Literature Review of Miscellaneous Energy Loads (MELs) in Residential Buildings

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1. Executive Summary

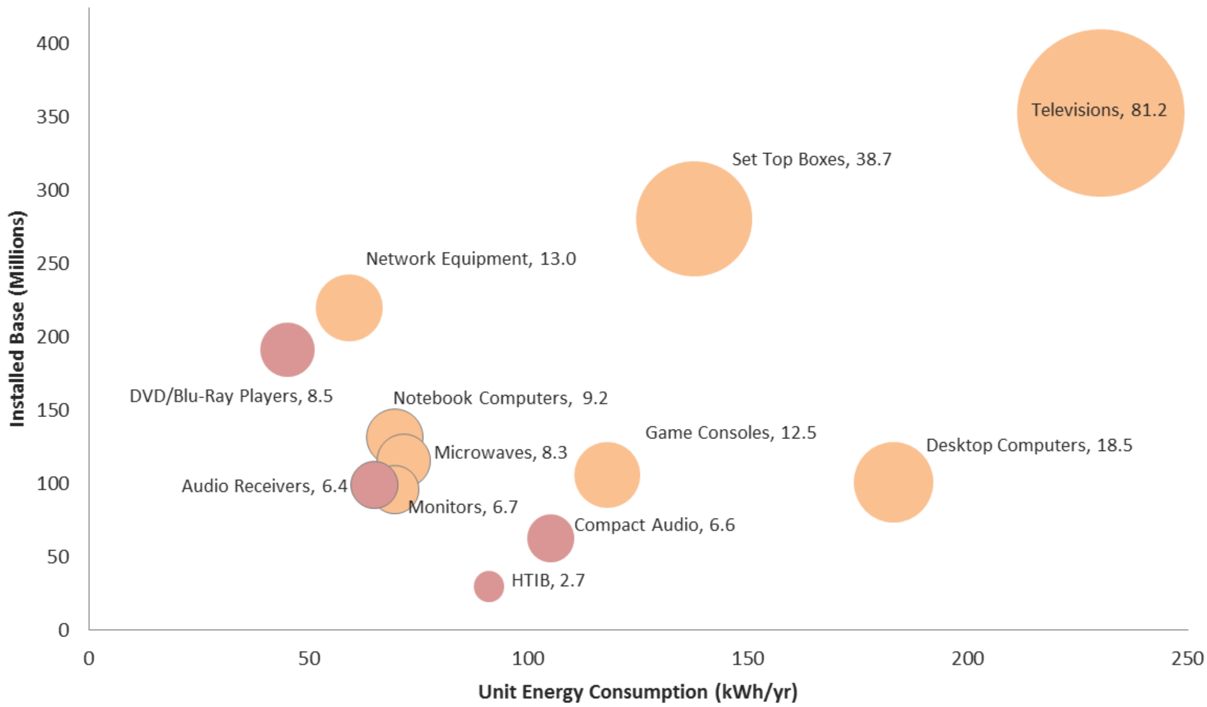
Energy consumption from Miscellaneous Energy Loads (MELs) in Residential buildings is growing faster than any other end use category and has offset some of the efficiency gains made in lighting, HVAC, and water heating (EIA 2013). Historically, it has been difficult to develop precise estimates of MEL energy use, and the highly distributed nature of MEL energy use makes it time-consuming and expensive to collect meaningful data across the wide number of end uses. While there are a wide range of studies that estimate energy consumption for individual MELs, it is difficult to evaluate their relative uncertainty without an in-depth review of study methodology. From a ZNE planning perspective, understanding the relative confidence in MEL estimates is critical.

The purpose of this study is to evaluate the relative certainty of existing estimates by conducting a literature review of existing MEL studies and to identify their underlying respective methodologies. Due to the limited scope of this study, it does not include original, primary research on MEL energy use or significant manipulation of existing study data. Based on this information, we identify best available estimates, identify gaps in existing information, and develop recommendations for future study. In addition, this report provides an overview of alternative methods of estimating energy use and load disaggregation techniques using Non-Intrusive Load Monitoring (NILM), which has the potential to improve accuracy and lower the costs of estimating MEL energy use. It is important to note that this literature review is, by nature, a backward looking study, and does not reflect the most up-to-date usage or energy consumption of new devices coming to market; rather, it is a review of existing estimates to clarify the uncertainty of existing data and identify best available information for existing stock.

Overall, we found that existing MEL energy estimates have a relatively high degree of uncertainty. While there have been significant studies to characterize usage, power, and/or installed base of MELs, they typically lack the scale and comprehensiveness to provide a high level of certainty. A major source of uncertainty is usage hours, which are typically more variable than power or installed base estimates and have the greatest impact on Unit Energy Consumption (UEC, measured in kWh/yr) and Annual Energy Consumption (AEC, measured in TWh/yr). Power in each mode, although better understood, changes more rapidly than usage and is a major driver of shifting UEC values over time. In most cases, installed base estimates have the least amount of variation. As consumer electronics products go through varying phases of popularity, the greatest uncertainty for the installed base is understanding how many products within the installed base are actually used and plugged in.

The “Big Three”, Televisions, Set Top Boxes (STB), and Desktop Computers, dominate AEC, representing 65% of combined AEC of the twelve end uses. However, this is expected to change significantly due to recent efficiency gains for TV and STB products, as well as decreases in the installed base of desktop computers. As the major MEL end uses decrease in both AEC and UEC, it is likely that MEL energy use will become even more widely distributed, concentrated around the existing clusters shown in Figure 1. This suggests that over time, energy use within the MEL category will become even more distributed than it currently is and will require innovative policy and program approaches to successfully address MEL energy consumption.

Figure 1: Overview of Selected MEL Energy Estimates and their level of Certainty



1: Bubble Size corresponds to Annual Energy Consumption (TWh/yr).

2: Bubble Color corresponds to overall level of certainty of end use energy data. (Medium=Orange, Low=Red)

As MELs (and the broader category of plug-in equipment as a whole) become an increasingly large component of building energy use, it is critically important that MELs energy usage is accurately represented in ZNE models. Inaccurate modeling will create one of two undesirable outcomes: a) If plug-in equipment energy use is significantly higher than modeled, the home will not actually be ZNE; or b) if plug-in equipment energy use is significantly lower than modeled, developers will be required to unnecessarily increase the size of the rooftop PV system, which presents additional cost to the developer. While this study does not quantify the impact on ZNE modeling absent this true-up, the potential implications are sufficiently large to warrant future study.

The broader issue of plug-load modeling centers around three points:

1) How to incorporate MELs and other plug loads into the existing HERS model,
2) How to collect MEL data on an ongoing basis and integrate updated data into the HERS model; and
3) How to assess the accuracy of this data.

We believe that this study provides a useful framework for assessing study accuracy and the start of developing higher resolution estimates of MELs. Our recommendations focus on the first two points above[1] and are separated into “Next Steps” and “M&E Research Roadmap Recommendations”.

Next Step Recommendations

Recommendation #1: Update the HERS model to incorporate large MEL end-uses

We estimate that the twelve end uses described in detail in this report account for roughly 60-70% of household MEL energy consumption. However, based on the 2008 Home Energy Rating System (HERS) technical manual, miscellaneous electricity consumption is modeled as a function of square footage, and the only plug loads that are individually modeled are refrigerator/freezers, dishwashers, clothes dryers, clothes washers, and range/ovens.[2] The current ZNE modeling equation does not disaggregate within this broad MEL category, which does not allow for developing individual MEL estimates or refining them over time as they change. We recommend that the next version of the HERS model be updated to individually account for major MELs. At a minimum, this would include televisions but would ideally be extended to other MELs with high AEC values and a large installed base, including, but not limited to, desktop and notebook computers, set top boxes, network equipment, and microwaves. In addition, we recommend that the Investor-owned Utilities (IOUs) engage Non-Intrusive Load Monitoring (NILM) technology vendors to discuss the feasibility of modeling large, non-MEL end uses to better understand the fractional home energy use of MELs.

Recommendation #2: Develop a Stock-Flow model to inform ZNE modeling efforts

Most MELs, especially consumer electronic (CE) devices, experience rapid product turnover and require frequent updates to maintain accurate estimates of usage, power, and installed base. Therefore, accurate modeling of CE devices requires an understanding of both existing stock energy use *and* how that stock energy use is expected to change over time. For example, TVs have by far the highest energy consumption of all MELs, both in terms of UEC and AEC. However, new TVs coming to market are highly efficient, and Active Mode Power for new TVs has decreased by approximately 65% during the 2008-2013. By 2020, a significant portion of the existing TV stock will have turned over and be composed of products purchased in 2014 or later, and therefore TV stock energy use will be substantially smaller than it is today. To accurately model and forecast future energy use, we recommend creating a stock-flow analysis a major MELs to model how new products coming to market will impact stock energy use over time. This consists of identifying the following:

- How technology usage patterns change over time,
- How power draw of new products entering the market changes over time, and

[1] While our recommendations our focused on improving ZNE modeling efforts, these recommendations also have implications for utility efficiency programs. While not discussed in detail here, a number of these strategies are outlined in the Northeast Energy Efficiency Partnership’s (NEEP) 2013 Business and Consumer Electronics Strategy document. https://neep.org/Assets/uploads/files/market-strategies/BCE/2013%20BCE%20Strategy_FINAL.pdf

[2] See Section 4.5.6, Equation 10 in CEC 2008. http://www.energy.ca.gov/2008publications/CEC-400-2008-012/CEC-400-2008-012-CMF.PDF

- The flow of products into the home and how they affect the installed base (Do they increase the installed base or provide a straight replacement of older products? Do certain devices replace other device types – such as a notebook or tablet replacing a TV and/or stereo.).

This stock-flow analysis is especially important to improve energy use estimates for end uses with medium confidence levels. For these end uses, there is a limited opportunity to improve upon existing estimates without a large-scale, comprehensive metering assessment that provides a higher degree of data resolution (see Recommendation #6). A stock-flow analysis can provide additional resolution for ZNE modeling without undertaking a large-scale, comprehensive metering assessment. While we recommend this as a next step, we believe it should also be considered as part of longer-term M&E research.

Recommendation #3: Improve existing data for MELs with low levels of confidence

For products with limited existing data on usage, power, and/or installed base, we recommend updating current estimates to better characterize existing energy use. To improve usage and power data, we recommend obtaining this data from large-scale metering studies instead of user surveys due to the limitations of survey data to accurately reflect actual usage for smaller consumer electronics. For installed base and saturation data, we recommend using saturation data from the forthcoming 2012 California Lighting and Appliance Saturation Survey (CLASS) (KEMA 2014).

Recommendation #4: Work with ENERGY STAR and other stakeholders to improve energy information for non-ENERGY STAR products

A major challenge in modeling MEL energy consumption is the very limited data for non-ENERGY STAR models. Developing a better understanding of the energy use of an entire product category is a critical component of developing a stock-flow model, as well understanding potential energy savings opportunities for future utility programs. While ENERGY STAR typically lists energy data for qualifying products, there is very little data on non-qualifying models entering the market. In some cases, especially Audio / Video devices, the little data that is available is limited and often has a low level of certainty. We recommend working with EPA and other stakeholders to identify opportunities to improve the existing knowledge base of non-qualifying products coming to market.

M&E Research Roadmap Recommendations

Recommendation #5: Support a Market Transformation (MT) approach to address MEL energy consumption

As the ZNE Technical Feasibility Study (PG&E 2012) highlights, reducing plug load energy consumption is a critical component to achieving ZNE goals. The unique challenge with plug loads, and MELs in particular, is that with the exception of a few large end uses such as TVs, Set Top Boxes, and Desktop and Notebook Computers, MEL energy use is highly distributed. As these three major end uses decrease in their UEC and/or installed base, MEL energy use will become even more broadly dispersed. This wide distribution across devices and minimal per-unit energy savings limits the effectiveness of traditional utility program mechanisms and is a key challenge for ZNE buildings. Due to the limited per-unit savings, an incentive-based, resource-acquisition program for MELs may have limited success if not coupled with a broader, market transformation approach.

We recommend supporting a market transformation (MT) approach which attempts to create large-scale changes in aggregate. Although most MELs have low energy consumption, many MELs, particularly CE devices, have high sales volumes and therefore significant change can be achieved by addressing the market as a whole. This includes, but is not limited to:

- Collaborating with utilities, efficiency organizations, and other stakeholders to improve the collective understanding of MEL energy use (see Recommendation #6)
- Participating in the ENERGY STAR specification revision process to update existing product specifications.
- Engaging manufacturers to identify efficiency opportunities in product design.
- Engaging retailers by offering incentives to stock and sell high efficiency products
- Improving energy labeling for CE devices (see Recommendation #7)

This MT approach is focused on achieving change at a national level, and therefore we recommend that the IOUs partner with other utilities and efficiency organizations to achieve economies of scale in addressing MEL energy use.

Recommendation #6: Consider conducting a large-scale, multi-year comprehensive metering study to improve plug load energy data within California

The Northwest Energy Efficiency Alliance (NEEA) is currently conducting a large-scale, multi-year metering study which measures home energy use for 100 homes throughout the Northwest. This study meters the vast majority of end-uses within the home, covering an estimated 80% of total load. This study will provide valuable information on usage patterns and device power consumption, and preliminary findings were recently released in late April 2014.[3] We are not aware of any existing metering studies within California that measure end use usage and power at this level of granularity, scale or monitoring duration.[4] We recommend that the IOUs consider conducting a study similar to NEEA's within California. However, we recommend that the IOUs review the NEEA study reports and lessons learned prior to considering a similar effort in California. NEEA's study began in March 2012, and therefore implementing a similar study in 2016-17 could provide valuable information on how energy consumption within the home has changed over time.[5]

Recommendation #7: Encourage policies to promote the measurement of power data for CE devices through minimum efficiency standards and labeling.

Most MEL products do not have any labeling or energy consumption measurement requirements, and it is therefore difficult to quantify the energy consumption of small MELs entering the market. This lack of energy information is key barrier in successfully achieving market transformation of MELs. We recommend that the IOUs continue to advocate for CE labeling policies and minimum efficiency standards for MELs, particularly consumer electronics products.

[3] The values from the NEEA study are not included in this study due to the timing of its release in late April. http://neea.org/docs/default-source/reports/residential-building-stock-assessment--metering-study.pdf?sfvrsn=6

[4] Although the CLASS study (KEMA 2014) does provide information on device saturation, it does not include long-term metering data on usage and power draw.

[5] This primarily relates to CE devices which are expected to have minimal geographic variation in power or usage.

2. Introduction

Energy consumption from Miscellaneous Energy Loads (MELs) is growing faster than any other end use category, and has offset some of the efficiency gains made in lighting, HVAC, and water heating (EIA 2013). MEL load growth is largely due to the introduction of new electrical devices in households, with little coverage by efficiency standards (EIA 2013). A recent study on the technical feasibility of achieving Zero Net Energy (ZNE) Buildings in California noted that "as more permanent subcomponents of a building continue to improve in efficiency (envelope, HVAC, and lighting) the remaining plug loads[6] are becoming a larger and larger portion of the overall load. In this 'stress test' of Zero Net Energy design objectives, *reducing the plug loads often proved critical to meeting the overall energy use targets*" (PG&E 2012: 51, emphasis added). While decreasing MEL energy use is critical to achieving California's ZNE goals and energy reduction targets, the energy use of MELs is not well understood. Key uncertainties include accurately modeling device usage, power draw (both present and future), and the continued growth in the number of plug load devices in homes. This lack of understanding makes MEL energy consumption far more uncertain than more traditional end-uses such as HVAC, lighting, and appliances, and poses significant cost and risk when modeling and sizing of ZNE buildings.

Historically, it has been difficult to develop precise estimates of MEL energy use due to a lack of comprehensive and current data. The highly distributed nature of MEL energy use makes it time consuming and expensive to collect meaningful data across the wide number of end uses. In addition, consumer electronics, an important subset of MELs, are rapidly changing both in functionality and energy consumption, and data collected can become quickly outdated. A number of recent studies (ACEEE 2013, Fraunhofer 2011, LBNL 2011, and TIAX 2007) used best available data to characterize energy use both at a unit-level and an aggregate, national level for the most common and energy intensive MELs. However, because the literature on MEL energy consumption is so limited, even the best available information may have significant uncertainty or limited applicability to the current stock. This lack of certainty in MEL data poses a significant challenge for ZNE planning, and without a detailed review of the primary data underlying each MEL estimate, it is difficult to reliably incorporate this information into the ZNE modeling process. For example, the current California Home Energy Rating System (HERS) model—the primary source for measuring residential ZNE compliance—could be improved to more accurately scale MEL energy use based on building square footage. A mechanism to account for future MEL codes and standards in the HERS model is also needed.[7]

The purpose of this study is to conduct a literature review of existing MEL studies in residential buildings[8] and identify the underlying methodologies used to determine MEL estimates. Based on this information, we develop best available energy estimates, identify gaps in existing information, and develop recommendations for future

[6] While the ZNE Technical Feasibility Study uses the terms 'Plug Loads' and 'MEL' interchangeably, we utilize the term MEL because it more accurately represents the subset of plug in equipment composed primarily of smaller end uses, and excludes larger plug-in equipment such as large appliances (with some notable exceptions, such as televisions). A detailed definition of the term 'MEL' is presented in the methodology section.

[7] The California Energy Commission has identified this as a need for the next version of the HERS model.

[8] Unless specifically noted as single-family or multi-family residential, all estimates are assumed to be drawn from representative samples of the entire residential sector as a whole.

study. In addition, we provide an overview of existing load disaggregation techniques using Non-Intrusive Load Monitoring (NILM), which have the potential to improve the accuracy and lower the costs of estimating end use energy consumption. It is important to note that this literature review is, by nature, a backward looking study, and does not reflect the most up-to-date usage or energy consumption of new devices coming to market; rather, it is a review of existing estimates to clarify the uncertainty of existing data and identify best available information for existing stock.

2.1 Project Scope

This study consists of four components:

a) Developing and prioritizing an initial list of MELs for review, based on energy consumption, relative uncertainty, and interest from IOU stakeholders.
b) For each selected MEL, conducting a literature review of all recent studies estimating energy consumption, including a review of their original data sources. This review evaluates both the study methodology and estimates of the power, usage, and installed base of each MEL.
c) Completing a comparative analysis of MEL data sources to identify best estimates of MEL energy consumption, gaps in existing information, and recommendations for further study.
d) Conducting a literature review of existing Non-Intrusive Load Monitoring (NILM) methods and identifying their relative cost, accuracy, and applicability for future estimates of residential MEL energy consumption.

Due to the limited scope of this study, it does not include original, primary research on MEL energy use or significant manipulation of existing study data.[9] In addition, although the study does discuss how individual MEL energy use is expected to change over time and identify recommendations for further study, it does not include quantitative forecasting of future MEL energy use.

[9] In a limited number of cases, we extrapolate on existing primary data to develop new estimates. For example, if a study identifies average daily usage, we multiply the number by 365 to develop an annual usage estimate if it is clear that this can be confidently extrapolated into an annual usage estimate. However, we do not make estimates if we are not confident that our extrapolation is an accurate reflection of the primary data.

3. Methodology

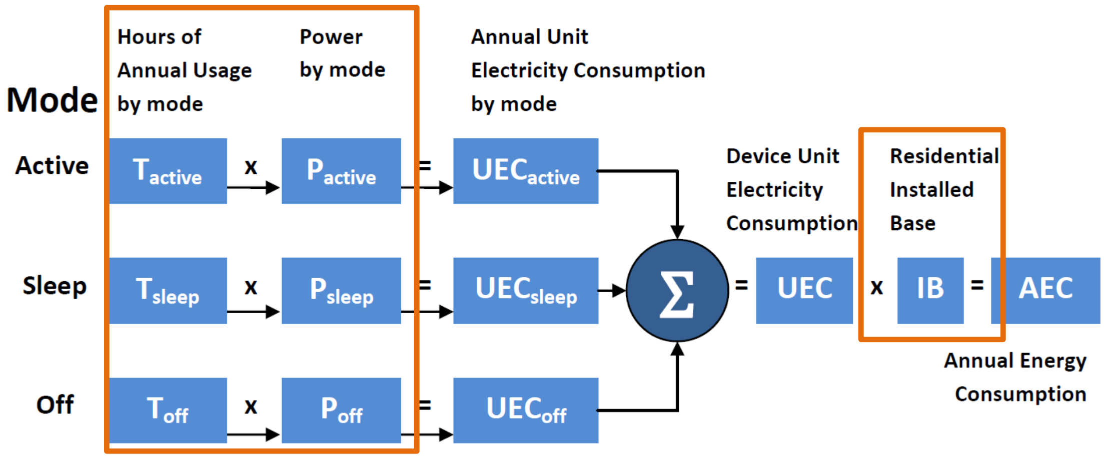
3.1 Developing a working definition of MELs

There is not a universally accepted definition of MELs, and definitions of MELs have changed over time.[10] Our definition of MEL is adopted from the ACEEE report *Miscellaneous Energy Loads in Buildings* (ACEEE 2013). ACEEE 2013 outlines 'critical building functions' (e.g., providing shelter, lighting, comfortable heating, cooling and ventilation) and 'principal building activity' (e.g., the primary purpose of a bank is to provide financial services, a home is to provide shelter and sustenance). All other devices that are introduced which do not serve the building's critical functions or principal activity can be classified as MELs. For example, a stove does not serve a critical building function, but cooking food is a principal activity of the home, and therefore a stove is not an MEL. However, supplemental cooking devices, such as a microwave or toaster, may be considered an MEL, since they are not a primary cooking device found within the home (ACEEE 2013). It is important to note that while there is general agreement on the definition for single function MELs such as Irons, Toasters, Coffee Machines, products with distinct subcategories, such as Imaging Equipment or Set Top Boxes, may have different definitions and different methods of splitting out associated subcategories. For example, some studies may include DVD Players and Blu-Ray players in one estimate while others create distinct estimates for each. Where applicable, we attempt to clarify definitions or subcategories to indicate that numbers cannot be compared directly.

3.2 Identifying unit level and aggregate level calculation methodologies

Unit Energy consumption (UEC) is a product of usage and power for each operating mode, summed over all modes. Annual Energy Consumption (AEC), is the product of UEC and the residential installed base, which are highlighted in Figure 2 (Roth 2002). Unless stated otherwise, AEC assumes a national installed base.

Figure 2: UEC and AEC Calculation Methodology (Roth et al 2002)



[10] EIA's Annual Energy Outlook (AEO) considers lighting, space conditioning, refrigeration and cooking, laundry and dishwashing, TV and set-top-boxes, and computers and related equipment as major residential end uses. All other end uses are categorized as 'Other' (EIA 2013). In previous versions of the AEO, consumer electronics were originally categorized as 'Other', but are now included as their own separate categories as EIA moves towards further disaggregation of MELs.

While numerous studies provide UEC and AEC estimates for a wide variety of MELs, most MELs have significant uncertainty for usage, power, or installed base due to the lack of robust or updated data. In some cases, the variance between individual estimates of usage, power, and installed base may be masked when they are rolled up and compared as a UEC or AEC value. We address this ambiguity by comparing usage, power, and installed base on an individual basis instead of as a rolled up UEC or AEC value.

3.3 Prioritizing a subset of MELs for further review

The broader residential MEL end use category is comprised of hundreds of devices. Each of these products has varying degrees of household penetration and UEC. For example, cordless phones have high saturation but relatively low UEC. Wine chillers may have low saturation but a high UEC. For the purposes of this study, we prioritized products by their AEC because ZNE modeling focuses on device saturation in an average home. However, we adopted UEC as a secondary filter because products with high UEC values are typically the best candidates for utility efficiency programs.

We prioritized MELs by evaluating four recent reports on MEL: ACEEE 2013, Fraunhofer 2011, LBNL 2011, and TIAX 2007, which collectively provide energy estimates for roughly 60 distinct end uses. Based on this list of products, we ranked each MEL by national AEC (TWh/year), as well as a secondary ranking UEC (kWh/yr). End uses were then divided into two tiers, primary and secondary, to prioritize end uses. After ranking end uses by AEC, they were prioritized based on the likelihood of significant growth in terms of UEC or saturation. For example, some of the smaller consumer electronic devices, such as notebook computers and network equipment, were prioritized as part of Tier 1 due to their potential for significant future load growth. Conversely, devices with resistive heating elements, such as portable space heaters, irons, and toasters, were de-prioritized because it is unlikely that their usage, power, or installed base will change significantly, and they are less of a concern for ZNE modeling purposes. The finalized list of Tier 1 and Tier 2 products are listed in in the table below.

Table 1: Tier 1 and Tier 2 MELs ranked by Annual Energy Consumption (AEC) and Unit Energy Consumption (UEC)

	List #	Plug Load Appliance	Average of Previous AEC Estimates (TWh/yr)	Average of Previous UEC Estimates (kWh/yr)
Tier 1	1	Televisions	72.2	213
	2	Set top boxes	28.0	152
	3	Desktop Computers	28.8	220
	4	Microwaves	14.7	158
	5	Monitors	11.2	69
	6	DVD/Blu-Ray Players	8.5	45
	7	Video Game Consoles	8.0	135
	8	Audio Receivers	6.4	65
	9	Compact Audio	6.3	93
	10	Notebooks (portable PCs)	4.5	48
	11	Home Theater in a box	2.5	90
	12	Network Equipment	2.2	53
Tier 2	13	Portable Space Heaters	10.0	500
	14	Cordless Phones	7.3	28
	15	Air Cleaners	6.0	300
	16	Iron	5.6	53
	17	Toasters	5.4	32
	18	Portable Vacuum Cleaners	5.2	55
	19	Mobile Phones / Tablets	1.0	5
	20	Printer and MFDs	1.8	12

[1]: Estimates based on an average of ACEEE 2013, LBNL 2011, Fraunhofer 2011, and TIAX 2007.

3.4 Data Collection

For each MEL selected for further study, we identified all publically available, recent studies that estimated MEL energy use. Although the term 'recent' is relative to each end use based on its effective useful life and the degree of recent technological change, our goal was to capture all key sources for stock estimates within the last six years.[11] However, we attempted to include studies prior to 2008 if we considered them especially important, or if a more recent study had cited them as a source of their data. For example, we included TIAX 2007 and TIAX 2006 because they are widely cited in MEL literature.

Across the twenty MEL categories selected, we reviewed over 120 distinct sources and identified the underlying study methodology and drivers of MEL energy consumption.[12] For each study, we identified all key sources that were used to develop the UEC and AEC estimates and reviewed these referenced studies. If publically available, we obtained the referenced studies and reviewed their respective methodologies to understand how they developed their UEC and AEC estimates. To the extent possible, we repeated this process until we arrived at primary data or references that were not publically available. Charting this network of studies, we developed a tree of data dependency to identify the linkages in developing study estimates. For example, Fraunhofer 2011's estimate for Audio Receivers usage is based on Foster-Porter et al 2006. Foster-Porter et al 2006 is an original metering study,

[11] Tablets and mobile phones have achieved widespread adoption in recent years, and therefore their energy use is likely underrepresented in Table 1.

[12] Many of the studies referenced include estimates for multiple MELs, and therefore the sum of total studies referenced per end use category is significantly greater than 120.

and the creator of original data. In this instance, we review both Fraunhofer and Foster-Porter's study methodologies to determine how they derive their estimates.

3.5 Classifying MEL study methodologies

For each source, we identified key components of the study methodology which are most likely to influence estimates of MEL usage, power draw, and installed base. These include:

- Study Type
- Study Year
- Sample Size
- Monitoring Duration (if a metering study)

For the purposes of this study, we divided study types into the following categories using the following definitions:

User Survey: A study which solicits user feedback in the form of a survey (via phone, e-mail, mail, in-home, in-store, etc.) to develop their estimates.
Metering: A study which conducts in-situ metering measurements of stock equipment. This method does not typically follow specified test methods used in manufacturer or independent test labs for ENERGY STAR qualification.
Dataset: A study which analyzes a dataset, such as ENERGY STAR or manufacturer test data. This method typically follows specified test methods used in manufacturer or independent test labs for ENERGY STAR qualification.
Market Research: A study which is based on historic sales transaction data or the forecast of future sales.
Literature Review: A study whose primary purpose is to review existing estimates and does not consist of its own primary research.
Other: All other sources which do not fall into the categories above.

In addition, each study type may be classified as "modified" or "unmodified". An *unmodified* reference is a direct pass through of numbers, while a *modified* reference cites a previous source and then builds on that estimate to develop its own value. For example, ACEEE 2013's UEC estimate for TVs is a literature review of LBNL 2011, Fraunhofer 2011, and TIAX 2007. However, it modifies their values by averaging three UEC values together. In this case, we characterize ACEEE 2013's UEC estimate as a *"Literature Review – Modified"*. In addition, we sought to identify product-specific differences in samples which might influence estimates between the studies, such as TV screen size. Based on the criteria above, each study was given a qualitative ranking of Low, Medium or High, based on the study's relevance, sampling methodology, sample size, and overall applicability to the current stock.[13] This ranking considers study publication date, the rate of technological change that has occurred since the publication date, and the relative accuracy we would expect based on the specific study type. For example, the most accurate

[13] ACEEE 2013 developed a ranking criteria of end uses by Level of Agreement: High: Two or more sources within close range; Medium: Two or more sources with wide range; and Low: Only one source of information. Our ranking does not focus on level of agreement, but rather on the confidence of the study results based on underlying study methodology.

method of determining device usage and power is through an extensive metering study with both a large sample size and long duration. The next best method is a large survey or metering study with a smaller sample size or duration. Based on this evaluation, we identify the most applicable sources and recommended values for usage, power, and installed base for each end use. We integrate these various values to develop new UEC and AEC estimates.

How to interpret summary tables presented in this report

Each table provides a summary of the basic information of the study, which includes:

- Key sources
- Method in which data was collected
- Study sample size and/or metering duration
- Results presented in that study
- Overall applicability to the current stock

Table 2 provides an overview of the sample table format used for each end use category. In most cases, data on a specific line comes directly from that study, not the sources it draws from. If we were able to trace the source, we typically created a separate line and listed the source as its own separate entry. In cases where a source was referenced but we were unable to locate it, such as the CMPC 2007 study listed in Table 2, we list the source type in parentheses as part of the TIAX 2008 line. For example, in Table 2 the data presented on the second line comes directly from TIAX 2008. There is no sample size because the TIAX 2008 study is a literature review and therefore does not include primary data. The correct interpretation of Table 2 is that Greenblatt et al 2013 is a primary research study using metering data from 122 devices over 42 days, while TIAX 2008 is based on a modified literature review of CMPC 2007, and CMPC 2007 in turn consists of data that is classified as 'Other' (in this case the data comes from a brochure developed by CMPC). The blue highlight indicates which study we believe is the most applicable estimate to the current stock.[14] The TIAX 2008 study is given a low applicability rating because underlying method of data collection is unknown. Greenblatt et al 2013 is given a medium applicability rating because it is has a relatively large sample size and is based on metered data over a relatively long duration. It is not given a 'high' rating, because its sample size is not geographically representative and the metering duration is not over the course of an entire year, which would incorporate seasonal variation in use. It should be noted that due to the significant time and expense required to undertake a comprehensive study, most studies do not achieve a 'high' applicability rating. This is not considered a deficiency on the part of the study but simply a reality of the existing limits in our collective understanding of MEL energy use.

Table 2: Sample Table Summary of Results

[14] The best data does not necessarily come from one study, and we take care to not highlight values that are not part of our final recommended estimates. For example, while a study may have the most representative data for power data for each mode, it may not have the best usage data and therefore we would not recommend its UEC value.

Device Subcategory	Year	Study	Key Source(s)	Study Type (Source Type)	Sample Size	Metering Sampling Duration (Days)	Usage Active (Hrs/yr)	Usage Standby (Hrs/yr)	Usage Off (Hrs/yr)	Applicability to Current Stock
Microwave	2013	Greenblatt et al 2013	Greenblatt et al 2013	Metering	122	42	53	7,131	1,568	Medium
Microwave	2008	TIAX 2008	CMPC 2007	Lit Review - Mod. (Other)	-	-	70	8,690	-	Low

Based on the selected values for each end use, we develop a recommended value for both UEC and AEC, as well as an overall level of certainty in these values. The format of these recommended values is presented in Table 3 below.

Table 3: Sample Table of Recommended Values for each end use

Metric		Value	Source
Installed Base - US (M)		116	ACEEE 2013
Usage (hrs/yr)	Active	53	Greenblatt et al 2013
	Standby	7,131	Greenblatt et al 2013
	Off	1,568	Greenblatt et al 2013
Power (W)	Active	1,094	Greenblatt et al 2013
	Standby	2	Greenblatt et al 2013
	Off	0	Greenblatt et al 2013
UEC (kWh/yr)		72	Calculated
AEC (TWh/yr)		8.3	Calculated
Overall Confidence		Medium	-

4. Literature Review of Selected Residential MEL Devices

This section provides an in-depth review of the twelve Tier 1 MELs selected in this study. Summary Tables of Tier 2 devices are included in the Appendix. Each section consists of an overview of device usage, power, and installed base estimates provided in summary tables, as well as recommended values based on the strength of their underlying study methodology and its overall applicability to the current stock. We provide a roll-up of these recommended values into new UEC and AEC estimates. Finally, we discuss gaps in existing information, opportunities for further research, and implications for ZNE planning.

4.1 Televisions

Overview: Televisions are one of the most widely studied MELs both in terms of existing stock and new products coming to market. New products are regulated under California's Appliance Efficiency Standard (Title 20) and are part of an ongoing Federal Appliance Standards Rulemaking. ENERGY STAR has developed six versions of its TV specification and the Federal Trade Commission mandates Energy Guide labeling. Traditionally, TVs have had two operating modes, Active and Standby.[15] Television energy consumption occurs almost entirely in Active Mode, and therefore most studies focus on active mode power.

Usage

Overview: TV usage estimates vary substantially, ranging from 1,387-2,467 hours per year in Active Mode—a 1.8 factor difference between the minimum and maximum value. The Table below summarizes the studies reviewed for TV usage estimates. Of these thirteen studies, two distinguish between digital and analog televisions (TIAX 2007 and TIAX 2008); the others address the entire market as a whole. While these values reflect average usage across all TVs within a house, many of these individual studies also provide usage estimates for individual TVs within the house (primary and non-primary TVs).

Across the studies, much of the variation in usage results can be attributed to differences in study methodology. In this case, provided there is a sufficiently large sample size for metering studies, metering is preferred to survey data due to common survey limitations, including social desirability bias, memory recall and multi-tasking (DOE 2012).

[15] An increasing number of TVs have integrated network connectivity while in Standby mode.

Table 4: Key Sources for Television Usage estimates

Device Subcategory	Year	Study	Key Source(s)	Study Type (Source Type)	Sample Size	Metering Sampling Duration (Days)	Usage Active (Hrs/yr)	Usage Standby (Hrs/yr)	Applicability to Current Stock
TVs	2013	ACEEE 2013	Fraunhofer 2011	Lit Review - Umod.	-		1,392	7,368	Medium
TVs	2013	EIA 2013	Unknown	Lit Review - Mod.	-	-	1,460	7,300	Medium
TVs	2013	NEEA 2013	NEEA 2013	Survey	537	-	2,467	6,293	Medium
TVs	2012	NEEA 2012	NEEA 2012	Survey	1,343	-	1,967	6,793	Medium
TVs	2012	Nielsen 2012a	Nielsen 2012a	Survey	4,540	-	1,862	6,898	High
TVs	2012	DOE 2012	Nielsen 2012b, EIA 2009	Lit. Review Mod. (Metering)	20,950	1460	2,008	6,753	High
TVs	2011	Fraunhofer 2011	Fraunhofer 2011	Survey	1,000	-	1,392	7,368	Medium
TVs	2010	Bensch et al 2010	Bensch et al 2010	Metering	108	27	1,278	7,483	Medium
TVs - Digital	2008	Tiax 2008	Tiax 2007	Lit. Review - Mod.	-	-	1,900	6,860	Medium
TVs - Analog	2008	Tiax 2008	Tiax 2007	Lit. Review - Mod.	-	-	1,900	6,860	Medium
TVs - Digital	2007	Tiax 2007	Tiax 2007	Survey	2,000	-	2,120	6,640	Medium
TVs - Analog	2007	Tiax 2007	Tiax 2007	Survey	2,000	-	1,882	6,878	Medium
TVs	2006	Foster Porter et al 2006	Foster Porter et al 2006	Metering	107	7	1,578	7,182	Low
TVs - Analog	1999	Rosen and Meier 1999	Nielsen 1998, Media Dynamics 1998	(Survey) - Mod.	Unknown	Unknown	1,443	7,317	Low

Recommended Values: Based on our review, the most applicable study is DOE 2012, which is based on Nielsen usage data and cites a value of 2,008 hours per year in active mode. This Nielsen data was part of DOE's usage analysis conducted for its proposed Television rulemaking.[16] Data was taken from a Nielsen household survey data in which metering devices were placed on each television within a participating household for four years (DOE 2012). This is an estimated average for *all* TVs in the house; whereas primary TV usage (2,557 hrs/yr) is significantly higher and non-primary TV usage (913 hrs/yr) is significantly lower. Although there are many recent studies which estimate usage hours with phone or in-home surveys, DOE 2012 is the most applicable due to its large sample size and the use of metering data over an extended period of time (four years).

Applicability to Current Stock: Due to its comprehensiveness, we have high confidence in DOE 2012's applicability to the current TV stock.

Power

Overview: Active mode power estimates range from 75 to 192W. However, studies after 2010 show more agreement, ranging from 91 to 127 W, or a 1.4 factor difference. The four recent metering studies, Greenblatt et al 2013, NEEA 2013, NEEA 2012 and Bensch et al 2010, show relative agreement in Active Mode Power, and the variance among them may be attributed to differences in stock vintage, screen size and display type.[17] There is significant uncertainty in the accuracy of Active Mode Power draw due to the rapid transition from CRTs to flat screen technologies such as plasma and LCD. While screen size has significantly increased, energy intensity (Watts per square inch) has rapidly declined since 2008.

Recommended Values: For Active Mode Power, we recommend using NEEA 2012 due to its large sample size and recent study date. However, this study does not have values for Standby Power. For Standby Mode, we recommend Greenblatt et al 2013 due to its recent data and significant sample size.

[16] Notice of Proposed Rulemaking. For more information on the TV NOPR, see: http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/34

[17] Bensch et al 2010 appears to be considerably lower due to the smaller average screen size of TV models tested.

Table 5: Key Sources for Television Power estimates

Device Subcategory	Year	Study	Key Source(s)	Study Type (Source Type)	Sample Size	Metering Sampling Duration (Days)	Power Active (W)	Power Standby (W)	UEC (kWh/yr)	Applicability to current stock
TVs	2013	ACEEE 2013	LBNL 2011, Fraunhofer 2011, Tiax 2008	Lit Review - Mod.	-	-			213	Medium
TVs	2013	EIA 2013	EIA 2013	Lit Review - Mod.	-	-	127.0	1.6	197	Medium
TVs	2013	NEEA 2013	NEEA 2013	Metering	439	Inst.	109.0	-	-	Medium
TVs	2013	Greenblatt et al 2013	Greenblatt et al 2013	Metering	95	42	93.5	0.9	238	Medium
TVs	2012	NEEA 2012	NEEA 2012	Metering	1,688	Inst.	111.6	-	-	Medium
TVs	2011	LBNL 2011	Unknown	Lit Review - Mod.					240	Low
TVs	2011	Fraunhofer 2011	Fraunhofer 2011, Tiax 2007	Dataset - Mod (Dataset)	385	-	103.8	3.2	183	Medium
TVs	2010	Bensch et al 2010	Bensch et al 2010	Metering	111	27	91.5	2.7	137	Medium
TVs - Digital	2008	Tiax 2008	Ostendorp 2005, CNET 2006	Lit Review - Mod. (Metering)	500	Inst.	192.0	4.0	392	Low
TVs - Analog	2008	Tiax 2008	Rosen and Meier 1999, Tiax 2007	Metering	44	Inst.	95.0	4.0	216	Low
TVs - Digital	2007	Tiax 2007	Energy Star 2007, Markwalter 2007	Dataset - Mod. (Dataset)	4	Inst.	162.0	4.8	401	Low
TVs - Analog	2007	Tiax 2007	Rosen and Meier 1999, Tiax 2007	Lit Review - Mod.	372	-	98.0	4.0	222	Low
TVs - Analog	1999	Rosen and Meier 1999	Rosen and Meier 1999	Metering	372	Inst.	75.0	4.5	150	Low

Applicability to Current Stock: Due to the lack of extensive, multi-year metering data, there is no data source that has a 'high' level of applicability to the current stock. However, we recommend reviewing NEEA's recently published metering study (NEEA 2014) for additional relevant data.

Installed Base

Overview: Installed base estimates range from 277 to 355 million units nationally,[18] and studies from 2011 onwards show relative consensus, ranging by less than 10%. Compared to usage or power data, there are relatively few publically available estimates of installed base.

Recommended Values: While there is relative agreement among most studies and they employ similar approaches to calculating installed base, the Fraunhofer 2011 methodology is most clearly described and therefore has the highest level of confidence.

Table 6: Key Sources for Television Installed Base estimates

Device Subcategory	Year	Study	Key Source(s)	Study Type	Installed Base Geography	Sample Size	Installed Base (Million)	AEC (TWh/yr)	Applicability to current stock
TVs	2013	ACEEE 2013	EIA 2012	Lit Review - Unmod.	National	N/A	329.3	70.1	Medium
TVs	2013	EIA 2013	Fraunhofer 2011	Lit Review - Mod.	National	-	355.0	70.0	Medium
TVs	2011	LBNL 2011	CEA 2009	Market Research - Mod.	National	Unknown	339.0	81.4	Medium
TVs	2011	Fraunhofer 2011	Fraunhofer 2011	Survey	National	1,000	352.6	64.7	Medium
TVs - Digital	2008	Tiax 2008	Tiax 2007	Lit. Review - Mod.	National	-	38.0	16.0	Low
TVs - Analog	2008	Tiax 2008	Tiax 2007	Lit. Review - Unmod.	National	-	237.0	51.0	Low
TVs - Digital	2007	Tiax 2007	Tiax 2007	Survey	National	2,000	40.0	16.0	Low
TVs - Analog	2007	Tiax 2007	Tiax 2007	Survey	National	2,000	237.0	53.0	Low
TVs - Analog	1999	Rosen and Meier	EIA 1999	Survey	National	Unknown	211.5	31.0	Low

Applicability to Current Stock: Due to the rapid transition from CRT to LCD televisions, it is somewhat uncertain what fraction of the older CRT TV stock will remain installed but unused. Thus, it is unclear if the installed base will increase or the makeup of the existing stock will change to predominantly LCD (as older CRTs are recycled). However, the small difference in installed base estimates suggests that it has a relatively small role in impacting AEC estimates.

[18] This figure includes the combination of Digital and Analog TVs into a single stock estimate.

Data Quality Evaluation and Recommended UEC Values

Data Quality Evaluation: Overall, TV data is relatively robust, and will improve further with future updates such as NEEA's recently released home energy use metering study (NEEA 2014). Although the selected values to develop new UEC and AEC values do not come from one comprehensive source, there is a medium to high level of confidence in the overall estimate relative to other MELs.

Table 7: Summary of Key Television Metrics

Device Subcategory	Year	Study	Installed Base (Million)	Usage		Power		UEC (kWh/yr)	AEC (TWh/yr)
				Active (Hrs/yr)	Standby (Hrs/yr)	Active (W)	Standby (W)		
TVs	2013	ACEEE 2013	329.3	1,392	7,368	-	-	213.3	70
TVs	2013	EIA 2013	355.0	1,460	7,300	127.0	1.6	197.0	70
TVs	2013	NEEA 2013	-	2,467	6,293	109.0	-	-	-
TVs	2013	Greenblatt et al 2013	-	-	-	93.5	0.9	237.7	-
TVs	2012	NEEA 2012	-	1,967	6,793	111.6	-	-	-
TVs	2012	Nielsen 2012a	-	1,862	6,898	-	-	-	-
TVs	2012	DOE 2012	-	2,008	6,753	-	-	-	-
TVs	2011	LBNL 2011	339.0	-	-	-	-	240.0	81
TVs	2011	Fraunhofer 2011	352.6	1,392	7,368	103.8	3.2	183.0	65
TVs	2010	Bensch et al 2010	-	1,278	7,483	91.5	2.7	137.1	
TVs - Digital	2008	Tiax 2008	38.0	1,900	6,860	192.0	4.0	392.0	16
TVs - Analog	2008	Tiax 2008	237.0	1,900	6,860	95.0	4.0	216.0	51
TVs - Analog	2007	Tiax 2007	237.0	1,882	6,878	98.0	4.0	222.0	53
TVs - Digital	2007	Tiax 2007	40.0	2,120	6,640	162.0	4.8	401.0	16
TVs	2006	Foster Porter et al 2006	-	1,578	7,182	-	-	-	-
TVs - Analog	1999	Rosen and Meier 1999	211.5	1,443	7,317	75.0	4.5	150.0	31

Recommended Television Values: We estimate that TVs presently consume 230 kWh/yr and 81.2 TWh/yr nationally. This is slightly higher than previous estimates, primarily due to a significant increase in operating hours compared to previous usage estimates. The overall confidence of this estimate is 'Medium' because of the lack of extensive power metering data.

Table 8: Recommended Television Values

Metric		Value	Source
Installed Base - US (M)		353	EIA 2013
Usage (hrs/yr)	Active	2,008	DOE 2012
	Standby	6,753	DOE 2012
Power (W)	Active	111.6	NEEA 2012
	Standby	0.9	Greenblatt et al 2013
UEC (kWh/yr)		230	Calculated
AEC (TWh/yr)		81.2	Calculated
Overall Confidence		Medium	-

Gap Analysis, Opportunities for Further Research and Implications for ZNE:

Gap Analysis and Opportunities for Further Research: Compared to most other MELs, TV stock energy use is relatively well understood. Although TV usage data has the most variability, the most significant existing gap in current stock estimates is Active Mode Power. Active Mode Power for new models has decreased dramatically since 2008 and continues to decline. The existing estimates should be improved by results from NEEA's recently released home energy metering study (NEEA 2014). TV Stock Energy Use is expected to significantly decrease in the next 5 years, as newer, more efficient TVs enter the home and replace older, less efficient ones. This has significant impacts for ZNE planning, since Televisions represent the largest MEL load in the home. Because there have been significant studies estimating recent stock estimates, there are only small incremental benefits to undertaking detailed stock measurements in the next 2-3 years. Energy data for new products entering the market is extremely good due to the recent implementation of Energy Guide labeling requirements. We recommend that further research focus on developing stock-flow models that estimate how new products impact the overall TV energy use within the home.

Implications for ZNE Planning and Future Utility Programs: While the current stock is well understood, TV energy use is expected to dramatically decrease by 2020 as older, energy intensive models are replaced with new, more efficient ones. It is possible that TV usage may shift as residents or spend more time with other electronic devices screens, such as notebooks, tablets, or mobile phones. The dramatic decreases in TV energy consumption since 2008 are apparent for new purchases, but will take a significantly longer time to see this decline in stock energy use. Opportunities for future utility programs may include support in ENERGY STAR specification development and potentially commercial incentive programs, although they may require innovative program designs to meet program cost-effectiveness requirements.

4.2 Set Top Boxes

Overview: Set Top Boxes (STBs) are a complex product category, demonstrated in part by its six subcategories and various sub-subcategories which provide a number of additional features to enhance programming for television audiences. The literature shows a variation in mode definitions, given evolving functionality, including the EIA's addition of Auto Power Down (APD) as a substitute for *off* (2013). EIA and the DOE, from which the CA IOUs 2013c drew its mode distinction, have also added *multi-stream* to the mix as well. The following section provides details for the two highest consuming products— cable and satellite— determined by annual energy consumption, or AEC. While the discussion only addresses the cable and satellite subcategories, all six subcategories are presented in the summary tables in this section and recommended values in Appendix A.

Usage

Overview: Across the same eight studies for both cable and satellite, usage estimates show an extremely wide range of 1,825 – 8,760 hours per year in Active Mode, which is a 4.8 factor difference (see Table 9). The cause of this discrepancy is likely due to the methodology differences in data collection. For metered data, the modes are typically determined by mode thresholds, rather than mode functionality, while manufacturer data is typically captured through testing using a formal test procedure. For survey data, there are significant unknowns about the translation of device usage from participants to quantitative estimates.

Recommended Values: For both cable and satellite, we recommend the values from CA IOUs 2013b taken from DOE's (2013a) Test Procedure NOPR for STBs.[19]

[19] It is important to note that there were four separate duty cycles described in the CA IOUs 2013b study, depending on the functionality of the box. We selected the duty cycle with multi-stream without APD.

Applicability to Current Stock: As described in CA IOUs 2013b, this duty cycle (and the three other described in the study) are generally accepted by industry. Given the comparison of the other studies, it's difficult to assess any trends to know the direction the market is taking, and how long these assumptions will last.

Power

Overview: Across the same eleven studies for both cable and satellite, active mode power estimates show a significant range for cable from 10.2 to 43.0W, or a 4.2 factor difference, and less significant for satellite from 12.2 to 27.6W, or a factor 2.3 difference (see Table 10). Part of this spread is likely due to including sub-sub categories of devices, including video recording functionality, but also the age of studies, at least for cable. Excluding the oldest study (Foster Porter et al 2006) results in a narrow spread from 16.0 to 27.4 W, or a 1.7 factor difference. For satellite, the story is less clear.

Recommended Values: The wattage values from Greenblatt et al 2013 are recommended, given that the study merges the most recent metering study of stock.

Applicability to Current Stock: The recommended values for STBs have medium applicability to the current stock given that while recent metering data is available, the sample size is somewhat limited, and none of the studies have reported multi-stream data. The trend to move to from multiple STBs to a main STB and thin clients, such as DISH Network's Hopper and Joey setup, may substantially impact individual STB power. In addition, major cable and satellite STB providers have made public commitments to meeting ENERGY STAR Version 3 for new boxes, which will decrease STB energy consumption over time as these new boxes penetrate the installed base.

Installed Base

Overview: Across five studies, cable installed base estimates have significant variation, from 42 to 87 million units nationally, a 2.1 factor difference (see Table 11). Removing the lowest value, given that LBNL 2011 includes cable-digital only, results in relatively tight range of 77 – 87 million units, or a 1.1 factor difference. Across the same five studies, satellite installed base estimates have a smaller range, from 61 to 92 million, a 1.5 factor difference.

Recommended Values & Applicability to Current Stock: We recommend CA IOUs & NRDC 2013 with medium confidence. On the one hand, these estimates are the most up-to-date, the estimates were derived using sales data and an expected useful life (eight years). However, there is limited public data on the real EUL of STBs and how EUL is affected by a service providers' willingness to upgrade its customers to new STBs to provide new functionality. For example, the EUL for DISH Network's STBs may decrease as they try to move customers onto their Hopper and Joey (STB + Thin Client) setup.

Table 9: Key Sources for Set Top Box Usage estimates

Device Subcategory	Year	Study	Key Source(s)	Study Type	Sample Size	Metering Sampling Duration (Days)	Usage				Applicability to Current Stock
							Active (Hrs/yr)	Multi-stream (Hrs/yr)	Standby / Sleep (Hrs/yr)	APD / Off (Hrs/yr)	
Cable, Satellite, IPTV, OTT	2013	EIA 2013	EIA 2013, DOE 2013a	Lit Review - Mod.	-	-	3,173	615	3,650	1,322	Medium
Cable	2013	CA IOUs 2013c	DOE 2013a	Lit Review - Unmod.	-	-	3,285	1,825	3,650	-	Medium
Cable	2013	Greenblatt et al 2013	Greenblatt et al 2013	Metering	44	42	7,823	-	815	123	Medium
Cable	2011	Fraunhofer 2011	Fraunhofer 2011	Survey	1,000	-	3,942	-	-	4,818	Low
Cable	2010	Bensch et al 2010	Bensch et al 2010	Metering	5	27	8,687	-	73	-	Low
Cable	2008	TIAX 2008	TIAX 2007	Lit Review - Unmod.	-	-	2,730	-	6,030	-	Medium
Cable	2007	TIAX 2007	TIAX 2007	Survey	2,000	-	2,729	-	6,031	-	Medium
Cable - Analog	2006	Foster Porter et al 2006	Foster Porter et al 2006	Metering	1	7	8,760	-	-	-	Low
Cable - Digital	2006	Foster Porter et al 2006	Foster Porter et al 2006	Metering	11	7	8,760	-	-	-	Low
Cable - PVR	2006	Foster Porter et al 2006	Foster Porter et al 2006	Metering	1	7	8,760	-	-	-	Low
Cable - Analog	2005	NRDC 2005	NRDC 2005	Other	-	-	1,825		6,935	-	Low
Cable - HD	2005	NRDC 2005	NRDC 2005	Other	-	-	1,825		6,935	-	Low
Digital Television Adapter	2013	CA IOUs 2013c	DOE 2013a	Lit Review - Unmod.	-	-	3,285	1,825	3,650	-	Medium
Digital Television Adapter	2011	Fraunhofer 2011	Fraunhofer 2011	Survey	1,000	-	7,884	-	-	876	Medium
Internet Protocol / Telco	2013	CA IOUs 2013c	DOE 2013a	Lit Review - Unmod.	-	-	3,285	1,825	3,650	-	Medium
Internet Protocol / Telco	2011	Fraunhofer 2011	Fraunhofer 2011	Survey	1,000	-	4,198	-	-	4,563	Medium
Satellite	2013	CA IOUs 2013c	DOE 2013a	Lit Review - Unmod.	-	-	3,285	1,825	3,650	-	Medium
Satellite	2013	Greenblatt et al 2013	Greenblatt et al 2013	Metering	11	42	6,631	-	2,120	-	Medium
Satellite	2011	Fraunhofer 2011	Fraunhofer 2011	Survey	1,000	-	4,198	-	-	4,563	Medium
Satellite	2010	Bensch et al 2010	Bensch et al 2010	Metering	23	27	8,030	-	730	-	Low
Satellite	2008	TIAX 2008	TIAX 2007	Lit Review - Unmod.	-	-	3,240	-	5,520	-	Medium
Satellite	2007	TIAX 2007	TIAX 2007	Survey	2,000	-	3,239	-	5,521	-	Medium
Satellite	2006	Foster Porter et al 2006	Foster Porter et al 2006	Metering	6	7	3,504	-	2,891	2,365	Low
Satellite	2005	NRDC 2005	NRDC 2005	Other	-	-	1,825	-	6,935	-	Low
Satellite - HD	2005	NRDC 2005	NRDC 2005	Other	-	-	1,825	-	6,935	-	Low
Satellite - PVR	2006	Foster Porter et al 2006	Foster Porter et al 2006	Metering	2	7	6,833	-	1,840	-	Low
Stand-alone	2007	TIAX 2007	TIAX 2007	Survey	2,000	-	2,082	-	6,678	-	Medium
Stand-alone - DVR	2011	Fraunhofer 2011	Fraunhofer 2011	Survey	1,000	-	4,198	-	-	4,563	Medium
Stand-alone - DVR	2010	Bensch et al 2010	Bensch et al 2010	Metering	1	27	8,760	-	-	-	Low
Stand-alone - DVR	2005	NRDC 2005	NRDC 2005	Other	-	-	1,825	-	6,935	-	Low
Stand-alone - OTA-DTA	2011	Fraunhofer 2011	Fraunhofer 2011, EPA 2011a	Survey	1,000	-	3,942	-	-	4,818	Medium
Stand-alone - PVR	2008	TIAX 2008	TIAX 2007	Lit Review - Unmod.	-	-	2,080	-	6,680	-	Medium
Stand-alone - PVR	2006	Foster Porter et al 2006	Foster Porter et al 2006	Metering	3	7	8,760	-	-	-	Low
Thin Client / Remote	2013	CA IOUs 2013c	DOE 2013a	Lit Review - Unmod.	-	-	3,285	1,825	3,650	-	Medium
Unidentified	2013	Greenblatt et al 2013	Greenblatt et al 2013	Metering	4	42	8,760	-	-	-	Medium
Unidentified	2013	Greenblatt et al 2013	Greenblatt et al 2013	Metering	9	42	7,069	-	1,437	254	Medium

Table 10: Key Sources for Set Top Boxes Power estimates

Device Subcategory	Year	Study	Key Source(s)	Study Type	Sample Size	Metering Sampling Duration (Days)	Power				UEC (kWh/yr)	Applicability to current stock
							Active (W)	Multi-stream (W)	Standby / Sleep (W)	APD / Off (W)		
All	2013	ACEEE 2013	Fraunhofer 2011	Lit Review - Unmod.	-	-	-	-	-	-	152	Medium
Cable, Satellite, IPTV, OTT	2013	EIA 2013	EIA 2013, DOE 2013	Lit Review - Mod.	-	-	17.1	8.0	16.3	6.6	127	Medium
Cable	2013	ACEEE 2013	US DOE 2011	Lit Review - Unmod.	-	-	-	-	-	-	165	Medium
Cable	2013	CA IOUs 2013c	EPA 2013a, EPA 2011	Dataset - Mod.	-	-	-	-	-	-	146	Medium
Cable	2013	Greenblatt et al 2013	Greenblatt et al 2013	Metering	44	42	23.1	-	3.3	-	183	Medium
Cable	2011	Fraunhofer 2011	EPA 2010a	Lit Review - Mod.	-	-	17.7	-	-	16.6	150	Medium
Cable	2011	FSEC 2011	TIAX 2008	Lit Review - Unmod.	-	-	-	-	-	-	133	Low
Cable	2010	Bensch et al 2010	Bensch et al 2010	Metering	5	27	28.3	-	0.5	-	221	Medium
Cable	2008	TIAX 2008	TIAX 2007	Lit Review - Unmod.	-	-	16.0	-	15.0	-	133	Low
Cable	2007	TIAX 2007	TIAX 2007 , NRDC 2005	Metering	7	Inst.	16.0	-	15.0	-	134	Low
Cable - Analog	2006	Foster Porter et al 2006	Foster et al 2006	Metering	1	7	10.2	-	-	-	90	Medium
Cable - Analog	2005	NRDC 2005	NRDC 2005	Metering	14	Inst.	16.3	-	15.6	-	138	Low
Cable - Digital	2011	LBNL 2011	TIAX 2007a	Lit Review - Unmod.	-	-	-	-	-	-	123	Low
Cable - Digital	2006	Foster Porter et al 2006	Foster et al 2006	Metering	11	7	26.4	-	-	-	230	Medium
Cable - DVR	2013	ACEEE 2013	US DOE 2011	Lit Review - Unmod.	-	-	-	-	-	-	245	Medium
Cable - HD	2005	NRDC 2005	NRDC 2005	Metering	2	Inst.	27.4	-	26.5	-	234	Low
Cable - PVR	2006	Foster Porter et al 2006	Foster et al 2006	Metering	1	7	43.0	-	-	-	375	Medium
Digital Television Adapter	2013	CA IOUs 2013c	EPA 2013a, EPA 2011	Dataset - Mod.	-	-	-	-	-	-	26	Medium
Digital Television Adapter	2011	Fraunhofer 2011	CNET 2010, Apple 2011	Lit Review - Mod.	-	-	8.0	-	-	6.0	68	Medium
Internet Protocol / Telco	2013	CA IOUs 2013c	EPA 2013a, EPA 2011	Dataset - Mod.	-	-	-	-	-	-	92	Medium
Internet Protocol / Telco	2013	ACEEE 2013	US DOE 2011	Lit Review - Unmod.	-	-	-	-	-	-	105	Medium
Internet Protocol / Telco	2011	Fraunhofer 2011	EPA 2010a	Dataset - Unmod.	-	-	14.0	-	-	12.1	115	Medium
Satellite	2013	ACEEE 2013	US DOE 2011	Lit Review - Unmod.	-	-	-	-	-	-	125	Medium
Satellite	2013	CA IOUs 2013c	EPA 2013a, EPA 2011	Dataset - Mod.	-	-	-	-	-	-	106	Medium
Satellite	2013	Greenblatt et al 2013	Greenblatt et al 2013	Metering	11	42	26.5	-	2.9	-	176	Medium
Satellite	2011	Fraunhofer 2011	EPA 2010a	Dataset - Unmod.	-	-	13.5	-	-	12.1	112	Medium
Satellite	2011	FSEC 2011	TIAX 2008	Lit Review - Unmod.	-	-	-	-	-	-	129	Low
Satellite	2011	LBNL 2011	TIAX 2007a	Lit Review - Unmod.	-	-	-	-	-	-	113	Low
Satellite	2010	Bensch et al 2010	Bensch et al 2010	Metering	23	27	22.8	-	0.2	-	191	Medium
Satellite	2008	TIAX 2008	TIAX 2007	Lit Review - Unmod.	-	-	15.0	-	14.0	-	129	Low
Satellite	2007	TIAX 2007	TIAX 2007	Metering	6	Inst.	15.0	-	14.0	-	129	Low
Satellite	2005	NRDC 2005	NRDC 2005	Metering	6	Inst.	12.2	-	12.1	-	106	Low
Satellite	2006	Foster Porter et al 2006	Foster et al 2006	Metering	6	7	16.0	-	12.3	11.1	125	Medium
Satellite - DVR	2013	ACEEE 2013	US DOE 2011	Lit Review - Unmod.	-	-	-	-	-	-	220	Medium
Satellite - HD	2005	NRDC 2005	NRDC 2005	Metering	3	Inst.	19.5	-	18.3	-	162	Low
Satellite - PVR	2006	Foster Porter et al 2006	Foster et al 2006	Metering	2	7	27.6	-	24.8	-	240	Medium
Stand-alone	2007	TIAX 2007	TIAX 2007	Metering	1	Inst.	27.0	-	27.0	-	237	Low
Stand-alone DVR	2011	Fraunhofer 2011	TIAX 2007, Bensch et al 2010	Lit Review - Mod.	-	-	33.0	-	-	30.0	275	Medium
Stand-alone DVR	2010	Bensch et al 2010	Bensch et al 2010	Metering	1	27	27.4	-	-	-	480	Low
Stand-alone DVR	2005	NRDC 2005	NRDC 2005	Metering	5	Inst.	31.1	-	29.9	-	264	
Stand-alone PVR	2008	TIAX 2008	TIAX 2007	Lit Review - Unmod.	-	-	27.0	-	27.0	-	237	Low
Stand-alone PVR	2006	Foster Porter et al 2006	Foster et al 2006	Metering	3	7	37.0	-	-	-	325	Medium
Stand-alone OTA-DTA	2011	Fraunhofer 2011	EPA 2010a, LBNL 2011a	Lit Review - Mod.	-	-	6.5	-	-	0.8	29	Medium
Thin Client / Remote	2013	CA IOUs 2013c	EPA 2013a, EPA 2011	Dataset - Mod.	-	-	-	-	-	-	54	Medium
Unidentified	2013	Greenblatt et al 2013	Greenblatt et al 2013	Metering	4	42	12.0	-	4.4	-	105	Medium
Unidentified	2013	Greenblatt et al 2013	Greenblatt et al 2013	Metering	9	42	17.0	-	2.0	-	120	Medium

Table 11: Key Sources for Set Top Box Installed Base estimates

Device Subcategory	Year	Study	Key Source(s)	Study Type (Source Type)	Installed Base Geography	Sample Size	Installed Base (Million)	AEC (TWh/yr)	Applicability to current stock
All	2013	ACEEE 2013	Fraunhofer 2011	Lit Review - Unmod.	National	-	192	28.0	Medium
Cable, Satellite, IPTV, OTT	2013	EIA 2013	EIA 2013, DOE 2013	Lit Review - Mod.	National	-	176	22.4	Medium
Cable	2013	CA IOUs 2013c	SNL Kagan 2012	(Market Research) - Mod.	National	Unknown	83	12.2	Medium
Cable	2011	Fraunhofer 2011	Fraunhofer 2011, SNL Kagan 2010	Survey	National	1,000	87	13.0	Medium
Cable	2008	TIAX 2008	Amann 2004, Kagan Research 2004	Lit Review & (Market Research) - Mod.	National	-	77	10.0	Low
Cable	2007	TIAX 2007	Amann 2004, Kagan Research 2004	Lit Review & (Market Research) - Mod.	National		77	10.0	Low
Cable - Digital	2011	LBNL 2011	TIAX 2007a	Lit Review - Unmod.	National	-	42	5.2	Medium
Digital Television Adapter	2013	CA IOUs 2013c	SNL Kagan 2012	(Market Research) - Mod.	National	Unknown	37	0.9	Medium
Digital Television Adapter	2011	Fraunhofer 2011	CEA 2010a	(Market Research) - Unmod.	National	-	9	0.6	Medium
Internet Protocol / Telco	2013	CA IOUs 2013c	SNL Kagan 2012	(Market Research) - Mod.	National	Unknown	32	2.9	Medium
Internet Protocol / Telco	2011	Fraunhofer 2011	Fraunhofer 2011, SNL Kagan 2010,	Survey, (Market Research) - Mod.	National	1,000	16	1.8	Medium
Satellite	2013	CA IOUs 2013c	SNL Kagan 2012	(Market Research) - Mod.	National	Unknown	92	9.7	Medium
Satellite	2011	Fraunhofer 2011	Fraunhofer 2011, SNL Kagan 2010,	Survey, (Market Research) - Mod.	National	1,000	76	8.5	Medium
Satellite	2011	LBNL 2011	TIAX 2007a	Lit Review - Unmod.	National	-	61	6.9	Medium
Satellite	2007	TIAX 2007	Amann 2004, Kagan Research 2004, FCC 2006	Lit Review & (Market Research) - Mod.	National	-	70	9.0	Low
Satellite	2008	TIAX 2008	TIAX 2008, FCC 2006	Lit Review & (Market Research) - Mod.	National	-	70	9.0	Low
Stand-alone	2007	TIAX 2007	Amann 2004, Kagan Research 2004	Lit Review & (Market Research) - Mod.	National	-	2	0.4	Low
Stand-alone DVR	2011	Fraunhofer 2011	Nielsen 2009, Gorman 2010	(Market Research) - Unmod.	National	-	3	0.8	Medium
Stand-alone PVR	2008	TIAX 2008	Kagan Research 2004	Market Research	National	-	2	0.4	Low
Stand-alone OTA-DTA	2011	Fraunhofer 2011	Fraunhofer 2011, CEA 2010b	Lit Review - Mod.	National	1,000	33	1.0	Medium
Thin Client / Remote	2013	CA IOUs 2013c	SNL Kagan 2012	(Market Research) - Mod.	National	Unknown	2	0.1	Medium

Table 12: Summary of Key Set Top Box Equipment Metrics

Device Subcategory	Year	Study	Installed Base (Million)	Usage: Active (Hrs/yr)	Usage: Multi-stream (Hrs/yr)	Usage: Standby / Sleep (Hrs/yr)	Usage: APD / Off (Hrs/yr)	Power: Active (W)	Power: Multi-stream (W)	Power: Standby / Sleep (W)	Power: APD / Off (W)	UEC (kWh/yr)	AEC (TWh/yr)
All	2013	ACEEE 2013	192	-	-	-	-	-	-	-	-	152	28.0
Cable, Satellite, IPTV, OTT	2013	EIA 2013	176	3,173	615	3,650	1,322	17.1	8.0	16.3	6.6	127	22.4
Cable	2013	ACEEE 2013	-	-	-	-	-	-	-	-	-	165	-
Cable	2013	CA IOUs 2013c	83	3,285	1,825	3,650	-	-	-	-	-	146	12.2
Cable	2013	Greenblatt et al 2013	-	7,823	-	815	123	23.1	-	3.3	-	183	-
Cable	2011	FSEC 2011	-	-	-	-	-	-	-	-	-	133	-
Cable	2011	Fraunhofer 2011	87	3,942	-	-	4,818	17.7	-	-	16.6	150	13.0
Cable	2010	Bensch et al 2010	-	8,687	-	73	-	28.3	-	0.5	-	221	-
Cable	2008	TIAX 2008	77	2,730	-	6,030	-	16.0	-	15.0	-	133	10.0
Cable	2007	TIAX 2007	77	2,729	-	6,031	-	16.0	-	15.0	-	134	10.0
Cable - Analog	2006	Foster Porter et al 2006	-	8,760	-	-	-	10.2	-	-	-	90	-
Cable - Analog	2005	NRDC 2005	-	1,825		6,935	-	16.3	-	15.6	-	138	-
Cable - Digital	2011	LBNL 2011	42	-	-	-	-	-	-	-	-	123	5.2
Cable - Digital	2006	Foster Porter et al 2006	-	8,760	-	-	-	26.4	-	-	-	230	-
Cable - DVR	2013	ACEEE 2013	-	-	-	-	-	-	-	-	-	245	-
Cable - HD	2005	NRDC 2005	-	1,825		6,935	-	27.4	-	26.5	-	234	-
Cable - PVR	2006	Foster Porter et al 2006	-	8,760	-	-	-	43.0	-	-	-	375	-
Digital Television Adapter	2013	CA IOUs 2013c	37	3,285	1,825	3,650	-	-	-	-	-	26	0.9
Digital Television Adapter	2011	Fraunhofer 2011	9	7,884	-	-	876	8.0	-	0.0	6.0	68	0.6
Internet Protocol / Telco	2013	ACEEE 2013	-	-	-	-	-	-	-	-	-	105	-
Internet Protocol / Telco	2013	CA IOUs 2013c	32	3,285	1,825	3,650	-	-	-	-	-	92	2.9
Internet Protocol / Telco	2011	Fraunhofer 2011	16	4,198	-	-	4,563	14.0	-	0.0	12.1	115	1.8
Satellite	2013	ACEEE 2013	-	-	-	-	-	-	-	-	-	125	-
Satellite	2013	CA IOUs 2013c	92	3,285	1,825	3,650	-	-	-	-	-	106	9.7
Satellite	2013	Greenblatt et al 2013	-	6,631	-	2,120	-	26.5	-	2.9	-	176	-
Satellite	2011	FSEC 2011	-	-	-	-	-	-	-	-	-	129	-
Satellite	2011	Fraunhofer 2011	76	4,198	-	-	4,563	13.5	-	-	12.1	112	8.5
Satellite	2011	LBNL 2011	61	-	-	-	-	-	-	-	-	113	6.9
Satellite	2010	Bensch et al 2010	-	8,030	-	730	-	22.8	-	0.2	-	191	-
Satellite	2008	TIAX 2008	70	3,240	-	5520-	-	15.0	-	14.0	-	129	9.0
Satellite	2007	TIAX 2007	70	3,239	-	5521-	-	15.0	-	14.0	-	129	9.0
Satellite	2006	Foster Porter et al 2006	-	3,504	-	2,891	2,365	16.0	-	12.3	11.1	125	-
Satellite	2005	NRDC 2005	-	1,825	-	6,935	-	12.2	-	12.1	-	106	-
Satellite - DVR	2013	ACEEE 2013	-	-	-	-	-	-	-	-	-	220	-
Satellite - HD	2005	NRDC 2005	-	1,825	-	6,935	-	19.5	-	18.3	-	162	-
Satellite - PVR	2006	Foster Porter et al 2006	-	6,833	-	1,840	-	27.6	-	24.8	-	240	-
Stand-alone	2007	TIAX 2007	2	2,082	-	6,678	-	27.0	-	27.0	-	237	0.4
Stand-alone DVR	2011	Fraunhofer 2011	3	4,198	-	-	4,563	33.0	-	0.0	30.0	275	0.8
Stand-alone DVR	2010	Bensch et al 2010	-	8,760	-	-	-	27.4	-	-	-	480	-
Stand-alone DVR	2005	NRDC 2005	-	1,825	-	6,935	-	31.1	-	29.9	-	264	-
Stand-alone PVR	2008	TIAX 2008	2	2,080	-	6,680	-	27.0	-	27.0	-	237	0.4
Stand-alone PVR	2006	Foster Porter et al 2006	-	8,760	-	-	-	37.0	-	-	-	325	-
Stand-alone OTA-DTA	2011	Fraunhofer 2011	33	3,942	-	-	4,818	6.5	-	0.0	0.8	29	1.0
Thin Client / Remote	2013	CA IOUs 2013c	2	3,285	1,825	3,650	-	-	-	-	-	54	0.1
Unidentified	2013	Greenblatt et al 2013	-	8,760	-	-	-	12.0	-	4.4	-	105	-
Unidentified	2013	Greenblatt et al 2013	-	7,069	-	1,437	254	17.0	-	2.0	-	120.2	-

Data Quality Evaluation and Recommended UEC Values

Data Quality Evaluation: Overall, the current studies for Set Top Boxes provide a decent summary of the key metrics, but as discussed, the ever-changing nature of the product make for some uncertainties. There will likely continue to be changes in device usage, wattage and sales, similar to Game Consoles, and it is unlikely these current values will maintain their accuracy for a sustained period.

Recommended UEC and AEC Values: We estimate that cable and satellite boxes currently consume 183 and 176 kWh/yr (Greenblatt et al 2013), and 15 and 16 TWh/yr, respectively. Collectively, we estimate that on average, STBs consume 138 kWh/yr and collectively consume 38.7 TWh/yr across the entire installed base. This value was developed by taking a weighted average of UECs across the installed base for each STB technology, and is presented in Table 13 below. However, STB energy use is highly dependent on technology type, and we recommend using data for individual STB technologies when applicable. Refer to Appendix A for the tables of all STB subcategories.

Table 13: Recommended UEC and AEC values for Set Top Boxes

All

Metric		Value	Source
Installed Base - US (M)		281	Sum of Sources
Usage (hrs/yr)	Active	3,372	Weighted Avg.
	Multistream	1,591	Weighted Avg.
	Standby / Sleep	3,182	Weighted Avg.
	APD / Off	615	Weighted Avg.
Power (W)	Active	19	Weighted Avg.
	Multistream	8.0	EIA 2013
	Standby / Sleep	16.3	EIA 2013
	APD / Off	6.6	EIA 2013
UEC (kWh/yr)		138	Calculated
AEC (TWh/yr)		38.7	Calculated
Overall Confidence		Medium	-

Gap Analysis, Opportunities for Further Research, and Implications for ZNE:

Gap Analysis and Opportunities for Further Research: The existing STB research is quite extensive for some product subcategories, especially the higher energy consumption ones. At the same time, however, changes in the market necessitate constant monitoring given the rapid market evolution of this technology class. Similar to desktop and notebook computers, using internet connectivity to update data could prove highly beneficial to understanding product usage, behavior and opportunities for improvement. For stock estimates, traditional survey methods should be sufficient. Moreover, perhaps an increased role from service providers could assist in the tracking of product stock and useful life, given the vast majority of products are not owned by customers.

Implications for ZNE Planning and Future Utility Efficiency Programs: For the purposes of ZNE planning in 2020, it is important to model the energy consumption of new STB models and configurations coming onto the market since they will likely be part of the stock in 2020. Potential utility programs include engaging STB vendors to make changes to their existing and future models, and is a program design currently being trial by SCE with select providers.

4.3 Desktop Computers

Overview: Desktops have undergone significant changes over the past decade and are in another transition period characterized by reduced sales and a form factor shift towards integrated desktops. In addition, industry and ENERGY STAR have developed more nuanced mode definitions making it somewhat difficult to compare existing wattage measurements with previous studies. While the new mode definitions better represent actual usage, it can be difficult to capture this in metering data. Metering data is limited in its accuracy as modes are typically determined by thresholds (resulting in two distinct modes) rather than by mode functionality or captured through testing using a formal test procedure (resulting in four distinct modes for computers). The latest update to mode definitions from EPA (2013b) seems to be partly a semantic one, but also reflects technological advances in usability, with improved faster response times to user input (e.g., replacing the term *hibernation*). There is also a common practice of documenting products across both sectors (residential and commercial), which makes isolating the residential data somewhat challenging. Nevertheless, we are able to reasonably characterize the energy use of residential desktop computers using the available data.

Usage

Overview: Desktop computer usage estimates vary considerably across the fourteen studies surveyed, ranging from 2,794 – 4,088 hours per year in Active Mode, or a 1.46 factor difference (see Table 14). A few key complications with comparing the studies usage are the difference in mode definitions, the challenges in differentiating the various modes during metering, and the recent shift in definitions through the ENERGY STAR 6.0 specification development process. Of these twelve studies, one study (CA IOUs & NRDC 2013) distinguishes between conventional desktops and integrated desktops (see the Table 4 below) while the remainder address the entire market as a whole.

Recommended Values: We recommend using Microsoft 2008 for usage data across all operating modes. While over half a decade old, Microsoft 2008 draws from a very large sample size as part of its Customer Experience Improvement Program. It is also the primary source for residential usage that ENERGY STAR used to derive estimates for its new blended residential/commercial mode weightings (EPA 2013b). It is an especially strong method for data collection because it captures the usage through well-defined modal functionality that are the same across all PC's (with Windows operating systems) rather than through metering wattage thresholds which are typically limited to a bi-modal delineation than multi-modal, and can apply differently to each unit tested.

Applicability to Current Stock: While this study's age appears to be one limitation, it is also not yet clear how usage has shifted since 2008. On the one hand, it is possible that device usage has declined given the increased saturation of tablets and notebooks. However, overall usage of desktops could have increased, given greater saturation of internet usage, e.g., social media, media streaming. The other limitation to the Microsoft 2008 study is that it excludes non-Windows units. Given the limitations of the other studies and that the most recent ENERGY STAR specification uses these to derive its 2013 estimates, we recommend this assessment as the best device usage values for desktops.

Power

Overview: Active mode power estimates range across the 14 studies reviewed from 42 to 70W, or a 1.80 factor difference (see Table 15). However the lower end values, derived from metering (CA IOUs & NRDC 2013), were limited to products being sold on the market versus the stock. Removing this outlier, the range is only 1.32 factor difference. The granularity of detail provided by CA IOUs & NRDC 2013 suggests there is further opportunity for power management shifting from high power long-idle to standby (39.8 watts for 438 hours per year). Overall, there appears to be a slight downward trend of active mode power, which seems to follow market efficiency improvements over time, perhaps due to the shift toward integrated desktops as well as overall efficiency improvements in the conventional form factor.

Recommended Values: CA IOUs & NRDC 2013 is the only wattage testing performed using the latest ENERGY STAR 6.0 test procedure which outlines the latest industry thinking on mode definitions. We therefore recommend using these values for Long Idle, Standby and Sleep, despite the limitation of the sample not fully reflecting current stock, as mentioned above. For Active/Short Idle, we recommend using Greenblatt et al 2013 given that it has the most recent metering data for current stock.

Applicability to Current Stock: The recommended values for desktops have medium applicability to the current stock given that the metering data sample size for active mode is somewhat limited and the other mode wattage is taken from an even smaller sample of metering data, and is intended to estimate sales, not stock.

Installed Base

Overview: Installed base estimates have a significant range from 41 to 138 million units nationally,[20] but can be explained by the fact that the high end includes commercial sales data (ACEEE 2013), and the low end is derived through sales multiplied by expected useful life rather than a traditional survey data (CA IOUs & NRDC 2013). There is some uncertainty in using expected useful life because there can be significant variability between units.

Recommended Values: We believe Fraunhofer 2011 is the best value due to its recent publish date, use of primary survey data, and large sample size.

Applicability to Current Stock: Due to the recent shift in consumer preferences towards mobility – notebooks and tablets – it is likely that the value from Fraunhofer overstates existing stock. One important consideration this study <u>does</u> account for is ensuring the stock is clearly defined in the survey as products that have been *plugged in during the past month*. It also points out that a similar study was conducted with inquiring about all units *owned*, resulting in about 20% higher estimate.

[20] This figure includes the combination of Conventional and Integrated Desktops into a single stock estimate for CA IOUs & NRDC 2013.

Table 14: Key Sources for Desktop Usage estimates

Device Subcategory	Year	Study	Key Source(s)	Study Type	Sample Size	Metering Sampling Duration (Days)	Usage: Active / Short Idle (Hrs/yr)	Long Idle / Standby (Hrs/yr)	Standby / Sleep / Hibernation (Hrs/yr)	Sleep / Off (Hrs/yr)	Applicability to Current Stock
Desktops - Conv.	2013	CA IOUs & NRDC 2013	EPA 2013	Lit Review - Unmod.	-	-	3,066	1,314	438	3,942	Medium
Desktops - Int.	2013	CA IOUs & NRDC 2013	EPA 2013b	Lit Review - Unmod.	-	-	3,066	1,314	438	3,942	Medium
Desktops	2013	EIA 2013	Fraunhofer 2011	Lit Review - Unmod.	-	-	3,420	-	2,150	3,190	Medium
Desktops	2013	EPA 2013b	Microsoft 2008, ECMA-383 2010	Lit Review - Mod.	-	-	3,066	1,314	438	3,942	Medium
Desktops	2013	Greenblatt et al 2013	Greenblatt et al 2013	Metering	39	42	2,794	-	4,214	1,734	Medium
Desktops - Conv.	2012	PG&E 2012	EPA 2012	Lit Review - Unmod.	-	-	3,066	1,314	438	3,942	Medium
Desktops	2011	Fraunhofer 2011	Fraunhofer 2011	Survey	1,000	-	3,420	-	2,150	3,190	Medium
Desktops	2010	Bensch et al 2010	Bensch et al 2010	Metering	42	27	4,088	4,672	-	-	Medium
Desktops	2008	Microsoft 2008	Microsoft 2008	Other	37,388	90	3,574	438	613	4,687	Medium
Desktops	2008	TIAX 2008	TIAX 2008, TIAX 2006	Lit Review - Mod.	-	-	2,968	-	333	5,457	Medium
Desktops	2007	TIAX 2007	TIAX 2007, TIAX 2006	Lit Review - Mod.	-	-	2,990	-	330	5,440	Medium
Desktops	2006	Foster Porter et al 2006	Foster Porter et al 2006	Metering	39	7	3,066	526	5,168	-	Low
Desktops	2006	TIAX 2006	TIAX 2006	Survey	1,000	-	2,954	-	350	5,456	Medium

[1]: Multiple modes in the same column is due to the definition variation of the studies. For more information refer to the discussion at the beginning of Section 4.2.

[2]: Abbreviations: Conv. = Conventional, Int. = Integrated

Table 15: Key Sources for Desktop Power estimates

Device Subcategory	Year	Study	Key Source(s)	Study Type	Sample Size	Metering Sampling Duration (Days)	Power: Active / Short Idle (W)	Long Idle / Standby (W)	Standby / Sleep / Hibernation (W)	Sleep / Off (W)	UEC (kWh/yr)	Applicability to current stock
Desktops	2013	ACEEE 2013	Fraunhofer 2011, DOE 2009	Lit Review - Mod.	-	-	-	-	-	-	158	Medium
Desktops - Conv.	2013	CA IOUs & NRDC 2013	CA IOUs & NRDC 2013, PG&E 2012	Metering	8	Inst.	41.5	39.8	2.1	0.6	183	Medium
Desktops - Int.	2013	CA IOUs & NRDC 2013	NRDC 2013	Dataset - Mod.	-	Inst.	-	-	-	-	129	Medium
Desktops	2013	EIA 2013	Fraunhofer 2011, TIAX 2008	Lit Review - Mod.	-	-	57.0	-	3.8	1.9	220	Medium
Desktops	2013	Greenblatt et al 2013	Greenblatt et al 2013	Metering	39	42	67.2	-	2.4	-	198	Medium
Desktops - Conv.	2012	PG&E 2012	PG&E 2012	Metering	4	Inst.	-	-	-	-	213	Medium
Desktops	2011	FSEC 2011	TIAX 2008	Lit Review - Unmod.	-	-	-	-	-	-	235	Low
Desktops	2011	Fraunhofer 2011	Bensch et al. 2010, TIAX 2007	Lit Review - Mod.	-	-	60.0	-	4.0	3.0	220	Medium
Desktops	2011	LBNL 2011	TIAX 2007a	Lit Review Unmod.	-	-	-	-	-	-	235	Low
Desktops	2010	Bensch et al 2010	Bensch et al 2010	Metering	42	27	70.0	-	2.5	-	262	Medium
Desktops	2008	TIAX 2008	EPA 2005, Roberson et al 2004	Lit Review - Mod.	-	-	75.0	-	4.0	2.0	235	Low
Desktops	2007	TIAX 2007	EPA 2005, Roberson et al 2004	Lit Review - Mod.	-	-	75.0	-	4.0	2.0	237	Low
Desktops	2006	Foster Porter et al 2006	Foster et al 2006	Metering	43	7	69.7	17.2	4.4	-	255	Low
Desktops	2006	TIAX 2006	EPA 2005, Roberson et al 2004	Lit Review - Mod.	-	-	75.0	-	4.0	2.0	230	Low

[1]: Multiple modes in the same column is due to the definition variation of the studies. For more information refer to the discussion at the beginning of Section 4.2.

[2]: Abbreviations: Conv. = Conventional, Int. = Integrated

Table 16: Key Sources for Desktops Installed Base estimates

Device Subcategory	Year	Study	Key Source(s)	Study Type (Source Type)	Installed Base Geography	Sample Size	Installed Base (Million)	AEC (TWh/yr)	Applicability to current stock
Desktops	2013	ACEEE 2013	Fraunhofer 2011, TIAX 2007	Lit Review - Mod.	National	-	138	22	Low
Desktops - Conv.	2013	CA IOUs & NRDC 2013	IDC 2012, 2013a, 2013b, Hamm & Greene 2008	Lit Review, (Market Research) - Mod.	National	-	30	9	Low
Desktops - Int.	2013	CA IOUs & NRDC 2013	IDC 2012, 2013a, 2013b, Hamm & Greene 2008	Lit Review, (Market Research) - Mod.	National	-	11	2	Low
Desktops	2013	EIA 2013	Fraunhofer 2011	Lit Review - Mod.	National	-	102	23	Medium
Desktops	2011	Fraunhofer 2011	Fraunhofer 2011, CEA 2010a	Survey	National	1,000	101	22	Medium
Desktops	2011	LBNL 2011	TIAX 2007a	Lit Review - Unmod.	National	-	90	21	Low
Desktops	2008	TIAX 2008	TIAX 2006	Lit Review - Mod.	National	-	90	21	Low
Desktops	2007	TIAX 2007	TIAX 2006, EIA 2006	Lit Review - Mod.	National	-	90	21	Low
Desktops	2006	TIAX 2006	TIAX 2006	Survey	National	1,000	85	20	Low

[1]: ACEEE 2013 values combine residential and commercial estimates
[2]: CA IOUs & NRDC 2013 is derived from annual sales multiplied by expected useful life (4 years), which may explain some of the discrepancy with other values

Table 17: Summary of Key Desktop Metrics

Device Subcategory	Year	Study	Installed Base (Million)	Usage: Active / Short Idle (Hrs/yr)	Usage: Long Idle / Standby (Hrs/yr)	Usage: Standby / Sleep / Hibernation (Hrs/yr)	Usage: Sleep / Off (Hrs/yr)	Power: Active / Short Idle (W)	Power: Long Idle / Standby (W)	Power: Standby / Sleep / Hibernation (W)	Power: Sleep / Off (W)	UEC (kWh/yr)	AEC (TWh/yr)
Desktops	2013	ACEEE 2013	138	-	-	-	-	-	-	-	-	158	22
Desktops - Conv.	2013	CA IOUs & NRDC 2013	30	3,066	1,314	438	3,942	41.5	39.8	2.1	0.6	183	9
Desktops - Int.	2013	CA IOUs & NRDC 2013	11	3,066	1,314	438	3,942	-	-	-	-	129	4
Desktops	2013	EIA 2013	102	3,420	-	2,150	3,190	57.0	-	3.8	1.9	220	23
Desktops	2013	EPA 2013b	-	3,066	1,314	438	3,942	-	-	-	-	-	-
Desktops	2013	Greenblatt et al 2013	-	2,794	-	4,214	1,734	67.2	-	2.4	-	198	-
Desktops - Conv.	2012	PG&E 2012	-	3,066	1,314	438	3,942	-	-	-	-	213	-
Desktops	2011	FSEC 2011	-	-	-	-	-	-	-	-	-	235	-
Desktops	2011	Fraunhofer 2011	101	3,420		2,150	3,190	60.0	-	4.0	3.0	220	22
Desktops	2011	LBNL 2011	90	-	-	-	-	-	-	-	-	235	51
Desktops	2010	Bensch et al 2010	-	4,088	4,672	-	-	70.0	-	2.5	-	262	-
Desktops	2008	Microsoft 2008	-	3,574	438	613	4,687	-	-	-	-	-	-
Desktops	2008	TIAX 2008	90	2,968	333	-	5,457	75.0	-	4.0	2.0	235	21
Desktops	2007	TIAX 2007	90	2,990	-	330	5,440	75.0	-	4.0	2.0	237	21
Desktops	2006	Foster Porter et al 2006	-	3,066	526	5,168	-	69.7	17.2	4.4	-	255	-
Desktops	2006	TIAX 2006	85	2,954	-	350	5,456	75.0	-	4.0	2.0	230	20

[1]: Multiple modes in the same column is due to the definition variation of the studies. For more information refer to the discussion at the beginning of Section 4.2.
[2]: Abbreviations: Conv. = Conventional, Int. = Integrated

Data Quality Evaluation and Recommended UEC Values

Data Quality Evaluation: Overall, desktops have a solid foundation of data from multiple sources, however the recent market changes suggest that the data could be significantly improved to more accurately depict current stock. Moreover, future market changes will likely increase the uncertainty and decrease usage, unit power, and installed base, resulting in lower UEC and AEC values.

Recommended UEC and AEC Values: We estimate that desktops presently consume 183 kWh/yr, based on the estimates from CA IOUs NRDC 2013. Multiplying this UEC value by the Fraunhofer 2011 stock estimate produces an estimate of 18.5 TWh/yr. These values align relatively closely to other previous estimates, which show a slight downward trend of UEC, although most studies likely understate UEC given that they represent sales not current stock.

Table 18: Recommended UEC and AEC values for Desktops

Metric		Value	Source
Installed Base - US (M)		101	Fraunhofer 2011
Usage (hrs/yr)	Active/Short Idle	3,066	Microsoft 2008
	Long Idle	1,314	Microsoft 2008
	Standby	438	Microsoft 2008
	Sleep/Off	3,942	Microsoft 2008
Power (W)	Active	41.5	CA IOUs & NRDC 2013
	Long Idle	39.8	CA IOUs & NRDC 2013
	Standby	2.1	CA IOUs & NRDC 2013
	Sleep/Off	0.6	CA IOUs & NRDC 2013
UEC (kWh/yr)		183	CA IOUs & NRDC 2013 (and calculated)
AEC (TWh/yr)		18.5	Calculated
Overall Applicability to Existing Stock		Medium	

Gap Analysis, Opportunities for Further Research and Implications for ZNE:

Gap Analysis and Opportunities for Further Research: Like several products discussed in this report, the research on desktops is quite extensive and provide a decent snapshot of the current stock. However, changes in the market necessitate constant monitoring given the rapid market evolution of this technology class. For device usage, similar data collection to the Microsoft 2008 effort would be ideal. As discussed previously, this type of methodology has significant advantages over traditional metering studies for capturing duty cycles since it is comprehensive and requires a much smaller degree of effort compared to a home metering study. For modal power, a larger sample metering data study would be useful. If not already being developed, perhaps a similar program to the Customer Improvement Experience could be developed for capturing wattage in addition to usage. For stock estimates, additional phone or in-person household surveys should be sufficient.

Implications for ZNE Planning and Future Utility Efficiency Programs: For the purposes of ZNE planning in 2020, although the existing stock is relatively well understood, desktop computer energy use is expected to decrease over time, although it is uncertain to what degree this will occur. Therefore, we recommend developing a stock-flow estimate to model energy consumption over time, much of which can be developed with the use of existing datasets, minimizing study costs. Utility program opportunities remain in low-touch settings such as power management and policy setting, such as Title 20 or ENERGY STAR specification process.

4.4 Notebook Computers

Overview: Like desktops, notebooks have undergone significant changes over the past decade and are in another transition period characterized by reported reduced sales (not documented in the literature). There is limited data from previous notebook metering studies because of the challenges associated with metering portable equipment. In addition, industry and ENERGY STAR has recently developed more nuanced mode definitions making it difficult to compare existing data wattage measurements with previous ones. In-home metering data is limited in its accuracy as modes are typically determined by power measurement thresholds (resulting in two distinct modes) rather than by mode functionality, typically captured through testing using a formal test procedure (resulting four distinct computer modes). The latest update to mode definitions from EPA (2013b) seems to be partly a semantic one, but also reflects technological advances, with improved faster response times to user input (e.g., replacing the term *hibernation*). There is also a common practice of documenting products across both sectors (residential and commercial), which makes isolating the residential data somewhat challenging. Nevertheless, we are able to reasonably characterize the notebook market using the available data.

Usage

Overview: Across eight studies, notebooks usage estimates vary considerably, ranging from 1,367 – 3,796 hours per year in Active Mode, or a 2.8 factor difference. A few key complications with comparing the studies' usage are the difference in mode definitions, the challenges in differentiating the various modes during metering, and the recent shift in definitions through the ENERGY STAR 6.0 specification development process.

Recommended Values: While almost six years old, Microsoft 2008 draws from a very large sample size as part of its Customer Experience Improvement Program. It is also the primary source for residential usage that ENERGY STAR used to derive estimates for its new blended residential/commercial mode weightings (EPA 2013b). It is includes an especially strong method for data collection because it captures the usage through well-defined modal functionality that are the same across all PCs (with Windows operating systems) rather than through metering wattage thresholds which are typically limited to a bi-modal delineation than multi-modal, and can apply differently to each unit tested.

Applicability to Current Stock: This study's age is one obvious limitation, but it's not clear yet how notebook usage has shifted since 2008. On the one hand, it's possible that device usage has declined given the increased saturation of tablets. On the other hand, overall usage of notebooks could have increased, given greater saturation of internet usage, e.g., social media, media streaming. The other limitation is that the notebooks monitored exclude non-Windows units.[21] Given the limitations of the other studies and that the most recent ENERGY STAR specification uses these to derive its 2013 estimates, we recommend this assessment as the best device usage values for notebooks.

Power

Overview: Across eight studies, active mode power estimates range from 18 to 40W, or a 2.2 factor difference, with limited metering data available. With the exception of Greenblatt et al 2013, there appears to be a slight

[21] In 2013, this represented 5% of the market globally (CA IOUs & NRDC 2013), although this is likely higher in the U.S.

downward trend of active mode power; however, more recent shifts downward are simply modifications to older data rather than new metered data.

Recommended Values: While the data is limited, we recommend using Bensch et al 2013 for Active and Standby given that it has the most recent metering data for current stock, and Fraunhofer 2011 for Sleep. While Greenblatt et al 2013 is more recent, the high active mode relative to other studies suggests it could be an outlier.

Applicability to Current Stock: The recommended values for notebooks have medium applicability to the current stock given that the metering data sample sizes are limited.

Installed Base

Overview: Across seven studies, installed base estimates have a significant range from 35 to 165 million units nationally,[22] but can be explained by the fact that the high end includes tablets (EIA 2013), and the low end (TIAX 2006) and several of the others which are based on these values are over a half a decade old, before a significant shift of consumer preferences towards mobility.

Recommended Values: Fraunhofer 2011 is most recent survey performed and is referred to by several studies, so is the recommended value.

Applicability to Current Stock: Due to market discussion about shifts in consumer preferences towards even greater mobility to tablets, it is possible that this value overstates existing stock.

[22] This figure includes the combination of Conventional and Integrated Desktops into a single stock estimate for CA IOUs & NRDC 2013.

Table 19: Key Sources for Notebooks Usage estimates

Device Subcategory	Year	Study	Key Source(s)	Study Type	Sample Size	Metering Sampling Duration (Days)	Usage Active / Short Idle (Hrs/yr)	Long Idle / Standby (Hrs/yr)	Standby / Sleep / Hibernation (Hrs/yr)	Sleep / Off (Hrs/yr)	Applicability to Current Stock
Notebooks	2013	CA IOUs & NRDC 2013	EPA 2013b	Lit Review - Unmod.	-	-	2,628	876	3,066	2,190	Medium
Notebooks - incl. tablets	2013	EIA 2013	Fraunhofer 2011	Lit Review - Mod.	-	-	2,915	-	2,232	3,613	Medium
Notebooks	2013	EPA 2013b	Microsoft 2008, ECMA -383 2010	Lit Review - Mod.	-	-	2,628	876	3,066	2,190	Medium
Notebooks	2013	Greenblatt et al 2013	Greenblatt et al 2013	Metering	11	42	1,367	-	3,650	3,705	Medium
Notebooks	2011	Fraunhofer 2011	Fraunhofer 2011	Survey	1,000	-	2,915	-	2,210	2,726	Medium
Notebooks	2010	Bensch et al 2010	Bensch et al 2010	Metering	12	27	3,796	-	4,964	-	Low
Notebooks	2008	Microsoft 2008	Microsoft 2008	Other	35,195	90	2,330	823	499	5,107	Medium
Notebooks	2008	TIAX 2008	TIAX 2006	Lit Review - Mod.	-	-	2,383	-	918	5,458	Low
Notebooks	2007	TIAX 2007	TIAX 2007, TIAX 2006	Lit Review - Mod.	-	-	2,368	-	935	5,457	Low
Notebooks	2006	Foster Porter et al 2006	Foster Porter et al 2006	Metering	4	7	2,978	964	4,117	701	Low
Notebooks	2006	TIAX 2006	TIAX 2006	Survey	1,000	-	2,368	-	935	5,457	Low

[1]: Multiple modes in the same column is due to the definition variation of the studies. For more information refer to the discussion at the beginning of Section 4.3.

Table 20: Key Sources for Notebook Power estimates

Device Subcategory	Year	Study	Key Source(s)	Study Type	Sample Size	Metering Sampling Duration (Days)	Power Active / Short Idle (W)	Long Idle / Standby (W)	Standby / Sleep / Hibernation (W)	Sleep / Off (W)	UEC (kWh/yr)	Applicability to current stock
Notebooks	2013	CA IOUs & NRDC 2013	NRDC 2013	Dataset - Mod.	-	-	-	-	-	-	35	Low
Notebooks - incl. tablets	2013	EIA 2013	Fraunhofer 2011	Lit Review - Mod.	-	-	18.0	-	1.9	1.0	60	Medium
Notebooks	2013	Greenblatt et al 2013	Greenblatt et al 2013	Metering	11	42	40.1	-	1.1	-	59	Medium
Notebooks	2011	FSEC 2011	TIAX 2008	Lit Review - Unmod.	-	-	-	-	-	-	72	Low
Notebooks	2011	Fraunhofer 2011	Bensch et al. 2010, TIAX 2007	Lit Review - Mod.	-	-	19.0	-	2.0	1.0	63	Medium
Notebooks	2011	LBNL 2011	TIAX 2007a	Lit Review - Unmod.	-	-	-	-	-	-	72	Low
Notebooks	2010	Bensch et al 2010	Bensch et al 2010	Metering	17	27	29.7	-	0.7	-	113	Medium
Notebooks	2008	TIAX 2008	EPA 2005, Roberson et al 2004	Lit Review - Mod.	-	-	25.0	-	2.0	2.0	72	Low
Notebooks	2007	TIAX 2007	EPA 2005, Roberson et al 2004	Lit Review - Mod.	-	-	25.0	-	2.0	2.0	72	Low
Notebooks	2006	Foster Porter et al 2006	Foster et al 2006	Metering	7	7	21.9	-	2.5	1.8	80	Low
Notebooks	2006	TIAX 2006	EPA 2005, Roberson et al 2004	Lit Review - Mod.	-	-	25.0	-	2.0	2.0	72	Low

[1]: Multiple modes in the same column is due to the definition variation of the studies. For more information refer to the discussion at the beginning of Section 4.3.

Table 21: Key Sources for Notebook Installed Base estimates

Device Subcategory	Year	Study	Key Source(s)	Study Type (Source Type)	Installed Base Geography	Sample Size	Installed Base (Million)	AEC (TWh/yr)	Applicability to current stock
Notebooks	2013	CA IOUs & NRDC 2013	IDC 2012, 2013a, 2013b, Hamm & Greene 2008	Lit Review, (Market Research) - Mod.	National	-	72	2.0	Low
Notebooks - incl. tablets	2013	EIA 2013	Fraunhofer 2011, DisplaySearch 2013	Lit Review - Mod.	National	-	165	9.8	Medium
Notebooks	2011	Fraunhofer 2011	CEA 2010	Survey	National	1,000	132	8.3	Medium
Notebooks	2011	LBNL 2011	TIAX 2007a	Lit Review - Mod.	National	-	39	4.2	Medium
Notebooks	2008	TIAX 2008	TIAX 2007	Lit Review - Unmod.	National	-	39	2.8	Low
Notebooks	2007	TIAX 2007	TIAX 2006, EIA 2006	Lit Review - Mod.	National	-	39	2.8	Low
Notebooks	2006	TIAX 2006	TIAX 2006, Scherf 2004	Survey & Lit Review - Mod.	National	1,000	35	2.6	Low

Table 22: Summary of Key Notebook Metrics

Device Subcategory	Year	Study	Installed Base (Million)	Usage: Active / Short Idle (Hrs/yr)	Usage: Long Idle / Standby (Hrs/yr)	Usage: Standby / Sleep / Hibernation (Hrs/yr)	Usage: Sleep / Off (Hrs/yr)	Power: Active / Short Idle (W)	Power: Long Idle / Standby (W)	Power: Standby / Sleep / Hibernation (W)	Power: Sleep / Off (W)	UEC (kWh/yr)	AEC (TWh/yr)
Notebooks	2013	CA IOUs & NRDC 2013	72	2,628	876	3,066	2,190	-	-	-	-	35	2.0
Notebooks - incl. tablets	2013	EIA 2013	165	2,915	-	2,232	3,613	18.0	-	1.9	1.0	60	9.8
Notebooks	2013	EPA 2013b	-	2,628	876	3,066	2,190	-	-	-	-	-	-
Notebooks	2013	Greenblatt et al 2013	-	1,367	-	3,650	3,705	40.1	-	1.1	-	59	-
Notebooks	2011	FSEC 2011	-	-	-	-	-	-	-	-	-	72	-
Notebooks	2011	Fraunhofer 2011	132	2,915	-	2,210	2,726	19.0	-	2.0	1.0	63	8.3
Notebooks	2011	LBNL 2011	39	-	-	-	-	-	-	-	-	72	4.2
Notebooks	2010	Bensch et al 2010	-	3,796	-	4,964	-	29.7	-	0.7	-	113	-
Notebooks	2008	Microsoft 2008	-	2,330	823	499	5,107	-	-	-	-	-	-
Notebooks	2007	TIAX 2007	39	2,368	-	935	5,457	25.0	-	2.0	2.0	72	2.8
Notebooks	2006	Foster Porter et al 2006	-	2,978	964	4,117	701	21.9	-	2.5	1.8	80	-
Notebooks	2006	TIAX 2006	35	2,368	-	935	5,457	25.0	-	2.0	2.0	72	2.6
Notebooks	2006	TIAX 2008	39	2,383	-	918	5,458	25.0	-	2.0	2.0	72	2.8

[1]: Multiple modes in the same column is due to the definition variation of the studies. For more information refer to the discussion at the beginning of Section 4.3.

Data Quality Evaluation and Recommended UEC Values

Data Quality Evaluation: Overall, notebook computer research has a solid foundation; however, the recent market changes suggest that the data could be improved to more accurately depict current stock. Moreover, likely future market changes will increase the uncertainty and decrease the relevance of this data.

Recommended UEC and AEC Values: We estimate that notebooks currently consume 70 kWh/yr and 9.2 TWh/yr, calculated using combined sources of EPA 2013b, Fraunhofer 2011, and Greenblatt et al 2013.

Table 23: Recommend UEC and AEC values for Notebooks

Metric		Value	Source
Installed Base - US (M)		132	Fraunhofer 2011
Usage (hrs/yr)	Active/Short Idle	2,330	Microsoft 2008
	Long Idle	823	Microsoft 2008
	Standby	499	Microsoft 2008
	Sleep/Off	5,107	Microsoft 2008
Power (W)	Active	29.7	Bensch 2010
	Long Idle	-	-
	Standby	0.7	Greenblatt et al 2013
	Sleep/Off	-	-
UEC (kWh/yr)		70	Bensch et al 2010
AEC (TWh/yr)		9.2	Calculated
Overall Applicability to Existing Stock		Medium	

Gap Analysis, Opportunities for Further Research, and Implications for ZNE:

Gap Analysis and Opportunities for Further Research: Like several products discussed in this report, the research on notebooks is quite extensive, however changes in the market necessitate constant monitoring given the rapid market evolution of this technology class. For device usage, similar data collection to the Microsoft 2008 effort would be ideal. As discussed previously, this type of methodology has significant advantages over traditional metering studies for capturing duty cycles. For modal power, a larger sample metering data study would be useful. If not already being developed, perhaps a similar program to the Customer Improvement Experience could be developed for capturing wattage in addition to time in each mode and relayed anonymously by Microsoft. For stock estimates, additional phone or in-person household surveys should be sufficient.

Implications for ZNE Planning and Future Utility Efficiency Programs: For the purposes of ZNE planning in 2020, it is important to model the energy consumption of new notebooks on the market and conduct a stock-flow model to understand how they integrate and impact the overall stock.

4.5 Microwave Ovens

Overview: Microwave ovens have historically had high penetration due to their unique functionality as a kitchen appliance. Recent studies have identified the microwave oven as having substantial energy consumption among

MELs. While there is no existing ENERGY STAR specification for microwave ovens, DOE recently established energy conservation standards for standby and off mode with a compliance date of June 17, 2016.[23] Updated standards are expected in 2019. In February 2013, DOE released the active mode test procedure Notice of Proposed Rulemaking, and the Final Rule for this test procedure is expected at the end of 2014.

Usage

Overview: Microwave usage estimates for Active mode range from 53 to 70 hours per year, a 1.3 factor difference. The estimate from TIAX 2008 cites a resource from the Central Maine Power Company (CMPC) that could not be retrieved. Usage data is measured for active, standby, and off power modes.

Table 24: Key Sources for Microwave Oven Usage

Device Subcategory	Year	Study	Key Source(s)	Study Type (Source Type)	Sample Size	Metering Sampling Duration (Days)	Usage Active (Hrs/yr)	Usage Standby (Hrs/yr)	Usage Off (Hrs/yr)	Applicability to Current Stock
Microwave	2013	Greenblatt et al 2013	Greenblatt et al 2013	Metering	122	42	53	7,131	1,568	Medium
Microwave	2008	TIAX 2008	CMPC 2007	Lit Review - Mod. (Other)	-	-	70	8,690	-	Low

Recommended Values: We recommend values from the most recent study, which is a metering study conducted over the course of 42 days and with a sample size of 122 microwave ovens. This study was conducted in Northern California, although it is uncertain whether or not there are differences in microwave usage patterns between this region and the rest of the nation. In addition, this study was conducted during the summer, which may have lower microwave usage than the rest of the year due to potentially greater consumption of fresh produce. Greenblatt et al 2013 provides estimates in each usage mode (active, standby, and off) as a percentage of time spent in each mode, thus to achieve the values in the table, we multiplied these estimates with the total number of hours per year. The study defines off mode usage as a period when the microwave draws no power, standby mode usage as a period when it draws low power, and active mode usage during times of high power draw. TIAX 2008 provides usage estimates in only two modes (Active and Standby), however the lack of source information adds uncertainty to the estimates.

Applicability to Current Stock: Greenblatt et al 2013 provides recent metering data and has a relatively large sample size. However, given the seasonality of microwave use, we believe that microwave usage can be best captured through a multi-year metering study. Microwave oven usage is not expected to change drastically over future years due to its unique functionality as a kitchen appliance.

Power

Overview: Active mode power draw estimates, which measure the power draw when the microwave oven is performing its primary function to provide electromagnetic radiation, range from 1,094 to 1,500 W from only two studies. Microwaves may typically not have an off mode and remain in standby mode until activated by the user, thus they draw standby power at all other times when the microwave is not in active mode. Some microwaves

[23] The Final Rule published in August of 2013 by DOE requires a maximum standby power of 1 W for microwave-only ovens and countertop convection ovens and 2 W for built-in and over-the-range convection microwave ovens.

allow users to actively select the power level most appropriate for their use, which directly impacts active mode power draw. DOE standards for microwave ovens in standby and off mode allow a maximum standby power draw of only 1 W and will go into effect in June 2016. This is expected to substantially decrease the power draw in standby mode over the next decade as new products meeting this requirement begin to penetrate the existing stock.

Table 25: Key Sources for Microwave Oven Power Estimates

Device Subcategory	Year	Study	Key Source(s)	Study Type (Source Type)	Sample Size	Metering Sampling Duration (Days)	Power Active (W)	Standby (W)	Off (W)	UEC (kWh/yr)	Applicability to current stock
Microwave	2013	Greenblatt et al 2013	Greenblatt et al 2013	Metering	122	42	1094.3	1.9	0.0	71	Medium
Microwave	2013	ACEEE 2013	Parekh and Wang 2012, TIAX 2008	Lit Review - Mod.	-	-	-	-	-	121	Low
Microwave	2012	Parekh and Wang	Parekh and Wang 2012	Survey	720	-	-	-	-	111	Low
Microwave	2008	Tiax 2008	ADL 1998	Lit. Review - Mod.	-	-	1500.0	3.0		131	Medium

Recommended Values: We recommend using the power estimates from Greenblatt et al 2013 due to its large sample size and extensive metering duration. The duration of the metering study is also large enough to capture the variability in active mode power levels that end users have the capability to alter. Based on the definition of off mode provided in the study, we assumed off mode power draw to be 0 W even though an estimate for this mode was not explicitly stated

Applicability to Current Stock: We believe these estimates to have medium applicability to the current stock. Active Mode power draw estimates for existing stock are not expected to change significantly until Federal or state standards regulate active mode power draw. Federal rulemakings for standby mode power draw may decrease the standby power draw. However, this may be limited, since the standby power estimate of 1.9 W is already close to the adopted standard of 1 W. This slight decrease will result in roughly 10% overall energy savings.[24]

Installed Base

Overview: Based on two studies, installed base estimates range from 110 to 116 million microwave ovens across the United States. The most recent source is based on the Residential Energy Consumption Survey (RECS) conducted by the EIA in 2009. The previous installed base estimate is based on market research from Appliance Magazine. Both are credible sources of installed base information.

Table 26: Key Sources for Microwave Oven Installed Base Estimates

Device Subcategory	Year	Study	Key Source(s)	Study Type	Installed Base Geography	Sample Size	Installed Base (Million)	AEC (TWh/yr)	Applicability to current stock
Microwave	2013	ACEEE 2013	EIA 2009	Lit Review - Unmod. (Survey)	National	-	116.0	15.0	High
Microwave	2008	TIAX 2008	Appliance Magazine 2005a, 2005b	Market Research	National	-	110.0	14.4	Medium

Recommended Values: We recommend the installed base estimate from ACEEE 2013, which cites the 2009 RECS survey. This survey collected data from 12,083 households nationally which are meant to represent housing units across the United States. The estimate from TIAX 2008 which cites market research from 2005 may slightly

[24] Based on the estimate of 7,131 hours in standby mode, a decrease of 0.9 W corresponds to a decrease of 6.4 kWh/yr.

underrepresent the installed base of microwaves since it is almost a decade old. We expect microwave penetration to remain fairly constant and the installed base to continue to rise, reflecting an increase in the population and number of households.

Applicability to Current Stock: Although the recommended values have a large sample size and are derived from Federal survey data, we expect the installed base of microwaves to have increased slightly since 2009. Assuming that both sources accurately represent the stock during the year in which the studies were conducted, we estimate that the installed base increased by 1.5 million per year for four years. Assuming the same rate of increase through 2014, noting the uncertainty of this assumption, today the installed base estimate is likely closer to 123.5 million units, an increase of 7.5 million over 5 years.

Data Quality Evaluation and Recommend Values

Data Quality Evaluation: Usage and power estimates come from a metered data source, and given that the study was conducted recently, we believe that UEC estimates are representative of the current stock of microwave ovens. Although the sample is located in primarily Northern California, a sample size of 122 captures variation in power draw across different microwaves as well as variation in usage patterns. An overview of the energy consumption values is found in Table 27.

Table 27: Overview of Microwave Oven Energy Consumption Estimates

Device Subcategory	Year	Study	Installed Base (Million)	Usage			Power			UEC (kWh/yr)	AEC (TWh/yr)
				Active (Hrs/yr)	Standby (Hrs/yr)	Off (Hrs/yr)	Active (W)	Standby (W)	Off (W)		
Microwave	2013	ACEEE 2013	116.0	-	-	-	-	-	-	121.0	15
Microwave	2008	TIAX 2008	110.0	70	8,690	-	1500.0	-	3.0	131.0	14.4
Microwave	2013	Greenblatt et al 2013	-	53	7,131	1,568	1094.3	1.9	0.0	-	-

Recommended UEC and AEC values: The recommended UEC value, found in Table 28, across three usage modes is 72 kWh/yr, and with an installed base of 116 million units, the AEC is approximately 8.3 TWh/yr. Due to the incorporation of recent power draw estimates, UEC and AEC estimates are significantly lower than those found in TIAX 2008, which relies on power draw estimates from over a decade ago and usage data that may be limited in applicability. However, because we were unable to locate the primary usage data in this case, we are unable to speculate on its applicability.

Table 28: Recommended Microwave Oven Values

Metric		Value	Source
Installed Base - US (M)		116	ACEEE 2013
Usage (hrs/yr)	Active	53	Greenblatt et al 2013
	Standby	7,131	Greenblatt et al 2013
	Off	1,568	Greenblatt et al 2013
Power (W)	Active	1,094	Greenblatt et al 2013
	Standby	1.9	Greenblatt et al 2013
	Off	0	Greenblatt et al 2013
UEC (kWh/yr)		72	Calculated
AEC (TWh/yr)		8.3	Calculated
Overall Confidence		Medium	-

Gap Analysis, Opportunities for Further Research, and Implications for ZNE:

Gap Analysis and Opportunities for Further Research: The lack of national, multi-year usage data is the most significant limitation of existing microwave usage estimates. The installed base is expected to increase in the next decade, thus accurately capturing microwave oven energy consumption within ZNE modeling efforts is crucial to ensure accurate estimates of overall household energy consumption. Market research can help inform recent installed base estimates as well as metering studies with larger sample sizes.

By combining recent metering data with national installed base survey data, we developed a significantly lower AEC, as we believe that previous studies may have overestimated the AEC of microwave ovens. National usage data would be most helpful in refining the calculated UEC and AEC estimates.

Implications for ZNE Planning and Future Utility Efficiency Programs: For the purposes of ZNE planning, it is recommended that existing microwave usage and power data be updated with future usage data from ENERGY STAR or DOE proceedings. We also recommend using the most updated saturation surveys for California (RASS and CLASS) for developing California specific saturation estimates, although they are expected to be similar to the rest of the United States. Because the microwave market is relatively predictable and stable, the installed base can be modeled as a function of the number of households. As microwaves with lower standby power come onto the market, we recommend developing an elementary stock-flow model to estimate microwave energy consumption over time.

4.6 Game Consoles

Overview: Game Consoles are a unique product because of frequent, somewhat cyclical design changes. Not only are new product versions released every five to six years as new *generations*, models can change in subsequent releases between generations, especially in terms of energy consumption (Hittinger et al 2012). These changes can also impact mode definitions, in addition to wattage. Consequently, given that these products are competing not only with each other for market share but with other forms of entertainment, device usage and sales can also shift significantly as consumers respond. All of these factors therefore create significant uncertainty in making market estimates. While the studies surveyed provide a reasonable snapshot of the current market, ongoing monitoring of these products is crucial for maintaining a solid understanding of game console energy consumption.

Usage

Overview: Across nine studies, game console usage estimates show a very wide range of 405 – 8,497 hours per year in Active Mode. The cause of this discrepancy is likely due to the methodology differences in collecting metered or survey data in the earliest studies. Removing these extremes from the range result in a narrower, but still broad range of 1,011 – 1,743 hours per year (a 1.71 factor difference) in Active mode, which includes both game or media play. The high end from Greenblatt et al 2013 likely includes navigation mode as well, given its metering methodology, so summing the hours in active (in some cases two active modes) and navigation results in an even narrower range, 1,450 to 1,743 when looking at three cross model surveys, Fraunhofer 2011, CA IOUs 2013b and Greenblatt et al 2013.

Recommended Values: We recommend the values from CA IOUs 2013b derived from the most comprehensive known study regarding usage (CEA 2010).

Applicability to Current Stock: The main limitation of this study is the age of the source study and the fact that a new generation of products— Xbox One, PS4, and Wii U—were since released, and therefore device usage may have changed.

Power

Overview: Across ten studies, active mode power estimates show a significant range, from 24.2 to 137W, or a 5.7 factor difference. There are two known explanations: 1) the high end values, derived from metering (NRDC 2013a), are of the latest, high performing generation, and are representative of the latest sales, not stock; and 2) the low end values are derived from metering nearly two generations ago, also representative of the current stock. Recent testing reported by CA IOUs (2013b) and Greenblatt et al (2013) demonstrate an increase in power from the early studies, however also don't include the introduction of the latest generation.

Recommended Values: The wattage values from CA IOUs & NRDC 2013a are recommended, given that the study merges the most recent metering study of stock, and also accounts for the introduction of the new generation into its estimates, although not through metering data. Given that the new generation has been tested (NRDC 2013a), incorporating the estimates using this data, along with new sales data, could be useful.

Applicability to Current Stock: The recommended values for game consoles have medium applicability to the current stock given that the metering data sample size is somewhat limited and the other mode wattage is taken from even smaller metering data to estimate sales, not stock.

Installed Base

Overview: Across eleven studies, installed base estimates have a significant range, from 62 to 109 million units nationally, with a narrower range from three of the more recent studies — CA IOUs & NRDC 2013a, LBNL 2013 and Fraunhofer 2011 — at 103.1 to 109 million units. [25]

Recommended Values & Applicability to Current Stock: We recommend CA IOUs & NRDC 2013 with medium confidence. On the one hand, these estimates are closely aligned with other studies, but on the other, the values don't account for the introduction of the new generation releases, which may have further shifted the installed base.

[25] ACEEE 2013 is also recent, but is based on Fraunhofer 2011, so would be redundant to include.

Table 29: Key Sources for Game Consoles Usage estimates

Device Subcategory	Year	Study	Key Source(s)	Study Type	Sample Size	Metering Sampling Duration (Days)	Usage: Active (Hrs/yr)	Media Play / Other (Hrs/yr)	Navigation (Hrs/yr)	Sleep / Standby (Hrs/yr)	Sleep / Off (Hrs/yr)	Applicability to Current Stock
Game Consoles	2013	CA IOUs & NRDC 2013a	CA IOUs 2013b	Lit Review - Unmod.	-	-	605	407	460	144	7,150	Medium
Game Consoles	2013	CA IOUs 2013b	CEA 2010	Lit Review - Mod.	-	-	605	407	460	144	7,150	Medium
Game Consoles	2013	Greenblatt et al 2013	Greenblatt et al 2013	Metering	111	42	1,743	-	-	4,012	3,005	Medium
Game Consoles	2013	LBNL 2013	Greenblatt et al 2013	Lit Review - Unmod.	-	-	1,743	-	-	4,012	3,005	Medium
Game Consoles - Xbox One	2013	NRDC 2013a	NRDC 2013a	Other	-	-	1,460	-	Unknown	-	Unknown	Medium
Game Consoles - PS4	2013	NRDC 2013a	NRDC 2013a	Other	-	-	1,059	-	Unknown	-	Unknown	Medium
Game Consoles	2011	Fraunhofer 2011	CEA 2010a	Survey	-	-	750	370	330	-	7,310	Medium
Game Consoles - Xbox, PS3 &	2008	NRDC 2008	Nielsen 2007	Lit Review - Mod.	-	-	-	-	-	-	-	Low
Game Consoles	2008	TIAX 2008	TIAX 2007	Lit Review - Unmod.	-	-	405	-		560	7,795	Low
Game Consoles	2007	TIAX 2007	TIAX 2007	Survey	2,000	-	405	-		560	7,795	Low
Game Consoles	2006	Foster Porter et al 2006	Foster Porter et al 2006	Metering	8	7	8,497	-	-	263	-	Low

[1]: Multiple modes in the same column is due to the definition variation of the studies. For more information refer to the discussion at the beginning of Section 4.4.

Table 30: Key Sources for Game Consoles Power estimates

Device Subcategory	Year	Study	Key Source(s)	Study Type (Source Type)	Sample Size	Metering Sampling Duration (Days)	Power: Active (W)	Media Play / Other (W)	Navigation (W)	Sleep / Standby (W)	Sleep / Off (W)	UEC (kWh/yr)	Applicability to current stock
Game Consoles	2013	ACEEE 2013	Fraunhofer 2011, Reeves et al 2012	Lit Review - Unmod.	-	-	-	-	-	-	-	115	Medium
Game Consoles	2013	CA IOUs & NRDC 2013a	CA IOUs 2013b	Lit Review - Mod.	-	-	77.0	72.0	74.0	7.0	1.0	118	Medium
Game Consoles	2013	CA IOUs 2013b	CA IOUs 2013b	Metering	4	Inst.	49.5	42.3	44.3	7.0	0.6	106	Medium
Game Consoles	2013	Greenblatt et al 2013	Greenblatt et al 2013	Metering	111	42	54.6	-	-	1.6	0.0	101	Medium
Game Consoles	2013	LBNL 2013	Greenblatt et al 2013	Lit Review - Unmod.	-	-	-	-	-	-	-	68	Medium
Game Consoles - Xbox One	2013	NRDC 2013a	NRDC 2013a	Metering	1	Inst.	110.0	74.0	72.0	18.0	1.3	253	Medium
Game Consoles - PS4	2013	NRDC 2013a	NRDC 2013a	Metering	1	Inst.	137.0	90.0	88.0	8.8	0.5	184	Medium
Game Consoles	2012	Hittinger et al 2012	NRDC 2008, Hollister 2010	Lit Review - Mod.	-	-	85.2	-	66.2	2.1	-	330	Medium
Game Consoles	2011	Fraunhofer 2011	NRDC 2008, Moskovciak 2009, PlaystationPro2 2011,	Lit Review - Mod.	-	-	89.0	-	-	75.0	2.0	135	Medium
Game Consoles	2011	LBNL 2011	LBNL 2011, Nielsen 2006	Lit Review - Mod.	-	-	-	-	-	-	-	55	Low
Game Consoles - Xbox, PS3 & Wii	2008	NRDC 2008	NRDC 2008	Metering	11	Inst.	118.8	110	117.5	-	3.1	-	Medium
Game Consoles	2008	TIAX 2008	TIAX 2007	Lit Review - Unmod.	-	-	36.0	-	36.0	-	0.8	41	Low
Game Consoles	2007	TIAX 2007	TIAX 2007	Metering	4	Inst.	36.0	-	-	36.0	0.8	41	Low
Game Consoles	2006	Foster Porter et al 2006	Foster et al 2006	Metering	8	7	24.2	-	-	1.0	-	16	Medium

[1]: Multiple modes in the same column is due to the definition variation of the studies. For more information refer to the discussion at the beginning of Section 4.4.

[2]: For NRDC 2008, PS3 & Wii have the following power, respectively: Active (W) - 150.1, 16.4, Idle - 152.9 & 10.5, and Off - 1.1, 1.9. PS3 also had a Media Play of 148 (W).

Table 31: Key Sources for Game Consoles Installed Base estimates

Device Subcategory	Year	Study	Key Source(s)	Study Type	Installed Base Geography	Sample Size	Installed Base (Million)	AEC (TWh/yr)	Applicability to current stock
Game Consoles	2013	ACEEE 2013	Fraunhofer 2011, Reeves et al. 2012	Lit Review - Mod.	National	-	102.5	10.5	Medium
Game Consoles	2013	CA IOUs & NRDC 2013a	CA IOUs & NRDC 2013a, VGChartz 2013	Market Research - Mod.	National	-	105.9	12.5	Medium
Game Consoles	2013	CA IOUs 2013b	CA IOUs 2013b, VGChartz 2013	Market Research - Mod.	National	-	103.7	-	Medium
Game Consoles	2013	LBNL 2013	CEA 2012, Greenblatt 2013	Survey & Lit Review - Mod.	National	-	105.0	7.1	Medium
Game Consoles	2013	NRDC 2013a	NRDC 2013a	Other	-	-	-	11.0	Medium
Game Consoles	2012	Hittinger et al 2012	VGChatz 2011	Lit Review - Mod.	National	-	48.5	16.0	Medium
Game Consoles	2011	Fraunhofer 2011	CEA 2010a	Market Research - Unmod.	National	-	109.0	14.7	Medium
Game Consoles	2011	LBNL 2011	NRDC 2008, Nielsen 2006	Lit Review - Mod.	National	-	63.0	3.5	Low
Game Consoles	2008	NRDC 2008	NPD Group 2008	Lit Review - Unmod.	National	-	62.0	16.3	Medium
Game Consoles	2008	TIAX 2008	TIAX 2007	Lit Review - Unmod.	National	-	64.0	2.6	Low
Game Consoles	2007	TIAX 2007	TIAX 2007	Survey	National	2,000	64.0	2.6	Low

Table 32: Summary of Key Game Console Metrics

				Usage					Power						
Device Subcategory	Year	Study	Installed Base (Million)	Active (Hrs/yr)	Media Play / Other (Hrs/yr)	Navigation (Hrs/yr)	Sleep / Standby (Hrs/yr)	Sleep / Off (Hrs/yr)	Active (W)	Media Play / Other (W)	Navigation (W)	Sleep / Standby (W)	Sleep / Off (W)	UEC (kWh/yr)	AEC (TWh/yr)
Game Consoles	2013	ACEEE 2013	102.5	-	-	-	-	-	-	-	-	-	-	115	10.5
Game Consoles	2013	CA IOUs & NRDC 2013a	105.9	605	407	460	144	7,150	77.0	72.0	74.0	7.0	1.0	118	12.5
Game Consoles	2013	CA IOUs 2013b	103.7	605	407	460	144	7,150	49.5	42.3	44.3	7.0	0.6	106	-
Game Consoles	2013	Greenblatt et al 2013	-	1,743	-	-	4,012	3,005	54.6	-	-	1.6	0.0	101	-
Game Consoles	2013	LBNL 2013	105.0	1,743	-	-	4,012	3,005	-	-	-	-	-	68	7.1
Game Consoles - Xbox One	2013	NRDC 2013a	-	1,460	-	Unknown	-	-	110.0	74.0	72.0	18.0	1.3	253	11.0
Game Consoles - PS4	2013	NRDC 2013a	-	1,059	-	Unknown	-	-	137.0	90.0	88.0	8.8	0.5	184	11.0
Game Consoles	2012	Hittinger et al 2012	48.5	-	-	-	-	-	85.2	-	66.2	2.1	-	330	16.0
Game Consoles	2011	Fraunhofer 2011	109.0	750	370	330	-	7,310	89.0	-	-	75.0	2.0	135	14.7
Game Consoles	2011	LBNL 2011	63.0	-	-	-	-	-	-	-	-	-	-	55	3.5
Game Consoles	2008	NRDC 2008	62.0	-	-	-	-	-	118.8	110	117.5	-	3.1	-	16.3
Game Consoles	2008	TIAX 2008	64.0	405	-	-	560	7,795	36.0	-	36.0	-	0.8	41	2.6
Game Consoles	2007	TIAX 2007	64.0	405	-	-	560	7,795	36.0	-	-	36.0	0.8	41	2.6
Game Consoles	2006	Foster Porter et al 2006	-	8,497	-	-	263	-	24.2	-	-	1.0	-	16	-

[1]: Multiple modes in the same column is due to the definition variation of the studies. For more information refer to the discussion at the beginning of Section 4.4.

[2]: For NRDC 2008, PS3 & Wii have the following power, respectively: Active (W) - 150.1, 16.4, Idle - 152.9 & 10.5, and Off - 1.1, 1.9. PS3 also had a Media Play of 148 (W).

Data Quality Evaluation and Recommended UEC Values

Data Quality Evaluation: Overall, the current studies for game consoles provide a sufficiently accurate summary of the usage, power, and installed base, but as discussed, the ever-changing nature of the product make for significant uncertainties, especially given recent, new generation releases. There will continue to be changes in device usage, wattage and sales, so it's unlikely these current how values will maintain their accuracy for very long.

Recommended UEC and AEC Values: We estimate that game consoles currently consume 118 kWh/yr and 12.5 TWh/yr taken from CA IOUs & NRDC 2013a, since this study takes into consideration anticipation of the new generation releases.

Table 33: Recommend UEC and AEC values for Game Consoles

Metric		Value	Source
Installed Base - US (M)		106	CA IOUs & NRDC 2013a
Usage (hrs/yr)	Active	605	CA IOUs & NRDC 2013a
	Media Play / Other	407	CA IOUs & NRDC 2013a
	Navigation	460	CA IOUs & NRDC 2013a
	Sleep / Standby	144	CA IOUs & NRDC 2013a
	Sleep / Off	7,150	CA IOUs & NRDC 2013a
Power (W)	Active	77.0	CA IOUs & NRDC 2013a
	Media Play / Other	72.0	CA IOUs & NRDC 2013a
	Navigation	74.0	CA IOUs & NRDC 2013a
	Sleep / Standby	7.0	CA IOUs & NRDC 2013a
	Sleep / Off	1.0	CA IOUs & NRDC 2013a
UEC (kWh/yr)		118	CA IOUs & NRDC 2013a
AEC (TWh/yr)		12.5	CA IOUs & NRDC 2013a
Overall Confidence		Medium	-

Gap Analysis, Implications for ZNE and Opportunities for Further Research:

Gap Analysis and Opportunities for Further Research: Like several products discussed in this report including desktops, game consoles research is quite extensive; however, changes in the market necessitate constant monitoring given the rapid market evolution of this technology class. As discussed previously for desktops and notebooks, a more advanced approach compared to traditional methods of capturing device usage, given increased internet connectivity with these products, could prove highly beneficial to better understand product behavior and opportunities for improvement. In terms of power, a fair amount of testing has been performed but not yet consolidated, given that the new generation from Sony and Microsoft were released after CA IOUs & NRDC 2013 was published. In the short-term a refresh of the data accounting for these products could prove useful. For stock estimates, additional phone or in-person household surveys should be sufficient. Alternatively, improved approaches for estimating useful life could help supplement traditional surveys.

Implications for ZNE Planning and Future Utility Efficiency Programs:

For the purposes of ZNE planning in 2020, it is important to understand how the cyclical introduction of new game consoles impacts the energy consumption of the existing game consoles stock. For the purposes of ZNE planning, we recommend developing a stock-flow model to estimate how new consoles impact installed base.

4.7 Monitors

Overview: While monitors have undergone significant energy consumption changes over the past decade shifting from CRTs to LCDs, the trends in the data suggest that much of this shift is complete. The result is that recently the monitor market has made relatively moderate changes in recent years. Device usage has also followed a similar trend, but the sales data is less consistent across studies. Monitors have had a six ENERGY STAR specifications, and categorization and mode definitions seem to have been consistent over time.

Usage

Overview: Monitor usage estimates have a reasonably small range, from 1,861 – 2,573 hours per year in Active Mode, or a 1.38 factor difference, most likely due to the increase of computer usage over time, demonstrated by the studies' upward trend by year. While some studies separate subcategory data, e.g., CRT, LCD, they also provided overall averages for the whole category so these values were highlighted exclusively. Moreover, this distinction is not a determining factor of usage.

Table 34: Key Sources for Monitor Usage estimates

Device Subcategory	Year	Study	Key Source(s)	Study Type	Sample Size	Metering Sampling Duration (Days)	Usage Active (Hrs/yr)	Usage Sleep (Hrs/yr)	Usage Off (Hrs/yr)	Applicability to Current Stock
Monitors	2013	ACEEE 2013	Fraunhofer 2011	Lit Review - Unmod.	-	-	2,519	-	-	Medium
Monitors	2013	CA IOUs 2013d	Fraunhofer 2011	Lit Review - Unmod.	-	-	2,519	3,541	2,701	Medium
Monitors	2013	EIA 2013	Fraunhofer 2011	Lit Review - Mod.	-	-	2,573	3,505	2,682	Medium
Monitors	2013	Greenblatt et al 2013	Greenblatt et al 2013	Metering	23	42	2,400	4,529	1,831	Medium
Monitors	2011	Fraunhofer 2011	Fraunhofer 2011	Survey	1,000	-	2,519	3,541	2,701	Medium
Monitors	2010	Bensch et al 2010	Bensch et al 2010	Metering	38	27	1,927	6,833	-	Medium
Monitors	2008	TIAX 2008	TIAX 2006	Lit Review - Mod.	-	-	1,861	869	6,029	Medium
Monitors	2007	TIAX 2007	TIAX 2007, TIAX 2006	Lit Review - Mod.	-	-	1,865	875	6,020	Medium
Monitors	2006	TIAX 2006	TIAX 2006	Survey	1,000	-	1,861	881	6,018	Medium

Recommended Values: While survey data is less desirable than metering data, Fraunhofer 2011 draws from a significantly larger sample size than the metering studies. Moreover, the limited number of display modes makes the survey data more reliable than other products, as survey responders can reasonably assess the device usage.

Applicability to Current Stock: Fraunhofer 2011 has some limitations given that survey responders may not be able to accurately distinguish between sleep and off, however the most recent metering data from Greenblatt et al 2013 seems to generally support these values.

Power

Overview: Across eleven studies, active mode power estimates show a significant range, from 23.5 to 45.0W, or a 1.92 factor difference. There are two known explanations. The most substantial cause is that the market has seen a significant shift from less efficient CRTs to more efficient flat screens. An additional reason is that the lowest end values, derived from metering (CA IOUs 2013d), were limited to current sales versus a stock assessment.

Recommended Values: Greenblatt et al 2013 is the most recent metering study of stock, so is the recommended value for active and sleep. Given that it does not meter off mode, we recommend using metering data from CA IOUs 2013d for Off Mode, despite the fact that the study reflects sales instead of stock.

Table 35: Key Sources for Monitor Power estimates

Device Subcategory	Year	Study	Key Source(s)	Study Type	Sample Size	Metering Sampling Duration (Days)	Power Active (W)	Sleep (W)	Off (W)	UEC (kWh/yr)	Applicability to current stock
Monitors	2013	ACEEE 2013	Fraunhofer 2011	Lit Review - Mod.	-	-	-	-	-	69	Medium
Monitors	2013	CA IOUs 2013d	CA IOUs 2013d	Metering	6	Inst.	23.5	0.3	0.2	61	Medium
Monitors	2013	EIA 2013	Fraunhofer 2011	Lit Review - Mod.	-	-	34.0	1.1	0.8	99	Medium
Monitors	2013	Greenblatt et al 2013	Greenblatt et al 2013	Metering	23	42	26.0	1.0	-	67	Medium
Monitors	2011	FSEC 2011	TIAX 2008	Lit Review - Unmod.	-	-	-	-	-	85	Low
Monitors	2011	Fraunhofer 2011	TIAX 2007	Lit Review - Mod.	-	-	36.0	1.1	0.6	97	Low
Monitors	2011	LBNL 2011	TIAX 2007a	Lit Review - Unmod.	-	-	-	-	-	96	Low
Monitors	2010	Bensch et al 2010	Bensch et al 2010	Metering	26	27	31.0	0.8	-	70	Medium
Monitors	2008	TIAX 2008	TIAX 2007, Roberson et al 2004	Lit Review - Unmod.	-	-	42.0	1.0	1.0	85	Low
Monitors	2007	TIAX 2007	ENERGY STAR 2005a, Roberson et al 2004	Lit Review - Mod.	-	-	42.0	1.0	1.0	85	Low
Monitors	2006	TIAX 2006	ENERGY STAR 2005a, Roberson et al 2004	Dataset & Lit Review - Mod.	-	-	45.0	2.0	1.0	78	Low

Applicability to Current Stock: The recommended values for monitors have medium applicability to the current stock given that the metering data sample size is somewhat limited and the other mode wattage is taken from even smaller metering data to estimate sales, not stock.

Installed Base

Overview: Across eight studies, Installed Base estimates have a very large range, from 65 to 150 million units nationally,[26] but the range can be explained by the fact that the high end includes commercial sales data and the low end is derived through sales multiplied by useful life rather than a traditional survey data. Sales may have dropped recently given the decline in desktop computer sales as well, but this is unlikely to be a main cause for the discrepancy even when comparing the recommended value of 96 million to the low end. It is uncertain how the shift towards multiple screens for computer usage or the replacement of TVs with internet connected monitors will impact the installed base of the monitor market.

Recommended Values: Although sales may have since changed, Fraunhofer 2011 is the most recent survey performed and is referred to by several studies, so it is the recommended value.

[26] This figure includes the combination of Conventional and Integrated Desktops into a single stock estimate for CA IOUs & NRDC 2013.

Table 36: Key Sources for Monitor Installed Base estimates

Device Subcategory	Year	Study	Key Source(s)	Study Type (Source Type)	Installed Base Geography	Sample Size	Installed Base (Million)	AEC (TWh/yr)	Applicability to current stock
Monitors	2013	ACEEE 2013	Fraunhofer 2011	Lit Review - Unmod.	National	-	111	13.0	Medium
Monitors	2013	CA IOUs 2013d	IHS 2012	(Market Research) - Mod	National	-	65	3.4	Medium
Monitors	2013	EIA 2013	Fraunhofer 2011	Lit Review - Mod.	National	-	130	12.8	Medium
Monitors	2011	Fraunhofer 2011	Fraunhofer 2011	Survey	National	1,000	96	12.7	Medium
Monitors	2011	LBNL 2011	TIAX 2007a	Lit Review - Unmod.	National	-	150	14.4	Low
Monitors	2008	TIAX 2008	TIAX 2007	Lit Review - Unmod.	National	-	90	7.7	Low
Monitors	2007	TIAX 2007	TIAX 2006	Lit Review - Mod.	National	-	90	7.6	Low
Monitors	2006	TIAX 2006	TIAX 2006	Survey	National	1,000	85	7.7	Low

Applicability to Current Stock: Given the large sample size, the installed base estimate is considered to be relatively good. It is uncertain to what degree this figure considers older monitors that are no longer used but are considered part of the installed base.

Data Quality Evaluation and Recommended UEC Values

Data Quality Evaluation: Overall, the current data for monitors is reasonably robust. There may continue to be changes in device usage, wattage and installed base, so there is some uncertainty about how long the values maintain their accuracy.

Table 37: Summary of Key Monitor Metrics

Device Subcategory	Year	Study	Installed Base (Million)	Usage Active (Hrs/yr)	Usage Sleep (Hrs/yr)	Usage Off (Hrs/yr)	Power Active (W)	Power Sleep (W)	Power Off (W)	UEC (kWh/yr)	AEC (TWh/yr)
Monitors	2013	ACEEE 2013	111	2,519	-	-	-	-	-	69	13.0
Monitors	2013	CA IOUs 2013d	65	2,519	3541	2701	23.5	0.3	0.2	61	3.4
Monitors	2013	EIA 2013	130	2,573	3505	2682	34.0	1.1	0.8	99	12.8
Monitors	2013	Greenblatt et al 2013	-	2,400	4529	1831	26.0	1.0	-	67	-
Monitors	2011	FSEC 2011	-	-	-	-	-	-	-	85	-
Monitors	2011	Fraunhofer 2011	96	2,519	3541	2701	36.0	1.1	0.6	97	12.7
Monitors	2011	LBNL 2011	150	-	-	-	-	-	-	96	14.4
Monitors	2010	Bensch et al 2010	-	1,927	6833	-	31.0	0.8	-	70	-
Monitors	2008	TIAX 2008	90	1,861	869	6029	42.0	1.0	1.0	85	7.7
Monitors	2007	TIAX 2007	90	1,865	875	6020	42.0	1.0	1.0	85	7.6
Monitors	2006	TIAX 2006	85	1,861	881	6018	45.0	2.0	1.0	78	7.7

Recommended UEC and AEC Values: We estimate that monitors currently consume 70 kWh/yr and 6.7 TWh/yr based on calculations using combined sources. The UEC value aligns with the most recent metered data given that device usage is quite similar in both Fraunhofer 2011 and Greenblatt et al 2013. The AEC is significantly different than the survey estimates given that the UEC is derived from a heavily CRT saturated market.

Table 38: Recommend UEC and AEC values for Monitors

Metric		Value	Source
Installed Base - US (M)		96	Fraunhofer 2011
Usage (hrs/yr)	Active	2,519	Fraunhofer 2011
	Sleep	3,541	Fraunhofer 2011
	Off	2,701	Fraunhofer 2011
Power (W)	Active	26.0	Greenblatt et al 2013
	Sleep	1.0	Greenblatt et al 2013
	Off	0.2	CA IOUs 2013d
UEC (kWh/yr)		70	Calculated
AEC (TWh/yr)		6.7	Calculated
Overall Confidence		Medium	-

Gap Analysis, Opportunities for Further Research, and Implications for ZNE:

Gap Analysis and Opportunities for Further Research: The monitors research is quite extensive and provides a robust snapshot of the current market. Like other products within this technology class, constant monitoring of the key metrics is needed, although perhaps not as frequent. Moreover, given the direct correlation with desktops, there are opportunities to develop estimates using this overlapping product for device usage and stock. For power estimates, while there continue to be energy-efficiency opportunities, the big shift from CRTs to flat-screens seems to be nearly complete, and already contributed significantly to a reduction in energy consumption. Therefore the current estimates may continue prove to be useful for a sustained period. As discussed previously for desktops and notebooks, a more advanced approach compared to traditional methods of capturing device usage, given increased internet connectivity with these products, could prove highly beneficial to better understand product behavior and opportunities for improvement. For stock estimates, additional phone or in-person household surveys should be sufficient. Alternatively, improved approaches for estimating useful life could help supplement these traditional surveys.

Implications for ZNE Planning and Future Utility Efficiency Programs: For the purposes of ZNE planning in 2020,we recommend developing a stock-flow model to estimate how new products on the market are integrated into the installed base. The low UEC values for monitors makes a traditional utility incentive program difficult. However, there are opportunities for future utility programs provided they can scale impact effectively; this includes support in ENERGY STAR specification development and potentially commercial incentive programs, although they may require innovative program designs to meet program cost-effectiveness requirements.

4.8 DVD/Blu-Ray Players

Overview: DVD / Blu-Ray Players are media playback devices which play DVD or Blu-Ray discs. For the purpose of this literature review, we have separated this category into five subcategories:

- All DVD / Blu-Ray Players (combined)
- DVD Player

- DVD Recorder
- DVD / VCR Combo[27]
- Blu-Ray Player

Since the DVD / Blu-Ray format war[28] in 2008, there has been an increase in Blu-Ray Players in the market (Fraunhofer 2011). However, this category has been fundamentally changed with the rise of streaming content, which may substantially decrease DVD/Blu-Ray usage. Standby Mode power draw is regulated under Title 20. DVD / Blu-Ray players are included under the ENERGY STAR Audio / Video specifications, with power requirements for Active, Idle, and Standby Mode.

In addition, ENERGY STAR's modal distinction makes it somewhat difficult to compare existing wattage measurements with metering studies. While the ENERGY STAR method better represent actual usage, it can be difficult to capture this in metering data. Metering data is limited in its accuracy as modes are typically determined by thresholds (resulting in two distinct modes) rather than by mode functionality or captured through testing using a formal test procedure.

Usage

Overview: There are four key studies which have estimated DVD / Blu-Ray Player usage since 2007. Combined Active/Idle and Idle usage ranges from 910 – 8,432 hours. Excluding the high end from Bensch et al 2010, which appears to be an outlier due to constant usage, the range is 910-2,993, or a 3.3 factor difference. Where possible, we prioritized metering studies due to the limitations of survey data for products with low consumer mindshare and its significant potential for under-reporting in Idle mode for products without an Auto Power Down (APD) function.

Recommended Values: For DVD players, DVD / VCR Combos, and Blu-Ray players, we recommend using Greenblatt et al 2013 due to its use of metering data.[29] For DVD Recorders, we recommend using Fraunhofer 2011.

Applicability to current stock: The wide variance in usage estimates suggests there is low applicability to given stock. While Greenblatt et al is based on metering data, it is a fairly small sample size and has a limited metering duration, and therefore cannot account for seasonal variations in usage.

Power

Overview: Although Active Mode Power draw is relatively low for DVD Players, it accounts for the majority of overall energy consumption. DVD Player Active Mode Power values range from 10.4-13 W, a 1.3 factor difference (see Table 40). DVD Recorder Active Power values ranged from 11 to 20 W, a 1.9 factor difference. Active Mode for Blu-Ray players ranged from 30.0-31.8 W, a 1.1 factor difference.

[27] Because DVD / VCR Combo devices are expected to substantially decrease their usage and installed base in the future, we have excluded them from the discussion. However, they are included in the summary tables.
[28] For more information on the 'Format Wars', see http://en.wikipedia.org/wiki/High_definition_optical_disc_format_war
[29] Because Greenblatt et al combines Active and Idle modes, we recommend their study as one single value for both units. For a usage estimate of Idle Mode by itself, we recommend Fraunhofer 2011.

Recommended Values:
Similar to the usage values, we recommend using Greenblatt et al for DVD players, DVD/VCR Combos, and Blu-Ray players. Due to the lack of robust metering data for DVD Recorders, we recommend Fraunhofer 2011.

Applicability to Current Stock: The use of metering and the recent data suggest that Greenblatt et al 2013 has medium applicability to the current stock. Although the power data is relatively uniform for most categories, the limited sample size is some cause for uncertainty. ENERGY STAR's APD requirements took effect in 2010 as part of the Version 2.0 specification[30], and so it is likely that the existing installed base consists of both products with and without APD enabled. As of 2012, both DVD and Blu-Ray players had ENERGY STAR market penetration of 61%,[31] further suggesting that the current installed base is comprised of products both with and without APD.

Installed Base

Overview: The installed base ranges from 120-236 million units, a factor of 2.0 (see Table 41).[32] It is uncertain how the installed base will change over time. There is a potential for an increase in Blu-Ray player sales as consumers transition from the DVD format, however it also possible that the prevalence of high-speed internet connections and streamed content significantly decreases the stock of these players over time.

Recommended Values: We recommend using ACEEE 2013 for the entire product category, and Fraunhofer 2011 for the individual subcategories.

Applicability to Current Stock: We believe these values have medium applicability in that they are based on a 2011 survey and likely accurately capture ownership. However, it is uncertain how many of these devices are actively being used as consumers increasingly opt to use streaming media, the use of which is likely to increase over time.

[30] http://www.energystar.gov/ia/partners/product_specs/program_reqs/AV_V2_Specification.pdf
[31] http://www.energystar.gov/ia/partners/downloads/unit_shipment_data/2012_USD_Summary_Report.pdf?d47b-7eee
[32] The 236 million is derived by summing all units accounted for in the Fraunhofer 2011 study.

Table 39: Key Sources for DVD / Blu-Ray Player Usage Estimates

Device Subcategory	Year	Study	Key Source(s)	Study Type	Sample Size	Metering Sampling Duration (Days)	Usage Active / Idle (Hrs/yr)	Idle (Hrs/yr)	Sleep (Hrs/yr)	Off (Hrs/yr)	Applicability to Current Stock
DVD Player	2013	Greenblatt et al 2013	Greenblatt et al 2013	Metering	35	42	2,059	-	1,848	4,853	Medium
DVD Player	2011	Fraunhofer 2011	Fraunhofer 2011	Survey	1,000	-	210	700	7,850	-	Low
DVD Player	2010	Bensch et al 2010	Bensch et al 2010	Metering	37	27	2,993	-	-	-	Low
Stand-alone DVD	2008	TIAX 2008	TIAX 2007	Lit Review - Unmod.	-	-	270	900	-	7,590	Low
Stand-alone DVD	2007	TIAX 2007	TIAX 2007	Survey	2,000	-	270	900	-	7,590	Low
DVD Recorder	2011	Fraunhofer 2011	Fraunhofer 2011	Survey	1,000	-	410	900	7,450	-	Low
DVD Recorder	2010	Bensch et al 2010	Bensch et al 2010	Metering	1	27	8,432	-	-	-	Low
DVD Recorder	2008	TIAX 2008	TIAX 2007	Lit Review - Unmod.	-	-	270	900	-	7,590	Low
DVD Recorder	2007	TIAX 2007	TIAX 2007	Survey	2,000	-	270	900	-	7,590	Low
DVD/VCR Combo	2013	Greenblatt et al 2013	Greenblatt et al 2013	Metering	17	42	6,386	-	613	1,761	Medium
DVD/VCR Combo	2011	Fraunhofer 2011	Fraunhofer 2011	Survey	1,000	-	300	900	7,560	-	Low
DVD/VCR Combo	2010	Bensch et al 2010	Bensch et al 2010	Metering	12	27	402	-	-	-	Low
DVD/VCR Combo	2008	TIAX 2008	TIAX 2007	Lit Review - Unmod.	-	-	425	900	-	7,435	Low
DVD/VCR Combo	2007	TIAX 2007	TIAX 2007	Survey	2,000	-	420	900	-	7,440	Low
Blu-Ray Player	2013	Greenblatt et al 2013	Greenblatt et al 2013	Metering	23	42	1,226	-	1,191	6,342	Medium
Blu-Ray Player	2011	Fraunhofer 2011	Fraunhofer 2011	Survey	1,000	-	300	30	8,430	-	Low

Table 40: Key Sources for DVD / Blu-Ray Player Power Estimates

Device Subcategory	Year	Study	Key Source(s)	Study Type (Source Type)	Sample Size	Metering Sampling Duration (Days)	Power Active (W)	Power Idle (W)	Power Sleep (W)	Power Off (W)	UEC (kWh/yr)	Applicability to current stock
DVD/Blu-Ray Players - All	2013	ACEEE 2013	LBNL 2011b, Fraunhofer 2011	Lit Review - Mod.	-	-	-	-	-	-	45	Low
DVD/Blu-Ray Players - All	2011	LBNL 2011	TIAX 2007a	Unknown	-	-	-	-	-	-	36	Low
DVD Player	2013	Greenblatt et al 2013	Greenblatt et al 2013	Metering	35	42	10.4	-	0.6	0.0	-	Medium
DVD Player	2011	Fraunhofer 2011	Bensch et al 2010, EPA 2009a	Lit Review - Mod.	Unknown	-	9.0	5.0	1.5	-	18	Low
DVD Player	2010	Bensch et al 2010	Bensch et al 2010	Metering	37	30	7.9	-	0.4	-	24	Low
Stand alone DVD	2008	TIAX 2008	TIAX 2007	Lit Review - Unmod.	-	-	13.0	10.0	-	2.3	30	Low
Stand alone DVD	2007	TIAX 2007	TIAX 2007, LBNL 2004	Metering	35	Inst.	13.0	10.0	-	2.3	30	Low
DVD Recorder	2011	Fraunhofer 2011	Bensch et al 2010, EPA 2009a	Lit Review - Mod.	Unknown	-	18.0	14.0	3.0	-	42	Low
DVD Recorder	2010	Bensch et al 2010	Bensch et al 2010	Metering	1	27	11.0	-	1.0	-	93	Low
DVD Recorder	2008	TIAX 2008	TIAX 2007	Lit Review - Unmod.	-	-	20.0	15.0	-	2.0	34	Low
DVD Recorder	2007	TIAX 2007	TIAX 2007, LBNL 2004	Metering	35	Inst.	20.0	15.0	-	2.0	34	Low
DVD/VCR Combo	2013	Greenblatt et al 2013	Greenblatt et al 2013	Metering	17	42	9.3	-	0.7	0.0	-	Medium
DVD/VCR Combo	2011	Fraunhofer 2011	Bensch et al 2010, EPA 2009a	Lit Review - Mod.	Unknown	-	12.0	8.0	3.0	-	34	Low
DVD/VCR Combo	2010	Bensch et al 2010	Bensch et al 2010	Metering	12	27	17.4	-	2.5	-	28	Low
DVD/VCR Combo	2008	TIAX 2008	TIAX 2007	Lit Review - Unmod.	-	-	15.0	11.0	-	4.5	50	Low
DVD/VCR Combo	2007	TIAX 2007	TIAX 2007, LBNL 2004	Metering	35	Inst.	15.0	11.0	-	4.5	50	Low
Blu-Ray Player	2013	Greenblatt et al 2013	Greenblatt et al 2013	Metering	23	42	31.8	-	0.5	0.0	-	Medium
Blu-Ray Player	2011	Fraunhofer 2011	CNET 2010, Oeko-Institut e.V. 2009	Lit Review - Mod. (Metering)	9	Inst.	30.0	16.0	0.5	-	14	Low

Table 41: Key Sources for DVD / Blu-Ray Player Installed Base Estimates

Device Subcategory	Year	Study	Key Source(s)	Study Type (Source Type)	Installed Base Geography	Sample Size	Installed Base (Million)	AEC (TWh/yr)	Applicability to current stock
DVD/Blu-Ray Players - All	2013	ACEEE 2013	Fraunhofer 2011	Lit Review - Mod.	National	-	191.5	8.1	Medium
DVD/Blu-Ray Players - All	2011	LBNL 2011	TIAX 2007a	Lit Review - Unmod.	National	-	120.0	4.3	Low
DVD Player	2011	Fraunhofer 2011	Fraunhofer 2011, CEA 2010c	Survey; Lit Review - Mod. (Mkt Research)	National	1,000	107.0	1.9	Medium
Stand alone DVD	2008	TIAX 2008	CEA 2006	Lit Review - Unmod. (Market research)	National	-	75.0	2.3	Low
Stand alone DVD	2007	TIAX 2007	CEA 2006	Lit Review - Unmod. (Market research)	National	-	75.0	2.3	Low
DVD Recorder	2011	Fraunhofer 2011	Fraunhofer 2011, CEA 2010c	Survey; Lit Review - Mod. (Mkt Research)	National	1,000	55.8	2.4	Medium
DVD Recorder	2008	TIAX 2008	CEA 2006	Lit Review - Unmod. (Market research)	National	-	10.0	0.3	Low
DVD Recorder	2007	TIAX 2007	CEA 2006	Lit Review - Unmod. (Market research)	National	-	10.0	0.3	Low
DVD/VCR Combo	2011	Fraunhofer 2011	Fraunhofer 2011, CEA 2010c	Survey; Lit Review - Mod. (Mkt Research)	National	1,000	60.2	2.0	Low
DVD/VCR Combo	2008	TIAX 2008	CEA 2006	Lit Review - Unmod. (Market research)	National	-	35.0	1.8	Low
DVD/VCR Combo	2007	TIAX 2007	CEA 2006	Lit Review - Unmod. (Market research)	National	-	35.0	1.8	Low
Blu-Ray Player	2011	Fraunhofer 2011	CEA 2010c	Lit Review - Mod.	National	1,000	13.0	0.2	Medium

Table 42: Overview of DVD / Blu-Ray Player Estimates

Device Subcategory	Year	Study	Installed Base (Million)	Usage: Active / Idle (Hrs/yr)	Usage: Idle (Hrs/yr)	Usage: Sleep (Hrs/yr)	Usage: Off (Hrs/yr)	Power: Active (W)	Power: Idle (W)	Power: Sleep (W)	Power: Off (W)	UEC (kWh/yr)	AEC (TWh/yr)
DVD/Blu-Ray Players	2013	ACEEE 2013	191.5	-	-	-	-	-	-	-	-	45	8.1
DVD/Blu-Ray Players	2011	LBNL 2011	120.0	-	-	-	-	-	-	-	-	36	4.3
DVD Player	2013	Greenblatt et al 2013	-	2,059	-	1,848	4,853	10.4	-	0.6	0.0	-	-
DVD Player	2011	Fraunhofer 2011	107.0	210	700	7,850	-	9.0	5.0	1.5	-	18	1.9
DVD Player	2010	Bensch et al 2010	-	2,993	-	-	-	7.9	-	0.4	-	24	-
Stand alone DVD	2008	TIAX 2008	75.0	270	900	-	7,590	13.0	10.0	-	2.3	30	2.3
Stand alone DVD	2007	TIAX 2007	75.0	270	900	-	7,590	13.0	10.0	-	2.3	30	2.3
DVD Recorder	2011	Fraunhofer 2011	55.8	410	900	7,450	-	18.0	14.0	3.0	-	42	2.4
DVD Recorder	2010	Bensch et al 2010	-	8,432	-	-	-	11.0	-	1.0	-	93	-
DVD Recorder	2008	TIAX 2008	10.0	270	900	-	7,590	20.0	15.0	-	2.0	34	0.3
DVD Recorder	2007	TIAX 2007	10.0	270	900	-	7,590	20.0	15.0	-	2.0	34	0.3
DVD/VCR Combo	2013	Greenblatt et al 2013	-	6,386	-	613	1,761	9.3	-	0.7	0.0	-	-
DVD/VCR Combo	2011	Fraunhofer 2011	60.2	300	900	7,560	-	12.0	8.0	3.0	-	34	2.0
DVD/VCR Combo	2010	Bensch et al 2010	-	402	-	-	-	17.4	-	2.5	-	28	-
DVD/VCR Combo	2008	TIAX 2008	35.0	425	900	-	7,435	15.0	11.0	-	4.5	50	1.8
DVD/VCR Combo	2007	TIAX 2007	35.0	420	900	-	7,440	15.0	11.0	-	4.5	50	1.8
Blu-Ray Player	2013	Greenblatt et al 2013	-	1,226	-	1,191	6,342	31.8	-	0.5	0.0	-	-
Blu-Ray Player	2011	Fraunhofer 2011	13.0	300	30	8,430	-	30.0	16.0	0.5	-	14	0.2

Data Quality Evaluation

Data Quality Evaluation:

Overall, usage data for all DVD and Blu-Ray Players is highly variable, resulting in low confidence of the end use estimates. This is primarily due to the differences in mode definitions that makes it difficult to combine survey and metering data.

Recommended Values:

We recommend using ACEEE 2013 for the entire DVD/Blu-Ray player category, since there are no other existing recent studies which provide a value for the entire product categories.

Table 43: Overview of DVD / Blu-Ray Player Estimates

DVD/Blu-Ray Players - All			
Metric		Value	Source
Installed Base - US (M)		191.5	ACEEE 2013
Usage (hrs/yr)	Active	-	
	Idle	-	
	Sleep	-	
	Off	-	
	Active	-	
	Idle	-	
	Sleep	-	
	Off	-	
UEC (kWh/yr)		45	ACEEE 2013
AEC (TWh/yr)		8.1	ACEEE 2013
Overall Confidence		Low	-

Table 44: Overview of DVD Player Estimates

DVD Player			
Metric		Value	Source
Installed Base - US (M)		107	Fraunhofer 2011
Usage (hrs/yr)	Active/Idle	2,059	Greenblatt et al 2013
	Idle		-
	Sleep	1,848	Greenblatt et al 2013
	Off	4,853	Greenblatt et al 2013
Power (W)	Active	10.4	Greenblatt et al 2013
	Idle	5.0	Fraunhofer 2011
	Sleep	0.6	Greenblatt et al 2013
	Off	0.0	Greenblatt et al 2013
UEC (kWh/yr)		23	Calculated
AEC (TWh/yr)		2.4	Calculated
Overall Confidence		Low	-

Table 45: Overview of Blu-Ray Player Estimates

Blu-Ray Player			
Metric		Value	Source
Installed Base - US (M)		13	Fraunhofer 2011
Usage (hrs/yr)	Active / Idle	1,226	Greenblatt et al 2013
	Idle	-	-
	Sleep	1,191	Greenblatt et al 2013
	Off	6,342	Greenblatt et al 2013
Power (W)	Active	31.8	Greenblatt et al 2013
	Idle	-	-
	Sleep	0.5	Greenblatt et al 2013
	Off	0.0	Greenblatt et al 2013
UEC (kWh/yr)		40	Calculated
AEC (TWh/yr)		0.5	Calculated
Overall Confidence		Low	-

Gap Analysis, Opportunities for Further Research, and Implications for ZNE:

Gap Analysis and Opportunities for Further Research: The greatest gap in existing DVD / Blu-Ray player estimates is the lack of accurate usage data. Because there is little discrepancy in existing power data, most of the variance within the UEC values is due to variance in usage estimates. While the existing metering studies suggest that these players spend a significant portion of their time in Active/Idle mode, additional multi-year data would be extremely useful in refining usage estimates. We recommend reviewing NEEA's recently released home energy use metering study (NEEA 2014) to provide additional resolution to usage estimates.

Implications for ZNE Planning and Future Utility Efficiency Programs: Similar to other A/V products, usage estimates are difficult to determine. This in turn creates high variability in UEC and AEC values. This product may see significant shifts in usage, power, and installed base over time, as consumers move increasingly towards streaming content and APD requirements become standard in all players. Similar to other A/V products, there is a lack of data on the UEC difference between ENERGY STAR and non-ENERGY STAR products, which can make it difficult to estimate potential savings opportunities.

4.9 Network Equipment

Overview: The data for network equipment demonstrates a relatively straightforward product in terms of the key metrics – device usage, wattage, UEC and installed base; the studies show relatively consistent data and wattage for all products is under 10 watts for active mode. There are however seven different device subcategories, not including the modem – cable/DSL delineation. The following narrative focuses primarily on the top two priority products in terms of estimated: modems and routers.

Usage

Overview: Across 13 studies, network equipment usage estimates have a considerably large range, from 4,380 – 8,760 hours per year in Active Mode for both modems and routers (see Table 46). However when excluding the study with the lower bound, the range changes to 7,826 – 8,760 hours per year, or 1.12 factor difference. In sum, despite some small variance, network equipment is estimated to be on and active nearly 100% of the time.

Recommended Values: For modems, routers and integrated access devices (IADs, or joint modem/router units) we recommend 8,760 hours per year, which is assumed by the majority of the studies, as well as metered by Greenblatt et al 2013.

Applicability to Current Stock: The literature provides little evidence to suggest any past or current trends that will shift these products from being on/active 8,760 hour per year. Despite the small sample size of the metering study, there is relatively high confidence in this estimate.

Power

Overview: Across eleven studies for modems (some just DSL or Router, and some both aggregated), active mode power estimates show a somewhat large range between 5.1 and 9.5 watts, or 1.87 factor difference. Across seven studies for routers, active mode power estimates show a smaller range between 4.6 and 7.1 watts, or 1.6 factor difference. Across two more recent studies for IADs, active mode power estimate show a very narrow range from 6.6 to 7.0 watts, or 1.06 factor difference (see Table 47).

Recommended Values: For modems and routers, Greenblatt et al 2013 is the most recent metering study of stock, so is the recommended value for active modes. For IADs, we recommend using CA IOUs 2013e because it has the only data delineating different types of network equipment within the IAD subcategory.

Applicability to Current Stock: The recommended values for modems and routers have medium applicability to the current stock given that the metering data sample size is somewhat limited. For IADs, the recommended values also have medium applicability given that values are taken from the ENERGY STAR dataset (EPA 2013), so they are reflective on the most efficient products being offered for sale, not necessarily the existing stock. Regarding sales vs. stock, IADs are relatively new to the marketplace, so this estimate still may be close to reflecting existing stock.

Installed Base

Overview: Across nine studies for modems, installed base estimates have a very large range, from 32 to 70 million (2.2 factor difference). Across four studies for routers, and two studies for IADs, installed base estimates also have a very large range, 43 and 90 million and 42 and 82 million units nationally (see Table 48). The growth in IADs and the decline in modems support the assumption that IADs are replacing modems. The cause for the apparent increase of growth in routers is unknown.

Recommended Values: We recommend using all of the values from CA IOUs 2013e. While the methodology for estimating stock is not through a traditional survey (it was derived by calculating sales by the expected useful life of five years), these values provide the greatest level of detail for sub and sub-sub categories.

Table 46: Key Sources for Network Equipment Usage estimates

Device Subcategory	Year	Study	Key Source(s)	Study Type	Sample Size	Metering Sampling Duration (Days)	Usage Active (Hrs/yr)	Usage Sleep / Off (Hrs/yr)	Applicability to Current Stock
Modems, Routers, Hubs, Switches & IADs	2013	EIA 2013	Fraunhofer 2011, TIAX 2008	Lit Review - Mod.	-	-	8,760	-	Medium
Access Point	2013	CA IOUs 2013e	Lanzisera et al. 2010	Lit Review - Mod.	-	-	8,760	-	Medium
Integrated Access Device	2011	Fraunhofer 2011	Bensch et al 2010, Meier et al 2008	Lit Review - Mod.	-	-	7,826	934	Medium
Integrated Access Device - Analog DSL	2013	CA IOUs 2013e	Lanzisera et al. 2010	Lit Review - Unmod.	-	-	8,760	-	Medium
Integrated Access Device - Cable	2013	CA IOUs 2013e	Lanzisera et al. 2010	Lit Review - Unmod.	-	-	8,760	-	Medium
Integrated Access Device - V DSL	2013	CA IOUs 2013e	Lanzisera et al. 2010	Lit Review - Unmod.	-	-	8,760	-	Medium
Modem	2013	Greenblatt et al 2013	Greenblatt et al 2013	Metering	16	42	8,760	-	High
Modem	2011	Fraunhofer 2011	Bensch et al 2010, Meier et al 2008	Lit Review - Mod.	-	-	7,826	934	Medium
Modem	2008	TIAX 2008	TIAX 2008	Other	-	-	8,760	-	Medium
Modem	2006	TIAX 2006	TIAX 2006	Survey	1,000	-	8,760	-	Medium
Modem - Cable	2013	CA IOUs 2013e	Lanzisera et al. 2010	Lit Review - Unmod.	-	-	8,760	-	Medium
Modem - Cable	2010	Lanzisera et al 2010	Lanzisera et al 2010	Other	-	-	8,760	-	Medium
Modem - Cable	2008	Meier et al 2008	Meier et al 2008	Survey	306	-	Unknown	Unknown	Low
Modem - Cable	2006	Foster Porter et al 2006	Foster Porter et al 2006	Metering	2	7	4,380	4,380	Low
Modem - DSL	2013	CA IOUs 2013e	Lanzisera et al. 2010	Lit Review - Unmod.	-	-	8,760	-	Medium
Modem - DSL	2010	Bensch et al 2010	Bensch et al 2010	Metering	4	27	8,541	219	Medium
Modem - DSL	2010	Lanzisera et al 2010	Lanzisera et al 2010	Other	-	-	8,760	-	Medium
Modem - DSL	2008	Meier et al 2008	Meier et al 2008	Survey	306	-	Unknown	Unknown	Low
Modem - DSL	2006	Foster Porter et al 2006	Foster Porter et al 2006	Metering	6	7	8,760	-	Medium
Optical Network Termination Device	2013	CA IOUs 2013e	Lanzisera et al. 2010	Lit Review - Unmod.	-	-	8,760	-	Medium
Router	2013	CA IOUs 2013e	Lanzisera et al. 2010	Lit Review - Unmod.	-	-	8,760	-	Medium
Router	2013	Greenblatt et al 2013	Greenblatt et al 2013	Metering	27	42	8,760	-	High
Router	2010	Bensch et al 2010	Bensch et al 2010	Metering	7	27	8,760	-	Medium
Router - Wireless	2006	Foster Porter et al 2006	Foster Porter et al 2006	Metering	3	7	8,760	-	Medium
Router & other devices	2011	Fraunhofer 2011	Bensch et al 2010, Meier et al 2008	Lit Review - Mod.	-	-	7,826	934	Medium
Switch	2013	CA IOUs 2013e	Lanzisera et al. 2010	Lit Review - Unmod.	-	-	8,760	-	Medium

Table 47: Key Sources for Network Equipment Power estimates

Device Subcategory	Year	Study	Key Source(s)	Study Type (Source Type)	Sample Size	Metering Sampling Duration (Days)	Power Active (W)	Power Standby / Off (W)	UEC (kWh/yr)	Applicability to current stock
Modems, Routers, Hubs, Switches & IADs	2013	EIA 2013	Fraunhofer 2011, TIAX 2008	Lit Review - Mod.	-	-	5.6	-	51	Medium
Access Point	2013	CA IOUs 2013e	EPA 2013	(Dataset) - Unmod.	-	Inst.	6.1	-	64	Medium
Integrated Access Device	2011	Fraunhofer 2011	Lanzisera et al 2010, Lanzisera et al 2010a	Lit Review - Mod.	-	-	6.6	1.5	53	Medium
Integrated Access Device - Analog DSL	2013	CA IOUs 2013e	EPA 2013	(Dataset) - Unmod.	-	Inst.	7.0	-	62	Medium
Integrated Access Device - Cable	2013	CA IOUs 2013e	EPA 2013	(Dataset) - Unmod.	-	Inst.	6.9	-	61	Medium
Integrated Access Device - V DSL	2013	CA IOUs 2013e	EPA 2013	(Dataset) - Unmod.	-	Inst.	10.1	-	89	Medium
Modem	2013	Greenblatt et al 2013	Greenblatt et al 2013	Metering	16	42	5.8	-	51	Medium
Modem	2013	ACEEE 2013	Fraunhofer 2011, TIAX 2008	Lit Review - Unmod.	-	-	-	-	49	Medium
Modem	2011	Fraunhofer 2011	Lanzisera et al 2010, Lanzisera et al 2010a	Lit Review - Mod.	-	-	5.6	0.1	44	Medium
Modem	2011	FSEC 2011	TIAX 2008	Lit Review - Unmod.	-	-	-	-	53	Low
Modem	2008	TIAX 2008	Nordman & McMahon 2004, Foster Porter et al 2006	Lit Review - Mod.	-	-	6.0	-	53	Low
Modem	2007	TIAX 2007	TIAX 2006	Lit Review - Unmod.	-	-	6.0	-	53	Low
Modem	2006	TIAX 2006	Nordman & McMahon 2004, Schlomann 2005	Lit Review - Mod.	-	-	6.0	-	53	Low
Modem - Cable	2013	CA IOUs 2013e	EPA 2013	(Dataset) - Unmod.	-	Inst.	6.6	-	58	Medium
Modem - Cable	2010	Lanzisera et al 2010	Unknown	Lit Review - Mod.	-	-	9.5	-	83	Medium
Modem - Cable	2011	LBNL 2011	Lanzisera et al 2010	Lit Review - Unmod.	-	-	-	-	45	Medium
Modem - Cable	2008	Meier et al 2008	Meier et al 2008	Metering	8	Inst.	6.3	3.8	-	Low
Modem - Cable	2006	Foster Porter et al 2006	Foster et al 2006	Metering	10	7	6.4	4.5	60	Low
Modem - DSL	2013	CA IOUs 2013e	EPA 2013	(Dataset) - Unmod.	-	Inst.	5.1	-	48	Medium
Modem - DSL	2011	LBNL 2011	Lanzisera et al 2010	Lit Review - Unmod.	-	-	-	-	55	Medium
Modem - DSL	2010	Bensch et al 2010	Bensch 2010	Metering	4	27	5.6	0.8	38	Medium
Modem - DSL	2010	Lanzisera et al 2010	Unknown	Lit Review - Mod.	-	-	7.1	-	62	Medium
Modem - DSL	2008	Meier et al 2008	Meier et al 2008	Metering	20	Inst.	5.4	1.4	-	Low
Modem - DSL	2006	Foster Porter et al 2006	Foster et al 2006	Metering	6	7	5.6	-	49	Low
Optical Network Termination Device	2013	CA IOUs 2013e	EPA 2013	(Dataset) - Unmod.	-	Inst.	6.7	-	59	Medium
Router	2013	CA IOUs 2013e	EPA 2013	(Dataset) - Unmod.	-	Inst.	7.3	-	53	Medium
Router	2013	ACEEE 2013	Fraunhofer 2011, TIAX 2008	Lit Review - Unmod.	-	-	-	-	44	Medium
Router	2013	Greenblatt et al 2013	Greenblatt et al 2013	Metering	27	42	6.7	-	59	Medium
Router	2011	LBNL 2011	Unknown	Other	-	-	-	-	42	Medium
Router	2010	Bensch et al 2010	Bensch 2010	Metering	7	27	4.6	-	35	Medium
Router - Wireless	2006	Foster Porter et al 2006	Foster et al 2006	Metering	7	7	6.2	1.7	48	Low
Router & other devices	2011	Fraunhofer 2011	Lanzisera et al 2010, Lanzisera et al 2010a	Lit Review - Mod.	-	-	5.4	1.7	44	Medium
Switch	2013	CA IOUs 2013e	EPA 2013	(Dataset) - Unmod.	-	Inst.	5.7	-	50	Medium

Table 48: Key Sources for Network Equipment Installed Base estimates

Device Subcategory	Year	Study	Key Source(s)	Study Type (Source Type)	Installed Base Geography	Sample Size	Installed Base (Million)	AEC (TWh/yr)	Applicability to current stock
Modems, Routers, Hubs, Switches & IADs	2013	EIA 2013	Fraunhofer 2011, TIAX 2008	Lit Review - Mod.	National	-	138	7.0	Medium
Access Point	2013	CA IOUs 2013e	Infonetics 2013	(Market Research) - Mod.	National	-	8	0.4	Medium
Integrated Access Device	2011	Fraunhofer 2011	Lanzisera et al 2010a	Lit Review - Unmod.	National	-	42	2.2	Medium
Integrated Access Device - Analog DSL	2013	CA IOUs 2013e	Infonetics 2012	(Market Research) - Mod.	National	-	33	2.3	Medium
Integrated Access Device - Cable	2013	CA IOUs 2013e	Infonetics 2012	(Market Research) - Mod.	National	-	43	2.6	Medium
Integrated Access Device - V DSL	2013	CA IOUs 2013e	Infonetics 2012	(Market Research) - Mod.	National	-	6	0.6	Medium
Modem	2013	ACEEE 2013	Fraunhofer 2011	Lit Review - Unmod.	National	-	46	2.0	Medium
Modem	2011	Fraunhofer 2011	Lanzisera et al 2010a	Lit Review - Unmod.	National	-	46	2.0	Medium
Modem	2008	TIAX 2008	JD Power 2006, EIA 2006	Lit Review - Mod.	National	-	46	2.6	Medium
Modem	2007	TIAX 2007	TIAX 2006, J.D Power 2006	Lit Review - Mod.	National	-	46	2.4	Medium
Modem	2006	TIAX 2006	TIAX 2006, IDC 2004, Horrigan 2005	Survey & Lit Review - Mod.	National	1,000	32	1.7	Medium
Modem - Cable	2013	CA IOUs 2013e	Infonetics 2012	(Market Research) - Mod.	National	-	30	1.8	Medium
Modem - Cable	2010	Lanzisera et al 2010	OECD 2009, FCC 2009	Lit Review - Mod.	National	-	53	4.4	Medium
Modem - Cable	2011	LBNL 2011	Lansizera et al 2010	Lit Review - Unmod.	National	-	40	1.8	Medium
Modem - DSL	2013	CA IOUs 2013e	Infonetics 2012	(Market Research) - Mod.	National	-	2	0.01	Medium
Modem - DSL	2011	LBNL 2011	Lanzisera et al 2010	Lit Review - Unmod.	National	-	30	1.7	Medium
Modem - DSL	2010	Lanzisera et al 2010	OECD 2009, FCC 2009	Lit Review - Mod.	National	-	42	2.6	Medium
Optical Network Termination Device	2013	CA IOUs 2013e	Infonetics 2012	(Market Research) - Mod.	National	-	1	0.1	Medium
Router	2013	CA IOUs 2013e	Infonetics 2012	(Market Research) - Mod.	National	-	92	5.8	Medium
Router	2013	ACEEE 2013	Fraunhofer 2011	Lit Review - Unmod.	National	-	49	2.1	Medium
Router	2011	LBNL 2011	Lanzisera et al 2010	Lit review - Unmod.	National	-	43	1.8	Medium
Router and other devices	2011	Fraunhofer 2011	Lanzisera et al 2010a	Lit Review - Unmod.	National	-	50	2.1	Medium
Switch	2013	CA IOUs 2013e	Infonetics 2013	(Market Research) - Mod.	National	-	6	0.3	Medium

[1] The cause for the discrepancies in Router installed based and AEC is unknown. One possible cause is the methodology for CA IOUs 2013e is through multiplying sales by the expected useful life (5 years)

Table 49: Summary of Key Network Equipment Metrics

Device Subcategory	Year	Study	Installed Base (Million)	Usage: Active (Hrs/yr)	Usage: Sleep / Standby (Hrs/yr)	Usage: Sleep/Off (Hrs/yr)	Power: Active (W)	Power: Off (W)	UEC (kWh/yr)	AEC (TWh/yr)
Modems, Routers, Hubs, Switches & IADs	2013	EIA 2013	138	8,760	-	-	5.6	-	51	7.0
Access Point	2013	CA IOUs 2013e	8	8,760	-	-	6.1	-	64	0.4
Integrated Access Device	2011	Fraunhofer 2011	42	7,826	-	934	6.6	1.5	53	2.2
Integrated Access Device - Analog DSL	2013	CA IOUs 2013e	33	8,760	-	-	7.0	-	62	2.3
Integrated Access Device - Cable	2013	CA IOUs 2013e	43	8,760	-	-	6.9	-	61	2.6
Integrated Access Device - V DSL	2013	CA IOUs 2013e	6	8,760	-	-	10.1	-	89	0.6
Modem	2013	ACEEE 2013	46	-	-	-	-	-	49	-
Modem	2013	Greenblatt et al 2013	-	8,760	-	-	5.8	-	51	-
Modem	2011	Fraunhofer 2011	46	7,826	-	934	5.6	0.1	44	2.0
Modem	2011	FSEC 2011	-	-	-	-	-	-	53	-
Modem	2009	CEC 2010	-	-	-	-	-	-	-	1.8
Modem	2008	TIAX 2008	46	8,760	-	-	6.0	-	53	2.6
Modem	2007	TIAX 2007	46	8,760	-	-	6.0	-	53	2.4
Modem	2006	TIAX 2006	32	8,760	-	-	6.0	-	53	1.7
Modem - Cable	2013	CA IOUs 2013e	30	8,760	-	-	6.6	-	58	4.4
Modem - Cable	2011	LBNL 2011	40	-	-	-	-	-	45	-
Modem - Cable	2010	Lanzisera et al 2010	53	8,760	-	-	9.5	-	83	2.6
Modem - Cable	2008	Meier et al 2008	-	-	-	-	6.3	3.8	-	-
Modem - Cable	2006	Foster Porter et al 2006	-	4,380	4,380	-	6.4	4.5	60	-
Modem - DSL	2013	CA IOUs 2013e	2	8,760	-	-	5.1	-	48	0.01
Modem - DSL	2011	LBNL 2011	30	-	-	-	-	-	55	1.7
Modem - DSL	2010	Bensch et al 2010	-	8,541	219	-	5.6	0.8	38	-
Modem - DSL	2010	Lanzisera et al 2010	42	8,760	-	-	7.1	-	62	1.8
Modem - DSL	2006	Foster Porter et al 2006	-	8,760	-	-	5.6	-	49	-
Modem - DSL	2008	Meier et al 2008	-	-	-	-	5.4	1.4	-	-
Optical Network Termination Device	2013	CA IOUs 2013e	1	8,760	-	-	6.7	-	59	0.1
Router	2013	CA IOUs 2013e	92	8,760	-	-	7.3	-	53	5.8
Router	2013	Greenblatt et al 2013	-	8,760	-	-	6.7	-	59	-
Router	2013	ACEEE 2013	49	-	-	-	-	-	44	2.1
Router	2011	LBNL 2011	43	-	-	-	-	-	42	1.8
Router	2010	Bensch et al 2010	-	8,760	-	-	4.6	-	35	-
Router - Wireless	2006	Foster Porter et al 2006	-	8,760	-	-	6.2	1.7	48	-
Router and other devices	2011	Fraunhofer 2011	50	7,826	-	934	5.4	1.7	44	2.1
Switch	2013	CA IOUs 2013e	6	8,760	-	-	5.7	-	50	3.0

Data Quality Evaluation and Recommended UEC Values

Data Quality Evaluation: Overall, the current data for network equipment is reasonably robust. Moreover, with the no noticeable historical changes in device usage and wattage suggest, this data may be sufficient for several years. The discrepancy in stock values between studies, either due to historical changes or the differences between studies in methodology for calculating, is a cause for greater uncertainty.

Recommended UEC and AEC Values: For IADs — Analog DSL, Cable and V DSL — we recommend utilizing CA IOUs 2013e for UEC and AEC values, 62, 61 and 89, and 2.3, 2.6, and .6 respectively. For Modems and Routers, we recommend utilizing a combination of Greenblatt et al 2013 for UEC and CA IOUs 2013e for AEC values. The recommendation of Network Equipment as an entire category is presented in Table 50. However, when possible, we recommend using individual estimates for network equipment sub-categories as opposed to the broader Network Equipment category as a whole. For a complete listing of all recommended values, please see Appendix A.

Table 50: Recommended UEC and AEC values for Network Equipment [33]

All			
Metric		Value	Source
Installed Base - US (M)		220	Sum of Individuals
Usage (hrs/yr)	Active	8,760	Weighted Average
Power (W)	Active	6.70	Weighted Average
UEC (kWh/yr)		59.14	Weighted Average
AEC (TWh/yr)		13.0	Weighted Average
Overall Confidence		Medium	-

Gap Analysis, Implications for ZNE and Opportunities for Further Research:

Gap Analysis and Opportunities for Further Research: The existing network equipment research is quite extensive and provides a robust snapshot of the current market. Like other products within this technology class, constant monitoring of the key metrics and growth in subcategory stock beyond modems and routers is needed, although perhaps not as frequently as other end uses. For device usage especially and power and stock a lesser degree, current estimates may continue prove to be useful for a sustained period. For power estimates, traditional metering methods seem adequate, although larger sample sizes would be beneficial. For stock estimates, additional phone or in-person household surveys should be sufficient. Alternatively, improved approaches for estimating useful life could help supplement these traditional surveys.

Implications for ZNE Planning and Future Utility Efficiency Programs: For the purposes of ZNE planning in 2020, we recommend developing a stock-flow model to measure new products entering the market, since it is likely that the entire network equipment stock will completely turn over by 2020. Because consumers have limited customer

[33] The summary here is for the entire network equipment category. For recommended values for the subcategories, please see Appendix A.

selection for network equipment and it typically comes with an internet package, we recommend working with internet service providers (ISPs) on potential efficiency opportunities.

4.10 Compact Audio

Overview: Compact audio systems consist of a center component that has multiple audio player capabilities and two or more detached speakers (TIAX 2008).[34] The CEC defines a "compact audio product" as an audio device with an amplifier and radio tuner, attached or separable speakers, and audio playback capabilities. The CEC explicitly states that this category does not include audio devices that can be independently powered by internal batteries or that have video output signals. Appliance efficiency standards in California for compact audio products have been in place since 2007 and regulate maximum standby/passive mode power draw.[35] There is a slight variation in mode definitions between major studies. The most recent primary study, conducted by Bensch et al 2010, estimates usage for two modes, Active and Standby, in which Standby mode is when the unit is plugged in but turned off. TIAX 2008 and TIAX 2007 estimate usage in three distinct modes: Active, Idle, and Off. The difference between Idle and Off mode, as described in TIAX 2007, is that during Idle mode the unit is still on without any audio functions being performed. In Off mode, the unit is plugged in but turned off. We attempt to accommodate for these modal distinctions by clarifying definitions wherever necessary.

There have been three versions of the ENERGY STAR Audio/Video Specifications to date. Compact audio systems fall under the category of home consumer electronics and typically operate either as a separate unit or while connected to a television or other multimedia device. Today, many compact audio systems are designed to be compatible with a wide range of audio playing devices, such as mobile phones and tablets, while some are designed exclusively to be operated with mobile phones and tablets exclusively.

Usage

Overview: We found three studies with usage data for compact audio systems, with active mode usage varying from 840 to 2,482 hours, a 3.0 factor difference (see Table 51). This is partially due to the definitions in modal usage.

Table 51: Key Sources for Compact Audio Usage Estimates

Device Subcategory	Year	Study	Key Source(s)	Study Type	Sample Size	Metering Sampling Duration (Days)	Usage: Active / Idle (Hrs/yr)	Usage: Idle (Hrs/yr)	Usage: Standby / Off (Hrs/yr)	Applicability to Current Stock
Compact Audio	2011	Fraunhofer 2011	TIAX 2007, Bensch et al 2010	Lit Review - Mod.	-	-	2,482	-	6,278	Low
Compact Audio	2010	Bensch et al 2010	Bensch et al 2010	Metering	15	27	2,482	-	6,278	Low
Compact Audio	2008	TIAX 2008	TIAX 2007	Lit Review - Unmod.	2,000	-	840	730	7,190	Low
Compact Audio	2007	TIAX 2007	TIAX 2007	Survey	2,000	-	840	730	7,190	Low

[34] A more recent metering study by Bensch et al in 2010 categorized this appliance as compact stereo, however it does not specify the number of detached speakers powered by the unit.

[35] The 2010 Appliance Efficiency Regulations adopted by the California Energy Commission specify a maximum standby power draw of 4 W for units with a permanently illuminated display and 2 W for those without display.

[1]: Multiple modes in the same column is due to the definition variation of the studies. For more information refer to the discussion at the beginning of Section 4.10.

Recommended Values: We believe that Bensch et al 2010 is most reflective of typical compact audio system use at 2,482 hours per year in Active Mode. However, there is significant uncertainty due to the small metering sample size. We chose this value over TIAX 2007 due to the significant potential for under-reporting for audio devices and the limitation for discerning between Idle and Off Mode.

Applicability to Current Stock: While we believe that although Bensch et al is most applicable because of its metering data, its small sample size and short metering duration provides the study a low level of certainty. The large difference between Bensch et al and TIAX 2007 indicates that compact audio usage requires further study.

Power

Overview: Although a number of studies provide UEC estimates, there are only two primary metering studies from which modal power data has been derived, as seen in Table 52. Bensch et al 2010 is based on metering data, whereas TIAX 2007 is based on instantaneous measurements of 51 compact audio systems in active mode. Similar to other CE devices, the studies have significantly different mode definitions which makes it difficult to compare power values across modes. This is discussed in further detail in the Compact Audio overview section above.

Table 52: Key Sources for Compact Audio Power Estimates

Device Subcategory	Year	Study	Key Source(s)	Study Type (Source Type)	Sample Size	Metering Sampling Duration (Days)	Power Active / Idle (W)	Idle (W)	Standby / Off (W)	UEC (kWh/yr)	Applicability to current stock
Compact Audio	2013	ACEEE 2013	Unknown	Unknown	-	-	-	-	-	93	-
Compact Audio	2011	Fraunhofer 2011	Bensch et al 2010	Lit Review - Unmod.	-	-	31.6	-	4.3	105	Low
Compact Audio	2011	LBNL 2011	TIAX 2007	Lit Review - Unmod.	-	-	-	-	-	81	Low
Compact Audio	2010	Bensch et al	Bensch et al 2010	Metering	15	27	31.6	-	4.3	-	Low
Compact Audio	2008	TIAX 2008	TIAX 2007	Lit Review - Unmod.	-	-	23.0	16.0	7.0	81	Low
Compact Audio	2007	TIAX 2007	TIAX 2007, LBNL 2004, EPA 2006	Metering, Lit Review - Mod. (Metering, Other)	51	Inst.	23.0	16.0	7.0	81	Low

[1]: Multiple modes in the same column is due to the definition variation of the studies. For more information refer to the discussion at the beginning of Section 4.10.

Recommended Values: We recommend all power draw estimates be taken from Bensch et al 2010. We believe that this best represents the integration of Active/Idle modes to provide an overall estimate of power when the device is turned on. In TIAX 2007, Active Mode was determined by measurements of 51 compact audio systems in active mode. For Idle mode power draw, TIAX 2007 cites LBNL 2004, which states that the ratio of Idle mode power draw to Active mode power draw is approximately 50%. Noting uncertainty, TIAX 2007 increases this ratio to estimate standby power as 70% of active mode draw. Thus, there is no measured data for Idle Mode in TIAX 2007. Due to recent ENERGY STAR specifications and California's Title 20 appliance efficiency regulations for Standby/Off Mode, we believe the Standby/Off mode power draw to be closer to the lower end of the estimates.

Applicability to Current Stock: We believe that the values from Bensch et al 2010 are moderately representative of the existing stock, although they were conducted nearly five years ago. It is uncertain how compact audio form factors have changed since that time to accommodate changes in digital technology and the move to MP3 music formats. The standards adopted by the California Energy Commission and recent ENERGY STAR specifications may impact the compact audio system market by reducing power in standby mode.

Installed Base

Overview: Installed base estimates for compact audio range from 76 to 83 million units, 1.1 factor difference. The most recent study does not cite a source for its installed base estimate, while the oldest estimate is based on market research.

Table 53: Key Sources for Compact Audio Installed Base

Device Subcategory	Year	Study	Key Source(s)	Study Type	Installed Base Geography	Sample Size	Installed Base (Million)	AEC (TWh/yr)	Applicability to current stock
Compact Audio	2013	ACEEE 2013	-	-	National	-	83.0	6.6	-
Compact Audio	2011	Fraunhofer 2011	Bensch et al 2010	Lit Review - Mod. (Survey)	National	260	63.0	6.6	Low
Compact Audio	2011	LBNL 2011	TIAX 2007	Lit Review - Mod.	National	-	76.0	6.2	Low
Compact Audio	2008	TIAX 2008	TIAX 2007	Lit Review - Unmod. (Survey)	National	-	76.0	6.2	Low
Compact Audio	2007	TIAX 2007	CEA 2005	Lit Review - Unmod. (Market Research)	National	2,000	76.0	6.2	Low

Recommended Values: We recommend installed base estimates from Fraunhofer 2011. Although Fraunhofer 2011 cites Bensch et al 2010 for their national installed base estimate of 63 million units, it is unclear as to how this estimate is derived from the available data from the cited source. Bensch et al conducted a mailed appliance survey to 260 homes in Minnesota which found that there are 0.58 compact stereo devices per home. Fraunhofer's estimate requires scaling the Bensch et al estimate by the number of households in the United States, which Fraunhofer 2011 does not explicitly state when presenting data on compact audio devices. Assuming there were 114.7 million households, as stated elsewhere in the report,[36] and 0.58 devices per household, the national installed base is approximately 67 million units. This estimate is larger than the stated estimate in Table 53 by 4 million units, suggesting that the assumption of 114.7 million households is larger than the assumption made in the table. In addition, even though the sample size is significant, the study is limited in applicability by the location of its sample.

Applicability to Current Stock: The installed base estimates have low applicability due to their age and application to the current market. Because of recent introductions of new compact audio players which also serve as docking stations for music players such as iPods and mobile phones (e.g. iHome audio system), it is uncertain if the older models reflected in this stock estimate are actually being used.

Data Quality Evaluation and Recommended Values

Data Quality Evaluation: The various definitions of compact audio devices allows for the inclusion of a wide range of audio systems with varying speaker configurations as well as functional capabilities. There is significant uncertainty with all three compact audio estimates (usage, power, and installed base), which come from the three studies, due to the small sample size and potential change in the installed base product type.

[36] Fraunhofer 2011 cites the 2010 Buildings Energy Data Book prepared by D&R International for the Department of Energy Building Technologies Program.

Table 54: Overview of Compact Audio Energy Consumption Estimates

Device Subcategory	Year	Study	Installed Base (Million)	Usage: Active / Idle (Hrs/yr)	Usage: Idle (Hrs/yr)	Usage: Standby / Off (Hrs/yr)	Power: Active / Idle (W)	Power: Idle (W)	Power: Standby / Off (W)	UEC (kWh/yr)	AEC (TWh/yr)
Compact Audio	2013	ACEEE 2013	83.0	-	-	-	-	-	-	93	6.6
Compact Audio	2011	Fraunhofer 2011	63.0	2,482	-	6,278	31.6	-	4.3	105	6.6
Compact Audio	2011	LBNL 2011	76.0	-	-	-	-	-	-	81	6.2
Compact Audio	2010	Bensch et al 2010	-	2,482	-	6,278	31.6	-	4.3	-	-
Compact Audio	2008	TIAX 2008	76.0	840	730	7,190	23.0	16.0	7.0	81	6.2
Compact Audio	2007	TIAX 2007	76.0	840	730	7,190	23.0	16.0	7.0	81	6.2

[1]: Multiple modes in the same column is due to the definition variation of the studies. For more information refer to the discussion at the beginning of Section 4.10.

Recommended UEC and AEC Values: The recommended UEC across three usage and power modes from two different studies is 105 kWh/yr, and with an installed base of 63 million units, the AEC is 6.6 TWh/yr. These values are found in Table 55 below.

Table 55: Recommended Compact Audio Values

Metric		Value	Source
Installed Base - US (M)		63	Fraunhofer 2011
Usage (hrs/yr)	Active / Idle	840	Bensch et al 2010
	Idle	-	-
	Standby / Off	7,190	Bensch et al 2010
Power (W)	Active / Idle	23.0	Bensch et al 2010
	Idle	-	-
	Standby / Off	4.3	Bensch et al 2010
UEC (kWh/yr)		105	Calculated
AEC (TWh/yr)		6.6	Calculated
Overall Confidence		Low	-

Gap analysis, Opportunities for Further Research, and Implications for ZNE

Gap Analysis and Opportunities for Further Research: Overall, the compact audio category has a very low level of certainty. There are existing gaps in for usage, power, and installed base data. Higher resolution usage data would strike a balance between the existing, highly variable usage estimates. More comprehensive metering data would provide additional insight into how compact audio players have integrated new technology advancements. In addition, a more recent estimate of installed base, specifically from industry market research based on yearly sales data, would be helpful in capturing the shifts that have occurred in the stock as a result of ENERGY STAR specifications and Title 20 Appliance Efficiency Regulations.

Implications for ZNE Planning and Future Utility Efficiency Programs: The broader category of Audio/Video is changing rapidly as single devices can serve multiple functionalities. We expect the use of traditional compact audio to decrease somewhat and be replaced with different speakers that connect to phones or MP3 players, merging multiple Audio subcategories. Because power data is so poorly understood, it is difficult to model this end use for ZNE planning or develop a utility efficiency program strategy.

4.11 Audio Receivers

Overview: Audio receivers (also known as audio video receivers) combine a variety of functions, including a multi-channel speaker amplifier, radio tuner, and video signal input and output capabilities. ENERGY STAR specifications categorize this device as an Audio/Video product, and qualifications include an auto-power down feature as well as a maximum sleep mode power requirement. Audio receivers can be purchased separately and are typically connected to two or more speakers as well as a television or set top box. Audio receivers may also be packaged and sold as a home theater in a box, which contains two or more speakers and a central audio video receiver. Audio receivers can be responsible for providing power to connected speakers, and their usage largely depends on the devices to which they are connected. There have been only a few studies which have characterized energy consumption estimates for audio receivers. Across the two major studies which investigate audio receivers, there is some variation in mode definition due to different study methodologies.

Usage

Overview: The estimates for active mode usage vary from 950 to 2,190 hours. The higher end estimate comes from a metering study from 2006, which metered 18 audio receiver devices for a period of 7 days. Only two usage modes were identified as part of this study – active and standby. The more recent study by Fraunhofer 2011 estimates usage based on a survey and identifies three usage modes – active, sleep, and off. The device is in sleep mode when the receiver is plugged in but receiving no audio signal and can be activated remotely, whereas in off mode the amplifier has been turned off but it is still plugged in. Off mode would require a user to manually power the device with a switch.

Table 56: Key Sources for Audio Receiver Usage Estimates

Device Subcategory	Year	Study	Key Source(s)	Study Type	Sample Size	Metering Sampling Duration (Days)	Usage Active (Hrs/yr)	Usage Sleep (Hrs/yr)	Usage Standby (Hrs/yr)	Usage Off (Hrs/yr)	Applicability to Current Stock
Audio Receiver	2011	Fraunhofer 2011	Fraunhofer 2011	Survey	1,000	-	950	7,610	-	200	Low
Audio Receiver	2006	Foster Porter et al 2006	Foster Porter et al 2006	Metering	18	7	2,190	-	6,570	-	Low

Recommended Values: We recommend using the Fraunhofer 2011 study due to its larger sample size and recent publish date for usage estimates. There is significant uncertainty in its applicability due to the limitations of survey data for products with low consumer mindshare and its significant potential for under-reporting. Despite the limited sample size and sampling duration from Foster Porter et al 2006, its significantly higher Active mode value highlights the uncertainty in usage between Operational (Active) and non-operational modes (Sleep, Standby, or Off).

Applicability to Current Stock: Usage estimates for audio receivers are not expected to have changed drastically since the most recent study in 2011. We do not expect there to have been a shift in user preference in audio receivers since that time. However, there is significant potential for under-reporting of Active Mode usage estimates and therefore there is limited applicability for existing estimates. We recommend updating this category with usage data from NEEA's recently released home energy use metering study (NEEA 2014).

Power

Overview: Power draw estimates for audio receivers do not vary greatly, even though they are five years apart. Although the most recent study from ACEEE 2013 does not explicitly cite the source of its audio receiver UEC estimate, it may be inferred that this estimate is from the Fraunhofer 2011 study, which conducted metering to derive active, sleep, and off mode power draw estimates. Active power mode consumption is substantially higher than off or sleep/standby mode, which are between 1-2 W.

Table 57: Key Sources for Audio Receiver Power Estimates

Device Subcategory	Year	Study	Key Source(s)	Study Type	Sample Size	Metering Sampling Duration (Days)	Power Active (W)	Sleep (W)	Standby (W)	Off (W)	UEC (kWh/yr)	Applicability to Current stock
Audio Receivers	2013	ACEEE 2013	Fraunhofer 2011	Lit Review - Unmod.	-	-	-	-	-	-	65	Low
Audio Receivers	2011	Fraunhofer 2011	Fraunhofer 2011	Metering	9	Inst.	52.0	2.0		1.0	65	Low
Audio Receivers	2006	Foster Porter et al 2006	Foster Porter et al 2006	Metering	18	7	50.1		3.3	-	-	Low

Recommended Values: We recommend power values from Fraunhofer 2011, which conducted in-store measurements of nine audio receivers, measuring all the units which were plugged in. The sample consisted of audio receivers connected to a receivers varying in surround sound speaker capacity from 2.1, 7.0, 7.1, and 7.2 channels.

Applicability to Current Stock: Because the Fraunhofer study was conducted only a few years ago, we believe the power mode estimates to be somewhat representative of audio receivers found in homes today. However, a larger sample size is needed to more accurately capture the variability in how audio receivers may be configured by the end user. A larger, in-home metering study may be more accurate in estimating the power draw estimates.

Installed Base

Overview: Although two studies provide estimates for installed base, they are from the same source. The ACEEE 2013 study references Fraunhofer 2011, which has an installed base estimate that comes from CEA market research.

Table 58: Key Sources for Audio Receiver Installed Base Estimates

Device Subcategory	Year	Study	Key Source(s)	Study Type	Installed Base Geography	Sample Size	Installed Base (Million)	AEC (TWh/yr)	Applicability to current stock
Audio Receiver	2013	ACEEE 2013	Fraunhofer 2011	Lit Review - Unmod.	-	-	99.0	6.4	Medium
Audio Receiver	2011	Fraunhofer 2011	CEA 2010c	Lit Review - Unmod. (Market Research)	National	-	99.0	6.4	Medium

Recommended Values: Based on our review, we believe that the best estimate of the audio receiver installed base is 99.0 million. To the best of our knowledge, the market research from the CEA is currently the only available comprehensive data for installed base estimates of audio receiver devices.

Applicability to Current Stock: We do not expect any significant shifts in consumer preferences for audio receiver devices since there have not been any changes in the composition of home audio products. Audio receivers play a central role in the overall home audio system as they are responsible for connectivity to multiple devices as well as powering speakers.

Data Quality and Recommended UEC Values

Data Quality Evaluation: Although there have not been a significant amount of studies on audio receivers, we believe that the current estimates of usage, power, and installed base are fairly accurate in describing the current stock. Audio receivers are not part of a category of home audio that is expected to undergo significant changes in the next decade as their functionality as a central component of any home audio system has remained relatively constant. Although these estimates come from one source, the large sample size of the usage survey may result in estimates which are still accurate. Power draw estimates can be improved, however.

Table 59: Overview of Audio Receiver Energy Consumption Estimates

Device Subcategory	Year	Study	Installed Base (Million)	Usage				Power				UEC (kWh/yr)	AEC (TWh/yr)
				Active (Hrs/yr)	Sleep (Hrs/yr)	Standby (Hrs/yr)	Off (Hrs/yr)	Active (W)	Sleep (W)	Standby (W)	Off (W)		
Audio	2013	ACEEE 2013	99	-	-	-	-	-	-		-	65	6.4
Audio Receive	2011	Fraunhofer 2011	99	950	7,610	-	200	52.0	2.0		1.0	65	6.4
Audio Receive	2006	Foster Porter et al 2006	-	2,190	-	6,570	0	50.1	-	3.3	-	-	-

Recommended UEC and AEC Values: The recommended UEC and AEC values are from the same source. The UEC estimate is 65 kWh/yr, and the AEC estimate, based on an installed base of 99 million units, is 6.4 TWh/yr.

Table 5: Recommended Values for Audio Receivers

Metric		Value	Source
Installed Base - US (M)		99	Fraunhofer 2011
Usage (hrs/yr)	Active	950	Fraunhofer 2011
	Sleep	7,610	Fraunhofer 2011
	Off	200	Fraunhofer 2011
Power (W)	Active	52.0	Fraunhofer 2011
	Sleep	2.0	Fraunhofer 2011
	Off	1.0	Fraunhofer 2011
UEC (kWh/yr)		65	Calculated
AEC (TWh/yr)		6.4	Calculated
Overall Confidence		Low	-

Gap Analysis, Opportunities for Further Research, and Implications for ZNE:

Gap Analysis and Opportunities for Further Research: The major gap in existing estimates is the uncertainty of audio receiver usage data. The current estimates have a 2.3 factor difference, which could more than double the UEC and AEC values if the higher usage estimate is found to be more accurate. More robust metering studies can inform usage and power estimates for audio receivers. Actual power draw values for audio receivers depend largely on how home audio systems are configured with the audio receiver, thus in-store configurations from which power draw measurements were taken may not be the most accurate representation of how such devices are configured. We recommend updating usage estimates since survey responses may not reflect actual use in the field.

Implications for ZNE Planning and Future Utility Efficiency Programs: For purposes of ZNE planning, it is important to note the role that device configuration plays in typical usage and power values. The stock may increase slightly in the coming years as consumers continue to purchase new home audio systems, of which audio receivers are an important piece. However, similar to all audio devices, this is dependent on the functionality of audio devices changes over time.

4.12 Home Theater in a Box (HTIB)

Overview: According to ENERGY STAR, a home theater in a box (HTIB) is a subcategory of home audio that can also be categorized as a multi-component audio system.[37] HTIBs consist primarily of an audio receiver and two or more speakers, but may also include a DVD/Blu-ray player, subwoofer, and integrated radio tuner. These devices are packaged and sold together and are typically connected to a television and/or a set top box. However, individual audio and video components can be purchased separately and connected to create a home theater system, similar in function to HTIBs. Functioning as a key component of living room entertainment, HTIBs normally contain more speakers than compact audio systems and may have higher total power draw since they contain a group of devices. Given the wide variety of HTIB configurations available, identifying the individual components of an HTIB is crucial to understanding its energy consumption as a whole. We have identified only one original study as a source of HTIB usage and power draw data.

Usage

Overview: Although there are three studies which contain usage data information for HTIBs, they are derived from a survey in conducted for TIAX 2007. HTIB usage may mirror television and/or set top box usage since HTIBs complement those devices. ENERGY STAR specifications requiring an auto power down feature, which automatically switches a device from on to sleep mode after a predetermined period of time, may impact the amount of time HTIBs spend in active mode as ENERGY STAR-qualified HTIBs enter the market. As defined in TIAX 2007, active mode is defined as when audio and/or video is being played or recorded through the system. When no audio or video functions are being performed while the system is on, the system is defined as being in idle mode. During off mode, the power has been turned off but the system remains plugged in.

Table 60: Key Sources for HTIB Usage Estimates

Device Subcategory	Year	Study	Key Source(s)	Study Type	Sample Size	Metering Sampling Duration (Days)	Usage Active (Hrs/yr)	Usage Idle (Hrs/yr)	Usage Off (Hrs/yr)	Applicability to Current Stock
HTIB	2011	Fraunhofer 2011	TIAX 2007	Lit Review - Unmod.	-	-	1,580	730	6,450	Low
HTIB	2008	TIAX 2008	TIAX 2007	Lit Review - Unmod.	-	-	1,580	730	6,450	Low
HTIB	2007	TIAX 2007	TIAX 2007	Survey	2,000	-	1,580	730	6,450	Low

[37] ENERGY STAR Audio/Video Program Requirements Version 3.0 define “multi-component system” as “a product consisting of several components with separate enclosures that are sold as and intended for use as a single system” and cites the HTIB as an example of such a system. For such systems, qualification requires that each power-consuming component must meet applicable ENERGY STAR criteria. http://www.energystar.gov/index.cfm?c=revisions.audio_video_spec

Recommended Values: We recommend estimates from TIAX 2007 in Table 60, which are derived from a national survey with a sample size of 2,000. The other two studies cite this source for HTIB usage and do not modify the estimates. Active mode usage hours are somewhat similar to that of televisions, supporting the claim that HTIBs may typically be operated simultaneously with televisions as part of a home theater entertainment system.

Applicability to current stock: The recommended values have low applicability because there are significant limitations of survey data for products with low consumer mindshare and the significant potential for under-reporting. End users may not be actively aware of the time their HTIB system spends in idle versus off mode, thus their responses on the survey may not accurately reflect the time spent in each mode. In addition, ENERGY STAR specifications may already have impacted the time a system spends in idle mode as defined by TIAX 2007 since the auto power down feature switches a system to sleep mode[38] after a predetermined amount of time. A metering study would provide more accurate usage estimates as it may be possible to capture differences between idle and off mode usage.

Power

Overview: HTIBs generally have higher power draw than compact audio systems, given that they are composed of a group of devices which may include a DVD/Blu-ray player. It is important to identify exactly which devices operate simultaneously as an HTIB system in order to accurately estimate the total power draw from such a system, as active mode power draw can vary greatly depending on the number of devices operating. Based on metering, TIAX 2007 provides power estimates in active, idle, and off modes.

Table 61: Key Sources for HTIB Power Estimates

Device Subcategory	Year	Study	Key Source(s)	Study Type (Source Type)	Sample Size	Metering Sampling Duration (Days)	Power Active (W)	Power Idle (W)	Power Off (W)	UEC (kWh/yr)	Applicability to current stock
HTIB	2013	ACEEE 2013	-	-	-	-	-	-	-	90	Low
HTIB	2011	Fraunhofer 2011	TIAX 2007	Lit Review - Mod.	-	-	37.0	33.0	1.3	91	Low
HTIB	2008	TIAX 2008	TIAX 2007	Lit Review - Mod.	13	Inst.	38.0	34.0	0.6	89	Low
HTIB	2007	TIAX 2007	TIAX 2007, Rosen and Meier 1999	Metering (Metering)	13	Inst.	37.0	33.0	1.3	89	Low

Recommended Values: We recommend estimates from TIAX 2007 in Table 61 as the other sources simple cite its power draw estimates across the three different modes. As part of the TIAX 2007 study, CEA collected active mode power draw data on best-selling HTIB units at that time. The number of speakers in this sample of 13 HTIBs ranged from two to six, and nine of the HTIBs contained a DVD player as part of the system. For the units with DVD players, power draw estimates were taken while the DVD was playing. For idle mode, TIAX 2007 cites Rosen and Meier 1999, which estimates that idle mode power draw for "a receiver based component stereo system" was approximately 4 W less than active mode power draw.

Applicability to Current Stock: We believe the power draw estimates to have low applicability due to the age and challenge in estimating energy consumption of the entire HTIB system. Sleep mode requirements for multi-

[38] Sleep mode requirements for ENERGY STAR include a maximum 1 W power allowance, which is similar to off mode power draw estimates in Table 60. This implies that the current stock may spend less time in idle mode.

component systems as described by ENERGY STAR, which specify a maximum allowance of 1 W, are similar to the off mode power draw estimates. The applicability of idle mode power draw estimates depend on if the stock of current HTIBs contain an idle mode, as defined by TIAX 2007. Metering conducted of more recent HTIBs can yield more accurate active mode power draw estimates.

Installed Base

Overview: Installed base estimates for HTIBs range from 25 million to 30 million units. Both estimates are from market research conducted by the CEA. The most recent study by ACEEE does not cite a source, but it may be inferred that it cites Fraunhofer 2011 since the estimates are the same.

Table 62: Key Sources for HTIB Installed Base Estimates

Device Subcategory	Year	Study	Key Source(s)	Study Type	Installed Base Geography	Sample Size	Installed Base (Million)	AEC (TWh/yr)	Applicability to current stock
HTIB	2013	ACEEE 2013	-	-	-	-	30.0	2.7	Medium
HTIB	2011	Fraunhofer 2011	CEA 2010c	Lit Review - Unmod. (Market Research)	National	-	30.0	2.7	Medium
HTIB	2008	TIAX 2008	CEA 2006	Lit Review - Unmod. (Market Research)	National	-	25.0	2.2	Low
HTIB	2007	TIAX 2007	CEA 2006	Lit Review - Unmod. (Market Research)	National	-	25.0	2.2	Low

Recommended Values: We recommend values from Fraunhofer 2011, which cites the 12th Annual household CE Ownership and Market Potential market research report. HTIB installed base appears to have increased since 2007.

Applicability to Current Stock: Given that the study was conducted in 2010, we believe this installed base to have medium applicability. An increase in the installed base since 2010 is likely since the function of HTIBs as a central entertainment system have not been replaced by other technologies, and we believe that the increase in population and the corresponding consumer demand for entertainment products has likely resulted in an increase in the overall stock.

Data Quality Evaluation

Data Quality Evaluation: Given that variation among HTIB configurations and the lack of comprehensive usage and power data, the energy consumption estimates of HTIBs in Table 63 have considerable uncertainty. Installed base estimates are somewhat more certain and are likely to have increased incrementally. Deriving accurate energy consumption estimates involves identifying the individual components of an HTIB system and the primary modes in which the system operates.

Table 63: Overview of HTIB Energy Consumption Estimates

Device Subcategory	Year	Study	Installed Base (Million)	Usage: Active (Hrs/yr)	Usage: Idle (Hrs/yr)	Usage: Off (Hrs/yr)	Power: Active (W)	Power: Idle (W)	Power: Off (W)	UEC (kWh/yr)	AEC (TWh/yr)
HTIB	2013	ACEEE 2013	30.0	-	-	-	-	-	-	90	2.7
HTIB	2011	Fraunhofer	30.0	1580	730	6450	37.0	33.0	1.3	91	2.7
HTIB	2008	TIAX 2008	25.0	1580	730	6450	38.0	34.0	0.6	89	2.2
HTIB	2007	TIAX 2007	25.0	1580	730	6450	37.0	33.0	1.3	89	2.2

Recommended Values: Based on three usage modes from TIAX 2007, we recommend a UEC of 91 kWh/yr. Combining this UEC with an installed base estimate from Fraunhofer 2011 of 30 million units, we recommend an AEC of 2.7 TWh/yr found in Table 64.

Table 64: Recommended HTIB Values

Metric		Value	Source
Installed Base - US (M)		30	Fraunhofer 2011
Usage (hrs/yr)	Active	1580	TIAX 2007
	Standby	730	TIAX 2007
	Off	6450	TIAX 2007
Power (W)	Active	37.0	TIAX 2007
	Standby	33.0	TIAX 2007
	Off	1.3	TIAX 2007
UEC (kWh/yr)		91	Calculated
AEC (TWh/yr)		2.7	Calculated
Overall Confidence		Low	-

Gap Analysis, Opportunities for Further Research, and Implications for ZNE:

Gap Analysis and Opportunities for Further Research: There are significant gaps in research on HTIBs. HTIBs can serve as the central living room entertainment device in households across the United States and can include a variety of speaker configurations as well as media playback devices. Understanding the modes of operation for current HTIB systems is crucial to accurately estimating their energy consumption. This presents a unique challenge, because this may difficult to assess both during in-home metering studies and in-store measurements. As such, understanding the composition of the installed base with respect to the types of HTIBs (e.g. ENERGY STAR qualifying or non-qualifying, number of speakers, and inclusion of a DVD/Blu-ray player) is also crucial to accurately quantify HTIB energy consumption.

Implications for ZNE Planning and Future Utility Efficiency Programs: For the purposes of ZNE planning, we recommend improving HTIB energy estimates with updated study data as it becomes available. One significant challenge is the metering studies may choose to distinguish between individual parts and not identify a particular home setup as a HTIB equipment package. In addition, we recommend engaging ENERGY STAR to better understand the power difference of qualifying and non-qualifying products on the market.

5. Review of Emerging Non-Intrusive Load Monitoring Techniques

While individual sub-metering has traditionally been the primary method of deriving device-level energy data, Non-Intrusive Load Monitoring (NILM) has garnered interest as an alternative to sub-metering of individual end uses. NILM uses analytical methods to distinguish individual loads from a single metering point without the use of sub-metering (PNNL 2013). While there are a number of start-up companies with unique approaches to NILM, they are all in early stages of product commercialization and their individual accuracy is not yet well understood. Pacific Northwest National Laboratory (2013) distinguishes NILM technologies into three distinct categories:

Current Transformer (CT) Based Device: CT-based devices use field-installed CTs and voltage taps to measure whole building energy use at the customer electrical panel, then disaggregate loads using analytics once data is uploaded to vendor servers.

Utility-Meter-Based Device: These devices use single-point metering installed at the utility meter, such as a collar or meter base. Load disaggregation is completed using analytics once data is uploaded to vendor servers.

Software-Only Solutions: Software-only technologies use third-party hardware (such as a utility Smart Meter or an energy measurement device) to collect and transmit energy-use data to a server where the load is disaggregated using software algorithms.

Key Players in the NILM Space and Existing Field Research

In a recent NILM Literature Review, PNNL (2013) identified six key players in the NILM space (see Table 65).

Table 65: NILM Technology Vendors

Utility Meter Device	Software-only	CT-Based Device
Belkin	Bidgely	Energy Aware
Enetics	PlottWatt	Energy, Inc.

Bidgely has a number of contracts with utilities using Green Button or AMI data or hourly intervals to identify large residential end uses such as heating, cooling and pump loads, as well as rooftop solar. Provided that Home Area Network data is also available, they claim to be able to identify water heaters, stove, dryers, hot tubs, or EVs.[39]

To date, there is very limited publically available test data on the effectiveness of NILM technologies. In 2012, the Electric Power Research Institute (EPRI) began a trial of four NILM technologies, two software-only products and two hardware-based products (EPRI 2013). The primary objective of this study was to measure:

- The accuracy of measurement relative to the actual metered energy use,
- Ability to separate aggregate loads into individual devices (load disaggregation), and
- Repeatability of successful load disaggregation.

[39] http://www.greentechmedia.com/articles/read/Can-Bidgely-or-PlotWatt-Compte-With-Opower-in-Home-Energy-Engagement

In addition to these metrics, the study hoped to compare the relative accuracy versus cost of each technology, as well as compare the relative performance of software-only approaches versus hardware.[40]

In a preliminary discussion of their test results, EPRI noted that HVAC and water heating are the easiest for NILM technologies to assess, with both software and hardware solutions achieving a range of 84-89% accuracy over a daily and weekly interval. Of the four products tested, three products could only provide disaggregation for 4-5 major loads (HVAC, Water Heater, Clothes Dryer, Refrigerators/Freezers, and Pool Pumps). One product, referred to as 'Product D', which used a hardware-based solution to identify aggregate power consumption and then used a waveform analysis to disaggregate loads, had particularly strong results. It was able to accurately disaggregate ten different loads, most of which within 80% accuracy. In addition, it was able to identify the loads in intervals as small as five minutes. Figure 3 below shows the measurement accuracy of 'Product D' relative to actual consumption. Green shading indicates a relatively high level of accuracy, while red reflects a low level of accuracy.

Figure 3: Average Measurement Accuracy of NILM Product Technology (EPRI 2013)

Period	Interval	HVAC	Water Heater	Pool Pump	Clothes Dryer	Refrigerator	Freezer	Lights	Range	Microwave	Fans
10/8/12-12/21/12	5 min.	0.838	0.858	0.585	0.828	0.784	0.802	0.844	0.828	0.798	0.845
	15 min.	0.842	0.868	0.687	0.842	0.776	0.848	0.866	0.838	0.823	0.854
	60 min.	0.866	0.876	0.884	0.804	0.789	0.864	0.868	0.848	0.838	0.848
	Daily	0.880	0.874	0.894	0.848	0.804	0.878	0.884	0.847	0.820	0.842
	Weekly	0.894	0.881	0.898	0.852	0.828	0.872	0.875	0.842	0.838	0.843

EPRI plans to complete a second round of NILM product testing 2014, including three to four new vendors.[41] In addition, the Northwest Energy Efficiency Alliance (NEEA) and PNNL plan to complete an in-home study of 30 actual homes as well as two PNNL Test Bed Homes.[42] This research is focused on the largest appliance loads and is unlikely to cover MELs with the exception of microwaves.

Limitations to existing NILM methods and Implications for ZNE Modeling

Due to the limitations in existing NILM technology, current NILM efforts are primarily focused on large end-uses, such as appliances, or products with significant load signatures caused by power spikes, such as microwaves and ceiling fans. Their focus on large appliances is both due to technology feasibility and cost-effectiveness: MELs are significantly harder to detect than large appliances, and their individual savings opportunity is significantly smaller.

At this point, NILM technologies do not have the accuracy to replace revenue-grade sub-metering for any loads, let alone MELs. However, as these technologies continue to improve over the next few years, they could be quite useful for validating usage and power data for larger appliances, and help customers identify wasteful behaviors or indicate which appliances cost them the most money to operate (GreenTech Media 2013). At some point, NILMs may be able to disaggregate an increasing number of the largest MELs, although the smaller MELs are likely to remain out of reach for the foreseeable future. However, as NILMs improve the capabilities in identifying larger household loads, MEL energy usage will be better understood by subtracting larger loads from the overall load,

[40] http://e3tnw.org/Documents/NILMs%20Showcase%20Aug2013.pdf
[41] St John, Jeff. 2013. "Putting Energy Disaggregation Tech to the Test". GreenTechMedia, November 18, 2013. http://www.greentechmedia.com/articles/read/putting-energy-disaggregation-tech-to-the-test
[42] http://labhomes.pnnl.gov/experiments/nilm.stm

which nets the MEL load. This added resolution can provide a significant improvement to existing ZNE modeling methods for MELs, which currently account for MELs by calculating energy use as a function of square footage without accounting for changes over time.

6. Results

MEL energy usage has a high degree of uncertainty, which is primarily due to the distributed nature of the MEL end use category, and the significant time and expense required to collect comprehensive data on all MELs. As shown in Table 66, the only high confidence estimates for the entire MEL category are Televisions, Microwaves and Network Equipment usage. In each case, the reason for the high certainty is slightly different: for TVs, DOE recently completed a comprehensive usage analysis as part of existing Federal Standards rulemaking; for microwaves, household saturation is high and the product has not changed significantly over the past decade; for Network Equipment, there is convincing evidence that devices operate continuously in Active Mode which greatly simplify usage calculations. These high confidence estimates are exceptions, as most major end uses within the MEL category have a medium or low confidence level. While there have been significant studies to characterize usage, power, and/or installed base, they typically lack the scale and comprehensiveness to provide a high level of certainty. Estimates with low confidence are primarily due to the lack of existing data, which is primarily due to their low AEC. It is important to remember that the broader MEL category is made up of hundreds of end uses, although we believe that these twelve end uses likely represent between 60-70% of the entire MEL category.

A major source of uncertainty is usage hours, which are typically more variable than power or installed base estimates and have the greatest impact on UEC and AEC. This uncertainty has especially significant implications for large end-use categories, such as computers and televisions, which had a significant variance in the usage hours (a 1.5 and 1.8 factor difference, respectively). Power in each mode, although better understood, changes more rapidly than usage and is a major driver of shifting UEC values over time. In most cases, installed base estimates have the least amount of variation. The greatest uncertainty for the installed base is understanding how many products within the installed base are actually used. For example, existing desktop installed base estimates are based on sales data, but without comprehensive usage data, it would be unclear how many of these products are unplugged or rarely used.

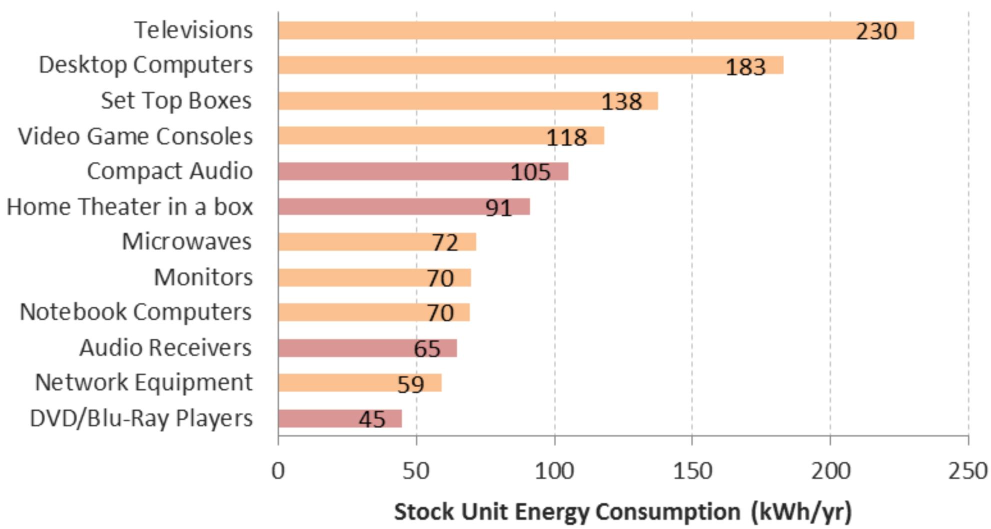
Table 66: Summary of UEC, AEC and Overall Confidence by End Use

			Confidence Level of Existing Estimates			
End Use	Aggregate Energy Consumption (TWh/yr)	Unit Energy Consumption (kWh/yr)	Usage	Power	Installed Base	Overall
Televisions	81.2	230	High	Med.	Med.	Med.
Set Top Boxes	22.4	127	Med.	Med.	Med.	Med.
Desktop Computers	18.5	183	Med.	Med.	Med.	Med.
Video Game Consoles	12.5	118	Med.	Med.	Med.	Med.
Notebook Computers	9.2	70	Med.	Med.	Med.	Med.
DVD/Blu-Ray Players	8.5	45	Low	Low	Med.	Low
Microwaves	8.3	72	Med.	Med.	High	Med.
Network Equipment	7.0	51	High	Med.	Med.	Med.
Monitors	6.7	70	Med.	Med.	Med.	Med.
Compact Audio	6.6	105	Low	Low	Low	Low
Audio Receivers	6.4	65	Low	Low	Med.	Low
Home Theater in a Box	2.7	91	Low	Low	Med.	Low

UEC is dominated by TVs and Desktop Computers, with significant clustering of UEC from 60-105 kWh/yr, as shown in Figure 4. However, AEC is much more concentrated. As Figure 5 shows, the “Big Three” (Televisions, Set Top

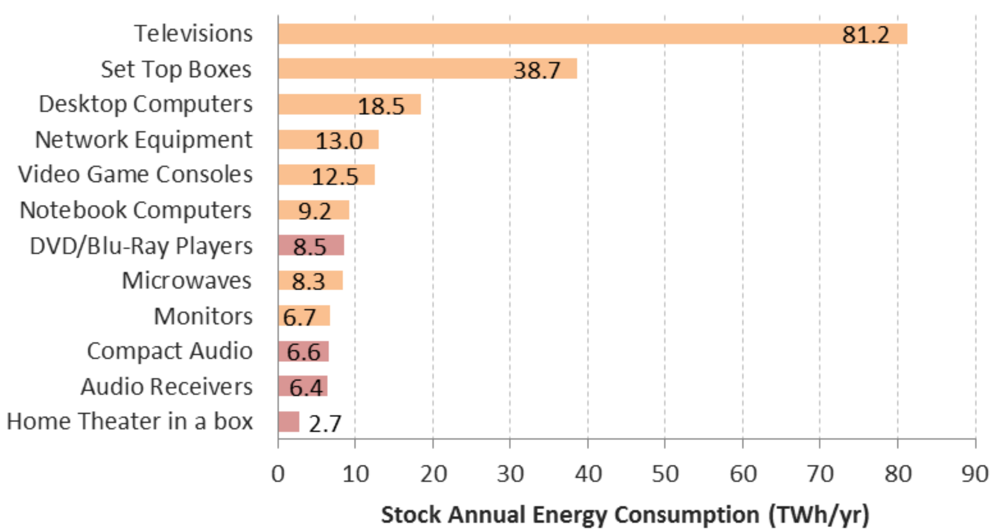
Boxes, and Desktop Computers) dominate AEC, representing 65% of combined AEC of the twelve end uses. However, this is expected to change significantly due to recent efficiency gains for TV and STB products, as well as decreases in the installed base of desktop computers. As the major MEL end uses decrease in both AEC and UEC, MEL energy use will become even more widely distributed, concentrated around the existing clusters shown in Figure 6. Figure 7 shows the highly distributed AEC across these twelve products. Over time, as energy use within the MEL category grows and the major end uses decrease in AEC, it will become even more distributed than it currently is today. Successfully reducing device energy consumption across these highly distributed loads will require innovative policy and program approaches.

Figure 4: Unit Energy Consumption by MEL End Use



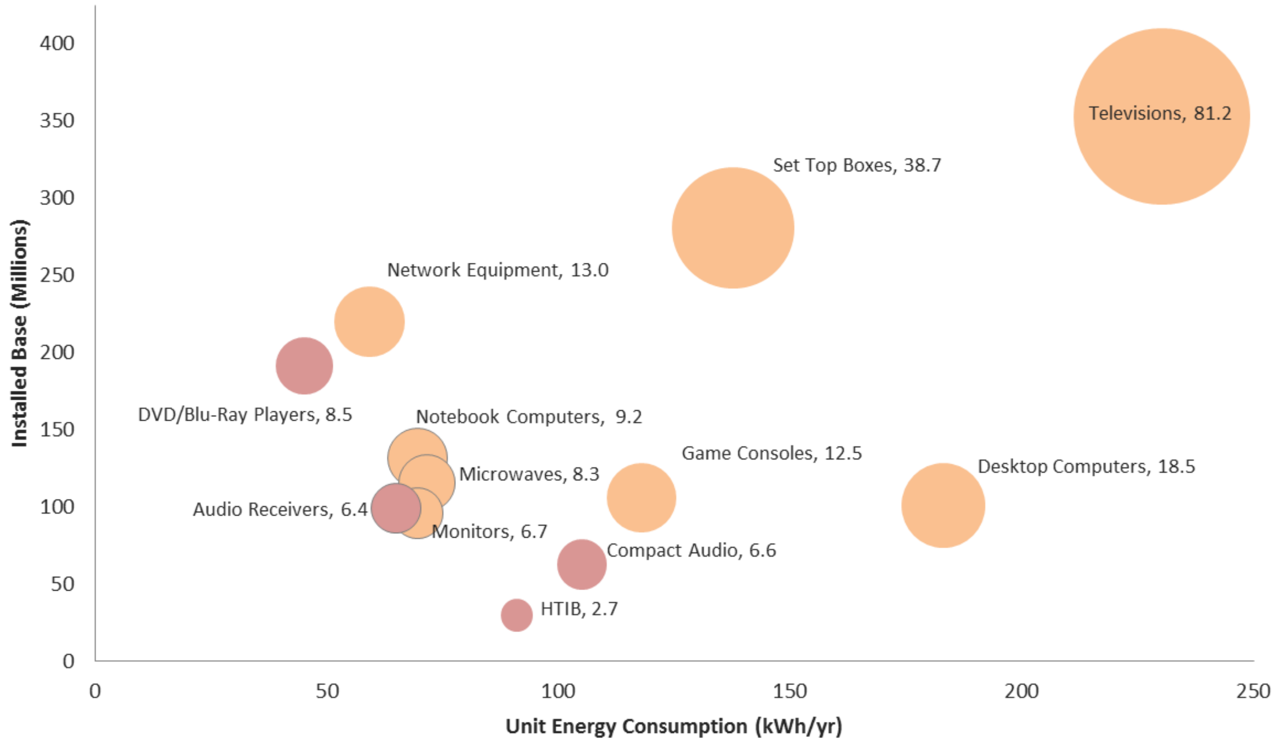
1: Line color corresponds to overall level of certainty of end use energy data. (Medium=Orange, Low=Red)

Figure 5: Annual Energy Consumption by MEL End Use



1: Line color corresponds to overall level of certainty of end use energy data. (Medium=Orange, Low=Red)

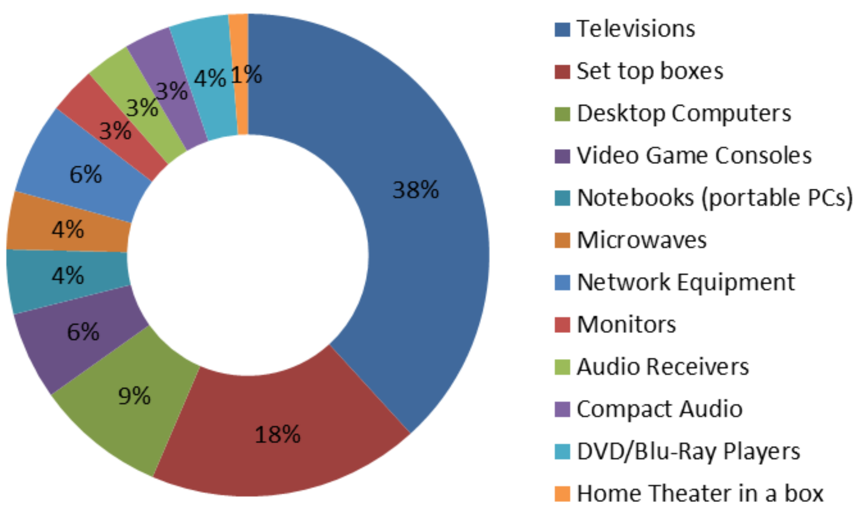
Figure 6: Overview of Selected MEL Energy Estimates and their level of Certainty



1: Bubble Size corresponds to Annual Energy Consumption (TWh/yr).

2: Bubble Color corresponds to overall level of certainty of end use energy data. Medium=Orange, Low=Red)

Figure 7: Distribution of Annual Energy Consumption (AEC) among the twelve end uses



1: While these twelve end uses represent the majority of MEL energy consumption, there are many other MELs which are not included in this chart. Including more MELs would reduce the individual share of each end use.

7. Summary Recommendations for Future ZNE Planning

As MELs (and the broader category of plug-in equipment as a whole) become an increasingly large component of building energy use, it is critically important that MELs energy usage is accurately represented in ZNE models. Inaccurate modeling will create one of two undesirable outcomes: a) If plug-in equipment energy use is significantly higher than modeled, the home will not actually be ZNE; or b) if plug-in equipment energy use is significantly lower than modeled, developers will be required to unnecessarily increase the size of the rooftop PV system, which presents additional cost to the developer.[43]

The broader issue of plug-load modeling centers around three points:

4) How to incorporate MELs and other plug loads into the existing HERS model,
5) How to collect MEL data on an ongoing basis and integrate updated data into the HERS model; and
6) How to assess the accuracy of this data.

We believe that this study provides a useful framework for assessing study accuracy and the start of developing higher resolution estimates of MELs. Our recommendations focus on the first two points above[44] and are separated into 'Next Steps' and 'M&E Research Roadmap Recommendations'.

7.1 Next Step Recommendations

Recommendation #1: Update the HERS model to incorporate large MEL end-uses

We estimate that the twelve end uses described in detail in this report account for roughly 60-70% of household MEL energy consumption. However, based on the 2008 Home Energy Rating System (HERS) technical manual, miscellaneous electricity consumption is modeled as a function of square footage, and the only plug loads that are individually modeled are refrigerator/freezers, dishwashers, clothes dryers, clothes washers, and range/ovens.[45] The current ZNE modeling equation does not disaggregate within this broad MEL category, which does not allow for developing individual MEL estimates or refining them over time as they change. We recommend that the next version of the HERS model be updated to individually account for major MELs. At a minimum, this would include televisions but would ideally be extended to other MELs with high AEC values and a large installed base, including, but not limited to, desktop and notebook computers, set top boxes, network equipment, and microwaves. In addition, we recommend that the Investor-owned Utilities (IOUs) engage Non-Intrusive Load Monitoring (NILM) technology vendors to discuss the feasibility of modeling large, non-MEL end uses to better understand the fractional home energy use of MELs.

[43] While this study does not quantify the impact of ZNE modeling absent this true-up, the potential implications are sufficiently large to warrant future study.

[44] While our recommendations our focused on improving ZNE modeling efforts, these recommendations also have implications for utility efficiency programs. While not discussed in detail here, a number of these strategies are outlined in the Northeast Energy Efficiency Partnership's (NEEP) 2013 Business and Consumer Electronics Strategy document. https://neep.org/Assets/uploads/files/market-strategies/BCE/2013%20BCE%20Strategy_FINAL.pdf

[45] See Section 4.5.6, Equation 10 in CEC 2008. http://www.energy.ca.gov/2008publications/CEC-400-2008-012/CEC-400-2008-012-CMF.PDF

Recommendation #2: Develop a Stock-Flow model to inform ZNE modeling efforts

Most MELs, especially consumer electronic (CE) devices, experience rapid product turnover and require frequent updates to maintain accurate estimates of usage, power, and installed base. Therefore, accurate modeling of CE devices requires an understanding of both existing stock energy use *and* how that stock energy use is expected to change over time. For example, TVs have by far the highest energy consumption of all MELs, both in terms of UEC and AEC. However, new TVs coming to market are highly efficient, and Active Mode Power for new TVs has decreased by approximately 65% during the 2008-2013. By 2020, a significant portion of the existing TV stock will have turned over and be composed of products purchased in 2014 or later, and therefore TV stock energy use will be substantially smaller than it is today. To accurately model and forecast future energy use, we recommend creating a stock-flow analysis a major MELs to model how new products coming to market will impact stock energy use over time. This consists of identifying the following:

- How technology usage patterns change over time,
- How power draw of new products entering the market changes over time, and
- The flow of products into the home and how they affect the installed base (Do they increase the installed base or provide a straight replacement of older products? Do certain devices replace other device types – such as a notebook or tablet replacing a TV and/or stereo.).

This stock-flow analysis is especially important to improve energy use estimates for end uses with medium confidence levels. For these end uses, there is a limited opportunity to improve upon existing estimates without a large-scale, comprehensive metering assessment that provides a higher degree of data resolution (see Recommendation #6). A stock-flow analysis can provide additional resolution for ZNE modeling without undertaking a large-scale, comprehensive metering assessment. While we recommend this as a next step, we believe it should also be considered as part of longer-term M&E research.

Recommendation #3: Improve existing data for MELs with low levels of confidence

For products with limited existing data on usage, power, and/or installed base, we recommend updating current estimates to better characterize existing energy use. To improve usage and power data, we recommend obtaining this data from large-scale metering studies instead of user surveys due to the limitations of survey data to accurately reflect actual usage for smaller consumer electronics. For installed base and saturation data, we recommend using saturation data from the forthcoming 2012 California Lighting and Appliance Saturation Survey (CLASS) (KEMA 2014).

Recommendation #4: Work with ENERGY STAR and other stakeholders to improve energy information for non-ENERGY STAR products

A major challenge in modeling MEL energy consumption is the very limited data for non-ENERGY STAR models. Developing a better understanding of the energy use of an entire product category is a critical component of developing a stock-flow model, as well understanding potential energy savings opportunities for future utility programs. While ENERGY STAR typically lists energy data for qualifying products, there is very little data on non-qualifying models entering the market. In some cases, especially Audio / Video devices, the little data that is available is limited and often has a low level of certainty. We recommend working with EPA and other stakeholders to identify opportunities to improve the existing knowledge base of non-qualifying products coming to market.

7.2 M&E Research Roadmap Recommendations

Recommendation #5: Support a Market Transformation (MT) approach to address MEL energy consumption

As the ZNE Technical Feasibility Study (PG&E 2012) highlights, reducing plug load energy consumption is a critical component to achieving ZNE goals. The unique challenge with plug loads, and MELs in particular, is that with the exception of a few large end uses such as TVs, Set Top Boxes, and Desktop and Notebook Computers, MEL energy use is highly distributed. As these three major end uses decrease in their UEC and/or installed base, MEL energy use will become even more broadly dispersed. This wide distribution across devices and minimal per-unit energy savings limits the effectiveness of traditional utility program mechanisms and is a key challenge for ZNE buildings. Due to the limited per-unit savings, an incentive-based, resource-acquisition program for MELs may have limited success if not coupled with a broader, market transformation approach.

We recommend supporting a market transformation (MT) approach which attempts to create large-scale changes in aggregate. Although most MELs have low energy consumption, many MELs, particularly CE devices, have high sales volumes and therefore significant change can be achieved by addressing the market as a whole. This includes, but is not limited to:

- Collaborating with utilities, efficiency organizations, and other stakeholders to improve the collective understanding of MEL energy use (see Recommendation #6)
- Participating in the ENERGY STAR specification revision process to update existing product specifications.
- Engaging manufacturers to identify efficiency opportunities in product design.
- Engaging retailers by offering incentives to stock and sell high efficiency products
- Improving energy labeling for CE devices (see Recommendation #7)

This MT approach is focused on achieving change at a national level, and therefore we recommend that the IOUs partner with other utilities and efficiency organizations to achieve economies of scale in addressing MEL energy use.

Recommendation #6: Consider conducting a large-scale, multi-year comprehensive metering study to improve plug load energy data within California

The Northwest Energy Efficiency Alliance (NEEA) is currently conducting a large-scale, multi-year metering study which measures home energy use for 100 homes throughout the Northwest. This study meters the vast majority of end-uses within the home, covering an estimated 80% of total load. This study will provide valuable information on usage patterns and device power consumption, and preliminary findings were recently released in late April 2014.[46] We are not aware of any existing metering studies within California that measure end use usage and power at this level of granularity, scale or monitoring duration.[47] We recommend that the IOUs consider conducting a study similar to NEEA's within California. However, we recommend that the IOUs review the NEEA study reports

[46] The values from the NEEA study are not included in this study due to the timing of its release in late April. http://neea.org/docs/default-source/reports/residential-building-stock-assessment--metering-study.pdf?sfvrsn=6

[47] Although the CLASS study (KEMA 2014) does provide information on device saturation, it does not include long-term metering data on usage and power draw.

and lessons learned prior to considering a similar effort in California. NEEA's study began in March 2012, and therefore implementing a similar study in 2016-17 could provide valuable information on how energy consumption within the home has changed over time.[48]

Recommendation #7: Encourage policies to promote the measurement of power data for CE devices through minimum efficiency standards and labeling.

Most MEL products do not have any labeling or energy consumption measurement requirements, and it is therefore difficult to quantify the energy consumption of small MELs entering the market. This lack of energy information is key barrier in successfully achieving market transformation of MELs. We recommend that the IOUs continue to advocate for CE labeling policies and minimum efficiency standards for MELs, particularly consumer electronics products.

[48] This primarily relates to CE devices which are expected to have minimal geographic variation in power or usage.

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9. Appendix A: Supplemental Tables for Tier 1 Devices

Network Equipment

Access Point

Metric		Value	Source
Installed Base - US (M)		8	CA IOUs 2013e
Usage (hrs/yr)	Active	8,760	CA IOUs 2013e
Power (W)	Active	6.1	CA IOUs 2013e
UEC (kWh/yr)		64	CA IOUs 2013e
AEC (TWh/yr)		0.4	CA IOUs 2013e
Overall Confidence		Medium	-

Integrated Access Device - Analog DSL

Metric		Value	Source
Installed		33	CA IOUs 2013e
Usage (hr	Active	8,760	CA IOUs 2013e
Power (W	Active	7.0	CA IOUs 2013e
UEC (kWh/yr)		62	CA IOUs 2013e
AEC (TWh/yr)		2.3	CA IOUs 2013e
Overall Confidence		Medium	-

Integrated Access Device - Cable

Metric		Value	Source
Installed Base - US (M)		43	CA IOUs 2013e
Usage (hrs/yr)	Active	8,760	CA IOUs 2013e
Power (W)	Active	6.9	CA IOUs 2013e
UEC (kWh/yr)		61	CA IOUs 2013e
AEC (TWh/yr)		2.6	CA IOUs 2013e
Overall Confidence		Medium	-

Integrated Access Device - V DSL

Metric		Value	Source
Installed		6	CA IOUs 2013e
Usage (hr	Active	8,760	CA IOUs 2013e
Power (W	Active	10.1	CA IOUs 2013e
UEC (kWh/yr)		89	CA IOUs 2013e
AEC (TWh/yr)		0.6	CA IOUs 2013e
Overall Confidence		Medium	-

Modem

Metric		Value	Source
Installed Base - US (M)		32	CA IOUs 2013e
Usage (hrs/yr)	Active	8,760	CA IOUs 2013e
Power (W)	Active	5.8	Greenblatt et al
UEC (kWh/yr)		51	Greenblatt et al
AEC (TWh/yr)		4.4	CA IOUs 2013e
Overall Confidence		Medium	-

Optical Network Termination Device

Metric		Value	Source
Installed		1	CA IOUs 2013e
Usage (hr	Active	8,760	CA IOUs 2013e
Power (W	Active	6.7	CA IOUs 2013e
UEC (kWh/yr)		59	CA IOUs 2013e
AEC (TWh/yr)		0.1	CA IOUs 2013e
Overall Confidence		Medium	-

Router

Metric		Value	Source
Installed Base - US (M)		92	CA IOUs 2013e
Usage (hrs/yr)	Active	8,760	Greenblatt et al 2013
Power (W)	Active	6.7	Greenblatt et al 2013
UEC (kWh/yr)		59	Greenblatt et al 2013
AEC (TWh/yr)		5.8	CA IOUs 2013e
Overall Confidence		Medium	-

Switch

Metric		Value	Source
Installed		6	CA IOUs 2013e
Usage (hr	Active	8,760	CA IOUs 2013e
Power (W	Active	5.7	CA IOUs 2013e
UEC (kWh/yr)		50	CA IOUs 2013e
AEC (TWh/yr)		3.0	CA IOUs 2013e
Overall Confidence		Medium	-

Set Top Boxes

Cable, Satellite, IPTV, OTT

Metric		Value	Source
Installed Base - US (M)		176	EIA 2013
Usage (hrs/yr)	Active	3,173	EIA 2013
	Multistrea	615	EIA 2013
	Standby /	3,650	EIA 2013
	APD / Off	1,322	EIA 2013
Power (W)	Active	17.1	EIA 2013
	Multistrea	8.0	EIA 2013
	Standby /	16.3	EIA 2013
	APD / Off	6.6	EIA 2013
UEC (kWh/yr)		127	EIA 2013
AEC (TWh/yr)		22.4	EIA 2013
Overall Confidence		Medium	-

Cable

Metric		Value	Source
Installed Base - US (M)		83	CA IOUs 2013c
Usage (hrs/yr)	Active	3,285	CA IOUs 2013c
	Multistream	1,825	CA IOUs 2013c
	Standby / Sleep	3,650	CA IOUs 2013c
	APD / Off	-	CA IOUs 2013c
Power (W)	Active	23.1	Greenblatt et al 2013
	Multistream	-	-
	Standby / Sleep	3.3	Greenblatt et al 2013
	APD / Off	-	-
UEC (kWh/yr)		183	Greenblatt et al 2013
AEC (TWh/yr)		15.3	Calculated
Overall Confidence		Medium	-

Digital Television Adapter

Metric		Value	Source
Installed Base - US (M)		37	CA IOUs 2013c
Usage (hrs/yr)	Active	3,285	CA IOUs 2013c
	Multistrea	1,825	CA IOUs 2013c
	Standby /	3,650	CA IOUs 2013c
	APD / Off	-	-
Power (W)	Active	8	Fraunhofer 2011
	Multistrea	-	-
	Standby /	-	-
	APD / Off	6	Fraunhofer 2011
UEC (kWh/yr)		68	Fraunhofer 2011
AEC (TWh/yr)		2.5	Calculated
Overall Confidence		Medium	-

Internet Protocol

Metric		Value	Source
Installed Base - US (M)		32	CA IOUs 2013c
Usage (hrs/yr)	Active	3,285	CA IOUs 2013c
	Multistream	1,825	CA IOUs 2013c
	Standby / Sleep	3,650	CA IOUs 2013c
	APD / Off	-	-
Power (W)	Active	14.0	Fraunhofer 2011
	Multistream	-	-
	Standby / Sleep	-	-
	APD / Off	12.1	Fraunhofer 2011
UEC (kWh/yr)		92	-
AEC (TWh/yr)		2.9	-
Overall Confidence		Medium	-

Satellite

Metric		Value	Source
Installed Base - US (M)		92	CA IOUs 2013c
Usage (hrs/yr)	Active	3,285	CA IOUs 2013c
	Multistrea	1,825	CA IOUs 2013c
	Standby /	3,650	CA IOUs 2013c
	APD / Off	-	-
Power (W)	Active	26.5	Greenblatt et al 2013
	Multistrea	-	-
	Standby /	2.9	Greenblatt et al 2013
	APD / Off	-	-
UEC (kWh/yr)		176	Greenblatt et al 2013
AEC (TWh/yr)		16.1	Calculated
Overall Confidence		Medium	-

Stand-alone DVR

Metric		Value	Source
Installed Base - US (M)		3	EIA 2013
Usage (hrs/yr)	Active	4,198	Fraunhofer 2011
	Multistream	-	-
	Standby / Sleep	-	-
	APD / Off	4,563	Fraunhofer 2011
Power (W)	Active	33.0	Fraunhofer 2011
	Multistream	-	-
	Standby / Sleep	-	-
	APD / Off	30.0	Fraunhofer 2011
UEC (kWh/yr)		275	Fraunhofer 2011
AEC (TWh/yr)		0.8	Fraunhofer 2011
Overall Confidence		Medium	-

Stand-alone - OTA-DTA

Metric		Value	Source
Installed Base - US (M)		33	Fraunhofer 2011
Usage (hrs/yr)	Active	3,942	Fraunhofer 2011
	Multistrea	-	-
	Standby /	-	-
	APD / Off	4,818	Fraunhofer 2011
Power (W)	Active	6.5	Fraunhofer 2011
	Multistrea	-	-
	Standby /	-	-
	APD / Off	0.8	Fraunhofer 2011
UEC (kWh/yr)		29	Fraunhofer 2011
AEC (TWh/yr)		1.0	Fraunhofer 2011
Overall Confidence		Medium	-

Thin Client / Remote

Metric		Value	Source
Installed Base - US (M)		2	CA IOUs 2013c
Usage (hrs/yr)	Active	3,285	CA IOUs 2013c
	Multistream	1,825	CA IOUs 2013c
	Standby / Sleep	3,650	CA IOUs 2013c
	APD / Off	-	-
Power (W)	Active	-	-
	Multistream	-	-
	Standby / Sleep	-	-
	APD / Off	-	-
UEC (kWh/yr)		54	-
AEC (TWh/yr)		0.1	-
Overall Confidence		Medium	-

DVD / Blu-Ray Players

DVD/Blu-Ray Players - All

Metric		Value	Source
Installed Base - US (M)		223	Fraunhofer 2011
Usage (hrs/yr)	Active	-	
	Idle	-	
	Sleep	-	
	Off	-	
	Active	-	
	Idle	-	
	Sleep	-	
	Off	-	
UEC (kWh/yr)		45	ACEEE 2013
AEC (TWh/yr)		8.1	ACEEE 2013
Overall Confidence		Low	-

DVD Player

Metric		Value	Source
Installed Base - US (M)		107	Fraunhofer 2011
Usage (hrs/yr)	Active/Idle	2,059	Greenblatt et al 2013
	Idle		-
	Sleep	1,848	Greenblatt et al 2013
	Off	4,853	Greenblatt et al 2013
Power (W)	Active	10.4	Greenblatt et al 2013
	Idle	5.0	Fraunhofer 2011
	Sleep	0.6	Greenblatt et al 2013
	Off	0.0	Greenblatt et al 2013
UEC (kWh/yr)		23	Calculated
AEC (TWh/yr)		2.4	Calculated
Overall Confidence		Low	-

Blu-ray player

Metric		Value	Source
Installed Base - US (M)		13	Fraunhofer 2011
Usage (hrs/yr)	Active / Idle	1,226	Greenblatt et al 2013
	Idle	-	-
	Sleep	1,191	Greenblatt et al 2013
	Off	6,342	Greenblatt et al 2013
Power (W)	Active	31.8	Greenblatt et al 2013
	Idle	-	-
	Sleep	0.5	Greenblatt et al 2013
	Off	0.0	Greenblatt et al 2013
UEC (kWh/yr)		40	Calculated
AEC (TWh/yr)		0.5	Calculated
Overall Confidence		Low	-

DVD/VCR Combo

Metric		Value	Source
Installed Base - US (M)		60	Fraunhofer 2011
Usage (hrs/yr)	Active/Idle	6,386	Greenblatt et al 2013
	Idle	-	-
	Sleep	613	Greenblatt et al 2013
	Off	1,761	Greenblatt et al 2013
Power (W)	Active/Idle	9.3	Greenblatt et al 2013
	Idle	8.0	Fraunhofer 2011
	Sleep	0.7	Greenblatt et al 2013
	Off	0.0	Greenblatt et al 2013
UEC (kWh/yr)		60	Calculated
AEC (TWh/yr)		3.6	Calculated
Overall Confidence		Low	-

DVD Recorder

Metric		Value	Source
Installed Base - US (M)		56	Fraunhofer 2011
Usage (hrs/yr)	Active	410	Fraunhofer 2011
	Idle	900	Fraunhofer 2011
	Sleep	7,450	Fraunhofer 2011
	Off	-	
Power (W)	Active	18.0	Fraunhofer 2011
	Idle	14.0	Fraunhofer 2011
	Sleep	3.0	Fraunhofer 2011
	Off	-	
UEC (kWh/yr)		42	Calculated
AEC (TWh/yr)		2.4	Calculated
Overall Confidence		Low	-

10. Appendix B: Tables for Tier 2 Devices

10.1 Humidifiers / Dehumidifiers

Key Sources for Dehumidifier / Humidifier Usage Estimates

Device Subcategory	Year	Study	Key Source(s)	Study Type	Sample Size	Metering Sampling Duration (Days)	Usage Active (Hrs/yr)	Usage Standby (Hrs/yr)
Dehumidifier	2013	EIA 2013	DOE 2010	Other	Unknown	-	-	-
Dehumidifier	2010	Bensch et al 2010	Bensch et al 2010	Metering Study	14	30	2,081	6,680
Humidifier	2010	Bensch et al 2010	Bensch et al 2010	Metering Study	4	30	4,709	4,052

Key Sources for Dehumidifier / Humidifier Power Estimates

Device Subcategory	Year	Study	Key Source(s)	Study Type	Sample Size	Metering Sampling Duration (Days)	Power Active (W)	Power Standby (W)	UEC (kWh/yr)
Dehumidifier	2013	EIA 2013	DOE 2010	Other	Unknown	-	-	-	710
Dehumidifier	2010	Bensch et al 2010	Bensch et al 2010	Metering	14	30	449.3	3.2	457
Air Cleaners / Humidifiers	2011	LBNL 2011	-	Unknown	-	-	-	-	300
Humidifier	2010	Bensch et al 2010	Bensch et al 2010	Metering	4	30	33.9	0.0	85

Key Sources for Installed Base Estimates

Device Subcategory	Year	Study	Key Source(s)	Study Type	Installed Base Geography	Sample Size	Installed Base (Million)	AEC (TWh/yr)
Dehumidifier	2013	EIA 2013	DOE 2010	Other	National	-	15.6	11.1
Air Cleaners/Humidifiers	2011	LBNL 2011	-	-	National	-	20.0	6.0

Overview of Energy Consumption Estimates

Device Subcategory	Year	Study	Installed Base (Million)	Usage Active (Hours/yr)	Usage Standby (Hours/yr)	Power Active (W)	Power Standby (W)	UEC (kWh/yr)	AEC (TWh/yr)
Dehumidifier	2013	EIA 2013	15.6	-	-	-	-	710	11.1
Dehumidifier	2010	Bensch et al 2010	-	2,081	6,680	449.3	3.2	457	
Air Cleaners/Humidifiers	2011	LBNL 2011	20.0	-	-	-	-	300	6.0
Humidifier	2010	Bensch et al 2010	-	4,709	4,052	33.9	0.0	85	-

10.2 Clothes Irons

Key Sources for Clothes Iron Usage Estimates

Device Subcategory	Year	Study	Key Source(s)	Study Type	Sample Size	Metering Sampling Duration (Days)	Usage Active (Hrs/yr)	Usage Off
Clothes Iron	2008	TIAX 2008	Rowenta 2005	Lit Review - Unmod. (Survey)	4,000	-	39	8,721

Key Sources for Clothes Iron Power Estimates

Device Subcategory	Year	Study	Key Source(s)	Study Type (Source Type)	Sample Size	Metering Sampling Duration (Days)	Power Active (W)	Power Off (W)	Power UEC (kWh/yr)
Clothes Iron	2008	TIAX 2008	TIAX 2008	Survey	13	Inst.	1,350.0	0.0	39
Clothes Iron	2010	Bensch et al 2010	Bensch et al 2010	Metering	1	30	-	-	31

Key Sources for Clothes Iron Installed Base Estimates

Device Subcategory	Year	Study	Key Source(s)	Study Type	Installed Base Geography	Sample Size	Installed Base (Million)	AEC (TWh/yr)
Clothes Iron	2008	TIAX 2008	Appliance Magazine 2005a	Market Research	National	Unknown	106.0	5.6

Overview of Clothes Iron Energy Consumption Estimates

Device Subcategory	Year	Study	Installed Base (Million)	Usage Active (Hours/year)	Usage Off (Hours/year)	Power Active (W)	Power Off (W)	UEC (kWh/yr)	AEC (TWh/yr)
Clothes Iron	2008	TIAX 2008	106.0	39	8,721	1350.0	0.0	39.0	5.6
Clothes Iron	2010	Bensch et al 2010	-	-	-	-	-	31.0	-

10.3 Mobile Phones and Tablets

Key Sources for Mobile Phone / Tablet Usage Estimates

Device Subcategory	Year	Study	Key Source(s)	Study Type	Sample Size	Metering Sampling Duration (Days)	Usage: Active (Hrs/yr)	Usage: Handset Attached (Hrs/yr)	Usage: Idle (Hrs/yr)	Usage: Off (Hrs/yr)
Mobile Phones	2011	Fraunhofer 2011	Bensch et al 2010	Lit Review - Unmod.	-	-	110	-	-	8,650
Mobile Phones	2011	Bensch et al 2010	Bensch et al 2010	Metering	4	30	110	-	-	8,650
Cell phone	2008	TIAX 2008	Foster Porter et al 2006	Lit Review - Unmod.	-	-	438	175	-	7,446
Mobile Phone	2007	TIAX 2007	McAllister and Farrell 2004	Lit Review - Unmod. (Survey)	34	-	265	1,050	-	7,445
Cell phone	2006	Foster Porter et al 2006	Foster Porter et al 2006	Metering	26	7	438	175	-	7,446

Key Sources for Mobile Phone / Tablet Power Estimates

Device Subcategory	Year	Study	Key Source(s)	Study Type (Source Type)	Sample Size	Metering Sampling Duration (Days)	Power: Active (W)	Power: Handset Attached (W)	Power: Idle (W)	Power: Off (W)	Power: UEC (kWh/yr)
Mobile Phones	2011	Fraunhofer 2011	Bensch et al 2010, Meier et al 2008	Lit Review - Unmod.	-	-	4.0	-	2.2	0.2	-
Mobile Phones	2011	Bensch et al 2010	Bensch et al 2010	Metering	4	30	4 -		0.1 -		4.1
Cell phone	2008	TIAX 2008	Foster Porter et al 2006	Lit Review - Mod.	-	-	2.6	0.5	-	0.3	-
Mobile Phone	2007	TIAX 2007	McAllister and Farrell 2004, Ecos 2005	Lit Review - Mod. (Metering)	9	Inst.	3.7	0.5	-	0.3	-
Cell phone	2006	Foster Porter et al 2006	Foster Porter et al 2006	Metering	27	7	2.6	0.5	0.2	-	-
Tablets	2013	EIA 2013	EPRI 2013	-	-	-	11.9	-	-	-	-

Key Sources for Mobile Phone / Tablet Installed Base Estimates

Device Subcategory	Year	Study	Key Source(s)	Study Type	Installed Base Geography	Sample Size	Installed Base (Million)	AEC (TWh/yr)
Mobile Phones	2011	Fraunhofer 2011	CEA 2010c	Survey	National	-	223.0	0.5
Cell phone	2008	TIAX 2008	"2006 Analysis"	Lit Review - Mod.	National	-	200.0	-
Mobile Phone	2007	TIAX 2007	CTIA 2006, CEA 2005,	Market research	National	-	219.0	0.8
Tablets	2011	Fraunhofer 2011	Rotmann 2010	Other	National	-	4.0	-

Overview of Mobile Phone / Tablet Energy Consumption Estimates

Device Subcategory	Year	Study	Installed Base (Million)	Usage: Active (Hrs/yr)	Usage: Handset Attached (Hrs/yr)	Usage: Idle (Hrs/yr)	Usage: Off (Hrs/yr)	Power: Active (W)	Power: Handset Attached (W)	Power: Idle (W)	Power: Off (W)	UEC (kWh/yr)	AEC (TWh/yr)
Mobile Phones	2011	Fraunhofer 2011	223.0	110	-	-	8650	4	-	2.2	0.2	-	0.5
Mobile Phones	2011	Bensch et al 2010	-	110	-	-	8650	4	-	0.1	-	4.1	-
Cell phone	2008	TIAX 2008	200.0	438	175	-	7446	2.6	0.5	-	0.3	-	-
Mobile Phone	2007	TIAX 2007	219.0	265	1050	-	7445	3.7	0.5	-	0.3	-	0.8
Cell phone	2006	Foster Porter et al 2006	-	438	175	-	7446	2.6	0.5	0.2	-	-	-
Tablets	2013	EIA 2013	-	-	-	-	-	11.9	-	-	-	-	-
Tablets	2011	Fraunhofer 2011	4.0	-	-	-	-	-	-	-	-	-	-

10.4 Space Heaters

Key Sources for Space Heater Usage Estimates

Device Subcategory	Year	Study	Key Source(s)	Study Type	Sample Size	Metering Sampling Duration (Days)	Usage Active (Hrs/yr)	Usage Off (Hrs/yr)
Portable Space Heater	2010	Bensch et al 2010	Bensch et al 2010	Metering	8	30	584	8,176

Key Sources for Space Heater Power Estimates

Device Subcategory	Year	Study	Key Source(s)	Study Type (Source Type)	Sample Size	Metering Sampling Duration (Days)	Power Active (W)	Power Off (W)	Power UEC (kWh/yr)
Portable Space Heater	2011	LBNL 2011	NEMS EIA	Other	-	-	-	-	500
Portable Space Heater	2010	Bensch et al 2010	Bensch et al 2010	Metering	8	30	1,320.0	0.6	314

Key Sources for Space Heater Installed Base Estimates

Device Subcategory	Year	Study	Key Source(s)	Study Type	Installed Base Geography	Sample Size	Installed Base (Million)	AEC (TWh/yr)
Portable Space Heaters	2011	LBNL 2011	Unknown	-	National	-	20.0	10.0

Overview of Space Heater Energy Consumption Estimates

Device Subcategory	Year	Study	Installed Base (Million)	Usage Active (Hrs/yr)	Usage Off (Hrs/yr)	Power Active (W)	Power Off (W)	UEC (kWh/yr)	AEC (TWh/yr)
Portable Space Heater	2011	LBNL 2011	20.0	-	-	-	-	500.0	10
Portable Space Heater	2010	Bensch et al 2010	-	584	8,176	1,320	0.6	313.9	-

10.5 Vacuum Cleaners

Key Sources for Vacuum Cleaner Usage Estimates

Device Subcategory	Year	Study	Key Source(s)	Study Type	Sample Size	Metering Sampling Duration (Days)	Usage Active (Hrs/yr)	Usage Off (Hrs/yr)
Portable Vacuum Cleaners	2010	Bensch et al 2010	Bensch et al 2010	Metering	3	30	37	8,724
Portable Vacuum Cleaners	2008	TIAX 2008	MTP 2006, Dong et al 2004	Lit Review - Mod. (Survey)	-	-	39	8,721

Key Sources for Vacuum Cleaner Power Estimates

Device Subcategory	Year	Study	Key Source(s)	Study Type (Source Type)	Sample Size	Metering Sampling Duration (Days)	Power Active (W)	Power Off (W)	Power UEC (kWh/yr)
Portable Vacuum Cleaners	2013	ACEEE 2013	Bensch et al 2010	Lit. Review - Mod.	-	-	-	-	55
Portable Vacuum Cleaners	2011	LBNL 2011	TIAX 2007a	Survey	-	-	-	-	40
Portable Vacuum Cleaners	2010	Bensch et al 2010	Bensch et al 2010	Metering	3	30	542.4	-	55
Portable Vacuum Cleaners	2008	TIAX 2008	TIAX 2008	Survey	64	Inst.	1,080.0	-	42

Key Sources for Vacuum Cleaner Installed Base Estimates

Device Subcategory	Year	Study	Key Source(s)	Study Type	Installed Base Geography	Sample Size	Installed Base (Million)	AEC (TWh/yr)
Portable Vacuum Cleaners	2013	ACEEE 2013	-	-	National	-	113.0	6.2
Portable Vacuum Cleaners	2011	LBNL 2011	-	-	National	-	115.0	4.6
Portable Vacuum Cleaners	2008	TIAX 2008	Appliance Magazine 2005a, 2005b	Market Research	National	-	113.0	4.7

Overview of Vacuum Cleaner Energy Consumption Estimates

Device Subcategory	Year	Study	Installed Base (Million)	Usage Active (Hours/year)	Usage Off (Hours/year)	Power Active (W)	Power Off (W)	UEC (kWh/yr)	AEC (TWh/yr)
Portable Vacuum Cleaners	2013	ACEEE 2013	113.0	-	-	-	-	55	6.2
Portable Vacuum Cleaners	2011	LBNL 2011	115.0	-	-	-	-	40	4.6
Portable Vacuum Cleaners	2010	Bensch et al 2010	-	37	8,724	524.4	-	55	-
Portable Vacuum Cleaners	2008	TIAX 2008	113.0	39	8,721	1,080.0	-	42	4.7

10.6 Imaging Equipment

Key Sources for Imaging Equipment Usage Estimates

Device Subcategory	Year	Study	Key Source(s)	Study Type	Sample Size	Metering Sampling Duration (Days)	Usage: Active (Hrs/yr)	Usage: Ready (Hrs/yr)	Usage: Standby (Hrs/yr)	Usage: Off (Hrs/yr)
Single function - inkjet	2011	Fraunhofer 2011	Fraunhofer 2011	Survey	1,000	-	5	35	1,220	7,500
Printer	2010	Bensch et al 2010	Bensch et al 2010	Metering	45	30	329	-	-	8,432
Inkjet Printer	2008	TIAX 2008	TIAX 2006	Lit Review - Unmod.	-	-	88	-	-	8,672
Inkjet Printer	2006	Foster Porter et al 2006	Foster Porter et al 2006	Metering	18	7	88	-	8,672	-
Inkjet Printer	2006	TIAX 2006	Nordman & Meier 2004	Lit Review - Mod.	-	-	52	1,606	-	7,102
Multi function - inkjet	2011	Fraunhofer 2011	Fraunhofer 2011	Survey	1,000	-	7	105	1,211	7,437
Multi function - laser	2011	Fraunhofer 2011	Fraunhofer 2011	Survey	1,000		12	352	1,175	7,221
Multi function - inkjet	2008	TIAX 2008	Foster Porter et al 2006	Lit Review - Mod.	-	-	283	659	-	7,818
Multi function - inkjet	2006	Foster Porter et al 2006	Foster Porter et al 2006	Metering	13	7	263	613	7,271	-
Multi function devices	2006	TIAX 2006	Nordman & Meier 2004	Lit Review - Mod.	-	-	52	1,606	-	7102
Laser Printers	2011	LBNL 2011	-	-	-	-	-	-	-	-
Single function - laser	2011	Fraunhofer 2011	Fraunhofer 2011	Survey	1,000		10	280	1,186	7,284

Key Sources for Imaging Equipment Power Estimates

Device Subcategory	Year	Study	Key Source(s)	Study Type (Source Type)	Sample Size	Metering Sampling Duration (Days)	Power				
							Active (W)	Ready (W)	Standby (W)	Off (W)	UEC (kWh/yr)
Single function - inkjet	2011	Fraunhofer 2011	APP 2010, HP 2011	Lit Review - Mod.	-	-	17.0	6.0	2.0	1.0	-
Printer	2010	Bensch et al 2010	Bensch et al 2010	Metering	45	30	12.5	-	-	4.3	40.3
Inkjet Printer	2008	TIAX 2008	Foster Porter et al 2006	Lit Review - Unmod.	-	-	8.9	3.2	1.7	-	-
Inkjet Printer	2006	Foster Porter et al 2006	Foster Porter et al 2006	Metering	18	7	8.9	3.2	1.7	-	-
Inkjet Printer	2006	TIAX 2006	Nordman & Meier 2004	Lit Review - Mod.	-	-	13.0	5.0	-	2.0	-
Multi function - inkjet	2011	Fraunhofer 2011	APP 2010, HP 2011	Lit Review - Mod.	-	-	22	7	4.0	0.7	-
Multi function - laser	2011	Fraunhofer 2011	APP 2010, HP 2011	Lit Review - Mod.	-	-	420	12	8.0	0.4	-
Multi function - inkjet	2008	TIAX 2008	Foster Porter et al 2006	Lit Review - Unmod.	-	-	15.2	9.1	-	6.2	-
Multi function - inkjet	2006	Foster Porter et al 2006	Foster Porter et al 2006	Metering	13	7	15.2	9.1	6.2	-	-
Multi function devices	2006	TIAX 2006	Nordman & Meier 2004	Lit Review - Mod.	-	-	19	11	-	7	-
Laser Printers	2011	LBNL 2011	Zogg et al 2009, TIAX 2007a	Survey	-	-	-	-	-	-	236
Single function - laser	2011	Fraunhofer 2011	APP 2010, HP 2011	Lit Review - Mod.	-	-	400	11	7.0	0.4	-

Key Sources for Imaging Equipment Installed Base Estimates

Device Subcategory	Year	Study	Key Source(s)	Study Type	Installed Base Geography	Sample Size	Installed Base (Million)	AEC (TWh/yr)
Single function - inkjet	2011	Fraunhofer 2011	CEA 2010c	Survey	National	-	10.0	-
Inkjet Printer	2008	TIAX 2008	TIAX 2006	Survey	National	-	25.0	-
Inkjet Printer	2006	TIAX 2006	TIAX 2006	Survey	National	-	75.0	-
Multi function - inkjet	2011	Fraunhofer 2011	CEA 2010c	Survey	National	-	92.0	-
Multi function - inkjet	2011	Fraunhofer 2011	Eddy 2010	Unknown			6.0	
Multi function - inkjet	2008	TIAX 2008	CEA 2006, Appliance 2006	Market research	National	-	76.0	-
Multi function devices	2006	TIAX 2006	Appliance 2003	Market research	National	-	13.0	-
Laser Printers	2011	LBNL 2011	Zogg et al 2009, TIAX 2007a	Survey	National	-	13.9	3.3
Single function - laser	2011	Fraunhofer 2011	Eddy 2010	Unknown	-	-	5.0	-

Overview of Imaging Equipment Energy Consumption Estimates

Device Subcategory	Year	Study	Installed Base (Million)	Usage: Active (Hrs/yr)	Usage: Ready (Hrs/yr)	Usage: Standby (Hrs/yr)	Usage: Off (Hrs/yr)	Power: Active (W)	Power: Ready (W)	Power: Standby (W)	Power: Off (W)	UEC (kWh/yr)	AEC (TWh/yr)
Single function - inkjet	2011	Fraunhofer 2011	10	5	35	1,220	7,500	17.0	6.0	2.0	1.0	-	-
Printer	2010	Bensch et al 2010	-	329	-	-	8,432	12.5	-	-	4.3	40.3	-
Inkjet Printer	2008	TIAX 2008	25	88	-	-	8,672	8.9	3.2	1.7	-	-	-
Inkjet Printer	2006	Foster Porter et al 2006	-	88	-	8,672	-	8.9	3.2	1.7	-	-	-
Inkjet Printer	2006	TIAX 2006	75	52	1,606	-	7,102	13.0	5.0	-	2.0	-	-
Multi function - inkjet	2011	Fraunhofer 2011	92	7	105	1,211	7,437	22.0	7.0	4.0	0.7	-	-
Multi function - laser	2011	Fraunhofer 2011	6	12	352	1,175	7,221	420.0	12.0	8.0	0.4	-	-
Multi function - inkjet	2008	TIAX 2008	76	283	659	-	7,818	15.2	9.1	-	6.2	-	-
Multi function - inkjet	2006	Foster Porter et al 2006		263	613	7,271	-	15.2	9.1	6.2	-	-	-
Multi function devices	2006	TIAX 2006	13	52	1,606	-	7,102	19.0	11.0	-	7.0	-	-
Laser Printers	2011	LBNL 2011	13.9	-	-	-	-	-	-	-	-	236.0	3.3
Single function - laser	2011	Fraunhofer 2011	5.0	10	280	1,186	7,284	400.0	11.0	7.0	0.4	-	-

10.7 Toasters

Key Sources for Toaster Usage Estimates

Device Subcategory	Year	Study	Key Source(s)	Study Type	Sample Size	Metering Sampling Duration (Days)	Usage Active (Hrs/yr)	Usage Off (Hrs/yr)
Toasters	2008	TIAX 2008	Sanchez et al 1998	Other	-	-	37	-
Toaster Oven	2008	TIAX 2008	Sanchez et al 1998	Other	-	-	25	-

Key Sources for Toaster Power Estimates

Device Subcategory	Year	Study	Key Source(s)	Study Type	Sample Size	Metering Sampling Duration (Days)	Power Active (W)	Power Off (W)	Power UEC (kWh/yr)
Toasters	2013	ACEEE 2013	Bensch et al 2010	Metering	-	-	-	-	32
Toaster/toaster oven	2011	LBNL 2011	TIAX 2007a	Lit Review - Mod.	-	-	-	-	35
Toaster	2010	Bensch et al 2010	Bensch et al 2010	Metering	2	30			32
Toasters	2008	TIAX 2008	TIAX 2008, LBNL 2004	Survey	11	Inst.	-	1050.0	39
Toaster Oven	2008	TIAX 2008	TIAX 2008, LBNL 2004	Survey	7	Inst.	-	1300.0	33

Key Sources for Toaster Installed Base Estimates

Device Subcategory	Year	Study	Key Source(s)	Study Type	Installed Base Geography	Sample Size	Installed Base (Million)	AEC (TWh/yr)
Toasters	2013	ACEEE 2013	-	-	National	-	104.0	6.0
Toaster/toaster oven	2011	LBNL 2011	-	-	National	-	170.0	6.0
Toasters	2008	TIAX 2008	Appliance Magazine 2005a, 2005b	Market research	National	-	104.0	4.1
Toaster Oven	2008	TIAX 2008	Appliance Magazine 2005a, 2005b	Market research	National	-	64.0	2.1

Overview of Toaster Energy Consumption Estimates

Device Subcategory	Year	Study	Installed Base (Million)	Usage: Active (Hrs/yr)	Usage: Off (Hrs/yr)	Power: Active (W)	Power: Off (W)	UEC (kWh/yr)	AEC (TWh/yr)
Toasters	2013	ACEEE 2013	104.0	-	-	-	-	32	6.0
Toaster/toaster oven	2011	LBNL 2011	170	-	-	-	-	35	6.0
Toaster	2010	Bensch et al 2010	-	-	-	-	-	32	-
Toasters	2008	TIAX 2008	104	37.0	-	1,050	-	39	4.1
Toaster Oven	2008	TIAX 2008	64	25.0	-	1,300	-	33	2.1

10.8 Cordless Phones

Key Sources for Cordless Phone Usage Estimates

Device Subcategory	Year	Study	Key Source(s)	Study Type	Sample Size	Metering Sampling Duration (Days)	Usage: Active (Hrs/yr)	Handset Removed (Hrs/yr)	Handset attached (Hrs/yr)	Idle (Hrs/yr)	Charging (Hrs/yr)
Cordless Phones	2011	Fraunhofer 2011	Bensch et al 2010, SELINA 2010	Lit Review - Unmod. (Survey)	-	-	7,045	-	-	1,715	-
Cordless Phones	2010	Bensch et al 2010	Bensch et al 2010	Metering	9	30	7,045	-	-	1,716	-
Cordless Phones	2007	TIAX 2007	Rosen et al 2001	Lit Review. - Unmod.	-	-	350	2,015	5,695	-	700
Cordless Phones	2001	Rosen et al 2001	Rosen et al 2001	Survey	-	-	350	2,015	5,695	-	700
Phone Base Station	2010	Bensch et al 2010	Bensch et al 2010	Metering	9	30	7,045	-	-	1,715	-
With Integrated Answering Device	2007	TIAX 2007	Rosen et al 2001	Lit Review. - Unmod.	-	-	350	2,015	5,695	-	700
With Integrated Answering Device	2001	Rosen et al 2001	Rosen et al 2001	Survey	-	-	350	2,015	5,695	-	700

Key Sources for Cordless Phone Power Estimates

Device Subcategory	Year	Study	Key Source(s)	Study Type (Source Type)	Sample Size	Metering Sampling Duration (Days)	Power: Active (W)	Handset Removed (W)	Handset attached (W)	Idle (W)	Charging (W)	UEC (kWh/yr)
Cordless Phones	2013	ACEEE 2013	-	-	-	-	-	-	-	-	-	28
Cordless Phones	2011	Fraunhofer 2011	Bensch et al 2010	Lit Review - Mod. (Metering)	-	-	2.0	-	-	1.0	-	16
Cordless Phones	2011	LBNL 2011	-	-	-	-	-	-	-	-	-	45
Cordless Phones	2010	Bensch et al 2010	Bensch et al 2010	Metering	9	30	1.9	-	-	0.5	-	12
Cordless Phones	2007	TIAX 2007	Rosen et al 2001	Lit Review - Unmod.	-	-	3.1	2.3	3.1	-	4.0	-
Cordless Phones	2007	Rosen et al 2001	Rosen et al 2001	Metering	20	Inst.	3.1	2.3	3.1	-	4.0	-
Phone Base Station	2010	Bensch et al 2010	Bensch et al 2010	Metering	9	30	1.9	-	-	0.5	-	-
With Integrated Answering Device	2007	TIAX 2007	Rosen et al 2001	Lit Review - Unmod.	-	-	3.9	2.8	3.8	-	4.4	-
With Integrated Answering Device	2007	Rosen et al 2001	Rosen et al 2001	Metering	21	Inst.	3.9	2.8	3.8	-	4.4	-

Key Sources for Cordless Phone Installed Base Estimates

Device Subcategory	Year	Study	Key Source(s)	Study Type	Installed Base Geography	Sample Size	Installed Base (Million)	AEC (TWh/yr)
Cordless Phones	2013	ACEEE 2013	-	-	National	-	170.0	12.9
Cordless Phones	2011	Fraunhofer 2011	Bensch et al 2010	Lit Review - Mod. (Metering)	National	-	137.0	2.2
Cordless Phones	2011	LBNL 2011	-	-	National	-	200.0	9.0
Cordless Phones	2007	TIAX 2007	CEA 2005a	Market Research	-	-	122.0	3.8
With Integrated Answering Device	2007	TIAX 2007	CEA 2005a	Market Research	-	-	57.0	1.2

Overview of Energy Consumption Estimates

Device Subcategory	Year	Study	Installed Base (Million)	Usage					Power					UEC (kWh/yr)	AEC (TWh/yr)
				Active (Hrs/yr)	Handset Removed (Hrs/yr)	Handset attached (Hrs/yr)	Idle (Hrs/yr)	Charging (Hrs/yr)	Active (W)	Handset Removed (W)	Handset attached (W)	Idle (W)	Charging (W)		
Cordless Phones	2013	ACEEE 2013	170.0	-	-	-	-	-	-	-	-	-	-	28	12.9
Cordless Phones	2011	LBNL 2011	200.0	-	-	-	-	-	-	-	-	-	-	45	9.0
Cordless Phones	2011	Fraunhofer 2011	137.0	7,045	-	-	1,715	-	2.0	-	-	1.0	-	16	2.2
Cordless Phones	2010	Bensch et al 2010	-	7,045	-	-	1,716		1.9	-	-	0.5	-	12	-
Cordless Phones	2007	TIAX 2007	122.0	350	2,015	5,695	-	700	3.1	2.3	3.1	-	4.0	-	3.8
Cordless Phones	2001	Rosen et al 2001	-	350	2,015	5,695	-	700	3.1	2.3	3.1	-	4.0	-	-
Phone Base Station	2010	Bensch et al 2010	-	7,045	-	-	1715	-	1.9	-	-	0.5	-	-	-
With Integrated Answering Device	2007	TIAX 2007	57.0	350	2,015	5,695	-	700	3.9	2.8	3.8	-	4.4	-	1.2
With Integrated Answering Device	2001	Rosen et al 2001	-	350	2,015	5,695	-	700	3.9	2.8	3.8	-	4.4	-	-