



BSI Standards Publication

Household appliances network and grid connectivity

Part 1: General requirements, generic data modelling and neutral messages

National foreword

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The UK participation in its preparation was entrusted to Technical Committee CPL/59, Performance of household electrical appliances.

A list of organizations represented on this committee can be obtained on request to its committee manager.

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**Household appliances network and grid connectivity –
Part 1: General requirements, generic data modelling and neutral messages**



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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**Household appliances network and grid connectivity -
Part 1: General requirements, generic data modelling
and neutral messages**

FOREWORD

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Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

The structure and editorial rules used in this publication reflect the practice of the organization which submitted it.

This document was developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

A list of all parts in the IEC 63510 series, published under the general title *Household appliances network and grid connectivity*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn, or
- revised.

INTRODUCTION

Energy management systems will more and more become necessary due to change from fossil and nuclear to renewable production and the associated decentralization. Since an appropriate standard for a home and building management is in preparation, this document specifies how sets of products from multiple manufacturers can exchange information with Home and Building / Customer Energy Management Systems, located in a home network or in the cloud.

This document focuses on interoperability of household appliances and describes the necessary control and monitoring. It defines a set of functions of household and similar electrical appliances. The functions in this document cover next to energy-management main remote-control and – monitoring use cases.

This document does not deal with safety and security requirements. Safety requirements have been set in the IEC 60335 series [2]¹.

The IEC 63510 series provides interoperability on information exchange among various appliances in the home. The IEC 63510 series is split into 4 parts:

IEC 63510-1: Household appliances network and grid connectivity – Part 1: General Requirements, generic data modelling and neutral messages

IEC 63510-2: Household appliances network and grid connectivity – Part 2: Product specific mappings, details, requirements and deviations

IEC 63510-3-x: Household appliances network and grid connectivity – Part 3: Specific Data Model Mapping

IEC 63510-4-x: Household appliances network and grid connectivity – Part 4: Communication Protocol Specific Aspects

Data communication heavily depends on the environment of appliances. Sometimes low bitrate or energy efficient communication puts strict requirements to selected communication technologies. Therefore, popular and de facto standards had been and will be developed by the industry to fulfil such requirements. To not influence common data modelling for appliances because of such restrictions, the standardized data models and neutral message structures need to be applied to communication technologies.

This standard series therefore is intended to separate data modelling and neutral message structure from the attached communication.

Part 1 defines general requirements, generic data modelling and generic neutral messages without relation to any specific communication technology or any product specific layout.

Part 2 lists and specifies product specific requirements and implementation guidance based on the generic data model and generic neutral messages.

Part 3 defines the mapping of neutral messages to examples of typical data models like SPINE, SPINE-IoT, OCF, and so forth. These data models are neither mandatory nor to be seen as complete spectrum of data models.

¹ Numbers in square brackets refer to the Bibliography.

Part 4 defines the mapping of neutral messages to examples of typical communication protocols. These communication protocols are neither mandatory, nor do they provide an exhaustive list of communication protocols.

1 Scope

This document defines data models for Interoperable Connected Household Appliances. The data models are derived from a logical decomposition of use cases into functional blocks that themselves were realized by abstract actions on the data model itself.

This document is part of the IEC 63510 series, which defines the information exchange between Smart Appliances and management systems in homes and buildings including energy management.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at <https://www.electropedia.org/>
- ISO Online browsing platform: available at <https://www.iso.org/obp>

3.1

"alternatives" group

grouping of one or more Power sequences over a specified time

3.2

appliance

electrical apparatus intended for household or similar use

EXAMPLES Refrigerators, dishwashers, clothes washers, clothes dryers, air conditioners, water heaters, circulation pumps, heat pumps, etc.

3.3

Appliance Energy Flexibility

ability of an appliance to change power consumption in response to an external stimulus

3.4

client

role that specifies that a node uses data from a "server" or can request for change

3.5

command

functional part of a Message

3.6

CCM

Customer Connectivity Manager

component or set of functions with the capability to:

1. Receive and process Grid Information, Appliance Information and User Instructions, and
2. Manage one or more Smart Appliances

Note 1 to entry: A CCM may be integrated with a Smart Appliance or may be physically separate.

Note 2 to entry: A CCM manages the energy-using behaviour as well as other aspects of device behaviour (e.g. setting of job status like starting, stopping, pausing, parameters like temperature, notifications...) of one or more Smart Appliances.

Note 3 to entry: In other documentation, CCM is often called Customer Energy Manager (CEM) with a dedicated focus on energy management or called Energy Management System (EMS) with a dedicated focus on energy management.

3.7

data model

definition of possible data (data structures, values) for the exchange of information (especially for communications systems)

3.8

Demand Response

DR

action resulting from management of the electricity demand in response to supply conditions

[SOURCE: IEC 60050-617:2011, 617-04-16]

3.9

Demand Side Management

DSM

process that is intended to influence the quantity or patterns of use of electric energy consumed by end-use customers

3.10

DHW

Domestic Hot Water

3.11

grid information

information received by a CCM directly from or relating to the electricity grid

Note 1 to entry: Such information may include (but is not restricted to) the following categories:

- current and future energy prices;
- current and future network constraints;
- emissions-intensity of electricity supply;
- level of renewable energy generation;
- requests or instructions for load modification;
- directly sensed information (e.g. frequency and voltage).

3.12**interoperability**

property permitting smart appliances and energy management systems in homes and buildings to exchange data together for the purpose of energy management

[SOURCE: IEC 60050-871:2018, 871-05-06, modified – "diverse systems or components" has been changed to "smart appliances and energy management systems in homes and buildings", "work together for a specified purpose" has been changed to "exchange data together for the purpose of energy management".]

3.13**HAN**

Home Area Network

3.14**JWG****Joint Working Group**

Joint working Group Use Cases & Requirements is a working group under the roof of IEC/TC 57/WG 21; it is a cross functional working group and develops Smart Grid and Smart Home & Building related user stories and use cases

Note 1 to entry: See IEC TR 62746-2:2015 Use cases and requirements [1].

3.15**manual operation**

operation of a Device under direct user control

Note 1 to entry: Includes operation under the influence of remote controls provided with the appliance or device.

3.16**manual override**

return to Normal User Operation that terminates or prevents a period of Smart Operation, that is initiated by the User

3.17**neutral message**

information exchange that is independent of any specific communication solution

Note 1 to entry: IEC 63510-4-1 describes the mapping of neutral messages to examples of typical communication protocols.

3.18**power sequence**

expected power consumption over time (i.e., represented as a "curve" of power over time) including options on its flexibility

3.19**power slot**

single step of a Power sequence; each power slot is modelled with at least one constant power value for its duration

3.20**RMS****rms**

abbreviation for "root mean square" (used for electricity measurement)

3.21

scope

Scope Type

definition of scope types to allow identification of specific functionalities unambiguously

EXAMPLE Outside Air Temperature.

3.22

server

role that specifies that a node offers own data to be read or written by a node with role client

Note 1 to entry: A server can notify its data to other nodes (with role client).

3.23

smart appliance

appliance that is capable of Smart Operation

Note 1 to entry: Notwithstanding the possibly broader concept related to the term "smart appliance", a smart appliance under the framework of this document needs to be understood as follows:

- 1) It is an appliance that can respond to an external stimulus initiated by a CCM and/or Remote Agent to provide activities such as
 - a) Support Appliance Energy Flexibility,
 - b) job status related functions such as starting, stopping, pausing,
 - c) content or level related functions such as temperature, door status;
- 2) The appliance will respond when the user sets conditions and its status allows for a response;
- 3) The response is a change of the appliance's behaviour like electricity consumption, job status and/or level or content pattern, or a notification thereof;
- 4) The specific technical smart capabilities need not be activated when the product is placed on the market; the activation can be done at a later point in time by the consumer or a service provider.

Note 2 to entry: Smart appliances in this context can communicate through a Customer Connectivity Manager function processing external signals, such as price information or availability of Renewable Energy Sources (demand response), or direct control signals (demand side management), being able to consider households' preferences or the behaviour of the other home appliances.

3.24

smart operation

operation of an Appliance where the CCM has been set to modify operation automatically in response to Trigger Criteria

Note 1 to entry: Smart operation may be initiated by a CCM.

3.25

SPINE

Smart Premises Interoperable Neutral-message Exchange

3.26

SPINE-IoT

Smart Premises Interoperable Neutral-message Exchange for Internet of Things

3.27

subscription

functionality that enables the receiving of messages of interest from another device without polling it

3.28

use case

textual description of a re-usable functionality, consisting of one or more messages from one or more participating actors, which may be visualized with a sequence diagram

EXAMPLE "A CCM shifts the energy usage of a washing machine".

3.29**Use Case Functions**

functions which group basic functionalities that had been derived from use cases, and which provide the entire information exchange required to implement the considered use cases and user stories

3.30**user story**

complete (but specific) business case described from the perspective of a user which can be separated into several use cases

EXAMPLE "The user wants to get the laundry done by 8:00 pm".

4 Process and requirements to enable interoperability**4.1 Introduction**

Energy management systems will more and more become a requirement due to the switch from fossil and nuclear to renewable production and the associated decentralization. The success of energy management is highly dependent on interoperability of the smart appliances within the premises, which means that all devices will need a common, manufacturer-independent and brand-independent understanding of messages and data (in a broader perspective, it does not matter if it is an energy-related message, a home management message or an information message); see also [8].

This document specifies how different products from different manufacturers can exchange information with Home and Building / Customer Energy Management Systems located in a home network or in the cloud. It defines a set of functions of household and similar electrical appliances covering energy management, remote control and monitoring.

There exist different networking technologies for interoperability in Homes and Buildings. Regardless of the communication technology, they all have rules or standards (collectively known as protocols) that define the syntax, semantics and synchronization of communication and error recovery methods which have to be taken into account when defining specific protocols used for the scope. IEC 63510-4 defines this process.

4.2 Process

The Smart Grid Architecture Model (SGAM) [9], published by the Smart Grid Coordination Group based on EU mandate M/490, defines five interoperability layers representing business objectives and processes, functions, information exchange and models, communication protocols and components.

Figure 1 shows the interoperability layer and the corresponding domains and zones, defined in the SGAM Model.

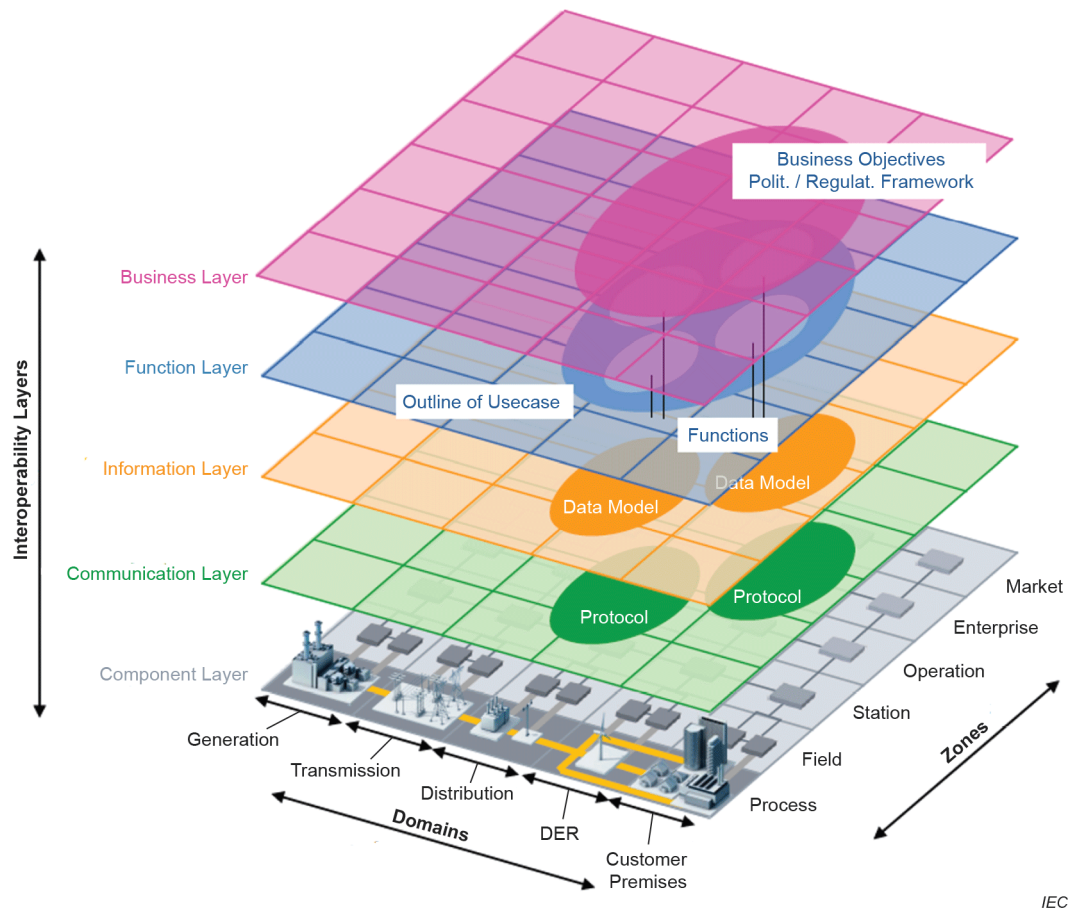


Figure 1 – SGAM Framework (from [9])

In analogy to the SGAM Framework, this series of documents uses a top-down process and sequence of steps to describe an open interface for integrating with Smart Appliances within the Customer Premises SGAM domain (see Figure 2).

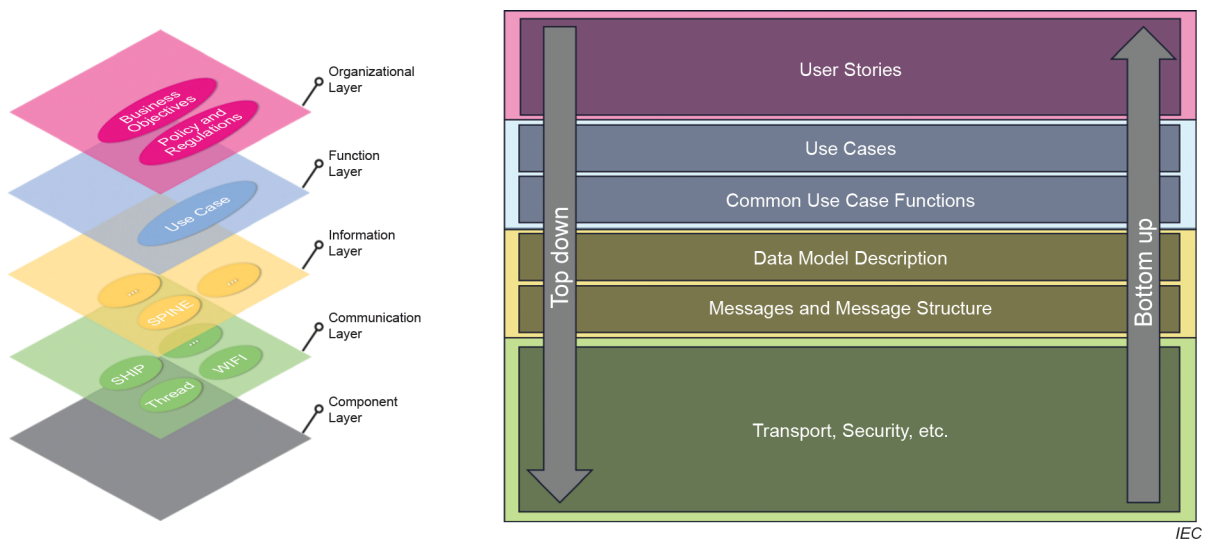


Figure 2 – Process used in this document

User stories and derived use cases are collections of ideas how to use Smart Appliances. User stories and use cases are not binding and describe one possible solution (see Clause 6 and 7).

However, they can be used to deduce common Use Case Functions which can be used/referenced in certain use cases.

Use Case Functions (see Clause 8) contain a set of information and instructions to be exchanged between two peers such as CCM and Device, described as a data model.

The data model needs to be placed into a message, combined with rules like addressing scheme, capabilities of addressee and so forth. As this is specific to the protocol(s) at hand, this mapping to specific protocols has been split out of this document into IEC 63510-4-x.

4.3 Architecture

In general, a Smart Appliance connects to a CCM, but has in principle three operation modes:

- Standalone: The end user directly controls the Smart Appliance and all its functionality.
- Local: The Smart Appliance is connected to a local CCM via the HAN.
- IoT/Cloud: The Smart Appliance communicates via its cloud representation or directly with an IoT/cloud based CCM.

NOTE As described in 3.6, the CCM manages the energy-using behaviour and may as well manage other aspects of device behaviour. Thus, in Figure 4, it represents a logical component that in reality may be represented by one or more physical and/or logical entities. According to EN 50491-12-x, for example, it might represent the combination of a Customer Energy Manager (CEM) and a Resource Manager. IEC 63510 series does not prescribe the architecture of the CCM.

This document will describe further in detail the local and IoT/Cloud operation modes. The standalone mode is not described in this document.

Figure 3 describes the application of IEC 63510 series for the local and IoT/Cloud based operating modes.

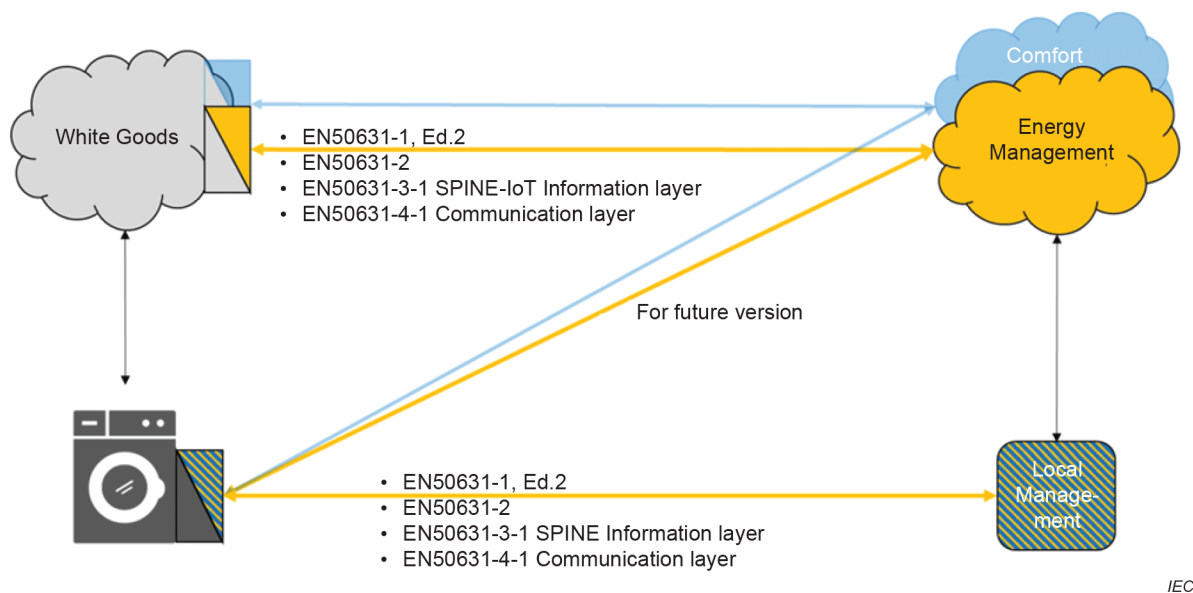


Figure 3 – Application of IEC 63510 series for the local and IoT/Cloud based operating modes

As the Use Case Functions are described in a general way without detailing the mapping of the information content to specific protocols, it is possible to refer to these Use Case Functions both in a local Home Area Network (HAN) and in a cloud. While the transport layer may change, the information content shall remain the same. Figure 4 clarifies this concept showing a case of a "HAN-based protocol A" using a specific "transport protocol C" and a "web-based protocol B".

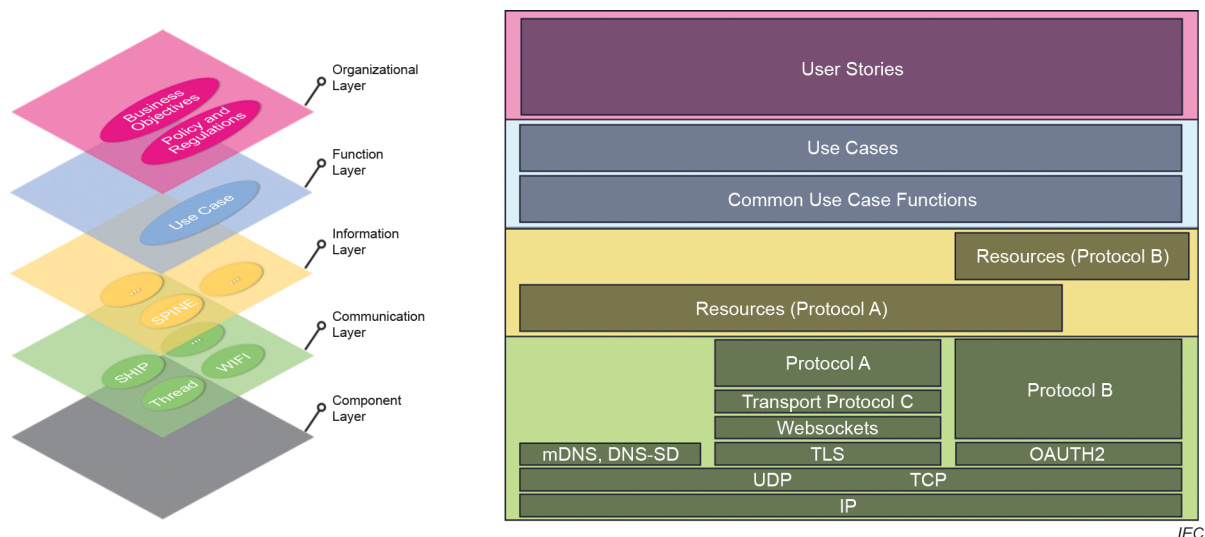
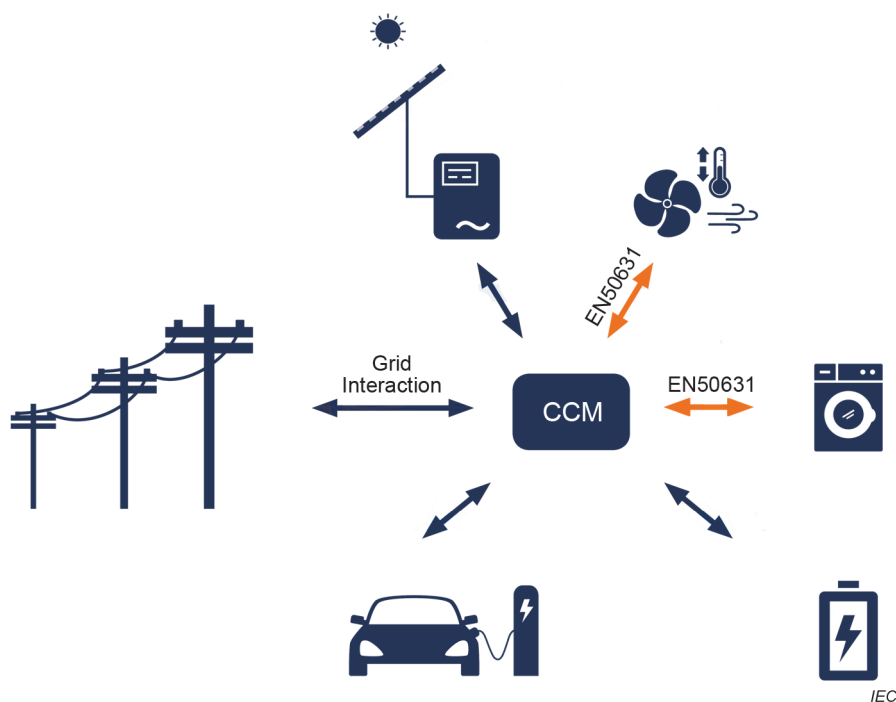


Figure 4 – Applicability of resources to different scenarios

This series of standards focuses on the interface between Smart Appliances and the CCM and describes this interface from the Smart Appliance's point of view. Figure 5 shows the applicability of IEC 63510 series (orange arrows). All participating actors described in this figure are logical actors. The CCM may have other interactions with the grid or with other actors in the premises, different from smart appliances, but these interactions are not in the scope of IEC 63510 series.



NOTE Arrows represent logical data flows. Images used with kind permission from EEBUS Initiative e.V.

Figure 5 – Applicability of IEC 63510 series

Protocols covered in IEC 63510 series will be SPINE, SPINE-IoT, and SHIP as shown in Figure 6. Other protocols will be added later.

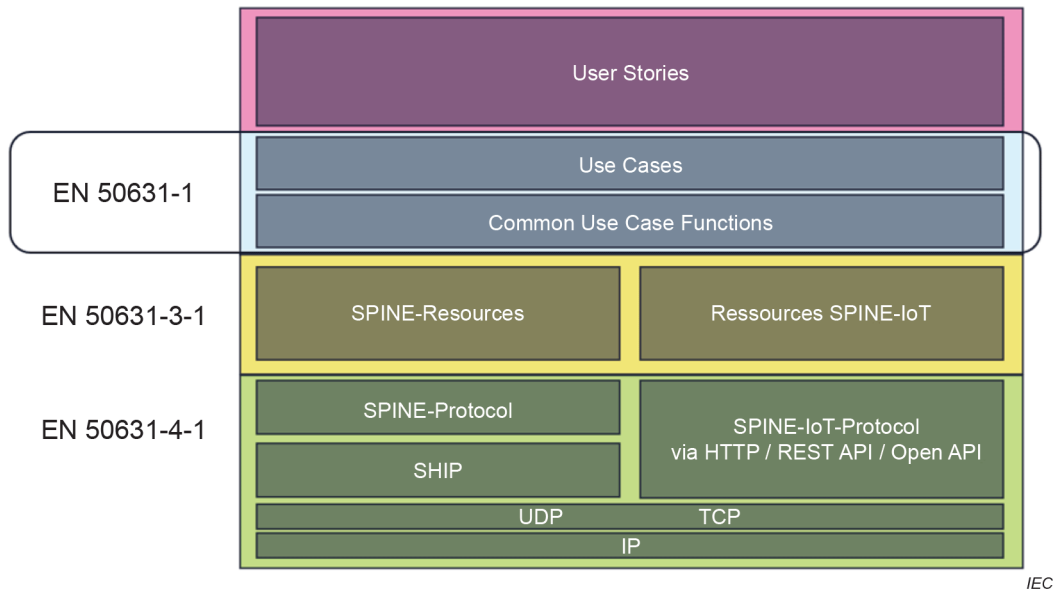


Figure 6 – Planned application of IEC 63510 series using SPINE and SHIP

5 Reader's guide

5.1 Finding the right information

This set of documents follows a top-down approach, starting at a high level and becoming more and more detailed.

This document provides background information on Smart Home, the Top-Down approach used, and the process followed to derive a possible technical solution in Clause 4.

Clause 6 starts with different high-level user stories, breaking them down into more specific use cases at a generic level in Clause 7. Each use case is subsequently broken up into scenarios, which can be mapped to common Use Case Functions.

The Use Case Functions are described in Clause 8. Each Use Case Function is documented in detail in a generic way.

Clause 9 provides a glossary of definitions for the Elements used in Clause 8.

The mapping of the Use Case Functions from IEC 63510-1 to SPINE Resources and SPINE-IoT Resources is described in IEC 63510-3-1. The transport protocols for Home and Wide Area Networks as well as cloud connectivity; in this case, SPINE, SPINE-IoT, and SHIP are described in IEC 63510-4-1.

5.2 Reading the tables

Abbreviations for the presence indication of Elements listed in the tables are defined in Table 1:

Table 1 – Presence indication description

Abbreviation	Meaning	Link to requirement keywords
M	Mandatory	SHALL
R	Recommended	SHOULD
O	Optional	MAY
F	Forbidden	SHALL NOT

5.3 Reading the graphics

5.3.1 Flowcharts

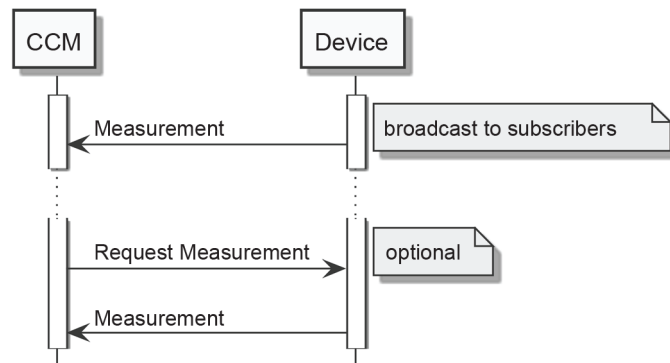
Table 2 explains the use of symbols in the flowcharts.

Table 2 – Explanation of symbols used in flowcharts

	Solid dot	Start
	Bull's eye	Stop
	Arrow	Indicates the flow of time. Text next to the arrow may give additional information.
	Diamond	Connection
	Rounded rectangle	Scenario
	Lozenge	Condition/Decision

5.3.2 Sequence diagram

Communication sequence diagrams visualize the messages sent between actors as part of a Use Case Function or scenario, as shown in the example in Figure 7:



IEC

Figure 7 – Example communication sequence diagram

The participating actors are represented by rectangles with their names at the top of the diagram (and optionally at the bottom), as well as by a connecting vertical line.

Horizontal arrows indicate the types of information content sent as well as their direction. Note that time always flows from top to bottom.

6 User Stories

6.1 Introduction

There are different layers of operation classes which all exist in parallel (see Figure 8: The different layers of operation classes) and serve specific purposes or handle different types of instructions and thereby cover different use cases.

NOTE IEC TS 62950 provides a classification of operations, instructions and related terms.

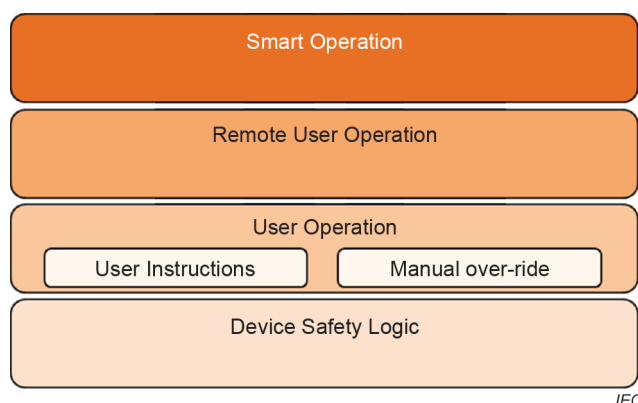


Figure 8 – The different layers of operation classes

These use cases, obviously, need to be understood in the context of the big picture of all the possible decision-making options which exist in the context of household appliances, as described above.

The following user stories and use cases have been taken as input for our use cases, data model and neutral message decomposition.

6.2 User stories

6.2.1 General

6.2.1.1 Epic 0

As a Homeowner, I want to optimize the total energy consumption in my household so that I save money.

6.2.2 Appliance Energy Flexibility

6.2.2.1 General

Smart Appliances can provide Energy Flexibility in cooperation with a CCM by changes in electric power consumption from their normal pattern in response to an external trigger.

6.2.2.2 Epic 1

As an Energy Provider, I want to distribute available energy as best as I can so that it is not wasted.

6.2.2.3 Epic 2**6.2.2.3.1 General**

As a Smart Appliance User, I want to get a process (e.g. washing laundry) completed by a given end time at the lowest possible energy cost or CO₂ footprint or percentage of renewable energy so that I can save grid energy and money or protect the environment while maintaining comfort.

6.2.2.3.2 Story 2.1

As a Smart Appliance User, I want to specify a latest end time for a process (e.g. washing laundry) so that it is done when I need it.

6.2.2.3.3 Story 2.2

As a Smart Appliance User, I want to use electricity for a process at the lowest available cost so that I save money.

6.2.2.3.4 Story 2.3

As a Smart Appliance User, I want to use as much energy from renewable sources as possible so that I have a good conscience.

6.2.2.3.5 Story 2.4

As a Smart Appliance User, I want to use as much energy from sources with a low CO₂ footprint as possible so that I have a good conscience.

6.2.2.4 Epic 3**6.2.2.4.1 General**

As a Smart Appliance User, I want to limit my power consumption to my own local production so that I do not consume grid energy.

6.2.2.4.2 Story 3.1

As a Smart Appliance User, I want to instruct my CCM to limit power consumption to the amount of my own decentralized power so that I do not consume grid energy.

6.2.2.4.3 Story 3.2

As a Smart Appliance User, I want to specify time ranges for the limitation of power to apply so that I can adjust power consumption.

6.2.2.4.4 Story 3.3

As a Smart Appliance User, I want to exclude devices from the limitation of power so that their correct operation is always ensured.

6.2.2.4.5 Story 3.4

As a Smart Appliance User, I want to receive a warning when turning on a device would exceed the limitation so that I can either postpone consumption or overrule the limit.

6.2.2.4.6 Story 3.5

As a Smart Appliance User, I want to make sure I'm injecting as little locally generated power as possible into the grid.

6.2.2.5 Epic 4**6.2.2.5.1 General**

As a Smart Appliance User, I want to use or store excess/surplus PV energy for later use so that I can optimize energy costs.

6.2.2.5.2 Story 4.1

As a Smart Appliance User, I want to thermally or electrically store excess/surplus PV energy for later use so that I can optimize heating/cooling and energy costs.

Typical use case:

- Optimization of Self Consumption by Heat Pump Compressor Flexibility, see 7.11

6.2.2.5.3 Story 4.2

As a Smart Appliance User, I want to use excess/surplus PV energy so that I can optimize energy costs.

Typical use case:

- Limit Consumption to own production, see 7.4

6.2.2.6 Epic 5**6.2.2.6.1 General**

As an Energy Supplier, I want to adjust users' load in case of grid stability issues so that grid stability is restored/ensured.

6.2.2.6.2 Story 5.1

As an Energy Supplier, I want to reduce a user's load so that the overall load on the grid is reduced in times of high demand.

6.2.2.6.3 Story 5.2

As an Energy Supplier, I want to increase a user's load so that the overall load on the grid is increased in times of high supply.

6.2.2.6.4 Story 5.3

As a Homeowner, I want to offer load flexibility to my energy supplier in exchange for a compensation so that I can optimize energy costs.

6.2.2.7 Epic 6**6.2.2.7.1 General**

As a Smart Appliance User, I want to cover my energy needs with low environmental or monetary costs so that I can save money and/or protect the environment.

6.2.2.7.2 Story 6.1

As a Smart Appliance User, I want to cover my energy needs with low monetary costs so that I can save money.

6.2.2.7.3 Story 6.2

As a Smart Appliance User, I want to cover my energy needs with low environmental costs so that I have a good conscience.

Typical use cases Appliance Energy Flexibility are described below:

- Limitation of Power Consumption (Epic 5) – see 7.4
- Incentive Table-based Power Consumption Management (Epic 6) – see 7.4

6.2.3 Remote Control of a Smart Appliance**6.2.3.1 General**

These user stories collect several typical remote initiated operations like

- Starting, stopping, pausing a device
- Setting parameters
- etc.

In this case, the CCM sends a message to the Smart Appliance, if applicable and allowed (e.g. based on safety requirements).

An example use case for Remote Control is described below:

- Monitoring and Control of Smart Grid Ready Conditions – see 7.9

6.2.3.2 Epic 7**6.2.3.2.1 General**

As a Smart Appliance User, I want to remotely control my Smart Appliances so that I can control them all from a central unit (e.g. the CCM).

6.2.3.2.2 Story 7.1

As a Smart Appliance User, I want to change the status of a job on my device so that I can automate control of the device.

6.2.3.2.3 Story 7.2

As a Smart Appliance User, I want to change a value or quantity on my device so that I can automate control of the device.

6.2.3.2.4 Story 7.3

As a Smart Appliance User, I want to change a function setting on my device so that I can automate control of the device.

6.2.4 Remote Monitoring of a Smart Appliance**6.2.4.1 General**

These user stories collect several typical remotely initiated monitoring operations or Smart Appliance initiated notifications. Typical Use Cases are:

- Monitoring and Control of Smart Grid Ready Conditions – see 7.9
- Monitoring of Power Consumption – see 7.10

In this case, either the CCM sends a message to the Smart Appliance to request the information, or the Smart Appliance notifies the CCM about any changes, if applicable.

For maintenance purposes, the operation of a smart device shall be transparent to the CCM and the user. Most likely, the user is not interested in technical logging information, but it is essential for interoperability, testing and maintenance. This feature does not provide additional capabilities but is a more general feature that might include a common test interface.

This information may occur at any time and in any circumstances, such as manual operation, remote operation, user turns off remote operation back to manual operation, re-synchronization after communication drop down, notification about pending or updated jobs or upon user and/or CCM requests.

6.2.4.2 Epic 8

6.2.4.2.1 General

As a Smart Appliance User, I want to remotely monitor my Smart Appliances so that I can monitor them all from a central unit (e.g. the CCM).

6.2.4.2.2 Story 8.1

As a Smart Appliance User, I want to monitor manufacturer information on my device so that I can monitor it from a central unit (e.g. the CCM).

6.2.4.2.3 Story 8.2

As a Smart Appliance User, I want to monitor my device's operating state so that I can monitor it from a central unit (e.g. the CCM).

6.2.4.2.4 Story 8.3

As a Smart Appliance User, I want to monitor my device's power consumption so that I can monitor it from a central unit (e.g. the CCM).

6.2.4.2.5 Story 8.4

As a Smart Appliance User, I want to monitor parameters on my device so that I can monitor it from a central unit (e.g. the CCM).

6.2.4.2.6 Story 8.5

As a Smart Appliance User, I want to monitor the smart grid readiness condition of my device so that I can monitor it from a central unit (e.g. the CCM).

6.2.5 Manual Operation of a Smart Appliance

6.2.5.1 General

Even if manually operated, the Smart Appliance can inform the CCM about status and other useful information like power consumption and so forth to support CCM in keeping the overview up to date.

EXAMPLE User starts cooking, cooking plate informs CCM about power current consumption with an indefinite duration.

The corresponding use cases are described in 7.8.

6.2.5.2 Story 9.0

As a Smart Appliance User, I want to provide a manually operated appliance's current power consumption to the CCM so that it can be monitored and included into the CCM's calculations.

7 Use cases

7.1 Introduction

For each of the Epics/User Stories, this clause captures one or more derived Use Cases. The following Table 3 provides a mapping between the User Stories and the Use Cases in this clause.

Every Use Case will be broken down step by step to their re-usable functional blocks, called Use Case Functions, see also Table 3. This is done by means of packages and sequence diagrams with the functions identified and labelled.

Every sequence diagram consists of references to common functions. De-coupling of sequence diagrams from common functions enables re-usage of same common functions in various use cases.

NOTE Use cases describe a possible path to achieve a solution. They are not mandatory and are not treated exclusively.

7.2 User Stories and Use Cases

Table 3 – Mapping of User Stories, Use Cases, and Use Case Functions

Epic	Use cases	Use Case Functions
Appliance Energy Flexibility Epic 1, 2	Flexible Start for White Goods	UCF_Plan_With_Power_Sequences UCF_Select_Power_Sequence UCF_Shift_Preferred_Power_Sequence UCF_Configure_Current_Power_Sequence
Appliance Energy Flexibility Epic 1, 3, 4	Optimization of Self Consumption by Heat Pump Compressor Flexibility	UCF_Plan_With_Power_Sequences UCF_Select_Power_Sequence UCF_Report_Status_Of_Power_Sequence UCF_Shift_Preferred_Power_Sequence UCF_Configure_Current_Power_Sequence
Appliance Energy Flexibility Epic 4	Limit Consumption to own production	See "Incentive table-based Power Consumption Management"
Appliance Energy Flexibility Epic 4, 5	Limitation of Power Consumption	UCF_Power_Limit UCF_Device_Configuration UCF_Heartbeat (60s) UCF_Characteristics
Appliance Energy Flexibility Epic 6	Incentive table-based Power Consumption Management	UCF_Device_Configuration UCF_Incentive_Table UCF_Consumption_Curve
Remote Control Epic 7	Monitoring and Control of Smart Grid Ready Condition	UCF_System_Function UCF_Overrun

Epic	Use cases	Use Case Functions
Remote Monitoring Epic 8	Monitoring and Control of Smart Grid Ready Condition	UCF_System_Function UCF_Overrun
	Monitoring of Power Consumption	UCF_AC_Measurement
Manual Operation Story 9	Manual Operation	UCF_Plan_With_Power-Sequences UCF_Report_Status_Of_Power_Sequence UCF_AC_Measurement
Network Management n/a	Install/Remove Smart Appliance	UCF_Device_Connected

7.3 Flexible Start for White Goods

7.3.1 General

A residential household includes a variety of electric consumers – such as a dishwasher, washing machine and tumble dryer – each of which can offer its flexibility or information to an energy management system. In the further description, such devices are referred to as Smart Appliances. Depending on availability of cheap or green electricity, a Customer Connectivity Manager (CCM) can let a Smart Appliance run when it is most advantageous for the customer, achieving low costs or low CO₂ emissions. Figure 9 depicts the high-level information exchange between the CCM and the Smart Appliance.

While the Smart Appliance has not yet started, its start time can be changed. To be able to find optimal start times for the Smart Appliance, the CCM needs to know its expected "power sequence" (time-dependent power consumption) with constraints such as its earliest start time, latest end time, and interrupt options. The Smart Appliance may also offer the CCM to select an alternative power sequence.

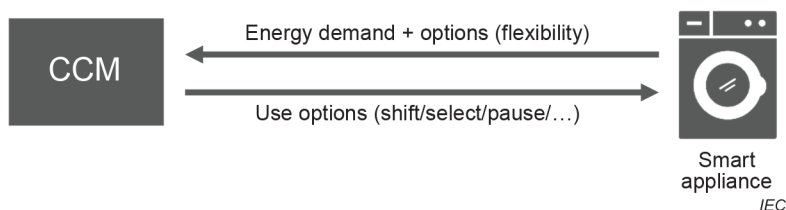


Figure 9 – Energy management with smart appliance and CCM

Added value: The CCM may run the devices at the lowest energy costs or with zero carbon dioxide emission footprint.

User Story as an example

The user wants to optimize their energy cost or CO₂ footprint, respectively, and offers flexibility by programming the washing machine to get the laundry done by 8:00 pm latest. The CCM evaluates the overall situation at home and then chooses the best start time for the washing machine.

Power sequence, basic properties

A simple power sequence with some main properties is shown in Figure 10.

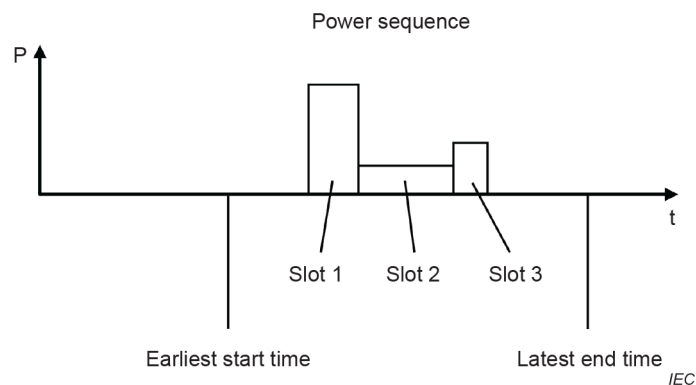


Figure 10 – Power sequence: $P(t)$ (power-over-time) modelling with slots and time constraints

A power sequence models a (usually) shiftable curve. This includes

1. Schedule constraints:

An earliest start time and latest end time between which the curve should be executed. These are given by the power plan and are not part of the power sequence.

2. Power sequence:

A power sequence is modelled by a consecutive sequence of slots:
Each slot expresses a power magnitude (*1) and its duration (*2).

(*1) In general, a slot may express multiple kinds of magnitudes. Examples are minimum value, maximum value, average value.

(*2) The total duration of all slots needs to fit into the time frame of the schedule constraints. This rule holds in every case. For example, a Smart Appliance's UI should not permit a user to select a latest end time that does not permit the complete execution of all slots.

Figure 10 does not contain an explicit start time. Without explicit start time, a power sequence just models a potential $P(t)$ curve. But if a power sequence is also to be executed at a specific time, further properties like a start time are required, as shown in Figure 11.

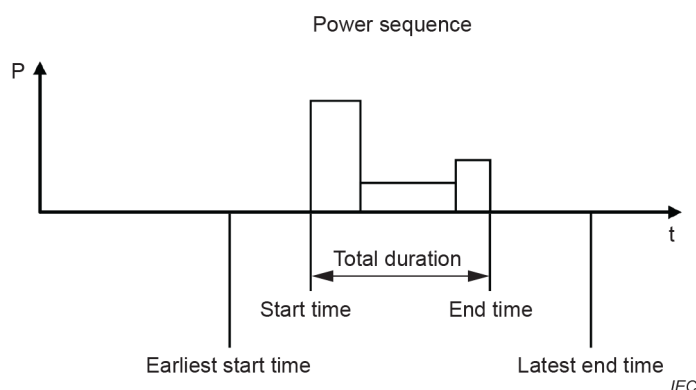


Figure 11 – Further possible properties of a scheduled power sequence

Schedule phases and states

The pre-announcement and execution of the consumption of an announced energy demand are distinct phases of a Smart Appliance:

A. Pre-announcement phase:

Before the Actor Smart Appliance begins with the energy consumption according to its announced plan, a power sequence can have one of these schedule states:

1. Preferred power sequence

A preferred power sequence has a start time. The Smart appliance will execute this power sequence at this start time (unless the Actor Smart Appliance receives a different configuration).

2. Optional power sequence

An optional power sequence has no start time. Consequently, the Smart appliance will NOT execute this power sequence autonomously.

3. Invalid power sequence

A power sequence with status "invalid" will not be executed by a Smart Appliance and cannot be selected by Actor CCM. In this phase, this type of power sequence is used only if a Smart Appliance withdraws a formerly preferred or optional power sequence. Power sequences can become invalid in this phase for a number of reasons, e.g. if they have a long runtime and can no longer be completed before the latest end time due to the CCM waiting for the optimal start time.

During the pre-announcement phase, the Actor Smart Appliance SHALL have exactly one preferred power sequence.

Scenario 3 (see 7.3.5.3) describes how an optional power sequence can become the (new) preferred power sequence and the formerly preferred power sequence then becomes an optional or invalid power sequence.

B. Execution phase:

As soon as the start time of a preferred power sequence is reached, the schedule states change:

1. Current power sequence

The preferred power sequence is now called "current power sequence" and the Actor begins with the corresponding consumption of energy. Within this schedule state, the so-called activity state expresses whether the energy consumption is currently paused or not or has been stopped. Configuration options are described in Scenario 4 (see 7.3.5.4).

NOTE The schedule state and activity state together make up the overall state of a power sequence.

2. Invalid power sequence

An optional power sequence becomes an invalid power sequence.

"Alternatives" groups of power sequences and identification

If the Actor Smart appliance announces a plan with a demand, it puts one or more power sequences into a group called "alternatives". Within such an alternatives group, the power sequences are meant to be alternatives to each other. This means that the group contains

1. exactly one power sequence that will be or is executed (preferred power sequence or current power sequence),
2. and optionally any number of optional or invalid power sequences (see above).

Each power sequence is identifiable.

This Use Case does not permit more than one "alternatives" group with power sequences.

7.3.2 Actors

7.3.2.1 General

The following actors participate in this use case:

7.3.2.2 CCM

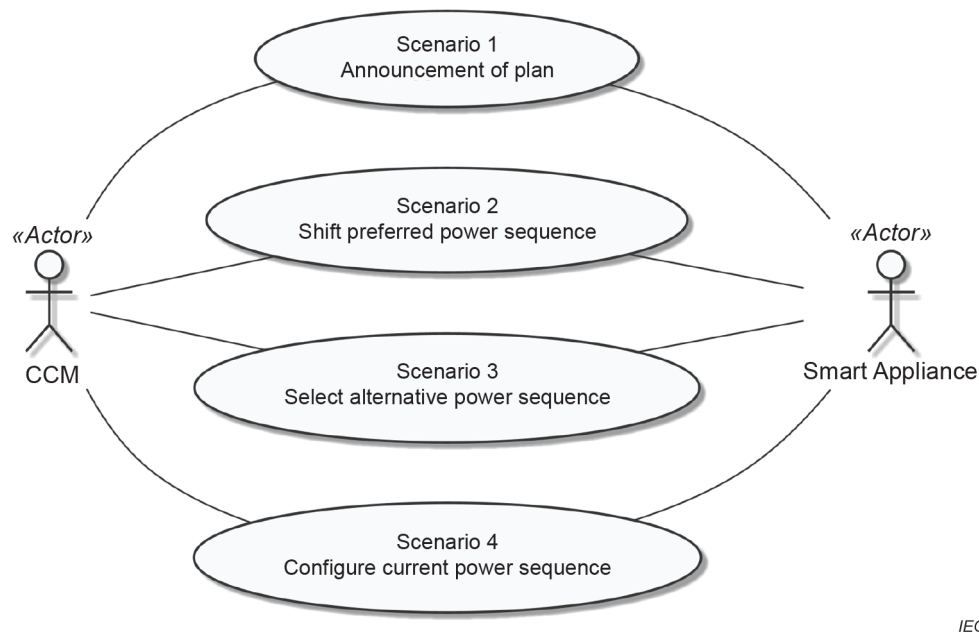
The CCM actor performs energy management tasks. It receives demands, configurations, and schedules from smart appliances. Based on the collected data the CCM adjusts the energy demand (e.g. shift a demand in time) of the smart appliances.

7.3.2.3 Smart Appliance

A smart appliance can announce the energy demand of tasks it needs to execute or is currently executing. It may allow these tasks to be adjusted in ways defined by the smart appliance (e.g. pause the current task).

7.3.3 Scenario overview

The following Scenarios apply to this Use case (see Figure 12):



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Figure 12 – Scenario overview for Flexible Start for White Goods

7.3.4 Scenario support requirements

Table 4 below lists the requirements for each actor needed to support the scenarios listed.

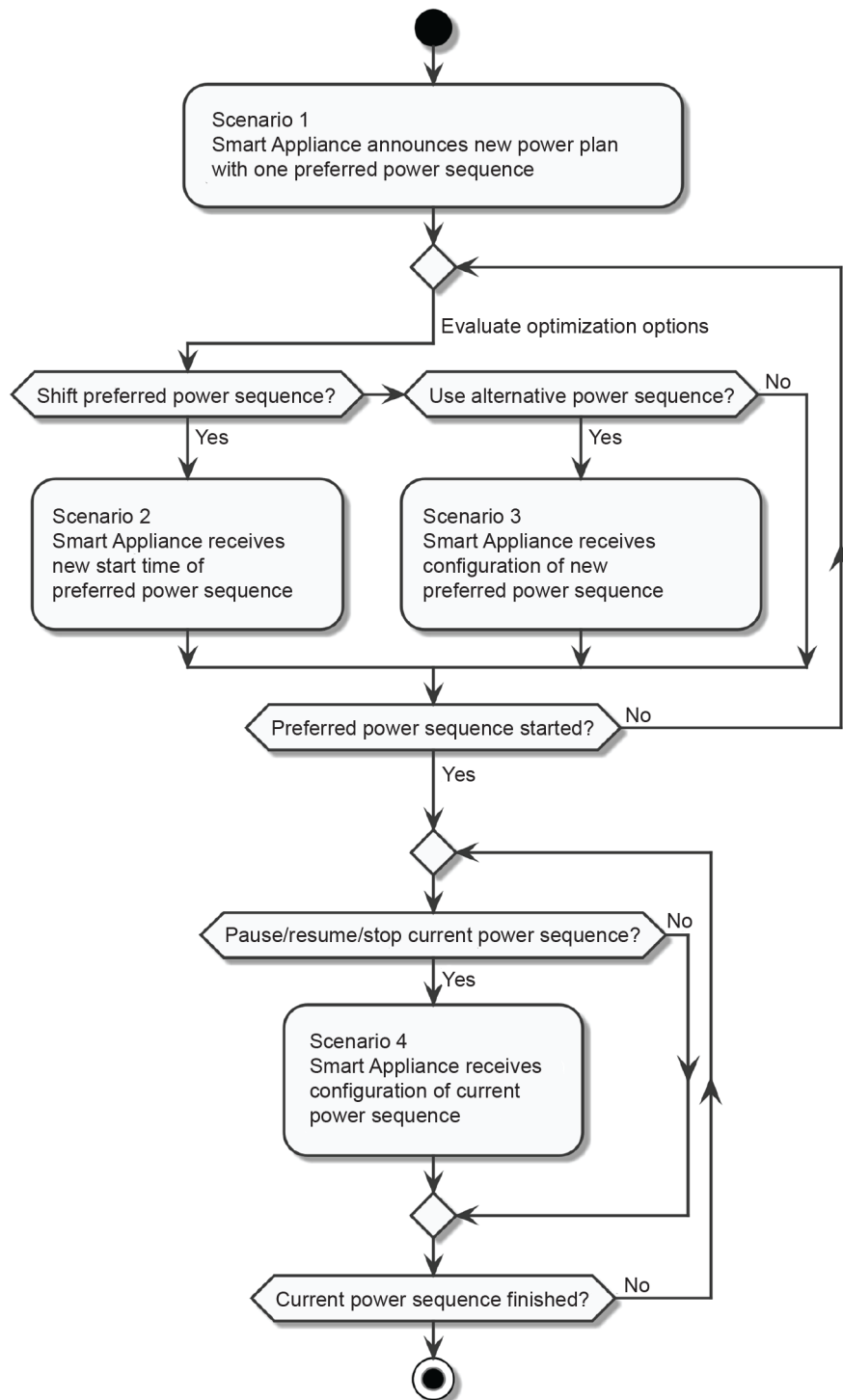
Table 4 – Flexible Start for White Goods scenario implementation requirements for Actors

Scenario number	Scenario name	CCM	Smart Appliance
1	Announcement of plan	M	M
2	Shift preferred power sequence	M	R
2	Select alternative power sequence	M	R
4	Configure current power sequence	R	O
In addition, at least one of the Scenarios 2 or 3 SHALL be supported by the Actor Smart Appliance.			

7.3.5 Scenario flow

Figure 13 shows the workflow of this Use Case. The Scenarios mentioned in the figure are explained in more detail in 7.3.5. It can be summarized as follows:

1. The Actor Smart Appliance is responsible for announcing a new (or updated) energy demand incl. its options (Scenario 1).
2. As long as the Actor Smart Appliance has not started consuming the announced energy demand, it will accept configurations to adjust the energy demand, according to its announced capabilities (Scenarios 2 and 3).
3. As soon as the Actor Smart Appliance starts consuming the announced energy demand, it will accept to pause/resume/stop its energy demand, according to its announced capabilities (Scenario 4).



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NOTE Questions in the figure above are asked from the CCM's point of view.

Figure 13 – Workflow of this Use Case

7.3.6 Scenario details

7.3.6.1 Scenario 1 – Announcement of plan

7.3.6.1.1 Description

The Actor Smart Appliance announces its current plan with one or more power sequences. This plan corresponds either to the pre-announcement phase or to the execution phase.

7.3.6.1.2 Conditions

Triggering Event:

The Scenario is triggered when the Actor Smart Appliance has a new or updated energy demand.

Pre-condition:

The Smart Appliance is in a state where it is remote controllable by the CCM with regards to the parameters described in this Scenario.

Post-condition:

Depending on the phase, available schedule states, and time, the Actor Smart Appliance may receive appropriate requests to adjust the plan or start with the energy consumption of a preferred power sequence when its start time is reached.

7.3.6.2 Scenario 2 – Shift preferred power sequence

7.3.6.2.1 Description

This Scenario applies only to the pre-announcement phase.

After receiving a plan from a Smart Appliance, a CCM estimates whether the total energy consumption within a household can be optimized by shifting the start time of the currently preferred power sequence of that Smart Appliance. If so (and provided there is no better option), the CCM sets a new start time for that power sequence. If the new start time satisfies the schedule constraints, the Smart Appliance shall accept it and announce a new plan that reflects the changes. The scheduled power sequence shall be executed by the Smart Appliance at the new start time.

7.3.6.2.2 Conditions

Triggering Event:

The Scenario is triggered when the CCM receives either an updated plan from the Smart Appliance or updated information from any external party that affects its energy management task.

Pre-condition:

The Smart Appliance is in a state where it is remote controllable by the CCM with regards to the parameters described in this Scenario.

Post-condition:

As long as no further configuration occurs afterwards, future plans of the Smart Appliance reflect all changes done to the current configuration with regards to this Scenario. Additionally, if no reconfiguration occurs, the Smart Appliance executes its current plan autonomously.

7.3.6.3 Scenario 3 – Select alternative power sequence

7.3.6.3.1 Description

This Scenario applies only to the pre-announcement phase.

After receiving a plan from a Smart Appliance (see Scenario 1), a CCM estimates whether the total energy consumption within a household can be optimized by selecting an optional power sequence of that Smart Appliance over the currently preferred one. This scenario applies only if the announced plan contains one or more optional power sequences (in addition to the currently preferred power sequence). The CCM selects an optional power sequence and sets a start time to it. If the new start time satisfies the schedule constraints the Smart Appliance shall accept it and announce a new plan that reflects the changes. If no further configuration is done to the Smart Appliance, the selected power sequence will be executed at the configured start time.

The Actor Smart Appliance reports in the plan whether it supports the selection of a different optional power sequence only once or multiple times. The latter means that the CCM can select a different optional power sequence at a later point in time.

7.3.6.3.2 Conditions

Triggering Event:

The Scenario is triggered when the CCM receives either an updated plan from the Smart Appliance or updated information from any external party that affects its energy management task.

Pre-condition:

The Smart Appliance is in a state where it is remote controllable by the CCM with regards to the parameters described in this Scenario.

Post-condition:

As long as no further configuration occurs afterwards, future plans of the Smart Appliance reflect all changes done to the current configuration with regards to this Scenario. Additionally, if no reconfiguration occurs, the Smart Appliance executes its current plan autonomously.

7.3.6.4 Scenario 4 – Configure current power sequence

7.3.6.4.1 Description

This Scenario applies only to the execution phase.

The CCM changes the activity state (running, paused, e.g.) of the current power sequence. Depending on the current state of the power sequence as well as its configuration, different state transitions are allowed (e.g. a washing machine may not be paused for an extended period in the middle of a washing program, because it can lead to clothes developing an unpleasant odour). The Smart Appliance can express valid state transitions at runtime. Additionally, the Smart Appliance SHALL ensure that all constraints are satisfied during execution of the program (e.g. a paused program needs to be resumed if the remaining time would exceed the user defined latest end time).

More precisely, the following state changes are allowed:

1. If a power sequence can be paused, the CCM may pause and resume a power sequence.
2. If a power sequence can be stopped, the CCM MAY stop a power sequence. It cannot be resumed afterwards.

7.3.6.4.2 Conditions

Triggering Event:

The Scenario is triggered when the CCM receives either an updated plan from the Smart Appliance or updated information from any external party that affects its energy management task.

Pre-condition:

The Smart Appliance is in the execution phase, where it is remote controllable by the CCM with regards to the parameters described in this Scenario (see section "Schedule phases and states", B, above).

Post-condition:

As long as no further configuration occurs afterwards, future plans of the Smart Appliance reflect all changes done to the current configuration with regards to this Scenario. Additionally, if no reconfiguration occurs, the Smart Appliance executes its current plan autonomously.

7.3.7 Scenarios and Use Case Functions (UCFs)

For each scenario, the "primary" Use Case Functions are given as described in Table 5.

Table 5 – Flexible Start for White Goods: Scenarios and primary Use Case Functions (UCFs)

Scenario	Primary Use Case Functions
Scenario 1 Announcement of plan	UCF_Plan_With_Power_Sequences
Scenario 2 Shift preferred power sequence	UCF_Shift_Preferred_Power_Sequence
Scenario 3 Select alternative power sequence	UCF_Select_Power_Sequence
Scenario 4 Configure current power sequence	UCF_Configure_Current_Power_Sequence

7.3.8 Dependencies to other Use Cases

None.

7.3.9 Assumptions and Prerequisites

None.

7.4 Incentive Table-based Power Consumption Management

7.4.1 Actors

7.4.1.1 General

The following actors participate in this use case:

7.4.1.2 Energy Consumer

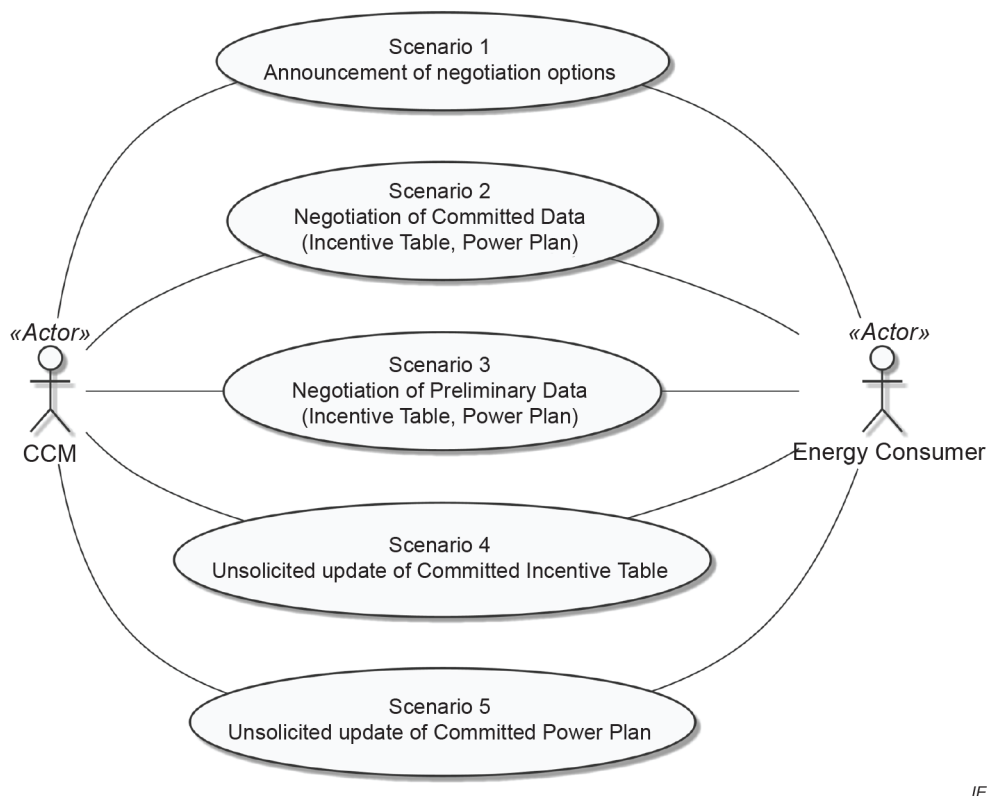
The Actor Energy Consumer is the Energy Consumer that wants to cover its energy needs with low environmental or monetary costs. Within this Use Case, only one CCM SHALL be connected to an Energy Consumer, while multiple Energy Consumers MAY be connected to a CCM.

7.4.1.3 CCM

The Actor CCM delivers incentives. Multiple Energy Consumers MAY be connected to a CCM. However, only one CCM SHALL be connected to an Energy Consumer.

7.4.2 Scenario Overview

The following Scenarios apply to this Use case (see Figure 14):



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Figure 14 – Scenario Overview

7.4.3 Scenario support requirements

Table 6 below lists the requirements for each actor needed to support the scenarios listed.

Table 6 – Scenario implementation requirements for Actors

Scenario number	Scenario name	Energy Consumer (M)	CCM (M)
1	Announcement of negotiation options	M	M
2	Negotiation of Committed Data	M	M
3	Negotiation of Preliminary Data	O	O
4	Unsolicited update of Committed Incentive Table	M	O
5	Unsolicited update of Committed Power Plan	O	M

7.4.4 Scenario Flow

The order in which the scenarios occur is defined by the trigger (see Figure 15). For some scenarios data of other scenarios is relevant, while other scenarios can run in parallel.

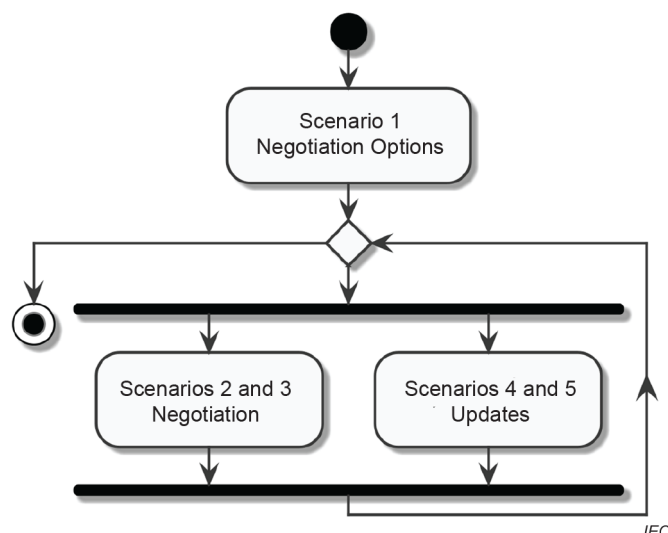


Figure 15 – Workflow of this Use Case

7.4.5 Scenario Details

7.4.5.1 Scenario 1 – Announcement of negotiation options

7.4.5.1.1 Description

The Use Case comprises several processes (Scenarios) with negotiation options of Actor Energy Consumer. These options need to be fetched and considered properly by Actor CCM. This Scenario 1 primarily summarizes the negotiation options in Table 7. Rules and further details on the negotiation options can be found in the respective Scenarios or below Table 7.

Table 7 – Scenario 1 – Negotiation options

Data point name	Data point description	Support indication
Maximum simulation cycles	Scenario 3: The maximum number of successive simulation cycles (Scenario 3) permitted by Actor Energy Consumer. Once the number of completed successive simulation cycles reaches this maximum, Actor Energy Consumer does not support further simulation cycles unless a negotiation of committed data (Scenario 2) completed successfully. A maximum number of zero denotes that Actor Energy Consumer does not support Scenario 3 at all. The value SHALL be a non-negative integer.	M
Concurrent negotiation capability	Scenario 3 (and 2): Value "true" = Actor Energy Consumer is capable of executing calculations of Scenario 3 in parallel to Scenario 2; otherwise, the value is "false". See details below table.	M ^a
TIMEOUT_INCENTIVE_REQUEST	Scenario 2: Maximum waiting period of Actor Energy Consumer to receive a valid update of the Committed Incentive Table. See details in 7.4.5.2.	M
WAIT_INCENTIVE_WRITEABLE	Scenario 2: Waiting period of Actor Energy Consumer before it permits execution of Scenario 4. See details in 7.4.5.2.	M
^a Mandatory if Scenario 3 is supported.		

On data point "Concurrent negotiation capability":

In Scenarios 2 and 3, Actor Energy Consumer computes a Committed or Preliminary Power Plan based upon a respective Incentive Table. The CPU of Actor Energy Consumer may not have sufficient computing resources to calculate a Preliminary and a Committed Power Plan at the same time and deliver results within the required time constraints. There might be further reasons that prevent Actor Energy Consumer from parallel computations of these plans. In these cases, Actor Energy Consumer SHALL set the data point "Concurrent negotiation capability" to "false". Otherwise, Actor Energy Consumer SHOULD set the data point "Concurrent negotiation capability" to "true".

NOTE Scenario 3 also describes how a computation of a Preliminary Power Plan can be aborted by Actor Energy Consumer (see 7.4.5.3.1.4).

7.4.5.1.2 Conditions**Triggering Event:**

This Scenario is triggered by Actor CCM to get negotiation options of Actor Energy Consumer to execute further Scenarios of this Use Case properly.

Pre-condition:

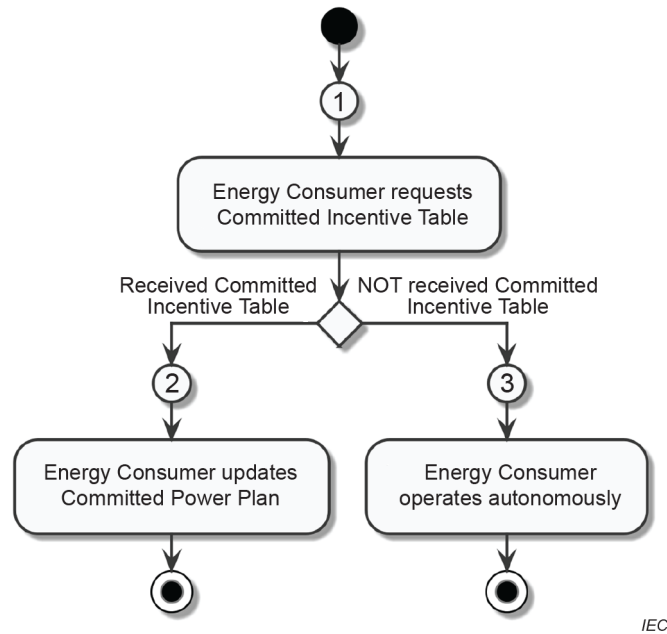
The Actor CCM has no or "old" negotiation options of Actor Energy Consumer.

Post-condition:

In case of success, the Actor CCM received updated negotiation options of Actor Energy Consumer.

7.4.5.2 Scenario 2 – Negotiation of Committed Data**7.4.5.2.1 Description****7.4.5.2.1.1 General**

In this Scenario, the Actor Energy Consumer explicitly requests an update of its Committed Incentive Table. If the Actor Energy Consumer receives a valid Committed Incentive Table in time, it updates its Committed Power Plan. Otherwise, the Actor Energy Consumer operates autonomously (with regards to this Use Case). An overview is shown in Figure 16.



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Figure 16 – Overview of Scenario 2 activity

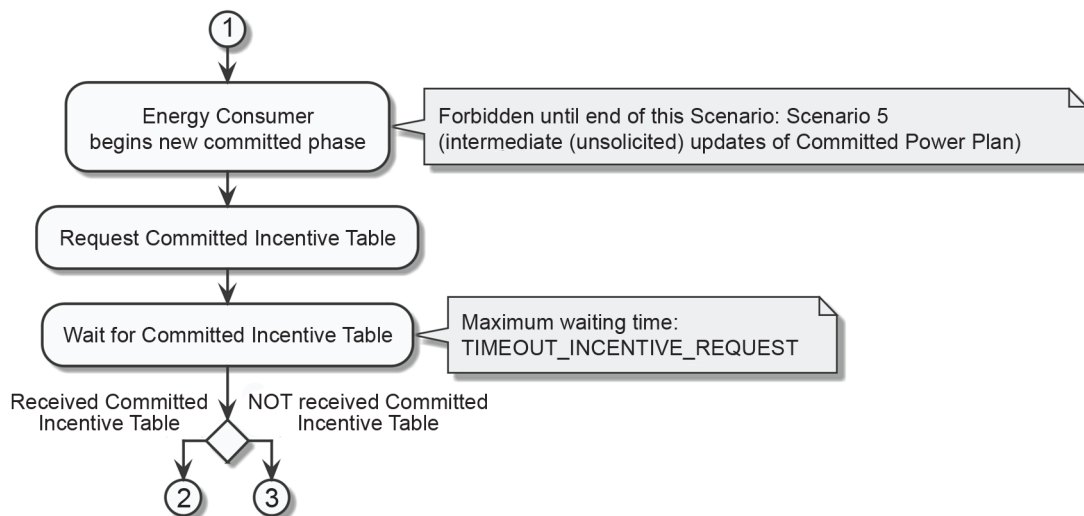
The activity is split into several segments which begin at the circled numbers shown in Figure 16:

1. Activity begin ①
2. Activity branch "Update of Committed Power Plan" ②
3. Activity branch "Autonomous operation" ③

Details are described in the subsequent subclauses.

7.4.5.2.1.2 Activity begin ①

The Actor Energy Consumer is ready to initiate a negotiation of committed data. It requests for a (new or updated) Committed Incentive Table and waits for the receipt. This is shown in Figure 17.



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Figure 17 – Activity begin diagram of Scenario 2