BEYOND NETWORK STANDBY

A POLICY FRAMEWORK AND ACTION PLAN FOR LOW ENERGY NETWORKS

4E Standby Power

A report prepared for the IEA 4E Standby Annex

ENERGY EFFICIENT STRATEGIES

Prepared by Lloyd Harrington and Bruce Nordman

International Energy Agency: Implementing Agreement on Efficient Electrical End-Use Equipment (4E)

Standby Power

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EXECUTIVE SUMMARY

INTRODUCTION

Networks are a new and exciting area of rapid technology development that promises a wide range of services to users. This issue of network connectivity has not been addressed to any great extent in existing energy policies, which have tended to focus on low power modes of electronic products. This seems to have occurred for a variety of reasons:

- The technology of networks is unfamiliar to many energy policy analysts and experts;
- There are significant complexities in network technologies and their associated protocols;
- Networks are evolving rapidly on many parallel fronts; and
- The number and type of products with network capabilities are expanding rapidly.

Now is an important time to bring focused attention to this topic area, to ensure that future energy use associated with these functions is not unnecessarily high, and to achieve highly cost-effective energy savings. "Network Standby" is a topic area that covers additional energy use of devices in low power modes attributable to their connection to a communications network, and the associated technologies and policies that can be utilized to improve these attributes.

The policy discussion and activity to date has been focused on limiting the network-related power consumption within a product, primarily in low power modes as well as increasing the time spent in low power modes. However, the concern should be on more than just power use in low power modes. Network connectivity can induce considerable extra energy consumption by keeping products in higher power modes when they would otherwise be able to enter low power modes (both the product itself and other products on the network). These are all part of the 'cost' of having network connectivity. Network equipment, which forms the basis of networks, does not have any low power mode that is relevant to the discussion, yet they are an important product to include within the scope. To ensure that we help to shape the efficient low energy networks of the future, it is important that we move beyond the issue of "network standby" and look at the overall energy impact of networks. Networks hold both the risk of significant increases in energy use, as well as the potential to implement cost-effective approaches to reduction. In particular, policy needs to engage with the highly useful functional aspects of network connectivity, to gain more attention and resources to the topic, and to better engage the technology developments that will save energy in all modes.

NETWORK FOUNDATIONS

This report examines a range of issues that are critical in understanding how networks operate and how products that are connected to a network can minimise the network energy overhead. A network is made up of individual devices, communication paths between the devices, and technologies for managing the communication and data flow. This report is limited to digital networks.

There are three basic product groupings that need to be considered in the content of energy policy for networks:

- Network equipment – the devices and infrastructure whose primary function is to pass network traffic, to provide the network
- Electronic Edge Devices – devices connected to a network where the primary function is data
- Other Edge Devices – devices connected to a network where the primary function is not data.

Distinguishing these basic categories of product types is critical because their characteristic and drivers for energy use and energy efficiency are all very different. This in many ways dictates how we approach energy policies for these product types.

When considering the issue of energy in networks, it is important to understand how energy is used and what approaches can be used to influence and improve the energy requirements. The main ways to save energy for all products (not just those connected to networks) are:

- Optimise energy for the network link
- Make the primary function as efficient as possible (both non-network and network functions)
- Power scaling (turn off unnecessary functions in all modes, modulate energy in proportion to services provided for electronic products)

TABLE ES1: OVERVIEW OF TECHNOLOGY OPTIONS TO REDUCE NETWORK ENERGY BY PRODUCT TYPE

Product type ▶ / Technology ▼	Network equipment	Electronic Edge device	Other Edge device	Notes
Link Power	High	Medium	Low	Defined in technology standards, ability to modulate power
Primary Function Efficient (not network)	Low	High	High	Covered by product policies
Network Function(s) Efficient	High	Medium to Low	Low	Important where network functions dominate energy use (does not include link power)
Power Scaling	High	High	Low	Product design, hardware and software availability critical
Moving to low power modes - network aspects	Low	High	Low	General energy management also of interest for edge products

Key – applicability level: **High**, **Medium**, **Low**

- Power management (automatically reduce the time spent in higher power modes and increase the time spent in lower power modes).

Each of these approaches has been examined for each of the major product types and the potential for energy saving has been assessed. This assessment helps us to map out the key approaches to include in an energy policy framework.

As an underpinning for any sensible policy, it is important to have a set of broad objectives that can guide the development of a roadmap into the future. This is particularly important in a field as complex as energy policies for networks, where there are many factors to consider. Not the least of these is how to deal with product interdependence and minimise overall complexity, while maintaining effective outcomes.

A 2007 IEA workshop produced the *Guiding Principles for Good Network Design* that set out nine broad principles that can lead to the evolution of greater energy efficiency across networks. This report has examined each in detail and has assessed their applicability to each product type and against each of the energy saving technologies available in network connected products. The report concludes that the Guiding Principles are as relevant today as they were when they were first written.

Deeper analysis has identified a range of key considerations when developing policies and test procedures for equipment connected to networks:

- Managing complexity is a core challenge as it burdens all stakeholders
- Resist inventing new policy content; existing approaches can (usually) be adapted
- Develop new content in an open process
- Reward products that dynamically optimise their energy consumption under different usage conditions, while keeping requirements realistic and simple
- Pursue transparency – networks offer great potential to make visible information that was previously unavailable
- Autonomous power management can optimise energy consumption
- Plan and implement a "technology strategy": identify network technologies needed, ensure that these are developed, plan how they will then be accelerated into the market.

MAPPING A PATHWAY FORWARD

The recommended pathway forward covers three main areas:

- Definitions
- Test procedures
- A new energy policy framework for achieving efficient low energy networks into the future.

The report examines the issue of definitions, specifically where some work has been done but where conflict and ambiguity remains. The report contains recommendations on this issue to remove it as an impediment to progress, so that energy policy can become more outward looking with respect to networks. We recommend that energy policy in this area moves beyond network standby and consider energy in products with a network function in a more holistic way, considering both individual products and how these impact other devices on the network. It is important to have an understanding of how policies that target individual products may impact on the energy consumption of the network as a whole. Making all elements of the network more efficient is always beneficial except where individual product operation or behaviour may have detrimental energy impacts elsewhere on the network - this is would be limited to specific cases.

The next key issue is test procedures and policies. We recommend that the overall objectives with respect to test procedures for network connectivity should be to:

- Define test procedure elements that complement IEC62301 to allow the measurement of relevant modes of equipment where one (or more) network function(s) are present
- Provide a platform for a globally relevant, uniform test methods for products with network functions (as far as possible)
- Set out relevant modes and configurations that should cover levels of network functionality likely to occur in typical use
- Support existing and future energy policies.

There are a number of existing test procedures, program requirements, and regulations that cover products with network functions that define at least some of the required elements for energy testing. What is now needed is a pathway through the current maze of documents towards a simpler global solution that is more representative of the range of typical network configurations and operation.

The pathway to alignment of network-related test elements is straightforward, but will require careful research, documentation and negotiation. The process includes:

- Identifying all key testing components required for consistent testing
- Documenting existing requirements in all significant test methods, specifications, and regulations
- Identifying cases where there is a gap (important details not defined in any method; may anticipate future technologies or policies)
- Identifying cases where there is already a satisfactory single technical specification
- Identifying cases where there are multiple technical specifications
- Recommend the preferred specification for each key test element and the rationale as to why it these are preferred - develop a menu of items in some cases.

This process requires significant initial effort, will produce a database of results, but it will require ongoing curation and maintenance. Development of aligned international test procedures is a key recommendation of this report as this will provide information to improve network energy efficiency and will give a firm basis for policy development in this area.

Incorrect or inadequate testing will reduce actual energy savings achieved by programs and sends wrong design signals to manufacturers and product designers. Manufacturers necessarily focus on how their products fare under an energy policy and test procedure. So, it is incumbent on energy policy makers to set requirements in energy policies (and their associated test procedures) that do encourage and reward product designs that will minimise energy consumption across the range of typical use. Test procedures should document the potential impact of energy of other devices on the network across operating modes as far as possible (in a qualitative sense, if a quantitative assessment is not possible). Poor specifications can decrease energy consumption in individual products but can increase energy in other parts of the network, so a more holistic understanding is an important policy consideration.

The concluding section of the report is a synthesis of our understanding of products types and characteristics, technologies to save energy in networks and the Guiding Principles for Good Network Design into a broad policy framework for networks. This can be considered in future energy policy deliberations regarding networked products for each of the main product types identified, and the role of energy policy in technology development.

The policy framework documents 3 key elements for each product type:

- Overview of the product purpose, design, usage and characteristics that affect energy consumption and how this can be reduced
- The types of product characteristics, attributes and energy technologies that are desirable in a low energy network context
- Energy policy elements that can encourage and reward these desirable attributes in real products when operated across a range of typical use.

The key policy elements are included below for each main product type.

Policy framework to drive the development of efficient low energy attributes in network equipment:

- Set power benchmarks under fully active operation

- Assess changes in power with a reduced number of links
- Assess changes in power with reduced network traffic
- Consider potential energy impact of operating modes on other devices on the network
- For each link technology incorporated into a product, specify the minimum version of the technology standard that offers the greatest scope for power modulation according to data traffic load.

Policy framework to drive the development of efficient low energy attributes in electronic edge devices with a network function:

- Set benchmarks for active mode
- Assess changes in power when functions are shut down (requiring this to be present)
- Assess power management with low network traffic and no user interaction/demand
- Set reasonable power limits for low power modes
- Consider potential energy impact of operating modes on other devices on the network
- For each link technology incorporated into a product, specify the minimum version of the technology standard that offers the greatest scope for power modulation according to data traffic load.

Policy framework to drive the development of efficient low energy attributes in other edge devices with a network function:

- Set benchmarks for product energy efficiency (already included where applicable in product policies)
- Set reasonable power limits for low power modes.

Finally, policy in this area needs to move beyond simply regulating the burden of network connectivity, but to also cover its benefits. Policy can expand to include select types of application-layer functionality to include technologies that provide useful features that can help to save energy. While this adds complexity, it also significantly increases the value to the end consumer in scope and so can bring sufficient attention to the issues to lead to action.

This report adds new dimension and depth in the understanding of energy aspects of network connectivity. It draws together much of the knowledge and expertise gleaned through the course of the 4E Standby Annex and maps a pathway forward for more effective energy policies in the important field of network connectivity.

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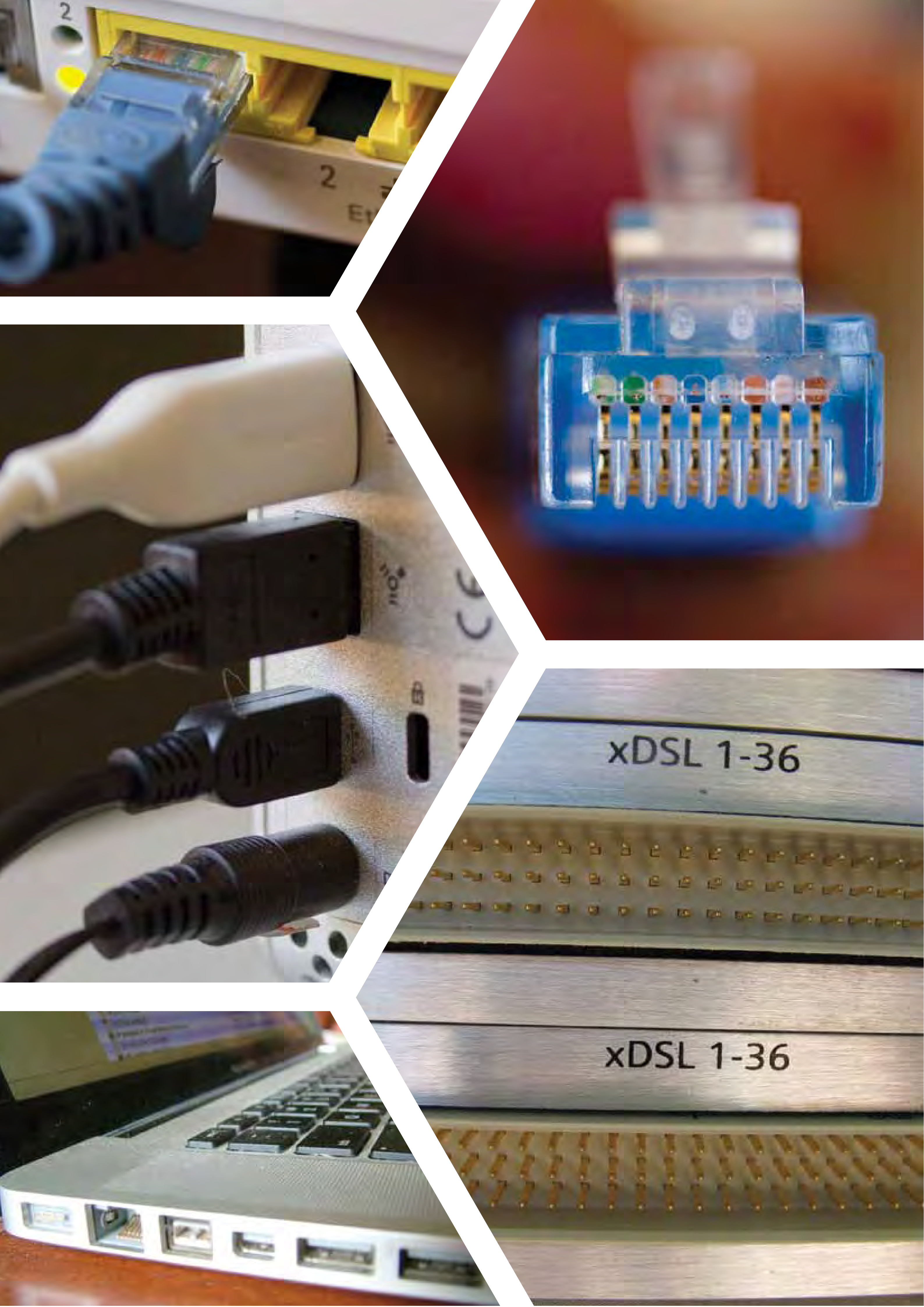
ABBREVIATIONS AND ACRONYMS

4E	IEA Implementing Agreement on Efficient Electrical End-use Equipment
ADSL	Asymmetric Digital Subscriber Line (user end) – asymmetric form of DSL (usually faster down than up)
APEC	Asia Pacific Economic Cooperation
APP	Asia Pacific Partnership on Clean Development and Climate
ARP	Address Resolution Protocol for Internet Protocol Version 4 (IPv4)
DOCSIS	Data Over Cable Service Interface Specification
DSL	Digital Subscriber Line (user end) - a data communications technology that enables fast data transmission over copper telephone lines
DSLAM	Digital Subscriber Line Access Multiplexer (exchange end of DSL)
DVD	Digital Video (Versatile) Disk
EES	Energy Efficient Strategies P/L
EU	European Union
HDMI	High-Definition Multimedia Interface for transmitting uncompressed digital data
HE	Home Entertainment equipment (audio and/or video)
IEA	International Energy Agency, Paris
IEC	International Electrotechnical Commission, Geneva
IEEE	Institute of Electrical and Electronic Engineers, USA
IP	Internet Protocol - used for transmitting data across a packet-switched network using the Internet Protocol Suite
ITU	International Telecommunications Union, Geneva
LAN	Local area network – usually limited to one or several buildings
Modem	A device that uses an analogue signal to encode digital information (and then decodes) transmitted information (modulator-demodulator)
OSI	Open System Interconnection Model (ISO7498)
PSTN	Public Switched Telephone Network
Router	A router is a device that interconnects two or more computer networks, and selectively interchanges packets of data between them.
SNMP	Simple Network Management Protocol (UDP-based protocol)
TCP	Transmission Control Protocol (member of the Internet Protocol Suite); often referenced as in TCP/IP
UDP	User Datagram Protocol (member of the Internet Protocol Suite)
USB	Universal Serial Bus (serial communications)
VOIP	Voice Over Internet Protocol (see also IP)
WAN	Wide area network - a computer network that covers a broad area (connects LANs to each other or to the wider Internet)
WLAN	Wireless Local Area Network based on the IEEE802.11 standards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1 INTRODUCTION

1.1 BACKGROUND

The traditional "Standby" topic covers energy use by devices that are off or in a similar inactive state. Considerable amounts of electricity are used in such low-power modes. For over 20 years, energy policies have been developed to bring attention to this topic and to exert pressure on industry to create new products with considerably better non-active power attributes. This has been very successful and many countries have now enacted policies to address this issue for a wide range of appliances and equipment. The list of countries adopting such policies continues to grow. The number of products that consume power in low power modes continues to grow as electronic controls and electronic "information based" products become ubiquitous, so it is important that ongoing pressure is applied to manufacturers and designers to keep low power modes as low as possible. Technologies to achieve efficient low power designs are now readily available and cost effective, so excessive low power mode consumption for stand-alone products is generally due to poor design or lack of attention to detail.

Even though addressing standby power for stand-alone products has been successful, an increasing number of products are adding network connectivity in order to bring new services and functionality for users, thus creating a new challenge for energy policy. Network-connected low-power modes are not new; they have been present in some electronic devices for over 20 years, particularly computers and printers. There has been considerable policy attention paid to some products, mostly in the promotion of efficient sleep modes. However, more electronic devices are getting network connectivity, notably audio/video products, and many non-electronic devices are beginning to acquire it, such as kitchen and laundry appliances, HVAC systems, lighting, and other end uses. Additionally, network equipment is needed to create the infrastructure for passing data among the networked devices and to connect to the wider Internet.

1.2 OVERVIEW OF NETWORK STANDBY ISSUE

When standby power was first identified in the 1990s, the Internet was in its infancy and only a few product types had network connectivity and complex low power modes. Standby policies developed at this time necessarily concentrated on stand-alone products with relatively simple low power mode configurations. Over the past decade, the prevalence of networks has expanded massively, and this is set to continue at an accelerated rate for the coming decades. The policies that have been developed for stand-alone products are still important, but there is now an urgent need to effectively address the issue of products that are connected to networks.

"Network Standby" is a topic area that covers additional energy use of devices attributable to their connection to a communications network, and the associated technologies and policies that can be utilized to improve these attributes. Networks hold both the risk of significant increases in energy use, as well as the potential to implement cost-effective approaches to reduction. Network standby is distinct from using communications to better manage energy use or to shift demand patterns in response to building or grid signals.

Now is an important time to bring focused attention to this topic area, to ensure that future energy use associated with these functions is not unnecessarily high, and to achieve highly cost-effective energy savings. In addition, we can ensure that energy efficiency is built in as much as possible to the underlying network technologies to ensure that future savings are as easy and cost-effective to attain as possible.

Network connectivity has not been well-addressed in existing policies that focus on low power modes of products. This has occurred for a variety of reasons: the technology of networks is unfamiliar to many energy policy analysts and experts; there are significant complexities in network technologies and their associated protocols; networks are evolving rapidly on many parallel fronts and the number and type of products with network capabilities are expanding rapidly. The last two points in particular generate significant complexity within this topic. Ultimately, the issue of dealing with networks is a distinct topic area best treated separately from conventional standby.

However, there are a number of issues that make dealing with networks a more difficult area of energy policy. Network connectivity inherently involves interdependency among multiple devices. Some devices on a network can demand functions and services from other devices, which can induce higher energy consumption in these other devices on the network. This presents some challenges for effective energy policy development and implementation as the traditional approach has been to consider products in isolation. In a network context, it is sometimes necessary to consider interconnected products as a system, and in particular the technologies that enable that interconnection.

Successful energy policies rest on a number of important foundations. One of the most important of these is test procedures. Without sound, reliable and realistic test procedures, it is not possible to develop effective energy policies. While there are many test procedure elements that have already been developed, this is an area of particular focus in this report. There are many gaps and some conflicts in existing approaches. Development of a core set of globally relevant and accurate test procedures is a key component of the pathway forward. As most network technologies and products span countries and continents, harmonization and minimization of these conflicts is important to reduce the burden of policy. Critical to this will be a "library" of test procedure excerpts to maximize harmonization across products and countries.

Another important issue is the development of efficiency metrics. This is another issue for networks topic that is very different in the way that it applies to traditional policy. Energy efficiency policy normally considers a certain energy service being delivered for a certain amount of energy – to increase efficiency, the aim is to maximise the service delivered and/or reduce the energy required. Network functions are not the primary function of a device (except in the case of network equipment), and devices can simultaneously be implementing multiple network (and other) functions. Energy use for network functions is primarily about maintaining capability for action, rather than carrying out significant action as with conventional products. Thus, network functions are fundamentally different to many more typical energy services provided by appliance and equipment. The most transparent metric – power consumed – is clear and measurable. The challenge is to ensure that required functionalities are maintained while reducing the power required. It is neither necessary nor possible to effectively put multiple network functions into a traditional efficiency context.

Networks also introduce technical limitations that can hamper effective policy development to reduce power. Network protocols and technology standards can unlock substantial energy savings where they are designed with energy efficiency in mind, but this is not always the case. Identification of the key obstacles and working with technology standard developers (formally known as Standards Development Organisations) is one of the key areas yet to be addressed. Historically, considerations of energy use have only been given a high priority during the design of networks in mobile (battery powered) devices where battery life is a primary design objective of the technology (and efficiency plays a key role in maximising this). Unfortunately, much less attention has been paid to technology standards that are more commonly deployed in mains powered devices. Once technology standards are designed and implemented, it can then be difficult to retrofit them with power management capabilities, as compatibility with legacy equipment is imperative.

1.3 MOVING ON FROM NETWORK STANDBY – RECASTING THE PROBLEM

Networks are becoming increasingly ubiquitous. Some estimates put the number of devices connected to networks globally at tens of billions by as early as 2020. While many of these devices will be mobile or battery powered, there is some concern that a lack of attention to the power consumption of mains powered networked devices could result in large amounts of wasted energy.

Most policy concern has been about the marginal energy consumption of all these network connections (with some justification). The policy discussion and activity to date has been focused on limiting the network-related power consumption within a product, primarily in low power modes. However, the concern should be on more than just power use in low power modes. Network connectivity can induce considerable extra energy consumption by keeping products in higher power modes when they would otherwise be able to enter low power modes (both the product itself and other products on the network). These are all part of the 'cost' of having network connectivity.

We should also be attentive to the fact that networks offer opportunities to use this functionality for many good energy related purposes. An example is reducing energy consumption through advanced energy management techniques, which can take many forms. This can be achieved through implementing appropriate product designs and technology standards that allow power reductions during periods of low network utilisation and encouraging product designs that automatically scale power in proportion to the level of energy service required. Allowing network link power to modulate when data rates are low is also important - this is dictated by link technology standards. The second critical component is facilitating coordinated power management among related devices. For example, when a television powers down, other edge devices that provide it with a video stream can go to sleep if this information is shared and used for autonomous decision making. Another important element that could be available from many networks is information on energy consumption and usage of each end-use device.

Standby mode energy use in networked devices is not a problem that, by itself, seems able to garner a critical mass of policy attention and development for these products, in part, because for many products connected to networks the total energy they use in such modes is a small portion of their total use. To be successful, it is necessary to attach it to a larger topic area – to move beyond Network Standby. This should be expanded to include a wider range of energy aspects related to network connectivity, to cover functions that occur in active modes.

Finally, network connectivity is critical to the emerging areas of "Smart grids" and "building networks". These areas are being subjected to intensive examination in a wide range of fora. However, the majority of effective work in smart grids is concentrated in the transmission and distribution network, which is upstream of the customer meter. Annex B of this report undertakes an initial examination of building networks and how these may interface with the smart grid. In particular it considers the types of requests that smart grid could make on end use appliances such as emergency load shedding, load shifting (short and long duration) and short term increases in power use to utilise excess renewable capacity on the system. There are a variety of relationships possible between the building and the grid, and these are explored for their energy and other consequences.

The final section of this report details a recommended path forward for efficiency policy in the area of networks. As we move forward, it makes sense to broaden the scope of inquiry from just those efforts which reduce the energy 'cost' of networking, to also include aspects that use network connectivity to provide energy and other benefits. This can enable greater synergies between these domains, and reduce the burden of energy-focused activities by tying them to features that are actively sought out by industry and consumers.

1.4 HOW CAN POLICIES MAKE A DIFFERENCE FOR NETWORKS?

Policy for network connectivity operates in three primary ways: power levels, time distribution and policies specific to network equipment.

Power Levels: Power level reductions should be sought in various modes. While a network-connected sleep (or ready) mode is a primary focus, it is often the case that technologies that save energy in this mode also save energy while the device is in active mode (and also network-connected).

Time Distribution: The total time distribution among modes should be moved towards lower power modes. The primary way to save energy is to shift time from active modes to sleep modes when the device does not need to be active. In some cases it may be possible to drop network connectivity for periods of time in low-power modes without compromising the required functionality.

Network Equipment: Network equipment do not have low-power modes; reducing the power levels they require for typical operation is a natural part of a network-oriented policy.

Power levels for network connectivity are in part dictated by a combination of the technology standards they implement and the state of semiconductor technology today. These are not always within control of individual manufacturers, making it essential for energy policy to fully understand the energy consequences of technology standards, as well as to actively engage in the development and modification of these standards to include improved energy performance. Facilitating the diffusion of efficient low energy semiconductor designs is also important. Policy makers need to be aware of these issues and influence these issues where possible (even if indirectly).

For low power modes with no network connectivity, the core strategy was to establish a 1-Watt global goal for devices in the relevant low power mode. A common test procedure was then required to support this objective to allow policies (voluntary and mandatory) that implemented the high level goal. Since these products were performing no function (or close to no function), this approach was successful.

For low power modes with network connectivity, the same method can be applied, but in contrast with stand-alone products, some non-trivial functions are being performed. This means that test procedures and power levels need to be cognizant of those functions, and that requirements may necessarily vary by product type and network technology. In addition, network technologies are always evolving—adding complexity—and electronic technologies are always improving—reducing power requirements. This requires test procedures and policies to be updated on a regular basis to be relevant to current products.

1.5 POLICY DEVELOPMENT

Since 2010, there has been a focused effort to intensify and harmonize efforts internationally on network standby. This has resulted in a number of research projects to provide insight and data for policy development. Policies in place span from detailed requirements for individual product types, to broad limits on nearly all products, as well as some that apply to groupings of similar product types. The optimal mix of these is still being determined, but some use of a variety of approaches is likely to be warranted.

The combination of diverse product types, many countries, and complex collections of network technologies means that managing—to limit as much as possible—the complexity of the policies is a central challenge, and a key driver for international harmonization. Policy makers are focused on minimising the burden of policy in this area (for industry and government) while maximising the benefit to users through reduced energy use. Energy policies cannot realistically address every possible configuration or use of products connected to networks. However, it is critical that policies encourage designs to automatically optimise their energy consumption across a range of typical use.

1.6 CONTEXT FOR THIS REPORT

The report was commissioned by the IEA Implementing Agreement for a Co-operating Programme on Efficient Electrical End-Use Equipment (4E), specifically its Standby Annex. The Standby Annex was formed in 2009 and has worked effectively in an international context to enhance international cooperation in the area of standby power. The Standby Annex will conclude in 2014. While the issue of standby of products connected to networks was part of the original Annex scope, during the course of the Annex, it became apparent that network connectivity was a topic that required much more in-depth examination. While many important studies were undertaken in the field of network connectivity during the life of the Annex, a range of issues remain open. This purpose of this report is to help Annex members and other interested stakeholders to take stock of the state of knowledge with respect to network connectivity issues and to map out any key areas of further work that may be required in this field. Elements of this work may be of interest to and could be considered by the proposed 4E Electronic Devices and Networks Annex (EDNA), which is under discussion in late 2013.

1.6.1 Previous Reports

A 2010 4E report called “Standby Power and Low Energy Networks – issues and directions” laid out many of the policy considerations in this field (Harrington/Nordman, 2010). Since then a range of technical reports and other developments have been completed. Many of these are summarised in Maia Consulting (2012b). The relevant reports to this discussion are included in the references.

1.6.2 IEA Book

The International Energy Agency has produced a book on the topic of Network Standby, building on its own research and results from three international workshops they organized on the topic. The content of this report and the IEA book are complementary, with minimal overlap. The IEA book is comprehensive in its coverage of the topic. This report is more surgical, with focused attention on definitions, test procedures and a broader policy framework for products with network connectivity. This report sets out next steps and maps out a range of key decision points on specific issues to progress policy in the area.

1.6.3 Workshops

The IEA, together with the 4E Standby Annex, SEAD and APEC, have been active in this area for some years and there have been several workshops that cover the topic of network standby. These workshops contain many valuable technical and policy contributions and are an important source of information for stakeholders interested in these issues.

IEA/4E/SEAD Network Standby Workshop: Beyond 1-Watt – Towards energy efficiency in the digital age, Paris, France, September 2013, see http://www.iea.org/workshop/iea4eseadnetworkstandbyworkshop.html

IEA / 4E / SEAD and Natural Resources Canada Workshop: Networked Standby Policy Framework, Toronto, Canada, March 2013, see http://www.iea.org/workshop/networkedstandbypolicyframeworkworkshop.html

IEA/4E Network Standby Workshop: Data Collection, Methodology & Policy Development, Stockholm, Sweden, May 2012, see http://www.iea.org/workshop/networkedstandbydatacollection-070512.html

APEC/APP/4E Conference: Moving Towards 1 Watt and Beyond, Tokyo, Japan, October 2010. see http://www.energyrating.gov.au/blog/resources/events-calendar/201010-2/

1.6.4 Future Directions within 4E

As the IEA 4E Standby Annex wraps up its focused effort on Standby and Network Standby, it has the opportunity to open a new initiative that covers network connectivity, but with a significantly different emphasis. Rather than being limited to power and energy use in low power modes, it should cast a wider net. The rationale for this is covered in the previous section on "Moving on from Network Standby". This is an area that may be of interest to the new 4E Electronic Devices and Networks Annex (EDNA), which should cover this topic directly.

1.6.5 Project Team

This report was commissioned by the IEA Implementing Agreement for a Co-operating Programme on Efficient Electrical End-Use Equipment (4E) Standby Annex. The contract for the work was managed for the Standby Annex through Maia Consulting, the operating agent of the Standby Annex.

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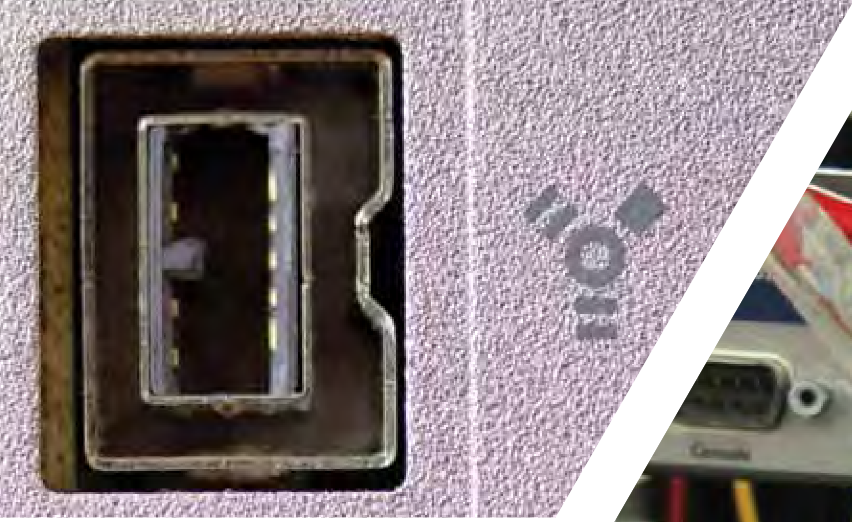
This study was undertaken by Lloyd Harrington of Energy Efficient Strategies in Australia and Bruce Nordman of the USA. Bruce works as a scientist for Lawrence Berkeley National Laboratory, but worked on this report as a private consultant.

While this report was commissioned by the IEA 4E Standby Annex, any views expressed in this report are those of the authors. While the authors have taken every care to accurately report and analyse the data and verify the information included in this report, the authors are not responsible for any use or misuse of data or information provided in this report or any loss arising from the use of this data.

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2 POLICY FOUNDATIONS

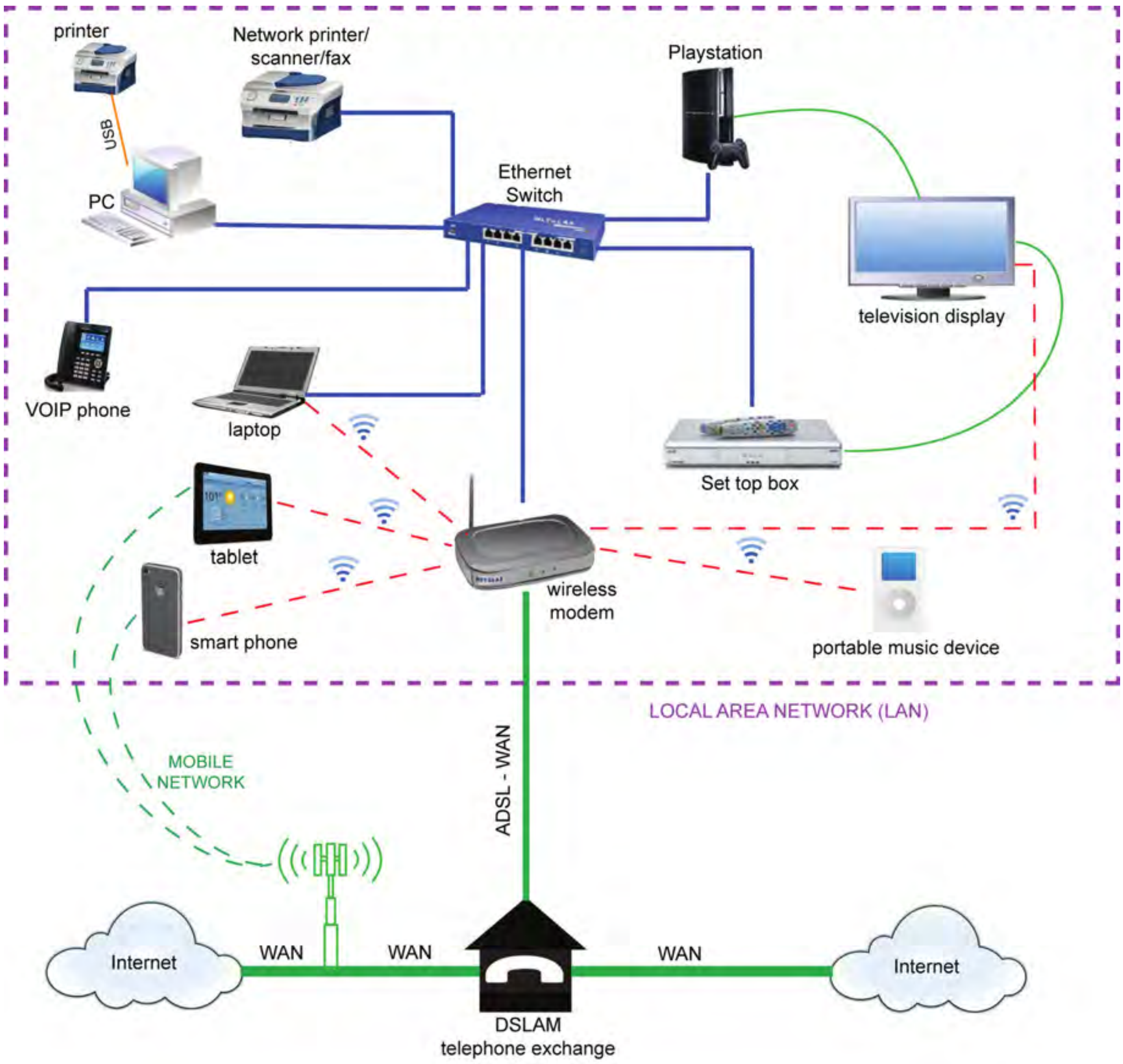
2.1 WHAT IS A NETWORK?

A network is made up of individual devices, communication paths between the devices, and technologies for managing the communication and data flow. The paths are called links, with each link typically being between only two devices. Most networks have a large number of products and many links. By using many links, a network enables data to be exchanged between any two devices within the network, usually via one or more intermediate devices.

In most cases, a product (edge device) connected to a network will have one link (sometimes a few), while network equipment devices usually have several to many links.

While some devices can have analogue communication links, this report only considers digital networks, which usually include a large number of interconnected links and devices. In digital networks, the primary and only function is the transmission of data packets (some wired networks can also supply limited amounts of power through a network connection, such as power over Ethernet, but

FIGURE 1: CONCEPTUAL LAYOUT OF A TYPICAL LAN & WAN



this is independent and unrelated to the main network function).

A Local Area Network (LAN) usually connects devices within a single building (or within a relatively small geographic area). LANs are self-contained and allow data to be passed between devices within it. While there usually is a connection to the outside world (typically an Internet connection), this is not required or such a connection may be intermittent.

The other type of common network is the Wide Area Network (WAN), which cover larger geographical areas (towns, suburbs, regions). The Internet core has many WANs, which link most Internet connected devices in the world to each other. Another common type of WAN is telephone systems (mobile and fixed).

Technologies that enable data links between two devices but do not have direct network connections (USB is a common example) are not true network technologies but have enough in common with them that it makes sense to cover them in the same policies. That is, the real scope of the policies is digital communication generally, but we use "network" as the core term.

A large number of different physical technologies are used to establish links between devices. These links can be between pieces of network equipment, between an edge device and network device, or occasionally directly between edge devices. Link technologies are either wired (usually copper), fibre optic, or wireless. There are also a large number of network protocols that define the rules of how data packets are transferred across links for different physical configurations and link technologies, and the meaning of data transmitted. Most (but not all) data packets use the Internet Protocol (IP) to define how data packets are transported within networks and across network boundaries. Except where otherwise mentioned, the term "network" in this report means those that use Internet Protocol connectivity.

More detail on the characteristics of networks can be found in Harrington and Nordman (2010).

2.2 PRODUCT GROUPING AND CATEGORISATION

While some discussions of networks consider all devices with network connections together, there are really three broad groupings that each requires a different policy approach, at least for some components. Product functionality and energy service sets some important policy boundaries. There are four basic product groupings that need to be considered in the content of energy policy for network connectivity:

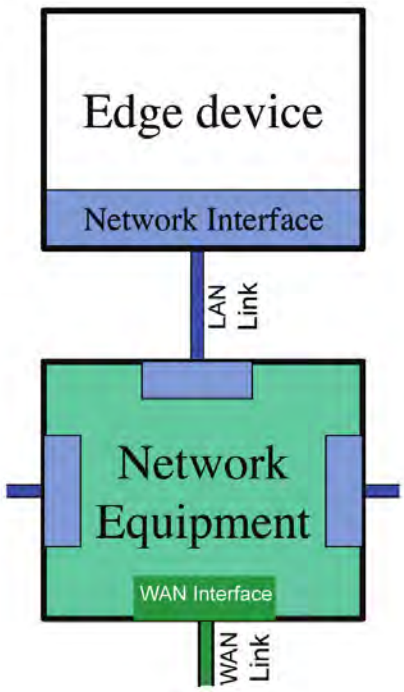
- Network equipment – the devices and infrastructure whose primary function is to pass network traffic, to provide the network
- Electronic edge devices - where the primary function is data
- Other edge devices - where the primary function is not data
- Stand-alone products - devices that are not connected to a network.

Each of these is described in detail below. Edge devices are the devices that provide energy services to users. This includes a vast array of appliances and equipment that have network connections. In some cases the network connection is central to the products ability to provide its main function; in other cases the network connection is incidental. Two specific types of edge device are examined below.

2.2.1 Network Equipment

Network equipment are devices that have as their primary function the provision of the network itself. This includes a range of devices including switches, routers, access points, and modems. These devices usually have several or many links active at the same time. They can include links within a LAN as well as a link to a WAN.

As the function of network equipment is to transmit data packets whenever that are received, and as this can



happen at any time, network equipment has to remain in active mode continuously. While there are techniques and technologies to reduce the energy consumption of network equipment (in some cases by a substantial amount), these need to work in a way that does not compromise the principle of continuous availability. Thus, there is no traditional low power mode for these products other than turning the device off. This is an important policy consideration.

2.2.2 Electronic Edge Devices

Electronic products are those devices where the main function is data. They may undertake any combination of acquire, process, store, transmit, or display information. Common types of electronic products are computers, printers, tablets, phones, set-top boxes, televisions, and other audio and video equipment. The reason that these types of products are a separate category for network connectivity is that their primary function is usually highly involved with the network. The amount of data that is stored, transmitted and processed is often large, and device interactions complex, so the types of network functionality and the peak bandwidth requirements that they need is much greater than for other types of products.

For some electronic product types, the network or data transmission related component can be small. For example, the energy consumption of a television is usually dominated by the energy to generate the picture and it may have no network connection. Similarly, most of the energy used by a laser printer is in rendering the image on a sheet of paper rather than the energy associated with the transmission of the data and coding the image within the printer. For ink-jet printers, with low imaging energy and low usage, communications and low power mode consumption can be the dominant use of energy. For products like a set-top box, the communication energy may be a significant share of total energy. However, for most products in this category, the network connectivity element is a relatively small part of the overall energy requirement.

For energy efficiency efforts related to conventional products, the laws of physics generally define the energy service delivered and the energy consumption required to deliver that service. For electronic products and network equipment the relationship between energy consumed, the energy service delivered and the network connectivity aspects of products is less direct and more complex. Many electronic functions require continuous power, even when they are not used. For some link technologies, the data flow rate may not affect the required power to any great extent. So, internal power management of functions and operations is critical if overall energy is to be optimised.

Most electronic devices can be operated without a network connection. Many PC applications do not require a network connection and a phone can be used on a plane to play games or write notes. But, a set-top box is of little use without a connection to a television or other type of display. So the dependence and level of integration of the network connection varies by product.

2.2.3 Other Edge Devices

The remainder of networked devices considered in this report are those that are not electronic in nature - their primary function is not about data. This category is potentially large and contains all appliances and equipment other than electronic devices. These include kitchen and laundry appliances, cooking equipment, heating and cooling equipment, lighting, and all manner of commercial and industrial equipment.

There are two important things to note about this category of products. First, today most do not have network connections and they can operate satisfactorily without a network connection. Second, the purpose of most network connections is to enhance some element of user interaction (such as remote control using a smart phone) or to provide response to the Smart Grid or optimisation under real time tariffs (for example). While these functions are valuable, the bandwidth requirements and protocol complexities for these types of secondary functions are generally low. So in practice, the energy overhead associated with network connections for these devices should be small.

2.2.4 Stand-alone Devices

Historically, most devices were not connected to networks. However, it is likely that few products will fall into this category into the future. These products can be covered by stand-alone standby power policies if they have low power mode consumption of concern.

2.3 TECHNOLOGIES TO REDUCE ENERGY IN NETWORKS AND EDGE DEVICES

When considering the issue of energy in networks, it is important to understand how energy is used and what approaches can be used to influence the energy requirements. The main ways to save energy for all products (not just those connected to networks) is:

- Optimise energy for the network link
- Make the primary function as efficient as possible (both non-network and network functions)

- Power scaling (turn off unnecessary functions and adjust processing power in electronic products)
- Power management (automatically reduce the time spent in higher power modes and increase the time spent in lower power modes).

It is useful to break these down into key elements that can be considered in an energy policy context.

2.3.1 Optimising link power

A common element of all devices that have a network connection is that some energy is used to power the interface that maintains the network link. For edge devices, link energy consumption is generally a small part of active power, though can be a significant contributor to sleep power. For network equipment, aggregated link energy can dominate total power requirements.

Reducing link power is applicable to nearly all products with a network link. Electronic edge devices often have network technologies capable of high data transfer rates. Other edge devices have bandwidth requirements that are likely to be very small (e.g. only for control, scheduling and tariffs only) so the link power could be quite low.

For some network technologies, the power required to maintain the network link at a certain bandwidth is often relatively fixed and is fairly independent of data throughput. For example the power requirement for Ethernet used to[1] increase as the maximum bandwidth increased (see Harrington and Nordman, 2010). As the link has to be more or less instantly available to deal with any data packets that arrive or that need to be sent, there are technical challenges in reducing power requirements while maintaining high levels of service.

Link energy consumption optimisation has several key components:

- Making the power required to operate the link as low as possible
- Having the ability to modulate the link power to lower levels during periods of low or no data transmission (dictated by the relevant link technology standards)
- Ensuring that any impacts of link power management are compatible with the operation of the network.

These issues are discussed in more detail in following sections.

For the issue of link power, it is useful to divide devices into three main categories of products:

- Those that operate primarily in Local Area Networks (LAN);
- Those that link to a Wide Area Network (WAN); and
- Those that operate primarily within and between Wide Area Networks (WANs) - this includes the Internet backbone, regional links and international links.

Products within a LAN are all under the control of the local administrator and can be optimised (in terms of matching equipment and link technologies). External service providers control the technologies used in, and energy management of, WAN links to both LANs and select individual end use devices (e.g. mobile phones and tablets). LAN users (or any end use devices) do not usually interact with WAN to WAN devices and so these are not specifically examined in this report.

2.3.2 Efficient primary functions

For energy efficiency policy, delivering energy services as efficiently as possible is an overarching paradigm. Many products (edge devices) are already covered by product specific requirements, especially where there overall energy consumption is significant. It is important for policy makers to consider and evaluate, as far as possible, the impact of specific product requirements on the energy use of typical network structures in addition to the energy impact on the individual device.

For non-electronic edge devices like kitchen and laundry appliances, cooking equipment, heating and cooling equipment, lighting and all manner of commercial and industrial equipment are all deserving of attention with respect to the energy efficiency of their primary function. For these types of products, energy is overwhelmingly used for delivery of the primary function; the energy required for any network connection is usually incidental.

For electronic edge devices (where the primary function is data), energy efficiency is still an important objective, although this can be challenging to define for some types of products. Devices like televisions and printers can be assessed on an efficiency basis fairly readily. Some devices like computers are general purpose machines and so can perform many disparate functions individually or simultaneously. They also consume substantial energy just for being available to be used even when no active user computation is taking place. The energy consumed by network functions is usually a small to modest share of

1 Ethernet network interface silicon is improving in efficiency all the time, and Energy Efficient Ethernet (EEE or IEEE802.3az) now allows the link to rapidly sleep and wake up, so power now appears to be proportional to data throughput for links where both network interfaces support EEE.

total energy (depending on the type of product). Devices that require extremely fast network response times may need special consideration in some cases.

For network equipment, the energy service is to provide network functionality. Much of the energy use of these devices is determined by interface and link technology standards, so is out of the control of equipment manufacturers. As with any device, the use of efficient low energy components is critical and total energy or power to provide these functions is important. Another consideration is how the equipment performs in a range of typical installations and configurations. Efficiency specifications are moderately new for certain types (e.g. the EU Code of Conduct for Broadband Equipment), and very new for others (e.g. Energy Star specifications for Small Network Equipment). The provision of network functions dominates energy consumption, so these require separate consideration.

Key summary of making the main function as efficient as possible:

- This is a fundamental basis of energy policy
- This is already widely done for edge devices - the energy overheads associated with the network are often modest in these products
- Efficient network functions in network equipment are important.

For network equipment and electronic edge devices, it is important to think of energy efficiency as having two very different dimensions. One is that the efficiency of the main function(s) delivered should be as high as possible (using the lowest energy components that are suitable for the task). The second is that the device should be able to reduce or modulate its power during periods of low data processing demand (or where certain functions are not required). This is covered by the next section on power scaling and to some extent the previous section, which discusses the ability of link technology standards to provide some modulation of link power.

2.3.3 Power scaling

A generic term for the family of techniques used to reduce power in active modes is power scaling. This includes a range of techniques that can be used to deliver substantial energy reductions by adjusting the device capability to more closely match the end use data related demands at any point in time (non data-related power modulation is not considered power scaling).

For most appliances and equipment (those where the energy service is not data related), there is typically only one main function. So, while some of these products can and do have secondary functions in active mode, these functions are usually incidental to the primary function (and usually the marginal energy consumption is low). Many devices do modulate their energy use in response to need, such as those controlled by thermostats or other sensors, but the details and testing are specific to each product type and often these elements are covered by product specific policies and test procedures. Power scaling is a label for techniques that can apply broadly to many electronic products. So this concept is NOT generally applicable to products like kitchen and laundry appliances, cooking equipment, heating and cooling equipment, lighting and all manner of commercial and industrial equipment when in active mode.

For electronic products (including network equipment), there are often many functions operating in parallel. A concrete example is a computer – this has the capability to perform many data related functions at the same time. These include functions as diverse as performing calculations, maintaining a network connection, browsing the Internet, sending and receiving email, playing music, copying data, rendering an image on a monitor and so on. If a device is only playing music, then many of the other data related functions could (in theory) be turned off.

The main approaches to implement power scaling are briefly summarised below:

- **Multi-core processors:** While these are a relatively recent for consumer products, multi-core processors have become the norm in many product types as the size and power density of increasingly large and powerful processors started to reach limits dictated by laws of physics – the heat and power density of single-core processors was becoming too large (and cooling requirements were oppressive). For devices with high requirements for processing power, multiple cores operating in parallel were developed. This presented challenges in terms of organising work streams into tasks that were suitable for parallel processing (including overheads such as the disaggregation of tasks, management of processors and recombination of data streams) (rather than the traditional serial processing), but this design approach is now very common in almost all computationally-intensive devices. An advantage of multi-core processors is that several cores can be turned off or put to sleep when data processing needs are low. So, not only did these processors become much more efficient by reducing internal power densities and heat dissipation, they also added much greater flexibility in operation by being able to shut down excess capacity when not required.

- **Frequency scaling:** The speed that a processor operates directly affects the computational power. Many modern processors allow their operating frequency to be adjusted to better match the computational power available with the data processing requirement at any point in time. Higher frequency operation consumes more power, so this is another technique that can reduce energy in periods of low data demands. In practice, voltage and frequency are usually adjusted together, as lower voltages are only possible at lower frequencies.
- **Voltage scaling:** The energy use of a processor scales with the voltage applied to the supply rail, but lower voltages are only possible with lower frequencies that reduce the computational power.
- **Power islands:** Not all functions are supplied by microprocessors. A master processor can monitor data processing requirements and identify functions that are not required. Where the product is designed well, all of the power for these functions can be turned off whenever they are not required (processors and associated components), reducing the power significantly. Power islands can be created on a single integrated circuit, or on a circuit board with many components. Power islands have some overheads due to management and leakage effects, so the energy impacts depend on specific product designs and configuration.

Much more technical detail on these techniques is available from Siva (2010) and Siva (2013). Supporting data are also available in Ecos (2011b). One issue to be considered is how quickly sleeping cores or functions can be reactivated and what degree of flexibility there is within a device to shift functional operations to other parts of the processor.

Collectively, these four power scaling techniques can be used to substantially reduce the energy consumed in many products that have data as their primary function. We know that this type of approach can work brilliantly as shown by its sophisticated implementation in most mobile phones and some mains powered mobile edge devices. This has occurred because of the quest for long battery life. However, implementation in mains powered products has been much less widespread and effective to date.

Siva (2013) succinctly summarised the key elements required to ensure that there is widespread power scaling available in products:

- Drive low power options in technical standards (liaise with Standards Development Organisations – see previous section on power for network links)
- Ensure that efficient low power designs are readily available
- Encourage silicon designers to produce efficient low power designs
- Seed low power reference software as open source
- Create awareness with consumers (demand pull)
- Incentivise and reward service providers and equipment providers to offer efficient low power products (energy policies can play a role).

Power scaling can be achieved through a wide range of approaches – it is not possible, nor necessary, to prescribe how power scaling should be achieved in any particular product as this will be specific to individual product designs. The presence of low energy technology standards, software and hardware designs are helpful, but some of the techniques are specific to individual product designs and functions.

Massive energy savings can be achieved by deep implementation of power scaling approaches, including in network equipment. In order to be most effective, power scaling has to automatically adapt to changing demands from second to second. It is a practical manifestation of minimising energy consumption while maintaining adequate energy service.

The key for energy policy is to ensure that test procedures allow measurement of product energy use at a range of performance and functional levels, and that specifications and policies appropriately reward those devices that utilize aggressive power scaling techniques. Setting appropriate power levels requires an ongoing iterative review of what the best designs can deliver.

Key summary of power scaling:

- Not applicable to edge devices that do not have data as their main function.
- Highly applicable to network equipment and for most complex edge devices that have data as their main function.
- Allows power consumption to be scaled in proportion to data processing or data throughput requirements.
- Implementation requires careful product design – each product will be unique to some extent.
- The availability of efficient low energy designs, technology standards, silicon, and software will facilitate implementation.
- Energy policies and consumer demand are important pull factors.
- Test procedures and energy specifications need to reward power scaling.

2.3.4 Power Management

Power management is the ability of a device to change its power state to meet user needs and minimize energy use (this is about changing modes, in contrast to the previous section on power scaling which is adjustment of power in active mode). In this technique, saving energy is principally accomplished by automatically reducing the time a device spent in higher power modes.

Making the delivery of the energy service as efficient as possible is a key part of energy policy. A related part is minimising waste associated with delivering energy services when they are not required. This can be achieved by (automatically) shifting to lower power modes when the main function is not required. As energy use is the multiplication of power and the time spent in each mode, energy can be reduced by reducing power levels for all modes (including low power modes) and by shifting time spent in higher power modes to lower power modes.

Power management in this sense is not applicable to network equipment as they are always in active mode during their normal operation (of course they can reduce energy by modulating link power and power scaling).

Putting products into lower power modes when they are not needed is a clear and desirable goal. However, it is not always easy or possible for a product to ascertain when it is not needed. The challenge is to enable automatic power management to be able to achieve this in a reliable way, powering down whenever possible, and powering up whenever needed, when the device can discern it. Requirements on when a device needs to power up include consideration of product resume times and the level of functionality required for specific requests. Power management is applicable to any edge device (but generally not network equipment), whether or not it is connected to a network.

For this report, an interesting issue is how to deal with additional energy that is induced by a network connection. This issue primarily applies to electronic edge devices. A poorly designed network technology or product can create traffic on the network that serves little useful function but keeps some products on the network in a higher state or mode than they otherwise might be.

In their 2010 report, Harrington and Nordman (2010) outlined 2 broad approaches that could allow edge devices to enter lower power modes more often when connected to networks. These were:

- Changing product power state without cooperation of the network – hiding the fact that a device is asleep from a network which assumes devices are always fully on; or
- Changing product power state in coordination with the network – creating network technologies that understand when devices go to sleep and properly deal with them.

An example of the first approach is using a proxy to maintain a network presence while the device is asleep. This can be effective but it has some limitations; if the proxy has too little functionality within the sleep mode, this will limit the possible sleep time and consequently the energy savings the proxy can deliver.

The second approach requires that a network-aware sleep state be designed into the network protocols; this has rarely been done. More information on this topic is covered in Annex A and also in Nordman (2011a). It is also discussed in some detail in the following section on Guiding Principles for Good Network Design.

Key summary of reducing time in higher power modes:

- Not applicable to network equipment (other techniques can be used).
- Applicable to all edge devices. In a network context, most relevance to products that have data as their primary function where network activity can keep a product in a higher power mode.
- Some examples already in place, but currently these have limited applicability for widespread application.
- Status signalling has large potential as a base to develop an integrated energy management platform for interconnected products.

2.3.5 Summary of Approaches to Optimising Network Energy

Table 1 summarises the applicability of each of the main methods to reduce energy in networks and networked devices. It builds on the previous sections that cover product definitions and energy saving technologies.

2.4 IEA GUIDING PRINCIPLES FOR GOOD NETWORK DESIGN

As an underpinning for any sensible policy, it is important to have a set of broad objectives that can guide the development of a roadmap into the future. This is particularly important in a field as complex as network connectivity, where there are many factors to consider, not the least is how to deal with product and technology interdependence and minimise overall complexity while maintaining effective outcomes.

TABLE 1: OVERVIEW OF TECHNOLOGY OPTIONS TO REDUCE NETWORK ENERGY BY PRODUCT TYPE

Product type ▶ / Technology ▼	Network equipment	Electronic Edge device	Other Edge device	Notes
Link Power	High	Medium	Low	Defined in technology standards, ability to modulate power
Primary Function Efficient (not network)	Low	High	High	Covered by product policies
Network Function(s) Efficient	High	Medium to Low	Low	Important where network functions dominate energy use (does not include link power)
Power Scaling	High	High	Low	Product design, hardware and software availability critical
Moving to low power modes - network aspects	Low	High	Low	General energy management also of interest for edge products

Key – applicability level: High, Medium, Low

A 2007 IEA workshop produced the Guiding Principles for Good Network Design (IEA, 2007) which set out broad principles that can lead to the evolution of low(er) energy consumption in networks. These principles have been simplified and summarised. There are five hardware and technology design principles:

- Products should support effective power management
- A network function should not stop power management internally
- A network function should not stop power management in other devices on the network
- Products should cope with legacy equipment on the network (that may have poor behaviour or lack suitable energy management features)
- Products should scale power requirements in proportion to the service being provided.

The principles also identify four energy policy principles:

- Require power management to automatically enter low power modes
- Put reasonable power limits on low power modes
- Encourage networked products to minimise their total energy consumption, using "...industry-wide protocols for power management" [in networks]
- Keep performance requirements generic; require specific hardware or software technologies only after careful consideration.

This report will set out key steps to achieve these objectives. In some cases, specific approaches and technologies are already available that can be adopted (even mandated). In other cases, further work is needed in order to develop required technology and policy. Technology standards that enable automatic energy management in networks is a particular area where further developments are required.

2.5 UNPACKING THE GUIDING PRINCIPLES

The Guiding Principles for Good Network Design were developed in 2007 and have stood the test of time – they are generally as relevant today as they were when they were written. These types of guiding principles are necessarily general in nature and it is not always obvious how to turn these into effective and practical policy measures. This section looks at the Guiding Principles individually in the context of product types and the available technologies to reduce energy in networks (previous sections) and outlines the practical policy elements and approaches that are most relevant to each.

There are five hardware and technology design principles and four broad energy policy principles.

2.5.1 Principle 1: Products should support effective power management

While this is a very broad requirement, it clearly is addressed by two of the technology options to reduce energy in networks.

Link power management: While the absolute power consumption to operate a link is of some concern, this principle focuses on the ability of the link to scale (modulate) power with the amount of data transmitted. Link power (and its ability to modulate power) is significantly dictated by the relevant technology standards, so product designers are at the mercy of existing technology standards and what power management options are available within each of these.

Technology standards define the rules of communication, interoperability and the management of states in network links. Standards Development Organisations, who develop these technology standards, need to be encouraged continually to introduce power management capabilities into their technology standards for network links. As these technologies are developed and become available, energy policies need to encourage their use by rewarding products that implement them. Using technology standards that allow power management of links is only possible if they exist, so this is a fruitful area for medium term energy policy activity.

This approach is most relevant to:

- Network equipment
- Electronic edge devices

There is low applicability for other edge devices as low data rates mean there is little room to scale down. The low data rates associated with other edge devices make it critical that these devices support link power management features that also enable power savings on associated network equipment and other devices on the network.

Device power management: This is applicable to all edge devices, and is about reducing energy consumed when services are not required. This is most relevant to electronic edge devices. Power management can be accomplished with or without the cooperation of the network. There is more discussion on this issue in the next guiding principle.

Not applicable to network equipment (LAN and WAN) and low applicability to other edge devices (with respect to their networks functions), as power management of internal functions does not change the mode of the product - this is covered by power scaling (Principle 5).

2.5.2 Principle 2: A network function should not stop power management internally

This principal applies to both the design of network protocols and the design of products. Network protocols should not be so onerous to participate in when a function is not active that a device has to stay in a high power state to do so. Similarly, devices should be designed to implement all protocols that they need to participate in while asleep without waking or waking for only short time periods. This applies only to electronic edge devices. It is not applicable to network equipment (no low power modes) and not to other edge devices (their protocols are sufficiently simple to easily implement at low power).

2.5.3 Principle 3: A network function should not stop power management in other devices on the network

This principle is also a subset (or extension) of Principle 1. This objective relies on protocols within LAN networks that do not pointlessly keep devices awake, and on devices that do not send out unnecessary data packets that do the same.

Principles 1, 2 and 3 are closely related and for them to be effectively implemented, protocols with suitable power management capability need to be developed. This guiding principle primarily applies to edge devices. Network equipment usually generates only specific types of network traffic that every device should handle without issue. Network equipment simply passes the vast majority of traffic, and they do not enter a low power mode.

2.5.4 Principle 4: Products should cope with legacy equipment on the network

This is a core principle in the design of all network equipment, technology standards, and protocols and this should be maintained into the future. There is a vast investment in infrastructure for networks, and it is not practical to replace all of this equipment whenever there is a change in technology standards or hardware requirements. It is a key ongoing consideration for equipment designers (even though in some cases it can severely limit options for energy improvements).

This principle can be split into two separate issues:

- New equipment should cope with poorly behaved older equipment that may be present on the network (e.g. devices that continually ping for no useful reason);
- New equipment should cope with older items that may not have advanced energy management protocols built into the relevant technology standards.

In any energy policy content, this principle is of relatively low priority as cases where this occurs are not common (because of commercial pressures to ensure backward compatibility), but in some cases checks may be required to ensure that adverse energy effects are not produced by interactions with legacy equipment. Inclusion of a general statement in energy policies to ensure that such adverse effects do not occur is wise insurance to cover such occurrences.

2.5.5 Principle 5: Products should scale power requirements in proportion to the (network) service being provided

This is an incredibly important principle and it is probably the one that has the largest potential to save energy in networks in network equipment and many electronic edge devices. It is also probably the principle that is least understood, has the newest technological developments, and is least encapsulated in existing policies.

From a user perspective, the only important and visible attribute is that the power changes when the task changes – the details of what is done and how this is achieved is of no relevance. Ensuring that the product is usable under different power scaling levels is also critical (performance has to be maintained).

The key points with respect to power scaling with respect to networks are:

- It only applies to electronics (network equipment and many electronic edge devices)
- It has to be automatic and continuous to be effective – it has to be designed into the product architecture
- The implementation is highly product specific – it is determined by internal product design rather than general technology standards
- The result should be invisible to the user except in less power consumption.

Developing effective policies that encourage and reward power scaling will be critical for an efficient low energy network future.

Next are the four energy policy principles.

2.5.6 Principle 6: Require power management to automatically enter low power modes

Power management has to be automatic and continuous to be effective. This is common sense, but setting robust and reliable rules to ensure that this is done in a way that does not detract from the user experience or have negative effects (performance or energy) elsewhere on the network is not always trivial. This is an area that is particularly challenging for energy policy, as the product has to be as usable with power management activated as it is with it disabled. Creating the requirements for effective power management is also fundamentally different from traditional regulations that specify power limits, etc., and unfamiliar to most policy professionals. If power management makes the product difficult or inconvenient to use, users will disable it, eliminating any potential energy savings from the policy or technology. Power management always has to be considered in the context of product usability. Anecdotes are common of cases where power management has been disabled because users do not like it.

2.5.7 Principle 7: Put reasonable power limits on low power modes

This has been the core approach that has been applied to simple standby (products not connected to networks), but as we have seen in many reports and investigations over the past years, this approach has to be applied differently in the case of equipment connected to a network. This approach is not applicable to network equipment as these products do not have low power modes. For edge devices, limits need to take into account whatever functions the device is performing when tested and for which a regulation or specification chooses to make a provision (including the level of network connection required or necessary). A set of reasonable allowances is needed.

This principle is most relevant to:

- Non-electronic edge devices (fairly straight forward).
- Electronic edge devices (may be more complex).

Not applicable to for network equipment (LAN and WAN).

2.5.8 Principle 8: Encourage networked products to minimise their total energy consumption, using … "industry-wide protocols for power management" [in networks]

This is the policy corollary of hardware Principles 1, 2 and 3. The main shortcoming with this principle is that, at present, there are no "industry-wide protocols for power management" in networks that can be encouraged. There are certainly many components of energy management that are important and that should be encouraged as set out in Principle 1. This is a key area of work for the future. These types of power management approaches are applicable only to edge devices.

A broad interpretation of this principle would also be that "internal power management" through energy scaling (Principle 5) should also be included within its scope. This is an important area that is poorly developed in existing policies.

2.5.9 Principle 9: Keep performance requirements generic; require specific hardware or software technologies only after careful consideration

The concept of keeping performance requirements generic in nature is a very sound one and this has been the overarching principle of most appliance and equipment policies for many years. The only measure to be assessed is how much energy is required to complete a specific task (and whether the completed task is of sufficient quality) – how this is achieved is up to the manufacturer. Keeping performance requirements generic encourages innovation in the field of energy efficiency.

One topic where specific hardware or software technologies come into play is link technology standards. Some versions of technology standards for network links offer significant power management features and these versions should be given preference in energy policies over those versions that do not. As long as technology standards are open, specifying a particular (or minimum) version that delivers the required performance features should be of little concern. One concern underlying this principle is that proprietary technologies should not be mandated in energy policies. Most link technology standards are open; the most widely use one that is proprietary is HDMI. Even in this case, policies could be worded to state that if a certain link technology is incorporated into a product, then it must comply with a version that has the required minimum power management capabilities. Policies should rarely or never favour or mandate the use of one link technology over another as this undermines market forces and innovation. Rather, the policies should specify how the chosen technology is deployed.


OUTPUT 100A
INPUT 100A

3 CURRENT APPROACHES

While network functionality presents a range of problems and challenges for energy policy, a range of approaches for regulations and other measures have already been developed and successfully implemented in different regions of the world. Regulations and voluntary programs for energy efficiency are inextricably tied to the test procedures they rely on. The regulations can only cover quantitative measurements made by a test procedure, and the test procedure's primary function is to serve the needs of the regulations. That said, it is important to keep the two distinct.

There are several limitations to the historical approaches set out in this section. Firstly, many electronic products are becoming more complex with many different types of functions offered and a large number of potential modes, making these broad approaches more difficult to apply. Secondly, product specific policies tend to ignore energy impacts that may occur in other parts of the system – this can be an issue within a network in specific cases, where low energy in one product may generate higher energy elsewhere in the system. But it is important to understand the historical and current policy context. A more pro-active and forward looking approach is included in the next section.

3.1 REGULATIONS AND ENERGY PROGRAMS

For devices that have network connectivity, several general approaches have been developed and applied to programs in addition to many specific technical details. Traditional (stand-alone) standby is an issue that is uniformly applicable to a wide range of product types and so well suited to a horizontal policy. For network connectivity, three major categories product policy approaches have been used:

- Vertical – requirements are created for individual product types, usually in conjunction with the active (on) mode
- Horizontal – requirements are applied uniformly across a large range of product types
- Clustered horizontal – requirements are applied uniformly to specific groups of product types (that have similar relationship to the network in technology and functionality).

For any approach, requirements can be uniform, or vary with the presence of specific functions and features (network or other) in the product, including their number and type. In practice, the low power mode levels reasonably required in products vary across products so that providing allowances for specified features and functions is warranted. There can be limits on the number of type of adders that can be applied, and adder values should be no more an no less than clearly needed. Many policies globally include adder systems, such as the EU Codes of Conduct, and many Energy Star specifications.

3.1.1 Vertical Approaches

Vertical approaches are most commonly used for products with aggregate energy consumption significant enough to warrant attention irrespective of any low power modes. These generally use a test procedure specific to the product type in question, and have requirements narrowly tailored to the product and market offerings. These require the largest amount of policy development but also can lead to the greatest energy savings. An example of this type of approach is the Energy Star specification for computers and its accompanying test procedure.

3.1.2 Horizontal Approaches

Horizontal approaches cover all products of a general nature (e.g. all those intended for residential use) minus any specified exceptions. A fully horizontal standard applies a single limit to all products irrespective of functions or attributes. This covers the greatest number of products at the lowest burden for policymakers, but it does not necessarily mean that individual product designs are optimised or that network wide energy savings are achieved. An example horizontal requirement is the European Commission's regulation on standby power, which was recently amended to include products with network functions. This regulation covers most household and commercial products and recognises four major variants in product type:

- Products with no network connection and no display
- Products with no network connection with a display

- Products with a network connection with a high network availability requirement (essentially this is network equipment)
- Other products with a network connection.

3.1.3 Clustered Horizontal Approaches

Intermediate between the classical vertical and horizontal approaches is those with common requirements for smaller clusters of products. This has been implemented in Korea for a large number of products, many with network functions in their low power modes. While this approach allows adjustment of requirements to suit individual clusters of product types, it requires more policy effort to maintain and update several parallel documents. The best example of this type of approach is the Energy Star requirements for Audio/Video Products; it applies a common set of requirements to a broad category of devices. Other examples are the Energy Star requirement for Small Network Equipment and the European Code of Conduct on Energy Consumption of Broadband Equipment. These use a common adder structure for many device types, though do have different base values. Part of this is due to the fact that these are for network equipment and so really covering active modes.

In summary, there are a wide range of approaches already implemented to date. Many of these have built on approaches developed for simple standby in products without a network connection, so have many some technical limitations. Many of the policies that attempt to deal with network connectivity do so in a way that does not reward products designs that achieve flexible efficient low energy network designs. We believe a new policy approach is required to enhance existing approaches. This derives from the clustered horizontal approach, and is set out in the last section on future directions.

3.2 TEST PROCEDURES

A test procedure is a method to accurately measure the power consumption of products under defined and controlled conditions, using equipment with sufficient accuracy to provide repeatable and reproducible results. Test procedures underpin all energy policies and programs such as:

- Mandatory energy standards
- Voluntary energy standards
- Labelling programs (comparative, endorsement)
- Purchaser/consumer information
- Policy insight / monitoring / comparisons

This report focuses on the use of test procedures to support energy policy with respect to network connectivity.

An ideal test procedure should be:

- Repeatable (same result on the same product in the same lab)
- Reproducible (same result on the same product in a different lab)
- Produces measurements of power or energy consumption and service provision that are representative of those in real use
- Inexpensive
- Universally recognised

In general, it is ideal to have a consistent global approach to test procedures. Many governments have a policy of aligning test procedures with best practice international approaches. There is a large global trade in products with network connectivity. The benefits of international alignment are large for both government and industry.

- Industry can test once and sell in many regions
- Supports regional and international cooperation on energy policies
- Allows comparisons and benchmarking of products
- Facilitates trade and diffusion of advanced technologies.

It is sometimes difficult to find the right balance among these factors and many compromises are needed. "Representative" may not be a single condition or an average condition, as typical usage can often be best represented as a distribution. It is sometimes much more useful to measure at high and low conditions, especially when there is some understanding of what may lie in between. Often it depends on what attributes we are trying to assess with the test procedure – this is particularly important with respect to some aspects of network connectivity.

IEC62301 Edition 2 recognises that products will often have network connections and separately defines a category ("Network mode") of low power modes where this function is present. The procedure does not define any of the necessary configuration and mode requirements that may be required to get a suitable measurement for network modes. A range of work is now required in order to build on this sound technical measurement base. The current test standard implies that it is not suitable for power measurement in active modes. This is certainly not the case for most electronics, including network equipment and it should be used for power measurements on these types of products.

As network technologies and many products with network connectivity are produced for global markets, it is even more important in this domain to have global alignment, as far as possible.

At the present time, a limited number of test procedures that include network connectivity (likely to be less than 20) are in place around the globe. Most of these are for specific products and in order to support local policies. However, the number and complexity of these policies is likely to increase quickly in the coming years. Existing approaches have some gaps and some conflicts; later sections of this report provide a roadmap for greater global alignment with respect to test procedures that cover network connectivity.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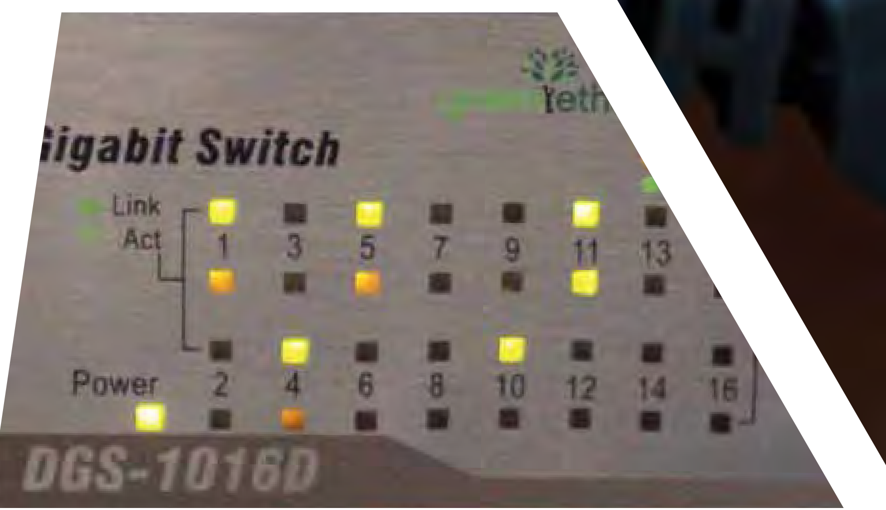
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4 LOOKING FORWARD - MOVING BEYOND NETWORK STANDBY

The past few years has generated significant interest in network standby, but little forward movement to evolve policy in an effective and coordinated way. We see that there are several essential ingredients to gain traction, improve the policy development process, and ultimately save substantial amounts of energy. These include agreement on some core definitions, a process and mechanism to coordinate and align test procedures, and expanding the scope of networks to include how they actively provide services, in all modes, rather than focusing strictly on their burden of increased energy use. Finally, developing energy policies and programs based on a deep understanding of product design, function and use will result in better outcomes.

This section encapsulates our recommendations on how to move forward in this area. Separate sections are included for:

- Definitions - how to resolve outstanding issues and move on
- Test procedures - process for getting global alignment and addressed outstanding issues
- Policy framework - based on a deeper understanding of how products with network connectivity work and what characteristics policies need to encourage, a new policy framework has been developed for consideration.

4.1 DEFINITIONS

Discussions of policy around standby power, and the resulting policies themselves, have been long hampered by confusion and disagreement around definitions of key terms. Many terms do not exist in isolation, but are parts of systems of terminology that all work together. Unfortunately, there are several such systems that are partly incompatible with each other and that are in common use in energy policy. A recent study (Nordman, 2013), examined this topic and proposed a set of definitions that sought to be a workable compromise that could be acceptable to all involved, so that policy work could move forward without getting frequently derailed by definition issues. This remains an open topic but we believe that the recommended direction is sensible and important to adopt.

The Nordman report reviewed the different types of terms used in standby and network standby discussions. It analysed the four dominant contexts within which terms and definitions occur: energy policy, test procedures, technology standards, and user interfaces. It then presented four systems of terms: minimum power mode, standby as a mode, standby as a condition, and the sleep paradigm. The following are key conclusions from the report.

The various purposes and contexts of terms will continue to exist, and past usages of terms are not likely to be dropped overnight, so that what is needed is a broad system of terms of different types that can co-exist with each other while creating a minimum of confusion. The following recommendations, if adopted, could move the process forward.

Note: *The scope of work in this report is much broader than the issues of "network standby" as defined below and the authors believe that future work should leave this definition behind as it is unnecessarily restrictive and causes confusion and misunderstanding in this policy space. Future policy development should instead focus on network connectivity, in products and technologies.*

4.1.1 Minimum power mode

The original 'standby' term was the "minimum power mode" and this was included in IEC62301 Edition 1 as an internal definition, though has been widely used in some regions. This concept has some usefulness and use so that maintaining the concept is warranted. IEC TC59 directed the working group to remove this original definition from IEC62301 as it did not relate to specific modes, and it has now been removed from IEC62301 Edition 2. The most simple and direct way to express this concept (where required) is "minimum power mode".

4.1.2 Network standby

"Network standby" is widely used as the topic area of technologies, policies, etc., around energy use of low power modes with network connectivity. It seems appropriate to use this term for the general topic area, and to not assign it a more specific meaning. There appears to be no policy need for it to have a more specific meaning. In general, interest in power levels in low power modes is accompanied by attention to promoting power management to enter those modes, so assuring power management in the context of network connectivity is also part of the general rubric of network standby. The term "standby" has strong meanings related to low power modes, so it is recommended that the term network standby only be used to cover issues related to low power modes and not to mean issues related to broader network connectivity in all modes.

4.1.3 Networked standby

The EU widely-horizontal policy approach created the need for a "condition" of a device that is in a low power mode with network connectivity. "Networked standby" does not seem to have other usages and so can be safely used for that specific meaning. That this differs by only two letters from 'network standby' and can sound the same when spoken will likely lead to some confusion, but there seems to be no better alternative.

4.1.4 Standby

IEC62301 Edition 2 definition of "standby" will likely get significant use for the foreseeable future, but as there are many other definitions of the word, clarity can be accomplished by always referring to it as "IEC 62301 standby" when that specific meaning is intended. It is important to note that this definition is a category of modes rather than any specific product mode.

For the term "standby" unqualified, it is often used to refer to the topic area of "low power modes" generally, so that it should have that general meaning only. Where possible, the use of the term low power modes is preferable in technical discussions.

There is the question of whether a "network standby" mode is contained within, or distinct from, the set of "standby" modes. For standby as a topic area, low power modes with network connectivity are within scope as any low power mode is. In contrast, network standby is not part of the IEC62301 Edition 2 standby definition. IEC62301 Edition 2 does define "network mode" as a distinct low power mode with an active network connection and so IEC62301 Standby and IEC62301 Network Mode are mutually exclusive low power modes. This issue is an example of why it is critical to distinguish these two terms.

4.1.5 Sleep

For product user interfaces, "sleep" is an unambiguous state between on and off for electronic devices, and should continue to have this meaning. While sleep modes often include network connectivity, it is not required.

For kitchen and laundry appliances, "sleep" as a term does not well apply, so that we would expect such devices to have "ready" and possibly "off" modes, and either could have network connectivity.

4.1.6 Low Power Modes

A common usage of "low power modes" is any mode where the primary function is not active. This is useful as it does not rely on other (possibly ambiguous) definitions. IEC62301 Edition 2 defines "low power modes" as "a product mode that falls into one of the following broad mode categories: "off mode(s), standby mode(s), network mode(s)". This general definition states that in these three broad categories of modes, the main function is not active. It also relies on other definitions for meaning and may not include disconnected time as the more general definition of low power mode does.

4.2 AIMING FOR GLOBAL ALIGNMENT ON TEST PROCEDURES

4.2.1 Test Procedure Objectives

We recommend that the overall objectives with respect to test procedures for network connectivity should be to:

- Define test procedure elements that complement IEC62301 to allow the measurement of relevant modes of equipment where one (or more) network function(s) are present
- Provide a platform for globally relevant, uniform test methods for products with network functions (as far as possible)
- Set out relevant modes and configurations that should cover levels of network functionality likely to occur in typical use
- Support existing and future energy policies.

As this topic is new and evolving, test procedures will need to account for what is specifically needed to support current policies, as well provide a sound basis for future policies, which may require new approaches or different measurements. Where new approaches are required, some consideration is needed on how to transition towards these in an orderly way that minimises the overall testing burden in a global context. There may be some need to provide for different measurements for different countries, but the amount of any such diversity should be minimised as far as possible.

When developing test procedure elements, it is important to consider what is being measured and whether this (and the policy that it supports) will encourage suppliers to design products that perform efficiently in practice (see policy framework section). Some such test configurations may not be defined under existing policies.

Aligning network related elements is important because:

- Network connectivity adds significant complexity and this can quickly get out of hand
- The complexity is often independent of product type but is dependent on network technology type
- Testing needs to evolve with technologies as technology standards develop
- While the concept of assessing a product performance and energy across the range of typical use is laudable, this needs to be done in a way that minimises the testing burden while delivering sufficient information to differentiate products – this means that an understanding of the factors that drive energy across the range of normal use is needed and a minimum set of tests to assess those characteristics should be developed.

Complexity is a significant potential burden for policymakers, manufacturers, and test labs.

Incorrect or inadequate testing will reduce actual energy savings achieved by programs and sends wrong design signals to manufacturers and product designers. Manufacturers necessarily focus on how their products fare under an energy policy and test procedure. A product designer will focus on saleable features of the product as a first priority and will then optimise energy to the existing test methods and policies. The energy the product uses in actual use is much less important for product designers because they do not pay for the energy used, and good field energy performance does not sell any more products (and such claims are hard to substantiate). Many product designers may not even understand or know how their products are typically used. So, it is incumbent on energy policy makers to set requirements in energy policies (and their associated test procedures) that do encourage and reward product designs that will minimise energy consumption across the range of typical use.

4.2.2 Test Procedure Scope and Product Categories

Previous sections of this report have made a strong case for separate classification and treatment of three different categories of product types with respect to network connectivity: network equipment, electronic edge devices, and other edge devices. The basic setup and configuration for testing each of these is likely to be fundamentally different so in many respects they need to be treated differently in test procedures as well.

Within these broad categories, there are further "clusters" of product types with high amounts of commonality. Network equipment could be divided into small and large groupings; as an example Energy Star defines "small" being anything with less than twelve wired ports or having wireless capability. "Small" devices are most commonly found in residences, with large network equipment found in commercial buildings, data centres, and telecom facilities. Any such division requires knowledge and understanding of both the application and usage for different product types in order to develop sensible groupings.

For electronic edge devices, there is a cluster of devices with audio/video data as their primary function, and these can be treated as a group for low power mode consumption. Other electronics generally require vertical standards (e.g. PCs, printers, and televisions) but could be harmonized with others for many aspects of low power mode consumption and network connectivity.

Non–electronic edge devices are only in the early stages of having a network connection as part of their main-stream functionality. However, given the trend towards network functions being common in these products, they can be grouped into four general clusters with similar network functionality: kitchen and laundry major appliances, lighting (sources and controls), climate conditioning (heating, cooling, ventilation, controls, plus water heating), and other (miscellaneous) devices. For example, lighting systems need near-instant responsiveness to meet user needs but are unlikely to be receiving external control requests. By contrast, climate controls have much less stringent time response needs, but may be critical for load shedding on request from a Smart Grid.

4.2.3 Components of test procedures with network connectivity

Test procedures cover a range of standard topics. A review of test procedure requirements for devices with network connectivity found these broad topics:

- Definitions and Network Technologies
- Product Configuration and Setup Requirements
- Network Connectivity
- Modes and Network Traffic
- Power Measurement (reference IEC62301)
- Reporting Requirements (to ensure regulator or program needs are met).

The areas that need to be most closely examined are configuration and setup, and network traffic. Once these elements are clearly defined, power measurement using IEC62301 is straightforward.

Test procedures underpin all energy policies and programs. To successfully test a product with a network capability, a range of technical test details need to be defined in order to get consistent, reproducible measurements (Nordman, 2011). The types of issues that need to be specified are:

- Cable type/length
- Radio conditions
- Capabilities of devices connected to the tested equipment
- Functions provided by or to other connected devices
- Cloud / service provider context; provision of full Internet connection
- Data traffic packet details – quantity, timing, size, and content
- Network service environment – addressing, discovery
- Typical usage (levels, not pattern of use) and modes/ functions to be measured.

There are already a range of established test procedures and technical specifications which define many network-related elements. With diverse product types, many countries, and a variety of network technologies, the number of potential network-related items that could be defined within a test procedure is already very large. However, many of these elements could easily be standardised across countries and many product types, so that the actual number needed could be vastly reduced. The key then is to create a process which accomplishes this standardization globally; that is described below as the "library" process.

Networks bring some special considerations to test procedures:

- Technology standards for network links frequently change
- The testing may need to consider the version of the standard in the unit being tested
- Allowing a product to update its firmware prior to test (e.g. via an Internet connection) could change the result
- There is a need to understand those protocols in the product that substantially affect energy use to determine how these should be assessed and reported.

One risk that faces many test procedures is "gaming" or circumvention, where a product's energy consumption appears to be good under a test procedure but is relatively poor in the field during use. Well-designed test procedures will reduce this risk, especially where a range of configurations are routinely tested. However, there is always a chance that an unrepresentative result may be obtained because the test procedure (or policy) is not well designed, or a manufacturer exploits a loophole in the tests or policy.

For edge devices, it is best that specific product modes are generally NOT included into the library content. Modes generally will be defined in separate product specific test procedures. Product experts and policy analysts are best placed to define the modes at a product level that are required for specific energy policies. The approach of externally referencing product test modes has worked very well in IEC62301 and is likely to be highly applicable for edge devices with a network connection.

For electronic edge devices, this may cover a range of modes including active mode. Past experience has shown that mode definitions are best left to individual product types, though general harmonization across products is desirable and is sometimes feasible.

For other edge devices, most measurements with respect to networks will be in low power modes. Always on appliances (like refrigerators) could have differential measurements (with and without the network active).

For network equipment, the test procedure should be able to define the most important configuration options for testing. Network equipment does not have low-power modes used in normal operation.

4.2.4 Pathway to Global Alignment

There are a number of existing test procedures, program requirements, and regulations that cover products with network functions that define at least some of the required elements for energy testing. What is now needed is a pathway through the current maze of documents towards a simpler global solution that is more representative of the range of typical network configurations and operation.

For each of the network elements identified in the previous section, there are a number of possible situations at present when all of the existing policies and their associated test procedures are considered in total:

- There is a single or uniform definition of the test element (either only one test procedure defines a requirement or all test procedures define equivalent or the same requirements)
- No test procedure defines a requirement (test procedure gap)
- Several or many test procedures define different or conflicting requirements (it may be possible to address many of these conflicts through a menu of testing options, especially where these relate to number of links and network traffic).

Documenting the relevant network components is a significant piece of technical work – at least 20 existing test procedures and regulations currently exist and each would have to be carefully reviewed and documented. Some work has already been done by Nordman (2011b), but there is much more to do.

The pathway to alignment of network-related elements is straightforward, but will require research, documentation and negotiation. The process includes:

- Identifying all key testing components required for consistent testing
- Documenting existing requirements in all significant test methods, specifications, and regulations
- Identifying cases where there is a gap (important details not defined in any method; in current or future technologies)
- Identifying cases where there is already a satisfactory single or uniform technical specification
- Identifying cases where there are multiple technical specifications
- Recommend the preferred specification for each key test element and the rationale as to why it these are preferred.

This process will require significant effort, will produce a database of results, and will require ongoing curation and maintenance. The result will be in many ways analogous to a “library”, where large amounts of content are found, with a clear indexing scheme, with an organization that decides what to acquire, and when to remove something from the collection. Without a library, a librarian, and funding to create them, the process of harmonization for network content will move forward only very slowly and haphazardly. Thus, this is a key need and recommendation of this report.

Note that in some cases products may reasonably need diverging elements from the norm. This should be provided for, so long as the merit of doing so is clear. Also, some elements will necessarily change over time, as technology and consumer usage both evolve. Managing these changes will be difficult, with different test procedures and specifications on different schedules - but would be even more difficult in the absence of a library.

The library should cover not only test procedures, but also regulations and specifications. The box below shows some example library entries (“elements”) derived from the test procedure for a voluntary energy efficiency specification. Many elements will reference specific network issues or technologies. Elements will be specific extracts from existing documents, and might be a sentence, a paragraph, a table, or some numeric values. Library content can be dropped into product test procedures as needed, and updated as technologies change. An underlying principle is “be as horizontal as feasible / reasonable – and no farther”.

Example: Energy Star Requirements for Small Network Equipment

The following list includes some of the configuration requirements for a small network equipment test procedure; most elements could also apply to other product types.

- “All Ethernet cables used for testing shall meet ANSI/EIA/TIA-568 Category 5e (Cat5e) specifications and shall be 1 to 2 meters in length.”
- “If the UUT supports IEEE 802.3az protocol, all connected devices must support IEEE 802.3az”.
- “Ethernet ports shall be connected at the maximum supported link rate unless otherwise specified in this test procedure.”
- “The 1 kb/s data rate test traffic used for qualification shall contain random data in a variety of datagram (or frame) sizes based on an Internet traffic mix (IMIX) sent at random intervals. For the high data rate test traffic, frame size may be increased up to the maximum transmission unit (MTU) as needed to sustain the high data rate traffic.”
- “Tests are performed at two data rates, 1 kb/s (0.5 kb/s in each direction), and the highest rate supported by the link shown in Table 8.”

Given the diverse nature of network elements and the fast evolution of many technologies, this type of work may not be well suited to IEC technical committees, at least in the short term. So, some other mechanism will most likely be required.

The following steps need to be undertaken to move this topic area forward.

A. select a librarian

B. document existing technical options for each testing and specification element

C. select a preferred option or minimal set of preferred options

D. create a library of these testing elements

E. create a global consultation process to review and update the library on an ongoing basis.

Step E above is a significantly active process. It would include in-depth discussion (and possibly negotiation) with key stakeholders (notably the owners of the policies and or associated test procedure). That would involve determining how to consolidate test procedure requirements down to one or a few options, either in the short term or the longer term. Policies that are already in place may already define test procedure requirements (at least to some extent) so that it may be challenging to change these test procedure elements in the short term. However, such discussions could establish a path for future alignment in the next generation of policies. This approach could provide much greater levels of alignment in the medium term, which is desirable, but would require significant effort.

4.2.5 DC Power

A critical area that needs to be addressed in IEC62301 is the inclusion of DC-powered products. This is related to networks as several network technologies can also provide power on the same cable, managed by the digital communications on the link. Any device with an AC/DC external power supply is supplied with DC power, but the issue here is devices that use a standard DC supply technology, such as USB, Ethernet, the traditional 12V supply in cars, or the emerging standard for 380V DC.

A few energy specifications already cover DC-powered products. It is quite likely that the range of products available with standard DC powering, and the number of such products sold, will rise significantly in the coming years, so that more and more specifications will, and will need to, cover DC power.

4.2.6 Next steps for Test Procedures

Given the extensive government use of many test procedures and their application in energy policies, it is important that governments commission and control this project. This work could be undertaken by the proposed 4E Electronic Devices and Networks Annex or under the SEAD Network Standby project. There are several questions that need to be considered:

- Who is librarian?
- What content applies as regulations and library content evolve over time?
- Who creates/reviews new content?
- Who updates and maintains content?
- Who does interpretation?
- What does this mean for IEC62301?
- Once compiled, how would this preferred test procedure content be maintained? – who would be responsible?

It is clear that the content should be referenced to IEC62301 with respect to power measurement requirements. In the medium term, once the content is codified and more settled, this could be developed as a companion document to IEC62301 or a sub-part. However, as noted above, this type of continually evolving test procedure is not well suited to current IEC procedures and structures (it would need to be able to reference dynamic content).

Many network test elements and content already exists in test procedures. The task ahead is to compile this content and document the details. This process will ensure that content gaps are covered, elements that are already aligned are consolidated, any conflicts are examined carefully and included as menu options or, in some cases, it may be possible to consolidate and align requirements in the medium term through discussion.

There are several areas of work that are ongoing or that could impact on this potential project. IEC TC59 has a working group in home networks and this is progressing with a range of issues. TC59 has asked MT9 to examine IEC62301 and make recommendation on what elements need to be included to address the testing of network connectivity. Both of these issues have significant potential crossover (and conflict) with this potential project. Another area of work is the 4E Communities of Practice group that is looking to engage with IEC and ISO at a higher level to have more direct government input into international standards processes. This project could facilitate any work that was to be moved into the IEC structure in the future.

There is a clear pathway forward to move towards global alignment of test procedures, but this will require some active management and coordination of key stakeholders into the future. Government action may be needed to ensure that this occurs, and the process has the resources for it to be done correctly and in a timely manner. Input from industry will provide transparency and innovation. There may also be a need to coordinate across several Standards Development Organisations into the future. Neglect of these issues is likely to result is a wide range of disparate measurement approaches with poor outcomes for policy makers and industry.

4.3 HIGH LEVEL POLICY FRAMEWORK FOR PRODUCTS IN A NETWORK

4.3.1 Beyond Low-Power Modes

Attention to the topic of Network Standby has been hindered by its origin in the topic of traditional standby power, in which devices are performing no function. Since network connectivity is added to devices for the purposes of accomplishing some function, this is fundamentally different. Policy development would be more successful if it were primarily attached to consideration of the positive functions that network connectivity accomplishes. This could leverage more interest, activity, and resources. We strongly recommend that the policy context for this work be network connectivity and that the previous topic of network standby be no longer used (although it is fully subsumed by the topic of network connectivity).

4.3.2 Key policy issues and context

The objective of creating efficient low energy networks brings several unique challenges to policy development. Unlike conventional products, the energy consumption of products connected to networks can be influenced by other devices on the network. This is in part determined by the manufacturer's design choices and in part by what technology standards require or enable. The historical focus of energy policy has been on individual product energy consumption: the challenge for policy makers in a network context is to widen the focus on energy to broader network related effects, where these are significant, while limiting complexity. Together, these issues present many challenges to policy makers to find a balanced and sensible way forward. Technology for electronics and networks develops rapidly, presenting a challenge to traditional policy timelines. Network technology is inherently global and products with network functionality are increasingly traded globally.

Given the complexity of the issues surrounding networks, a single, simple, clear goal like the successful "1-Watt" (for simple standby) is not achievable. In addition, strategic choices need to be made to make best use of the limited public resources available for this area. Product designers always have to consider and control product costs: this will limit the extent and speed that energy saving can be practically delivered by energy policies for end users.

The following are important considerations when developing future roadmap and policy approaches to networked products:

- Managing complexity is a core challenge as it burdens all stakeholders;
- Where possible, policy makers should resist inventing new policy content; the many existing approaches can (usually) be adapted to most policy needs;
- When new content is needed, seek to develop it in an open process which enables wide participation and has diversity in geography and type of stakeholder;
- It is important to reward products that optimise their energy consumption under different usage conditions, while keeping requirements realistic and simple;
- Policies should allocate additional power only for additional functionality that needs it (and be able to incorporate scalability of new and upcoming technologies);
- Pursue transparency locally – networks offer great potential to make visible information that was previously unavailable, for better coordination and management;
- Pursue transparency overall – networks offer potential to make much more and much better data available about typical product use and performance;
- Fully coordinate collections of devices to optimise energy consumption, in addition to managing the power of individual products in individual modes; autonomous power management can use fine-grained knowledge to minimize the use of arbitrary time limits for the activation of energy management as well as how optimise use of individual services across products;
- Plan and implement a "technology strategy" to identify network technologies needed to make progress in reducing energy use, ensure that these are developed (when feasible and of good quality), and plan how they will then be accelerated into the market with other policy instruments.

4.3.3 Recommended Policy Framework for Networks

So far this report has explored different equipment types and why their characteristics mean that different policy approaches are necessary with respect to networks. It has also examined the main technologies that can reduce overall energy consumption, mainly with reference to network related functions. The report has also examined the IEA Guiding Principles for Good Network Design and what these mean in terms of practical policy.

This section synthesises these elements into a broad policy framework to address the issue of network connectivity. This can be considered in future energy policy deliberations regarding networked products for each of the main product types identified, and the role of energy policy in technology development. Each of the main product types are considered in turn in the following sections.

4.3.4 Network Equipment

Product description: Network equipment has its main function as the provision of the network for edge devices (if there were no edge devices, there would be no need for a network – however individual pieces of network equipment may not be directly connected to edge devices). They have to always remain in active mode in order to deliver the required functionality. The link technologies incorporated can be wireless or wired (or in some cases optical fibre) and they can include links for LANs, WANs or a combination of both.

Desirable attributes to be encouraged in an energy policy: The following general attributes are desirable in network equipment:

- Good (efficient) power attributes when all functions are active
- Ability to scale internal power requirements with changes in number of links active
- Ability to scale internal power requirements with changes in data flow rates
- Incorporation of link technologies and the minimum version of a technology standard that allows power management (link power modulation and other energy management).

Policy framework to drive the development of these attributes: The following policy elements operating together should encourage and reward the most efficient network equipment across a range of typical use:

- Set power benchmarks under fully active operation
- Assess changes in power with a reduced number of links
- Assess changes in power with reduced network traffic
- Consider the energy impacts (if any) of power management on other equipment on the network
- For each link technology incorporated into a product, specify the minimum version of the technology standard that offers the greatest scope for power modulation in the link in response to changes in network traffic.

This addresses the Guiding Principles for Good Network Design as follows:

GP1 - Support effective power management: Yes through link power modulation

GP2 - Network does not stop internal power management: Yes overall power scaling

GP3 - Not stop power management in other devices: Not applicable

GP4 - Cope with legacy equipment: Covered by technology standards

GP5 - Power scaling: Yes

GP6 - Automatic enter low power modes: Not applicable

GP7 - Limits on low power modes: Not applicable

GP8 - Industry wide protocols for power management: Not applicable

GP9 - Generic performance, caution in specifying software or hardware: Yes – require technology standard with best power modulation options where a specific link technology is present.

This policy framework also addresses the issue of efficiency of network functions, which is not directly addressed by the existing Guiding Principles.

4.3.5 Electronic Edge Devices

Product description: Electronic edge devices cover a wide range of products that have data as their primary function. They usually have many complex functions, many of which are (or should be) controlled independently, depending on user demands. The product functionality is often closely integrated with network connectivity and the required bandwidth capacity is large at times (but also there are often long periods with low levels of network activity and low data processing needs).

Desirable attributes to be encouraged in an energy policy: The following general attributes are desirable in electronic edge devices:

- Efficient when providing their main function(s)
- Ability to scale internal power requirements to match functional requirements
- Ability to scale internal power requirements when data processing loads are low
- Incorporation of link technologies scale power with data traffic levels.

Policy framework to drive the development of these attributes: The following policy elements operating together should encourage and reward the most efficient electronic edge devices across a range of typical use:

- Set benchmarks for active mode
- Assess changes in power when functions are shut down (requiring this to be present)
- Assess power management with low network traffic and no user interaction/demand
- Set reasonable power limits for low power modes
- Consider the energy impacts (if any) of power management on other equipment on the network
- Where a particular link technology is incorporated into a product, specify the minimum version of the technology standard (where applicable) that offers the greatest scope for power modulation in the link in response to changes in network traffic.

This addresses the Guiding Principles for Good Network Design as follows:

GP1 - Support effective power management: Yes link power modulation and internal power management

GP2 – Network does not stop internal power management: Some options to achieve this under low traffic, but no network wide generic protocol to do this as yet

GP3 - Not stop power management in other devices: No network wide generic protocol to do this as yet

GP4 - Cope with legacy equipment: Covered by link technology standards

GP5 - Power scaling: Yes

GP6 - Automatic enter low power modes: Yes (criteria to assess may be complex)

GP7 - Limits on low power modes: Yes

GP8 - Industry wide protocols for power management: Internal power management covered but no network wide generic protocol to do this as yet

GP9 - Generic performance, caution in specifying software or hardware: Yes – require technology standard with best power modulation options where a specific link technology is present.

4.3.6 Other Edge Devices (non-electronic)

Product description: Non-electronic edge devices cover a very wide range of products and have a primary function that is not data related. These would include kitchen and laundry appliances, heating and cooling equipment, lighting, and all manner of commercial and industrial equipment. Many of these products are covered by separate product policies and standards. Their product functionality is almost always unrelated to any network connection (today most of these types of products do not have a network connection). Network functionality is usually to enhance some user related aspects (e.g. remote control) or to integrate the product with Smart Grid or demand response systems, so bandwidth requirements should be very low. Some of these types of products will have little requirement for network functionality when they are off or in low power modes as most network interaction relates to periods of active use. Some "always on" products like water heaters and refrigerators will have a continuous but low bandwidth requirement.

Desirable attributes to be encouraged in an energy policy: The following general attributes are desirable in other edge devices:

- Efficient when providing their main function(s) (separate product policy)
- Low power levels in low power modes.

Policy framework to drive the development of these attributes: The following policy elements operating together should encourage and reward the most efficient other edge devices across a range of typical use:

- Set benchmarks for product energy efficiency (already included where applicable in product policies)
- Set reasonable power limits for low power modes.

This addresses the Guiding Principles for Good Network Design as follows:

GP1 - Support effective power management: Network power management not relevant

GP2 - Network does not stop internal power management: No network wide generic protocol to do this as yet

GP3 - Not stop power management in other devices: No network wide generic protocol to do this as yet

GP4 - Cope with legacy equipment: Covered by link technology standards

GP5 - Power scaling: No applicable

GP6 - Automatic enter low power modes: Power management of the main function should be addressed by product policy if relevant

GP7 - Limits on low power modes: Yes

GP8 - Industry wide protocols for power management: No network wide generic protocol to do this as yet

GP9 - Generic performance, caution in specifying software or hardware: Not relevant for low bandwidth applications.

5 CONCLUSIONS

This report has explored a range of issues related to network connectivity. This topic has historically presented energy policy makers with many problems and difficulties. Through a detailed understanding of how different types of equipment work and how their network connectivity is integrated into their normal operation, the report has revealed some of the main approaches that can be deployed to unlock energy savings in products connected to networks. The Guiding Principles for Good Network Design have been reviewed and have been found to be robust and provide a sound set of objectives around which to develop a new set of energy policies.

While there have been a number of policies that cover the issue of network connectivity, some of these appear to have significant shortcomings, because techniques that have worked well for standby on stand-alone products appear to be less effective and more problematic for devices with network connections.

This report has set out clear directions and recommendations in three key areas.

First, it has reviewed the issue of definitions and has set out some proposals that will allow all stakeholders to move forward with minimal confusion in areas where there has been some past conflict. This should be a less critical issue in terms of future policy as the topic of prime interest should be network connectivity in general rather than network standby, which is too limited and narrow to be effective.

Second, the issue of test procedures has been explored in some depth. Test procedures for products with network connectivity are an area of great potential complexity and already there is significant divergence in testing approaches in different regions and for different products. This has the potential to be a substantial burden on all stakeholders into the future. A project to review test procedures and create a pathway towards greater global alignment is proposed. This is a significant piece of work and will require some ongoing resources to keep it active and relevant.

Finally, the report undertakes a synthesises of several important areas: our understanding of products types and characteristics, technologies to save energy in networks and the Guiding Principles for Good Network Design into a broad policy framework for networks. This can be considered in future energy policy deliberations regarding networked products for each of the main product types identified, and the role of energy policy in technology development.

Policy in this area needs to expand to include select types of application-layer functionality. This will move beyond simply the burden of connectivity, to also cover benefits. In many cases it is necessary for technology and practical reasons to expand the scope to get some types of energy savings. Importantly, the energy impacts (if any) of power management on other equipment on the network need to be considered so that overall energy consumption of networks is optimised by energy policies.

This report adds new dimension and depth in the understanding of energy aspects of network connectivity. It draws together much of the knowledge and expertise gleaned through the course of the 4E Standby Annex and maps a pathway forward for more effective energy policies in the important field of network connectivity.

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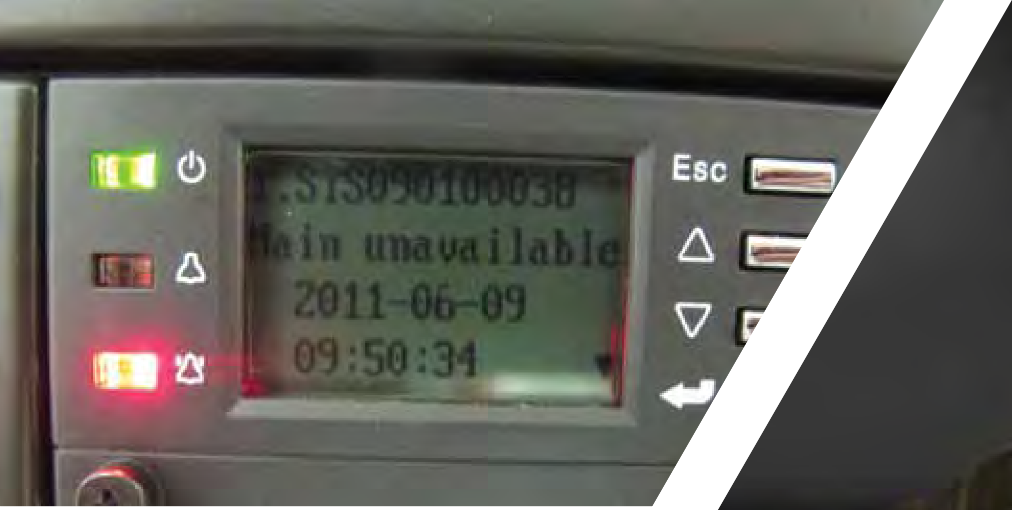
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ANNEX A – ENERGY REPORTING

SUMMARY

"Energy Reporting" refers to the ability of an energy-using device to report to another device on its local network information about its own energy use. Conventionally, building managers and others have had to rely on whole-building utility billing data as their only quantitative reporting on energy use. Other insights can be gained from knowledge of the inventory, characteristics, and pre-defined schedules for various devices. However, these sources are often unreliable, costly to obtain, and not at all granular. In addition, they fail to provide information about equipment that is not identified, operates differently to the way that is intended, malfunctioning, or otherwise performing in a way that the operator would want to know about. Direct Energy Reporting can, over time, overcome all of these problems, and for devices that would already have communications ability for some other reason, do so at no incremental cost.

Energy policy needs to engage with Energy Reporting with regards to technology standards development, moving the technology into products, management systems, and deployment. In addition, energy policy may be able to use data from Energy Reporting to reduce policy costs and improve policy outcomes.

BACKGROUND

There is no device whose primary function is to consume energy. Energy use is a necessary input into products to enable them to function and provide energy services that users want. Communications ability has been added to devices for functional purposes. In some cases, such as telephones, televisions, and network equipment, they are unable to function at all without communications. Other devices, such as computers, can be quite useful without communications, but even more so with it. While it is possible to add communications to a device solely for the purpose of reporting on energy use, this will be rare.

Communications can be over a data link from one device to another directly connected device. USB is an example of this type of link, where a PC and an attached printer can communicate with each other over the USB link. While this has some use, network connections enable communication to devices not directly connected, which is the core technology required to implement Energy Reporting.

Today, only a limited amount of Energy Reporting occurs. Only a small portion of installed products have the capability, and many of the products that do are in buildings that lack a management system that is able to collect it. 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. Ultimately, Energy Reporting should lead to some energy savings that would not otherwise occur, cause them to occur earlier than otherwise, or avoid more expensive ways to accomplish them. Thus, advancing this topic area should be a priority for public policy. It will also lead to a better understanding of energy use and reduce the costs of data collection.

TECHNICAL ISSUES

The basic case of Energy Reporting is an individual device reporting on its own energy information to a single management system ("self-reporting"). This will likely cover most devices, most buildings, and most energy use. That said, there are other cases that are necessary parts of the Energy Reporting universe.

- Devices that report on behalf of a second device ("other-reporting")

- Devices that report on aggregations of devices
- Buildings with multiple management systems.

Other-reporting can occur for several reasons. The second device may not have measurement or reporting ability internally, but the reporting device may have the ability to have this data and so do the reporting[2]. Another case occurs when the second device only implements a legacy or proprietary protocol, or has only a data link, not network connectivity; the reporting device is needed to relay the data into the open network context. A third case is when the reporting device serves as an intermediary for efficiency or other practical purposes.

In the past, only dedicated meters could measure energy use. Today, an increasing number of devices have the internal ability to measure their energy consumption, and some others can measure electricity they provide to other devices. In addition, devices that have processors (and any device that can communicate does) can use knowledge of what they are, what hardware they have installed, and their operational modes and patterns of use to create a reliable estimate of power and energy use. For many purposes, the accuracy of such estimates is sufficient.

Some devices communicate with devices outside the building they are in for functional reasons; others do not. Regardless, it is advantageous to consider Energy Reporting as limited to reporting to a management system within a building. This has security and other advantages. This does not limit the ability of management systems to do some reporting to outside entities (relaying the information they receive), but that can be considered to be outside the scope of the general Energy Reporting topic.

Management systems can be used to control devices, and may use data from Energy Reporting, and even Energy Reporting protocols to do the control. However, control is not central to the idea of Energy Reporting so is not a significant part of this discussion.

In principle, any type of energy use can be reported, but electricity is by far the core type of concern for Energy Reporting.

There are a variety of protocols and other standards that exist or are in development that address Energy Reporting. There is a need to coordinate across these to minimize aspects of them that conflict, maximize harmonization, and to minimize the total number of them that are ultimately developed. Two of these efforts that have the most detail developed are the Internet Engineering Task Force (IETF) working group on Energy Management (EMAN)[3] and the Facility Smart Grid Information Model (FSGIM) conducted by the American Society for Heating Refrigeration and Air Conditioning Engineers (ASHRAE), through its committee SPC 201P[4]. Both cover a lot of specific issues, though the actual area of direct overlap is modest.

DATA

There are many types of data that could be reported over an Energy Reporting protocol, but the most important type in general is that which a utility meter provides — a meter reading of accumulated energy use and a timestamp for it. With two of these readings, subtraction provides a difference in time (which could be anything from seconds to years) and the incremental energy use over that time. Division of these two values then provides an average power level over that period. Another common type of data is a snapshot of the current power level (also with a timestamp). Any such power measurement is necessarily an average over some period of time; for AC power, commonly at least one cycle (or commonly one second).

Another type of data is identifying information about the device. Some of this is data that could be set at time of manufacture and is fixed, such as the brand and model of the device. Other data, such as a local name or other local attributes (e.g. location) can be dynamic. One item not currently included is a device classification. This would be a standard device "type" such as computer, refrigerator, light, television, etc.

Power details are characteristics of the power supplied, such as voltage, frequency (for AC power), and measures of power quality.

Most devices have a single source of power, and do not provide power to other devices. Thus, their power consumption rate is no more complicated than a single flow of power into it. Other devices have more complicated relationships. Some have more than one power supply (this most common in data centers where this increases reliability), and some provide power to other devices (most notably Power Distribution Units as used in data centers, and Power-over-Ethernet supplying devices). In addition, it can be helpful to know how devices are connected to each other, to track power flows and account for totals by electrical circuit. For these situations, the concept of "power interface" was developed in the IETF[5]. This enables unambiguous tracking of power flows into, out of, and between devices, in a simple but general way. While

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2 This particularly occurs if power to the second device flows through the reporting device as with a Power Distribution Unit (PDU), or Power over Ethernet (PoE) switch.

3 https://datatracker.ietf.org/wg/eman/

4 http://spc201.ashraepcs.org/

5 https://datatracker.ietf.org/doc/draft-quittek-eman-reference-model/

many applications do not need this, some do, and as power distribution technologies become more varied and sophisticated, the need for it will grow.

Devices with internal batteries similarly add a difference between the net power flowing into a device and the amount consumed for productive purposes. In general, it is possible to report on components of devices in addition to the entire device. A component could be any discrete piece of hardware or subsystem, e.g. a motor, fan, disk drive, display, printed circuit board, etc., as well as a battery.

DEPLOYMENT

Energy Reporting requires two entities to work - the one doing the reporting, and the one receiving the report. This creates some initial difficulty to overcome before it can be useful, since multiple new devices are needed and they must share a common protocol. Effort should be made to ensure that some products – of any type – come with the feature by default, so that many building owners will discover that they own some Energy Reporting devices without actively seeking them out. Similarly, devices that have routine software upgrades done over a network, such as computers and set-top boxes, could have Energy Reporting features added as part of such updates. This is because Energy Reporting based on estimates requires no new hardware. Automatic software updates could also be used to add the management system function to computers as an application or utility. Once the feature is known to exist and people start to use it, then demand for it in additional products should begin and at some point will become a widely desired feature routinely added to products by manufacturers.

Energy efficiency programs could also mandate or reward the presence of Energy Reporting features. Another likely early need is for inexpensive external meters that can report on behalf of legacy devices to which they are connected; this is most likely to be used on large devices, such as space heating, space cooling, or water heating equipment.

It would be helpful to have free open-source management system software available for a variety of platforms. This does not preclude companies from selling more highly-featured systems, just as the availability of the Linux operating system has not made alternatives such as Windows and MacOS obsolete. The free systems would enable anyone to add Energy Reporting to their building at very low cost, then upgrade if they need to.

Once the market for Energy Reporting is launched, public sector involvement can shift to a guidance role, to ensure that reporting is not encumbered by proprietary protocols or open protocols that are incompatible.

OTHER PUBLIC AND PRIVATE PURPOSES

Energy Reporting's basic purpose is to provide information to those who manage energy use in buildings. However, the data could be used for other public and private purposes. A building owner could use Energy Reporting to bill tenants in a building for energy they use based on time of use, type of device, or both. This would not be an electric utility relationship so that accuracy requirements would not need to follow those for revenue utility meters. Energy Reporting can also be used for automatic inventorying of devices in buildings. At present, when inventories are done, it is usually an expensive manual process, done on a periodic basis in companies or government agencies. Energy Reporting enables this to be done at very low cost as often as desired.

Aggregations of Energy Reporting data can be used in building science research, to better understand device efficiencies and operating patterns. It could also be used to inform voluntary and mandatory energy standards, by providing comprehensive field data on actual use of products by brand/model as an accompaniment to laboratory test procedure results. Standards and rebates for products could be keyed to their actual performance rather than test procedure results, providing incentives for manufacturers to account for real-world issues that products encounter, and ensure efficient operation over the entire product lifetime.

Devices that monitor themselves and report on energy use could identify potential or definite maintenance issues, as could management systems. For example, a refrigerator that suddenly requires more energy to maintain temperature may have compressor or gasket malfunctions that are the cause. Observation of the change, or of the device using more than test procedure results indicate, could be flagged to building operators, or (on an opt-in basis) to manufacturers.

It is also quite likely that Energy Reporting will find common and valued use not anticipated before its deployment. This has happened with many useful IT technologies.

MANAGEMENT SYSTEMS

From the perspective of an energy using device, a management system (MS, sometimes called Energy Management System, EMS or EnMS) is simply the entity on a local network that requests Energy Reporting data and has the result delivered to it. The device need not know anything about the MS. There could be multiple MS in a building that perform similar or different functions, or cover different types of devices or locations within a building.

While possible, it is unlikely that many buildings would have a device devoted only to the MS function. Rather, it may be one of many functions that an already-existing device performs. This could be a central building control system, security system, network router, or simply a convenient computer in the building. The MS function might be somewhat or very related to the other functions of a device, or have no connection to it. For example, broadband IADs (integrated access devices that include both modem and router functions) could have MS data gathering as a feature. Some companies will no doubt want to put MS functionality into "the cloud" for practical or marketing reasons. In this case, there should be a local entity that is the gateway between the individual device reporting and the cloud system. The gateway then will address security and privacy issues raised by exporting the data outside the building, and whether it uses the same protocol as used within the building, or a different protocol, is not important.

As noted above, it would be helpful for basic management system software to be available that is free and open source, to provide a floor of functionality for any building.

PUBLIC POLICY CONTEXT

Energy Reporting is an aspect of device operation that is of a peculiar type; it is not inherently related to the primary function of a device. In this respect it is like product safety, or, more related, low power mode energy use (aka standby power). Thus, it can and should be treated in a horizontal fashion, to some degree across all products, and even more so within groupings ("clusters") of product types (e.g. all electronic devices, all appliances, all lighting, etc.). While the services that products provide are highly varied, the fact that they use electricity is common.

Information from Energy Reporting raises privacy and security issues. This is a key reason to define it as only applying to communication within a local network in a building. Any relaying of data to outside the building should be on an opt-in basis, and with appreciation for privacy and security issues. For example, while a building owner may want to track device energy use on a day-by-day basis, for public policy evaluation of product performance, monthly or annual information may be sufficient. Many public purposes could also use anonymized and/or aggregated data. No security mechanisms specific to Energy Reporting are needed, but ones already developed for other or general purposes should be utilized as appropriate. An issue which then arises is how a device knows that a querying management system should be authorized to request such data. One possible approach is for the reporting device to only share data with a device that it has established a relationship with for some functional purpose. Regardless, security and privacy should remain key concerns.

PUBLIC POLICY ACTION

Above it was noted that there are four main actions that need to occur for Energy Reporting to become available and used - standards, product support, management systems, and deployment — and there is a public policy role for each.

Standards

Public policy needs to have ongoing tracking of existing and in-development technology standards for Energy Reporting. These are of two types of such standards: information models, and information transport protocols. Some technology standards address both. The FSGIM/ASHRAE 201P process provides an information model. The IETF EMAN working group is defining an information model and an implementation of that in a specific protocol (SNMP MIBs[6]). Zigbee SEP 2.0 (Smart Energy Profile) includes an Energy Reporting feature. Many protocols include a generic facility for reporting time-varying numeric data, as from a sensor. These can be readily used to report energy and power.

In addition to standardizing information models and protocols, there is some development needed of specific types of data. Some information models include a URL that points to a place on the Internet where additional product data could be found (most likely at a manufacturer web site). These should ideally have at least two components - machine readable (e.g. XML), and human readable (e.g. plain text or HTML). The nature of information for each could be standardized, such as including energy test procedure results.

Another needed data type is device classification. There is a need for a simple, universal classification system, e.g. of 200 or so entries, that any device on the planet could be slotted into. There are classification systems that are domain specific (e.g. HVAC equipment), or enormously complicated, but neither of these serves this need[7].

Another type of data is brand/model. It is unrealistic to think that model numbering will have consistency across manufacturers (or even within them), but some basic conventions could be established. For example,

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6 SNMP is the Simple Network Management Protocol; it uses data structures called MIBs - Management Information Base - to encode data to be requested, set, or transferred.

7 http://tools.ietf.org/html/draft-nordman-classification-00, tools.ietf.org/agenda/82/slides/appsawg-8.pdf

is capitalization of letters significant? Should spaces be allowed in model numbers? Also, some manufacturers have named lines of products different from the manufacturer name, for marketing purposes, or due to company acquisition. How should these be treated? Also, some companies make small or substantial changes to the hardware in products over time and use the same name and/or model number. Some versioning should be included to be able to differentiate these, and when the product is first introduced, it may not be known that successive versions will be created. This topic needs further attention.

Product Support

Policy can encourage or require products to have Energy Reporting features, and the nature of those (specific protocols used, and types of data supported). This need not preclude devices from having additional proprietary features, or features beyond the minimum required, but provides a floor of functionality that anyone should expect. This is similar to safety requirements that mandate certain minimum behaviours or characteristics, but don't prevent devices from going beyond that.

Practicality suggests that there be a limited set of protocols for Energy Reporting. This makes implementation of management systems easier since there is a limit to how many each must support. For the foreseeable future, there will be multiple protocols in common use. In some cases this will be due to a larger functional protocol a device implements (e.g. BACNET, Zigbee SEP, Z-wave, or SNMP). To some degree, the success or not of particular protocols is best left to the market to determine. However, it is appropriate for policy to identify a set of protocols that any device in question must support at least one of the available options.

The Energy Star program has encouraged the inclusion of Energy Reporting features in several specifications. For example, the current server specification states:

> *A computer server must provide data on input power consumption (W), inlet air temperature (°C), and average utilization of all logical CPUs. 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.*

and further:

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

Management systems

The primary need for public policy for management systems is funding the development of basic ones that are freely available. There are likely others, including standard reporting mechanisms from management systems, and user interface standards so that people who receive management system information get it in ways that are common.

Deployment

Once all the above are in place, then it is needed for people to actually use Energy Reporting technology for productive purposes. Policy will need to support early test and demonstration of the technology to be able to verify and explain its utility. It may need to incentivize users to adopt the technology. Eventually, we should expect the technology to "sell itself" through common experience and word of mouth so this activity will eventually become unnecessary.

RELATED FUNCTIONS

Some other types of data could be relayed with Energy Reporting protocols that is similarly unrelated to or abstracted from device functionality. One is ambient temperature around a device. Buildings may find this useful or important to know, and this could be a free or inexpensive way to get additional sources for temperature data. Ambient light and sound levels could be similarly reported, as could the device's assessment of occupancy of the space around it.

Another possible function is reporting the location of a device within a building. How a device determines its location is outside the scope of Energy Reporting, but if it knows, this could be reported. To do this would require a standard way of representing location, something which does not yet exist. Policy could support research to define how this might be done.

SUMMARY

Energy Reporting has great potential to increase the efficiency of energy use at very low cost to society. It should eventually become a universal feature of all products and buildings. In the near term, there are specific actions needed by public policy to improve and accelerate the development and adoption of Energy Reporting technology, on a horizontal basis.

ANNEX B – DEMAND RESPONSE AND BUILDING NETWORKS

INTRODUCTION

Over the past 5 years there has been intense discussion about Smart Grids and what improvements they can make with respect to the way we use electricity. The concept has been widely embraced at the political level and has been enthusiastically championed by the power industry and others. One of the key features claimed for Smart Grids is the ability to utilise a wider range of energy sources that are more variable (less dispatchable, i.e. from renewables). In practical terms, this requires increased flexibility in electricity end use loads on the power system and/or some form of storage of energy (direct or indirect).

This Annex examines how appliances and equipment in a building may interface with the Smart Grid and how additional flexibility could be incorporated into their normal operation through the utilisation of building networks and communicating appliances. This paper also discusses the broader issue of energy management and energy efficiency of end uses in the context of networks inside buildings. Building networks offer increased functionality at many levels – the energy benefits that can accrue from building networks are in many ways secondary.

In electricity supply systems, the input from generation (entering the grid) has to match the electricity demand (supplied by the grid) at every instant. Not only that, every link in the transmission and distribution system has to be able to supply whatever load is demanded and maintain supply voltage within a narrow range. To accomplish this, very rigorous technical requirements must be continually met by utilities. The following discussion needs to be considered in this context.

DEMAND RESPONSE

Demand response, in a broad sense, is the ability to shape end use loads to more closely fit the available electricity generation capacity available at each moment (or in some cases the transmission and distribution capacity available in certain areas). These can cover short term modifications (hour to hour) or they can be strategic, long term approaches to encourage loads and load shapes that better fit available resources into the future. Demand response is one of the tools in the demand side management tool box. Demand response introduces flexibility into the underlying electricity demand, to shape it to more closely fit the available supply: this can be achieved by a range of approaches. Demand side management activities fall into several categories as follows:

- Load shifting - moving loads that occur when power is scarce to other times when it is plentiful
- Load filling – building up the load during periods where capacity is under-utilised or where there is excess energy available (also called load building)
- Peak shaving - reducing the peak power demand, usually by reducing some services during a peak but without replacing these at some other time
- Energy efficiency – reducing overall demand while maintaining the same energy service delivery (it can also include maintaining demand while increase energy service delivery).

Most of these approaches involve long term, systematic changes to the way electricity is used. While some have short term effects (e.g. peak shaving and other types of demand response controls), most need to be considered as long term strategic changes to the way energy is used. Generally equipment and/or controls (and to some extent users) have to be adapted for these changes and have these capabilities built in. Each of these is discussed briefly below.

Load Shifting and Load Filling

These approaches attempt to change the way electricity is used to more closely match the available supply in the long term. Utilities have been active in this area for a very long time (50 years or more). Common approaches include using time-of-use tariffs, real time tariffs and direct utility control of some end-use loads (like storage water heaters that are disconnected during peak times). Controlled loads can be set via time clocks or via utility controlled central switching (e.g. ripple control). Energy use is moved from peak periods to off peak periods. This is generally only feasible where there is a significant storage component in the way end-use energy is used (e.g. for hot water, heating can occur at one time and hot water use can occur at a different time) so that the user demand for energy services is not significantly compromised by the intermittent availability of energy.

Peak Shaving

Utilities have explored peak shaving in more recent years to curb very high system peak demands, which only occur on extreme weather days or with supply disruption. Without flexibility on peak days, the system may have to shed load through forced outages. Such peaks create huge demands on the system and drive investment in electricity supply assets that are rarely used at other times in the year. Peak shaving reduces energy services to end uses to reduce peak demand. One main approach is to reduce demand a small amount for many users so that together it makes a significant reduction on the system peak. If the reduction in energy services can be kept small across all users, individual users will be less concerned (or even oblivious) to the change in service level. Direct load control contributes to peak shaving (although most of these types of load would normally be already routinely off during system peaks).

This category of demand response also includes emergency load shedding – this is a significant reduction in overall demand or in a particular area in order to avoid a catastrophic collapse of parts of the grid (e.g. blackouts). This may occur due a generator trip or an interconnector drop out, which may affect small or large regions. Emergency events are generally for relatively short periods.

ENERGY EFFICIENCY

Energy efficiency is a change in the design and construction of end-use equipment and buildings that results in reduced energy consumption to deliver the same energy service (or greater energy services for the same energy consumption). Energy efficiency is not an attribute that is turned on and off. An efficient product can be subject to the other demand management measures, but there is less load to shift or shave compared to using a less efficient product. Energy management of a device would normally be classified as a type of energy efficiency measure as the objective is to minimise total energy consumption of the product during normal operation. Such management should be active at all times. Energy efficiency has much less relevance in an examination how building networks and how end use equipment may interact with the Smart Grid.

There is also energy efficiency in the control of products to deliver lower levels of an energy service (or no service at all) when appropriate. Using occupancy information to not deliver services to empty rooms is a prime example of this strategy.

CONCEPTS IN THIS ANNEX

A key element of the Smart Grid is increased functionality provided by communication gateways (often with smart meters) within the distribution system, especially to the customer or end-use equipment. This paper focuses on what the Smart Grid might mean with respect to the customer side of a smart meter, what sort of information may be communicated through such a gateway and how end-use loads can respond to this type of information.

For the purposes of this paper, the following broad definitions have been used:

- Smart Grid – the co-ordination of all elements of the generation, transmission, distribution and energy use system to maximise system reliability and optimise economic utilisation of assets – this includes system control at a regional or district level, at an individual distribution transformer, or load management functions for appliances;
- Smart meter – a utility meter that tracks energy use data by time bins, and can communicate this on an ongoing basis to the utility;
- Communications gateway – a communications path from the electricity supply system to a building network or individual appliances or other customer equipment. A communications gateway can use any physical medium (wireless, wired, power line) and may or may not be associated with a smart meter;
- Building network – a customer owned and operated digital network that is used to communicate and coordinate the operation of individual appliances and other equipment within a building (or series of buildings). Building networks can optimise energy related operations from a customer perspective and may have an interface to a Smart Grid gateway.
- Direct load control – an arrangement between an energy user and an electricity supplier to cede some level of control of selected equipment to the utility. The arrangement can be driven by financial or regulatory concerns.

PRICES

While traditionally, electricity has been sold at a constant (fixed) price, this is increasingly changing. Prices can vary over the course of the day, either fixed in advance, or based on dynamic conditions in the wholesale electricity market. Prices can be only current, or cover a forecast of future prices, for hours or even days. Prices can include shadow prices[8].

ENERGY RELATED FUNCTIONS THAT BUILDING NETWORKS COULD PROVIDE

In an integrated building network, one of the possible functions is to interface with the Smart Grid through a communications gateway. It is useful to consider the functions and associated information that could be provided by a building network. They can be broadly characterised as follows:

- Information about expected prices over the next day or week. These can be guaranteed prices or price forecasts. This can also include information about other financial instruments to indicate availability or marginal cost of supply or other energy attributes (such as emissions);
- Information about short term deficits in (or possibly excess of) supply. This could be in form of short term changes in prices, or specific requests to change the current load;
- Commands for remote control of individual appliances. This is a function that some consumers may value and elect to choose for some products – it is perhaps the oldest form of load shifting and has been in many systems for more than 50 years;
- Information (feedback) for the consumer on the present total power consumption (and possibly which products are consuming power), usually provided through an in-home display. This is an internal function and requires no information from the grid. Only fully dynamic tariffs require external real time information (fixed tariffs can be programmed into the system). It may be of interest to some parties to have this data accumulated and transmitted to a central repository outside of the building network. The display of real time energy and cost information (via a communications gateway) may encourage users to minimise discretionary use of appliances, so could be considered a form of manual load management (and therefore this is more about saving energy and less about demand response). This only works if the user happens to be present and looking at the display and understands the information in a way that enables them to make a sensible and rational decision to change behaviour, which they then choose to implement (and where they may be using services that may not require);
- Enable user control of appliances and equipment from outside the building; &
- Maximise energy management opportunities within the building based on a range of factors such as adjustment of equipment operation to better match end user demands and shutting down extraneous equipment that is not required (broadly classified as energy management). This requires no external communication (although the energy managers may be outside of the LAN so may require an external link).

8 Shadow prices reflect short term marginal utility supply costs, but these may not be reflected in the tariffs that most consumers may pay. However, some consumers may have an arrangement with a utility to use shadow prices as a basis for adjustment of electricity costs during defined periods of supply constraint where a specified level of end use response to a shadow price signal is achieved (end user would receive a benefit if there was a significant response, would pay the normal tariff if there was no response).

TABLE 2: SUMMARY OF POSSIBLE ENERGY FUNCTIONS OF BUILDING ENERGY NETWORKS

Building Network Function	Main focus	Gateway to Smart Grid	Notes
Price information	Optimise user energy costs	Required[1]	Days or weeks ahead
Rapid load response	Optimise operation of grid	Required	Mostly load shedding[3]
Direct load control	Optimise operation of grid	Range of technologies[2]	Utility control[3]
Equipment energy data	Information	Not applicable	Minor user response
Equipment remote control	User convenience	Range of technologies[2]	
Energy management	Energy optimisation	Not applicable[4]	Internal function

Note 1: This could include real time or dynamic pricing, or some other direct or indirect price indicator. Few users have full dynamic pricing and this presents some financial risks to end users.

Note 2: The range of possible options could include a Smart Grid gateway

Note 3: Rapid load response is load shedding where possible (user control only) while direct load control can be used to achieve more general load shifting and/or load shedding (utility control).

Note 4: Building energy management systems often have remote monitoring and control functions, but these are a link between a specific building and the building manager.

So while there are six distinct energy related functions that could be provided by a building network, only the first two require an interface to the Smart Grid. Direct load control is operated by the utility directly (owners cede some control to the utility), so while serving the overall Smart Grid objectives, it does not require any information flow to or from a building network for it to operate. In practice, such a control may be implemented through a smart meter or communications gateway and could be delivered by a building network.

Remote user control of appliances only requires an interface from the appliance to the Internet. This may also pass through a building network, but is unlikely to involve the Smart Grid. Remote end-use monitoring can be aggregated by third-party entities. Energy management functions are internal and require no communication with the Smart Grid. Remote management is common in larger buildings.

It is not envisaged that any communication would be required from a building network back to the Smart Grid (utilities have access to the total building load via the smart meter).

SMART GRID ENERGY RESPONSES FROM END USES

The Smart Grid can have two types of communication with end users: price information and requests or commands to change electricity usage. These can be broadly categorised as follows:

Pre-determined time-varying prices: This facilitates the orderly management and optimisation of consumer costs by allowing end users to schedule their loads (where applicable) to minimise operating costs or other energy parameters. This applies to loads where there is some discretion about when these operate. Prices can manifest as a time of day tariff, and may vary from day to day, week to week, or season to season. This is a long term set of operating parameters that define orderly interaction between end users and the grid.

Requests to change power levels: This is to effectively deal with some sort of short term grid imbalance (most commonly a shortage of supply, but can be an excess of supply). This request could be for a temporary load reduction (turning off or reducing loads that do not directly impact on energy service in the short term) or a reduction in energy services (e.g. dimming lights or displays, changing thermostat set points). It could also be a request to increase short term energy consumption in response to an excess of energy, particularly storage devices

Fully dynamic prices: This facilitates the optimization of consumer costs in a way that most closely resembles grid costs which should be more valuable to the grid and so less costly to the user.

Price changes that are pre-determined create an orderly and anticipated situation. It reflects long term operating arrangements between end users and electricity suppliers and allows anticipation or forecast of actual prices over the short term (of the order of days).

Demand response signals may not always be reliably anticipated. They can be used in urgent or emergency situations that occur infrequently for a relatively short period (from minutes to several hours) where end users are requested to curb demand as much as possible (even if inconvenient). Any response has to be automatic if it is to be effective. A level of urgency could be indicated.

Fully dynamic prices create a hybrid case of these two. When there is an unforeseen significant shortfall of supply, spot prices become very high and this may be reflected in the price charged to buildings. Users can make decisions on how to respond to this short term price spike if they are exposed to it. Any load response then becomes an economic decision, but the techniques used to respond are similar to those used in a request to change power levels. Spot prices generally reflect overall balance between generation and demand. While transmission and distribution constraints are sometimes reflected in local spot prices, translating this to prices presented to users is complex and it may not be possible to have dynamic prices that are sufficiently fine-grained in timing and in geography.

Energy efficiency as a specific attribute does not play a role in the response to a Smart Grid request. Energy efficiency is determined by product (or building) design and construction and cannot be altered to any significant extent once purchased or built. Energy management and optimisation, should always be operating at its maximum level in any system.

Price information can be accommodated via a number of strategies. Energy storage allows a mismatch between the time that energy is at the lowest cost and the time that energy services are required. A common example is a storage water heater that is heated overnight (when electricity costs are low) with hot water then used during peak periods. There is of course some cost with the provision of energy storage. Storage can be electrical (e.g. in a battery), but is more likely to be some sort of thermal storage.

Examples of storage systems are hot water tanks, heat storage systems (thermal mass or phase change), batteries (e.g. in electric vehicles), thermal mass of buildings, and thermal mass of the contents of a refrigerator or freezer. Many of these are installed for storage purposes, but can be used for storage when appropriate.

Some tasks can be scheduled to operate at times when energy costs are lower. This can be applied to end uses with discrete cycles that can be scheduled.

Examples of energy services that can be scheduled are cycles for a dishwasher, clothes washer, or clothes dryer. The batch task can be scheduled to operate at any time within a given window (e.g. overnight to be finished by the morning). Pool filters and pumps generally must be operated a certain number of hours per day – the actual time of operation is unimportant. This is already targeted for utility direct load control.

The same technologies can be used for orderly scheduling of energy use in response to prices as can be used to deal with short term emergency responses for load shedding (or load increases).

When a product receives a request to reduce power consumption, it can stop using energy from the grid if there is sufficient storage to provide the required energy services. However, if a product is required to provide energy services but there is little or no storage available, then it either has to use power from the grid or stop providing services. The corollary of this, for a request to increase power, is that a product can start using energy from the grid if there is space available to store more energy. If the energy storage is already full, it cannot take any more power from the grid. These are important considerations for both long term orderly responses to prices and short term "emergency" responses to grid supply demand imbalances.

Products with "batch" operation (washers, dryers and dishwashers) can stop for a period in the case of an urgent load shed request. Products that are already off cannot reduce their power further. Products that are off cannot respond to a request to increase power unless it is ready and safe to do so. For example, a clothes washer cannot be started by such a request unless is has clothes loaded and detergent and a program has been selected, in which case it is likely to be have been scheduled to operate in any case. There are few non storage end uses that could be activated in response a request to increase power or deactivated in response to a request to decrease power, such as pool pumps.

It is important to consider the context and role of energy prices in the likely response. For most businesses and households, the cost of energy is a small percentage (although the absolute cost may be significant). The elasticity (changes in demand) to changes in electricity price is generally very small (at least in the short term, which is the context under consideration). Even a doubling or quadrupling of price is unlikely to elicit much response. People want lights at night, offices need computers for people to do their work. The cost of wages and the value of output is many orders of magnitude larger than the cost of energy per worker, so only marginal responses could be expected from even sharp price increases. Householders are not going to sit in the dark and not eat their dinner or a workplace is not going to shut down and send workers home because electricity prices have increased or because there is a request from the Smart Grid.

Long-term price increases can drive changes in equipment, investment, and operation that can be economically justified in ways that short-term price fluctuations cannot.

TIME SCALE FOR END USE RESPONSES

In the previous section, a range of possible requests and responses have been examined. Emergency responses are likely to be of short duration, of the order of minutes to a few hours. Orderly and structured signals and responses to expected load availability (and prices) are likely to be built around the use of storage or rescheduling of loads over a day (time of use). This relies on forward knowledge of the likely price or availability of power over the next day or two.

Few end use loads can utilise storage or could reasonably be expected to defer operation for periods longer than a day or two. Therefore, requests from the Smart Grid could not reasonably expect any significant end use response to such extended periods of high prices. Periods of extended supply shortfall (e.g. where wind turbines producing little power for a week due to an extended lull in wind) would have to be met by alternative supply side options supplied by the utility in order to meet end user needs.

Similarly, requests from the Smart Grid (including price schedules) cannot be expected to change demand over longer time frames like seasons. Consistently high prices for electricity in summer or winter can encourage investment by end users in alternative sources of energy supply (this could be alternative fuels (substitution) or more efficient equipment). This type of investment is a logical economic response to price signals but has little to do with the Smart Grid. Energy using equipment and buildings have long lifetimes. For end users to make optimal decisions on investment and energy efficiency over their expected lifetime, some impression of the trajectory of future electricity costs is required. As this is rarely available, sub-optimal investments in demand side equipment and buildings are common. Uncertainty on future energy costs (and associated environmental costs) undermines investment in energy efficiency.

Electricity demand was long considered as a given parameter in the supply-demand equation. However, it is possible to change the nature and shape of electricity demand over the long term with strategic vision and long term policies. Electricity utilities have done this for many decades, as with shifting loads from peak to off peak periods. Consideration needs to be given to the likely temporal availability of future supply options and how long term investments in demand side equipment and buildings can be matched to that. A part of such a long term policy is to build in better automatic responses to short term requests from the Smart Grid to maximise short term flexibility of operation in future appliances and equipment.

The balance of this Annex considers Smart Grid responses for short term emergency requests (minutes to a few hours) and medium term signals such as prices over a day or two. Responses over longer periods are not considered as these cannot be supplied by existing end use equipment and buildings.

CASE STUDIES

It is useful to illustrate the above concepts with some practical examples. Where demand response arrangements are already in place for specific appliances and equipment, the utility will already be operating these types of loads to maximise their benefits, so they will already be activated (or deactivated) in response to these situations. Therefore products that are included in existing demand response arrangements are not considered in these examples.

Case 1: Orderly scheduling of appliance operation (based on prices)

This is where an appliance can be scheduled to operate at a later time and where the user elects to do this. It most commonly applies to appliances with delay start options (such as cycle based products such as clothes washers, clothes dryers and dishwashers). When the consumer starts the product in "flexible mode", the appliance looks at forecast prices and schedules itself to operate at the optimum conditions to meet user needs while minimising total cost. Some products can be disconnected from the network when it off; they only need to acquire price information when the user turns it on for use. Some low level network functionality may be required to allow interrogation of the appliance when off.

A different technical solution to optimise prices can apply to products with actual or effective storage like water heaters and space heaters where it does not materially affect the service provided to the consumer. It could possibly apply to a product like a separate freezer which could pre-cool and then remain off over high tariff periods (possibly up to 6 hours with plenty of advance notice). Electric vehicles are an important product type with storage. It can apply to loads that could be operated at any time (e.g. pool pumps). These types of products need to be specifically configured and designed to maximise this type of optimisation of costs.

Batch products that are not "on" do not need to be connected to a network to obtain prices. For example, a clothes washer can collect tariff information from the building network when it is switched on by the user and loaded. A product that is off and that is not scheduled to operate does not need to optimise its operation or know forthcoming tariff schedules. A product that is off cannot respond to Smart Grid requests to shed load (see case 2), because it is already at its lowest possible state. The amount of information that needs to be passed through these types of network connections is very small, so very low bandwidth (and low energy) network interfaces are the logical choice.

Case 2: Unexpected request for load reduction

The request can come from the Smart Grid to shed or curtail load or be in the form of a sharp price increase (it is expected that most requests will be to shed load rather than increase load). A request to increase load will have less effect as all essential end user loads will generally be operating normally. The duration of the load reduction will dictate what response can be provided.

Guidance would need to be obtained from Smart Grid experts on the likely duration of requests. These could be of the order of 5 to 10 minutes (to replace spinning reserve) or as long as several hours. The principle of short term load shed requests should be that overall energy services (including quality) should not be unduly affected (e.g. a television and lights cannot go out when the user is watching TV at night in response to such a request). Decisions to automatically shed load must be safe. The physical power supply to the appliance has to remain unaffected, but the appliances themselves would delay any activity under way for a short while, or reduce energy service for a short while. The decision is internally controlled in each appliance and based on automated self-management.

Many appliances can shed load up to 30 minutes when operating or scheduled to operate in the near future. Examples are cycle based appliances (wet products), water heaters, air conditioners and space heaters. Load sheds (up to 30 minutes) could be provided by refrigerators and up to 1 hour for freezers without any advanced notice. Non critical loads like pool pumps can be turned off for many hours. Reducing voltage (and hence power) will cause some marginal load response to resistive loads (which are becoming less common). Lamps and displays can be dimmed by some amount without unduly impacting on perceived end use service.

Devices under direct load control will respond immediately to a request from the grid operator. The decision to implement a load reduction (and the level that is implemented) is taken externally by the utility.

FUNCTIONAL MANAGEMENT CLASSIFICATION

From the previous discussions, it can be seen that there are a number of broad functional groupings for products in terms of their operation and management within a building network. These fall into four main functional management classifications and are briefly summarised below.

- Shed Load (unscheduled). Provide short term load shedding on request from the Smart Grid
- Optimise End User Operating Costs (scheduled). Optimise consumer costs or other energy parameters based on future price information.
- Network Energy Management (always active). Ongoing and persistent strategies to minimise power consumption through actions and strategies coordinated between inter-dependent products via sharing of information within a building network. This is the automatic management of internal functions in order to optimise short term operation in response to changes in user and network requirements, where internal management coordinated by the network will be effective in delivering energy reductions. These should operate on a persistent basis. It includes a range of strategies including minimisation of link power, optimising power consumption in low power modes, maximising time in low power modes (out of active modes), power scaling during low demand, reduction of energy services during low demand.
- Self Power Management (always active). Ongoing and persistent self energy management to minimise energy based only on local information (this not reliant on whether or not there is a building network connection. This is the overall strategic automatic minimisation of total energy consumption of a piece of equipment for a given level of energy service and functionality (duty cycle). Time delays to enter low power modes will vary depending on user expectations.

The last two categories are not considered further in great detail as they do not derive from a Smart Grid signal; they should always be activated to the maximum extent. However, they are included in the following section to illustrate the difference between types of network functionality that is possible for different products and to clarify what types of responses are associated with different strategies.

Provisional Product Assessment by Functional Management Classification

This section sets out a provisional classification of common product types in terms of their ability/suitability to operate within the two main Smart Grid functional management classifications as set out above. These classifications are qualitative only. However, it does provide a practical assessment of many common products and how they could fit conceptually into a building energy network and how automatic load response to the Smart Grid could be incorporated. This discussion defines the type of functionality that may be required in a building network and how this may interface with the Smart Grid.

The following provides provisional product assessment by functional management classification for products connected to a network.

Electronic Devices

Any electronic product: Network energy management with exposing power state to other products and acquiring product state from those products and by power managing network links. Self management with power scaling.

Any product with a display (television, computer monitor): Shed load and optimise energy costs by dimming the display. Self power manage by going to sleep on detection of no user presence.

Any product which provides an audio or video signal to another device (set-top box, media player, computer): Network energy management by going to sleep if no signal needed by connected devices.

Media player (DVD or BluRay): Go to sleep when media unit finished.

Devices with ongoing user interaction (television, computer, AV receiver): Self power management by going to sleep after a sufficient time of no user interaction.

Computer: Network energy management by instructing attached monitors to go to sleep after a time of no user interaction.

Battery-powered devices (computer): Load shed by switching to battery power even while mains connected.

Sleep if no video feed required by connected products.

Imaging equipment (printers, MFDs): Network energy management by going to sleep after a time of no interaction with computers over the network.

Appliances

Any product that has thermal mass (refrigerator, freezer, water heater, air conditioner, space heater). Shed load by adjusting set point within limits for short periods of time. Optimise energy costs by adjusting set point within limits for longer periods of time. Note: It will not be possible to shed load for refrigerator or freezers where the product is processing a significant load (i.e. internal temperature limits are already too warm). There may also be some restrictions or controls on restarting the compressor after this has been stopped (typically minimum off period is 5 min to allow internal refrigerant pressures to equalise).

Any product with a defrost cycle (refrigerator, freezer): Optimise energy costs by scheduling defrost cycle to times of lowest electricity cost. Note: It may not be possible to shed load during a defrost.

Any product with a batch cycle (dishwasher, clothes washer, clothes dryer): Shed load by pausing process for short periods of time. Optimise energy costs by scheduling process start for times of low electricity cost.

Any product providing thermal services to people (water heater, air conditioner, space heater): Optimise energy costs by changing set point when users are known to be away for extended times.

Other

Vehicles: Shed load by interrupting charging. Optimise energy cost by scheduling charging, or actually discharging, based on current and future electricity costs. Note: Vehicle charging of cars may have other functions to integrate with grid (e.g. load levelling) and there may be strict limits on local distribution transformer capacity available that restricts the ability to charge multiple vehicles simultaneously. Vehicle needs to remain usable when required.

Other battery charging: Optimise energy cost by scheduling charging.

A wider application of a building network not already mentioned is for each product to communicate its current state or mode. This would be greatly enhanced if it had the ability to also provide information on its current energy consumption (this is perhaps a long term objective and could be provided as a standard feature on power supplies as part of an initial stage for information). Such information would allow the current power consumption of all products on the network to be collected on a routine basis. This could be used for operational fine tuning of energy management processes, self-learning, user displays or for end use measurement purposes.

ELECTRIC VEHICLES

Battery charging for electric vehicles is a special class of load that is likely to be very prevalent in the future. These have relatively large amounts of electricity storage, often could be quite a bit more than the daily energy consumption of a typical house. These could operate as “normal” managed loads (optimise charging costs where there is some flexibility about when charging occurs), and may be able to act as load levelling devices to balance short term fluctuations in the availability of energy on the grid (by importing or exporting power as required, within the required charging period and storage limits). Exporting power to the grid (or even within a local site where there is no net export) requires a range of specified safety equipment and usually a reversible meter. There may need to be an additional functional requirement to limit the charge rate on individual units within a neighbourhood where there may be excess peak load on the local distribution system where a significant number of electric vehicles are connected and attempting to charge on a single distribution transformer (which may have a limited capacity). This would have to be coordinated through a local function provided by the local Smart Grid system. All such charging systems should be able to receive and understand information from the Smart Grid and internally control charge or discharge energy to maximise benefits for all local users.

As with other end-use loads with storage, vehicles cannot absorb more power if they are fully charged and cannot export power when they are empty. There is also the consideration of when the user is likely to need the vehicle next and the state of charge required. Some reasonable minimum charge needs to remain and information on the maximum charge, discharge rate, and likely usage patterns need to be included in the control strategy.

BUILDING NETWORK PRINCIPLES

It is important to consider that only a limited number of loads would be suitable for inclusion in any regime which responds to information from the Smart Grid. The relevant information from the Smart Grid communications gateway in most cases needs to be communicated over a building network to the relevant devices (and not other devices) (in some special cases there may be direct connections to specific appliances or equipment from a communications gateway). So within this context, the following broad principles may be useful when developing a building network for energy purposes:

- The user should always have priority in terms of when and how equipment is required to operate (effectively there is only one exception to this rule; direct load control, which is discussed below in special cases);
- Actions and responses should be automatic and automated within parameters of user acceptability (systems that rely on manual responses by users will be ineffective);
- The relevant devices need to have an algorithm which decides on the appropriate automatic response (in the main cases this will be to a) make a decision on when to schedule a flexible load or b) whether the function that it is currently being performed can be interrupted in response to a specific load reduction request) – distributed autonomy of appliance operation is likely to be much more acceptable than any centralised load control approach, which requires too much information and too many decisions. Centralised control and decision making for literally many millions of appliances is not possible where some local context in the decision making process is required;
- The building network architecture and design needs to itself consume the lowest possible power and should be designed in a way that is appropriate for the frequency and rate of likely information flow so as to minimise the adverse affects of increasing parasitic power consumption associated with the building network and networked products;
- Any network architecture should to be based on non-proprietary standards and technology;
- The network should comply with the Guiding Principles for Low Energy Networks;
- Any building network concepts should be independent of the physical network layer;
- Generally, communication from a building network to the Smart Grid would not be required for normal operational purposes (although for the functional of remote operation and control of appliances, communication to the Internet or some other system is likely to be necessary, but this is likely to be a dedicated communications application and to be separate from the Smart Grid). Users may elect to allow access of some information within the building network to external parties (such as utilities), but this necessarily creates security issues and it should only occur on a consent (opt-in) basis.


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