Getting Ready for Energy-Efficient Networking
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B. Claise
Everything OPS
L. M. Contreras
Telefonica
J. Lindblad
All For Eco
M. Palmero
Independent
E. Stephan
Orange
Q. Wu
Huawei

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Framework for Energy Efficiency Management
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Abstract

Recognizing the urgent need for energy efficiency, this document specifies a management framework focused on devices and device components within, or connected to, interconnected systems. The framework aims to enable energy usage optimization, based on the network condition while achieving the network’s functional and performance requirements (e.g., improving overall network utilization) and also ensure interoperability across diverse systems. Leveraging data from existing use cases, it delivers actionable metrics to support effective energy management and informed decision-making. Furthermore, the framework proposes mechanisms for representing and organizing timestamped telemetry data using YANG models and metadata, enabling transparent and reliable monitoring. This structured approach facilitates improved energy efficiency through consistent energy management practices.

About This Document

This note is to be removed before publishing as an RFC.

The latest revision of this draft can be found at https://marisolpalmero.github.io/draft-belm-green-framework/draft-belmq-green-framework.html. Status information for this document may be found at https://datatracker.ietf.org/doc/draft-belmq-green-framework/.

Discussion of this document takes place on the Getting Ready for Energy-Efficient Networking mailing list (mailto:green@ietf.org), which is archived at https://mailarchive.ietf.org/arch/browse/green/. Subscribe at https://www.ietf.org/mailman/listinfo/green/.

Source for this draft and an issue tracker can be found at https://github.com/marisolpalmero/draft-belm-green-framework.

Status of This Memo

This Internet-Draft will expire on 9 April 2026.

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1. TO DO and Open Issues

* IEC60050 reference needs a new URL

The following topics remain open for further discussion points:

1.1. Discovering Capabilities

* Enable automatic detection of power-saving features.

* Allow controllers to easily discover device-specific limits like transition time and duty cycle.

1.2. Understanding Device Capabilities

* Explore if Energy Objects can support multiple sets of power states.

* Make power states clearly described and understandable.

* Represent these capabilities in a machine-readable format.

1.3. Mapping Intents to Device Settings

* Develop ways to translate high-level energy goals (like “save energy at low utilization”) into actual device configurations.

* Create a standard method to describe this mapping across systems.

1.4. Handling Transitions and Ensuring Safety

* Consider how long it takes for an Energy Object to switch power states.

* Recommendation to standardize a data model for safe limits on frequency or speed of transitions to prevent device/component’s damage.

* Recommendation to standardize a data model to preserved measurement accuracy.

* Model SLAs that include both performance (e.g., transition time) and device safety (e.g., cycle limitations).

1.5. East-West Traffic/Energy Metrics

* Recommendation to standardize a data model for new equipment interconnected East-West with optimized energy consumption.

2. Introduction

[GreenUseCases], analyzing use cases such as the "Incremental Application of the GREEN Framework" and "Consideration of other domains for obtention of end-to-end metrics" reveals the critical need for a structured approach to transitioning network devices’ management towards energy-efficient operations, for:

* Standardization: Ensuring consistent practices across different devices and network segments to facilitate interoperability.

* Energy Efficiency Management: Providing guidelines to identify inefficiencies, look for the balance between energy usage and network/resource/component/capability utilization and implement improvements.

* Scalability: Offering solutions that accommodate growing network demands and complexity.

* Cost Reduction: Optimizing energy usage to lower operational costs and extend equipment lifecycles.

* Competitiveness: Enabling organizations to maintain a competitive infrastructure through enhanced sustainability.

* Environmental Impact: Supporting broader sustainability initiatives by reducing carbon footprints.

* Simplified Implementation: Streamlining the deployment of energy-efficient measures to minimize service disruptions.

* Security: Protecting sensitive operations related to power states and consumption.

This document specifies an Energy Management framework for devices within, or connected to, communication networks, for the use cases described in [GreenUseCases]. The devices, or the components of these devices (such as line cards, fans, and disks), can then be monitored and controlled. Monitoring includes measuring power, energy, demand, and attributes of power. Energy Control can be performed by setting a device’s or component’s state. The devices monitored by this framework can be either of the following:

* consumers of energy (such as routers and computer systems) and components of such devices (such as line cards, fans, and disks)

* producers of energy (like an uninterruptible power supply or renewable energy system) and their associated components (such as battery cells, inverters, or photovoltaic panels)

The Energy Management framework does not cover non-electrical equipment, nor does it cover energy procurement and manufacturing.

2.1. Terminology

The following terms are defined in [I-D.draft-bclp-green-terminology] and EMAN Framework [RFC7326]: Energy, Power, Energy Management, Energy Monitoring, Energy Control.

The following terms are defined in EMAN Framework [RFC7326], and cut/paste here for completeness:

Energy Management System (EnMS) An Energy Management System is a combination of hardware and software used to administer a network, with the primary purpose of Energy Management.

NOTES:

1. An Energy Management System according to [ISO50001] (ISO-EnMS) is a set of systems or procedures upon which organizations can develop and implement an energy policy, set targets and action plans, and take into account legal requirements related to energy use. An ISO-EnMS allows organizations to improve energy performance and demonstrate conformity to requirements, standards, and/or legal requirements.

2. Example ISO-EnMS: Company A defines a set of policies and procedures indicating that there should exist multiple computerized systems that will poll energy measurements from their meters and pricing / source data from their local utility. Company A specifies that their CFO (Chief Financial Officer) should collect information and summarize it quarterly to be sent to an accounting firm to produce carbon accounting reporting as required by their local government.

3. For the purposes of EMAN, the definition herein is the preferred meaning of an EnMS. The definition from [ISO50001] can be referred to as an ISO Energy Management System (ISO-EnMS).

Device A device is a piece of electrical or non-electrical equipment. Reference: Adapted from [IEEE100].

Component A component is a part of electrical or non-electrical equipment (device). Reference: Adapted from [TMN].

Meter (Energy Meter) A meter is a device intended to measure electrical energy by integrating power with respect to time. Reference: Adapted from [IEC60050].

Power Inlet A power inlet (or simply "inlet") is an interface at which a device or component receives energy from another device or component.

Power Outlet A power outlet (or simply "outlet") is an interface at which a device or component provides energy to another device or component.

Power Interface A Power Interface is a power inlet, outlet, or both.

Power State A Power State is a condition or mode of a device (or component) that broadly characterizes its capabilities, power, and responsiveness to input. Reference: Adapted from [IEEE1621].

Power State Set A Power State Set is a collection of Power States that comprises a named or logical control grouping.

Energy Object An Energy Object represents a piece of equipment that is part of, or attached to, a communications network that is monitored or controlled or that aids in the management of another device for Energy Management.

3. Motivation

3.1. Impact on Energy Metrics

The framework will significantly enhance the creation of energy metrics with actionable insights by:

* Standardizing Metrics: Establishing consistent measurement protocols for energy consumption and efficiency.

* Enhancing Data Collection: Facilitating comprehensive monitoring and data aggregation across devices.

* Supporting Real-time Monitoring: Enabling dynamic tracking and immediate optimization of energy usage.

* Integration Across Devices: Ensuring interoperability for network-wide data analysis.

* Providing Actionable Insights: Translating raw data into meaningful information for decision-making.

* East-West Traffic Impact: Addressing the growing energy footprint of East-West traffic in data centers and distributed systems by providing a framework for measuring and optimizing energy consumption in these environments.

3.2. Current Device Readiness

While many modern networking devices have basic energy monitoring capabilities, these are often proprietary. The framework will define requirements to enhance these capabilities, enabling standardized metric production and meaningful data contributions for energy management goals.

3.3. Why Now?

The decision to define the framework now, rather than later, is driven by:

* Immediate Benefits: Start realizing cost savings, reduced carbon footprints, and improved efficiencies.

* Rapid Technological Advancements: Aligning the framework with current technologies to prevent obsolescence.

* Increasing Energy Demands: Mitigating the impact of growing energy consumption on costs and sustainability.

* Regulatory Pressure: Preparing for compliance with existing and anticipated sustainability regulations.

* Competitive Advantage: Positioning organizations as leaders in sustainability and innovation.

* Foundational Work Ready: Building on the use cases and requirements established in Phase I.

* Proactive Risk Management: Minimizing risks associated with energy costs and environmental factors.

* Facilitate Future Innovations: Creating a platform for continuous improvements and adaptations.

* Stakeholder Engagement: Ensuring diverse perspectives are reflected for broader adoption.

In conclusion, establishing the framework for energy efficiency management now is strategic and timely, leveraging the current momentum of use cases and requirements to drive meaningful progress in energy efficiency management. Delaying its development could result in missed opportunities for immediate benefits, increased costs, and challenges in adapting to future technological and regulatory landscapes.

4. Reference Model

The framework introduces the concept of a Power Interface. A Power Interface is defined as an interconnection among devices where energy can be provided, received, or both. There are some similarities between Power Interfaces and network interfaces. A network interface can be set to different states, such as sending or receiving data on an attached line. Similarly, a Power Interface can be receiving or providing energy.

The most basic example of Energy Management is a single device reporting information about itself. In many cases, however, energy is not measured by the device itself but is measured upstream in the power distribution tree. For example, a Power Distribution Unit (PDU) may measure the energy it supplies to attached devices and report this to an Energy Management System. Therefore, devices often have relationships to other devices or components in the power network. An Energy Management System (EnMS) generally requires an understanding of the power topology (who provides power to whom), the Metering topology (who meters whom), and the potential Aggregation (who aggregates values of others).

The relationships build on the Power Interface concept. The different relationships among device(s)/component(s), as specified in this document, include power source, Metering, and Aggregation Relationships.

```
   +------------------------------------------------------------------+
   |                                                                  |
   |                  (3) Network Domain Level                        |-+
   |                                                                  | |
   +------------------------------------------------------------------+ |
                                                                        |
   (a)              (b)          (c)                                    v
   Inventory        Monitor        DataSheets/DataBase and/or          (g)
   Of identity      Energy        | via API,                           API
   and Capability   Efficiency    | Metadata and other             Service
        ^               ^         | device/component/network     Interface
        |               |         | related information to be:          ^
        |               |         |                                     |
        |               |         |  .Power/Energy related metrics      |
        |               |         |  .Origin of Energy Mix              |
        |               |         |  .Carbon aware based on location    |
        |               |         |                                     |
        |               |         |                                     |
        |               |         v                                     |
   +------------------------------------------------------------------+ |
   |                                                                  | |
   |       (2) controller (collection, compute and aggregate?)        |-+
   |                                                                  |
   +------------------------------------------------------------------+
                   ^                      ^                      ^ |
        (d)        |     (e)              |   (f)                | |
        Inventory  |     Monitor power    |   Control            | |
        Capability |     Proportion       |   (Energy saving     | |
                   |     Energy efficiency|   Functionality      | |
                   |     ratio, power     |   Localized mgmt/    | |
                   |     consumption,     |   network wide mgmt) | |
                   |     etc)             |                      | |
                   |                      |                      | v
   +--------------------------------------------------------------------+
   |                                                                    |
   |                       (1) Device/Component                         |
   |                                                                    |
   | +---------+  +-----------+  +----------------+  +----------------+ |
   | | (I)     |  | (II)      |  | (III)          |  | (IV)           | |
   | |         |  |           |  | Legacy         |  | ’Attached’(PoE | |
   | | Device  |  | Component |  | Device         |  | end Point)     | |
   | |         |  |           |  |                |  |                | |
   | +---------+  +-----------+  +----------------+  +----------------+ |
   +--------------------------------------------------------------------+
```

Figure 1: GREEN Reference Model

The main elements in the framework are as follows:

* (a), (d) Discovery and Inventory

* (b), (c) GREEN Metrics

* (b), (e) Monitor energy efficiency

* (f) Control Energy Saving

* (g) API Service Interface: enables access for service consumption, enabling data retrieval , control, and integration through API, e.g., [PetraApi].

The monitoring interface (e) obviously monitor more aspects than just power and energy, (for example traffic monitoring) but this is not covered in the framework.

Note that this framework specificies logical blocks, however, the Energy Efficiency Management Function might be implemented inside the device or in the controller or a combination of both.

Even the current reference model implicitly assume a hierarchical network structure, this assumption acknowledges that modern networks have flatter and anticipate more distributed topologies.

4.1. Typical Power Topologies

The following reference model describes physical power topologies that exist in parallel with a communication topology. While many more topologies can be created with a combination of devices, the following are some basic ones that show how Energy Management topologies differ from Network Management topologies. Only the controller, devices and components, are depicted here, as the Network Domain Level remains identical.

NOTE:

* "###" is used to denote a transfer of energy using Power Interface.

* "- >" is used to denote a transfer of information using Network Interface.

4.1.1. Basic Power Supply

This covers the basic example of router connected to Power Outlet in the wall.

```
   +--------------------------------------------------------------------+
   |                                                                    |
   |                  (3) Network Domain Level                          |
   |                                                                    |
   +--------------------------------------------------------------------+

   (a)              (b)              (c)
   Inventory        Monitor       +- DataSheets/DataBase and/or via API
   Of identity      Energy        |  Metadata and other device/component
   and Capability   Efficiency    |  /network related information:
        ^               ^         |
        |               |         |  .Power/Energy related metrics
        |               |         |   information
        |               |         |  .Origin of Energy Mix
        |               |         |  .Carbon aware based on location
        |               |         |
        |               |         |
        |               |         |
        |               |         v
   +--------------------------------------------------------------------+
   |                                                                    |
   |       (2) controller (collection, compute and aggregate?)          |
   |                                                                    |
   +--------------------------------------------------------------------+
                                                 ^   ^   ^ |
                                                 |   |   | |
                                                (d) (e)  (f)
                                                 |   |   | |
                                                 |   |     v
               +--------------+            +------------------+
               |              |            |                  |
               | Power Supply |############| Device/Component |
               |              |            |                  |
               +--------------+            +------------------+
```

Figure 2: Reference Model Example: Basic Power Supply

4.1.2. Physical Meter with Legacy Device

This covers the basic example of device connected to wall Power Outlet, with a Physical Meter placed in the wall Power Outlet, because the device can not monitor its power, energy, demand.

```
   +-----------------------------------------------------------------------+
   |                                                                       |
   |                  (3) Network Domain Level                             |
   |                                                                       |
   +-----------------------------------------------------------------------+

   (a)               (b)                (c)
   Inventory         Monitor         +- DataSheets/DataBase and/or via API
   Of identity       Energy          |  Metadata and other device/component
   and Capability    Efficiency      |  /network related information:
        ^                ^           |
        |                |           |  .Power/Energy related metrics
        |                |           |   information
        |                |           |  .Origin of Energy Mix
        |                |           |  .Carbon aware based on location
        |                |           |
        |                |           |
        |                |           |
        |                |           v
   +-----------------------------------------------------------------------+
   |                                                                       |
   |       (2) controller (collection, compute and aggregate?)             |
   |                                                                       |
   +-----------------------------------------------------------------------+
                                    ^
                                    |
                                   (e)
                                    |
                                    |
       +--------------+   +----------------+   +----------------+
       |              |   |                |   |                |
       | Power Supply |###| Physical Meter |###| Legacy Device  |
       |              |   |                |   |                |
       +--------------+   +----------------+   +----------------+
```

Figure 3: Reference Model Example: Physical Meter

When the EnMS discovers the physical meter, it must know for which Energy Object(s) it measures power or energy. This is the Metering Relatonship.

A Metering Relationship is a relationship where one Energy Object measures power, energy, demand, or Power Attributes of one or more other Energy Objects. The Metering Relationship gives the view of the Metering topology. Physical meters can be placed anywhere in a power distribution tree. For example, utility meters monitor and report accumulated power consumption of the entire building. Logically, the Metering topology overlaps with the wiring topology, as meters are connected to the wiring topology. A typical example is meters that clamp onto the existing wiring.

4.1.3. Physical Meter with New Device

This covers the example of device connected to wall Power Outlet, with a Physical Meter placed in the wall Power Outlet, because the previous device was not able to monitor its power, energy, demand.

```
   +--------------------------------------------------------------------+
   |                                                                    |
   |                  (3) Network Domain Level                          |
   |                                                                    |
   +--------------------------------------------------------------------+

   (a)              (b)              (c)
   Inventory        Monitor       +- DataSheets/DataBase and/or via API
   Of identity      Energy        |  Metadata and other device/component
   and Capability   Efficiency    |  /network related information:
        ^               ^         |
        |               |         |  .Power/Energy related metrics
        |               |         |   Information
        |               |         |  .Origin of Energy Mix
        |               |         |  .Carbon aware based on location
        |               |         |
        |               |         |
        |               |         |
        |               |         v
   +--------------------------------------------------------------------+
   |                                                                    |
   |       (2) controller (collection, compute and aggregate?)          |
   |                                                                    |
   +--------------------------------------------------------------------+
                                 ^                 ^   ^   ^ |
                                 |                 |   |   | |
                                (e)               (d) (e)  (f)
                                 |                 |   |   | |
                                 |                 |   |     v
       +--------------+   +----------------+   +------------------+
       |              |   |                |   |                  |
       | Power Supply |###| Physical Meter |###| Device/Component |
       |              |   |                |   |                  |
       +--------------+   +----------------+   +------------------+
```

Figure 4: Reference Model Example: Physical Meter with New Device

The most important issue in such a topology is to avoid the double counting in the Energy Management System (EnMS). The physical meter reports the Energy transmitted, while the connected Device/Component might also report its consumed Energy. Those two values are identical. Without the knowledge of this specific topology, that is the Metering Relationship between the two Energy Objects, the EnMS will double count the Energy consumed in the network.

4.1.4. Power over Ethernet

This covers the example of a switch port (Power Outlet) the provides energy with Power over Ethernet (PoE) to a PoE end points (camera, access port, etc.).

```
+---------------------------------------------------------------------+
|                                                                     |
|                  (3) Network Domain Level                           |
|                                                                     |
+---------------------------------------------------------------------+

(a)              (b)              (c)
Inventory        Monitor       +- DataSheets/DataBase and/or via API
Of identity      Energy        |  Metadata and other device/component
and Capability   Efficiency    |  /network related information:
     ^                ^        |
     |                |        |  .Power/Energy related metrics
     |                |        |   information
     |                |        |  .Origin of Energy Mix
     |                |        |  .Carbon aware based on location
     |                |        |
     |                |        |
     |                |        |
     |                |        v
+---------------------------------------------------------------------+
|                                                                     |
|       (2) controller (collection, compute and aggregate?)           |
|                                                                     |
+---------------------------------------------------------------------+
              ^   ^   ^ |                          ^   ^   ^ |
              |   |   | |                          |   |   | |
             (d) (e)  (f)                         (d) (e)  (f)
              |   |   | |                          |   |   | |
              |   |     v                          |   |     v
            +---------------+            +-----------------+
            |               |            |                 |
            | Device        |############| PoE End Point   |
            | (switch)      |            |                 |
            |               |            |                 |
            +---------------+            +-----------------+
```

Figure 5: Reference Model Example: Power over Ethernet

Double counting is also an issue in such an example. The switch port, via its Power Outlet, reports the Energy transmitted, while the PoE End Point, via its Power Inlet, reports its Energy consumed.

A second issue in such an example is the control topology. The controller must have the knowledge that, if it shuts down the switch port, it will also switch off the connected PoE End Point, as a consequence. This is the Power Source Relationship.

A Power Source Relationship is a relationship where one Energy Object provides power to one or more Energy Objects. The Power Source Relationship gives a view of the physical wiring topology -- for example, a PoE End Point receiving power from a switch port over PoE or a data center server receiving power from two specific Power Interfaces from two different PDUs.

On top of that, there might be two control points for the PoE End Point. First the connected switch port but also the controller direct connection to the PoE End Point (f). Via this interface, the controller might for example put the PoE End Point to a lower Power State.

4.1.5. Single Power Supply with Multiple Devices

This covers the example of a smart PDU that provides energy to a series of routers in a rack.

```
   +--------------------------------------------------------------------+
   |                                                                    |
   |                  (3) Network Domain Level                          |
   |                                                                    |
   +--------------------------------------------------------------------+

   (a)              (b)              (c)
   Inventory        Monitor       +- DataSheets/DataBase and/or via API
   Of identity      Energy        |  Metadata and other device/component
   and Capability   Efficiency    |  /network related information:
        ^               ^         |
        |               |         |  .Power/Energy related metrics
        |               |         |   information
        |               |         |  .Origin of Energy Mix
        |               |         |  .Carbon aware based on location
        |               |         |
        |               |         |
        |               |         |
        |               |         v
   +--------------------------------------------------------------------+
   |                                                                    |
   |       (2) controller (collection, compute and aggregate?)          |
   |                                                                    |
   +--------------------------------------------------------------------+
                 ^   ^   ^ |                   ^   ^   ^ |
                 |   |   | |                   |   |   | |
                (d) (e)  (f)                  (d) (e)  (f) ... N
                 |   |   | |                   |   |   | |
                 |   |     v                   |   |     v
               +--------------+            +--------------------+
               |              |            |                    |
               | Power Supply |############| Device/Component 1 |
               | (Smart PDU)  |  #         |                    |
               |              |  #         +--------------------+
               +--------------+  #
                                 #
                                 #         +--------------------+
                                 #         |                    |
                                 ##########| Device/Component 2 |
                                    #      |                    |
                                    #      +--------------------+
                                    #
                                    #      +--------------------+
                                    #      |                    |
                                    #######| Device/Component N |
                                           |                    |
                                           +--------------------+
```

Figure 6: Reference Model Example: Single Power Supply with Multiple Devices

4.1.6. Multiple Power Supplies with Single Device

```
   +--------------------------------------------------------------------+
   |                                                                    |
   |                  (3) Network Domain Level                          |
   |                                                                    |
   +--------------------------------------------------------------------+

   (a)              (b)              (c)
   Inventory        Monitor       +- DataSheets/DataBase and/or via API
   Of identity      Energy        |  Metadata and other device/component
   and Capability   Efficiency    |  /network related information:
        ^               ^         |
        |               |         |  .Power/Energy related metrics
        |               |         |   information
        |               |         |  .Origin of Energy Mix
        |               |         |  .Carbon aware based on location
        |               |         |
        |               |         |
        |               |         |
        |               |         v
   +--------------------------------------------------------------------+
   |                                                                    |
   |       (2) controller (collection, compute and aggregate?)          |
   |                                                                    |
   +--------------------------------------------------------------------+
         ^   ^   ^ |              ^   ^   ^ |               ^   ^   ^ |
         |   |   | |              |   |   | |               |   |   | |
        (d) (e)  (f)             (d) (e)  (f)              (d) (e)  (f)
         |   |   | |              |   |   | |               |   |   | |
         |   |     v              |   |     v               |   |     v
      +----------------+      +------------------+      +----------------+
      |                |      |                  |      |                |
      | Power Supply 1 |######| Device/Component |######| Power Supply 2 |
      |                |      |                  |      |                |
      +----------------+      +------------------+      +----------------+
```

Figure 7: Reference Model Example: Multiple Power Supplies with Single Device

4.2. Relationships

The framework for Energy Management need to describe a means to monitor and control devices and components, and it needs to describe the relationships among, and connections between, devices and components.

Two Energy Objects can establish an Energy Object Relationship to model the deployment topology with respect to Energy Management.

Relationships are modeled with a Relationship that contains the UUID of the other participant in the relationship, along with a Relationship type.

There are three types of relationships are Power Source, Metering, and Aggregations.

* A Power Source Relationship is a relationship where one Energy Object provides power to one or more Energy Objects. The Power Source Relationship gives a view of the physical wiring topology -- for example, a data center server receiving power from two specific Power Interfaces from two different PDUs.

  Note: A Power Source Relationship may or may not change as the direction of power changes between two Energy Objects. The relationship may remain to indicate that the change of power direction was unintended or an error condition.

* A Metering Relationship is a relationship where one Energy Object measures power, energy, demand, or Power Attributes of one or more other Energy Objects. The Metering Relationship gives the view of the Metering topology. Physical meters can be placed anywhere in a power distribution tree. For example, utility meters monitor and report accumulated power consumption of the entire building. Logically, the Metering topology overlaps with the wiring topology, as meters are connected to the wiring topology. A typical example is meters that clamp onto the existing wiring.

* An Aggregation Relationship is a relationship where one Energy Object aggregates Energy Management information of one or more other Energy Objects. The Aggregation Relationship gives a model of devices that may aggregate (sum, average, etc.) values for other devices. The Aggregation Relationship is slightly different compared to the other relationships, as this refers more to a management function.

In some situations, it is not possible to discover the Energy Object Relationships, and an EnMS or administrator must manually set them. Given that relationships can be assigned manually, the following sections describe guidelines for use.

4.3. Power State Set

The Energy Object contains a Power State Set attribute that represents a set of Power States a device or component supports.

A Power State describes a condition or mode of a device or component. While Power States are typically used for control, they may be used for monitoring only.

A device or component is expected to support at least one set of Power States consisting of at least two states: an on state and an off state.

The semantics of a Power State are specified by:

* The functionality provided by an Energy Object in this state.

* A limitation of the power that an Energy Object uses in this state.

* A combination of the first two.

The semantics of a Power State should be clearly defined. Limitation (curtailment) of the power used by an Energy Object in a state may be specified by:

* An absolute power value.

* A percentage value of power relative to the Energy Object’s Nameplate Power.

* An indication of power relative to another Power State. For example, specify that power in state A is less than in state B.

* For supporting Power State management, an Energy Object provides statistics on Power States, including the time an Energy Object spent in a certain Power State and the number of times an Energy Object entered a Power State.

There are many existing standards describing device and component Power States. TO BE COMPLETED

4.4. Power State Set Mapping and Intent

Defining and enforcing power states can be challenging, because each Energy Object’s technical capabilities must be mapped to high-level operational intents for energy-efficient operation. The following examples illustrate how an Energy Object’s power-saving capabilities can be aligned with typical intents:

* running at reduced capacity during predictable low-demand periods;

* lowering energy use while maintaining required performance levels;

* operating at a reduced service level when the site is on a backup power source during a grid outage.

By expressing such intents, a controller can decide which power state an Energy Object should enter at any given time and under what conditions.

4.4.1. Capability Discovery

Identifying what power states an Energy Object supports is crucial for onboarding and integration—especially for legacy systems. Key discovery elements include:

* Whether the energy object supports multiple Power State Sets.

* Semantics and limitations of each state (e.g., absolute power, relative power).

* Transition characteristics, such as the time required to move between states.

* Energy Object-specific state transition constraints like frequency, which may limit energy-saving measures to avoid damaging the device/components.

* Impacts on measurement accuracy.

4.4.2. Intent Mapping

The goal of intent mapping is to translate high-level energy-saving intents into specific device/component configurations. For example:

* An intent like "reduce power consumption at low utilization" might map to a predefined low-power state.

* Controllers may interpret intents variably, e.g., "run at half capacity but be ready to scale up if needed."

This is comparable to intent mapping in YANG-based systems— from high-level Customer-Facing Services (CFS) to Resource-Facing Services (RFS) and ultimately to device-specific configurations.

4.4.3. SLA Considerations

Meanwhile saving energy, the device or component shouldn' t drop below a certain performance threshold or allow a certain service reduction or degradation. Based on this, there are two kinds of service level expectations (SLAs) are associated with Power State behavior:

* Transition SLAs e.g., the maximum time allowed to transition between states.

* Operational SLAs e.g., device frequency or operational cycle limits that ensure long-term hardware health.

5. Conventions and Definitions

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

6. Security Considerations

Resiliency is an implicit use case of energy efficiency management which comes with numerous security considerations :

Controlling Power State and power supply of entities are considered highly sensitive actions, since they can significantly affect the operation of directly and indirectly connected devices. Therefore, all control actions must be sufficiently protected through authentication, authorization, and integrity protection mechanisms.

Entities that are not sufficiently secure to operate directly on the public Internet do exist and can be a significant cause of risk, for example, if the remote control functions can be exercised on those devices from anywhere on the Internet.

The monitoring of energy-related quantities of an entity as addressed can be used to derive more information than just the received and provided energy; therefore, monitored data requires protection. This protection includes authentication and authorization of entities requesting access to monitored data as well as confidentiality protection during transmission of monitored data. Privacy of stored data in an entity must be taken into account. Monitored data may be used as input to control, accounting, and other actions, so integrity of transmitted information and authentication of the origin may be needed.

7. IANA Considerations

This document has no IANA actions.

8. Acknowledgments

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Authors’ Addresses

Benoit Claise
Everything OPS
Email: benoit@everything-ops.net

Luis M. Contreras
Telefonica
Email: luismiguel.contrerasmurillo@telefonica.com

Jan Lindblad
All For Eco
Email: jan.lindblad+ietf@for.eco

Marisol Palmero
Independent
Email: marisol.ietf@gmail.com

Emile Stephan
Orange
Email: emile.stephan@orange.com

Qin Wu
Huawei
Email: bill.wu@huawei.com