Electronic Devices & Networks Annex
EDNA


# Energy Aware Devices

## Study of Policy Opportunities

**OCTOBER 2016**

connected devices
ALLIANCE

"4E" (Energy Efficient End-Use Equipment) is an International Energy Agency (IEA) Collaborative Technology Programme established in 2008, to support governments in co-ordinating effective energy efficiency policies. Twelve countries have joined together under the 4E platform to exchange technical and policy information focused on increasing the production and trade in efficient end-use equipment. However 4E is more than a forum for sharing information – it pools resources and expertise on a wide a range of projects designed to meet the policy needs of participating governments. Participants find that is not only an efficient use of available funds, but results in outcomes that are far more comprehensive and authoritative than can be achieved by individual jurisdictions. Current members of 4E are: Australia, Austria, Canada, Denmark, France, Japan, Korea, Netherlands, Switzerland, Sweden, UK and USA. Further information on 4E is available from www.iea-4e.org

This report was commissioned and paid for by 4E's Electronic Devices and Networks Annex (EDNA). Network connected devices, including the Internet of Things, are growing rapidly and offer enormous opportunities for improved energy management. At the same time, there is a responsibility to ensure that these devices use a minimal amount of energy to stay connected. EDNA works to align government policies in this area and keep participating countries informed as markets for network connected devices develop. Further information on EDNA is available from www.edna.iea-4e.org

The concept for this report was initiated by the Connected Devices Alliance (CDA). The CDA is a network of more than 350 government and industry participants that have come together to work on the energy efficiency opportunities provided by networked devices. These include opportunities for device standby mode energy savings as well as energy savings enabled by device connectivity ("intelligent efficiency"). The CDA was conceived in 2015 by the G20 Networked Devices Initiative, which is one of six initiatives under the 'G20 Energy Efficiency Action Plan: Voluntary Collaboration on Energy Efficiency', launched after the Brisbane G20 Summit in November 2014. Further information is available from cda.iea-4e.org

**This report is authored by Bruce Nordman[1] and Alan Meier[2,3]**

The authors would like to thank the following for their insight and contributions: Taylor Jantz-Sell, Simon Lee, Peter Morgan, Ulrike Nuscheler, Hans-Paul Siderius, Harinder Singh, Jan Viegand and Steven Beletich (EDNA Operating Agent, info@edna.iea-4e.org).



[1] Bruce Nordman, bruce.nordman@gmail.com, +1 510 848-1428
[2] Alan Meier, alan.meier@gmail.com, +1 510 528-7770
[3] The authors have worked for many years on standby power standards & network connectivity in the US & internationally

# Energy Aware Devices
# Study of Policy Opportunities

## Final Report

**Bruce Nordman and Alan Meier**

**Prepared for the Electronic Devices and Networks Annex (EDNA) of the IEA Technology Collaboration Programme on Energy Efficient End-Use Equipment (IEA-4E), Paris, France**

**October 2016**

**Report Number EDNA-EAD-1**

## Executive Summary


Saving energy in buildings has always suffered from a lack of detailed information on how much each individual device within a building actually uses. The topic of "energy aware" devices covers a set of technologies that can reveal data on each individual energy-using product. This report presents information and analysis of policy and program opportunities to reduce electricity use by *encouraging devices to become energy aware*. Its key findings are that:

- Energy aware devices are a key opportunity for more efficient building operation
- Energy aware devices can reduce costs for developing some energy policies and lead to better results
- Energy aware devices can be used for cost-effective monitoring and evaluation of energy efficiency projects and programs
- Energy aware devices can be implemented for relatively low cost
- Recommended policy actions are:
    - Work to guide technology development in this area
    - Establish minimum standards for energy aware device capabilities
    - Incorporate energy awareness requirements into voluntary programs
    - Set out a path to incorporating energy awareness requirements into mandatory standards
- Policies and technologies in this area should respect consumer privacy
- EDNA and the Connected Devices Alliance (CDA) can serve an important role to promote and coordinate policy in this area globally, to:
    - Work with standards organizations on communication protocols
    - Sponsor the development of free, open source management system software
    - Act as a global coordinator of policies and programs that promote energy aware devices.

In this report, "energy aware" refers to the capability of a device to measure or estimate its own power and energy use. "Energy reporting" refers to the capability of an energy aware device to report its power and energy use via a communications network.

# 1. Introduction

Buildings are responsible for about 30% of OECD primary energy consumption[4]. Policies to reduce energy consumption and greenhouse gas emissions must therefore target buildings and the equipment within. Policy measures complement efforts made by individual building owners to reduce energy use.

An essential starting point is an accurate understanding of a building's energy use. Unfortunately, knowledge of a building's energy use is almost always relatively crude, often limited to what is supplied by the building's utility meter, supplemented with generic performance information for some equipment models used in the building. Indirect measurements (such as equipment inventories and schedule information) sometimes permit inference of consumption of specific end uses or equipment. At the same time, energy use in buildings is becoming more complex because miscellaneous and electronic devices are proliferating, both in number and fraction of overall electricity use. As a result, many energy-saving efforts and policies target the wrong end uses, devices, or solutions. Worse, the absence of detailed policy-specific measurements prevents gaining experience and learning from feedback. As regulations to regulate the energy efficiency of end-use devices become ever stricter, the quality and quantity of data needed to determine and justify them only grows.

This report addresses a technical concept, "energy aware" devices, that enables energy use data of individual devices in buildings to be *made available by the devices themselves*. Energy aware devices make possible new methods for building owners to understand and reduce their energy use. They also set the stage for entirely new strategies to measure energy use and formulate energy-saving policies.

An example integrated circuit for energy measurement

We first describe the technological basis of energy aware devices. Next, we describe policies that will become possible as energy aware devices become more prevalent, as well as policies to encourage the development and adoption of energy aware devices.

A device is "energy aware" if it can determine its own energy use. The determination can occur directly if the device contains internal hardware to measure electricity consumption. Direct energy measurement is becoming increasingly simple and inexpensive—sometimes by adding just a single integrated circuit or additional logic on a chip already present in the device (see figure above). Direct measurement is especially feasible for larger equipment, for which the additional hardware is a small part of the total system cost.

Alternatively, many devices can *estimate* energy consumption based on certain operating data such as time spent in particular power modes, subsystem status, and level of service output. This information can be combined with known relationships between equipment mode and power draw to estimate electricity use over time. This calculation is done in software, so no additional hardware is needed for devices to become energy aware, using estimation. Many computers and other IT devices already monitor such internal operations to enhance operation or detect faults.

[4] http://www.oecd.org/env/consumption-innovation/oecdworkonsustainablebuildings.htm

However, “awareness” only becomes useful when the information can be communicated and presented in a way that it can be understood and acted upon.  For that reason, a highly desirable feature of energy aware devices is the ability to communicate energy use data to another device.  We call this capability “energy reporting”.  The combination of these two capabilities is a powerful tool for understanding and reducing energy use.

In this report, “local energy reporting” means communication between two devices in the same building.  “External energy reporting” refers to transmitting the data outside of the building, e.g. to the end-use device manufacturer, a service provider, or a research organization (as discussed later in this report, it is recommended that this should only occur with the express permission of the device owner).  “Energy reporting” unqualified covers both local and external energy reporting.

**Technical Aspects of Energy Aware Devices**

The principle of a device monitoring its own activity is not new.  For example, copiers have long tracked the number of pages printed or processed through particular subsystems, for billing purposes, to inform maintenance, and provide insight for future product design.  Aircraft and many types of industrial equipment monitor device usage times to assure that maintenance is performed in a timely manner.  Energy awareness is common in IT equipment.  For example, network equipment routinely track data throughput on each port.  Battery-powered phones, tablets and notebook computers carefully monitor energy use, and some devices now can track which applications are impacting the energy drawn from the battery.  Making devices energy aware is not so much creating a new capability as re-purposing an existing capability, disseminating this capability to many device types, and making the resulting information readily available.


Different entities would have responsibilities for energy awareness and energy reporting.  The mechanisms needed for a device to become energy aware are internal to it; they are features that the manufacturer designs into the device, like any other feature.  In contrast, the technologies for energy reporting rely on standard communication protocols.  This report focuses on how programs and policies can spur energy awareness and reporting to become available in many more devices, how they can be implemented in ways that best serve the needs of energy efficiency in buildings, and how the gathered data can be used to inform and improve energy policy.

The notion of “intelligent efficiency”—using IT to reduce energy use in ways difficult or impossible without it—has gained increasing attention in recent times, as has the related concept of “systems efficiency”.  Energy aware devices is a necessary component of a suite of technologies to enable intelligent efficiency technology in the first place, and to gather data to evaluate savings obtained by implementing it.

A report for IEA-4E (Harrington and Nordman, 2014), in an annex on energy reporting, stated:

> *Eventually we should attain a state in which the great majority of devices have the native ability to participate in Energy Reporting, so that nearly all end use energy could be tracked this way. Energy Reporting should become an expected standard*

*feature in all products. Getting to this future state will require a number of steps operating in parallel:*

- *Communications standards for Energy Reporting to be created*
- *Manufacturers to support such standards in their products*
- *Creation of management systems that can "harvest" and use the data*
- *People that can deploy the products and management systems and then use the data with supporting analysis to reduce energy use in buildings and/or provide greater energy services.*

*Public policy can work on each of these areas to cause progress to occur more quickly than it would otherwise, and to provide more effective results.*

Policies to encourage energy aware devices can, and should, be applied horizontally (that is, applied the same or similarly) to large groups of device types. This is because energy awareness and reporting are never a device's primary function; the details of the technology employed for energy awareness and reporting can be common across all devices.

**Applications of Energy Aware Devices**

The purpose of energy aware devices is to enable further activities that lead to energy savings. As indicated above, energy aware devices have two key features: self-assessment of energy use, and communication. These features enable a range of applications. Some applications local to the building in which the devices reside include:

- Energy accounting—understanding building energy use to make decisions about equipment replacement, repair, operation, etc., including fault detection (revealed by excessive or unexpected energy use).
- Billing—more accurately billing of tenants or vendors (e.g. that provide food and beverage vending machines) for electricity use.
- Building operation—better controlling energy use, e.g. inferring that when lights are turned off that space need no longer be climate controlled, or as an input to decisions about managing power use in a grid context.
- Monitoring and verification—comparing actual energy use to that estimated in building or efficiency measure design.

In addition, energy aware devices have other benefits to the user, some of which are completely unrelated to energy use. One example is inexpensive asset management, as unique device identification data are reported over the network along with the energy data.

Note that a device that lacks any conventional wired or wireless communication technology can still be energy aware[5]. An energy aware device can provide information to the owner via its user interface. An oven, for example, could display energy use data (or run-times for heating elements) on the temperature display. Millions of appliances already communicate error codes to their manufacturers via data encoded in audible tones that are transmitted over the owner's phone, so that required replacement parts can be sent with the service technician. A phone app could readily acquire data through such audio encoding, or via the phone's camera from the device's display. These procedures are nearly always unique to particular products and communicate energy data in a way that makes it difficult to be further processed and interpreted. These approaches to energy awareness will eventually be replaced by devices that have the internal capability to determine their energy use and

[5] While a device could add communication hardware only for the purpose of being able to report energy data, this is not likely to occur.

communicate that information over standard network protocols. For that reason, non-networked devices are not the primary focus of this report.

**Policy Applications of Energy Aware Devices**

Energy aware technologies have not been developed and installed for public purposes but, once available, can provide valuable inputs to public policies. Policy applications include:

- Developing baseline energy use values—to understand how much energy that devices of a particularly type actually use in ordinary operation, including how this changes over time, to create a strong foundation for research and analysis, and inform policy decisions.
- Verification—to understand how the actual energy use of a particular brand/model compares to corresponding laboratory test procedure results[6]. This information can also be used to improve the test procedures themselves[7].
- Program evaluation—to have more, better, and less expensive data than is currently available, enabling less expensive but higher quality evaluation of efficiency measures and programs.
- Rebate program design—to inform utility rebate programs in amounts distributed to building owners, incentives paid to program operators, or amounts paid to manufacturers.
- Rebate program operation—to provide rebates based on actual product performance or savings rather than indirect estimates, and tailor rebates to the individual user and/or product, rather than use savings assessed by prior studies or after-the-fact evaluations.
- Tracking performance over time—to inform policy and rebates. Products with mechanical components, and even those driven more by software, can reduce their service delivery over time, and/or increase energy use over time, from equipment degradation.
- Fixing principal-agent problems—shifting responsibility for energy costs to the technology provider. This approach—called “service provider pays” —makes the service provider responsible for the financial burden of powering equipment they place into the customer’s premises[8]. “Service provider pays” ensures that these providers have the correct economic incentive to optimize the energy use of necessary technology standards (including energy reporting), hardware devices they deploy, and software installed on the devices.

[6] Verification would help identify intentional circumvention or unintentional poor performance compared to test procedure results. Circumvention has occurred in Japan, Korea, Australia, the U.S. and the EU for refrigerators, air conditioners, autos and other energy-using devices.

[7] Laboratory test procedures necessarily must simplify and average conditions experienced by real-world products, and so understanding the relationship between these and the actual energy use and operation of devices is critical. This can confirm that lab test procedures are adequate, indicate changes that need to be made, and provide guidance on the usual relationship between lab test conditions and real-world operation. In some cases, as with some ENERGY STAR tests, the goal of the test procedure is more to provide a reliable ranking of the relative energy use of products more than to estimate average use in the field, so energy reporting data can help calibrate this difference.

[8] Products most relevant include set-top boxes, modems, security monitoring equipment, and vending machines.

Energy aware devices have additional policy benefits. Different regions may obtain greater benefits depending on their specific circumstances. We list below some of the most important benefits:

- Reducing uncertainty about analysis that informs or justifies policy actions, so that policy makers and others are more confident in them.
- Reducing data collection costs.
- Identifying or deterring manufacturers who deliberately cause products to appear to be more efficient than they actually are in standard test procedure measurements.

The costs of data collection related to energy efficiency policy are not small. As an example, "California currently spends about 4% of its utility energy efficiency budget, or about USD 40 million per year, on measurement and verification of energy savings." (Calwell, 2015).

The mere existence of energy aware devices creates a degree of transparency about device energy use that does not exist today. The fact that device energy use is readily available to users may lead to more efficient product design as manufacturers seek to avoid being associated with unnecessarily energy-intensive devices. As an example, EDNA recently tested a network-connected smart LED lamp that drew 3W while connected to the network but producing no light. Over a year, this fixed load adds up to more energy than consumed by an incandescent lamp in many usage scenarios. If this fixed load was readily apparent to users, the manufacturer would have probably minimized it when designing the lamp.

**Analogy - Vehicle Fuel Economy Display**

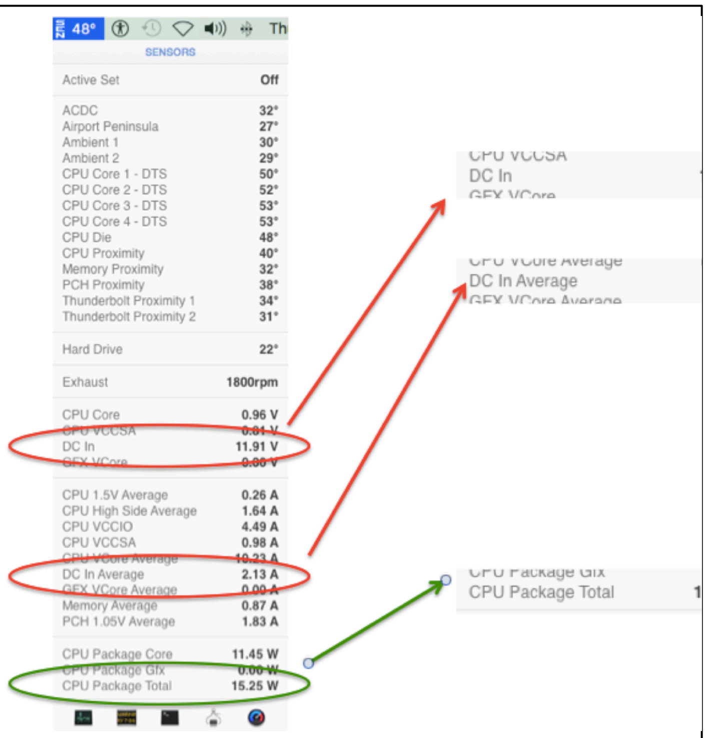

Many modern vehicles are able to communicate energy use—fuel use—to the user. This is because modern vehicles use electronic fuel injectors (rather than mechanical carburetors) which are controlled by a microprocessor. The microprocessor is easily able to calculate fuel efficiency from the controls signal sent to the fuel injectors, and the speed value received from the vehicle's speedometer. This is an excellent example of software-based energy awareness, and it is becoming ubiquitous in modern vehicles. The wide proliferation of this feature is due to the fact that the cost of including the additional software in a vehicle's electronics is effectively zero, as the source data are already available. Energy aware devices could work in the same way.

### Examples of Currently Available Energy Aware Devices

Electrical devices that are "energy aware" as a basic feature are uncommon today, so most people have not (at least not knowingly) used one. The following are examples of where they can be found today:

- In data centres, some computer server power supplies measure energy use and report that to the device's operating system, where it can then be relayed outside the device. Large network equipment devices also often include such capability, with the values reported along with other detailed metrics that the device tracks about system operation and performance.
- A few lighting control systems in commercial buildings track and report energy use on individual light circuits or devices; they are often coupled to cloud-based data systems. These systems are relatively new but are rapidly gaining in popularity.

- Internet connected thermostats—there are now over four million in North America—report run-times of heating and cooling systems, also generally to cloud data systems. When combined with capacity information, a heating or cooling system's energy consumption can be estimated.
- Power strips are widely used to control power delivered to devices plugged into them. Advanced versions of these can monitor and report power levels and energy use of the attached devices.
- Many Ethernet switches that deliver electricity to Power-over-Ethernet devices can monitor the power and energy delivered to each individual port.
- Energy awareness is a key aspect of mobile devices because maximizing battery life enhances usability. Some phones track energy use by application (e.g. recent versions of Apple iOS support this), though by % of use, not absolute values. For PCs, third-party applications are available to monitor device internal status.




The figure above shows example output from the iStat application (Bjango, Inc.) for Apple Mac computers. It takes internal sensor data available from the operating system and makes it readily available to the user. The full set of sensor output is shown, highlighting that there are voltage and current measurements of "DC in". The full power seen at the power input to the device could be estimated, adding AC/DC conversion losses based on the AC input voltage, which it could determine from its location. The input power use could be accumulated over time to record energy use. The CPU's power is also shown.

As discussed above, many automobiles now provide data about fuel economy on the dashboard, which is akin to energy reporting data in its potential usefulness for understanding device operation, energy use and efficiency.

Finally, a few products can accept energy reporting data from a variety of devices. One example is the Cisco Energy Management Suite (formerly Cisco EnergyWise), which both acquires and logs such data, and enables control functions to be applied to the same devices.

**Technology Infrastructure for Energy Aware Devices**

Effective policy development requires accurate data. To acquire this data, three additional elements beyond the capabilities of current energy aware devices are required:

- standard communication protocols for transferring the data out of the energy aware device in a consistent way

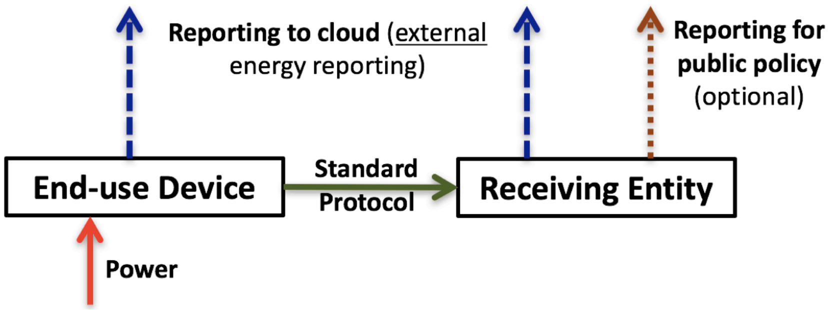
- a "receiving entity" to receive the data (can be a software application, for example on a smartphone)
- a mechanism to transfer data from the receiving entity to the outside world.

The first two are also needed to accomplish energy reporting for local purposes. Details of these requirements are discussed below.

In order to successfully communicate device energy use, it is necessary to have standard communication protocols[9] for transferring data from the individual device to a receiving entity. A key requirement for policy is to reference one or more standard communications protocols. For the foreseeable future, there will need to be several protocols (unlike web browsing, for example, in which all requests transit over HTTP and are all encoded in HTML).

Ultimately, the number of protocols should be minimized. In addition, the underlying "data model" used by these protocols should be harmonized as much as possible, so that the receiving entity can readily integrate and combine data from any of the protocols into a consistent whole. Policies will need to list the specific protocols acceptable for use, as well as some details of what features of each protocol to support.

The "receiving entity" is the device or software in a building that receives the data; this will typically be a new function of a device already present in the building. In small buildings, a network router is a good choice, because every building will have one, and it is always on and active. For large buildings, a central building or energy management system could readily provide this functionality.




**A conceptual diagram of an energy aware device, the receiving entity, and power and data flows.**

The data can be exported from this receiving entity to outside actors for policy purposes ("external energy reporting"). This can be the same protocol as used to transfer data within the building ("local energy reporting"), or a variant of it. The key is to centralize policy decisions about what data to share outside the building and with whom the data are shared. This could be optional, and/or involve making data anonymous and/or less granular in time, to address real privacy and security concerns. In addition to sharing with organizations with a policy interest, many companies would also like to have such data, to be able to sell services to the building or otherwise monetize the data. As with policy purposes, centralizing the buildings decision-making about such outside sharing of data and primarily keeping data within the building can help avoid unintended compromises of building and occupant privacy and security. While reporting directly from devices will occur, public policy need not encourage this.

The figure above shows how these features relate to each other.

[9] This report is only concerned with application-layer protocols, rather than lower layer protocols such as Wi-Fi and Zigbee, on which energy use data would be transmitted. It is assumed that all communication occurs over Internet Protocol networks in which case it is unimportant what physical layers convey the information.

## 2. Policy Actions to Accelerate Deployment of Energy Aware Devices

The primary beneficiaries of energy aware devices are building owners and occupants. The information from these devices will allow them to identify energy waste and opportunities for energy savings. Thus, the principal goal of new policy should be to encourage deployment of energy aware devices. Policy-makers can also benefit from the use of energy aware devices, but the technology is not principally designed or installed for policy purposes. This section addresses both purposes of energy aware devices. Examples of policy initiatives that promote the adoption of energy aware devices include:

- Encouraging or requiring energy reporting features in voluntary energy programs such as labelling (e.g. ENERGY STAR) or rebates.
- Encouraging or requiring energy reporting in mandatory energy standards.
- Investing in research to create better energy reporting technology and how to use its results.
- Declaring that future policy development will be informed by energy reporting data.

Potential policy actions for creating energy reporting technology should address two topics: communication protocols and the receiving entity. The public sector can carefully guide disparate companies and standards organizations towards common protocols. Publicly-funded research could create free basic software that implements the receiving entity function. These investments will assure that any building owner can benefit from energy reporting at no cost (so long as a suitable computer or smart phone/tablet is present). Many companies will create their own receiving entity software as stand-alone services, or more likely integrated into larger products. The free basic software will serve as a floor of functionality[10].

**How Accurate Should Energy Aware Devices Be?**

For some policy purposes there is a need to establish minimum standards for accuracy, the types of data made available, and the mechanisms used to transfer the data. These factors will vary depending on the type of product, the application, and the state of technology development (how expensive or otherwise burdensome it is to attain a particular degree of accuracy), and will also evolve over time. It is also important to distinguish between accuracy for each individual device, and accuracy for a brand/model on average. The data to be reported will likely include not only energy data, but other data types such as general and unique device identification. Fortunately, testing products for correct operation of energy reporting capability can be simple, involving only an electrical power test (in various device modes) and subsequent comparison to device-reported power (with an agreed tolerance). While this report does not address what levels of accuracy particular policies should require, any device should report the accuracy it supports.

In some discussions of energy aware devices, there is a focus on whether the data are directly measured or are estimated[11]. This misses the point, as measurements can be very accurate, or have large uncertainty. Similarly, estimates could be very good, or not. The

[10] This is similar to the earliest web browsers, which were developed by public entities but had only basic functionality. They were quickly superseded by more advanced designs from private companies.

[11] A small uncertainty in estimates of energy use arises when a device is off. Many devices may not know for the time they are off if the device was connected to power or not. If a device assumes that is always connected to power when off but is in fact disconnected for some of the time, it will over-estimate energy use (by the product of the off power level and the disconnected time). The reverse can occur if the device is assumed to be disconnected during off but is actually connected some of the time. This is not likely to be a major source of error but must be recognized.

bottom line in both cases is the accuracy involved. Ultimately, any accuracy should be expressed as a percentage variation from the reported value that the actual value is guaranteed to be within. Many devices might have a static accuracy they can reflect for any value; others may need to maintain data to estimate the accuracy on a more dynamic basis.

Energy aware devices in general should not be expected to provide revenue-grade metering. This does not preclude them from doing so. Even when energy reporting data are used for billing, as with billing tenants in a building that has a single utility meter, the accuracy requirements may be less strict than those for a utility.

**How Should Energy Awareness and Reporting Be Implemented?**

Key issues that policy makers need to consider in when and how to add energy reporting are: how useful the technology is to consumers and policy; how expensive it is to include in products; and whether there are any suitable alternatives to consider.

Earlier, we recommended that energy reporting capability should be a horizontal standard because it applies similarly to many and diverse product types. Most details of these requirements should be written into technology standards and into as few policy standards as possible. This arrangement would allow individual product energy standards to simply reference these common documents. In this way, the burden of creating and interpreting this content will be centralized, ensuring that the only variation among products in regards to energy reporting is that specifically needed for additional innovative features.

**Benefits of Energy Aware Devices**

Energy reporting should be promoted primarily for the benefits it offers to building and device owners. Building owners will be motivated to save money, with insights based on energy reporting data, to inform equipment replacement, maintenance, or changes to operation. Energy reporting should be promoted as a way for users to gain control and to assert autonomy of their devices.

Benefits for others—manufacturers, public policy, utilities, etc.—should be secondary, and to ensure privacy any proposals to share data outside the building should require affirmative, opt-in, action.[12] Energy reporting devices should have clear and credible messages about how they respect and facilitate privacy and security, and they should be completely transparent about how data are shared and stored. Many companies already collect such data for commercial gain, so these commercial activities (including some that cover energy reporting data) are clearly distinct from local energy reporting technology that focuses on data sharing only within a building.

**Existing Policies and Programs for Device Energy Awareness**

ENERGY STAR has referenced energy reporting as an idea for many years, beginning with enterprise servers, and more recently with other specifications such as for large network equipment, enterprise storage, white goods, air conditioners and lamps. However, manufacturers have often resisted proposals to make such features mandatory, and as of summer 2016, no ‘connected’ lamp products had been certified through ENERGY STAR, though the specification is relatively new.

---

[12] Data sharing can be made more acceptable with inclusion of effective anonymization procedures.

The European Union (EU) is considering the role of energy aware devices in the context of labelling (EU, 2015). Specifically, "whether and how energy classes describing the product's energy consumption during use should be shown on smart meters or on the product's interactive display" (12.3n). The EU considered energy reporting in the context of policy development under consideration of 'smart appliances' but is not expected to introduce any specific energy reporting content (VITO NV, 2015). It may be more likely for energy aware device requirements in the EU to emerge from a broader effort to combine electricity and IT systems, as with innovative grid management, including policies for the integration of substantial renewable electricity sources and storage.

ENERGY STAR Lamps

The ENERGY STAR Lamps specification illustrates how energy reporting features can be written into guidelines. ENERGY STAR defines some products as "Connected", and for connected lamps:

> *An ENERGY STAR eligible* ***connected*** *lamp includes elements (hardware and software or firmware) or instructions required to enable* ***communication*** *in response to consumer-authorized energy or performance related commands and complies with all requirements for connected lamps in the specification. These elements may reside inside or outside of the base lamp.*

Thus, it has the attribute of being 'connected' if it has the capability to 'communicate'. Note that the bulb can be standalone, or part of a multi-component lighting system, with other parts often "a home gateway or network controller to a cloud". If a lamp requires an external device to accomplish some of its communication capabilities, then ENERGY STAR requires that a description of the external device be available. The external device does not have to be sold with the lamp, though in such a case, the product must include clear labelling that a second device is required.

The Lamps specification requires use of "Open-standards communications" though it does not define an open standard. This specification allows communication with proprietary technologies, but notes that a fully documented "manufacturer-specific method" can be used to accomplish the goal of access via "open" standards. The requirements do not list specific protocols because these protocols have yet to be fully developed.

Data on "Energy Consumption Reporting" is specified to be energy over intervals of time, recommended to be "reported in watt-hours for intervals of 15 minutes" but other units or time period are allowed. In addition other data may be reported so long as the manufacturer documents how to calculate energy data from this. ENERGY STAR acknowledges that the data are often an estimate rather than a formal measurement. The device must also be able to report "operational status (e.g., on/off)". Finally, the communication is also required to allow control of the lamp.

ENERGY STAR Servers

The ENERGY STAR specification for Enterprise Servers does not include the formal concept of "connected" but this is probably because servers are, by definition, connected to networks. ENERGY STAR in general uses the term "reporting" primarily for the act of providing data to ENERGY STAR (and then generally made available freely on their web site); this use of the term "reporting" preceded attention to energy reporting over a network.

The reporting feature is in a section on "Standard Performance Data Measurement and Output Requirements", which distinguishes between "measurement" and "reporting". The energy/power data must be measured, though processor utilization reported through the same mechanism is explicitly allowed to be an estimate. That said, the accuracy requirements are modest[13], and it does seem plausible that many systems could accomplish such accuracy with an estimate. The requirement is that:

> *Data must be made available in a published or user-accessible format that is readable by third-party, non-proprietary management software over a standard network.*

Complex systems are only required to report data for the entire device, not individual component servers. Systems "classified as Class B equipment as set out in EN 55022:2006" do not have to implement energy reporting, to be compatible with European Union regulatory structures. The specification notes that there are a variety of ways to implement the requirement and the specification does not limit the choice among these so long as the result is obtained. Future directions are indicated with:

> *When an open and universally available data collection and reporting standard becomes available, manufacturers should incorporate the universal standard into their systems.*

Note that the power measurements are just that, power levels, not accumulated energy measurements.

The protocol for transferring data can be "push" (server autonomously sends out) or "pull" (external device initiates request). The device that receives the energy reporting data is responsible for determining the frequency at which the data are obtained, not the server. The other entity is "external management software". Thus, this specification anticipates the details of how the feature is to be used in actual operation.

ENERGY STAR Appliances

Several ENERGY STAR specifications for appliances have content on energy reporting, mostly with exactly the same text.

> *In order to enable simple, actionable energy use feedback to consumers and consumer authorized energy use reporting to 3rd parties, the product shall be capable of transmitting energy consumption data via a communication link to energy management systems and other consumer authorized devices, services, or applications. This data shall be representative of the product's interval energy consumption. It is recommended that data be reported in watt-hours for intervals of 15 minutes or less, however, representative data may also be reported in alternate units and intervals as specified in the product manufacturer's interface specification or API detailed in section 4C.*
>
> *The product may also provide energy use feedback to the consumer on the product itself. On-product feedback, if provided, may be in units and format chosen by the manufacturer (e.g., $/month).*

This is included in Clothes Washers, Clothes Dryers, Dishwashers, and Refrigerators and Freezers. Similar text is also in the specification for room air conditioners, and pool pumps.

[13] The specification specifies that "Measurements must be reported with accuracy of at least ±5% of the actual value, with a maximum level of accuracy of ±10W for each installed PSU (i.e., power reporting accuracy for each power supply is never required to be better than ± 10 watts) through the operating range from Idle to full power".

South Korean Labelling Regulation for Air Conditioners

The South Korean regulation for air conditioners requires that, in order to be labeled with energy label 'grade 1', units of 4-10kW in size must include "smart functions". Smart functions are defined as the ability to display power consumption using a smartphone, tablet or PC application, and the ability for the user to control the mode, temperature, air volume, and other functions using the application.

**Privacy Considerations**

Energy reporting can potentially be used to undermine user privacy and security. Policy-makers must ensure that users fully understand the implications of decisions, and should have to actively opt-in to sharing data with third parties if any risk could be involved. External reporting on an anonymous basis could be very useful for public policy development without undermining user autonomy or putting users at risk. Various measures could be undertaken to maximize privacy. For example, communication to outside entities might be centralized within a building to allow maximum user control of sharing with minimal effort. Communications within the building should be harmonized with external communications. While products may be sold that report data directly to an outside organization (e.g. manufacturer or service provider), such direct external reporting should **not** be part of any policy on energy reporting; it should be made clear that policies only encourage or require local reporting , for the benefit of the building owner, with optional external reporting for policy purposes.

**Additional Relevant Technologies**

The concept of energy aware devices described in this paper assumes that the energy-aware features are embedded in the device. Two alternative metering technologies, device-level external metering and Non-Intrusive Load Monitoring (NILM) are often proposed. Neither is a suitable replacement for energy reporting.

NILM generally involves adding sophisticated hardware measurement of building aggregate energy use (at the utility meter), and software systems that can disaggregate individual devices from the signal. NILM's principal limitations are that it:

- employs proprietary technologies.
- requires additional hardware that costs money to purchase, install, and power (these are substantial barriers to widespread deployment).
- lacks the ability to convey additional device information, such as individual identity (e.g. serial number) and general identity (e.g. brand/model).
- provides no mechanism for control.
- cannot penetrate direct current (DC) and battery circuits (e.g., power-over-Ethernet, USB-powered devices, photovoltaic systems, backup battery systems, etc.) which are seeing increased deployment in buildings.
- has limits on scaling in size of building and number of devices, particularly in commercial buildings with many of the same brand/model of device (unless an increased amount of submetering is installed, at significant additional cost).

Thus NILM is seen as very useful in certain niche applications, such as where devices are not networked and not energy aware. However in the long term energy reporting has the potential to become ubiquitous for networked devices.

The second approach is external monitoring of each device at point of use. It is possible to retrofit energy-awareness to existing devices, as with the following examples:

- The PowerBlade is a tiny metering and communications solution that slips onto an appliance's electrical plug. The PowerBlade is only a few millimetres thick, so it is almost invisible. It reports the device's electricity consumption via Bluetooth to a smartphone or other receiver device.
- The Belkin Wemo is an external monitoring and control device that sits between an end-use product and the power outlet. It is larger than the PowerBlade but communicates via Wi-Fi, allowing the device's energy consumption to be transmitted over the local network.
- Certain "advanced" power strips (or powerbars) contain internal measurement and communications capabilities, specific to each outlet.

These are not perfect replacements for embedding energy awareness into devices but demonstrate the concept and show that energy awareness can be retrofitted where needed. When a meter is dedicated to an individual device, the device's identity can be known, and control can be exercised (though limited to only powering and depowering, as opposed to fine-grained control possible by communicating with the device directly). External monitoring is excellent for limited, short-term data-gathering, but not suitable for permanent long-term monitoring of hundreds of devices within a building.

Building submetering, such as at electrical panels, can be an intermediate between building-wide NILM and individual device submetering, but again, this suffers from the limitations of both.

## 3. Recommendations for Policy Development

In the near term, voluntary programs are the best means of promoting energy aware technologies. Labelling products that contain local energy reporting capability, that meet a specified performance level, could help make the technology a feature desired by consumers during purchasing.

The types of voluntary initiatives that could be used include:

- Endorsement-label programs such as ENERGY STAR, European Eco-Label, etc.
- Voluntary industry agreements.
- Voluntary inclusion in MEPS or energy rating labels (e.g. inclusion of energy reporting in a product leading to more favourable ratings, etc.)
- Government purchasing specifications.
- Development of trusted third-parties that can receive and anonymize device data before sharing it with energy policy organizations.
- Public sector commitment to ongoing efforts to guide the development and improvement of energy reporting technology, particularly communication protocol standards development, to ensure usefulness and to minimize burden and cost for manufacturers and consumers.

Energy policy could respond to the opportunity presented by energy aware devices in four ways:

**Voluntary Programs**

The CDA report (CDA, 2015) recommended including energy reporting in voluntary programs (e.g. the ENERGY STAR Server specification) as the "most useful, immediate action". Energy reporting requirements could be introduced to specifications over time as merited and as they are revised, until a time when it is a feature of all specifications (for most only applying to products that have communication for some other purpose, or at least a suitable user interface for being energy aware without reporting). This should be the near-term priority.

**Mandatory Measures**

Energy reporting should not be mandatory until the technology achieves significant market adoption by building owners and the public. In general, any policy or program on energy efficiency could add energy awareness and energy reporting to its roadmap to make this mandatory in the long-term, at least for devices that can communicate. This is currently being considered in California. It necessarily comes after introduction into voluntary programs.

**Address Technical Barriers**

The key technical barriers impeding wider use of energy reporting include the creation of harmonized data communication protocols, and the specification of behaviours of reporting devices and receiving entity devices for best and consistent overall user experience. Policymakers should identify ubiquitous energy reporting capability as long term goal and make requirements more specific over time, as it becomes feasible. This activity should be coordinated internationally, and EDNA, ENERGY STAR, and the Consumer Technology Association (CTA) appear to be well suited, considering their policy interests, ability to affect product design, and activities in technology standards development.

A second barrier is the lack of free, open-source software for acquiring, storing, analysing, and displaying energy reporting data within a building.  Some proprietary systems already do this in a limited fashion, and increasingly transfer the data to the cloud.   A free, in-building solution, would promote wider adoption while ensuring privacy.

**Actions for EDNA to Consider**

The Electronic Devices and Networks Annex could constructively contribute to the promotion of energy aware devices in several ways.  First, EDNA could task consultants to work with standards organizations on communication protocols.  These consultants would work to ensure that effective standards are produced more quickly, are more harmonized, and best meet the needs of building owners and policy makers.  Second, EDNA could sponsor the development of the free receiving entity software.  Third, EDNA could act as a global coordinator of policies and programs related to energy aware devices.

## Appendix A – Technical Aspects / Further Work

### *Types of Information that should be included in Energy Reporting*

In a review of technical details of energy reporting (Nordman, 2014), the following possible types of reported data were identified:

- Energy. Accumulated energy use over time; essentially time stamps and associated meter readings.
- Power. Instantaneous power measurements, as well as voltage and current levels.
- Power State. As defined by the device, such as on, sleep, ready, idle, or off.
- General Identification. For example, brand and model of the device, as well as device classification.
- Individual Identification. Network addresses, serial numbers, and local names.
- Power details. More advanced power measurements such as multi-phase power readings, power factor, etc.
- Batteries and Components. Data on the consumption and status of individual components (e.g. fans, motors, major subsystems, etc.) and on internal batteries.

This report also described how "power interfaces" can be used to describe the electrical topology that connects energy using devices. This becomes more interesting and important as we see increasing deployment of electricity generation and storage within buildings, and inclusion of multiple power domains with varying reliability, power quality, and with some using direct current. Energy reporting can be the single mechanism needed to provide the understanding to manage such complex and diverse power systems.

The key for energy policy is to have just a few succinct collections and descriptions of such types of data that can be referenced in policy documents as what is required for products to implement, with clear correspondence to the fields in technology standards that provide the data.

### *Principles Underlying Energy Reporting*

There are several principles underlying the technology vision that the above policy directions propose. These include:

- Data should be communicated across a network interface to be most easily useful to building owners. Devices that are energy aware but do not communicate should be seen as a temporary interim step.
- Data should be reported only within the building that the device is present in. Decisions about how such data might be shared outside the building, whether to service providing companies, or to researchers for policy analysis, should be under the control of the building owner, and centralized for easy management.
- The data should follow a consistent format—"data model"—to facilitate maximum interoperability at lowest burden.
- The responsibility for deciding when measurements should be taken, and for collecting data over time, should be with the receiving entity collecting the data, not the individual devices that produce it.
- The data communicated should anticipate a future in which power distribution technologies are more diverse and networked than they are today.
- Policy should place a high priority on security and privacy of individual device data. With so many existing problems for IT systems for privacy and security, the last thing

to do is to create new ones, or even the perception of new ones.  The technology basis can greatly contribute to this.

### *Level of Detail of Energy Data Needed*

The level of detail or granularity of data needed to inform policy will vary greatly on the type of analysis.  Unfortunately, there is likely to be no one-size-fits-all approach.  Only research that uses actual energy reporting data will empirically show the incremental knowledge that can be gained from incremental data.  The results from future studies can revise and refine our understanding of data sharing needs outside buildings.  We can expect to see large data sets on relatively aggregate and anonymous data, with smaller sets of data that are much more granular and specific.

### *Additional Data and Mechanisms*

Additional “metadata” about devices should be standardized, particularly basic information such as device classification.  Another need is for standard product descriptions to be available on the Internet, with a pointer to these (e.g. a URL) specific to the brand and model of the device being reported on.  Such data should have two forms: one designed for primary reading by a human being, and another intended to be read by software systems.  This data can include elements such as laboratory test procedure results, to inform analysis of energy reporting data.

The mechanisms used for energy reporting, and the detailed data that can be made available, including device location, can be leveraged for other purposes.  Many devices have, or could have, direct or indirect assessments of occupancy or of temperature.  These could be relayed to a receiving entity for a variety of purposes.  These need not be required to be implemented, but will likely be implemented by many manufacturers as a value-added feature to provide to customers at little or no cost.

It is fairly trivial in most cases for the same protocol that receives energy reporting data to be used for controlling devices.  In most buildings, this is not likely to be the dominant mechanism for device control, but will have niche usefulness in many cases and so should be provided for.  Whether an individual device implements the control, and policies as to when to allow external control of devices, can be left to the device manufacturer.

## Appendix B – Text from ENERGY STAR Connected Device Requirements

**Clothes Dryers: clause 4.D. Energy Consumption Reporting**
In order to enable simple, actionable energy use feedback to consumers and consumer authorized energy use reporting to 3rd parties, the product shall be capable of transmitting energy consumption data via a communication link to energy management systems and other consumer authorized devices, services, or applications. This data shall be representative of the product's interval energy consumption. It is recommended that data be reported in watt-hours for intervals of 15 minutes or less, however, representative data may also be reported in alternate units and intervals as specified in the product manufacturer's interface specification or API detailed in section 4C.
The product may also provide energy use feedback to the consumer on the product itself. On-product feedback, if provided, may be in units and format chosen by the manufacturer (e.g., $/month).

**Clothes Washers: clause 4.D. Energy Consumption Reporting**
In order to enable simple, actionable energy use feedback to consumers and consumer authorized energy use reporting to 3rd parties, the product shall be capable of transmitting energy consumption data via a communication link to energy management systems and other consumer authorized devices, services, or applications. This data shall be representative of the product's interval energy consumption. It is recommended that data be reported in watt-hours for intervals of 15 minutes or less, however, representative data may also be reported in alternate units and intervals as specified in the product manufacturer's interface specification or API detailed in section 4C.
The product may also provide energy use feedback to the consumer on the product itself. On-product feedback, if provided, may be in units and format chosen by the manufacturer (e.g., $/month).

**Dishwashers: clause 5.D. Energy Consumption Reporting**
In order to enable simple, actionable energy use feedback to consumers and consumer authorized energy use reporting to 3rd parties, the product shall be capable of transmitting energy consumption data via a communication link to energy management systems and other consumer authorized devices, services, or applications. This data shall be representative of the product's interval energy consumption. It is recommended that data be reported in watt-hours for intervals of 15 minutes or less, however, representative data may also be reported in alternate units and intervals as specified in the product manufacturer's interface specification or API detailed in section 5C.
The product may also provide energy use feedback to the consumer on the product itself. On-product feedback, if provided, may be in units and format chosen by the manufacturer (e.g., $/month).

**Lamps: clause 12.9. Energy Consumption Reporting**
The lamp, or the gateway device or cloud service connected to it, shall be capable of interconnecting with consumer authorized entities to communicate data representative of its interval energy consumption. It is recommended that data be reported in watt-hours for intervals of 15 minutes; however, representative data may also be reported in alternate

units and intervals as specified in the product manufacturer's interface specification or API. If the lamp does not provide power consumption directly in watts, the manufacturer shall make available a method for estimating power consumption, in watts, from the representative data that is provided by the lamp.

**Luminaires: clause 15.2.3 Energy Consumption Reporting**
The product shall be capable of interconnecting with consumer authorized entities to communicate data representative of its interval energy consumption. It is recommended that data be reported in watt-hours for intervals of 15 minutes, however, representative data may also be reported in alternate units and intervals as specified in the partner's interface specification or API.

**Refrigerators and Freezers clause 4.D Energy Consumption Reporting**
In order to enable simple, actionable energy use feedback to consumers and consumer authorized energy use reporting to 3rd parties, the product shall be capable of transmitting energy consumption data via a communication link to energy management systems and other consumer authorized devices, services, or applications. This data shall be representative of the product's interval energy consumption. It is recommended that data be reported in watt-hours for intervals of 15 minutes or less, however, representative data may also be reported in alternate units and intervals as specified in the product manufacturer's interface specification or API detailed in section 4C.
The product may also provide energy use feedback to the consumer on the product itself. On-product feedback, if provided, may be in units and format chosen by the manufacturer (e.g., $/month).

**Room Air Conditioners clause 4.D Energy Consumption Reporting**
In order to enable simple, actionable energy use feedback to consumers and consumer authorized energy use reporting to 3rd parties, the product shall be capable of transmitting energy consumption data via a communication link to energy management systems and other consumer authorized devices, services, or applications. This data shall be representative of the product's interval energy consumption. It is recommended that data be reported in watt-hours for intervals of 15 minutes or less, however, representative data may also be reported in alternate units and intervals as specified in the product manufacturer's interface specification or API detailed in section 4.C.
The product may also provide energy use feedback to the consumer on the product itself. On- product feedback, if provided, may be in units and format chosen by the manufacturer (e.g., $/month).

**Pool Pumps clause 4.2 Energy Consumption Reporting**
Whenever pumping, the CPPS shall be capable of transmitting measured or estimated data representative of its interval energy consumption to consumers and consumer authorized third parties via a communication link.
Note: EPA recommends that energy consumption data be reported in watt-hours for intervals of 15 minutes or less, however, representative data may also be reported in alternate units, (e.g. real-time power) and intervals as specified in the ICD or API detailed in Section 4.1. The CPPS may also provide energy use feedback to the consumer on the product itself and use any units and format (e.g., dollars/month).

## References


Calwell, Chris, Plug Loads in an Era of Climate Constraints, Presentation to the CEC IEPR Workshop on Plug Load Efficiency, June 18, 2015, Ecos Research.

Connected Devices Alliance, Technical Report on Progress with International Initiatives on Networked Devices, November 2015.

DeBruin, S., Ghena, B., Kuo, Y.-S. & Dutta, P. Powerblade: A low-profile, true-power, plug-through energy meter. in Proceedings of the 13th ACM Conference on Embedded Networked Sensor Systems 17–29 (ACM, 2015).

CDA (Connected Devices Alliance), Technical Report on Progress with International Initiatives on Networked Devices, November 2015.

EU (European Commission), Proposal For A Regulation Of The European Parliament And Of The Council Setting A Framework For Energy Efficiency Labelling And Repealing Directive 2010/30/Eu, June 15, 2016.

Harrington, Lloyd, and Bruce Nordman, Beyond Network Standby: A Policy Framework And Action Plan For Low Energy Networks, prepared for IEA-4E Standby Annex, March 2014.

Lanzisera, S., Weber, A. R., Liao, A., Pajak, D. & Meier, A. K. Communicating Power Supplies: Bringing the Internet to the Ubiquitous Energy Gateways of Electronic Devices. IEEE Internet of Things Journal 1, 153–160 (2014).

Nordman, Bruce, Energy Reporting, prepared for the Northwest Energy Efficiency Alliance, January 2014.

U.S. EPA, ENERGY STAR Program Requirements for Lamps (Light Bulbs), Version 2.0., February 2015.

U.S. EPA, ENERGY STAR Program Requirements for Computer Servers, Version 2.0., Rev. Oct-2013.

VITO NV, Preparatory study on EU Smart Appliances (Lot 33), Task 1 Scope, December 21, 2015.