveillance, physical access control, intruder and fire detection, and electronic article surveillance (EAS) systems.
- Does not include IT equipment captured under other categories such as Ethernet switches and some computers and monitors.
- Video surveillance and intrusion/fire detection account for the majority of AEC.
- Strong growth expected due to security concerns, increased networking capabilities and integration with building energy management and controls systems, and increased cloud-hosted security as a service (Saas) offerings.

	Installed Base (000s)	UEC (kWh/yr)	AEC (kWh/yr)
Video Surveillance	2,900	1,500	4.3
Access Control	2,500	230	0.6
Intrusion & Fire Detection	4,200	540	2.3
Electronic Article Surveillance	1,100	260	0.3

Commercial security system components and setups vary significantly between buildings.

2011 Base Year Data	Installed Base (000s)	UEC (kWh/yr)	AEC (TWh/yr)
Assembly	1,020	750	0.8
Education	970	1,130	1.1
Food Sales	540	310	0.2
Food Service	500	330	0.2
Healthcare	20	10,530	0.2
Lodging	330	1,690	0.6
Large Office	100	7,550	0.8
Small Office	2,650	310	0.8
Mercantile & Service	2,370	500	1.2
Warehouse	1,080	950	1.0
Other	1,010	630	0.6

- 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 floor space and as a result is dominated by hospitals and large office buildings.
- AEC is fairly evenly distributed across building types except for healthcare which has a small installed base and food sales and service locations which have a small to moderate installed base and small UEC (due to small average floorspace)

We encountered many challenges while analyzing commercial security systems, primarily a lack of available data.

Installed Base:

» Installed base is primarily a function of building quantity and market saturation for each system type.

» The market saturation rate is about 52% for video surveillance, 45% for access controls, 75% for intrusion/fire detection, and 19% for EAS.

» Very little projection data available.

Power Consumption:

» Power consumption varies significantly by system type, building type, and building size.

» Power consumption for video surveillance, access control, and EAS systems determined by assuming a typical set of system components for a typically sized building and determining the power consumption of each component base on a sample of manufacturer specification sheets (subsequently, UEC was weighted by relative floor space of each building type).

» Little data was available to determine a "typical" set of components comprising an intrusion/fire detection system so the energy intensity (including power supplies) of residential security systems (about 7 watts per 1,700 sqft) was applied to average floor space by building type.

Hourly Usage:

» Commercial security systems are assumed to operate 24/7/365.

» As the usage patterns of commercial security systems will likely remain similar in the future, we assumed they would stay the same through 2040.

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The team analyzed 15 residential MELS.

Residential MELs	Description, examples
Dehumidifiers	Residential-size, standalone dehumidifiers
Set-top Boxes, All	Cable, Satellite, Fiber, IPTV, and Over-The-Top (OTT)
Modems & Routers	Equipment for home broadband internet and networking
External Power Supplies	Power chargers that are not integral to the product
Non-Computer Rechargeable Electronics	Mobile phones, digital cameras, handheld vacuums, etc.
Ceiling Fans	Ceiling Fans, not including lighting power consumption
Televisions	LCD and CRT televisions
DVD	DVD players and recorders and DVD-VCR combos
PCs, Laptop	Laptop computers, including tablet computers
PCs, Desktop	Desktop computers
Monitors (i.e. desktop PC monitors)	Monitors (used with both laptops and desktops)
Audio Equipment	Home theater, amplifiers, speakers, etc.
Portable Electric Spas	Electrically-heated hot tubs
Pools/Pool Pumps	Pools, in-ground and above-ground
Security Systems, Home	Residential security systems including pinpads, sensors, etc.

Dehumidifiers consumed 11 TWh in 2011, with minimal expected future growth.

		2011	2015	2020	2030	2040
Installed Base	(000s)	15,600	16,400	17,400	19,500	21,600
Power Draw (W)	Active Power	644	637	627	609	591
	Full/Removed	1.6	1.6	1.6	1.5	1.5
	Off-Cycle/Inactive/Off	0.5	0.5	0.5	0.5	0.5
	Unplugged	0	0	0	0	0
Annual Usage (hrs)	Active Hours	1,096	970	833	833	833
	Full/Removed	658	658	658	658	658
	Off-Cycle/Inactive/Off	3,004	3,126	3,263	3,263	3,263
	Unplugged	4,017	4,017	4,017	4,017	4,017
UEC	kWh/yr	710	620	530	510	490
AEC	TWh/yr	11.1	10.2	9.2	9.9	10.6

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

- DOE separates dehumidifiers into product classes by capacity (pints/day).
- Dehumidifiers are covered in the DOE codes and standards program, but anecdotal field data suggest that actual performance is highly variable and UEC/AEC are poorly understood in real world circumstances.
- This analysis includes only portable units, and excludes whole-home dehumidifiers that are built into the ductwork.

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Dehumidifiers (cont.)

Energy Efficiency:

» Conventional vapor-compression technology is approaching the end of cost-effective improvements, so the potential for technological advancement is unclear.

» EF is expected to improve by 33% over the next 10 years as some product classes are eliminated. We expect improvement in EF will be achieved through a 33% reduction in active mode hours needed to achieve the same level of water removal.

» Hours for standby, bucket full, and unplugged were taken from the dehumidifier 2010 test procedure notice of public rulemaking (NOPR).

Installed Base:

» Projections are based on the average of:
  – AHAM historical shipment data and the average lifetime of a dehumidifier
  – RECs estimate that 12% of homes have dehumidifiers in the US

» The installed base is expected to grow at a slow but consistent pace, which is consistent with the typical characteristics of homes that contain dehumidifiers.

» Market Share by capacity is from the dehumidifier TSD.

» Although the installed base is increasing slowly, the reduction in active mode hours will likely lower dehumidifier energy consumption in the US over time.

Set-Top-Boxes (STB) consumed 22.4 TWh in 2011 and will increase in coming years due in part to development of the OTT market.

		2011	2015	2020	2030	2040
Installed Base	(000s)	176,000	233,000	352,000	400,000	442,000
Power Draw (W)	Watch	17.1	15.0	13.5	10.3	10.1
	Sleep	16.3	13.4	11.4	8.7	8.5
	AutoPowerDown	6.6	6.0	5.9	8.3	8.5
	Multistream	8.0	8.4	8.8	7.5	7.3
Annual Usage (hrs)	Watch	3173	2845	2543	1894	1850
	Sleep	3650	3650	3650	3650	3650
	AutoPowerDown	1322	1608	1863	2509	2555
	Multistream	615	657	703	707	705
UEC	kWh/yr	127.2	106.8	92.9	77.3	76.3
AEC	TWh/yr	22.4	24.9	32.7	30.9	33.7

STBs include four sub categories of products for delivering TV content:

	Cable	Satellite	IPTV	OTT
2011 AEC	14.0	7.3	1.1	0.1

- » IPTV STBs (newer technology) use internet protocol to deliver traditional TV content
- » Over-The-Top (OTT) STBs, including Roku, Boxee, Apple TV, which stream internet content to the TV - newest market entrant, with high growth potential as available online content increases

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

NAVIGANT ENERGY

Set-Top-Boxes (cont.)

» Originally OTT STB were included with DVD players; products were re-categorized as STBs, based on content delivery method and customer/service provider relationship.

» Analysis is based on DOE standards rulemaking analysis*

Energy Efficiency:

» A trend of increasing per unit energy efficiency is tied to voluntary efforts of the National Cable and Telecommunications Association.** The forecasted efficiency levels show average energy use declining despite boxes providing greater functionality.

Installed Base:

» Near-term: Cable is losing market share to IPTV (Satellite is stable); due in part to new providers and infrastructure changeover by existing cable providers.

» The installed base jump through 2020 is due to a brief transition to a client server architecture (e.g. Dish's Hopper/Joey offering). The deployment of thin clients temporarily leads to an increase in shipments; but upon saturation, shipments will return to match replacements and nominal growth in subscribership.

» TIAX installed base data suggested a contraction tied to point-of-deployment slot functionality. Recent shipment growth indicates little advancement on this front.

*DOE STB notice of data availability: http://www1.eere.energy.gov/buildings/appliance_standards/rulemaking.aspx/ruleid/33
**CEA/NCTA voluntary agreement: http://www.ncta.com/news-and-events/media-room/article/2453

Modems and routers consumed 7 TWh in 2011, but due to consolidation of devices, this will decrease in coming years.

		2011	2015	2020	2030	2040
Installed Base	(000s)	138,000	120,000	120,000	120,000	130,000
Power Draw (W)	Active	5.6	5.0	4.3	3.2	2.3
	Idle/Ready/Off	0	0	0	0	0
Annual Usage (hrs)	Active	8760	8760	8760	8760	8760
	Idle/Ready/Off	0	0	0	0	0
UEC	kWh/yr	51	44	38	28	20
AEC	TWh/yr	7.0	5.2	4.5	3.3	2.6

This category includes:

- Broadband modems – including cable, DSL, fiber, satellite
- Routers, Hubs, Switches – equipment that provides networking capabilities for multi-computer access. Hubs and switches are the least common, and constitute a very small portion of the market share.
- Integrated Access Devices (IAD) – devices which include functionality of both a broadband modem and a router; these will become increasing common as many internet service provides move to use these exclusively

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

NAVIGANT ENERGY

Modems and routers (cont.)

Operating Modes:

» Fraunhofer (2011) reported that modems/routers spends some portion of time in "Off" Mode because in a small survey, a small percentage of responded that they unplugged their modems/routers when not in use.

» This is inconsistent with other reports, and is believed to be an insignificant portion of the market currently. These estimates assume zero time Off Mode.

Installed Base:

» Installed base data varies between sources, potentially due to rapid changes in the penetration of the equipment, and the transition to IADs (Power consumption estimates are consistent between a variety of sources).

» The market is reaching saturation; growth in the future will be due to household growth.

» As the replacement of modem + router combinations with IADs continues, the total installed base will actually decrease; this process will be more rapid than the growth of the number of households.

» There will still exist some applications where an additional hub or switch may be necessary; the Routers & Other Devices category may never totally disappear.

External power supplies (EPS) consumed 7 TWh in 2011.

		2011	2015	2020	2030	2040
Installed Base	(000s)	1,077,000	1,210,000	1,400,000	1,880,000	2,530,000
Power Draw (W)	Active	0.9	0.8	0.7	0.4	0.3
	No Attached Load/Standby	0.04	0.03	0.03	0.02	0.01
	Unplugged/Off	0	0	0	0	0
Annual Usage (hrs)	Active	6,389	6,389	6,389	6,389	6,389
	No Attached Load/Standby	521	521	521	521	521
	Unplugged/Off	1,853	1,853	1,853	1,853	1,853
UEC	kWh/yr	6.5	5.6	4.9	3.2	2.2
AEC	TWh/yr	7.0	6.8	6.8	6.0	5.7

- EPS category is based on the DOE-standard definition: power supplies and battery chargers that drive electronics, but are not an integral part of the product.
- Product classes are defined by the type of power they output (DC/AC) and the power.
- Computers and other electronics products require EPS for power, so we double count their energy consumption in each category (>95% of this MEL is counted elsewhere)

	2011 AEC	Examples
Product Class B: 2.5W	0.28	Mobile Phones, Answering Machines, Cordless Phones
Product Class B: 18W	0.84	LAN Equipment, Media Tablets, MP3 Speaker Docks
Product Class B: 60W	4.33	Laptop Computers, Video Game Consoles
Product Class B: 120W	1.16	Laptop Computers
Product Class C: AC-DC Low	0.16	Mobile Phones, Smartphones, Digital Cameras
Product Class D: AC-AC Basic	0.17	Home Security Systems, Aquarium Accessories, Water Softeners
Product Class E: AC-AC Low	0.01	Aquarium Accessories

Photo source: http://www.computershop.uk.com

NAVIGANT ENERGY

External power supplies (cont.)

» DOE, by statute, is required to revisit EPS efficiency standards every 5 years and where appropriate, increase standards.

» This analysis, in parallel with DOE definitions, includes EPS that are used in both residential and commercial buildings, and are often carried in between regularly.

Power Consumption:

» EPS use power in Active Mode (when powering the device) as well as in Standby Mode, when the EPS is plugged in, but the device is not connected.

» Growth rates based on average efficiency gains from one Candidate Standard Level (CSL) to the next in the DOE rulemaking analysis – Assumes that DOE standards will slowly work through the efficiency levels as technology progresses.

Double Counting:

» The double-coverage of EPS in other product categories, including rechargeable electronics, in DOE standards is a known issue.

» For some products, it is possible to avoid double counting of energy consumption, but for many product classes, it is not possible since the EPS works directly with the product and is tested that way.

Non-computer rechargeable electronics consumed 4.4 TWh in 2011, some of which overlaps (i.e., double counted) with EPS.

		2011	2015	2020	2030	2040
Installed Base	(000s)	1,200,000	1,350,000	1,570,000	2,110,000	2,840,000
Power Draw (W)	Active Mode	1.18	1.04	0.89	0.59	0.44
	Maintenance	0.93	0.82	0.71	0.47	0.47
	No Attached Load/Standby	0.28	0.25	0.21	0.14	0.14
	Off	0	0	0	0	0
Annual Usage (hrs)	Active Mode	796	504	504	504	504
	Maintenance	2,510	2,781	2,781	2,781	2,781
	No Attached Load/Standby	1,605	1,605	1,605	1,605	1,605
	Off	3,855	3,855	3,855	3,855	3,855
UEC	kWh/yr	3.7	3.2	2.8	1.8	1.8
AEC	TWh/yr	4.4	4.3	4.3	3.9	5.0

» Includes all products that require charging, except computers, making this a very complex analysis, the results of which obscure the nuances of each product (this occurs in many MELs, but is extreme in this case due to the vast number of included products).

	2011 AEC	Examples
Small Rechargeables (<100Wh, <4V)	2.90	Mobile Phones, Smartphones, Digital Cameras
Medium Rechargables (<100Wh, 4-10V)	0.28	Camcorders, Toy Ride on Vehicles, Portable DVD Players
Large Rechargeables (<100Wh, >10V)	0.47	Cordless Vacuums (Handheld, Stick, Robotic)
Small Inductive Wet Environment	0.60	Rechargeable Toothbrushes
Small DC-DC Chargers (<9V)	0.14	MP3 Players, Mobile Phones, Digital Cameras (USB charged)
Large DC-DC Chargers (≥9V)	0.01	In Vehicle GPSs

Non-computer rechargeable electronics (cont.)

» Analysis based primarily on engineering analysis for DOE rulemaking activity

Power Consumption:

» We derived Active Mode power use projections from the efficiency gains seen in external power supplies. This approach assumes that efficiencies will continue to increase at the same rate.

» Usage rates based on consumer habits; assumed to not change, with one exception:

- New energy efficiency standards issued by the CA Energy Commission (and closely followed by the US DOE) will shift hours away from active mode into maintenance mode – a change that is not related to consumer behavior
- As a result, subject matter experts from the DOE rulemaking process indicated manufacturers will have to introduce improved charging circuitry to cause the battery charger to enter maintenance mode (a lower power mode) earlier in the charge cycle
- Once products meet the initial standards, older circuit designs with will be eliminated; energy use reductions beyond 2015 will not be coupled with changes in hours in each mode

Installed Base:

» Mobile phone growth is estimated at 3% annually; they make up the majority of non-computer rechargeable shipments (~63%).

» Projected to be the largest category of MELs investigated in this project in terms of installed base with approximately 2 billion products in use in 2040.

Ceiling fans consumed 20 TWh in 2011.

		2011	2015	2020	2030	2040
Installed Base	(000s)	263,000	283,000	300,000	325,000	325,000
Power Draw (W)	High Speed	83	78	71	59	49
	Med Speed	35	33	31	28	25
	Low Speed	14	12	9	6	4
	Off	0	0	0	0	0
Annual Usage (hrs)	High Speed	425	428	432	438	444
	Med Speed	849	856	864	876	888
	Low Speed	849	856	864	876	888
	Off	6,637	6,621	6,601	6,571	6,541
UEC	kWh/yr	77	71	65	55	47
AEC	TWh/yr	20	20	20	18	15

- This category includes all household style ceiling fans that are permanently installed.
- Excludes attic and whole-house fans and energy consumption of attached light fixtures.
- More than 40% of all fans are in the southern US (based on Census Region).
- Installed base grows in parallel to housing starts.
- We base the hourly usage on assumptions from TIAX (2008) which are split by census division. This underestimates usage in cooling season, but overestimates usage in shoulder months and in heating season, which puts us as close to an actual estimate as we can make.* TIAX (2008) and FSEC (2010) both includes suggestions on calculation hours of use based on cooling-season weather; these approaches ignore heating-season usage entirely.

*Source: Roth Et. Al. TIAX 2008, "Residential Miscellaneous Electric Loads: Energy Consumption Characterization and Savings Potential in 2006 and Scenario-based Projections for 2020." and Florida Solar Energy Center. "Updated Miscellaneous Electricity Loads and Appliance Energy Usage Profiles for Use in Home Energy Ratings, the Building America Benchmark Procedures and Related Calculations." Revised 10 June 2011.

Ceiling fans (cont.)

» The number and usage of fans in the home varies by Census Region (based on FSEC 2010)*

Census Region	# Fans/House
Northeast	2.6
Midwest	2.8
South	3.2
West	2.4

» Reductions in UEC in the future may be from lower usage or lower power; this analysis assumes the gains are due to lower power consumption:
  – Because ceiling fans during cooling season only benefit nearby occupants, fan usage could optimally be controlled via occupancy sensor, thereby reducing the UEC; however, at this time this trend has not yet picked up and we exclude it from this analysis. (During heating season, reverse operation reduces air stratification and would provide benefit even for those not in the room.)
  – Instead, power consumption decreases corresponding to ENERGY STAR guidelines, using higher efficacy blades and more efficient motors.

» The trend of hourly usage will project along the same lines as the TIAX 2006 report

*Source: Parker, et. al., FSEC (2010) "Updated Miscellaneous Electricity Loads and Appliance Energy Usage Profiles for Use in Home Energy Ratings, the Building America Benchmark Procedures and Related Calculations "

Televisions consumed 70 TWh in 2011, but efficiency is improving with the changeover to LCDs; however increases in typical size counter some efficiency gains.

		2011	2015	2020	2030	2040
Installed Base	(000s)	355,000	364,000	388,000	444,000	501,000
Power Draw (W)	Active	127	95	83	69	62
	Off/Standby	1.62	1.13	0.49	0.40	0.4
Annual Usage (hrs)	Active	1,460	1460	1460	1460	1460
	Off/Standby	7300	7300	7300	7300	7300
UEC	kWh/yr	197	150	130	100	94
AEC	TWh/yr	70.0	54.6	50.4	44.4	47.1

This category includes:

» Cathode Ray Tubes (CRT) – 47% of installed base

» Liquid Crystal Displays (LCD) – 42% of installed base

» Plasma – 11% of installed base

Televisions (cont.)

Installed Base:

» 353 million in 2010 - represents ~65 TWh per year in energy use. We anticipate a slight rise in the AEC in 2011 due to the continued growth of the installed base.

» On average 3 TVs per household in the US (Fraunhofer 2011).*

» Transition to digital broadcasting (2009) accelerated CRT retirement (complete by 2030).

» To calculate the install base growth, the team assumed that the quantity will grow proportional to the growth of households (assuming constant number per household).

Energy Usage:

» To date, DOE has not established efficiency standards, but they are included in ENERGY STAR; in 2011, 97% of all new TVs were ENERGY STAR qualified.

» Active Mode power depends on the screen area. The majority of TVs sold are 40 to 44“.

» We assumed that in 2015, most TVs will still meet the new ENERGY STAR V 5.0 specification. While many TV's will be MORE efficient, insufficient data are available to determine to project to what extent.

» Projections to 2040 based on 10% reduction in power consumption for the current best-in-class, 42in ENERGY STAR qualified TV.

*Source: Fraunhofer (2010) “Energy Consumption of Consumer Electronics in U.S. Homes in 2010”

DVDs consumed 6 TWh in 2011, but rapid penetration of streaming media will reduce energy consumption in the near future.

		2011	2015	2020	2030	2040
Installed Base	(000s)	227,000	218,000	189,000	128,000	86,000
Power Draw (W)	Active	11.8	10.6	9.3	7.2	5.5
	Idle/Ready	8	7.0	6.1	4.6	3.5
	Sleep/Standby	2	1.8	1.4	0.9	0.6
	Off	0	0	0	0	0
Annual Usage (hrs)	Active	284	284	284	284	284
	Idle/Ready	804	804	804	804	804
	Sleep/Standby	7672	7672	7672	7672	7672
	Off	0	0	0	0	0
UEC	kWh/yr	27	23	19	13	9
AEC	TWh/yr	6.0	4.9	3.5	1.6	0.8

This category includes:

- » Standalone DVD players
- » DVD Recorders
- » DVD-VCR Combos
- » Excluded: Standalone VCRs because of a rapidly decreasing installed base, and blu-ray because Fraunhofer (2010) estimates 0.2 TWh/yr AEC*

Type	Active (W)	Idle (W)	Sleep (W)
Standalone DVD	9.0	5.0	1.5
DVD Recorder	18.0	14.0	3
DVD-VCR Combo	12.0	8.0	3

*Source: Fraunhofer (2010) "Energy Consumption of Consumer Electronics in U.S. Homes in 2010"

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DVD (cont.)

- DVDs are not covered by DOE efficiency standards; but they are included in ENERGY STAR; in 2011, 66% of all DVDs sold were ENERGY STAR qualified.
- There were on average 2.1 DVD's per household in the United States (Fraunhofer 2011).
- Fraunhofer 2011 reported 93% household penetration.
- The sale and installed base of DVDs is in decline as more consumers are moving away from DVDs and blu-ray discs, towards streaming online content.
- We estimate a drop in installed base of more than 60% between now and 2040.
- To forecast energy consumption, we assumed that calculated the energy improvement over the next 30yrs using the average power consumption of the best in class listed E* products today.

Laptops consumed 9.8 TWh in 2011 and rapid growth in installed base in tablets will increase energy consumption in the near term.

		2011	2015	2020	2030	2040
Installed Base	(000s)	165,000	240,000	390,000	430,000	470,000
Power Draw (W)	Active	18	13	10	5	2
	Idle/Ready	0	0	0	0	0
	Sleep/Standby	1.9	1.5	1.1	0.6	0.4
	Off	1.0	0.8	0.6	0.4	0.3
Annual Usage (hrs)	Active	2,915	2,915	2,915	2,915	2,915
	Idle/Ready	0	0	0	0	0
	Sleep/Standby	2,232	2,323	2,441	2,697	2,979
	Off	3,613	3,522	3,404	3,148	2,866
UEC	kWh/yr	60	45	33	17	9
AEC	TWh/yr	9.8	10.9	12.7	7.2	4.2

- Category includes laptops, netbooks, and tablet computers.
- TIAX estimated 75% fewer laptops in 2008, and while this estimate may have been low, growth has clearly exploded due to our inclusion of tablets.

Photo Source: www.cpsc.gov, http://today.lbl.gov

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Laptops (cont.)

Installed Base:

» Although approaching household computer saturation, the installed base continues to increase as more families get multiple computers, and more people acquire multiple "laptop" devices, e.g., a laptop and a tablet.

» Between 2010 and 2012, 74 million tablets were sold in the United States.*

» Some analysts expect to see Apple ship 100 Million iPads in 2013 (worldwide).*

Power Consumption:

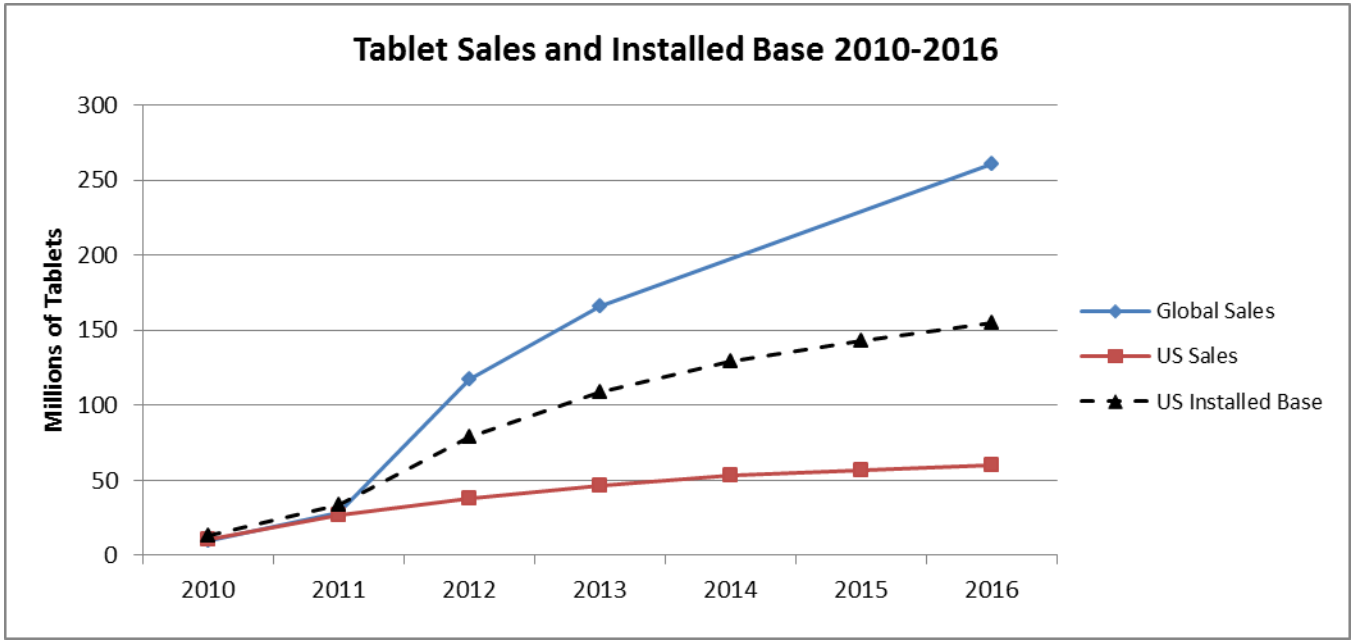
» The Active Mode power draw has decreased and will continue to do so because tablets are an increasing percentage of the installed base and they use less Active Power.

Hourly Usage:

» The number of hours spent in Sleep Mode will continue to increase (and off-mode hours to decrease) because tablets are rarely turned off.

*Source: http://www.statista.com/statistics/180656/sales-of-tablets-and-ipads-in-the-us-until-2012/, http://bgr.com/2012/12/14/ipad-shipments-2013-100-million/

Estimates show approximately 40 million annual tablet sales in the United States in 2012, reaching 60 million annual sales in 2016.



- U.S. 2011 estimated installed base: 34 million units*
- U.S. 2016 estimated installed base: 115 million units**
- Currently, tablets cannibalize the netbook market and seen by consumers as an addition to traditional computers, rather than a replacement, but we expect this trend to change as tablets evolve and their capabilities expand (and expand into the commercial market)***

*Gigaom.com 'tablet users' available at: http://gigaom.com/2011/11/21/u-s-tablet-sales-to-soar-as-sharing-of-devices-decreases/
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EPRI conducted testing on iPad tablets and estimated the UEC at less than 12 kWh/yr based on heavy usage.

Unit Energy Consumption

» Tested two generations of iPads*:
  – Gen 1: 25 Watt-hr capacity battery – **Estimated UEC: 7.2 kWh/yr**
  – Gen 2: 42.5 Watt-hr capacity battery – **Estimated UEC: 11.9 kWh/yr –** larger battery primarily servers to accommodate higher resolution screen

Usage Patterns

» Usage during testing based on assumed every-other-day charging, which we believe to represent very heavy usage patterns

» Anecodotal evidence suggest that casual users (excluding professionals using tablets in commercial settings), may charge tablets once per week or less in some cases

» Some tablet usage represents new electronic functionality for consumers, e.g., reading a newspaper on a tablet vs. print; however, a most usage replaces laptop/desktop usage

Annual Energy Consumption

» Despite rapid growth in installed base, the low UEC does not substantially increase the AEC of the laptop category; as tablet-use continues to grow and replaces laptop/desktop usage, total AEC will ultimately decrease.

* EPRI Study on Ipad Energy Use, Available at: www.epri.com/Our-Work/Documents/Energy%20Efficiency/iPadEnergyConsumeExecSummary6-2012Final.pdf

Desktop computers consumed 22.5 TWh in 2011.

		2011	2015	2020	2030	2040
Installed Base	(000s)	102,000	106,000	106,000	105,000	104,000
Power Draw (W)	Active	57	45	34	20	11
	Sleep/Standby	3.8	3.1	2.4	1.5	0.9
	Off	1.9	1.6	1.2	0.7	0.5
Annual Usage (hrs)	Active	3,420	3,420	3,420	3,420	3,420
	Sleep/Standby	2,150	2,150	2,150	2,150	2,150
	Off	3,190	3,190	3,190	3,190	3,190
UEC	kWh/yr	220	170	130	70	40
AEC	TWh/yr	22.5	18.0	13.8	7.4	4.2

This category includes:

» All desktop computers, including those with monitors integrated into the products (e.g., iMac).

» Monitors are excluded, except when integrated.

Desktop computers (cont.)

Installed Base:

» The installed base will decrease relative to the population as laptops and tablets increase their market shares.

» Two categories of residential users will continue to use desktops, both of which require greater processing power than is typically available on a laptop.
  – PC Gamers – driven by the need for high-power graphics processing
  – Video/photography editing capabilities

» Although desktops will maintain a constant presence, but lower saturation level, the recent rate of evolution in computers may indicate that the desktop market could re-invent itself in yet unknown ways.

Power Consumption:

» Power consumption will decrease, but eventually plateau.

Hourly Usage:

» Hourly usage will likely not change dramatically between now and 2040.

Computer Monitors consumed 12.8 TWh in 2011.

		2011	2015	2020	2030	2040
Installed Base	(000s)	130,000	125,000	119,000	109,000	99,000
Power Draw (W)	Active	34	28	21	21	21
	Idle/Ready	0.0	0.0	0.0	0.0	0.0
	Sleep/Standby	1.1	0.8	0.5	0.5	0.5
	Off	0.8	0.5	0.3	0.3	0.3
Annual Usage (hrs)	Active	2,573	2,573	2,573	2,573	2,573
	Idle/Ready	0	0	0	0	0
	Sleep/Standby	3,505	3,505	3,505	3,505	3,505
	Off	2,682	2,682	2,682	2,682	2,682
UEC	kWh/yr	99	75	56	57	57
AEC	TWh/yr	12.8	9.4	6.7	6.2	5.6

- Includes monitors connected to desktop computers or to laptop computers.
- Excludes monitors that are integrated with a desktop computer (e.g., iMac) or to a laptop (all).
- According to Fraunhofer (2011), approximately 73% of residential monitors are used with desktops and 27% are used with laptops.

Computer Monitors (cont.)

Installed Base:

» We based the installed base of residential monitors on Fraunhofer's (2011) sales data.

» It should also decrease as the number of residential desktops is also decreasing.

Type of Monitor:

» Screen size will continue to increase at a modest rate, similar to the historical rate.

» CRT monitors will reach insignificantly small levels by 2018, which is one lifecycle after 2008, when according to Fraunhofer (2011), "they disappeared from the market" (pg. 66).

Power Consumption:

» Although monitor size continues to increase, efficiency measures will too; therefore, the Active Mode power consumption will remain less than it was in 2011.

Usage Hours:

» Hourly usage is based on the Fraunhofer's (2011) usage hours for monitors associated with desktops and laptops.

Home Audio consumed 16 TWh in 2011 and is expected to grow slowly in the coming years.

		2011	2015	2020	2030	2040
Installed Base	(000s)	193,000	198,000	204,000	219,000	233,000
Power Draw (W)	Active	42.7	42.8	43.0	43.1	42.7
	Idle	0	0	0	0	0
	Sleep	2.7	2.2	1.8	1.4	0.9
	Off	0.5	0.5	0.4	0.3	0.3
Annual Usage (hrs)	Active	1,679	1,679	1,679	1,679	1,679
	Idle	0	0	0	0	0
	Sleep	6,980	6,980	6,980	6,980	6,980
	Off	102	102	102	102	102
UEC	kWh/yr	83	88	85	82	78
AEC	TWh/yr	16.0	17.3	17.3	18.0	18.2

This category includes:

» Component Audio – systems consisting of separate components, including stereo and multi-channel receivers, speakers, amplifiers, and other equipment that are typically mixed and matched to meet the user requirements.

» Compact Audio – smaller systems that frequently have an integrated multi-function hub (receiver/amplifier/CD player/iPod dock, etc.) and two or more matched speakers.

» Home Theater in a Box (HTIB) – a packaged set of audio equipment (receivers, speakers, etc.) designed to work with televisions to provide a "theater-like" audio experience.

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

Audio Equipment (cont.)

Installed Base:

» The installed base was largely based on Fraunhofer (2011) (component audio – 57 million multi-channel/42 million stereo systems; HTIB – 30 million; compact audio – 66 million)

» The projections assume the number of units per home will stay the same, although the penetration rates will vary by type of system.

» Within the component audio category the share of multi-channel (surround sound) systems is expected to increase at the expense of stereo systems.

» HTIB market shares will continue to decrease, per recent trends (CEA data).

» Compact audio market share is also projected to decline.

Power Consumption

» Active mode power consumption may see some modest efficiency gains in the component audio category, however, the move to multi-channel systems with increased power and reductions in stereo systems' market share, will result in a fairly small change in unit energy consumption

» Reductions in non-active power modes (e.g., sleep) are expected due to the effects of Energy Star and possible audio equipment standards.

Usage Hours:

» Usage hours are assumed to remain the same in future years.

Portable Electric Spas consumed 9.5 TWh in 2011 and is expected to grow slowly in the coming years.

		2011	2015	2020	2030	2040
Installed Base	(000s)	4,630	4,880	5,310	6,550	7,540
Power Draw (W)	Active	3,040	4,480	6,280	6,640	6,640
	Standby	225	222	218	218	218
Annual Usage (hrs)	Active	25	25	25	25	25
	Standby	8,735	8,735	8,735	8,735	8,735
UEC	kWh/yr	2,040	2,050	2,060	2,070	2,070
AEC	TWh/yr	9.5	10	11	14	16

- Includes pre-fabricated, self-contained spas or hot tubs that are electrically heated
- Does not include '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.
- Does not include spas that are heated using natural gas

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Portable Electric Spas (cont)

Installed Base:

» The installed base was determined by performing a trend analysis of household penetration rates from 1993 to 2009 using RECS data.

» The penetration rate trajectory was adjusted slightly downward to account for the recent economic recession as evidenced by a decline in spa sales data of over 50% between 2006 and 2012 (TIAX 2006 and APSP/PK Data 2012).

Power Consumption:

» Portable electric spas have two primary operating states: in-use and standby. While in use, the spa pump provides jet, filtering, and circulation function, while the spa maintains a temperature set point. In standby mode, the spa maintains a temperature set point and periodically runs the pump at low speed for filtering.

» Standby mode accounts for the majority of energy consumption (despite lower power consumption) due to much higher relative usage hours than in-use mode.

» Power consumption may see modest efficiency gains in standby mode largely driven by state-level regulations.

» Power consumption will increase while spas are in-use as a result of larger spas with more jets and larger pumps.

» Overall power consumption is expected to increase very slightly over time.

Usage Hours:

» Spas are use approximately 6.25 times per month for 20 min per use (TIAX 2007)

» Usage hours are assumed to remain the same in future years.

Pool Heaters/Pool Pumps consumed 26 TWh in 2011 and is expected to decrease modestly in the coming years.

		2011	2015	2020	2030	2040
Installed Base		10,400,000	11,100,000	11,900,000	13,700,000	15,400,000
Power Draw (w)	On	UEC estimated directly from monitoring, studies, and survey data				
	Off					
Annual Usage (hrs)	On					
	Off					
UEC (kWh/yr)		2,460	2,060	1,640	1,380	1,350
AEC (TWh/yr)		26	23	20	19	21

- 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 swimming pool pumps and pool heaters.
- Includes pool pumps and electric heaters
- Does not include natural gas fueled heating equipment

Pool Heaters/Pool Pumps (cont.)

Installed Base:

» The installed base for 2011 was estimated using data from the Association of Pool and Spa Professionals (APSP/PK Data 2011).

» The growth rate observed between 2001 and 2009 of approximately 175,000 pools per year is expected to continue, slightly outpacing housing growth (RECS 2001 & 2009)

» Only about 5% of pools are heated electrically resulting in a small relative installed base compared to pool pumps (RECS 2009).

Power Consumption:

» Power consumption is predominantly from pool pumps and a very small amount of electric heating (pool heating is predominantly natural gas).

» UEC was estimated directly from based on various studies and surveys however typical single-speed pump power consumption is about 2,000 watts and a new variable speed pump is about 500 – 1,000 watts.

» Power consumption is expected to decrease somewhat dramatically as variable speed pumps phase out single-speed models.

Usage Hours:

» Pool pumps typically run at least five to six hours per day, if not around the clock, consuming energy during the pool season (NREL 2012).

» The length of the pool season ranges from about 4 months in cooler climates to year-round in hot climates.

Home Security Systems consumed 1.3 TWh in 2011 and is expected to increase dramatically in the coming years.

		2011	2015	2020	2030	2040
Installed Base	(000s)	28,000	35,000	49,000	57,000	64,000
Power Draw (W)	Active Standby	5.1	5.1	5.0	5.0	5.0
	Passive Standby	5.1	5.1	5.0	5.0	5.0
	Off	0	0	0	0	0
Annual Usage (hrs)	Active Standby	4,990	4,990	4,990	4,990	4,990
	Passive Standby	3,770	3,770	3,770	3,770	3,770
	Off	0	0	0	0	0
UEC	kWh/yr	45	44	44	44	44
AEC	TWh/yr	1.3	1.6	2.2	2.5	2.8

- Includes primarily a control unit with keypad and a network of sensors that activate audible and visual alarms when an intrusion is detected.
- Does not include external power supplies (captured separately, see External Power Supplies; note that external power supplies were not captured separately in TIAX 2006)
- Does not include video surveillance equipment

Home Security Systems (cont.)

Installed Base:

» The installed base was determined using the following assumptions:
  – Household penetration of monitored security systems is expected to approach 30% by 2020 (Parks 2011)
  – 75-80% of all residential security systems are monitored (Parks 2010)
  – Penetration rate for new households is approximately 40% (Parks 2011)

Power Consumption:

» Power consumption occurs almost entirely in active standby and passive standby modes (on mode is considered to be when the alarm is sounding which 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 with the remaining 10% is from to sensors (Australian Government 2005).

Usage Hours:

» Usage hours are assumed to remain the same in future years.

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Appendix A: The amount of wastewater produced in the United States has been growing slower than the population in recent years.

- As of 2008, the U.S. had more than 21,500 publically owned wastewater treatment plants (WWTPs); privately (investor) owned WWTPs exist but account for a minority of the total population.[1]
- Public supply water consumption data available from the USGS indicate growth in potable water use is slower than growth in population (from 2000 to 2005)
- We expect that the amount of wastewater produced and treated in the US grows 2% every 5 years (for an average annual growth of 0.4%), based on the assumption that:
  - The trend in potable water consumption continues
  - The ratio of potable water consumption to wastewater production remains unchanged

	Nationwide Estimates			
	Public Supply Water		US Population	
Year	(Billion gallons /Day)	Average Annual Growth rate	(Millions)	Average Annual Growth rate
1995	40.2	N/A	266.3	N/A
2000	43.3	1.5%	282.2	1.2%
2005	44.2	0.4%	295.5	0.9%
2013	45.6	0.4%	315.6	0.8%

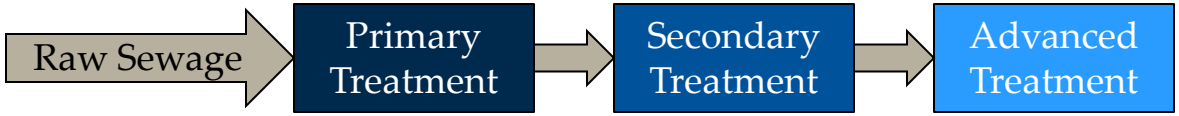
Source: Public Supply Water for 1995-2005 obtained from USGS (http://water.usgs.gov/watuse/), 2013 value is a Navigant Projection. Population data obtained from US Census

1: Source: http://css.snre.umich.edu/css_doc/CSS04-14.pdf

New Slide Sept 2013

Almost all WWTP capacity treats to secondary treatment levels or greater; more than half exceed secondary standards.

» Treatment processes are consecutive; therefore a WWTP that uses advanced treatment necessarily includes both primary and secondary treatment.



» Based on EPA data, approximately 98% (by capacity) of surveyed WWTPs contain secondary treatment and 57% of surveyed WWTPs also use greater than secondary treatment (advanced treatment); EPA is expected to update these data in early 2014.

Increasing Treatment Levels

Surveyed Treatment Facilities in Operation in 2008						
Maximum Treatment Level	Number of WWTPs*	Average Existing Flow (MGD)*	Rated Capacity Flow (MGD)*	Percent of U.S. Population Served*	Total Rated Capacity (MGD)**	Percent of Total Rated Capacity
Partial Treatment	115	190	287	0%	44,865	100%
Less than Secondary	30	422	546	1.2%	44,578	99%
Secondary	7,302	13,142	17,765	30.2%	44,032	98%
Greater than Secondary	5,071	16,776	23,710	36.8%	26,267	57%
No Discharge	2,251	1,815	2,557	5.5%	2,557	6%
N/A	*11*	*0*	*0*	*0%*	*0*	*0%*
Total	14,780	32,345	44,865	74%	-	-

Source: Navigant analysis based on: U.S. EPA. *Clean Watersheds Needs Survey 2008 - Report to Congress.* 2008. Table I-3.
* Based on the distinction of a WWTP's maximum treatment level
** Navigant calculation assuming all capacity listed as a higher level of treatment necessarily has the lower level of treatment. Calculated by summing Rated Capacity Flow (MGD) rows below and including the current row

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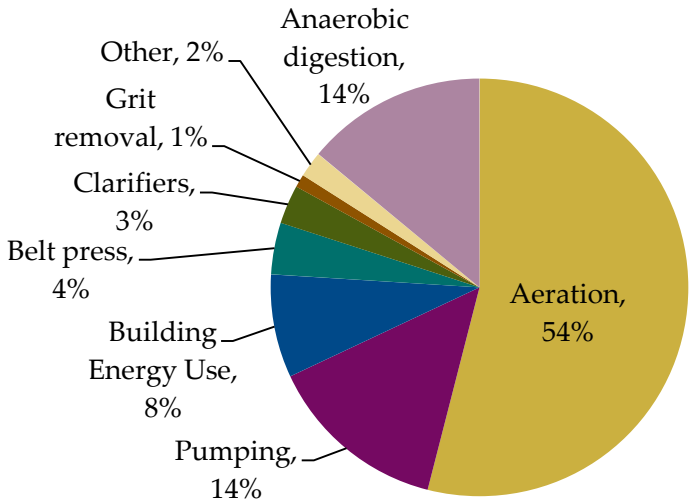
Energy use in Wastewater Treatment Plants (WWTPs) depends on plant size and treatment requirements.

- Higher levels of treatment (better effluent quality) requires more energy
- Economies of scale allow larger wastewater treatment plants to have lower energy intensities (kWh/million gallons treated) than smaller plants
- Majority of energy use in plants is for secondary treatment systems (e.g., aeration systems), pumping, and anaerobic digestion (if applicable)

	Energy Intensity (kWh/Million Gallons Treated)			
	Secondary Treatment		Greater than Secondary Treatment	
WWTP Size (Million Gal/Day)	Trickling Filter	Activated Sludge	Advanced Treatment	Advanced Treatment Nitrification
	Increasing Treatment Levels →			
1	1,811	2,236	2,596	2,951
5	979	1,369	1,573	1,926
10	852	1,203	1,408	1,791
20	750	1,114	1,303	1,676
50	687	1,051	1,216	1,588
100	673	1,028	1,188	1,558

Source: EPRI. *Water and Wastewater Industries: Characteristics and Energy Management Opportunities: A Report That Describes How Electricity is Used and Can Be Managed Efficiently in Water.* 1996.

Illustrative Energy Use For an Activated Sludge WWTP



Source: (SAIC). *Water and Wastewater Energy Best Practice Guidebook.* Focus on Energy. 2006.

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More recent energy intensity data for some California WWTPs are available, though large ranges exist in the data.

» A study commissioned by the California Public Utilities Commission (CPUC) collected 2008 vintage data from 14 wastewater utilities across California*
  – Goal: Calculate range of average energy intensity
  – Results were not disaggregated by treatment plant size

Key Findings:

» WWTPs with both primary and secondary treatment consumed 488-1,622 kWh/Mgal

» WWTPs with primary, secondary, and tertiary treatment consumed 1,086-4,531 kWh/Mgal

» Although the relation of energy intensity and plant size are not explicitly plotted in the study, reviewing some of the detailed data indicates the upper bounds of energy intensity are represented by smaller plants (less than 10 Mgal/day)

» Data on the Orange County Ground water replenishment system (an advanced 70 Mgal/Day plant using microfiltration, reverse osmosis and UV light) was found to use 3,161 - 3,771 kWh/Mgal, this is ***incremental*** to secondary treatment energy use.

1: GEI Consultants and Navigant Consulting. *Embedded Energy in Water Studies Study 2: Water Agency and Function Component Study and Embedded Energy-Water Load Profiles.* 2010

Targeting aeration systems and pumps offers the most opportunity for energy efficiency in WWTPs.

- Almost all WWTPs use secondary treatment, which uses aeration systems to provide dissolved oxygen to wastewater. Air compressors **(aeration blowers)** typically supply air through bubble aerators and account for 40-60% of WWTP energy use. Aeration energy reductions of up to 40% are possible with the following technologies:[1]
  - Fine bubble aerators
  - High efficiency blowers with variable speed drives
  - Automatic dissolved oxygen controls
- Pumping energy can be reduced through use of high efficiency pumps and motors and variable speed drives.
- Refurbishment and repair of existing pumps can offer a lower cost alternative that can reduce pumping energy use by 5-30% depending on the current condition of pumps.[2]
- Medium and large sized WWTPs have an opportunity to make beneficial use of biogas to self-generate electricity or for combined heat and power (CHP); heat is used to maintain optimal digester temperature.

Wastewater Aeration in Secondary Treatment

Pumps pre- (left) and post- (right) refurbishment

1: Additional details and case studies are available at: http://sustainca.org/programs/water_energy/measures/aeration_system_improvement
2: Additional details and case studies are available at: http://sustainca.org/programs/water_energy/measures/select_best_practices_pumps

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Future, more aggressive treatment requirements may increase WWTP energy consumption.

» The National Pollutant Discharge Elimination System (NPDES) permit system regulates point sources that discharge pollutants into waters of the United States. Permits are generally issued by each state; requirements can vary by state and region.

» The EPA requires a minimum of secondary treatment by Publicly Owned Treatment Works and sets minimum treatment guidelines regarding effluent concentrations. Approximately 2% of WWTP capacity does not meet secondary levels and must ultimately comply with this requirement, doing so would increase energy use. These plants are concentrated in CA, HI, MA, and Puerto Rico.[1]

» Emerging contaminants (such as pharmaceuticals and personal care products) are showing up in higher concentrations in wastewater systems and treated wastewater effluent. WWTPs may be required to add treatment equipment or processes in the future to meet NPDES requirements and ensure that emerging contaminants are removed.

» There are multiple examples of WWTPs installing more advanced treatment technologies in response to local water quality concerns
  – Sacramento Regional County Sanitation District adds tertiary treatment (http://www.sustainabledelta.com/SacRegionalFeature.html)
  – Orange County Sanitation District expands secondary treatment capacity to match primary treatment capacity (http://www.ocsd.com/modules/showdocument.aspx?documentid=14200)

1: U.S. EPA. *Clean Watersheds Needs Survey 2008 - Report to Congress.* 2008. Appendix I

Increased use of recycled water may increase energy use; difficulty in funding non-essential projects may delay investment in efficiency.

- Water planners in certain regions of the U.S. (e.g., CA and TX) are encouraging increased development and use of recycled water as a method to mitigate drought impacts.
  - California has a goal to produce and use 1 Million Acre-feet of recycled water by 2020; 2 Million by 2030.[1] Anecdotal information shows a strong interest in developing recycled water in Texas in response to extreme drought conditions.[2]
  - Recycled water requires advanced treatment (usually tertiary treatment) and disinfection. This could increase energy consumption in WWTPs as additional treatment processes are installed; however. overall national energy use could remain the same or decrease as other energy intensive supplies such as groundwater and imported water are used less.
  - Example: Orange County's Ground Water Replenishment system recycles wastewater to beyond drinking water standards, though at a relatively high energy **use** compared to typical WWTPs
- Wastewater utilities face challenges in securing approval and funding capital projects.
  - Spending is prioritized on critical projects such as expanding capacity, maintaining infrastructure), and compliance with new water quality standards and projects with short payback periods. Some energy efficiency and self generation investments take too long to payback, decreasing the likelihood of their adoption.
  - Approval from board of directors' may be required for projects above a certain dollar threshold. (e.g., $100,000). Boards comprised of elected officials may have to answer to the demands of customers to keep rates low (thus minimizing capital costs passed on to customers)[3]

1: http://www.waterboards.ca.gov/water_issues/programs/water_recycling_policy/docs/recycledwaterpolicy_approved.pdf
2: http://www.cnn.com/2011/US/08/10/texas.desperate.to.drink/index.html
3: KEMA. *Industrial Sectors Market Characterization: Water and Wastewater Industry*. 2012

Appendix B: Commercial MELs 2011 Base Year summary – 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
Water Distribution*	256,000	512,000	213,000	639,000	597,000	639,000	384,000	384,000	213,000	1,023,000	256,000	5,115,000
IT Equipment	12,200	101,000	5,800	5,400	21,400	19,000	148,000	94,000	45,300	14,100	21,400	487,000
MonitorsPC	2,300	19,000	1,100	1,000	4,100	3,600	28,000	18,000	8,700	2,700	4,100	93,000
DesktopPC	1,900	15,000	890	820	3,300	2,900	22,000	14,000	6,900	2,200	3,300	74,000
LaptopPC	1,600	13,000	750	690	2,800	2,500	19,000	12,000	5,800	1,800	2,800	63,000
Data Center Servers	0	0	0	0	0	0	0	0	0	0	12,200	12,200
Security Systems	1,000	970	540	500	20	330	110	2,600	2,400	1,100	1,000	11,000
Distribution Transformers	380	390	440	460	210	400	450	600	1,500	360	280	5,470
Video Displays	32	160	240	160	32	32	112	112	640	0	80	1,600
Lab R-Fs	0	215	0	0	340	0	0	0	0	0	445	1,000
Kitchen Ventilation	30	302	104	322	9	21	0	0	4	0	0	790
Medical Imaging Equipment	0	0	0	0	59	0	0	120	0	0	0	178
Large Format Video Boards	1	0	0	0	0	0	0	0	0	0	0	1

Note: Rows do not sum due to rounding

***Water Distribution is in Millions of Gallons per year (Mgal/yr)**

Appendix B: Commercial MELs 2011 Base Year summary – Unit Energy Consumption by building type.

UEC (kWh/yr)	Assembly	Education	Food Sales	Food Service	Healthcare	Lodging	Large Office	Small Office	Mercantile & Service	WareHouse	Other	Wtd Avg
Large Format Video Boards	152,000	152,000	152,000	152,000	152,000	152,000	152,000	152,000	152,000	152,000	152,000	152,000
Kitchen Ventilation	109,000	51,500	111,000	22,900	105,000	112,000	0	0	119,000	0	0	52,000
Medical Imaging Equipment	0	0	0	0	32,500	0	0	6,500	0	0	0	15,000
Distribution Transformers	7,400	8,500	6,400	6,100	10,800	8,500	10,900	6,000	7,900	8,800	8,900	7,900
Lab R-Fs	0	4,700	0	0	3,600	0	0	0	0	0	5,100	4,500
Security Systems	742	1,121	307	329	10,440	1,672	7,495	311	498	945	626	2,500
Data Center Servers	0	0	0	0	0	0	0	0	0	0	2,400	2,400
Water Distribution*	1,284	1,284	1,284	1,284	1,284	1,284	1,284	1,284	1,284	1,284	1,284	1,284
Video Displays	1,084	1,084	1,084	1,084	1,084	1,084	1,084	1,084	1,084	1,084	1,084	1,084
DesktopPC	402	402	402	402	402	402	402	402	402	402	402	400
MonitorsPC	198	198	198	198	198	198	198	198	198	198	198	198
LaptopPC	34	34	34	34	34	34	34	34	34	34	34	34
IT Equipment	25	25	25	25	25	25	25	25	25	25	25	25

Note: Rows do not sum due to rounding

***Water Distribution is in kWh/Mgal/yr or kWh per million gallons per year**

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Appendix B: Commercial MELs 2011 Base Year summary – Annual Energy Consumption by building type

AEC (TWh/yr)	Assembly	Education	Food Sales	Food Service	Healthcare	Lodging	Large Office	Small Office	Mercantile & Service	WareHouse	Other	Total
Distribution Transformers	2.8	3.3	2.8	2.8	2.3	3.4	4.9	3.6	12	3.2	2.5	43
Kitchen Ventilation	3.3	15.6	11.5	7.4	0.9	2.4	0.0	0.0	0.5	0.0	0.0	41
DesktopPC	0.8	6.0	0.4	0.3	1.3	1.2	8.8	5.6	2.8	0.9	1.3	30
Data Center Servers	0	0	0	0	0	0	0	0	0	0	29	29
MonitorsPC	0.5	3.8	0.2	0.2	0.8	0.7	5.5	3.6	1.7	0.5	0.8	18
IT Equipment	0.3	2.5	0.1	0.1	0.5	0.5	3.7	2.4	1.1	0.4	0.5	12
Security Systems	0.8	1.1	0.2	0.2	0.2	0.5	0.9	0.8	1.2	1.0	0.6	7.4
Water Distribution	0.3	0.7	0.3	0.8	0.8	0.8	0.5	0.5	0.3	1.3	0.3	6.6
Lab R-Fs	0.0	1.0	0.0	0.0	1.2	0.0	0.0	0.0	0.0	0.0	2.3	4.5
Medical Imaging Equipment	0.0	0.0	0.0	0.0	1.9	0.0	0.0	0.8	0.0	0.0	0.0	2.7
LaptopPC	0.1	0.4	0.0	0.0	0.1	0.1	0.6	0.4	0.2	0.1	0.1	2.1
Video Displays	0.0	0.2	0.3	0.2	0.0	0.0	0.1	0.1	0.7	0.0	0.1	1.7
Large Format Video Boards	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2

Note: Rows do not sum due to rounding

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Appendix C: Residential MELs 2011 Base Year summary

	Installed Base (000s)	UEC (kWh/yr)	AEC (TWh/yr)
Televisions	355,000	197	70.0
Pool Heaters & Pumps	10,400	2,460	25.5
Desktop PCs	102,000	220	22.5
Set Top Boxes	176,000	127	22.4
Ceiling Fans	263,000	77	20.2
Audio Equipment	193,000	83	16.0
Monitors	130,000	99	12.8
Dehumidifiers	15,600	710	11.1
Laptop PCs	165,000	60	9.8
Portable Electric Spas	4,630	2,040	9.5
Modems & Routers	138,000	51	7.0
External Power Supplies	1,077,000	6	7.0
DVD Players	227,000	27	6.0
Non PC Rechargeable Electronics	1,200,000	4	4.4
Home Security Systems	28,000	45	1.3

Appendix D: Residential MELs Installed Base Projections

	Installed Base (000s)					
	2011	2015	2020	2030	2040	Trendline
Non PC Rechargeable Electronics	1,200,000	1,350,000	1,570,000	2,110,000	2,840,000	
External Power Supplies	1,077,000	1,210,000	1,400,000	1,880,000	2,530,000	
Televisions	355,000	364,000	388,000	444,000	501,000	
Ceiling Fans	263,000	283,000	300,000	325,000	325,000	
DVD Players	227,000	218,000	189,000	128,000	86,000	
Audio Equipment	193,000	198,000	204,000	219,000	233,000	
Set Top Boxes	176,000	233,000	352,000	400,000	442,000	
Laptop PCs	165,000	240,000	390,000	430,000	470,000	
Modems & Routers	138,000	120,000	120,000	120,000	130,000	
Monitors	130,000	125,000	119,000	109,000	99,000	
Desktop PCs	102,000	106,000	106,000	105,000	104,000	
Home Security Systems	28,000	35,000	49,000	57,000	64,000	
Dehumidifiers	15,600	16,400	17,400	19,500	21,600	
Pool Heaters & Pumps	10,400	11,100	11,900	13,700	15,400	
Portable Electric Spas	4,630	4,880	5,310	6,550	7,540	

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Appendix D: Residential MELs UEC Projections

	UEC (kWh/yr)					
	2011	2015	2020	2030	2040	Trendline
Pool Heaters & Pumps	2,460	2,060	1,640	1,380	1,350	
Portable Electric Spas	2,040	2,050	2,060	2,070	2,070	
Dehumidifiers	710	620	530	510	490	
Desktop PCs	220	170	130	70	40	
Televisions	197	150	130	100	94	
Set Top Boxes	127	107	93	77	76	
Monitors	99	75	56	57	57	
Audio Equipment	83	88	85	82	78	
Ceiling Fans	77	71	65	55	47	
Laptop PCs	60	45	33	17	9	
Modems & Routers	51	44	38	28	20	
Home Security Systems	45	44	44	44	44	
DVD Players	27	23	19	13	9	
External Power Supplies	6.5	5.6	4.9	3.2	2.2	
Non PC Rechargeable Electronics	3.7	3.2	2.8	1.8	1.8	

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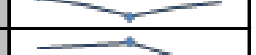
Appendix D: Residential MELs AEC Projections

	AEC (TWh/yr)					
	2011	2015	2020	2030	2040	Trendline
Televisions	70	55	50	44	47	
Pool Heaters & Pumps	26	23	20	19	21	
Desktop PCs	22	18	14	7.4	4.2	
Set Top Boxes	22	25	33	31	34	
Ceiling Fans	20	20	20	18	15	
Audio Equipment	16	17	17	18	18	
Monitors	13	9.4	6.7	6.2	5.6	
Dehumidifiers	11	10	9.2	9.9	11	
Laptop PCs	9.8	11	13	7.2	4.2	
Portable Electric Spas	9.5	10	11	14	16	
Modems & Routers	7.0	5.2	4.5	3.3	2.6	
External Power Supplies	7.0	6.8	6.8	6.0	5.7	
DVD Players	6.0	4.9	3.5	1.6	0.8	
Non PC Rechargeable Electronics	4.4	4.3	4.3	3.9	5.0	
Home Security Systems	1.3	1.6	2.2	2.5	2.8	

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Appendix E: Commercial MELs Installed Base and UEC Projections

	Installed Base (000s)					
	2011	2015	2020	2030	2040	Trendline
Water Distribution*	5,115,000	5,250,000	5,514,000	5,956,000	6,402,000	
IT Equipment	487,000	551,000	642,000	873,000	1,190,000	
MonitorsPC	93,000	91,000	86,000	77,000	71,000	
DesktopPC	74,000	69,000	61,000	47,000	36,000	
LaptopPC	63,000	77,000	92,000	120,000	150,000	
Data Center Servers	12,200	14,000	16,000	21,000	28,000	
Security Systems	11,000	12,000	14,000	18,000	22,000	
Distribution Transformers	5,470	5,700	6,000	6,600	7,300	
Video Displays	1,600	3,200	5,200	9,200	13,200	
Lab R-Fs	1,000	1,030	1,100	1,200	1,300	
Kitchen Ventilation	790	810	860	950	1,050	
Medical Imaging Equipment	178	186	195	215	238	
Large Format Video Boards	1.0	1.0	1.0	1.0	1.0	

Note: *Water Distribution is in Mgal/yr

	UEC (kWh/yr)					
	2011	2015	2020	2030	2040	Trendline
Large Format Video Boards	152,000	144,000	137,000	129,000	121,000	
Kitchen Ventilation	52,000	51,000	48,000	41,000	33,000	
Medical Imaging Equipment	15,000	15,000	15,500	15,400	15,400	
Distribution Transformers	7,900	7,900	7,500	6,800	6,100	
Lab R-Fs	4,500	4,200	3,900	3,400	3,000	
Security Systems	2,500	2,400	2,300	2,100	2,000	
Data Center Servers	2,400	2,500	2,600	3,000	3,400	
Water Distribution*	1,284	1,310	1,340	1,410	1,480	
Video Displays	1,084	1,252	1,311	1,216	929	
DesktopPC	400	301	216	111	47	
MonitorsPC	198	168	112	87	69	
LaptopPC	34	24	19	13	8	
IT Equipment	25	25	24	23	22	

Note: *Water Distribution is in kWh/Mgal/yr

Appendix E: Commercial MELs AEC projections.

	Annual Energy Consumption (TWh/yr)					
	2011	2015	2020	2030	2040	Trendline
Distribution Transformers	43	45	45	45	45	
Kitchen Ventilation	41	41	41	39	35	
DesktopPC	30	21	13	5.2	1.7	
Data Center Servers	29	35	42	63	95	
MonitorsPC	18	15	10	6.7	4.9	
IT Equipment	12	14	15	20	26	
Security Systems	7.4	8.2	9.2	11	13	
Water Distribution	6.6	6.9	7.4	8.4	9.5	
Lab R-Fs	4.5	4.3	4.3	4.1	3.9	
Medical Imaging Equipment	2.7	2.8	3.0	3.3	3.7	
LaptopPC	2.1	1.8	1.8	1.5	1.3	
Video Displays	1.7	4.0	6.8	11	12	
Large Format Video Boards	0.15	0.14	0.14	0.13	0.12	

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Appendix F: List of all candidate MELs.

Class	Technology
Food	Cuisinarts
	Microwave Ovens
	Ranges
	Ovens
	Broilers
	Griddles
	Fryers
	Steamers
	Toasters
	Toaster Ovens
	Preparation Tables
	Blenders
	Immersion Blenders
	Hand Mixers
	Waffle Makers
	George Foreman Grills
	Disposals
	Trash Compactors
	Ice Makers/Machines
	Dishwashers
	Hot Pots
	Electric Kettles
	Mixers
	Slicers
	Meat Grinders
	Food Processors
	Coffee Machines
	Kitchen Exhaust Hoods
Cleaning	Washing Machines
	Clothes Dryers
	Irons
	Vacuum Cleaners, Full Size
	Hand Vacuums
	Floor Washers

Class	Technology
Home Entertainment	Televisions, Analog
	Televisions, Digital
	DVD Players
	VCRs
	Streaming Media Players
	Video Game Consoles
	Set-Top Boxes, Cable
	Set-Top Boxes, Satellite
	Set-Top Boxes, DVR
	Set-Top Boxes, DTA
	Compact Audio Systems
	Component Stereos
	Home Theater in a Box
	Audio Equipment
Personal Electronics	MP3 Players
	Digital Cameras
	GPS units, Watches
	GPS units, Car-Mounted
Tools	Drills
	Saws
	Sanders
Personal Hygiene	Hair Dryers
	Hair Straighteners
	Razors, Electric
	Toothbrushes, Electric
Refrigeration	Residential Refrigerators and R/F
	Residential Freezers
	Walk-in refrigerators
	Open display cases
	Closed display case/merchandiser
	Unit coolers and freezers
	Refrigerated prep tables
	Supermarket Refrigeration
	Refrigerated Vending Machines

Class	Technology
Medical	X-Rays
	MRIs
	CT-Scanners
	Ophthalmoscope
	EKGs
	Ultrasounds
	Heating Pads
	Defibrillators
	IV carts
	Heart Rate Monitors
	Hospital Beds
	Exam Tables
	Exam Lights
	Sterilizers
	Endoscopes
	Electronic Doors
	Speaker Systems
Agricultural	Irrigation Systems
Communications	Cordless Phones
	Cellular Phones
	Bluetooth Headsets
Computer Devices	PCs, Desktop
	PCs, Laptop
	PCs, Netbook
	PCs, Tablet
	Monitors
	Routers
	Modems, Broadband
	Computer Docks
	Scanners
	Inkjet Printers
	Laser Printers
	Impact Printers
	MFDs
	External Hard Drives
	Electronic Books

Class	Technology
Residential misc.	Portable Electric Spas
	Dehumidifiers
	Ceiling Fans
	Whole House Fans
	Pools/Pool Pumps
	Water Bed Heaters
	Portable Lighting
	Outdoor Lighting
	Security Systems, Home
	Aquariums
	Garage Door Openers
	Space Heaters
	Fireplaces, Electric
	Disposals
	Hand Appliances
	Invisible Pet Fences
	Water Coolers
	Clocks
	Nightlights
	Air Purifiers
Commercial misc.	Non-Refrigerated Vending Machines
	Elevators
	Escalators
	Computer Servers
	Other Office Equipment
	Automated Teller Machines (ATMs)
	Coffee Brewers
	Shredders
	Copiers
	Security Cameras
	Electric Door Locks
	Electric Doors
	Fax Machines

Class	Technology
Public Works	Well Pumps/Water Distribution Systems
	Water Purification Systems
	Water Treatment Systems
Entertainment	Arcades
	Slot Machines
Fitness	Treadmills
	Ellipticals
	Stair Masters
	Stationary Bikes
	Rowing Machines
	Arc Trainers
Laboratory	Lab Fume Hoods
	Oscilloscopes
	Power Supply
	Multi-meter
	Furnaces
	Centrifuges
	Pumps
	Electronic Scales
	Microscopes
	Turbines
	Incubators
	Refractory
	Autoclaves
	Lab Refrigerators/Freezers
Non-Road Vehicles	Forklifts, Electric
	Burden carriers
	Utility Vehicles
	Sweeper-Scrubbers
	Burnishers
	Golf Carts
Other	Uninterruptible Power Supplies (UPSs)
	Point-of-Service Equipment
	Distribution Transformers
	Parking meters
	Street Lamps
	Mobile Phone Towers

Appendix G: Other residential MELs removed during secondary screening.

Item	Installed Base	AEC (TWh/yr)	Data Year
Washing Machines	83,443,800	75.18	2011
Refrigerators	107,768,400	69.08	2004
Clothes Dryers	59,108,400	31.35	
Freezers	22,172,700	9.02	2005
Dishwashers	54,707,000	8.26	2012
Monitors			
Ovens, Electric	9,177,600		2011
Power Tools			
Ranges, Electric	54,785,600		2011
Space Heaters			
Whole House Fans			

Appendix G: Other commercial MELs removed during secondary screening.

Item	Installed Base	AEC (TWh/yr)	Data Year
Ovens	1,122,000	14.40	2008
Ice Makers/Machines	2,600,000	11.00	2008
Printers	34,000,000	11.00	2008
Vending Machines	6,600,000	11.00	2008
Steamers	1,156,000	9.80	2008
Griddles	786,000	5.30	2008
Fryers	935,000	4.80	2008
Televisions	16,000	3.80	2008
Irrigation Systems		3.60	2008
Copiers	3,700,000	2.70	2008
Broilers	87,370	2.50	2008
Ranges	187,000	2.30	2008
Exam Lights			2012
Speaker Systems			

Appendix H: Projection Resources

	2009	2010	2011	2015	2020	2030	2040
U.S. Population	307,840,000	310,064,270	312,375,977	324,594,543	340,450,043	372,414,948	404,386,292
Number of Households	113,780,000	115,230,000	116,170,000	120,780,000	127,520,000	140,630,000	153,320,000
Household to Population Ratio	0.370	0.372	0.372	0.372	0.375	0.378	0.379
New Housing Starts	600,000	640,000	660,000	1,640,000	1,890,000	1,890,000	1,890,000
Avg Household square footage (ft^2)	1,646	1,653	1,659	1,682	1,704	1,740	1,767
Commercial Building Floorspace (MM ft^2)	80,300	81,100	81,700	84,100	89,100	98,100	108,800
Bldg Floorspace Growth Rate (%)		0.996%	0.740%	0.726%	1.162%	0.967%	0.967%
U.S. Gross Domestic Product (MM USD)	12,703,000	13,063,000	13,299,000	14,679,000	16,859,000	21,355,000	27,277,000
Annual Residential Elec Use (TWh)	1,366	1,445	1,424	1,366	1,418	1,571	1,767

» 2009 data from AEO 2012

» 2010-2040 data from AEO2013 Early Release

= Directly from sources (see above) **=Calculated**

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