ecova™ total energy and sustainability management

# FINAL REPORT

## Mapping Secondary Product Functions to Products and Operational Modes

SUBMITTED BY ECOVA
PETER MAY-OSTENDORP
JEFFREY SWOFFORD
CLANCY DONNELLY
PHILIP WALTERS
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1199 Main Ave #242
Durango CO 81301
970 259 6801

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# EXECUTIVE SUMMARY

Today's consumer products are largely composed of a limited number of functional "building blocks" that, when synthesized and orchestrated, produce the unique functions and experiences that define different product categories. Usually a few core features or primary functions define unique, vertical product categories like televisions, washing machines, or computers. However, a large family of secondary functions – those that do not perform the primary product function but that provide other necessary services to the device or user – exist that can be considered horizontal in nature in that they are used to varying degrees across all mainstream consumer products. This is because products and their users have similar needs regardless of the specific primary function. Devices need power sources, means of interacting with users, and in an increasing number of products, ways to communicate with other devices through networks. Secondary functions have implications for product energy use, particularly in low-power modes. If properly implemented, secondary functions like power management can minimize the energy use of products in low-power modes when they are not performing their intended primary functions. On the other hand, when secondary functions are poorly implemented from a power management standpoint, they can remain on unnecessarily in low-power modes and drive up standby power and overall total energy consumption.

This project comprehensively examined secondary functions for the first time by identifying, defining, and classifying the relevant functions across three broad categories of consumer products: major appliances (refrigerators, water heaters, laundry equipment, etc.), home entertainment (televisions, audio/video equipment), and office products (computers, network equipment, etc.). We conducted market research to identify the prevalence of each secondary function across products and to determine how frequently those functions are used in various modes of device operation. We then generated tables or "maps" of each function to identify clusters of functions with the greatest horizontal applicability across different products and modes of operation.

In addition to assessing the overall horizontal applicability of certain secondary functions, we used expert judgment to determine which functions may be rapidly growing or that are otherwise expected to have the greatest energy impact on products. We identified several key opportunities for continued technical research and potential policy action:

- **Displays and user interfaces**: Information displays continue to proliferate as secondary functions in a wide variety of products, often as a means to enhancing user interfaces. We see this across all three major product categories in devices that traditionally had no display technology, such as printers and laundry equipment. Luminous efficacy may not be as much of a concern in these applications, but appropriate power management strategies may play a more central role.

- **High-speed networking**: Both wired and wireless network functionality (e.g. Ethernet and Wi-Fi, respectively) have made their way into a broad array of consumer products beyond traditional information technology equipment. Many new home audio and video products include networking functions to facilitate digital media streaming from Internet sources.
- **Low-speed wireless networking for smart appliances**: Although still in their infancy, a growing number of "smart" appliances are currently entering the market that have the capability to interpret and act upon signals from smart grids (i.e. utility networks with Advanced Metering Infrastructure or AMI). Those appliances typically incorporate some form of wireless networking to communicate with the broader system. Devices that once had absolutely no standby power due to the use of hard mechanical disconnects now possess "soft" power controls and LCD display interfaces and will eventually incorporate some form of wireless networking for smart grid functionality. These trends all suggest that further investigation of low-power modes in the latest generation of major home appliances is merited.
- **Power management**: Power management is central to the energy efficiency of many other secondary functions and should be a cornerstone of any further secondary function technical research. Power management can be uniquely implemented in every appliance, but certain best-practice, universal principles could be developed to ensure that power management achieves maximum possible energy savings. This would require investigation of power management implementations across a wide cross-section of consumer products.
- **Power sources and power factor correction**: In electronic products, power electronics are a key bottleneck in power delivery and have proven to be an ideal place to address efficiency horizontally across a large number of products. Despite recent policy successes in addressing external power supply and battery charger efficiency, very little research has been done to date to document the typical efficiency of internal power supplies integrated into many other consumer products like home entertainment equipment. Furthermore, opportunities exist to improve the efficiency of advanced secondary or standby power supplies used to deliver electricity in low-power modes. Secondary power supplies now represent an opportunity for major appliances as well, since many whitegoods now incorporate soft switches and electronic power controls that require some amount of power at all times. Finally, power factor correction technology can provide benefits on both the grid and customer side of the electric meter, so requiring higher power factor in electronic products could present another important horizontal policy opportunity.

# INTRODUCTION

Standby power is a general term commonly used to describe the low-power mode(s) that many electrical and electronic products are in when not performing their primary function (Harrington and Nordman 2010). Standby power has become more complex in recent years, a trend likely to continue into the future. Not only are the number of possible functions and operating modes increasing, but the number of products with secondary functions has also increased. The presence of electronic controls in most products now provides a platform for the proliferation of these functions, which can provide users with new and useful features when the product is not in active mode. There may also be a range of functions present of which the user is not aware. The appearance of network-related modes in a wider range of products and the expansion of home networks is an important component of this trend. Many sophisticated network functions that are typically associated with computers and networking equipment are now proliferating to a wider variety of loads—ranging from traditional whitegoods like laundry equipment to screw-based lamps and lamp sockets to home entertainment equipment—in attempts to make products smarter, more interconnected, and compatible with smart grid technologies. Each of these so-called "secondary" product functions contributes to power consumption in standby mode (or other low-power modes).

Policies in major economies have started to address some aspects of standby power use, principally those associated with power supply losses. However, standby power has become more complex in recent years. This seemingly simple operational state has "suffered" from continuous product innovation and has become increasing difficult for policymakers to address. Policymakers today often deal with secondary functions by introducing new power allowances within "vertical" product specifications (i.e. specifications that only apply to one end use product). For example, the ENERGY STAR® program has recently addressed, in its specification for televisions, the power requirements of Download Acquisition Mode (DAM). DAM is a catch-all operational mode meant to capture the power associated with any network communication that occurs during what has—at least until recently—been called standby mode. However, as greater numbers of products begin incorporating functions that may affect standby power demand, there is a compelling opportunity to develop horizontal policies for standby power that address multiple end-use products. Recent successes in addressing the efficiency of common power electronics components—namely the external power supplies and battery charger systems found in billions of consumer and office electronics—have demonstrated that horizontally applicable policy approaches can be a powerful approach for achieving savings in plug and miscellaneous loads. This research is an effort to begin to identify some of the next large horizontal policy opportunities.

The rapid growth in secondary functions across many products is certain to compound the importance of standby power, yet a common understanding of their prevalence, the frequency and duration with which

they operate and their various applications does not exist. Recent work has proposed a new approach to defining the standby-related operating states of products and their associated functions (Harrington, Siderius, and Ellis 2008; Nordman et al. 2009; Harrington and Nordman 2010). This approach first defines functions and then modes as a combination of functions. This can be described as an "atoms and molecules" approach to operating states, in which functions are the atoms and modes are the molecules composed of individual atoms. The functional approach to low-power modes is attractive, because it is likely that only a limited number of functions exist which could then be used to characterize a large number of possible modes.

This paper aims to identify and analyze the secondary functions that contribute to standby power (or other low-power modes as applicable) and document their prevalence in various operational modes in several common products. There are two primary objectives of this research. The first is to provide clear documentation that identifies secondary functions, evaluate their market prevalence, and classify them into functional groups. The second objective is to map the secondary functions identified into the most common modes for each product category. Findings will help policymakers identify promising horizontal approaches for addressing standby power in a wide range of consumer goods.

## SCOPE

The scope of this research covers three product categories: major appliances, home entertainment, and office equipment. These products represent some of the most common plug loads used in homes and businesses and represent the vast majority of plug load energy consumption. Table 1 provides an overview of the major categories and their constituent products. Products grouped together in the table are considered to be similar in both the way they are used and the types of secondary functions they might possess. It should be noted that set-top boxes were excluded from the scope of home video products because of the host of unique secondary functionality considerations for these products that are largely being addressed by vertical energy efficiency efforts.

**Table 1: Products and Product Categories**

| Major Appliances | Home Entertainment | Office Equipment |
|---|---|---|
| Clothes washers, clothes dryers, and dishwashers | Televisions | Printers and multi-function devices |
| Refrigerators and freezers | Home audio (e.g. stereos, amplifiers) | Desktop and mobile computers |
| Water heaters | Home video (e.g. DVD players, streaming video devices; excluding set-top boxes) | Small network equipment |

# IDENTIFYING AND CLASSIFYING FUNCTIONS

## BACKGROUND AND METHODS

This project has fortunately been preceded by a small body of work describing the functional approach to addressing energy efficiency requirements in consumer products. In developing a list of secondary functions and classifying them into broader functional categories, we made attempts to build on the foundational thinking on this subject established by Nordman, Siderius, Harrington, Meier, and others in recent publications related to the activities of the International Energy Agency's (IEA) 4E Network Standby Annex (Harrington and Nordman 2010; Nordman et al. 2009). We also surveyed the EuP initiative's Lot 6 study (Nissen 2007) on standby power for additional insights on the definition and classification of functions. Before exploring the methodology used to identify secondary functions, it is useful to provide some background philosophy on our treatment of secondary functions.

Several closely related definitions of a product function have been developed by the energy efficiency community. The EuP's Lot 6 report describes a function as "a predetermined operation triggered by an interaction (of the user, of other technical systems, of the system itself, of a measurable input from the environment)" (Nissen 2007, 1-7). The authors further clarify that several functions may operate in a coordinated fashion to produce a "functionality." An example might be a clock, which employs a display, a clock circuit, and memory to provide the higher level clock functionality experienced by the user (Nissen 2007). We have generally adopted this definition but needed to further refine our use of functions to meet the needs of the project, as described below.

This project was interested namely in *secondary* functions, effectively those functions that are not related to the primary stated use of a product (noting that some secondary functions may be present in both active modes and low-power modes). Naturally there is some room for subjectivity in establishing what is a primary versus secondary function. For one, it is not always clear whether a function that *supports* a primary function should be considered primary as well. For example, in refrigerators supplementary heating elements are wrapped around refrigeration coils to periodically defrost them. One could argue that this directly supports the primary function of cooling perishable food by maintaining ice-free refrigeration coils. However, our research would generally define this function as secondary because it merely supports the primary function (refrigeration can and does occur even without a defrost function).

Another issue is that a secondary function in one product might be considered a primary function in another product. For example, we can examine display functions or the ability to display visual information to the user. In smart appliances, printers, or multi-function devices, displays are merely used

to serve a secondary interface function. However, in products like televisions and monitors, displaying information is a primary function. As will be seen later in this report, this was a key consideration in mapping functions to products.

Fortunately, it is usually straightforward to distinguish between primary and secondary functions. Primary functions tend to define whole end-use product classes, whereas secondary functions like those described in this report can typically be applied horizontally across a number of different products. To this end, we made our functions for this project deliberately broad and horizontal wherever possible. As a rule, if we found that a function only applied to one product category, we tried to broaden its functional scope.

## A Functional Framework

Our team identified several guiding principles early on in our research that helped to shape the development of our functional list and may aid others in applying the functional approach in the future. These principles are:

- **Functions should be technology-agnostic**. When defining a function, we tried not to tie it to one technology implementation (e.g. 802.11 networking or LCD displays). An easy litmus test for this principle is that if a function is defined so specifically that there is only one physical way to implement it, it may not be a function but rather a technology.
- **Functions should be defined close to the user**. Even with a very tight definition of secondary functions, one can imagine dozens of generic secondary functions that occur at lower layers, particularly in electronic products. If we consider the communication of digital over-the-air broadcast signals, what to the user may appear to be one function of a television may in fact comprise half a dozen sub-functions, such as tuning, demodulation of radio signals, decompression of a digital video or audio stream, and so on. One could make a compelling case that demodulation and decompression are valid secondary functions. They are horizontal, they are somewhat technology-agnostic, and they meet the basic definitions of functions provided earlier in this report. However, we have taken an approach that ignores such low-level functions because they are too far removed from the features in a product that actually impact the user experience. Broadly speaking, the functions we have captured in our work are at most one degree separated from the user experience. In other words, if a secondary function is not user-oriented (user input or power control), it should at least support a function that is.
- **Primary and secondary functions are usually (but not always) mutually exclusive**. Within a particular product, primary and secondary functions are necessarily mutually exclusive. As mentioned above, primary functions typically define a product class like clothes dryers or clock radios. However, when functions are viewed as a class (of functions), functions are not always

mutually exclusive. There are examples, particularly within the realm of consumer electronics, where a horizontal and cross-cutting function like “visual display of information” can be both a primary and secondary function. See the example of televisions above.

- **Build to last, but prepare to adapt**. We support the goal of developing a robust framework for examining secondary functions, but realistically we feel that any such framework will need to adapt and expand over time as new and previously unimaginable functions are added to products in the future.

## A Special Note About Networks

Network-related functions were particularly challenging for our team to categorize and define. On the one hand, networks are fairly simple to describe. They simply allow for the passing of information between two or more connected devices. On the other hand, networks are exceedingly complex and multi-layered. Due to this complexity and the numerous layers upon which networks are built, we could almost argue for separate consideration of network functions outside of the broad, multi-product framework of this project.

Our team debated two main approaches to networks. The first divided network-related functions based on the service they provide to the user. For example, network connections can either be wired or wireless, and they can vary in speed, all of which impact the user experience. The second approach examined the activities that are common between all networked connections. Every networked device needs to conduct error checking, use handshaking of some sort to confirm connections, and poll to see if another device is attempting to transmit information. Each approach has its pros and cons. The first approach separates network functions based on attributes that are more readily recognizable to users, but it could be seen as too focused on hardware implementation and not a truly generic functional approach. The second approach defines very broad and horizontally applicable network functions, but those functions are so broad that they might not prove useful in certain instances. For example, consider a product like televisions that may be able to connect to other devices through myriad interfaces, including HDMI connectors, Ethernet cables, Wi-Fi/802.11, or even Bluetooth. When mapping the prevalence of functions in this product, how do we indicate that certain models may have nearly a half dozen ways to communicate with broader data networks and other home entertainment equipment?

In the end, our project opted for the first approach, using both the speed and interface type (wired versus wireless) to establish network connection functions. This approach may not be perfect, but provided a practical path forward for this project. Future projects with a data/networking focus may choose to use the second more generic approach to network functions.

## SECONDARY FUNCTIONS AND CLASSIFICATIONS

Although there are a variety of ways we could categorize and organize different functions, we chose to adopt a similar approach taken by Nordman et al. (2009). We group similar functions into categories that are independent of product type, with the goal of defining and categorizing functions so that they can be applied globally. Table 2 shows the functional categories used for this project. Table 3, spanning the following pages, shows the secondary functions we identified and classifies them into the functional groups developed from Table 2.

**Table 2. Functional Categories**

| Category Name | Definition |
|---|---|
| Communication – Devices | Functions that enable a product to send or receive information in a variety of formats to or from other devices. |
| Communication – People and Environment | Functions that provide information to the user. |
| Controls | Functions that facilitate the dynamic operation of a product by sensing users and the environment and adapting operation accordingly. |
| Power | Functions related to the provision of power from electric mains. |
| Time | Functions involved with tracking time, both in a relative and absolute sense. |
| Other | Miscellaneous functions that do not fit in any other category but that may be present during low-power modes of operation. |

### Table 3. Secondary Functions and Classifications

| Functions | User or Internal Facing | Definition | Example Technologies and Implementations |
|---|---|---|---|
| **Communication - Devices** | | | |
| Low speed networking, wireless | Internal | Provide a low-speed (<10 Mbps) wireless network connection between devices to enable transfer of digital information. | Wireless protocols intended for home automation and smart grid applications, like ZigBee/802.15.4 and Z-Wave. |
| Low speed networking, wired | Internal | Provide a low-speed (<10 Mbps) wired network connection between devices to enable transfer of digital information. | Plug load carrier technologies directed at smart grid applications, like HomePlug GreenPHY. |
| High speed networking, wireless | Internal | Provide a high-speed (≥10 Mbps) wireless network connection between devices to enable transfer of digital information. | Wi-Fi/802.11 |
| High speed networking, wired | Both | Provide a high-speed (≥10 Mbps) wired network connection between devices to enable transfer of digital information. | Ethernet/802.3 |
| Peripheral device connectivity, wireless | Internal | Provide a wireless connection to nearby peripheral devices, excluding audiovisual equipment and displays. | BlueTooth/802.15.1, Near Field Communication |
| Peripheral device connectivity, wired | Both | Provide a wired connection to nearby peripheral devices, excluding audiovisual equipment and displays. | USB, FireWire/IEEE 1394, PS2. |
| AV connectivity, wireless | Internal | Enable dedicated wireless transmission of audio or video signals between devices. | Includes proprietary wireless audio and video transmission systems, such as Sonos wireless speakers. |
| AV connectivity, wired | Both | Enabled dedicated wired transmission of audio or video signals between devices. | HDMI, composite audio/video, component video. |
| Network bridging | Internal | Provide an interface between two networks that may operate on different communication protocols. | DSL or DOCSIS cable modems that bridge external wide area networks to local area networks. |
| External display connectivity | Internal | Ability to provide or accept video signals to external monitor devices. | DVI, VGA/SVGA or other display connections that predominantly carry video content and some monitor power management signaling. |
| **Communication – People and Environment** | | | |
| Indicator light | User | Provide visual product status indication via an illuminated device such as a lamp. | Typically LEDs. |
| Display, alphanumeric | User | Display character-based information to users. | Character-based LCD displays such as those used in alarm clocks, display panels on certain audiovisual equipment, etc. |
| Display, informational | User | Display any visual information, including text, still images or video, to users. | Active matrix LCD displays such as those used on printers and certain smart appliances. |
| Audio annunciation | User | Produce sound to indicate product status to users. | Speakers and buzzers used on a variety of appliances for audio signaling. |
| Video input | User | Sense visual input from product surroundings, such as through a camera. | Embedded cameras such as those found on laptops and certain televisions for video conferencing. |
| Audio input | User | Sense audio input from product surroundings, such as through a microphone. | Microphone/transducer. |
| **Controls** | | | |
| Power control | User | Ability for user to change the power state of the device through a physical interface located on the device. | "Soft" on/off switches like those found on consumer electronic products. |

| Functions | User or Internal Facing | Definition | Example Technologies and Implementations |
|---|---|---|---|
| Remote control sensing | User | Ability of product to respond to incoming signals from a remote control, including power signals. | Infrared sensors. |
| Occupancy sensing | User | Sense the presence of people in the vicinity of the product. | Certain advanced televisions can turn off their backlight if users are not present. |
| Contact sensing | User | Sense contact, pressure, or physical obstruction in or around a device. | Sense an open door (refrigerators/freezers, laptops, etc.) or detect obstructions/jams in printing devices. |
| Ambient light sensing | Internal | Sense the amount of visible light present in the vicinity of a device. | Photosensors such as those employed for automatic brightness controls in televisions. |
| Temperature sensing | Internal | Sense the temperature inside or near a device. | Thermistors used in a wide variety of whitegoods and consumer electronics. |
| Moisture/humidity sensing | Internal | Sense the moisture content of air or, more commonly, the conductivity of moist materials in contact with a sensor. | Moisture sensors for drying termination in clothes dryers. |
| User input | User | Accept user input from a physical interface located on the device that is not related to control of power state. | Keypads, soft switches that do not directly control power but remain energized in some way, like when you press the eject button on a DVD player. |
| Power management, external | Internal | Ability to respond to signals from an external device to change the operational state of the device. | Wake-on-LAN, Wake-on-Ring, Wake-on-Modem; HAN control; display power signaling; HDMI Consumer Electronic Control: any management of power state more complicated than "on/off" from a push button. |
| Power management, internal | Internal | Ability to alter the operational state of the device based on internal factors (i.e. excluding user input), such as a timer or schedule. | Internally managed power management functions, auto power down, sleep, etc. |
| Embedded motor drive | Internal | Control the speed of a motor either in discrete increments or in a fully variable fashion. | Could be for VSD but in residential appliances, more likely a 2- or 3-speed drive/controller. |
| **Time** | | | |
| Timer | Both | Measure elapsed time. | Enables the "delay" functions found on many washers, dryers, and dishwashers. |
| Clock | Both | Measure absolute time on a 12- or 24-hour clock. | Combined with a display, provides the ability to store and display local time, such as with alarm clocks or other clock displays found on consumer electronics equipment. |
| Schedule | Both | Coordinate product operation according to absolute time as governed by a "clock" function. | Certain "smart" appliances allow for operation on a set schedule rather than through a "delay" function. |
| **Power** | | | |
| Electromagnetic interference reduction | Internal | Control the conducted or radiated electromagnetic emissions from a product to its surroundings. | |
| Power factor correction | Internal | For power electronics with high displacement or distortion power factor, control the power supply in a manner that maximizes power factor and draws power sinusoidally and in phase with mains electricity. | PFC stage found on large (>75W) AC-DC power supplies. |
| Primary power source | Internal | Provide power conversion for product primary functions. | Main AC-DC power supply that powers the processor, drives, fans, etc. in a desktop computer. |
| Secondary power source | Internal | Provide power conversion for non-primary product functions. | So-called "standby" power supply that supports secondary functions occuring in standby and allows the primary power supply to be disabled during standby. |

| Functions | User or Internal Facing | Definition | Example Technologies and Implementations |
|---|---|---|---|
| Power connected devices | Internal | Provide power to connected peripheral devices. | A television or computer charging the battery of a peripheral connected through USB. |
| **Other** | | | |
| Task lighting | User | Light areas on or near the product to provide improved visibility to the user when performing tasks. | Lights inside of clothes washers and dryers allowing the user to clearly see the contents of the drum. |
| Ambient lighting | User | Light areas surrounding the product for visual effect. | Certain televisions will backlight the wall behind the appliance for visual effect. Desktop computer cases may contain decorative LEDs. |
| Maintain memory state | Internal | Maintain the state saved in any form of volatile memory device to preserve user settings. | Maintain the state of a computer, laptop, tablet, or other device while the device is in sleep mode. |
| Mechanical maintenance | Internal | Any mechanical function occuring in sleep/standby that "readies" the device to wake more efficiently or keeps certain components optimized. The function does not signal the device to wake up. | Many printers will perform automated mechanical tasks, such as preventing rubber parts from getting flat spots and maintaining consistent lubrication of certain components, in non-active modes on a timer. |
| Soft maintenance | Internal | Any network/digital function occuring in sleep/standby that "readies" the device to wake more efficiently or keeps certain components optimized. The function does not signal the device to wake up. | Program downloads in televisions or other updates to software/firmware that may occur in networked products. |
| Heating | Internal | Supplemental heating not related to a product's primary function. | Defrost coil heaters in refrigeration appliances. Maintaining fuser temperature in laser printers during sleep. |
| Access stored content | User | Access stored media (text, still images, video, audio) for display or reproduction to the user. | Screensavers for LCD displays in devices like printers, smart appliances, etc. |

# MAPPING FUNCTIONS BY PRODUCTS AND MODES

## METHODS

### Determining Prevalence of Functions in Products

Mapping the selected functions to product categories and individual products was largely a market research exercise. Our task was not to quantify the prevalence of secondary functions in the selected products but to qualitatively assess their prevalence using a survey of products commonly available on the market. For each combination of function and product, we applied a categorical labeling scheme to qualitatively denote the prevalence of functions by product. Our scheme borrows from the recommendations of Nordman et al. (2009) by labeling functions as always, sometimes, rarely, or not applicable. We used a "Harvey ball" labeling scheme in our actual maps, shown in Table 4.

**Table 4: Prevalence Indicators**

| | |
|---|---|
| ● | Always present |
| ◕ | Sometimes present |
| ○ | Rarely present |
| Blank | Not present or N/A |

We used an iterative process to determine function prevalence:

1. **Establish typical models for product categories.** We used readily available market data to establish "typical" models for the considered product categories. This research primarily used consumer product review services like Consumer Reports as well as sales data from big box and online retailers (Amazon.com, BestBuy, etc.) to establish the general market trends. In some instances where Ecova had in-house product expertise (e.g. televisions), we conferred with product experts and leveraged prior in-depth market research.
2. **Inventory secondary functions.** The selected typical models were next examined for secondary functionality. This phase of the research made heavy use of publicly available product literature, such as user manuals, technical specifications, and service manuals. Due to the broad scope of the project, it was not possible to conduct detailed primary research on this topic through manufacturer interviews. We iteratively updated our master list of secondary functions at intervals when new functions were uncovered or when certain products challenged our existing framework for secondary functions.

3. **Categorize secondary function prevalence.** For each function-product combination, we assigned a prevalence using the categories in Table 4. Our assignments were based on the initial sweep of typical models established in step 1.
4. **Test function assignments.** After making our initial prevalence assignments, we tested our mapping by examining products on the extremes of the market. This most often helped us to identify functions previously thought irrelevant and sometimes helped temper our assumptions about the ubiquity of certain very common functions. For example, based on a survey of typical laundry equipment, we initially assumed that high-speed networking functions would not be present in clothes washers and dryers. However, certain smart laundry appliances at the very top end of the market have begun incorporating these features via Wi-Fi/802.11 radios.

We add a caveat once again about interpreting our function-to-product mapping results. Our charge was only to map secondary functions. However, there are several functions on our list that might be considered primary functions depending on the product (e.g. heating in water heaters, or display in televisions). We specifically ignore the function if it directly contributes to primary functionality. Hence, "heating" is not present as a secondary function in water heaters, and "display, informational" is not present in televisions.

## Mapping Frequency of Function Occurrence by Operational Mode

Having identified the secondary functions that applied to major categories of products and their prevalence, we next identified how frequently those functions operated in certain modes of operation. We first made attempts to simplify our research tasks by lumping products with similar usage patterns together, similar to the approach taken in the EuP Lot 6 study reports that categorized products by "Product Use Categories" (Nissen 2007). For example, clothes washers, dryers, and dishwashers all handle fixed loads or jobs on some limited duration cycle, so we lumped these products into one category.

Our project's goal was not to establish universally accepted definitions for product operating modes, but rather to map secondary functions to generally understood modes of operation. Because of this, we also derived some very generic modal definitions for our product groupings, as described in our results later in this section. These operational modes may not be as precise or semantically correct as some of the more nuanced modal definitions described in the literature, but they generally provide guidance as to when secondary functions are active and help to serve the broader goal of this project: to identify functions that are horizontally applicable to numerous product categories in preparation for future study and policy action.

Our modal mappings represent the *frequency* and *duration* with which secondary functions are on or available during various modes of operation rather than the *prevalence* of those functions in different products (Table 5). We separated judgments about the prevalence of functions from this mapping exercise and attempted to answer the question: "given that a product possesses a certain secondary function, how frequently or persistently will it occur in different modes of operation?" Therefore, certain very rare functions like low-power wireless network connectivity can be presented as "always on," because *if* they were present in a product, they would most certainly be on frequently or continuously in various modes. Similarly, a very common function like "timer" could be labeled as "rarely used," because it is only activated at brief intervals by a direct use request (e.g. the "delay" function on certain household laundry appliances or dishwashers).

**Table 5: Frequency/Duration Indicators**

| | |
|---|---|
| ● | Frequently or continuously used |
| ◒ | Sometimes used |
| ○ | Rarely used |
| Blank | Not applicable or never used |

# MAJOR APPLIANCES

## Functions to Products

Major appliances are some of the most traditional electric end uses in homes and businesses today. Refrigerators, water heaters, and laundry equipment have been around for well over half a century. These products are generally "always on" and their primary energy-using functions relate to motors, heating, and refrigeration, so power use in low-power modes (in the traditional sense) has not typically been a concern. However, in recent years even whitegoods have begun to receive significant electronic components that may require some continuous power in low-power modes. A new wave of so-called "smart" appliances could increase this trend by introducing wireless networking capabilities and increased use of touch display interfaces.

As far as the snapshot of today's market goes, major appliances employ fewer secondary functions than any of the other major product categories we surveyed. This is expected, as many of the secondary functions we identified are more typical of electronics-dominated products like home electronics and office equipment. As shown in Table 6, some of the most prevalent secondary functions in the major appliance class are those that directly support mechanical processes (e.g. motor drives, temperature or humidity sensing) or those that enable user interaction and control (e.g. display functions, user input, indicator lights).

Table 6: Major Appliance Map of Functions to Products

| | | | Major Appliances | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Secondary Function** | **Example Technologies** | **User Orientation** | **Clothes Washers** | **Dryers** | **Dishwashers** | **Refrigerators** | **Freezers** | **Water Heaters** |
| **Communication - Devices** | | | | | | | | |
| Low speed networking, wireless | ZigBee, Z-Wave | Internal | ○ | ○ | ○ | ○ | ○ | ○ |
| Low speed networking, wired | Proprietary wired cycle coordination on certain washers/dryers | Internal | ○ | ○ | | | | |
| High speed networking, wireless | Wi-Fi/802.11 | Internal | ○ | ○ | | ○ | | |
| **Communication – People and Environment** | | | | | | | | |
| Indicator light | LEDs | User | ● | ● | ● | ◎ | ◎ | ○ |
| Display, alphanumeric | Fixed-character LCDs | User | ◎ | ◎ | ◎ | | | ○ |
| Display, informational | Active matrix LCDs | User | ◎ | ◎ | | ○ | | |
| Audio annunciation | Door alarm on fridge, buzzer on dryers | User | ◎ | ● | | ◎ | ○ | |
| **Control** | | | | | | | | |
| Power control | Soft switches/keypads | User | ◎ | ◎ | ◎ | | | |
| Temperature sensing | Thermistors, RCD | Internal | ● | ● | ● | ● | ● | ● |
| Moisture/humidity sensing | Moisture sensors in dryers, fridges | Internal | | ◎ | | ◎ | | |

| | | | Major Appliances | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Secondary Function** | **Example Technologies** | **User Orientation** | **Clothes Washers** | **Dryers** | **Dishwashers** | **Refrigerators** | **Freezers** | **Water Heaters** |
| User input | Keypads, capacitive touch devices | User | ◉ | ◉ | ● | ● | ● | ○ |
| Power management, external | Interact with smart grid power signaling | Internal | ○ | ○ | ○ | ○ | ○ | ○ |
| Power management, internal | Sleep functions, mainly for displays and user input panels | Internal | ◉ | ◉ | | ○ | | |
| Embedded motor drive | Multi-speed motor control | Internal | ● | ○ | ● | ● | ● | ○ |
| **Time** | | | | | | | | |
| Clock | Clock for user display or smart grid time-of-use applications | User | ○ | ○ | ○ | ◉ | ◉ | ○ |
| Timer | Door alarm on fridge, delay wash, timed wash/dry, etc. | Internal | ● | ● | ◉ | | | |
| Schedule | Some smart appliances allow scheduling jobs. | User | ○ | ○ | ○ | | | |
| **Power** | | | | | | | | |
| Electromagnetic interference filtering | Built-in EMI filters | Internal | ○ | ○ | ○ | ○ | ○ | ○ |
| Power factor correction | PFC stage in PSU | Internal | ○ | ○ | ○ | ○ | ○ | ○ |
| Primary power source | Main power supply | Internal | ● | ● | ● | ● | ● | ○ |
| Secondary power source | Standby power supplies | Internal | ● | ● | ● | ◉ | ◉ | ○ |
| **Other** | | | | | | | | |

| | | | Major Appliances | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Secondary Function** | **Example Technologies** | **User Orientation** | **Clothes Washers** | **Dryers** | **Dishwashers** | **Refrigerators** | **Freezers** | **Water Heaters** |
| Task lighting | Interior lighting for washers, dryers, fridges, freezers. | User | ○ | ◎ | | ● | ◎ | |
| Maintain memory state | Save settings | Internal | ◎ | ◎ | ◎ | ◎ | ◎ | ◎ |
| Heating | Defrost. | Internal | | | | ● | ● | ○ |
| Access stored content | Access media for LCD interfaces, screen savers, etc. | User | ○ | ○ | | ○ | | |

As noted above, the anticipated rise of smart appliances may help to drive increased use of some emerging and relatively rare functions. Wireless networking functionality (both high and low speed) enables smart appliances to communicate with home energy management or home automation systems, often implemented using technologies like Zigbee (802.15.4). This function mainly serves to deliver information on product energy use, power state, and potentially grid state (e.g. electricity prices) to and from a home energy management system to coordinate the operation of appliances within a household. Certain smart appliances are gaining amenities such as small color LCD touch displays to display recipes from the Internet, create shopping lists, view video content, or simply change product settings. These appliances not only support a host of secondary functions around user input and display, but also maintain a more persistent high-speed network connection to provide web-based content on screen.

## Functions to Operational Modes

We lumped major appliances into groups based on usage for the operational mode mapping. Clothes washers, dryers, and dishwashers were all lumped into the same category, as they are typically operated in a “job-based” fashion in which a cycle or load is performed at the user’s request and for a finite period of time. Refrigerators, freezers, and water heaters, on the other hand, are basically “always on” appliances in that they perform their primary function depending on internal system conditions that are not directly governed by the user (i.e. the user does not directly control when the compressor in a refrigerator or the heating element in an electric water heater turns on).

We found based on product documentation, prior technical expertise, and general product use experiences that most of the relevant major appliance secondary functions were either always on or always off during low-power modes of operation. There are a select few user-oriented functions – audio annunciation (end-of-cycle indications), indicator lights, displays, or task lights – that may only be available for brief periods during which users are actually interacting with the appliance. Table 7 provides an overview of our findings.

Table 7: Major Appliance Map of Functions to Operational Modes

| | | | Clothes Washer, Dryers, and Dishwashers | | Refrigerators and Freezers | Water Heaters |
|---|---|---|---|---|---|---|
| **Secondary Function** | **Example Technologies** | **User Orientation** | **Standby** | **On Cycle** | **Always On** | **Always On** |
| **Communication - Devices** | | | | | | |
| Low speed networking, wireless | ZigBee, Z-Wave | Internal | ● | ● | ● | ● |
| Low speed networking, wired | Proprietary wired cycle coordination on certain washers/dryers | Internal | ○ | ● | | |
| High speed networking, wireless | Wi-Fi/802.11 | Internal | ● | ● | ● | |
| **Communication – People and Environment** | | | | | | |
| Indicator light | LEDs | User | ◘ | ● | ◘ | |
| Display, alphanumeric | Fixed-character LCDs | User | ◘ | ● | ◘ | ○ |
| Display, informational | Active matrix LCDs | User | ◘ | ● | ◘ | |
| Audio annunciation | Door alarm on fridge, buzzer on dryers | User | ○ | ○ | ○ | |
| **Control** | | | | | | |
| Power control | Soft switches/keypads | User | ● | ● | | |
| Temperature sensing | Thermistors | Internal | | ● | ● | ● |
| Humidity sensing | Moisture sensors in dryers, fridges | Internal | | ● | ● | |

| | | | Clothes Washer, Dryers, and Dishwashers | | Refrigerators and Freezers | Water Heaters |
|---|---|---|---|---|---|---|
| **Secondary Function** | **Example Technologies** | **User Orientation** | **Standby** | **On Cycle** | **Always On** | **Always On** |
| User input | Keypads, capacitive touch devices | User | ○ | ● | ● | ● |
| Power management, external | Interact with smart grid power signaling | Internal | ● | ● | ● | ● |
| Power management, internal | Sleep functions, mainly for displays and user input panels | Internal | ◎ | ● | ◎ | |
| Embedded motor drive | Multi-speed motor control | Internal | | ● | ◎ | |
| **Time** | | | | | | |
| Clock | Clock for user display or smart grid time-of-use applications | User | ● | ● | ● | ● |
| Timer | Door alarm on fridge, delay wash, timed wash/dry, etc. | Internal | ◎ | ● | ◎ | |
| Schedule | Some smart appliances allow scheduling jobs. | User | ● | ● | ● | |
| **Power** | | | | | | |
| Electromagnetic interference filtering | Built-in EMI filters | Internal | | ● | ● | ● |
| Power factor correction | PFC stage in PSU | Internal | | ● | ● | ● |
| Primary power source | Main power supply | Internal | | ● | ● | ● |
| Secondary power source | Standby power supplies | Internal | ● | ● | ● | |
| **Other** | | | | | | |

| | | | Clothes Washer, Dryers, and Dishwashers | | Refrigerators and Freezers | Water Heaters |
|---|---|---|---|---|---|---|
| **Secondary Function** | **Example Technologies** | **User Orientation** | **Standby** | **On Cycle** | **Always On** | **Always On** |
| Task lighting | Interior lighting for washers, dryers, fridges, freezers. | User | ○ | ○ | ◉ | |
| Maintain memory state | Save settings | Internal | ● | ● | ● | ● |
| Heating | Defrost. | Internal | | ◉ | ◉ | |
| Access stored content | Access media for LCD interfaces, screen savers, etc. | User | ◉ | ● | ◉ | |

# HOME ENTERTAINMENT

## Functions to Products

Home entertainment products are at the core of the standby power issue. Owning a television has become a staple in households in the developed world. Playing music during a family gathering involves an increased variety of home audio devices. Home video equipment allows us to access our favorite network television shows and movies. These devices are more interconnected than ever before, spurring significant innovation and growth in secondary functionality. Televisions with internet-enabled capabilities, such as gaming, social networking and other so-called “apps,” are becoming more mainstream. Home audio and video equipment have a number of wireless functions that consumers have come to expect in nearly all consumer electronics. Overall, the number of secondary functions that may require some continuous power in low-power modes is on the rise in these products.

A large majority of the secondary functions identified in this project apply to the home entertainment category. Table 8 shows the most prevalent of these. Although we anticipated finding many functions related to increased network connectivity (e.g. Wi-Fi, Ethernet), the majority of functions identified correspond to enabling communications between people and environment (e.g. indicator lights, secondary displays, audio annunciation) and controls (e.g. remote control sensing, power management). We undoubtedly observed the expected trend of increased market share of internet-enabled or “smart” home entertainment products. However, we underestimated the increased secondary functionality in other categories, including miscellaneous functions such as powering connected devices and maintaining memory state. In terms of market outlook, it remains to be seen whether network connectivity functions such as wireless high speed networking will be a “requirement” for the next generation of these product groups. Mid- to high-end televisions, for example, almost always have Wi-Fi capability yet their entry level counterparts do not yet consistently integrate this function, at least in smaller screen sizes. These network functions usually support the primary function by delivering media in some fashion. Traditional secondary functions (e.g. standard TV connectors, remote control sensing) will remain commonplace and newer secondary functionality will be incorporated in parallel as home entertainment content becomes increasingly digital and on-demand.

Table 8. Home Entertainment Map of Functions to Products

| | | | Home Entertainment | | |
|---|---|---|---|---|---|
| **Secondary Function** | **Example Technologies** | **User Orientation** | **Televisions** | **Home Audio** | **Home Video** |
| **Communication - Devices** | | | | | |
| High speed networking, wireless | Wi-Fi/802.11, Philips Wireless MediaConnect, Airplay | Internal | ⊙ | ⊙ | ⊙ |
| High speed networking, wired | Ethernet | User | ⊙ | ○ | ⊙ |
| Peripheral device connectivity, wireless | BlueTooth | Internal | ○ | ⊙ | ⊙ |
| Peripheral device connectivity, wired | USB, Thunderbolt, FireWire | User | ⊙ | ⊙ | ⊙ |
| AV connectivity, wireless | Airplay, etc. | Internal | ○ | ⊙ | ○ |
| AV connectivity, wired | HDMI, DVI, etc. | User | ● | ⊙ | ● |
| **Communication – People and Environment** | | | | | |
| Indicator light | LEDs | User | ● | ⊙ | ● |
| Display, alphanumeric | Illuminated LCDs | User | | ⊙ | ⊙ |
| Display, informational | Active matrix LCDs | User | | ⊙ | ⊙ |
| Audio annunciation | loudspeaker | User | ● | ● | ○ |
| Video input | embedded camera, skype | User | ○ | | |

| | | | Home Entertainment | | |
|---|---|---|---|---|---|
| **Secondary Function** | **Example Technologies** | **User Orientation** | **Televisions** | **Home Audio** | **Home Video** |
| Audio input | microphone | User | ○ | ○ | |
| **Controls** | | | | | |
| Power control | on/off/reset buttons | User | ● | ● | ● |
| Remote control sensing | Infrared, LED | User | ● | ◘ | ● |
| Occupancy sensing | TV occupancy sensing related to auto-power-down when no one is present | User | ○ | | |
| Ambient light sensing | ABC in TVs | Internal | ◘ | | |
| User input | Keypads, soft switches | User | ○ | ◘ | ◘ |
| Power management, external | Consumer Electronics Control (CEC), VIERA LinkTM HDAVI Control, Samsung Anynet+™, Philips EasyLink | Internal | ◘ | | ◘ |
| Power management, internal | Standard power mgmt | Internal | ◘ | ◘ | ◘ |
| **Time** | | | | | |
| Clock | Clock for user display or internal time keeping | User | ● | ◘ | ● |
| Timer | For basic time functions | Internal | ◘ | ◘ | ◘ |

| | | | Home Entertainment | | |
|---|---|---|---|---|---|
| **Secondary Function** | **Example Technologies** | **User Orientation** | **Televisions** | **Home Audio** | **Home Video** |
| **Power** | | | | | |
| Electromagnetic interference filtering | EMI filtering | Internal | ● | ● | ● |
| Power factor correction | PFC stage on power supply | Internal | ◘ | ○ | ◘ |
| Primary power source | Main PSU | Internal | ● | ● | ● |
| Secondary power source | Standby power supply | Internal | ● | ● | ● |
| Power connected devices | Power attached iPod | User | ◘ | ◘ | ○ |
| **Other** | | | | | |
| Ambient lighting | illuminate back panel of TVs | User | ○ | | |
| Maintain memory state | Save settings | Internal | ● | ● | ● |
| Soft maintenance | Download program info for TVs | Internal | ◘ | ○ | ○ |
| Access stored content | screensaver, etc. | User | ◘ | | ◘ |

## Functions to Operational Modes

For the home entertainment category, we lumped home audio and home video equipment together and analyzed televisions as a standalone group. Home audio and video equipment share similar operational modes, and both are generally considered to be two-mode, “on/standby” products, as defined in the EuP Lot 6 study (Nissen 2007). Televisions are also considered to be part of the on/standby product use cluster. It is important to note that the home entertainment mapping exercise was more onerous than the equivalent mapping previously described for major appliances, given the increased complexity of operating modes in most consumer electronics products and the larger number of applicable functions. We used the following framework to characterize operational modes throughout our mapping analysis for home entertainment.

Rather than use modal definitions that are specific to individual regulatory or policymaking bodies like ENERGY STAR, we opted for more generic definitions of operational modes. For example, in its televisions specification ENERGY STAR currently supports three different types of standby modes. We lump all of those into a single mode (termed sleep for the purposes of this project). We chose modal definitions that represent the general understanding of international stakeholders. However, we also acknowledge that the purpose of this project is *not* to define and prescribe operational modes to a range of products in a way that pleases all stakeholders (and we make no attempt to do so). As mentioned above, the EuP Lot 6 study (Nissen 2007) is instructive by defining four product-use-clusters that were also useful when grouping our product types. For home entertainment (and office equipment) we defined concise mode definitions in order to facilitate consistency in mapping functions to modes across product categories. We used the following modal definitions:

> **Standby:** We use standby mode as the minimum power level with one or more user-oriented functions available. Functions available in this mode could include some indicator lights, power control input, time functions, power functions, and maintaining memory state.
>
> **Sleep:** We use sleep as the next mode “above” off/standby and as the first mode where connectivity is introduced to the product. There are many flavors of sleep (e.g. “light sleep” and “deep sleep” in cable set top boxes), and it certainly means different things for different products. However, we do not make such distinctions for this project. We simply define sleep as a level of functionality between off/standby and on/active in which connectivity between devices may be allowed or that allows a product to rapidly return to the on/active mode (e.g. as in computers).
>
> **On/Active:** We use on or active mode as the mode where a product is performing its primary function. We are less precise about the mapping in this mode of operation, because the priority of

the project is to identify horizontally applicable functions for low-power modes (off/standby and sleep).

Home entertainment products are generally considered to be “on/standby” devices, in which the transition from low-power modes to on needs to occur quickly for consumer acceptance purposes (Nissen 2007). These devices typically include a remote control, frequently used to manually activate the product from low-power modes for convenience. Based on market research and prior technical expertise, we found that most of the relevant home entertainment secondary functions were “frequently” or “continuously” used during low-power modes of operation. That is, only a few functions were considered to be “on-demand” functions, which do not require continuous power and may only be available for brief periods of time. One example of such an on-demand function is audio annunciation—a function used to briefly signal the user the device is entering (or leaving) a state. Other functions, such as clocks, power management, and power factor correction, are generally persistent in low-power modes independent of the user. Table 9 shows our comprehensive findings for mapping home entertainment products into modes.

Table 9. Home Entertainment Map of Functions to Operation Modes

| | | | Televisions | | | Home Audio and Home Video | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Secondary Function** | **Example Technologies** | **User Orientation** | **Standby** | **Sleep** | **On** | **Off/Standby** | **Sleep** | **Idle** | **Active** |
| **Communication - Devices** | | | | | | | | | |
| High speed networking, wireless | Wi-Fi/802.11, Philips Wireless MediaConnect, Airplay | Internal | | ● | ● | | ● | ● | ● |
| High speed networking, wired | Ethernet | User | | ● | ● | | ● | ● | ● |
| Peripheral device connectivity, wireless | BlueTooth | Internal | | ● | ● | | ● | ● | ● |
| Peripheral device connectivity, wired | USB, Thunderbolt, FireWire | User | | ● | ● | | ● | ● | ● |
| AV connectivity, wireless | Airplay, etc. | Internal | | ● | ● | | ● | ● | ● |
| AV connectivity, wired | HDMI, DVI, etc. | User | | ● | ● | | ● | ● | ● |
| **Communication – People and Environment** | | | | | | | | | |
| Indicator light | LEDs | User | | ● | ● | | ● | ● | ● |
| Display, alphanumeric | Illuminated LCDs | User | | ● | ● | | ● | ● | ● |
| Display, informational | Active matrix LCDs | User | | ● | ● | | ● | ● | ● |
| Audio annunciation | loudspeaker | User | | ● | ● | | ● | ● | ● |
| Video input | embedded camera, skype | User | | ● | ● | | ● | ● | ● |

| | | | Televisions | | | Home Audio and Home Video | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Secondary Function** | **Example Technologies** | **User Orientation** | **Standby** | **Sleep** | **On** | **Off/Standby** | **Sleep** | **Idle** | **Active** |
| Audio input | microphone | User | | ● | ● | | ● | ● | ● |
| **Controls** | | | | | | | | | |
| Power control | on/off/reset buttons | User | ● | ● | ● | ● | ● | ● | ● |
| Remote control sensing | Infrared, LED | User | | ● | ● | | ● | ● | ● |
| Occupancy sensing | TV occupancy sensing related to auto-power-down when no one is present | User | | ● | ● | | | | |
| Ambient light sensing | ABC in TVs | Internal | | | ● | | | | |
| User input | Keypads, soft switches | User | | ● | ● | | ● | ● | ● |
| Power management, external | Consumer Electronics Control (CEC), VIERA LinkTM HDAVI Control, Samsung Anynet+™, Philips EasyLink | Internal | | ● | ● | | ● | ● | ● |
| Power management, internal | Standard power mgmt | Internal | | ● | ● | | ● | ● | ● |
| **Time** | | | | | | | | | |
| Clock | Clock for user display or internal time keeping | User | ● | ● | ● | ● | ● | ● | ● |
| Timer | For basic time functions | Internal | ● | ● | ● | ● | ● | ● | ● |

| | | | Televisions | | | Home Audio and Home Video | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Secondary Function** | **Example Technologies** | **User Orientation** | **Standby** | **Sleep** | **On** | **Off/Standby** | **Sleep** | **Idle** | **Active** |
| **Power** | | | | | | | | | |
| Electromagnetic interference filtering | EMI filtering | Internal | ● | ● | ● | ● | ● | ● | ● |
| Power factor correction | PFC stage on power supply | Internal | | ● | ● | | ● | ● | ● |
| Primary power source | Main PSU | Internal | ● | ● | ● | ● | ● | ● | ● |
| Secondary power source | Standby power supply | Internal | ● | ● | ● | ● | ● | ● | ● |
| Power connected devices | Power attached iPod | User | | | ● | | | ● | ● |
| **Other** | | | | | | | | | |
| Ambient lighting | illuminate back panel of TVs | User | ● | ● | ● | ● | ● | ● | ● |
| Maintain memory state | Save settings | Internal | | ● | ● | | | | |
| Soft maintenance | Download program info for TVs | Internal | | ○ | ○ | | ○ | ○ | ○ |
| Access stored content | screensaver, etc. | User | | ⊙ | ⊙ | | ⊙ | ⊙ | ⊙ |

# OFFICE EQUIPMENT

## Functions to Products

Office equipment refers to both residential and commercial information and communications devices. This project focuses on print and multi-function devices, desktop and mobile computers, and small network equipment. Printers and multi-functional devices have remained necessary, and have evolved alongside our transition to a digital world. Computers are now cornerstone devices, a requirement for most businesses, hospitals, and schools. Small network equipment, intended to focus on non-enterprise network equipment, enables so many of our devices to connect with one another. The energy use of office products has significantly increased in recent years, as has the number of secondary functions available.

More secondary functions were identified in office equipment than in any other category reviewed for this project. Office equipment shared many secondary functions with the home entertainment category, as these are both fundamentally sub-categories of electronics. Like home entertainment equipment, office equipment saw several network connectivity functions. However, we identified several controls functions such as contact sensing and temperature sensing that were not present in most home entertainment products. We also observed common functions in the Communication – People and Environment category such as indicator lights and displays. We observed some form of soft maintenance function in each of the three product groups in the office equipment category. These maintenance functions, focused on “readying” a device to wake more efficiently, are on the rise as we see more portable consumer electronics devices such as tablets (e.g. iPad) that may need to receive software or firmware patches. It is clear that most consumers will not accept long wake times for their devices, and functions that support this convenience in low-power modes are being prioritized. Table 10 shows the most common secondary functions identified in office equipment.

Table 10. Office Equipment Map of Functions to Products

| | | | Office Equipment | | | |
|---|---|---|---|---|---|---|
| **Secondary Function** | **Example Technologies** | **User Orientation** | **Printers and multi-function devices** | **Desktop computers** | **Mobile computers** | **Small network equipment** |
| **Communication - Devices** | | | | | | |
| High speed networking, wireless | Wi-Fi/802.11, AirPlay | Internal | ◎ | ◎ | ● | ◎ |
| High speed networking, wired | Ethernet | User | ● | ● | ◎ | ◎ |
| Peripheral device connectivity, wireless | BlueTooth, Near Field Communication | Internal | ○ | ◎ | ◎ | ○ |
| Peripheral device connectivity, wired | USB, Thunderbolt, FireWire, SD card (also fit here?) | User | ● | ● | ● | ○ |
| AV connectivity, wired | HDMI | User | | ◎ | ◎ | |
| Network bridging | DOCSIS, MoCA | Internal | | | | ◎ |
| External display connectivity | Connection to pure displays via DVI, VGA, DisplayPort | User | | ● | ◎ | |
| **Communication – People and Environment** | | | | | | |
| Indicator light | LEDs | User | ● | ● | ● | ● |
| Display, alphanumeric | Illuminated LCDs | User | ◎ | ○ | ○ | ○ |
| Display, informational | Active matrix LCDs | User | ◎ | ○ | ○ | ○ |

| | | | Office Equipment | | | |
|---|---|---|---|---|---|---|
| **Secondary Function** | **Example Technologies** | **User Orientation** | **Printers and multi-function devices** | **Desktop computers** | **Mobile computers** | **Small network equipment** |
| Audio annunciation | beep signal on printers | User | ◉ | ● | ● | |
| Video input | embedded camera | User | | ○ | ◉ | |
| Audio input | microphone | User | | ○ | ● | |
| **Controls** | | | | | | |
| Power control | on/off/reset buttons | User | ● | ● | ● | ○ |
| Remote control sensing | Infrared, LED | User | ○ | ○ | ○ | |
| Contact sensing | Examples: door open, lid open, material lodged | Internal | ◉ | | ● | |
| Temperature sensing | CPU cooling in computers | Internal | ● | ● | ● | ◉ |
| Ambient light sensing | Automatic brightness control | Internal | | | ◉ | |
| User input | Keypads, soft switches, touchscreen | User | ● | ● | ● | ○ |
| Power management, external | WOL, WOR, WOM | Internal | ● | ◉ | ○ | ○ |
| Power management, internal | Standard PM function | Internal | ◉ | ● | ● | |

| | | | Office Equipment | | | |
|---|---|---|---|---|---|---|
| **Secondary Function** | **Example Technologies** | **User Orientation** | **Printers and multi-function devices** | **Desktop computers** | **Mobile computers** | **Small network equipment** |
| **Time** | | | | | | |
| Timer | basic time functions | Internal | ● | ● | ● | ● |
| Clock | clock for user display | Internal | ● | ● | ● | ● |
| Schedule | scheduling automatic downloads | Internal | ⊙ | ● | ● | ○ |
| **Power** | | | | | | |
| Electromagnetic interference filtering | EMI filters | Internal | ● | ● | ● | ● |
| Power factor correction | PFC stage in power supply | Internal | ⊙ | ⊙ | ⊙ | ○ |
| Primary power source | Main PSU | Internal | ● | ● | ● | ● |
| Secondary power source | Standby PSU losses | Internal | ● | ● | ● | ● |
| Power connected devices | Power from USB, etc. | User | ○ | ● | ⊙ | |
| **Other** | | | | | | |

| | | | Office Equipment | | | |
|---|---|---|---|---|---|---|
| **Secondary Function** | **Example Technologies** | **User Orientation** | **Printers and multi-function devices** | **Desktop computers** | **Mobile computers** | **Small network equipment** |
| Task lighting | illuminating job area for some printers | User | ◉ | | | |
| Ambient lighting | case lighting in desktops | User | | ○ | ○ | |
| Maintain memory state | store settings | Internal | ● | ● | ● | ● |
| Mechanical maintenance | gear hitch in printers | Internal | ● | | | |
| Soft maintenance | software patches | Internal | ◉ | ● | ● | ● |
| Heating | maintaining temp in printers | Internal | ◉ | | | |
| Access stored content | screensavers, etc | User | ○ | ◉ | ◉ | |

## Functions to Operational Modes

For the office equipment category, we lumped printers and multi-function devices together, desktop and mobile computers together, and analyzed small network equipment as a standalone group of products. Printers are “job-based” devices, similar to clothes dryers and dishwashers. Best categorized under product-use-cluster three in EuP Lot 6 (Nissen 2007), printers often transition to a low(er) power mode once a job is complete. The device may stay ready for some time (i.e. “ready state”), but transitions into a sleep mode after a period of inactivity. Our second product group, computers, are best categorized as “on/standby” products, product-use-cluster two in EuP Lot 6 (Nissen 2007). Computers must conveniently and quickly enter and exit their low-power modes. Computers often have customizable power management settings to allow users to choose when and how (e.g. close laptop lid) their device enters low-power modes. Small network devices are unique from most other consumer electronics, and are considered “always on” products under EuP Lot 6’s product-use-cluster zero (Nissen 2007). Always-on products are in active mode as soon as they are plugged into the mains and traditionally have no automated transitions between modes (Nissen 2007).[1] Small network equipment are always powered on, but we do make a distinction between active (transferring data) and idle (not transferring data) states within on mode.

For all office equipment, we implemented the same framework for consistent use of operational modes as described for home entertainment on page 28. Similar to most home entertainment functions, we found that most of the relevant office equipment secondary functions were frequently or continuously used during low-power modes of operation. There were, however, a few on-demand functions such as powering connected devices (e.g. charging a USB-connected device) and time-triggered mechanical maintenance in some printers. Table 11 shows our complete findings for mapping office products into modes.

[1] However, some new products are starting to move away from this “always on” characterization. For example, Energy Efficient Ethernet (EEE) and other power scaling technologies would allow small network equipment products to transition between different active and idle states, reducing energy consumption when the device is not actively transmitting data.

Table 11. Office Equipment Map of Functions to Operation Modes

| | | | Printers and Multi-function Devices | | | | Desktop and Mobile Computers | | | | Small Network Equipment | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Secondary Function** | **Example Technologies** | **User Orientation** | **Standby** | **Sleep** | **On Mode: Ready State** | **On Mode: Active State** | **Stand by** | **Sleep** | **Idle** | **Active** | **Idle** | **Active** |
| **Communication - Devices** | | | | | | | | | | | | |
| High speed networking, wireless | Wi-Fi/802.11, AirPlay | Internal | | ● | ● | ● | | ● | ● | ● | ● | ● |
| High speed networking, wired | Ethernet | User | | ● | ● | ● | | ● | ● | ● | ● | ● |
| Peripheral device connectivity, wireless | BlueTooth, Near Field Communication | Internal | | ● | ● | ● | | ● | ● | ● | ● | ● |
| Peripheral device connectivity, wired | USB, Thunderbolt, FireWire, SD card (also fit here?) | User | | ● | ● | ● | | ● | ● | ● | ● | ● |
| AV connectivity, wired | HDMI | User | | | | | | ● | ● | ● | | |
| Network bridging | DOCSIS, MoCA | Internal | | | | | | | | | ● | ● |
| External display connectivity | Connection to pure displays via DVI, VGA, DisplayPort | User | | | | | | ● | ● | ● | | |
| **Communication – People and Environment** | | | | | | | | | | | | |
| Indicator light | LEDs | User | ○ | ◎ | ● | ● | ◎ | ◎ | ● | ● | ● | ● |
| Display, alphanumeric | Illuminated LCDs | User | | ◎ | ● | ● | | ○ | ◎ | ● | ◎ | ◎ |
| Display, informational | Active matrix LCDs | User | | ◎ | ● | ● | | ○ | ◎ | ● | ◎ | ◎ |

| | | | Printers and Multi-function Devices | | | | Desktop and Mobile Computers | | | | Small Network Equipment | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Secondary Function** | **Example Technologies** | **User Orientation** | **Standby** | **Sleep** | **On Mode: Ready State** | **On Mode: Active State** | **Stand by** | **Sleep** | **Idle** | **Active** | **Idle** | **Active** |
| Audio annunciation | beep signal on printers | User | | ○ | ○ | ○ | | ○ | | ○ | | |
| Video input | embedded camera | User | | | | | | | ● | ● | | |
| Audio input | microphone | User | | | | | | | ● | ● | | |
| **Controls** | | | | | | | | | | | | |
| Power control | on/off/reset buttons | User | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| Remote control sensing | Infrared, LED | User | | ● | ● | ● | | ● | ● | ● | | |
| Contact sensing | Examples: door open, lid open, material lodged | Internal | | ● | ● | ● | | ● | ● | ● | | |
| Temperature sensing | CPU cooling in computers | Internal | | ● | ● | ● | | ● | ● | ● | ● | ● |
| Ambient light sensing | Automatic brightness control | Internal | | | | | | | ● | ● | | |
| User input | Keypads, soft switches, touchscreen | User | | ● | ● | ● | | ● | ● | ● | ● | ● |
| Power management, external | WOL, WOR, WOM | Internal | | ● | ● | ● | | ● | ● | ● | ● | ● |
| Power management, internal | Standard PM function | Internal | | | ● | ● | | | ● | ● | | |
| **Time** | | | | | | | | | | | | |

| | | | Printers and Multi-function Devices | | | | Desktop and Mobile Computers | | | | Small Network Equipment | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Secondary Function** | **Example Technologies** | **User Orientation** | **Standby** | **Sleep** | **On Mode: Ready State** | **On Mode: Active State** | **Stand by** | **Sleep** | **Idle** | **Active** | **Idle** | **Active** |
| Timer | basic time functions | Internal | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| Clock | clock for user display | Internal | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| Schedule | scheduling automatic downloads | Internal | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| **Power** | | | | | | | | | | | | |
| Electromagnetic interference filtering | EMI filters | Internal | | ● | ● | ● | | ● | ● | ● | | ● |
| Power factor correction | PFC stage in power supply | Internal | | ● | ● | ● | | ● | ● | ● | | ● |
| Primary power source | Main PSU | Internal | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| Secondary power source | Standby PSU losses | Internal | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| Power connected devices | Power from USB, etc. | User | | | ○ | ○ | | ○ | ◎ | ◎ | | |
| **Other** | | | | | | | | | | | | |

| | | | Printers and Multi-function Devices | | | | Desktop and Mobile Computers | | | | Small Network Equipment | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Secondary Function** | **Example Technologies** | **User Orientation** | **Standby** | **Sleep** | **On Mode: Ready State** | **On Mode: Active State** | **Stand by** | **Sleep** | **Idle** | **Active** | **Idle** | **Active** |
| Task lighting | illuminating job area for some printers | User | | | | ⊙ | | | | | | |
| Ambient lighting | case lighting in desktops | User | | | | | | ● | ● | ● | | |
| Maintain memory state | store settings | Internal | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| Mechanical maintenance | gear hitch in printers | Internal | | ○ | ○ | | | | | | | |
| Soft maintenance | software patches | Internal | | ○ | ○ | ○ | | ○ | ○ | ○ | ○ | ○ |
| Heating | maintaining temp in printers | Internal | | ⊙ | ⊙ | ⊙ | | | | | | |
| Access stored content | screensavers, etc | User | | ● | ● | ● | | ● | ● | ● | | |

Note: network-oriented functions in small network equipment are effectively the primary function.

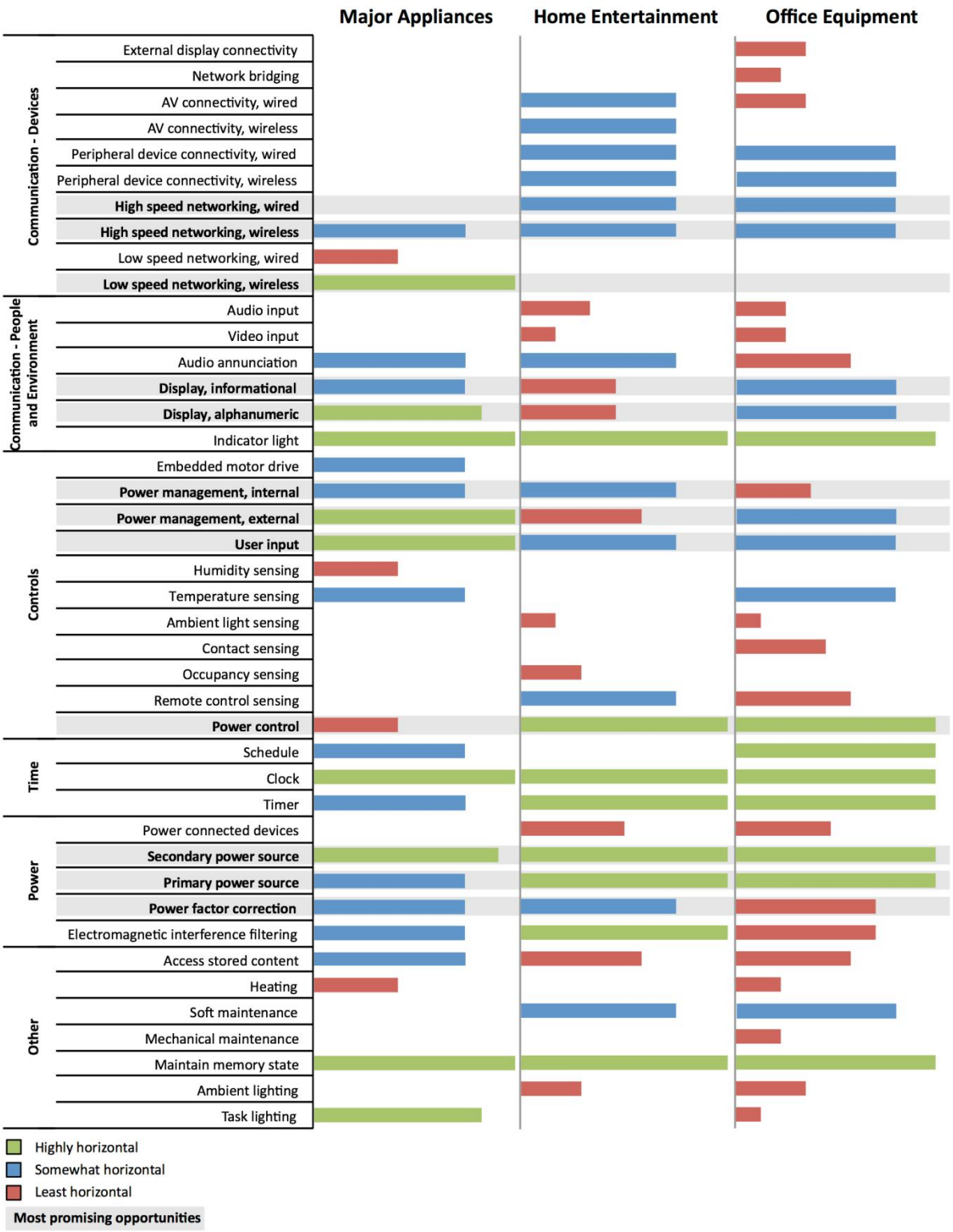
# DISCUSSION AND CONCLUSION

Generating detailed maps of secondary functions by product type and operational mode was a crucial task in this research, but only a means to an end. Ultimately the aim of this research was to identify emerging horizontal opportunities for energy efficiency policy action. To explore the results and make sense of the detailed mapping presented above, we developed a semi-quantitative scoring mechanism to rank individual functions by their prevalence in products and their frequency of use in low-power modes. The most horizontally applicable functions are ones that are both common in products and used very frequently in low-power modes, including many power and control functions. Depending on their individual power consumption, these functions have the potential to drive standby power in a large number of devices and present a key policy challenge to ensure that these functions are designed to use the minimum power possible. Conversely, functions that are both rare and infrequently used cannot be considered very horizontally applicable, regardless of the power consumed. Many of the secondary lighting functions fall into this category, because they have a niche application and are only used for limited periods of time in low-power modes (note: indicator lights are an exception and are considered a very horizontally applicable communication function). Even if they did consume high amounts of power when in use, such functions might not have significant energy impacts on large numbers of products and might be better addressed through vertical product specifications. Other functions may fall somewhere between these two extremes, meriting further investigation. Examples of these functions include many networking technologies that are gaining traction in a broad array of products. They may not be as ubiquitous and frequently used as clocks or power controls, but market trends suggest that they may soon be as prevalent in many product areas, particularly home entertainment and office equipment.

Figure 1 illustrates across each of the three major product categories which secondary functions are the most “horizontal” using the scoring method described above. The absolute value of the score is not important, but the relative differences between functions and product categories are of interest. The bars are color-coded in three categories to indicate functions that are highly (green), somewhat (blue), and least horizontal (red). The categories were assigned to the upper, middle, and lower third of scores, respectively.

Although an important indicator of the potential leverage that policymakers could have over a given secondary functionality, our scores only tell part of the story because they do not include important considerations like the anticipated energy use or marketplace growth of secondary functions. We used expert judgment to highlight certain functions (shown in grey with boldface text) that represent the best opportunities for continued research and policy effort. In the sections that follow, we discuss themes that we see within and across product categories and, more importantly, the implications for future research and policy efforts.

Figure 1: Most Promising Secondary Function Opportunities



## Secondary Function Trends

An examination of Figure 1 reveals several interesting, high-level observations and trends regarding secondary functions:

- **Home entertainment and office products flock together**: We observed significant overlap in secondary functionality between the home entertainment and office products categories. This is not surprising, since both of these product areas are dominated by electronics with similar components and subsystems. We see particular alignment in the areas of networking (Communication – Devices), user interfaces (Communication – People and Environment), Time, and Power. We see less overlap in the Control and Other categories, because individual product categories will often have unique secondary function needs in these areas (e.g. specialized temperature, humidity, or contact sensing requirements). High-speed networking functions are of particular interest in these categories because they are rapidly increasing in prevalence, can increase overall device power consumption, and may result in longer device operation if power management is not properly implemented.
- **Major appliances present a different set of secondary function opportunities**: Not surprisingly we observed that major appliances provided a slightly different array of secondary function trends. In these products we see far less activity in Communication – Devices than in the other electronics- and information-dominated categories. Functions in the Communication – People and Environment and Control categories were somewhat more horizontally applicable in these products due to a greater presence of user interface and control functions. In home entertainment and office products, some of these features are "embedded" in products' primary functions (e.g. on-screen user settings menus for home video equipment), whereas in major appliances those functions must be accessible through an interface that is arguably separate from the primary function of drying clothes or washing dishes, such as a touch-screen display.
- **The rising importance of networking in major appliances**: Although not yet a "highly horizontal" opportunity, we see networking technologies—particularly wireless networking—as an important area for policy focus in major appliances. All major appliance manufacturers are developing versions of their products—albeit luxury versions—with "smart appliance" connectivity features, such as the ability to send and receive energy and operational information according to protocols like Smart Energy Profile. Market researchers anticipate that such appliances will account for a significant portion of sales by mid-decade in countries with smart grids (Pike Research 2010). We have seen numerous examples of smart appliances in which the smart device connectivity is provided by high-speed 802.11 adapters rather than lower power and lower speed physical layers like Zigbee or Z-Wave. The bandwidth requirements of smart grid

applications are certainly within the capabilities of low-power protocols like Zigbee, so policymakers need to ensure that manufacturers are encouraged to utilize lower power communications as the next generation of appliances is developed.

- **Ubiquitous functions are not always impactful**: We saw a large number of secondary functions that are used in large numbers of products and remain active during low-power operational states. However, many of these functions are anticipated to be minimal in their power use and therefore do not represent opportunities for further energy efficiency gains. The time-related functions and "Maintain memory state" function are examples of this.
- **Power electronics continue to present promising areas for future research**: In electronic products, power electronics are a key bottleneck in power delivery and have proven to be an ideal place to address efficiency horizontally across a large number of products. Despite recent policy successes in addressing external power supply and battery charger efficiency, very little research has been done to date to document the typical efficiency of internal power supplies integrated into many other consumer products like home entertainment equipment. Furthermore, opportunities exist to improve the efficiency of advanced secondary or standby power supplies used to deliver electricity in low-power modes. Secondary power supplies now represent an opportunity for major appliances as well, since many whitegoods now incorporate soft switches and electronic power controls that require some amount of power at all times. Finally, power factor correction technology can provide benefits on both the grid and customer side of the electric meter, so requiring higher power factor in electronic products could present another important horizontal policy opportunity.
- **Displays are on the rise across all categories**: Information displays continue to proliferate as secondary functions in a wide variety of products, often as a means to enhancing user interfaces. We see this across all three major product categories in devices that traditionally had no display technology, such as printers and laundry equipment. Luminous efficacy may not be as much of a concern in these applications, but appropriate power management strategies may play a more central role.
- **A central role for power management**: Power management is central to the energy efficiency of many other secondary functions and should be a cornerstone of any further secondary function technical research. Power management can be uniquely implemented in every appliance, but certain best-practice, universal principles could be developed to ensure that power management achieves maximum possible energy savings. This would require investigation of power management implementations across a wide cross-section of consumer products.

## Recommendations and Next Steps

Based on the above trends, we identified several key areas for further technical research that pave the way for new horizontal policy opportunities that address power consumption in low-power modes. The opportunities are summarized in Table 12 and include both a justification and description of suggested research within topic areas.

**Table 12: Topics for Future Research**

| Opportunity | Product Category | Justification | Suggested Research |
|---|---|---|---|
| Wired and wireless high-speed networking | Home entertainment and office products | Network functionality continues to proliferate, and implementation of energy-saving technologies like Energy Efficient Ethernet is spotty and inconsistent. | Document market prevalence and implementation barriers to technologies like Energy Efficient Ethernet (EEE) through bench measurement of new routers and edge devices. In particular, investigate the consistency with which EEE is enabled on edge devices and suggest improvements to standard software settings to ensure proper enabling. |
| High- and low-speed wireless networking | Major appliances | Smart appliance connectivity functionality is emerging in high-end appliances, but implementation is not always energy efficient. | Compare the energy impacts of different wireless networking protocols used in smart appliances and verify through bench measurements. Examine existing policy framework for incenting smart device connectivity (i.e. per ENERGY STAR's latest whitegoods specifications in development) and compare energy allowances with measured power consumption. |
| Displays and user interfaces | All | Displays are now used to support secondary functions in every major product category and could drive increased power use in low-power modes if not appropriately power-managed. | Procure and test power consumption of displays in cross-section of consumer products (major appliances, home entertainment, and office products). Document savings associated with adopting best practices. |
| Power management | All | Power management is a core secondary functionality that is often implemented in unique ways for each product. Broad investigation of power management best practices may help identify principles that can be applied in all product categories. | Conduct a survey of power management functionality in a cross-section of consumer products and determine typical power management practices by product type (likely a combination of literature review and product inspections/measurements). Characterize power management based on degree of user configurability, aggressiveness of default settings, latency times, etc. Identify common principles of best-practice power management that could be encouraged across all devices. |
| Power sources | All | Primary and secondary power supplies are the main power bottlenecks in electrically powered consumer products. Research could help establish accurate baselines for internal power supply efficiency, highlighting products with | Use measurements to establish baseline primary and secondary/standby internal power supply efficiencies for a subset of home entertainment products and office equipment. Assess improvement potential achievable by moving to best practices (e.g. higher efficiency |

| Opportunity | Product Category | Justification | Suggested Research |
|---|---|---|---|
| | | improvement potential. The efficiency and power management of secondary power supplies can assist with reaching low standby power targets. | internal power supplies, near-zero-watt standby power supplies). |
| Power factor correction | Home entertainment and office products | The addition of power factor correction stages in power supplies can provide energy savings benefits both on the grid and customer side of the electric meter by helping to reduce system-wide resistive losses. Power factor correction could represent a new horizontal efficiency policy area for certain electronic devices. | Use a combination of literature review and product inspections/measurements to document the use of high-efficiency, active power factor correction technologies in larger consumer electronics products. Identify representative building-level energy savings and opportunities achievable by requiring higher power factor in devices powered by switch-mode power supplies. |

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